1995 Proceedings

49th Annual Broadcast Engineering Conference

NAB BROADCASTERS

*Includes papers from the 1995 NAB/ITS Advanced Teleproduction Conference

J BALLARD

1995 PROCEEDINGS

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Conference Proceedings

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1771 N Street, N.W.
Washington, DC 20036-2891
(202) 429-5346
Fax: (202) 775-4981

April 1995

Dear Industry Engineer:

On behalf of the NAB/SBE Conference Planning Committee, we are pleased to present the *1995 NAB Broadcast Engineering Conference Proceedings*.

The 49th NAB Broadcast Engineering Conference features presentations on existing and new broadcast technologies. As the broadcast industry continues its transition from analog to digital, you will find that a significant number of presentations have evolved around a digital theme. This year's conference highlights the latest developments in the areas of advanced television, digital audio broadcasting, data broadcasting and digital facilities design for radio and television. Traditional presentations from experts in the field of RF round out the conference. This publication contains material from many of these presentations.

The Society of Broadcast Engineers worked closely with NAB in developing the 1995 conference sessions. This joint effort has resulted in quality presentations that will be of long-term value to practicing broadcast engineering professionals around the world. In 1995, the NAB Broadcast Engineering Conference continues its long-standing tradition of providing important contributions related to broadcast engineering.

In 1995, NAB also inaugurated a new conference, the NAB/ITS Advanced Teleproduction Conference, in cooperation with the International Teleproduction Society, highlighting production and post production issues in the new age of multimedia, HDTV and all-digital environments. Six important papers from this conference are included in a special section of this Proceedings.

Our continuing goal is to provide quality conferences that will benefit all broadcasters. As we begin preparations for our fiftieth (!) NAB Broadcast Engineering Conference in 1996, we welcome your comments and suggestions.

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NAB/SBE Conference Committee Chairman

Lynn D. Claudy
Senior Vice President
Science & Technology

NAB/SBE CONFERENCE PLANNING COMMITTEE

Jerry Whitaker, Chairman
Technical Writer
3830 N.W. 172nd Place
Beaverton, OR 97006

Bill Beckner
Chief Engineer
WUSA-TV
4100 Wisconsin Avenue, NW
Washington, DC 20016

Marvin Born
Vice President of Engineering
WBNS-TV
770 Twin Rivers Drive
P.O. Box 1010
Columbus, OH 43216

Jerry Butler
WETA-TV
Box 2626
Washington, DC 20013

David Carr
Chief Engineer
KHOU-TV
1945 Allen Parkway
Houston, TX 77019

Dane Ericksen, P.E.
Hammett & Edison, Inc.
P.O. Box 280068
San Francisco, CA 94128

Doug Garlinger
Director of Engineering
Lesea Broadcasting
10511 Greenfield Avenue
Noblesville, IN 46060

Louis Libin
Director of Technology
National Broadcasting Company
30 Rockefeller Plaza
Room 2564
New York, NY 10112

Bill Ruck
Engineering Manager
KNBR-AM/KFOG-FM
55 Hawthorne Street, Suite 1100
San Francisco, CA 94111-1412

Milford Smith
Vice President, Engineering
Greater Media, Inc.
2 Kennedy Blvd.
East Brunswick, NJ 08816

TABLE OF CONTENTS

SPECIAL SECTION

BROADCAST ENGINEERING CONFERENCE OPENING CEREMONY

Sunday, April 9, 1995

Session Chairperson:
Jerry Whitaker, Technical Writer, Beaverton, OR

Keynote Speaker:
The Honorable James H. Quello
FCC
Washington, DC

ADVANCED TELEVISION TECHNOLOGY I

Sunday, April 9, 1995

Session Chairperson:
James C. McKinney, ATSC, Washington, DC

***INTRODUCTION TO THE GRAND ALLIANCE**
Richard E. Wiley
Chairperson, FCC ACATS
Wiley, Rein and Fielding
Washington, DC

***GRAND ALLIANCE SYSTEM OVERVIEW**
Jae Lim
MIT
Cambridge, MA

***VSB FIELD TESTS AND UPDATE**
Wayne Luplow
Zenith Electronics
Glenview, IL

***SYSTEM FLEXIBILITY: WHAT THIS MEANS TO BROADCASTERS**
Glenn Reitmeier
David Sarnoff Research Center
Princeton, NJ

***HDTV AND BROADCASTERS: THE EVOLUTION**
Peter Symes
Grass Valley Group
Grass Valley, CA

***TESTING UPDATE**
Peter Fannon
ATTC
Alexandria, VA

***STANDARDS DOCUMENTATION UPDATE**
Dr. Robert Hopkins
ATSC
Washington, DC

PANEL—IMPLEMENTING ATV BROADCASTING
Panelists:

John D. Abel
NAB
Washington, DC

Joseph Flaherty
CBS, Inc.
New York, NY

Michael Sherlock
NBC, Inc.
New York, NY

Saul Shapiro
FCC
Washington, DC

*Papers not available at the time of publication

ADVANCED TELEVISION TECHNOLOGY II

Sunday, April 9, 1995

Session Chairperson:
Marvin Born, WBNS-TV, Columbus, OH

***INVESTIGATION OF COFDM TECHNOLOGY FOR 6 MHZ DIGITAL TELEVISION TRANSMISSION**
Lynn D. Claudy
NAB
Washington, DC
Vidar Ringset
Sintef Delab
Trondheim, Norway
Yiyan Wu
CRC
Ottawa, Ontario, Canada

THE ART AND SCIENCE OF DIGITAL VIDEO COMPRESSION
Mauro Bonomi
Minerva Systems, Inc.
Santa Clara, CA

DIGITAL TELEVISION EXCITER AND RECEIVER FOR SATELLITE NEWS GATHERING: DIGITAL SATELLITE LINK PERFORMANCE
Frank N. Longo, Jr.
Satellite Transmission Systems, Inc.
Hauppauge, NY
Jay C. Adrick
Harris Allied Systems
Florence, KY

THE PBS ATV HANDBOOK: A PRACTICAL APPROACH TO THE RF CONVERSION PROCESS
Matthew Tietze
William Zou
PBS
Alexandria, VA
Thomas J. Vaughan
T. Vaughan & Associates
Manchester, NH

AN EFFECTIVE SPECTRAL USE OF 6 MHZ FOR SPECTRUM FLEXIBILITY
Dae Jin Kim Ph.D.
Goldstar Co. Ltd.
Seoul, Korea

A NEW APPROACH TO THE ANALYSIS OF ADJACENT STRUCTURE EFFECTS ON HDTV ANTENNA PERFORMANCE
Oded Bendov
Dielectric Communications
Cherry Hill, NJ

SO YOU'VE JUST BEEN ASSIGNED CHANNEL 68 FOR ATV—INTERPRETING ATV CHANNEL ASSIGNMENTS
Louis Libin
National Broadcasting Company Inc.
New York, NY

*Papers not available at the time of publication

THE ART AND SCIENCE OF DIGITAL VIDEO COMPRESSION

Mauro Bonomi
Minerva Systems, Inc.
Santa Clara, CA

Abstract

Video compression is the critical enabling technology for digital distribution of video material, which is in turn an important emerging market for cable carriers and telephone companies who wish to compete by offering new, interactive services such as video on demand. MPEG compression, though, is a highly subjective process. The quality of the final compressed video is dependent upon the compression system used to perform the encoding, the tools the system features, and the skill of the person operating the system. In a studio-type environment these factors can combine to significantly improve the quality of MPEG encoding, in a process known as "human-assisted" encoding. This paper provides a general introduction to human-assisted encoding process and describes specific techniques and their benefits.

Introduction

The video industry is going digital, opening a world of new markets and distribution opportunities for content providers. Digital distribution via CD-ROM, CD-I, and direct broadcast satellite (DBS) is already booming. Digital video delivery via Video CDs and via video servers over cable and telco networks will grow rapidly in 1995 and beyond. Video publishers are moving quickly to convert their assets to digital formats to take advantage of these new channels.

As this migration progresses the technology of digital video compression, also known as encoding, takes on a new and pivotal role. Encoding makes digital video distribution viable, trimming bulky video data down to fit bandwidth-constrained media such as CDs and coaxial cable.

Like any technical advance, encoding presents both challenges and rewards. The challenge consists of assimilating new tools and new skills. The payoff is that in mastering the technology video publishers can deliver compelling interactive products, thereby gaining a significant edge over competitors. For content distributors high quality compression lowers distribution costs. And for post-production houses, encoding represents a new service to offer customers.

Making good on these opportunities demands a combination of superior equipment and unique expertise. A sophisticated encoder system, which implements powerful compression algorithms, is essential, of course. But it is only the beginning. Beyond the automated phases of encoding lies an interactive process that can considerably enhance the finished video output. These "human-assist" procedures can make the difference between high quality images and mediocre ones, between efficient use of media and wasted bandwidth. Human-assist encoding and the systems that support it are likely to become a staple of high-end video post-production and publishing environments.

This white paper provides a general introduction to human-assist encoding. The main part of the paper describes the overall process of human-assist encoding, specific techniques and their benefits.

Compression Standards

Industry standards for video compression have been defined by the Moving Picture Experts Group (MPEG), a working committee of the International Standards Organization (ISO). The MPEG-1 standard, finalized in 1991, provides for VHS-quality video at bit rates as low as 1.14 mbps. Higher and lower bit rates are possible, with corresponding trade-offs in quality.

MPEG-1 typically processes images at SIF (standard interchange format) resolution, which is 352 x 240 pixels at 30 frames per second for NTSC television and 352 x 288 pixels at 25 frames per second for PAL. A second MPEG standard, MPEG-2, provides broadcast-quality video at data rates as low as 6-8 mbps. MPEG-2, due to be finalized by late 1994, provides a choice of resolutions, including CCIR 601 (720 x 480 pixels at 60 fields per second for NTSC; 720 x 576 pixels at 50 fields per second for PAL) and HDTV. MPEG-2 is a superset of MPEG-1, so MPEG-2 decoding systems will also play any MPEG-1 video stream.

At a target video data rate of 1.14 mbps, MPEG-1 provides a compression ratio of nearly 190:1 (uncompressed CCIR 601 video has a bandwidth of 216 mbps), matching the data rate of single-speed CD-ROM drives and enabling 72 minutes of video to be packed onto one CD. This opens the way for movies and music videos on CD, as well as wider use of full-motion video in CD-based games, training and educational software. But MPEG standards offer a range of compression ratios suitable to media and quality requirements beyond CDs.

There are trade-offs, of course: the greater the compression, the lower the quality. MPEG-2 achieves higher quality than MPEG-1 at higher bit rates; at lower bit rates, the two methods are roughly equivalent. While the inverse relation of compression ratio to quality is inescapable, the quality vs. bitrate curve as a whole can be raised by applying human-assist techniques.

In other words, human-assist encoding provides significant improvements in quality at a given bit rate. It makes possible the cost-effective use of hybrid fiber/coax phone systems, digital cable systems and direct broadcast satellite for delivery of digital video services and, in the case of the phone and cable systems, which permit two-way communication, interactive services such as video-on-demand. Using MPEG compression, a VHS-quality video stream could be piped over a 1.5 mbps T1 or ADSL [asymmetric digital subscriber line] phone line or broadcast directly to the home via satellite. A fiber/coaxial network could carry up to 500 broadcast-quality compressed channels.

Human-assist Encoding Explained

MPEG performs what is known as lossy compression. That is, it compacts by discarding data. To achieve a compression ratio of 190:1, for example, MPEG-1 must eliminate more than 99 percent of the data in a video stream. Given the extent of the data loss, it is remarkable how much quality is preserved. Nevertheless, some changes in the image are inevitable. These changes, known as artifacts, may include poorer image definition and, in some cases, visible by-products such as blocking, ringing, and jerky, irregular motion.

The goal of intelligent encoding is to minimize the impact of such artifacts, rendering them inconspicuous or even invisible. Success is in the eye of the viewer; it involves many subjective visual and aesthetic judgments. Though MPEG algorithms have been designed to account for some aspects of the human visual response—such as a relative insensitivity to high spatial frequencies—they cannot take into account the unique qualities of individual videos and films.

In other words, automatic encoding can only go so far. It cannot substitute for the trained eye of a video professional. It takes a human viewer to decide what kinds of visual artifacts are acceptable and which are unsightly—to determine, for example, that one artifact is nearly imperceptible because it falls in the edges of the scene while another is a glaring flaw because it shows up in the middle of an actor's face. Having made such evaluations, human operators can then fine-tune the encoding process and apply a range of special pre-processing effects to achieve the best-looking output. Put simply, high-quality video encoding is as much art as science.

In this sense, human-assist encoding is analogous to the telecine process. In telecine, a skilled professional, the colorist, uses methods such as color correction, filtering and noise reduction to ensure that the video version of a movie is as true to the original as possible. The job requires a combination of technical savvy and video artistry. Likewise in human-assist encoding, a highly skilled specialist, the "compressionist," applies techniques such as spatial and temporal filtering, inverse telecine and I-frame placement to reduce artifacts and boost quality.

An Iterative Process

Like telecine, human-assist encoding is an iterative process. The compressionist sets an encoding parameter, views the impact on the video scene and further modifies the parameter until the desired result is achieved. When the compressed video achieves the required quality, the encoding decision is entered on a list, called the encoder control list. Similar to an edit decision list (EDL), the encoder control list (ECL) spells out all the encoding decisions and the time codes at which they are to be executed. The ECL serves as a script for the encoding system, which automatically carries out the desired functions at the time of encoding. The work is incremental: the compressionist optimizes the encoding of a video sequence segment-by-segment.

The compressionist can apply a variety of useful human-assist techniques. Some, such as inverse telecine, noise reduction and color correction, fall under the heading of preprocessing—they treat the video content before it's encoded.

Others, such as I-frame placement and area of attention encoding, are enhancements made in the encoding process itself.

Human-Assist Techniques: Preprocessing Steps

Inverse Telecine

Encoding of video material derived from film can be greatly improved if the duplicate fields inserted during the telecine process are first removed. This removal, called inverse telecine, has several benefits. For one thing, it does away with redundant fields, allowing the compression system to allocate more bits to the remaining unique fields. Second and most important for MPEG 1 encoding, it avoids serious motion artifacts that might otherwise occur if the 3:2 sequence is left intact.

Inverse telecine is therefore essential for high-quality output, and it is a good example of a task requiring manual intervention, since it is too complicated for purely automated solutions. Some encoding systems do feature the ability to perform 3:2 extraction, automatically removing fields in a fixed pattern. This works fine so long as the extraction matches the rhythm of the original telecined video. The problem is that nearly every video derived from film contains disruptions in this cadence, places where film reels were joined or where edits were made subsequent to video transfer. Spotting these phase changes, and readjusting the 3:2 extraction accordingly, is something no automated system can do with complete accuracy. The transitions signaling a cut or splice can be very subtle, and it takes a skilled eye to identify them with certainty.

An ideal encoding system can help the process along in several ways. At a minimum, it should allow the operator to manually detect telecine phase changes and record them in the ECL. Then the encoding system, when recording, can readjust its 3:2 extraction whenever a disruption in the pattern occurs, following the directives of the ECL. Even better, a system could provide some form of automated 3:2 pattern detection. Though, as explained above, 100-percent detection accuracy is not possible, such a system could spot and record the majority of phase changes and allow the operator to manually review the encoder control list before encoding commences. The operator could override any incorrect decisions and/or add new changes missed by the automatic detector process.

Filtering and Noise Reduction

Filtering prior to encoding can be used to selectively screen out image information that might otherwise result in unwanted artifacts. Spatial filtering applies within a particular frame, and can be used to screen out higher frequencies, removing fine texture noise and softening sharp edges. The resulting picture may have a softer appearance, but this is often preferable to a blocking or ringing artifact. Similarly, temporal (recursive) filtering, applied from frame to frame, can be employed to remove temporal noise caused, for example, by grain-based irregularities in film. Motion may be slightly blurred as a consequence, but this is nevertheless better than the alternative (visible artifacts).

Even when encoding is being performed on a high-quality D1 source, filtering still has its uses, such as avoiding certain motion artifacts that can crop up during decoding. These artifacts can result from the field doubling that takes place during decoding, when the SIF-resolution image is restored to full CCIR 601 resolution. As the duplicated fields are then interleaved during display, diagonal lines that were originally smooth may become more jagged.

This phenomenon is subtle but may become noticeable in instances where edges are very sharp and are moving (e.g., scrolling titles), producing jittery movement. In that case, temporal filtering can be used to blur the motion slightly, mitigating the jittery motion artifact.

Whatever the reasons for its application, temporal filtering should ideally be applied after inverse telecine (in the case of film-based material). These filters tend to reduce differences among adjacent fields or frames, making it more difficult to detect telecine phase changes.

Color Correction

Color correction can be used in much the same way as filtering. It can smooth out uneven areas of color, reducing the amount of data the MPEG algorithms have to contend with, thus eliminating artifacts. Likewise, adjustments in contrast and brightness can serve to mask artifacts, achieving some image quality enhancements without noticeably altering the video content.

Human-Assist Techniques: Encoding Enhancements

I, B and P Frame Pattern Adjustment

The ideal pattern of I, B and P frames depends on the motion in the scene. For example, in situations with greater motion and hence rapidly changing picture content, it may be better to have more frequent I-frames (hence more reference pictures) Sequences with little motion, on the other hand, are better served with less frequent I frames and more frequent B and P frames. Systems which permit adjustment of the frame sequence on a timecode boundary give users greater flexibility in matching the compression strategy to the video content.

I-Frame Placement

In addition to re-setting the pattern as a whole, users can benefit from the ability to manually place I frames at selected points in the video, particularly at the beginning of scenes, and at the end of fades and wipes. At these points the picture content changes completely, making the predictive intercoding of P and B frames less effective. An I frame, which is intra-coded, ensures that the new scene starts with a high-quality image.

Entry Point Insertion

In addition to placing I frames, compressionists may need to place entry points—spots in the MPEG stream where decoding and playback can begin. This is critical in interactive video applications such as games, training and educational products. Creating an entry point consists of inserting an I frame preceded by a "group of pictures" header (GOP). The header information is necessary to initiate MPEG decoding.

Area of Attention Encoding

Ideally, compressionists should have as fine-grained a control over encoding as possible. They should be able to control the allocation of bits not only from frame to frame but also within the picture. That way, the compressionist could assign more bits to the particular region of the picture where the viewer's attention is focused. Take, for example, a scene in which a television reporter is standing in the lower left corner of the picture, flanked by a large crowd. The compressionist could define the lower left corner as the area of attention, sharpening the reporter's image, while permitting the crowd to appear somewhat softer.

Integrating The Encoding Environment

It goes almost without saying that compressionists need some way to control and synchronize the tools they wield. The encoding system itself can serve as a centralized point of control, provided it has the necessary control facilities, user interface and the ability to manage external equipment such as VTRs, noise reduction and color correction units. With time, encoder systems may come to include many of their own preprocessing functions, making it even easier to control the entire compression process through the encoder.

While encoder-based control will appeal to many users, others may prefer to run things through their familiar edit controller system. In such cases, it would be helpful if the encoder could function as a controlled device alongside other components in the edit bay.

Another important integration feature is the ability to import existing edit decision lists in standard formats. The encoder could then incorporate relevant aspects of these EDLs—time codes for edits and scene changes, telecine phase information, etc.—into its own encoder control list (ECL).

Summary: The "compressionist" process

The human-assist encoding process is a new step in video-post-production. Uncompressed video (YUV or D1) enters the encoding system from a VTR or other source. The compressionist, using the control interface of the encoding system, performs a series of adjustments in the configuration of the encoding engine, previewing the results on a monitor attached to the encoder. Working in iterative fashion, the compressionist applies inverse telecine (where appropriate), spatial filtering, noise reduction, I-frame placement, area of attention encoding and entry point insertion. These decisions are captured in the encoder control list (ECL). The ECL is then read by the encoder when it compresses the video in real-time. The work proceeds incrementally, scene-by-scene. As each segment is compressed, it is appended to the finished MPEG file.

DIGITAL TELEVISION EXCITER AND RECEIVER FOR SATELLITE NEWS GATHERING: DIGITAL SATELLITE LINK PERFORMANCE

Frank N. Longo, Jr.
Satellite Transmission Systems
(A California Microwave Company)
Hauppauge, NY

Jay C. Adrick
Harris Allied
Florence, KY

ABSTRACT

The move toward digital transmission of television signals presents new opportunities and advantages to broadcasters when compared with today's analog links. This is particularly evident in the transmission of television signals by satellite where the application of digital technology will have a positive impact through greater utilization of transponder resources, lower operating costs and improved link performance. A new digital satellite news gathering (DSNG) exciter/receiver built specifically for the SNG environment has been developed and will be discussed in this paper,

INTRODUCTION

Creating a new generation of Compressed Digital Television (CDTV) products for satellite news gathering required attention to a variety of issues such as cost effectiveness, high performance, flexible architecture, compact size, low weight, and a rugged design appropriate for small vehicles and fly-away terminals. A digital satellite news gathering (DSNG) exciter and studio-grade receiver has been developed to satisfy these requirements with an integrated design architecture that combines the following technologies in one package.

- MPEG-2 Encoder
- QPSK Modulator
- Frequency Upconverter
- Control and Monitoring CPU
- Universal Power Supply

The adoption of a single integrated product architecture provides DSNG operations with size, weight, cost and operational advantages when compared with alternative solutions that require multiple chassis configurations to provide encoding, modulation and frequency conversion elements.

The digital TV exciter incorporates advanced digital video encoding technology originally developed for rugged defense applications, QPSK modulation, C, Ku or X-band frequency conversion, and a control processor in a single, six-rack unit (10.5" high) chassis. Technical performance criteria have been established to meet the international MPEG-2 compression standard (with I, P and B frames) at the main profile, main level, and the CCIR 601 standard for broadcast quality signals. User selectable data rates provide the flexibility to operate over a wide range of worldwide satellite resources, while providing acceptable picture quality under difficult broadcasting conditions.

The DSNG exciter and receiver provide operator-selectable data rates of 2, 3, 4, 6, and 8 Mbps with video resolution of 720 x 480 (NTSC), 720 x 576 (PAL) or SIF. Since picture performance will vary as a result of the signal processing differences at each data rate, special attention has been given to motion compensation, picture stability, and signal robustness, the latter being essential in ensuring that digital TV signals are free from errors which can cause aberrations resulting from multiple signal processing operations. Superior motion compensation is achieved through enhancements to the MPEG-2 algorithm. Latency has been reduced to 0.5 seconds at 8 Mbps, an acceptable figure for satellite news gathering operations.

The integrated architecture adopted for the CDTV exciter and studio-grade receiver was driven by three operational needs:

1) The first being a recognized need for a lightweight, efficient, compact unit. This desire also produces a lower cost since the common elements such as the

CPU, Local Control Panel, Power Supply and, to an extent, the cooling arrangement will be common to all elements.

2) Second was to provide a modular and flexible design that could accommodate the changing needs of the DSNG market by the replacement of existing modules with newer technology, features or performance characteristics as they become available and desirable. For example, the Ku-band frequency converter can simply be replaced by a C-band converter, and the 8 Mbps modulator can be replaced by one capable of handling up 16 or 25 Mbps.

3) Thirdly, we looked at providing a simple user interface with the means of controlling the three major elements (encoder, modulator and frequency converter). In a conventional system this would require setting up three separate elements, and would require the operator to learn the various procedures for control and setup. The integrated architecture enables the individual elements to be harmonized under the control of a single CPU to simplify the operator involvement by automating many of the setup procedures required for proper operation of the exciter elements.

This paper discusses the key transmission parameters required for utilization of the DSNG exciter and receiver over a variety of satellite systems (domestic, regional, and international). The results of several typical link calculations are provided to demonstrate the advantages of compressed digital TV in terms of efficient transponder utilization as well as antenna size versus transmit power requirements. Finally, discussions are provided concerning the picture performance of digital TV programs, exciter and receiver operational features, and issues of importance to users who wish to combine digital TV and analog TV in a single transponder.

TRANSMISSION PARAMETERS

Broadcast television SNG requirements are predominantly Single Channel Per Carrier (SCPC) since this environment typically requires that one program be uplinked from a single location. This differs from the multiple-channel transmission requirements of DBS services, network program distribution, and cables head-ends, which must have all programs back hauled to a single uplink site. The digital TV exciter and studio-grade receiver are designed specifically for the single-channel requirements encountered in DSNG.

The exciter will accept component serial digital (CCIR 601) or analog video (composite or component), digital audio (AES/EBU) or two channels of analog audio, and a 64 Kbps auxiliary data channel. The aggregate data is convolutionally encoded (rate 3/4 FEC) with Reed Solomon concatenated coding, and QPSK modulated onto a 70 MHz IF carrier. Frequency conversion is either C, Ku or X-band depending upon the module selection.

The high performance studio-quality receiver allows compressed digital TV to be edited and rebroadcast for distribution to disparate locations. The receiver is designed with a feature and specification set equivalent to the exciter; the input, however, is L-band for use with low cost LNB's.

The studio-grade receiver will operate at an Eb/No threshold (the point at which no digital artifacts are visible) of approximately 4.8 dB; the receiver ceases to function entirely at an Eb/No of 4.5 dB. A typical satellite link would be designed to provide an Eb/No exceeding this figure for a specific availability and bit error rate (for example, an Eb/No = 5.8 dB provides a BER of 1 x 10-7). This facilitates the transmission and reception of exceptionally robust digital signals that can be concatenated several times with no aberrations due to the satellite link. Table 1 provides the guaranteed BER for a specific Eb/No with Reed-Solomon (RS) outer code. These figures comply with IESS-308 (Rev. 7), Appendix G: "Concatenation of Reed-Solomon Outer Coding with The Existing FEC."

Table 1.
BER versus Eb/No with RS Outer Code

BER	Eb/No, Rate 3/4 FEC
10-3	5.1 dB
10-4	5.3 dB
10-5	5.5 dB
10-6	5.6 dB
10-7	5.8 dB
10-8	6.0 dB
10-10	6.3 dB

A key advantage of digital compression is the resultant decrease in transponder bandwidth and power resources required for a TV program. Table 2 presents the carrier occupied bandwidth (with and without adjacent carrier spacing) corresponding to each operator selectable data rate, and the maximum number of carriers that can be uplinked to a single 36 MHz transponder. These calculations are based on IESS-503, "Performance Characteristics for Digital Television Transmission." The aggregate information data rates used for the calculation include compressed digital video and audio, framing, a 64 Kbps auxiliary data channel, and Reed Solomon outer code overhead. The symbol rate calculation is based on 3/4 rate FEC and QPSK modulation.

Table 2:
Data Rate and Occupied Bandwidth (OB)

Data Rate (Mbps)	Aggregate Rate (Mbps)	OB (MHz)	OB w/adj. carrier spacing (MHz)	No. Carriers (per 36 MHz)
8.192	9.216	7.4	8.6	4
6.144	6.912	5.5	6.5	5
4.096	4.640	3.7	4.3	8
3.072	3.615	2.9	3.4	10
2.048	2.368	1.9	2.2	16

The channel data rates listed in Table 2 include compressed video and the associated audio program. Table 3 provides the associated audio channel data rates.

Table 3: Audio Channel Data Rates

Channel Data Rate (Mbps)	Audio Channel Data Rate (Kbps)
2.048	96
3.072	96
4.096	128
6.144	196
8.192	196

SATELLITE LINK ANALYSES AND RESULTS

Typical link budgets have been performed for a variety of satellite systems to demonstrate the impact on antenna size and transmit power when utilizing the CDTV exciter and receiver in an SNG vehicle or fly away terminal. These calculations have been performed for single 2, 4 and 8 Mbps carriers over the following satellites:

Ku-Band	C-Band
TELSTAR 4 (US)	INTELSAT (Africa)
GSTAR 4 (US)	INTELSAT (Latin America)
EUTELSAT (Europe)	
PANAMSAT (Latin America)	
ASIASAT (Asia-Pacific)	
INTELSAT (Europe)	

All Ku-band links, including the minimum studio receive antenna size, have been optimized for approximately equal percentages of bandwidth and satellite power. This is an important consideration since the amount of transponder power required for the link is directly related to the cost of space segment. C-band links utilize a 9.0M receive antenna -- a typical size likely to be encountered.

The link analysis parameters common to all the examples are summarized in Table 4. A system fade margin is included in the calculations to ensure that each satellite link is available for a minimum of 99.6% of the year. In addition, the required system Eb/No of 5.8 dB is approximately 1 dB above receiver threshold to ensure that there will be no degradation in picture performance due to the satellite link.

Table 4: Link Parameters

Information Rate	2, 4, 8 Mbps
Code Rate	3/4
BER	1 x 10-7
Required System Eb/No	5.8 dB
Modulation	QPSK
Uplink Line Loss	2 dB (Ku); 1 dB (C)
Single Carrier HPA Back-Off	3 dB
Ku-Band LNB	120 K
C-Band LNB	50 K
Minimum Joint Availability	99.6%

The tradeoff between antenna size and transmit power is depicted in Tables 5.0 to 5.5 for Ku-band links and Tables 6.0 to 6.1 for C-band links. The minimum SNG terminal antenna size for each data rate was selected to prevent the transmit power amplifier requirement from exceeding 300 W at Ku-band and 400 W at C-band. Compact TWT and SSPA transmit power amplifiers are commercially available within these power ranges and in packages that typically do not exceed 3U in height. The link analysis results demonstrate that entire digital TV satellite uplink comprised of an exciter and transmit power amplifier is possible in 9U or 15.75", with antennas ranging in diameter from 0.95M to 2.4M.

Table 5.0: Ku-Band Link Over TELSTAR 402 (US)

Satellite: TELSTAR 402
SNG Uplink Location: Los Angeles
Studio Location: New York
Studio Antenna: 3.2 M
Availability: 99.8%

Data Rate (Mbps)	%EIRP / % BW	0.95 M	1.8 M
2	4% / 4%	62 W	17 W
4	8% / 8%	120 W	33 W
8	16% / 16%	228 W	64 W

Table 5.1: Ku-Band Link Over GSTAR 4 (US)

Satellite: GSTAR 4
SNG Uplink Location: Dallas
Studio Location: New York
Studio Antenna: 4.5 M
Availability: 99.7%

Data Rate (Mbps)	% EIRP / % BW	0.95 M	1.8 M
2	5% / 4%	254 W	71 W
4	10%/ 8%	--	136 W
8	17% / 16%	--	246 W

Table 5.2: Ku-Band Link Over EUTELSAT (Europe)

Satellite: EUTELSAT II SMS
SNG Uplink Location: Europe
Studio Location: London
Studio Antenna: 3.6 M
Availability: 99.8%

Data Rate (Mbps)	% EIRP / % BW	0.95 M	1.8 M
2	3 % / 3%	217 W	61 W
4	6% / 6%	--	116 W
8	12% / 12%	--	219 W

Table 5.3: Ku-Band Link over PANAMSAT (Latin America)

Satellite: PANAMSAT 3R, NA Beam
SNG Uplink Location: Buenos Aires
Studio Location: New York
Studio Antenna: 3.6 M
Availability: 99.8%

Data Rate (Mbps)	% EIRP / % BW	0.95 M	1.8 M
2	4% / 4%	121 W	34 W
4	8% / 8%	232 W	65 W
8	15% / 16%	--	123 W

Table 5.4: Ku-Band Link Over ASIASAT (Asia-Pacific)

Satellite: ASIASAT-2
SNG Uplink Location: S. Korea
Studio Location: S. Korea
Studio Antenna: 3.6 M
Availability: 99.8%

Data Rate (Mbps)	% EIRP & % BW	0.95 M	1.8 M
2	4% / 4%	88 W	25 W
4	8% / 8%	168 W	47 W
8	13% / 16%	300 W	84 W

Table 5.5.: Ku-Band Link Over INTELSAT (Europe)

Satellite: INTELSAT VIIA, Spot Beam
SNG Uplink Location: Sarajevo
Studio Location: New York
Studio Antenna: 4.5 M
Availability: 99.7%

Data Rate (Mbps)	% EIRP / % BW	0.95 M	1.8 M
2	3% / 3%	217 W	61 W
4	6% / 6%	--	120 W
8	12% / 12%	--	235 W

Table 6.0: C-Band Link over INTELSAT (Africa)

Satellite: INTELSAT VII, Hemi Beam
SNG Uplink Location: Cape Town
Studio Location: London
Studio Antenna: 9.0 M
Availability: 99.97%

Data Rate (Mbps)	% EIRP / % BW	2.4 M
2	3% / 3%	58 W
4	5% / 6%	115 W
8	10% / 12%	224 W

Table 6.1 C-Band Link Over INTELSAT (Latin America)

Satellite: INTELSAT VII, Hemi Beam
SNG Uplink Location: Rio De Janeiro
Studio Location: Miami
Studio Antenna: 9.0 M
Availability: 99.97%

Data Rate (Mbps)	% EIRP / % BW	2.4 M
2	2% / 3%	79 W
4	4% / 6%	155 W
8	8% / 12%	302 W

Data Rate & Picture Performance

The exciter and studio grade receiver provide the television broadcaster with the ability to select data rates for optimum use of available transponder resources or to meet the demand of program material being transmitted. This selection requires that the broadcaster or DSNG operator make a tradeoff between picture performance and satellite bandwidth availability. In general, higher data rates provide better picture performance for high motion content, high resolution images that may be concatenated during double satellite hops or studio editing. Lower data rates may be more appropriate for lower motion pictures that can be transmitted at SIF resolution.

A fast breaking news event may warrant sacrificing some picture performance in exchange for the timely transmission of the event over limited transponder resources. The environments that produce fast breaking news are typically harsh and the analog TV source material is usually noisy. Signal and noise are digitized and compressed with an attendant impact on picture performance. For this reason, acceptable TV picture performance may not require selection of the highest available data rate. The flexibility to make this determination, however, is the key advantage of digital TV transmission over satellites. Additionally, narrow band digital TV carriers can be located virtually anywhere in a transponder, provided sufficient bandwidth and power is available for the data rate chosen.

The exciter and studio grade receiver have been tested for robustness and artifact generation in multiple processing (concatenation) applications with favorable results. An 8 Mbps signal can be concatenated through the exciter and receiver approximately three times before artifact generation becomes objectionable to the trained eye. The picture content utilized for these tests included full motion images with production effects, fast scene switching, scrolling graphics, and sporting events.

Operational Features

Voice or data communications for coordination purposes may be essential in certain applications (such as the transmission of "fast breaking news" news) prior to uplinking TV. For this reason, consideration has been given to the need to transmit one-way voice or data prior to and during the transmission of digital TV. The exciter provides a 64 Kbps auxiliary data channel that can be used in conjunction with an external data concentrator or voice/data multiplexor to provide these utility functions. The auxiliary channel is multiplexed into the aggregate bit stream within the modulator element of the exciter.

The exciter is packaged in a single 6U (10.5" high) chassis that is 19" rack mountable and weighs approximately 70 lbs. (32 kg). This makes integration into existing or new SNG vehicles and fly-away terminals fairly straightforward. It is worth noting that although the weight of the exciter is greater than the equivalent analog TV equipment, overall terminal weight will decrease since antenna and power amplifiers become smaller.

The exciter and receiver are monitored and controlled from a user friendly control panel that provides a bright display of set-up functions, operating status, summary alarms and fault status. All set-up parameters for a particular link (e.g., video format, data rate, frequency, etc.) can be stored in any of up to twenty non-volatile memories that are front panel accessible to simplify start-up. Local or remote control is also selected from the front panel. For remote control, an RS 232/485 serial interface is provided for PC based control and monitoring.

Additional utility features include a continuous wave (CW) mode in the exciter that allows an unmodulated carrier to be uplinked for line-up testing, real-time BER and Eb/No measurements in the receiver to monitor link performance, and a temperature monitor in both units that can be used to alert the operator if maximum operating temperature is exceeded. The latter is particularly important since fly-away terminals may be deployed in harsh, high temperature environments from time-to-time.

Simultaneous Broadcasting of Analog and Digital TV

The transition from analog to digital TV is expected to be gradual, and may require that both analog and digital TV carriers utilize the same transponder resources simultaneously. Since digital TV carriers are robust and narrow band, they can be uplinked to transponders that may also be transmitting one or two analog TV programs. In applications such as these, the digital TV carrier can be placed in-between the analog TV programs for a simultaneous broadcast with no degradation in the performance of either program.

For digital and analog TV carriers that are uplinked from the same earth terminal, special consideration should be given to the uplink configuration. A single channel of analog TV is typically uplinked with a TWT power amplifier (PA) operated with little or no back-off. For multiple carriers, however, approximately 7 dB of back-off is typically required to ensure linear PA operation and to prevent intermodulation products. DSNG operators may need to consider uplinking digital and analog TV programs with separate transmit power amplifiers.

CONCLUSION

Digital technology and innovation have come together to make the transmission of compressed digital television signals possible with many potential long terms benefits for DSNG operations worldwide. There is little doubt that technology will continue to improve the performance, features and applications of digital video compression and transmission. We believe that the CDTV exciter and receiver discussed in this paper demonstrate the advantages of digital television transmission for SCPC satellite news gathering operations.

THE PBS ATV HANDBOOK: A PRACTICAL APPROACH TO THE RF CONVERSION PROCESS

William Zou and Matt Tietze
Public Broadcasting Service
Alexandria, VA

Thomas Vaughan
T. Vaughan & Associates
Manchester, NH

ABSTRACT

Adding an advanced television (ATV) RF system to an existing TV facility will be difficult and complex. Each station will require different design plans due to location, tower mechanical constraints, new channel assignments, ERP and coverage; no single conversion plan will satisfy even a small number of stations. To help its member stations prepare for the ATV RF conversion process, the Public Broadcasting Service (PBS) commissioned T. Vaughan & Associates to develop an ATV RF system feasibility handbook.

This paper presents a synopsis of the PBS ATV RF system feasibility handbook. Key elements of ATV conversion such as planning factors, pricing, and equipment are discussed. The mechanical constraints of the tower will be the limiting factor, since most stations will be forced by budget constraints and regulatory factors to use their existing tower. Examples of typical feasibility conversions including equipment list price will be presented for two PBS member stations.

OBJECTIVES OF HANDBOOK

With the progress of testing and standardization of the Grand Alliance (GA) HDTV system in the United States, it is expected that the FCC will adopt an advanced television system standard in 1996. The conversion to the ATV service will start right after the standard is adopted. As indicated by the FCC, the conversion will be a multi-stage process lasting fifteen years. Each eligible station will have three years to apply for a construction permit and six years to complete construction after the release of the ATV standard. As the schedule for conversion of ATV service in the U.S. advances and the date for implementing the new service appears on the horizon, stations must prepare plans to insure proper funding for conversion and to allow negotiation of licenses, leases, zoning, etc.

One of the main objectives for PBS is to assist its member stations in planning a major conversion that they will all be faced with in the not-to-distant future. This handbook is intended to provide management and engineering personnel with up-to-date information on advanced television (ATV) RF system implementation. It deals specifically with the station RF plant and what steps must be taken to get an ATV signal on the air. It is based on the FCC decisions and preliminary proposals to date as well as information obtained from the industry sponsored Advisory Committee on Advanced Television Service (ACATS).

HANDBOOK LAYOUT

A reference book dealing with a process as complex as ATV RF conversion needs to be clearly and efficiently laid out. To that end, the PBS handbook is designed with chapters that literally walk the reader/user through the process. After an introduction of ATV background, a flowchart of the entire conversion process is presented, and each chapter which follows also begins with a similar, more detailed flowchart.

Overall, there are six chapters making up the process portion of the book, followed by a chapter containing two ATV RF feasibility studies and a final chapter with appendices and reference material. The handbook chapters are titled as follows:

I. ATV Background
II. Regulatory, Scheduling, and Licensing
III. Tower Use and Alliances
IV. Coverage
V. Tower Stress Analysis
VI. System Proposal
VII. System Selection and Reporting
VIII. Example Feasibility Studies
IX. Appendices and References

I. ATV Background

The introductory chapter contains information on the development of ATV in the U.S., details of the structure and activity of the FCC Advisory Committee on Advanced Television Service (ACATS). To give readers comprehensive knowledge on the GA HDTV system, detailed system specifications are provided. Five sections describe the GA video picture format, video compression, audio compression, transport layer, and transmission system along with the system block diagram and table.

II. Regulatory, Scheduling, and Licensing

Chapter II discusses the regulatory, scheduling, and licensing aspects of implementation. Details of the current implementation schedule and the proposed FCC positions on various licensing items are included. Typical RF system cost factors are presented for various arrangements. The proposed ATV allocation tables are also discussed and referenced in the appendix.

Implementation schedule

The FCC has proposed an ATV implementation schedule based on an initial date when both the final channel allocation table and the final report and order have been released. After this date, stations may apply for ATV construction permits. Based on the schedules, a forecast of when stations will begin ATV operation is presented. The estimated ATV station implementation forecast can be used to determine industry capacity, and assist planning in specific markets.

License issues

The ATV licensing process has not been formally defined by the FCC, however some preliminary decisions have been made and other positions can be inferred. The preliminary and presumed positions of the FCC regarding ATV licensing are discussed. Also, a table which compares current NTSC position and proposed or likely position is given.

Channel allocation

A preliminary channel allotment/assignment table and the assumptions for its creation was released in January 1992. This table provided ATV conversion channels for each existing station in the U.S. The table lists the city of license and the channels allotted. More recently, MSTV, NAB, PBS and other broadcasters have submitted an alternate proposal to the FCC, where a specific channel is assigned to each station. Both the FCC proposal and broadcaster proposal are included in the appendix.

Implementation options and cost factors

In this section various implementation scenarios are discussed and presented. Initial implementation scenarios for both studio and RF portions of the system are defined in two stages: minimal and transitional. Block diagrams of typical station implementations are presented. Also, descriptions of the four types (two studio, two RF) are given.

The budget costs and typical parameters for several RF system variations are summarized. Costs are given for the equipment required to obtain coverage to a specified distance at various heights above terrain. The cost of implementation varies widely based on the set of pre-existing conditions, the scenario chosen, and the coverage required.

III. Tower Use and Alliances

This chapter discusses tower use and multichannel sites. The possible options for location of the ATV system must be defined before any study of the structure can be made. Alternatives to consider and costs for new tower installation are given as references.

Options

The most important part of defining a feasible ATV RF system implementation is finding a suitable location to mount the new ATV antenna and feedline. Many issues regarding selection of the best antenna location are technical. However, it is the economic and political issues that will probably decide the final choice. Other options include moving to an alternate site (either combined with another station or alone), or constructing a new tower site.

1. Current Site

The benefits of using the current NTSC transmitter and antenna location are significant from both a technical and a economic viewpoint. The use of common transmitter space, heating, ventilation and air conditioning (HVAC) systems, security, program input equipment (PIE), and other existing equipment will help lower overhead and start-up costs for the ATV operation. This may or may not be possible based on the station's current situation. A self-evaluation questionnaire is provided to assess a station's options.

2. Alternate site

If the current site cannot be used, an alternate site should be explored if sites near the existing location can share a combined common antenna. The alternate site should ideally be within a two mile radius of the current site to avoid channel assignment conflicts. Movement beyond two miles may require a change in the allotment or assignment of channels in that location.

3. New Site

If both of the options above do not produce an acceptable location for the ATV system, the construction of a new tower site should be considered. The advantages of a new site are obvious: total control of the structure, ability to choose tenants and partners, ability to design the structure for anticipated growth, and the ability to design a multichannel site and generate lease income.

The problems are unfortunately almost as obvious: the total cost, locating a site, obtaining the numerous approvals and permits, and dealing with tenants. A table is presented showing the costs and land requirements for typical medium to heavy duty guyed triangular towers of 500, 1000, 1500 and 2000 feet in height. The costs for a loaded tower include manufacture basic installation and relative costs as a function of the anchor distance to height ratio for both no ice and 1/2" ice loads are given. Real estate costs, which will differ at each location, are not included.

Multichannel operation

The use of a common site for each market has been recommended by the FCC. They suggest this as a way of reducing the costs and technical complexity of ATV implementation as well as ensuring the site remains within the FCC planning factor for interference. Combining ATV stations with ATV stations in all band antenna will provide many options for maximum use of the tower space available. In some installations it may be possible to combine VHF NTSC stations with an ATV station using a common transmission line. In this section both business and technical issues are addressed such as compatibility with the prospective tenants, system management, maintenance, combiner technology, broadband antennas and multichannel transmission line.

IV. Coverage

Chapter IV compares NTSC coverage to ATV coverage, defines peak to average power relationships and ATV effective radiated power (ERP) requirements. Proposed new F(50, 90) propagation prediction curves and their derivation and deployment are also included.

Power relationships

NTSC RF power (and ERP) is defined based on the peak envelope power (rms) of the sync pulse (peak of sync). ATV ERP is based on average power and remains constant over time. In this section the calculation of average and peak power for both NTSC and ATV is shown. Due to its transient nature, the ATV peak-to-average power ratio has to be measured statistically. By understanding the ATV peak-to-average power ratio, the peak power in the antenna and transmission line of multichannel ATV systems can also be calculated.

Coverage parameters

The problem of predicting coverage of an RF service has been around since its inception. It has always been desirable to know how large of an area and more importantly what segment of the population was receiving the signal. Numerous models and methods for predicting the propagation of RF energy radiated by a transmit antenna have been developed, some empirical and others theoretical. In this section, the methodology of NTSC coverage prediction is reviewed first. Furthermore, the transmission and reception characteristics of the 8-level vestigial-sideband (8-VSB) digital modulation system is examined.

Due to the nature of digital transmission, the received ATV signal can be either error-free or unviewable. The ATV coverage area is determined or estimated by the critical symbol error rate (SER), corresponding S/N, average propagation, and receiver system losses. A comparison of the NTSC and ATV UHF planning factors and required field strengths is provided. Also, charts of the ATV F(50,90) coverage and field strengths for variations of tower height, ERP, and distance are presented. Using these and other charts, the coverage of a new ATV station can be predicted.

V. Tower Stress Analysis

A physical inventory of all appurtenance on the tower must be made. The essential elements associated with tower stress analysis are:

1. Worksheets for obtaining appurtenance data are provided to ensure proper and complete information for the stress analysis

2. Determining the appropriate design standard for use in specifying and calculating environmental loads and defining safety factors and allowable member capacities.

3. Evaluating the results of the analysis and determining what modifications, if any, must be made to support the system proposal.

4. Making an economical feasibility determination for incorporating the required modifications.

5. Use of a system stress chart for comparing actual to allowable tower loads.

If modifications are possible, detailed plans need to be developed. Tables with typical modifications for various components along with an indication of their relative costs are provided. A cost estimate for all the necessary modifications including engineering, materials, fabrication, galvanizing, shipping and installation can then be prepared.

VI. System Proposal

Chapter VI presents guidelines for preliminary selection of the correct type of antenna, feedline and transmitter combination. Advantages and disadvantages of various types of current equipment are examined. New technologies are presented that may increase the available options.

System requirements

The main requirement of any ATV system proposal is that the antenna and feedline combination fit in the available aerodynamic envelope while providing the desired coverage for all stations using the system. It is this requirement that drives the proposal and selection of equipment. All alternatives must address and answer to this requirement. It is desirable to have several alternatives available to choose from.

System requirements other than the main requirement are secondary in nature but still must be met to insure a feasible long term solution. Requirements such as sufficient bandwidth, peak-to-average power ratio, power handling, low VSWR and group delay are considered secondary because if the system does not fit in the aerodynamic envelope these requirements are irrelevant.

In most systems the transmission line size and not the antenna will define the aerodynamic limit. The transmitter size will be determined by the transmission line power limitations.

To aid in the decision making, worksheets on transmitter power and ERP are provided. The transmitter power is used when the desired maximum ERP is known and the required transmitter output power is to be determined. The ERP worksheet determines the resulting ERP for a given transmitter output power. The worksheets permit accounting for the three important gain and loss items in the system: the antenna, the feedline, and the transmitter.

Antenna placement alternatives are presented. They cover currently available options for mounting an ATV antenna on an existing or new tower. The advantages and disadvantages of the various mounting options are examined in detail.

Antennas

The choice of antenna type, size, and performance is a complex problem. Generally, broadcast transmitting antennas fall into one of three basic design varieties: dipoles, dipole panels, and slot arrays.

Dipole panel arrays and slot arrays are the two most common antenna types used at UHF frequencies. Dipole panel arrays, being modular in design, can be mounted almost anywhere on the tower and provide highly customized azimuth and elevation patterns. Dipole panels use separate feedlines to each panel. A corporate-feed system of power dividers and cables carries power from the input connector to each of the panels. The inherent broadband capability of the dipole element and the corporate-feed system make the dipole panel an excellent choice for multichannel applications. They have been designed to cover the entire UHF band with excellent performance. Dipole panel arrays can be tower top mounted using a small dimension spline tower for omnicoverage or wrapped around the faces of the tower for directional coverage.

Slot arrays are by far the most common UHF antenna in the U.S. due to their simplicity, reliability, excellent pattern performance, and low windload. A slot array consists of a large diameter (6 to 18 inches) thick walled pipe with slots cut into it. Since the slot elements in this array are in series with each other the bandwidth of these antennas is narrow. These antennas do not make good multichannel systems unless the channels are very closely spaced. Top mount slot array antennas provide optimum omnidirectional pattern circularity and are the preferred arrangement. Side mount slot antennas are affected by the tower steel.

Charts are provided on comparison of various antenna types, multiplex capabilities, polarizations, patterns, number of feedlines and the aerodynamic area per unit length.

Feedlines

The purpose of the feedline is to carry the high power signal from the inside RF equipment up the tower to the antenna input port. It should do this with as little loss as possible while fitting in the available aerodynamic envelope.

The performance of feedlines must be examined with respect to windload, flange reflections, power handling, and attenuation. These issues are discussed in detail and illustrated with charts.

A new device called a dual channel common line coupler that permits and NTSC VHF channel to be combined with an ATV channel into a common transmission line and separated at the tower top so it can be fed to separate antennas is also discussed.

Multichannel combiners

A multichannel combiner is required when it is desired to radiate two or more channels from a common antenna. The combiner must provide total isolation between the channels with as little additional insertion loss and VSWR as possible. It must also be stable and reliable in operation under the environmental conditions required. There are two basic types of multichannel combiners available for use at UHF: constant impedance and star point.

The constant impedance combiner uses two identical filters and hybrids per module. Each module has a narrowband port and a wideband port. Constant impedance types typically are used for higher powered installations since they can be manufactured from waveguide. They are, however, large and expensive.

The star point combiner uses single channel filters for each of the input channels joined together at a common output. This type of combiner is also known as a junction combiner. This combiner must be built for the specific channels of operation. The star point types have provided a less expensive alternative to

the constant impedance modular approach, but typically with less isolation.
The performance characteristics of a combiner is assessed on the number of channels and expansion, power handling, channel spacing, isolation, insertion loss and group delay. Considerations for these items have been compiled in a table as they relate to both of the combiner types.

Transmitters

An ATV transmitter is similar in many ways to a NTSC transmitter. However, the major difference between them is the use of a diplexer to combine the visual and aural transmitters for NTSC versus a single amplifier for the ATV bit stream. This fact should make the conversion of existing NTSC backup transmitters to ATV straight-forward. There are currently five types of high power transmitters available and likely to be used for ATV operation at UHF frequencies.

A) IOT or Klystrode - This transmitter uses a tube which combines the characteristics of the klystron and tetrode tubes. These are commonly single tube devices. They are forced air or water cooled. Good linearity and efficiency are achievable at high power levels.

B) MSDC Klystron - This transmitter uses a tube which is similar to the standard klystron with improved efficiency. They are water cooled and provide very high power from a single tube.

C) Solid State - This transmitter uses many solid state transistor amplifier modules combined together in tree-like fashion to feed a single high power output. Air cooling is used for increased reliability. Solid state transmitters have proven to be highly reliable and easy to maintain. Any module can be removed for service. Power output levels are limited to medium power due to the complexity and cost of the large number of modules and combiners required. New transistors, under development and soon to be released, will provide approximately four times the output power of today's devices. This will allow higher powered, less costly transmitters.

D) Tetrode - This transmitter uses a tetrode tube amplifier. It offers good efficiency and linearity along with air cooling for a low cost. Its single tube output power is lower than a klystron derivative although several tubes can be combined for high power applications. Tetrode tube life is, however, shorter than others and scheduled replacement is suggested.

E) Hypervapor/Tetrode - This transmitter is similar to the tetrode except water vapor cooling is used. This allows more heat to be generated by the tube meaning higher power ratings. It also provides a longer tube life since heat is removed more effectively.

The main requirement for any transmitter is that it amplify the desired signal to high power levels without adding distortion, noise, harmonics and out-of-band products. It appears that a good quality NTSC transmitter should make an acceptable ATV transmitter and that performance levels relating to signal-to-noise ratio, intermodulation, amplitude and phase distortion and harmonics will be similar. A trade-off comparison table is provided to demonstrate the advantages and issues regarding each type of transmitter.

Filters and switching

The RF components between the transmitter output and the feedline provide high power filtering and switching of the output. The switching systems will be similar to those used for NTSC transmitters. Various coax and waveguide switches, switchless combiners and patch panels are used to route the proper transmitter to the load or antenna. The performance specifications on these systems is not expected to change.

A bandpass filter will be required to prevent radiation of intermodulation products by the antenna. This new high-power filter must absorb or reflect the out of band products created by the transmitter. Most of these products fall in the upper and lower adjacent channels. Absorptive filters, similar to an NTSC diplexer in principle, use two filters placed between hybrids and absorb the out of band products in loads. Reflective single filters can be used if the output amplifying device can handle reflected power.

VII. System Selection and Reporting

System installation issues are discussed in chapter VII. Details on the output of the feasibility study and how to evaluate the recommendations are discussed. Guidelines are shown for personnel protection and should be consulted before any tower work is done. The results of a typical radiation hazard study and how to use this information to guide workers is presented.

Installation considerations

Following the preliminary selection of feasible ATV RF system alternatives, examination of installation requirements of the system must be considered. Installation of the ATV system has three major considerations:

1) The room for the ATV transmitter in the existing building.

2) The rigging of the tower for the necessary addition of equipment or modification.

3) Worker safety.

These issues are addressed with examples, layouts and charts.

Bill of materials and costing

To thoroughly evaluate each ATV RF system alternative, a complete bill of materials including all costs must be prepared. The bill of materials should detail the type, size, and where applicable, the manufacturer and model number. System component budget costs including antenna, feedline, multichannel combiner, transmitter and installation are tabulated in this section. These cost estimates can be used for budget analysis of system proposals.

VIII. Example Feasibility Studies

To help station managers and engineers carry out the tasks based on the general procedures, two case studies of ATV coverage and RF system investment are included as examples of how the process is applied. The studies were performed at PBS member stations WKNO in Memphis, TN and KCTS in Seattle, WA. The two stations provide excellent examples of the unique problem of integrating a new service into existing facilities. Both stations are full power Hi-VHF operations.

Four options are proposed for each case study. The changes are made on the tower to accommodate the ATV antenna. The resultant coverage and cost are also provided.

Case study 1: WKNO Memphis, TN

WKNO's transmission facilities are located several miles from the center of town on top of a 988-foot guyed tower. Several other TV and FM operations are located on the tower. Their ATV options are limited due to the heavy current loading of the tower.

WKNO Option 1:

- No change to existing TV stations
- Remove all FM
- Add master FM
- Add single-channel ATV, side-mounted slot
- Coverage: 46 miles
- Transmitter: 11 kW
- Cost: $1.412 million

WKNO Option 2:

- No change to existing TV stations
- Remove all FM
- Add master FM
- Add multichannel ATV panel
- Coverage: 46 miles
- Transmitter: 6.6 kW each
- Cost: $1.207 million

WKNO Option 3:

- No change to existing TV stations
- Remove WKOX-FM, WRVR-FM
- Add single-channel ATV, side-mounted slot
- Coverage: 46 miles
- Transmitter: 7.7 kW
- Cost: $ 836 thousand

WKNO Option 4:

- No change to existing TV stations
- Remove nothing
- Add dual-band coupler on WKNO feedline
- Add single-channel ATV, side-mounted slot
- Coverage: 46 miles
- Transmitter: 5.7 kW
- Cost: $ 692 thousand

Case study 2: KCTS Seattle, WA

KCTS's transmission facilities are located in downtown Seattle on a 500-foot self supporting tower. In addition to the two broadcast tenants, there are a large number of public service and communications antennas located on the tower.

KCTS Option 1:

- No change to existing TV stations
- Remove nothing
- Add multichannel ATV panel
- Coverage: 49 miles
- Transmitter: 11.45 kW
- Cost: $ 775 thousand

KCTS Option 2:

- No change to existing TV stations
- Move FM antenna down
- Add single-channel ATV, side-mounted slot
- Coverage: 49 miles
- Transmitter: 11.4 kW
- Cost: $ 870 thousand

KCTS Option 3:

- No change to existing TV stations
- Remove nothing
- Add single channel ATV side-mounted slot
- Coverage: 49 miles
- Transmitter: 11.4 kW
- Cost: $ 860 thousand

KCTS Option 4

• No change to existing TV stations
• Remove nothing
• Add multichannel ATV panel
• Add duo-band coupler on KCTS feedline
• Coverage: 49 miles
• Transmitter: 9.0 kW
• Cost: 760 thousand

IX. Appendices and References

In this chapter extensive bibliography and glossary are provided. A section regarding satellite and studio to transmitter link (STL) is included. Some options of signal distribution through satellite and microwave are discussed. Also, the proposed allotment/ assignment tables are provided. Finally, a list of RF equipment manufacturers is provided.

CONCLUSION

As the schedule for the introduction of ATV service in the U.S. advances and the date for implementing the new service appears on the horizon, stations must prepare plans for their transition now to insure proper funding. This planning is absolutely necessary to insure that over the next ten to fifteen years terrestrial broadcasting does not become a technological dinosaur. ATV service can provide the link between broadcasters and the information revolution and we must not let the window of opportunity close.

AN EFFECTIVE SPECTRAL USE OF 6 MHZ FOR SPECTRUM FLEXIBILITY

Dae J. Kim, Yong H. Kim, Jong S. Park, and Yung G. Kim
Goldstar Co. Ltd., Image and Media Lab
Seoul, Korea

ABSTRACT

There are more and more needs for mobile communication. COFDM is very effective for moving antennas, whereas VSB modulation is effective for stationary antennas. And most broadcasters who have their own channel want to use the spectrum flexibly and independently.

In this paper a transmission method using the hybrid of VSB and COFDM within 6 MHz is proposed. In designing the spectrum the interference from NTSC was considered. VSB modulation was used for broadcasting high quality TV video signal and the cost evaluation of this system was performed in the points of both broadcasters and consumers. COFDM can be used for the mobile antenna and the data communication on the sub-bands of 6MHz.

INTRODUCTION

By the advent of digital television, the transmission technique of broadcasting becomes similar to that of communication. In digital television video and audio signals are digitized and compressed, and these compressed data are transmitted in the digital levels, for example, bi-levels, 4-levels, 6-levels, or 8-levels, et cetera. By the development of video and audio compression technique the bandwidth of 6 MHz can deliver more data, i.e., programs. Current technology can deliver about 3 ~ 5 NTSC quality programs in a 6 MHz bandwidth.

Broadcasting and communication for mobile antennas have become more and more popular. Special modulation technique is required for mobile antennas, because moving vehicles are always changing their direction and suffer from the multipath fading and Doppler spread fading. So the antenna direction and the fading effects must be considered in designing the transmission technique for mobile antennas. Fortunately COFDM (Coded Orthogonal Frequency Division Multiplexing) techniques[1] were developed and performed well on mobile antennas. It was well proved in the European digital audio broadcasting[3]. The multipath fading and Doppler spread fading can cause the distroion in the received digital signal. In COFDM, we can easily recover or reduce the fading distortion by designing the time domain symbol interval and the guard interval suitably. But we need very much arithmetic operation in the detection process of COFDM signal, mainly for the discrete Fourier transform (DFT). In the viewpoint of the cost, we have a barrier to overcome in the implementation of COFDM transmitter and receiver for digital broadcasting. Practically we have to limit the block length of DFT and we hope that the general purpose digital signal processor (DSP) can be used in detecting COFDM signal. Therefore the required computing power must be considered for the design of COFDM receiver.

Whereas, VSB (vestigial sideband) modulation technique to transmit digital television signal, especially HDTV (High Definition television), was well performed on the stationary antenna[4]. The main advantage of VSB modulation is the data capacity or the spectral efficiency. Even if it has high data rate, the complexity of receiver is low. It has also a good compatibility with the digital cable system which uses 16VSB modulation. The problem of VSB modulation is that it can't make fast equalization, thus it can't be used for the mobile antenna.

By transmitting television signal in digital form, the border of broadcasting and communication was collapsed, thus video data can be delivered through the communication media. Broadcasters who have their own channel have a desire to use the channel flexibly. So we believe they prefer FDMA (Frequency Division Multiple Access) rather than TDMA (Time Division Multiple Access). In other words they want to use their channel independently and accomodate not only television broadcasting but also data services. In this paper a transmission method using the hybrid of VSB and COFDM in a 6MHz channel is proposed. This spectrum is composed of 3 divisions, i.e., left COFDM channel, center VSB channel, right COFDM channel. The division is based on the NTSC picture and color carriers to avoid the interference from NTSC co-channel.

Center VSB channel can deliver about 10Mbps data by use of 8VSB transmission system[5]. This channel is enough to transmit 525 line progressive television signals that we call HQTV (High Quality Television). Authors believe that the HQTV video can be a practical next-step video format because we believe the broadcasters, advertisers, and consumers want the soft transition to the ATV (Advanced TV), i.e., they don't want to spend much money at a time. Availability of broadcasting equipment and the cost of digital home terminal is very promising in these days, which will be discussed in later section.

Fortunately we can use the DSP chip in detection of COFDM signal by reducing the spectrum width, in other words reducing the number of active frequency bins for DFT. One COFDM channel can be used as a broadcasting a LDTV (low definition television) for mobile antenna. The image format will be CIF (common image format) whose resolution will be 352 x 240. This image can be easily made by decimation from 525 progressive video. Thus this channel can be used for simulcasting the HQTV program in a low definition image format which will be discussed in detail.

The other COFDM channel can have many applications. Possible services are pager, digital radio broadcasting, tele-software, data broadcasting for mobile communication. Bidirectional communication can be obtained by using telephone line. The main advantages are the relatively simple implementation, the bandwidth efficiency and various services for mobile communication.

Effective Spectral Design of 6 MHz

With the advance of the digital coding techniques in audio and video signals, there were many attempts to transmit these signals through the NTSC channels. By transmitting these signals in digital format, we can have many advantages. First we can use the taboo channels by reducing the co-channel interferences (CCI) caused by analog NTSC spectrum. And we can transmit the NTSC picture without reducing its quality into a narrower spectrum band. If we want to broadcast digitally in order to get these advantages, there will be many choices in what we design for and how we design.

We can accommodate the HQTV video and audio signals into around 10Mbps data rate with the matured coding techniques satisfactorily. The VSB modulation technique has the high spectral efficiency and relatively simple implementation in synchronization. The HQTV signals can be accommodated within around 3.5 MHz frequency band with 8VSB modulation technique. The remnant frequency bands more than 2.0 MHz can be used in other applications such as LDTV broadcasting, digital radio services, paging services, and data services, et cetera. In this proposal we hope to consider the case to allocate the remnant sub-bands for LDTV broadcasting and the data services for mobile antenna.

In the mobile data communication, the fading distortion from the multipath signal reception and Doppler spreading is a serious problem to be solved. The VSB modulation which is spectrally efficient requires much computing power to estimate the channel states or equalize the channel adaptively. If not estimated correctly, the overall bit error rate (BER) performance will be deteriorated quickly. Therefore there is a limitation in employing the VSB modulation technique in mobile application. As mentioned above, the COFDM technique has a potential to be employed in mobile application because of its strong points against the fading distortion.

In design of the 6 MHz spectrum we can ask a question to ourselves; "Can we adopt the VSB modulation technique or COFDM modulation on the entire 6 MHz spectrum for multi-channel HQTV broadcasting?" Theoretically it is possible, we have to consider the following points. First, in VSB, we should equalize the multipath reception in higher speed than the case of using a section of 6 MHz. And we also have to consider the CCI from the adjacent analog NTSC broadcasting signals. In COFDM, we have to pay a big cost for arithmetic computation in higer speed DFT operation.

Here we come up with the following proposal that we can provide the various services by partitioning the 6 MHz to accomodate the VSB or COFDM techniques actually. The CCI interference problem is avoided by sectorizing the frequency band as shown in Fig. 1. The division is based on the frequency location of the analog NTSC video, color, and audio reference carreirs.

The center frequency band ranges about 3.58 MHz, the left band is about 1.25 MHz, and the right band is about 1.17 MHz. To reduce the cost for sharp band pass filtering of these three bands from 6 MHz

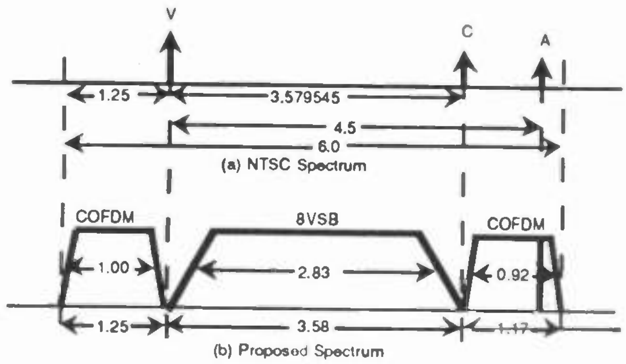

Figure 1. The proposed usage of 6 MHz frequency band.

spectrum, we allow the guard bands at both sides of each three bands. We adopt the enough guard bands not to increase the cost in individual receivers. The left and right bands have 125 KHz respectively, and the center band have 90 KHz at both sides. Also we can design the equal bandwidth of both side bands to be able to use the similar hardware in each receiver.

The right band will be experienced the interference from the audio reference carrier, but this interference will be easily removed by sending zero data into the corresponding frequency bins in COFDM signals.

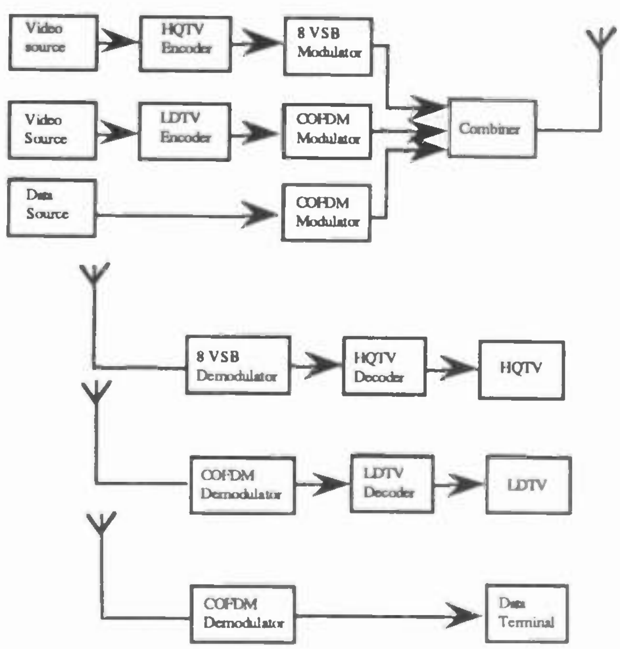

Figure 2. Block diagram for all encoder/decoder and transmitter/receiver systems.

The overall block diagram for our proposal is shown in Fig. 2. Three different services from three different bands within 6 MHz are provided to the subscribers who are supposed to have the receiver for a specific service.

8VSB Modulation and Digital Television Broadcasting

The current status of digital video is that MPEG 2 main level business is in the beginning status especially in the area of satellite and cable digital television. In the broadcasting side camera does not need to modify and many softwares can be used without any modification. The development of the real time encoder of MPEG 2 main level video makes the business of the digital video possible. In home side, the chips of MPEG 2 main level video, audio, transport, and modem, i.e., QAM or VSB begin to available in these days.

The development of HDTV, especially full digital HDTV system, has made a great impact on the industry. HDTV has great image quality and realistic sound, but takes only 6 MHz channel. But broadcasters hesitate to broadcast HDTV due to the system setup cost. The expense of buying broadcasting equipments (i.e., cameras, VCRs, and transmitters), the cost of making the programs, and the lack of available programs are the main cost to setup HDTV system.

We propose 525 line progressive video, i.e., HQTV as a next step digital video, because we believe this format makes a soft transition and the high quality TV broadcasting. Let's compare HQTV system with current EDTV system. Current EDTV system is to transmit 525 interlace videos. These interlace videos can be made by converting the video signals of 525 progressive camera and it can be originally 525 interlace videos. These videos are displayed in the format of 525 interlace or 525 progressive by using line doubler or 1050 interlace also by using line doubler. Whereas HQTV, i.e., 525 progressive videos are transmitted as a 525 progressive video format. These videos come from 525 progressive camera or line doubler which converts 525 interlace video to 525 progressive video. In the receiver side, 525 progressive videos are decompressed and they are displayed in the format of 525 progressive or 525 interlace if current CRT is going to be used.

If we calculate the setup cost, it will not be expensive. For the transmission of HQTV, camera and digital storage equipment can be made by the minor modification from currently existing camera and broadcasting VCR, i.e., D1, D3, and β-cam. The compatibility with NTSC is provided and existing NTSC software can be used by using line doubler equipment which is well proved and available now. It has also a good compatibility with MPEG 2 ML@MP. MPEG2 ML@MP chip can be used by only making speed-up the memory without any further extension of memory size. The HQTV format has very good compatibility with current monitor and VGA computer monitor. 8VSB modulation was used because the ATTC test result was good and cost effective.

The main parameters of video and audio is as follows.

Video

Coding algorithm : MPEG 2 Main Profile
\# of frames per second : 59.94/60.0 Hz, 30.0/29.97 Hz, 24.0/29.97 Hz
\# of fields per frame : 1:1 progressive
Total # of lines per frame : 525 lines
\# of active lines per frame : 480 lines
\# of active video samples per line : 720 samples
Aspect ratio : 16:9
Approximate bit rate : 8.5 Mbps

Audio Algorithm : Dolby 5.1 channel AC-3
Total bit rate : 384 Kbps
Sampling frequency : 48 KHz

Transport Encoder

Output bit rate : 10.24 Mbps

8VSB Transmitter

Symbol rate : 5.66 Msymbols/sec
Roll-off factor = 0.2
FEC : RS + Trellis coded modulation
RS parity : RS[208,188]
Total bandwidth : 3.40 MHz
Trellis encoder rate : 1/2

The designed block diagram of transmitting system is shown in Fig. 3. The video encoder input will be 60 Hz 525 line progressive video and audio encoder will take 5.1 channel Dolby AC-3 audio. These compressed data is multiplexed in the transport encoder. Forward error corrector has Reed-Solomon coding of RS[208,188] and trellis encoder of rate 1/2 to make trellis coded modulation. The roll-off factor was designed to be 0.2 to make the SAW filter cheaper which rejects out-of-band signal and does VSB filtering. This 8VSB system is exactly same with Grand Alliance 8VSB system except symbol rate and roll-off factor.

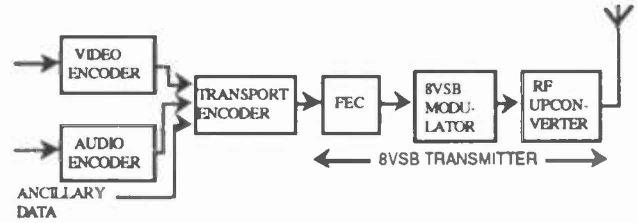

Figure 3. The block diagram of the digital television broadcasting.

The block diagram of home digital television system is shown in Fig. 4. Tuner has the capability to tune from 50MHz to 860MHz. Analog Demod has the function of demodulation, automatic gain control, filtering, and carrier and phase recovery. Digital RX has synchronization, adaptive equalization, Viterbi decoder, Reed-Solomon decoder.

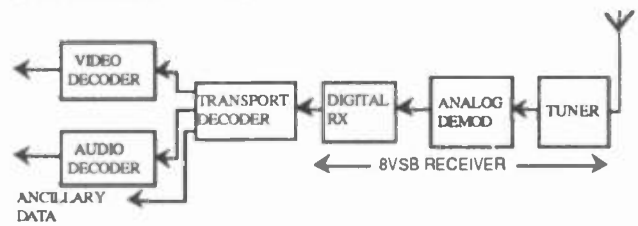

Figure 4. The block diagram of a digital television.

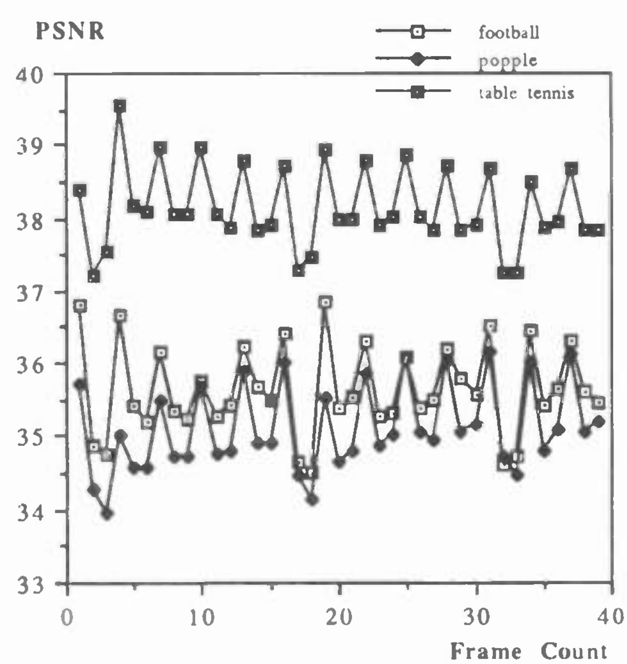

Figure 5. EDTV picture quality in simulation.

We have simulated to see the picture quality in EDTV system. Simulated images were football, popple, and table tennis. The size of GOP (Group of Picture) N is 15, and M value is 3 which means B (bidirectional) pictures are 2 between I (intra) or P (predictive) pictures. The maximum size of motion vectors in case of P pictures was +/-64 horizontally and +/-32 vertically. In case of B pictures the maximum size of motion vectors was +/-32 in both directions. We saw the PSNR (Peak Signal to Noise Ratio) of a HQTV encoded picture and the results are shown in Fig. 5. These images have the PSNR of about 35 dB ~ 40 dB. We can say that the picture quality of these images is quite good.

COFDM and Digital Television Broadcasting for Mobile Antenna.

In this section we cosider an example of the left channel application in mobile LDTV services. To provide the LDTV service for subscribers in mobility, we have to consider the distortion in transmission channel from the multipath and Doppler fading. It is well known that the OFDM modulation technique with coding and (de)interleaving gives a good performance in the point of the cost and the BER performance on this fading channels. And the trellis coded modulation (TCM) with (de)interleaving gives similar performance to a diversity reception.[1] The overall BER performance may be required around 10^{-7} to guarantee the good picture quality.

Fig. 6 shows the LDTV encoder and COFDM transmission system. We adopt the FEC as the RS(208,188) block coder to correct the burst errors in inner coded signal. The outer (de) interleaver is to destroy the burst errors in the inner coded data. This burst error length is much shorter than that from the

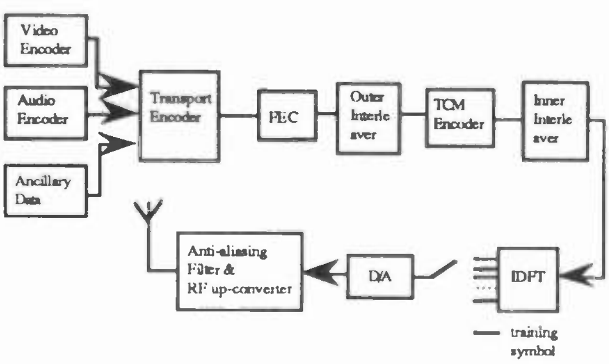

Figure 6. LDTV encoder and COFDM transmission system.

fading. Therefore we have to design the inner (de)interleaver to deploy the TCM coded data not to be distorted in a fading period by separating the same coded data sufficiently[2].

The LDTV decoder and COFDM receiver are constructed simply with inverse operation of the encoder and transmitter.

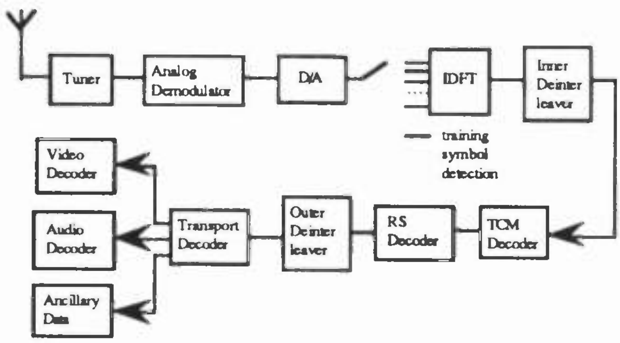

Figure 7. LDTV decoder and COFDM receiver system

Here we provide the COFDM parameters and LDTV system specification. We take into account the maximum delay spread and maximum Doppler spread in guard interval and total symbol interval respectively.

Video

coding algorithm:	MPEG 2 main profile low level
# of fields per frame:	1:1 progressive
# of lines per frame:	288 lines
# of active video samples per line:	352 samples
approximate bit rate:	1.2 Mbps

Audio

coding algorithm:	Dolby 5.1 channel AC-3
total bit rate:	384 Kbps
sampling frequency:	48 KHz

Transponder encoder

approximate output bit rate	1.8 Mbps

COFDM parameters

< Time domain >

sample rate:	2.0 MHz
FFT length:	256
guard interval:	64 μsec

total symbol interval:	320 µsec
< Frequency domain >	
# of carriers:	320
channel width:	1.25 MHz
active signal width:	1.0 MHz
modulation scheme:	16QAM with TCM

The DFT length for one symbol is choosen 256 to be able to apply the FFT algorithm. The required arithmetic oerations for 256 point complex FFT are $(N/2)\log_2 N$ = 1024 complex multiplications and $N\log_2 N$ = 2048 complex additions within a 320µsec symbol duration. That is, the amount of almost 26 x 10^6 arithmetic operation is required for this FFT operation. We think that we can implement this receiver using 2 or 3 general purpose DSP chips to get the amount of computing power.

We have simulated to see the picture quality in LDTV system. We saw the PSNR of a LDTV encoded picture and the results are shown in Fig. 8 with the same pictures as in EDTV simulation. The values of GOP are the same as those in the EDTV simulation. The maximum size of motion vectors in case of P pictures was +/-8 horizontally and vertically. In case of B pictures the maximum size of motion vectors was +/-6 in horizontally and +/-4 in vertically. We also saw the PSNR of the LDTV encoded pictures and the results are shown in Fig. 8. These images have the PSNR of about 27 dB ~ 36 dB, so that we think the quality of these images is reasonably good.

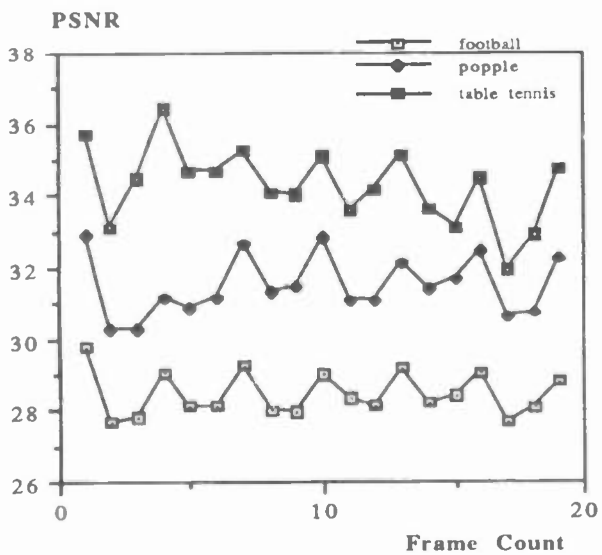

Figure 8. LDTV picture quality in simulation.

Data Communication

In these days the demands on data communication services are rapidly increased, for which broadcasters are willing to adopt these services eventually. Here we consider the case of the mobile data communication using the right frequency band in Fig. 1. At this time we will not specify the type of data communication services because several types can be employed depending on the broadcasters and we can support those services with this right sub-band actually. Currently we think that FAX, pager and digital radio services will be be possible with the change of packet format correspondingly. Hopefully we can use this right band in the private teleconferencing by changing the modulation parameters to improve the overall bit rates.

The right channel will be inevitably interfered by the audio reference carrier of the co-channel signals. We adopt the COFDM modulation to overcome this interference problem by sending null data in the corresponding carrier location. Also we can make the spectrum width as that of the left band to use the similar hardware. This is achieved by simply sending null data on the corresponding frequency bins although we may give an effort for gain control of received signal.

Here we show the maximally achievable transmission rate in the right band.

COFDM parameters

< Time domain >	
sample rate	1.84 MHz
FFT length	128
guard interval	48.9 µsec
total symbol interval	188.0 µsec
< Frequency domain >	
# of carriers	173
channel width	1.17 MHz
active signal width	920 KHz
audio ref. carrier location	795.5 KHz
modulation scheme	16 QAM with TCM
approximate total bit rate	1.4 Mbps

This COFDM receiver requires the arithmetic operation as 448 complex multiplications and 896 complex addition in 188.0 µsec, that is, it requires approximately 19.1 x 10^6 arithmetic operations.

Fig. 9 shows the data transmission system using COFDM modulator. As we can easily imagine, we solved the problems of fading distortion in mobile data terminal and CCI from audio reference carrier by employing the COFDM modulation and null data sending. Bit rates of the data services are varying depending on what data services are employed. For example, the DAB requires around 384 Kbps for a audio channel and FAX service does more than 9.6 Kbps.

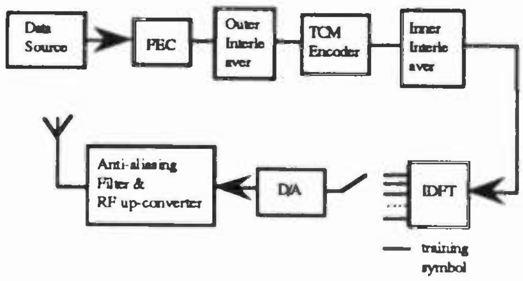

Figure 9. Data transmission system using COFDM modulator.

Fig. 10 shows the block diagram of the data receiver with COFDM demodulator. In this receiver, the general purpose DSP processor can be employed to demodulate the COFDM signal because of the relatively low data retc. The length of a RS coding block has to be chosen depending on the size of the packet length of a service.

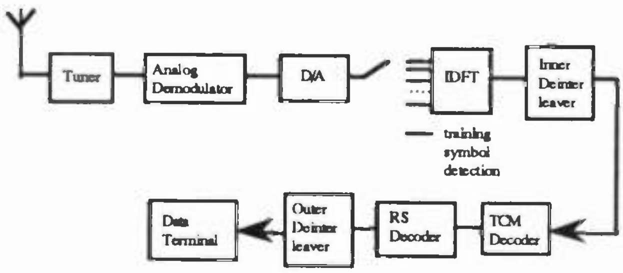

Figure 10. Block diagram for data receiver and COFDM demodulator

Conclusion

We proposed a flexible usage of 6 MHz to accommodate the broadcaster's diverse desire to satisfy the various subscribers requirement. First, we can broadcast the high quality TV using the center 3.4 MHz band only. The remant frequency sub-bands can be used for mobile applications by employing the COFDM modulation techniques. We showed an example to broadcast the LDTV for subscribers in mobility by using COFDM channel and discussed the maximum bit rate to be achieved in the mobile channel. Also we showed a data transmission system in mobile channel using the COFDM technique on the sub-band of 6 MHz.

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A NEW APPROACH TO THE ANALYSIS OF ADJACENT STRUCTURE EFFECTS ON HDTV ANTENNA PERFORMANCE

O. Bendov
Dielectric Communications
Cherry Hill, NJ

Introduction

In the US, many television towers support more than one TV antenna. In major markets these towers were designed to support up to 10 TV antennas and additional FM antennas. Some of these antennas are side-mounted below the top platform. Others are mounted on the top platform. Yet other antennas are mounted on separate towers that may be separated by no more than a 100 feet.

During the 60's and 70's, RCA invested substantially in developing the software that was required for multiple antenna tower design. The challenge was not limited to the expected service degradation resulting from the interaction among the antennas themselves and their interaction with the supporting tower. The challenge extended to include earthquake and wind gusting effects.

As part of the RCA program, operating scaled-down models were built to verify the accuracy of the patterns predicted by the software. For example, the entire top platform of the San Francisco tower with 9 TV antennas was built to 1/10 of its actual size.

The RCA software, developed for the design of top-mounted and side-mounted NTSC-TV antennas, has proved itself through repeated use. Unfortunately that software, in its present form, cannot be used for HDTV design.

In this paper, the method used for the analysis of adjacent structural effects on NTSC-TV antennas will be briefly reviewed. The failure of the NTSC approach to meet HDTV requirements will be outlined, and the proposed procedure for estimating the power penalties and the resulting loss of coverage for HDTV antennas in the presence of interfering structures of will be presented.

NTSC

The analysis and design of antennas for NTSC transmission in the presence of adjacent structures has been based on the minimization of three performance degradation factors as a function of azimuthal angle:

1. Azimuthal pattern distortion at the carrier frequency due to scattering and reflections from adjacent structures.
2. Gain variation across 4 Mhz, sometimes called "video response."
3. Visible echoes of $\geq$ .25μsec delay due to interception and reradiation by other transmitting antennas and towers sharing the same aperture.

Figure 1 is a top view of three antennas sharing the same aperture in a candelabra fashion. The antennas are mounted on a triangular platform and are separated by 50 feet from each other. The channel 4 operating antenna transmits circular polarization and is marked as TDM. The other two antennas are obstructions to the TDM antenna.

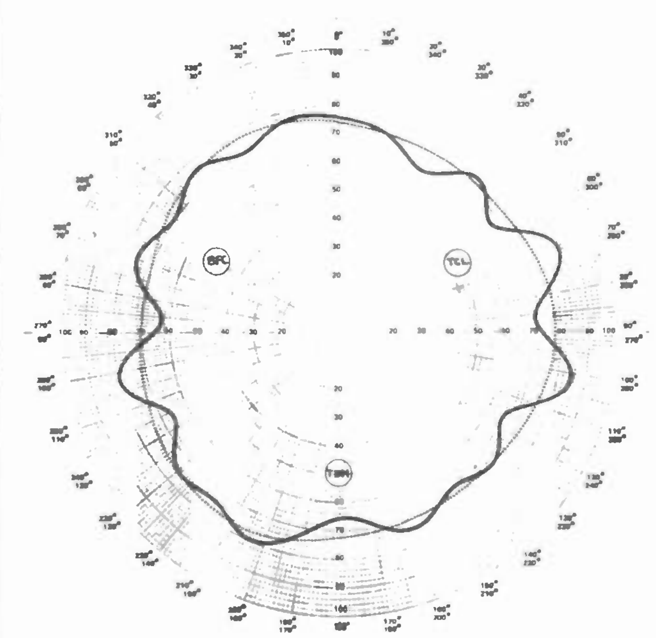

Figure 1.
Free-Space and Scatter Patterns of a Channel 4 TDM Antenna in the Presence of Two Obstructing Antennas.
Calculated at the Picture Carrier of Channel 4.

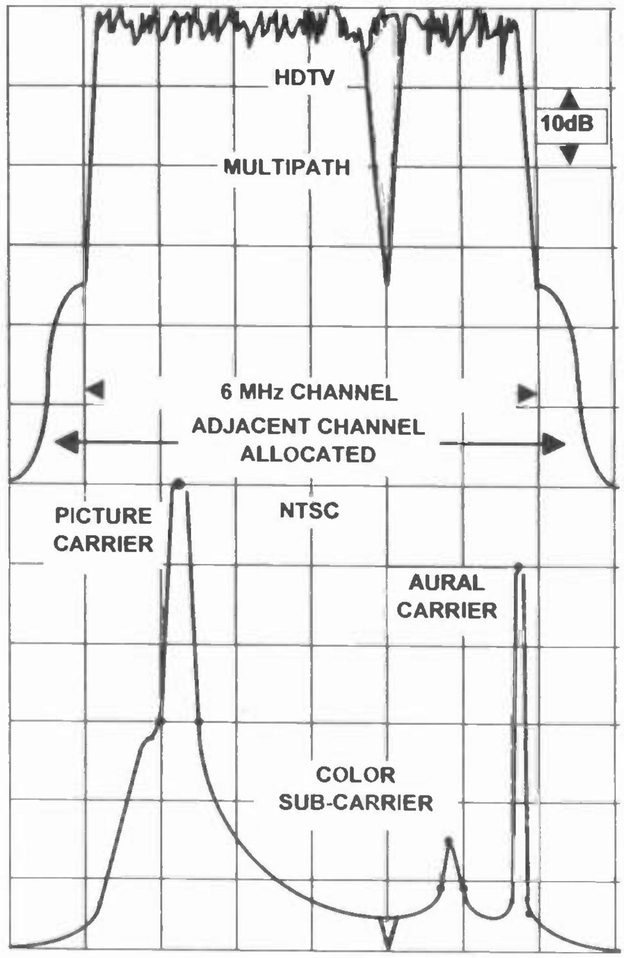

Figure 2.
RF Spectra of HDTV and NTSC.

The azimuthal patterns in Figure 1 are those of the TDM antenna with the interfering antennas (solid line), and without (dashed line). These patterns are normally plotted only at the carrier frequency of the operating antenna because, during program transmission, most of the picture energy is concentrated around the carrier. In effect, NTSC transmission is a relatively narrow band transmission even though three separate carriers occupy the 6 Mhz channel.

The distorted pattern (solid line) shows that in some directions the Effective Radiated Power (ERP), in the presence of the other antennas, increases over the authorized ERP. In other words, the reflections are assumed to add desirable energy so long as the associated picture degradation is acceptable.

Just what is an acceptable degradation has not been well defined. Over the years, two rules of thumb have been successfully used to define what is an acceptable picture distortion due to reflection from adjacent structures:

1. Gain variation limited to ≤ 2 dB over 4 Mhz in the critical directions.
2. Visible echos prevention by limiting the separation between the operating antenna and the interfering structures to a maximum of a 100 feet (≤ .2 μsec delay for a round-trip) and by the insertion of filters in the feed lines of the interfering antennas.

HDTV vs. NTSC

None of the three degradation factors used in the design and analysis of NTSC installations are useful in the design of installations for digital transmission of HDTV where no impairments are visible and where all the distortions and undesired signals, such as reflections, are manifested as reduced service.

The reduction in service can be evaluated from assessing a power penalty against the desired signal for each form of impairment. The sum of the penalties, in dB, is the ratio by which the ERP must be increased in order to restore the intended service. If the ERP cannot be increased, the power penalty translates into a shrinking coverage contour.

Implicit in the application of the power penalty method is that the post-equalizer Bit-Error-Rate (BER) at the HDTV receiver does not exceed $3x10^{-6}$. That may not always be possible under conditions of heavy interference from cochannels, adjacent channels, and impulse noise.

Not only are the three NTSC degradation factors not useful for HDTV, but the use of field strength to define service contours (e.g. Grade B = 64dBμ) is not applicable. This point can be understood by comparing the spectrum of NTSC with that of HDTV (without the pilot tone) as shown in Figure 2. As seen on a spectrum analyzer, the NTSC signal shows the precise locations within the 6 Mhz channel of the picture, color and aural carriers and their relative magnitude. In contrast, the HDTV spectrum, prior to being subjected to multipath and interference, is flat over the channel. That is, no specific carrier can be defined in the same manner as is done in the case of NTSC signal.

Accordingly, the ***useful*** HDTV "carrier" can only be defined as the total signal power, in dBk, within the 6 Mhz channel minus the power lost to the in-band uncorrectible distortions such as intermodulation products.

While the total signal power is useful in determining HDTV coverage contours limited by thermal noise, it is not useful in determining service contours when multipath, impulse noise and interferences are present.

The limited use of the total HDTV signal power for defining service contours in the presence of multipath and interference can be explained by referring to Figure 2 again. In Figure 2, the effect of multipath on both the NTSC and the HDTV spectra is shown as a notch. In the case of NTSC, the notch, located between the Visual carrier and Color subcarrier, has relatively little effect on the quality of the received picture, and no effect on the sound quality. In contrast, the notch in the HDTV spectrum will cause a loss of picture and sound even though the total signal power within the 6 Mhz channel has suffered only a minor change. Even though the notch may result in the loss of picture and sound, the total signal power, represented by the area under the spectrum curve, remains essentially unchanged.

Whereas the equalizer at the HDTV receiver may be able to correct the multipath notch if it is not too deep and if it is not random in its position within the channel, it cannot do so if the notch (or notches) were to result from impulse noise and interference as they vary randomly and fast, anywhere inside the channel. As the equalizer attempts to correct the distorted channel by raising the gain at the deficient frequencies, it inflicts a penalty on the HDTV signal that must be incorporated in the definition of the service contour.

HDTV

In the HDTV environment, the reflections and scattering of the primary signal due to the obstructions are viewed as undesirable multipath[1]. In other words, the structural obstructions to the transmitting antenna are best

[1] It is possible that in some directions, the reflections could be "useful" energy if they assist in equalizing the overall frequency response.

viewed as a filter whose attenuation and frequency response vary with the angle toward the receiver. The effects of the signal lost and frequency distortion due to obstructions in the vicinity of the transmitting antenna, can be quantified as power penalties on the desirable signal.

Penalty Due to the Signal Power Lost to Reflections and Scattering

The difference between the CNR (Carrier to Noise Ratio) of the HDTV channel with and without the obstructions is (Ref. 1):

$$(CNR)_{FS} - CNR = -10Log[\frac{1}{f_B}\int |H(j2\pi f)|^2 df_B]$$

where:

$(CNR)_{FS}$ = the available CNR when the operating antenna is in free-space in dB.

f_B = channel bandwidth.

$H(j2\pi f)$ = channel transfer function in the direction of the receiver and in the presence of the structural obstructions.

The difference between the available CNR in free space and that available in the presence of structural obstructions is the power penalty, in dB.

It is clear from the power penalty equation that the reflections, as well as the fee-space antenna patterns, must be processed over 6 Mhz rather than at the carrier frequency alone.

Penalty Due to Frequency Distortion in the Passband

The second power penalty on the available CNR is imposed by the equalizer at the receiver. For example, the equalizer attempts to compensate for the notch in Figure 2 by introducing an infinite gain at that frequency. This compensation is at the expense of enhancing the noise level and thereby reducing the available CNR.

The magnitude of the penalty depends on the choice of equalizer at the receiver. Peak Distortion, Mean Square Error and Decision Feedback are examples of known equalizers (Ref. 2).

While the exact magnitude of the noise power penalty depends on the choice of equalizer, the *worst case* is:

$$N - N_{FS} = 10Log[\frac{1}{f_B}\int \frac{df_B}{|H(j2\pi f)|^2}] \quad \text{dB}$$

where :

$N - N_{FS}$ is the power penalty inflicted by the equalizer on the noise level due to the distortion of the frequency response.

It is clear that any notches in the transfer function will cause the equalizer to raise the noise level to a point where the threshold CNR cannot be maintained, resulting in lost picture and sound.

CNR Coverage Contours

Since knowledge of the power penalties, in addition to the Effective Radiated Power (ERP), are essential in defining coverage contour of obstructed antennas, it would appear that a contour of threshold CNR, rather than field strength or power, will serve as the proper tool for coverage description. The two power penalties and the free-space ERP may be automatically incorporated within one number, the threshold CNR. The threshold CNR (≈15 dB) contour can then be drawn for various percentages of time and location availability depending on the margin between the available CNR and the threshold level.

HDTV Example

This example is based on an existing three-legged tower, with a hypothetical, omnidirectional HDTV antenna, mounted 8 feet due east from the line connecting legs B and C. The top view of tower cross-section and the HDTV antenna is shown in Figure 3. The width of the triangular legs is 9 feet and the separation between the legs is 63 feet. The calculations are all at channel 39.

The first step is to calculate the reflections and scattering from the three legs. The result is shown in Figure 4 where both the free-space (magnitude=1 for omnidirectional pattern) and the reflection azimuthal patterns are shown. In particular, note the large, undesired, reflection due East from the flat surface of leg A. Also note that the patterns were calculated and integrated over 6 Mhz in accordance with the principles set forth in this paper.

The next step is the assessment of the two power penalties. The results are shown in Figure 5. The total penalty is the sum of the penalty due to loss of primary signal resulting from the reflections and the penalty due to the distorted frequency response, which is also a by-product of the reflections. Note that the penalty due to the equalizer is relatively small since no notch such as that shown in Figure 2 was produced.

Finally, the calculated threshold CNR coverage contour is shown in Figure 6. Note the effect of the power penalties on the reduced coverage in some directions. This particular contour is based on the FCC propagation curves and the following receiver model:

Rx Noise Figure = 10 dB.
Rx Antenna Height = 30 feet.
Rx Antenna Gain = 10 dB.
Downlead Cable = 50 feet of RG-59/U.
Rx Antenna Balun Loss = .5 dB.
Threshold CNR = 15 dB.

Inside the contour, the CNR is ≥ 15 dB which is the threshold for yes/no HDTV. Finally, note that the contour is based on FCC(50,99) rather than the FCC(50,90) curves which are normally used for NTSC coverage analysis. The justification for the higher percentage of time availability in the case of HDTV broadcasting was explained earlier (Ref. 3).

Conclusion

Most US broadcasters will face the transmission tower capacity bottleneck as part of their transition plan to HDTV. In many locations, HDTV antennas will be installed next to other antennas or below the top of the tower. The HDTV antennas will then be subjected to reflections from nearby antennas and/or the supporting tower itself. The procedures outlined in this paper provide the means for quantifying the degradation, in any direction, as a function of the HDTV antenna position in the presence of undesirable structures.

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3. Bendov, O. "The Effect of Channel Assignment on Transmitter and Receiver Requirements for Equivalent HDTV/NTSC Coverage," NAB Proceedings, 1994.

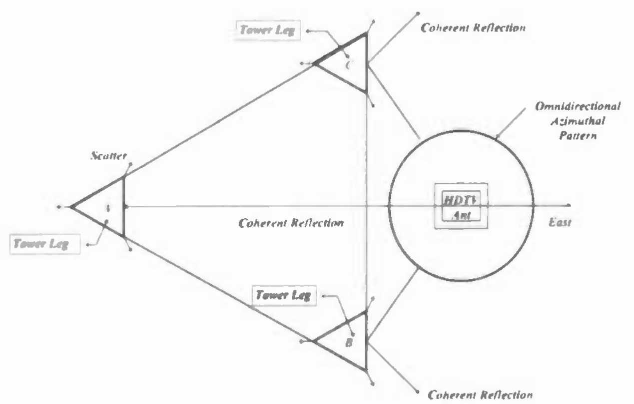
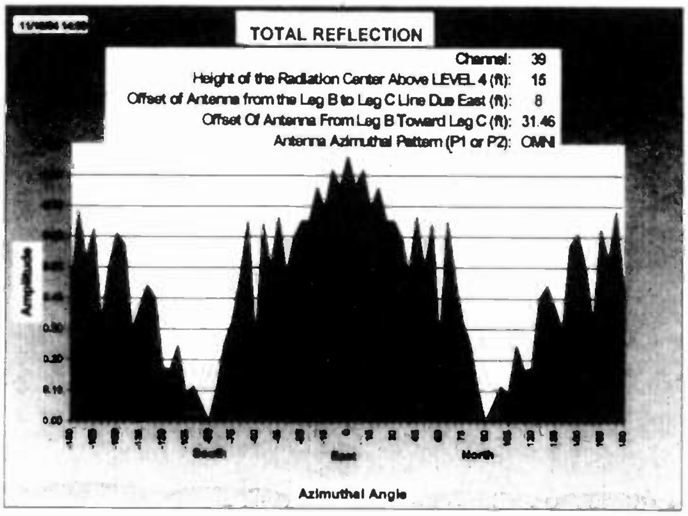


Figure 3.
Top View of a Side-Mounted, HDTV Antenna. Obstructed by Lower Legs A, B, and C.

Figure 4.



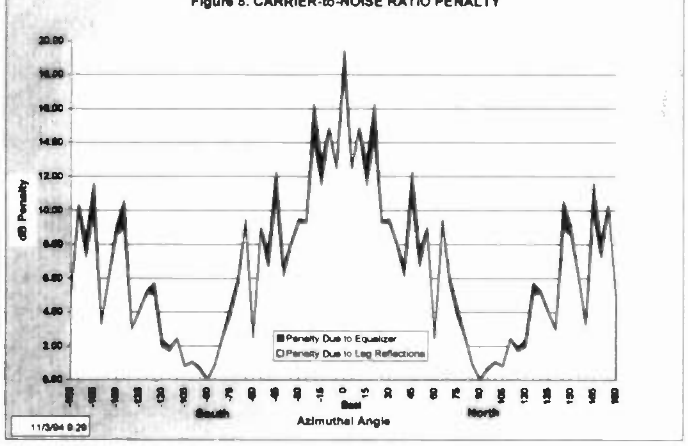


Figure 5. CARRIER-to-NOISE RATIO PENALTY

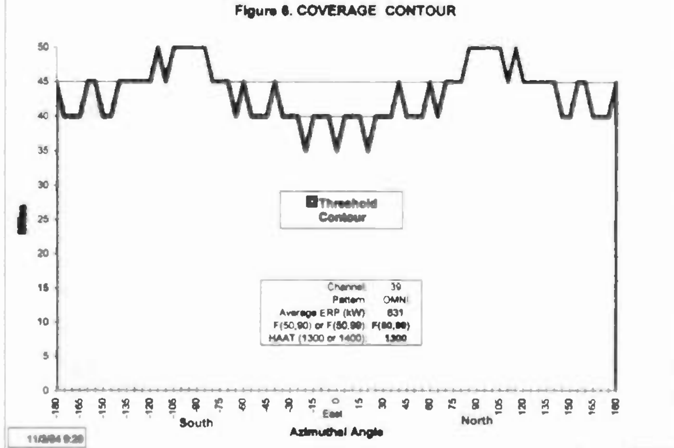


Figure 6. COVERAGE CONTOUR

SO YOU'VE JUST BEEN ASSIGNED CHANNEL 68 FOR ATV— INTERPRETING ATV CHANNEL ASSIGNMENTS

Louis Libin
National Broadcasting Company, Inc.
New York, NY

ABSTRACT

The ATV Broadcast Service is coming, and the FCC is planning to assign each television station a new channel. Most of the assignments will be in the UHF band. What is the basis for this assignment? What if you are assigned UHF channel 68? Will your current viewing audience be able to receive the new signal? How can the Chief Engineer assure the Station Manager that the new channel assigned to them is sufficient to provide good ATV coverage of their service area? How will ATV impact their NTSC service? *This paper will help Chief Engineers to better understand the basis for their assignments, the predicted coverage for this new service, and the fundamentals of UHF broadcasting.* The groundwork is laid for designing an efficient and effective ATV station.

INTRODUCTION

Broadcasters believe that, in a short time, the FCC will set a standard for a new Advanced Television Broadcast Service (ATV). The Commission will assign each of the approximately seventeen hundred television stations a new channel for ATV. The new channel will be paired with the current NTSC channel. Most of the new ATV assignments will be in the UHF band. Each NTSC station will be assigned a new ATV channel with a specific numeric value. What is the basis for this assignment? What if you are channel 4 now and you are assigned UHF channel 68? Will your viewers tune up to channel 68? Will your current viewing audience be able to receive the new signal? These are only a few of the questions that might be asked about the new service. The last two may be answered simply. Even the first generation of ATV receivers is expected to have "smart" features that will let you select stations by "WNBC" or another service provider. If an ATV signal is available, you will get ATV programming on channel 68. Otherwise, you will get the NTSC signal on channel 4. In most cases, a good, outside antenna comparable to today's "top-of-the-line", will let almost everyone who is able to receive NTSC on channel 4 to also receive ATV on channel 68. Early tests have confirmed that ATV can outperform NTSC transmission. ATV can deliver HDTV quality pictures into the fringe areas of NTSC and do it with lower transmitter power.

BACKGROUND

From the beginning, broadcasters took an active role with industry and government as the FCC Advisory Committee on Advanced Television Service worked to develop recommendations for the new broadcast system. Obtaining sufficient spectrum so that all broadcasters might introduce ATV without disrupting their present NTSC broadcasts became a key issue for the successful introduction of ATV broadcasts in the United States.

The Television Spectrum — The spectrum allotted for television broadcasting varies over an extremely wide frequency range. From the lower end of channel 2 (54 - 60 MHZ) to the upper end of channel 69 (800 - 806 MHZ) the variation in frequency is nearly fifteen to one. The TV broadcast channels occupy four noncontiguous bands.[1] The center channel wavelengths vary from 5.3 meters (209 inches) at channel 2 to 0.37 meters (14 inches) at channel 69. Signal propagation characteristics vary widely over such a broad range of spectrum. In general, for a given effective radiated power (ERP), the low band VHF channels produce a useable NTSC TV picture at much greater distances than UHF channels. In the early developmental years of television broadcasting, the

FCC set standards for the various channel groups in an attempt to provide approximately the same radius of minimally useful (Grade B) coverage and to allow for the greatest practicable channel reuse which would not result in unacceptable levels of interference. The maximum permissible ERP was set at 100 kilowatts (KW) for low-band VHF, 316 KW for high-hand VHF and 5000 KW for UHF channels. The antenna height above average terrain (HAAT) was limited to 2000 feet; except that in the heavily populated northeastern portion of the country termed Zone I, HAAT for the VHF channels was limited to 1000 feet. The FCC Rules have been converted to the metric system, and the HAAT limitations are now 300 meters for Zone I VHF stations and 600 meters for other stations.

In the early 1980s, Japan's NHK proposed its MUSE HDTV interlaced system, based on 1125 horizontal scan lines, for worldwide adoption. MUSE made the world aware of the goal of high-definition television with picture quality equivalent to motion pictures, including a wide-screen format.

FCC and ACATS -- In 1987, the FCC, at the request of broadcasters, initiated rulemaking on advanced television service and established a blue ribbon Advisory Committee on Advanced Television Service (ACATS) for the purpose of recommending a broadcast standard. Over the past seven years, hundreds of companies and organizations have worked together within the numerous Subcommittees, Working Parties, Advisory Groups and Special Panels of ACATS. The ACATS process -- an impressive example of government-industry cooperation -- has been marked by many important accomplishments:
ACATS developed a competitive process by which proponents of systems were required to build prototype hardware which would then be thoroughly tested. This process sparked innovation and an entrepreneurial response. There were 23 proposals for systems submitted to ACATS in September 1988. Hardware was actually built and tested for six systems.

The FCC made several key spectrum decisions that also helped spark innovation. The commission decided in early 1990 that new ATV systems would share television bands with existing services and would utilize 6 MHz TV channels as presently defined. The Commission also decided on a "simulcast" approach; this meant that the new HDTV signals would be broadcast on currently unusable TV channels and that broadcasters would be temporarily assigned a second channel to accomplish the transition to HDTV.

Digital Television -- Although the FCC had said in the spring of 1990 that it would determine whether all-digital technology was feasible, most observers viewed it as at least 10 years in the future. That same year, General Instrument became the first to announce an all-digital system. Later, all-digital systems were announced by MIT, the NBC, Philips, Thompson, Sarnoff consortium and by Zenith-AT&T. The FCC and ACATS anticipated the need for interoperability of the standard with other media. Initially, the focus was on interoperability with cable television and satellite delivery; both being crucial to any broadcast standard. With the advent of all-digital systems, computer-friendly progressive (non-interlaced) scanning became increasingly important. ACATS formed a special subgroup that worked for two years to assure that interoperability would be maximized in the new HDTV standard.

By 1991, ACATS had developed receiver planning factors and a model for predicting ATV coverage and interference. **Broadcasters supported this work of ACATS by providing computer resources and funding software development.**

ATV Testing -- Six systems (four of which were all-digital) underwent extensive testing in 1991 and 1992 at the Advanced Television Test Center (ATTC) in Alexandria, VA. Also participating in testing were Cable Television Laboratories Inc. (CableLabs) of Boulder, CO, which tested systems over a cable test bed at the ATTC, and the Advanced Television Evaluation Laboratory (ATEL) in Ottawa, Ontario, Canada.

Following testing, the Advisory committee decided in February 1993 to limit further consideration to the four all-digital systems: two systems proposed by GI and MIT, one proposed by Zenith and AT&T, and one proposed by NBC, Sarnoff, Philips and Thomson. The Advisory committee decided that, while all of the digital systems provided impressive results, no single system could then be proposed to the FCC as the U.S. HDTV standard. The committee ordered supplementary tests to evaluate improvements that had been made to individual systems since initial testing.

The Grand Alliance -- At the same time, the Advisory committee also adopted a resolution encouraging the digital HDTV groups to try to find a way to merge the four remaining all-digital systems into a single *grand alliance*. The committee recognized the merits of being able to combine the best features of each system. Negotiations between the parties began in earnest, and on May 24, 1993, seven companies announced formation of the Digital HDTV Grand Alliance. The Advisory Committee assigned its Technical Subgroup to evaluate the Grand Alliance proposal in detail. The Technical Subgroup approved most of the key system elements -- video compression, transport, scanning formats and the audio subsystem in October 1993. The final element, the modulation subsystem was approved by the Technical Subgroup in February 1994.

In the summer of 1994, the transmission subsystem underwent six weeks of extensive broadcast and cable field tests at Charlotte, NC. The tests proved that "*the Grand Alliance digital transmission technology will outperform today's analog transmission.*"

In January of 1995, the Broadcasters Caucus and the Association for Maximum Service Television (MSTV) submitted to the FCC their recommendation for a nationwide ATV channel assignment table. The table pairs a channel for ATV simulcast with every NTSC station. The filing was signed by 90 broadcast groups including the National Association of Broadcasters (NAB) and the four networks. The assignment table is a fair plan which optimizes ATV service for all broadcasters with minimal impact to existing NTSC service areas.

WHERE ARE WE TODAY?

The HDTV standard setting process has been and will continue to be a public, open process. The Grand Alliance is working closely with the FCC's Advisory Committee to complete the standard and launch HDTV. The Grand Alliance members have been working together to construct the prototype system. We are nearing the finish line of an eight year process. Chief Engineers and General Managers should be preparing for the roll-out of HDTV. Since 1987, NBC and the other networks have been working on the development of ATV and planning for the distribution and broadcast of HDTV pictures. The introduction of ATV will be a gradual process. Initially, the ATV market will be small. As ATV broadcasts begin, viewer interest and demand for ATV receivers will increase.

In early 1995, the Advisory Committee will conduct extensive laboratory tests of the entire system in the U.S. and Canada to verify that the system meets its expectations. The Advisory committee could then recommend the system to the FCC and simultaneously begin final field test verification of the system's performance. The FCC, in turn, would consider the committee's recommendation in a rulemaking proceeding which should be concluded in late 1995 or early 1996. In accordance with FCC requirements, the technology may be licensed to anyone on reasonable terms.

Broadcasters could then be assigned a second channel and begin preparing to broadcast an ATV service. Once licensed for the ATV service, many broadcasters would move quickly to commence the new service which will grow with consumer demand for ATV receivers and set-top converters.

It is anticipated that our Canadian and Mexican neighbors will simultaneously initiate similar, appropriate procedures to assure rapid adoption throughout North America. Moreover, because of early North American implementation, it is hoped that the rest of the world will adopt many of the elements of the North American HDTV standard.

THE FUTURE IS UHF

The FCC is planning to allocate a second TV channel to each VHF and UHF TV station for an Advanced Television System. The allocation of a second channel will allow every TV station to introduce an ATV broadcast service while maintaining its current NTSC broadcast service. In the future, the FCC plans to withdraw the current NTSC licenses so that stations will be required to broadcast only an ATV service. When the ATV broadcast service is introduced, the relative advantages of stations could change. The FCC has announced the intention to allocate only UHF channels for ATV. All channels within a market will be equally accessible on the ATV receiver. Most ATV channels will have coverage comparable to their NTSC population coverage. *From a service area perspective, most channels are equally valuable.*

NTSC Signal Strengths -- The quality of the received NTSC picture deteriorates gradually with decreasing signal-to-noise ratio as distance from the transmitter increases. This is a characteristic of NTSC television as an analog system. Beyond the Grade B contour, viewable pictures can generally be obtained only by means of special high-gain receiving antenna systems such as are employed by cable TV headends. Since NTSC television is an amplitude modulated system, the signals are subject to multipath "ghosts" and to natural and man-made electrical noise which shows up as annoying sparkles and lines in the picture. For the most part, excellent pictures are received within the City Grade contour nearest the transmitter; pictures of good, but not excellent quality, are received within the Grade A contour; and pictures of marginally useful quality are received out to the Grade B contour.

In reality, TV reception varies widely from location to location and from time to time. The different grades of reception are statistically derived on the basis of time and location variability. Last August during field tests of the Grand Alliance Prototype Transmission Subsystem, a high degree of UHF multipath variability was observed. The received signal strength was found to vary widely over brief time intervals and between nearby locations. Even an inch can result in a significant signal change. This variability can not be attributed to terrain blocking the path. It can be caused only by multipath interference.

Table 1 gives the basic parameters for NTSC channels: the Zone I ERP and HAAT limits for each channel group, along with the distances to City Grade, Grade A and Grade B contours. FAA concerns, zoning restrictions and costs frequently act to limit antenna height for UHF stations to less than the maximum permissible 600 meters.

The effect of the tremendous disparity in ERP can be seen in the City Grade contours. A comparison of Figures 1-3 reveals much about the differing propagation characteristic of the different channel groups. City Grade coverage extends much further for a UHF station than for a low-band VHF station.

The UHF station has greater "brute-force" signal strength to override man-made and natural noise and thus can provide excellent reception near the transmitter. On the other hand, because low band VHF stations can provide Grade B coverage at comparable distances with far less ERP than UHF stations, the low-band VHF station is permitted less ERP to overcome atmospheric and man-made electrical noise. Therefore a low-band VHF station has far less City Grade coverage than a comparable UHF station. A typical UHF station may have a HAAT of 300 meters. Figure 4 shows that, with an antenna height of 300 meters, a UHF station has a Grade B contour radius of about 85 kilometers. This is almost exactly the distance to the horizon for a transmitting antenna height of 300 meters. Beyond the horizon, UHF signals drop off rapidly in strength, while low band VHF signals fade much more gradually. A 100 KW low band VHF station with 300 meter HAAT provides Grade B service 20 kilometers beyond the horizon. In order to achieve a Grade B coverage radius of about 105 kilometers (65 miles) with ERP of 5000 KW, a UHF station must employ an antenna height of 600 meters. The horizon for 600 meter HAAT is 113 kilometers, so a maximum facility UHF station's Grade B contour falls eight kilometers short of the horizon, but you can still receive a signal out to the horizon.

ATV Signal Strengths -- ATV reception requires a certain minimum signal strength. ATV is a digital system; which means, in simple terms, that the picture and sound information is encoded into a data stream of binary numbers. So long as there is sufficient signal strength for the decoder to decode digital data, a perfect picture will result. If the signal strength falls below that level, the system crashes and no reception is possible. There is no gradual deterioration of picture quality with increasing distance from the transmitter as with NTSC television. Thus there are no grades of coverage; it is either all or nothing. Based on the reception planning factors used by the ATV Field Test subcommittee in calculating ATV service, minimum signal strength levels for ATV service were calculated for each channel from 2 through 69. The results are given in Appendix A. The propagation disparities between the different channel groups is easily seen. Channels 2 - 6 require signal strengths in the 20-30 microvolt per meter (uV/m) range. For channels 7 - 13, the requirement is around 60 uV/m, and for UHF it varies from 120 to 200 uV/m.

Power Requirements For ATV -- Power measurements for ATV are based on average transmitter power, while measurements for NTSC are based on peak power. However, ATV signals can

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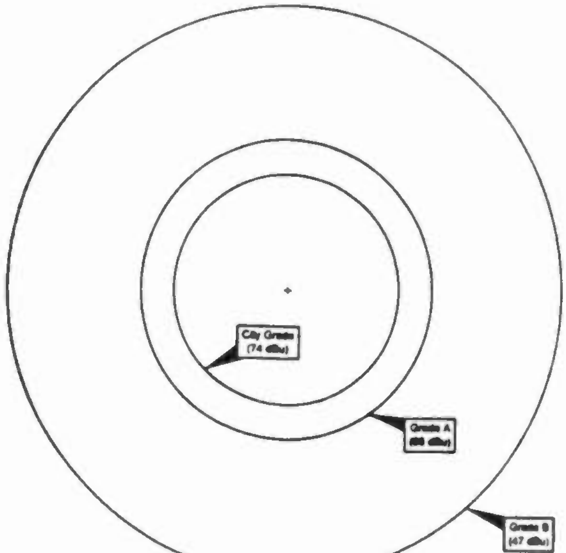
Figure 1



LOW-BAND VHF CHANNELS
(CHANNELS 2-6)
100 KW, 300 METERS

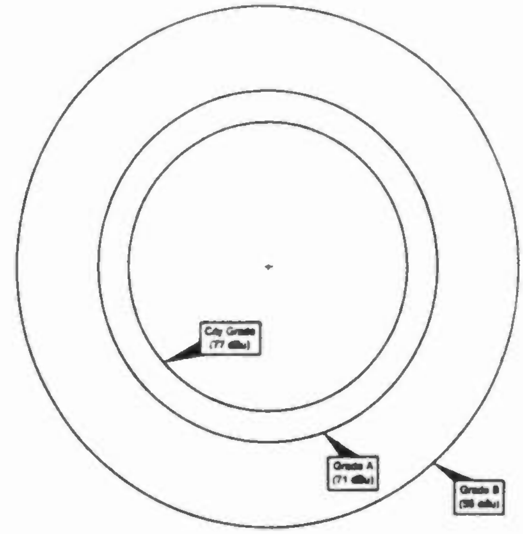
Prepared for
NATIONAL BROADCASTING COMPANY, INC.

Jules Cohen & Associates, P.C. Consulting Engineers

0 50 100 150 Kilometers

DECEMBER 1994

Figure 2



HIGH-BAND VHF CHANNELS
(CHANNELS 7-3)
316 KW, 300 METERS

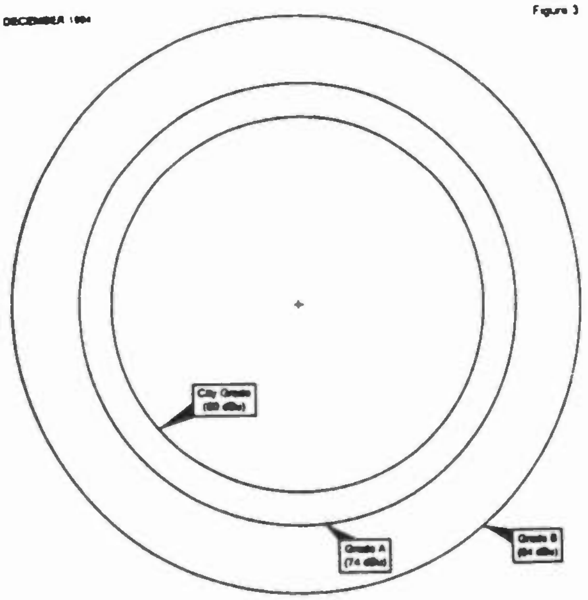
Prepared for
NATIONAL BROADCASTING COMPANY, INC.

Jules Cohen & Associates, P.C. Consulting Engineers

0 50 100 150 Kilometers

DECEMBER 1994

Figure 3



UHF CHANNELS
(CHANNELS 14-69)
5000 KW, 600 METERS

Prepared for
NATIONAL BROADCASTING COMPANY, INC.

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0 50 100 150 Kilometers

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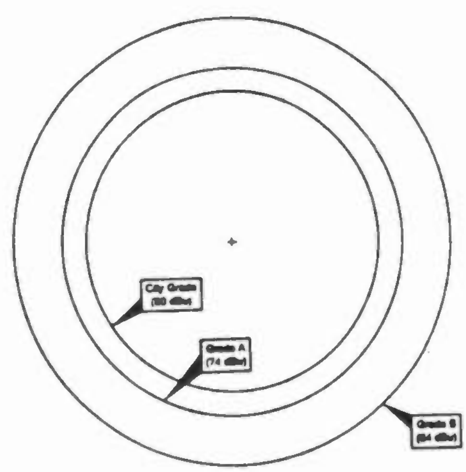
Figure 4



UHF CHANNELS, HAAT LIMITED TO 300 METERS
(CHANNELS 14-69)
5000 KW, 300 METERS

Prepared for
NATIONAL BROADCASTING COMPANY, INC.

Jules Cohen & Associates, P.C. Consulting Engineers

0 50 100 150 Kilometers

Zone I Maximum Permissible NTSC Television Station facilities						
				Distances to Coverage Contours		
Band	Channels	ERP (kW)	HAAT (meters)	City Grade (Km)	Grade A (Km)	Grade B (Km)
Lo-VHF	2--6	100	300	42.1	54.4	103.6
Hi-VHF	7--13	316	300	52.3	64.1	95.3
UHF	14--69	5000	600	69.0	81.5	106.6
UHF*	14--69	5000	300	55.4	64.5	82.8
*Limited HAAT; not max. facilities. (See text)						

Table 1

produce random peaks 6 dB or four times the average power. That is to say, in order to handle an average ATV signal power of 100 kW, a transmitter with a peak power rating of 400 kW must be employed. In order to estimate the power requirement for replication of NTSC service areas, a coverage radius of 105 km was assumed. This was based on the Grade B service radii of the maximum-facilities Zone I stations discussed above. Sample calculations were made with HAAT of 300 meters for channels 3, 9, 14 and 69. The calculations were repeated for the UHF channels with HAAT of 600 meters. The calculations assumed reasonable values of antenna gain and line loss for each channel group. The results are shown in Table 2. The peak power ratings of the transmitters are also shown, as well as estimated annual power costs based on an overall plant efficiency of 50% and power costs of eight cents per kilowatt-hour. With HAAT of 300 meters, ERP values vary from about 6.5 kW (Avg. 2 kW) for channel 3 to 2830 KW (Avg. 85 kW) for channel 14. With HAAT of 600 meters, the power is reduced to 207 KW (Avg. 6 kW) for channel 14. At channel 69, HAAT greater than 300 meters would be a necessity for ATV coverage to 105 kilometers. In order to provide ATV service to 105 kilometers with HAAT of 300 meters, ERP over 15 megawatts (Avg. 500 kW) would be required.[2] With HAAT of 600 meters, this is reduced to 1148 kW (Avg. 36 kW). Otherwise, assuming the required 2 megawatt peak rated ATV transmitter could be obtained, the capital cost would likely exceed the cost of building a 2000-foot tower, to say nothing of the annual power bill. A much less expensive way of extending coverage into the fringe areas is to use a receiver preamplifier mounted on the mast of a high-performance receiving antenna. Manufacturers report improvement in gains of up to 32 dB.

THE UHF ADVANTAGE

The UHF market is changing; the UHF stigma may soon be gone. Transmitters and antennas are now very good. Audience viewing habits are not the same anymore. Today programming is the issue. The bottom line is not VHF or UHF but "where can NBC be found in my market?" Today's programmable television receivers don't care about VHF or UHF. VHF reception indoors (no outdoor antenna) is normally poor. The noise level is high because of all of the appliances and electrical equipment in the typical home. For UHF, indoor reception Radio Frequency Interference (RFI) is not a problem. For outdoor reception, VHF will still outperform UHF;

HDTV Replication requirements for 105 kilometer Radius Coverage (Calculated for Representative Channels as Shown) (Based on FCC F(50-90) Field Strength/Distance Curves)						
Channel	FS (dBu)	HAAT (m)	ERP (kW)	Average Xmtr Pwr. Out (kW)	Xmtr Peak Pwr Rating (kW)	Est. Annual Power Bill ($1000's)
3	27.1	300	6.58	2	8	2.8
9	35.6	300	44.2	6	24	8.4
14	41.6	300	2830	85	340	120
14	41.6	600	207	6	24	8.4
69	46.2	300	15922	500	2000	700
69	46.2	600	1148	36	144	50

Table 2

but with maximum facilities and good transmitting equipment and with a good, clean signal from studios, UHF comes close. With minimum receiver specifications for UHF ATV reception, we will avoid the problems that we have today with UHF. HDTV will really push UHF over the edge.

Washington DC is a good example. In many areas, UHF Channel 20 comes into the home as good as VHF Channel 5. Channel 20 is fourth in the market. It is a full power, maximum-facility station. It has a better contour than some VHF stations. Washington, DC is a typical secondary market, another is Chicago, where there is a nice flat downtown area surrounded by a very large suburban area. Except for cities like New York with much multipath, if a station goes to maximum facilities, there is an excellent chance of reaching a 105 km contour.

ATV CHANNEL ASSIGNMENTS

In each area of the country, the new ATV channels will be found among those TV channels that are not used for NTSC broadcasting in that area. The broadcast channels for NTSC were allotted to cities across the country by a complex set of rules based upon providing for minimum separation distances between the use of certain pairs of channels. For instance, a UHF transmitter at maximum antenna height and power should not be located within 248.6 km of another transmitter on that same channel. The intent was to minimize the potential for the broadcasts of a distant station to interfere with the reception of a local station.

The possible channels for ATV in each area are to be found among the NTSC allotments that were never constructed and among the channels whose use for NTSC would cause objectionable interference to existing NTSC stations. The FCC has also announced the intention to allocate only UHF channels for ATV. This may not be entirely possible, but certainly most of the new ATV assignments will be in the UHF band. There may be some VHF ATV assignments where UHF assignments are not possible; these will be mostly in high population urban areas where there is a scarcity of available UHF channels for ATV. Even though the ATV system has been designed to minimize interference into NTSC broadcasts and, in turn, to be relatively immune to interference from other stations, the geographic distribution of NTSC channels across the country and the potential for interference between stations makes it very difficult to devise a nationwide set of ATV channel assignments that avoid all inequities among the channels assigned. The channel assignments must be carefully crafted for the major markets and for the nation as a whole.

Available channels having the larger cochannel separation distances are preferred. A table of ATV channel assignments has been recommended by broadcasters to the FCC.

How Channel Assignments Are Made And Evaluated -- The following goals were established for a channel assignment plan:

(1) That ATV spectrum be found within the existing VHF and UHF TV bands

(2) That all NTSC stations be paired with an ATV channel

(3) That the service area of each ATV station replicate as closely as possible the service area of the NTSC station to which it is paired

(4) That reception of existing NTSC stations not be significantly impacted by new interference from ATV stations

Chief Engineers should be prepared to evaluate the service area of their new ATV channel assignment and should begin preparing to build an ATV station. The FCC Office of Engineering Technology has long used computer software to optimally assign broadcast channels satisfying the technical and regulatory constraints for a particular service. ACATS technical committees have developed receiver planning factors and a model for predicting ATV coverage and interference. Broadcasters have supported this work of ACATS by providing computer resources and funding software development; they have also built upon and enhanced the assignment model used by the FCC.[3] The ATV service and interference characteristics of the assignment plan developed with the aid of these programs depend on parameters, assumptions and guidelines that must be determined prior to running the model. The following paragraphs describe those assumptions and provide additional description of some of the critical algorithms used in the channel assignment program.

The general approach to making the ATV channel assignments will be described briefly. The actual process is more complex and involves additional criteria which are discussed below. An allotment table is formed by considering each city or area in turn across the country. For each area, one prepares a list of channels which are candidates for ATV assignment. First, channels which are used in this or nearby cities are eliminated because their use for ATV would cause unacceptable interference to the reception of an existing NTSC station. Other channels are eliminated because they would be susceptible to interference from NTSC stations or ATV to ATV interference would result if both should be used. In this way the channels allotted to one city restrict the channels which can be allotted in nearby cities, and in turn, this effect spreads like a daisy chain across the United States. When a list of candidates has been prepared for each area, the service areas of the ATV channels are calculated and matched to the existing NTSC service areas. Adjustments are then made to better satisfy certain optimizing criteria and the process is continued until the results appear satisfactory.

Channel Assignment Program -- This program is used to assign an ATV channel number to every NTSC station in the US. The assignments are made so that minimum geographical separation distances are maintained between the use of certain pairs of ATV and NTSC assignments. The most important constraints are the distances between two uses of the same number channel for two ATV stations or for an ATV and a NTSC station, the cochannel constraint. The separations between channel numbers which differ by one -- the adjacent channel constraints are the second most important constraint. There are additional constraints at the Canadian and Mexican borders and between certain offsets of UHF channels termed the UHF taboos.

The program begins with a list of all the NTSC stations. For each station in turn the program calculates the distance to the nearest use of each TV channel. The channel with the greatest separation distance is examined first. If this channel satisfies all of the separation constraints, then a tentative ATV assignment is made. If not, then the channel with the next greatest separation is tested. If no channel satisfies all of the constraints, then no ATV assignment is made. This process is repeated for each NTSC station. There are many assignment tables that could be considered. Many of these tables have entries consisting of a pair of stations which violate one or more of the separation constraints. Also the resulting ATV service areas vary greatly from table to table. As an indication of the complexity of this process, even if a super-computer could evaluate an assignment in one second and ran for the entire age of the universe, it would only have just begun to attack the problem on a case by case evaluation.[4] In order to form a reasonable plan the program employs a number of heuristics that have been refined by a number of people over many years.

Coverage And Interference Model -- The channels of an assignment plan are evaluated by using the coverage and interference model. The ATV channel power is set so that the ATV signal can be received at the maximum radial of the paired NTSC channel's Grade B contour. Then the ATV coverage is calculated taking into account the transmitting antenna pattern of the NTSC station and signal propagation over the terrain. Finally the impact of other ATV and NTSC stations is considered to determine the loss of service area due to receiving interference from those stations. For most of the ATV channels, there will be no problem to satisfy the goal. However, a number of stations in spectrum congested metropolitan areas may not have completely satisfactory service areas.

Optimization -- Some areas like New York and Philadelphia have so many TV stations in close proximity that it is very difficult to fit in an equal number of ATV channels. As geographic problem areas are identified, the assignment program can be run separately for each area. The number of stations in one local area is small enough to completely optimize assignments in a reasonable time. Thus many local plans can be evaluated to optimize the service areas within that area. Then these local plans can be "seeded" into the list of NTSC stations for running the assignment program for the entire country. The resulting assignments are then evaluated using the coverage and interference model program to calculate service areas. This may in turn lead to adjustments in local assignments and a new national assignment table. This rather complex procedure has been repeated until the improvement in service areas become negligible. The result is a table of NTSC-ATV channel pairings with the assigned ATV power, the areas and populations of the NTSC and ATV coverages and the areas and populations lost to interference from NTSC and ATV stations.

INTERPRETING COVERAGE

Interpreting ATV coverage is a new ball game. Broadcasters need to evaluate how NTSC stations may impact the ATV channel. All local ATV channels must be thrown into the equation because they may impact either or both of the ATV and NTSC coverages. What, if any, new interference will there be into the NTSC service area? The existing service area of NTSC stations is the baseline against which ATV assignments are assessed. The NTSC service area is defined as the area within the predicted Grade B contour reduced by areas where interference caused by other NTSC stations exceeds the *slightly annoying level* as determined by tests at ATTC. The interference level is expressed as a desired-to-undesired (D/U) ratio of predicted signal strengths. An acceptable, or permitted, level of an undesired signal is a signal strength that is less than or equal to the signal strength of the desired signal by a specified D/U ratio measured in dB. That is, the strength of the desired signal must exceed the strength of the undesired signal plus the D/U ratio as measured at the receiver terminals. In this sense, the D/U ratio may be viewed as the threshold for the onset of unacceptable interference from that signal.

D/U Ratios -- A D/U ratio compares the signal strengths of the desired signal and an undesired interfering signal at a given location. The signal strengths are measured or derived according to a criteria of location and time availability . For instance, the desired ATV signal is determined according to a 50/90 rule and, except for close interferers, the undesired ATV or NTSC signal strength is determined according to a 50/10 rule. That is, the desired signal is to be available at 50% of locations for 90% of the time and the undesired signal is available at 50% of locations for no more than 10% of the time. A larger D/U ratio signifies a more stringent interference rejection criterion. There are individual D/U ratio parameters for each type of interference. The types of interference considered include cochannel, adjacent channels and taboo channels for all combinations of ATV and NTSC signals as the desired and undesired stations. For instance, the D/U value for NTSC-to-NTSC cochannel interference is 28 dB with normal frequency offset.

ATV Service Area -- The most critical parameter of an ATV allotment plan is the separation distance between a new ATV transmitter and an existing cochannel NTSC transmitter. When this cochannel separation parameter is set to the largest distance that will permit all existing NTSC stations to be paired with ATV channels, then an ATV transmitter power level which would support an ATV coverage area comparable to the existing NTSC Grade B contour could create interference within the service areas of other NTSC stations. The goal is to assign the ATV channels in such a way that any ATV interference into NTSC falls mostly in areas already lost to NTSC interference. Any reduction of NTSC service areas is termed *new interference*. An ATV transmit antenna is assumed to be at the same location and height and to have the same directional pattern as the antenna of the paired NTSC station. The noise-limited contour of an ATV station is where the predicted signal strength, in the absence of interference, is just sufficient for errors in the received signal to not exceed the threshold of visibility. The Advisory Committee has determined this threshold as a digital signal bit error rate of $3x10^{-6}$. This bit error rate is achieved at a signal-to-noise ratio of 14.9 dB. The ATV service area is the area within the noise-limited contour reduced by the areas where interference from ATV or NTSC stations is above this threshold of visibility.

An Example

Consider the NBC station WMAQ-TV located in Chicago. Assume that mid-UHF channel 47 was assigned for ATV. Assume also that the ATV power has been set so that the area of the noise-limited reception contour for ATV reception is equal to the area of the Grade B contour. The map in Figure 5 shows the NTSC contours for WMAQ-TV. The maximum radial to the Grade B contour is 100.6 km. Now the Chief Engineer and General Manager will want to *evaluate the assignment* and *verify that their new ATV coverage will indeed cover their existing market*. Next, they will evaluate the other local assignments to determine marketplace competetiveness. Assuming ATV channel assignments for all stations in the Chicago area, the new ATV interference into reception of the NTSC signal can be estimated. Note that WMAQ-TV already has some loss of Grade B area due to existing interference from other NTSC stations. For this example, the additional loss is 4.3% of the service area but only 0.8% of the population served.

Next the service area of the new ATV channel can be estimated. There may be some loss due to interference from the other new ATV stations; there is also some loss due to interference from the existing NTSC stations. The loss of ATV service in the grade B contour for this example is mostly due to interference

Figure 5 -- TV Fact Book

from NTSC stations: 0.9% of area and 0.1% of the population. 99.9% of the NTSC audience will be able to receive the ATV signal. The market impact of introducing ATV in terms of covered population is a near term loss of 0.8% of the NTSC market and a gain of 1.7% over NTSC for the ATV market. In terms of service areas, the NTSC service area is reduced by 4.3% and the ATV service area is larger by 15.0%. The calculations are summarized in Table 3.

CONCLUSIONS

ATV channels can be assigned so that ATV service areas closely replicate existing NTSC service areas. Generating a good assignment table is a lengthy and complex process, but one that is nearing completion. Terrain mapping data can be used to predict signal propagation, coverage and interference. The higher power of UHF stations can be used to advantage to provide robust signals in urban areas. Census data can then be used to make accurate estimates of population served. We Broadcasters have high expectations. We would all like to have the "best" channel in the market. Each channel will have its pros and cons; some may work out to be better than others. We should remember that the purpose behind the FCC assigning the second channel is to allow broadcasters to "jump-start" the HDTV market.

We have to be careful not to complain too much and challenge too many assignments because we could all lose. An early start would be denied, and the broadcast of HDTV will be delayed further. In the worst scenario for broadcasters, the unused channels may be assigned to new HDTV entrepreneurs or the FCC could release the unused spectrum to other services.

Reprise -- Last week my youngest son celebrated his eighth birthday. We had a party and my wife baked the cake. You know the kind of cake kids like, very little cake and lots of icing. So there was plenty of icing with a big red icing rose on the top, off to one side. Well, you could imagine the response from the kids. They all wanted the piece with the red rose on top. They were all getting cake, good cake, but of course they all wanted the flower.

Broadcasters have to understand that the FCC is giving us another channel. Not everyone can get the flower, but we are all getting good channels with comparable coverage.

ACKNOWLEDGMENTS

Special thanks is given to Burnett Sams of **d+ b Technology**. Burnett's decades of experience helped immensely with this work. Special thanks is also given to Norm Miller of **Jules Cohen and Associates** for his help with analysis and calculations. Special thanks is also given to Victor Tawil of **MSTV** for his propagation modelling and computer analysis . Thanks also to Susan Buckley and Diana Kirton for their editorial assistance. Last but not least , special thanks to Michael J. Sherlock of **NBC** for his direction and support of this study, and to my colleagues, Peter Smith and Stan Baron for their assistance in all my work.

Endnote:

1. The two bands containing channels 2 - 4 (54 - 72 Mhz) and channels 5 - 6 (76 - 88 Mhz) are collectively known as the low-band very high frequency (VHF) channel group. Channels 7 - 13 (174 - 216 MHZ) are known as the high-band VHF channels, and channels 14 - 69 (470 - 806 MHZ) fall into the ultra-high-frequency (UHF) portion of the spectrum.

2. Power Requirements For ATV -- Power measurements for ATV are based on average transmitter power, while measurements for NTSC are based on peak power. However, ATV signals can produce random peaks 6 dB or four times the average power. That is to say, in order to handle an average ATV signal power of 100 kW, a transmitter with a peak power rating of 400 kW must be employed. In order to estimate the power requirement for replication of NTSC service areas, a coverage radius of 105 km was assumed. This was based on the Grade B service radii of the maximum-facilities Zone I stations discussed above. Sample calculations were made with HAAT of 300 meters for channels 3, 9, 14 and 69. The calculations were repeated for the UHF channels with HAAT of 600 meters. The calculations assumed reasonable values of antenna gain and line loss for each channel group. The results are shown in Table 2. The peak power ratings of the transmitters are also shown, as well as estimated annual power costs based on an overall plant efficiency of 50% and power costs of eight cents per kilowatt-hour. With HAAT of 300 meters, ERP values vary from about 6.5 kW (Avg. 2 kW) for channel 3 to 2830 KW (Avg. 85 kW) for channel 14. With HAAT of 600 meters, the power is reduced to 207 KW (Avg. 6 kW) for channel 14.

3. See "Spectrum Studies for Advanced Television Service in the U.S." by William Meintel and published in the 1994 NAB Broadcast Engineering Conference Proceedings.

4. The number of possible nationwide assignment tables is greater than 10 followed by more than 3200 zeros.

WMAQ Channel 5 Chicago						
	AREA			POPULATION		
	Area (sq-km)	Losses	%	Population	Losses	%
NTSC Channel 5						
NTSC Grade B Contour	31,816		100.0%	8,583,805		100.0%
Existing NTSC Interference		4,394	13.8%		153,805	1.8%
NTSC Base Line Service Area	27,422		86.2%	8,430,000		98.2%
NTSC Base Line Service Area	27,422		100.0%	8,430,000		100.0%
New ATV Interference		1,179	4.3%		67,440	0.8%
Service Area With ATV	26,243		95.7%	8,363,000		99.2%
ATV Channel 47						
ATV Noise Limited Contour	31,816		100.0%	8,583,805		100.0%
Interference From NTSC Stations		300	0.9%		6,546	0.1%
Interference From ATV Stations		2	0.0%		1,375	0.0%
Combined Interference		301	0.9%		7,921	0.1%
ATV Service Area	31,515		99.1%	8,575,884		99.9%
NTSC Base Line Service Area	27,422		100.0%	8,430,000		100.0%
ATV Service Area	31,515		114.9%	8,575,884		101.7%
NTSC Area Match	27,395		99.9%			
NTSC Not Matched		27	0.1%	Est.	8,430	0.1%
ATV Service Gain Beyond NTSC	4,120		15.0%	NA		
Net ATV Service Gain	4,093		14.9%	145,884		1.7%

Table 3

Maximum Radial	100.9 km
HAAT	402.3 m
ATV Power	852.3 KW

APPENDIX A

Required Minimum Field Strength in dBu for Satisfactory HDTV Reception (Based on ATV Reception Planning factors in PS/WP-3 Document No. 0308)				
Channel	**Frequency (MHz)**	**Wavelength (m)**	**Field Strength (uV/m)**	**Field Strength (dBu)**
2	57	5.2632	20.4	26.2
3	63	4.7619	22.5	27.1
4	69	4.3478	24.7	27.8
5	79	3.7975	28.2	29.0
6	85	3.5294	30.4	29.7
7	177	1.6949	56.4	35.0
8	183	1.6393	58.3	35.3
9	189	1.5873	60.2	35.6
10	195	1.5385	62.1	35.9
11	201	1.4925	64.1	36.1
12	207	1.4493	66.0	36.4
13	213	1.4085	67.9	36.6
14	473	0.6342	119.7	41.6
15	479	0.6263	121.2	41.7
16	485	0.6186	122.7	41.8
17	491	0.6110	124.3	41.9
18	497	0.6036	125.8	42.0
19	503	0.5964	127.3	42.1
20	509	0.5894	128.8	42.2
21	515	0.5825	130.3	42.3
22	521	0.5758	131.8	42.4
23	527	0.5693	133.4	42.5
24	533	0.5629	134.9	42.6
25	539	0.5566	136.4	42.7
26	545	0.5505	137.9	42.8
27	551	0.5445	139.4	42.9
28	557	0.5386	141.0	43.0
29	563	0.5329	142.5	43.1
30	569	0.5272	144.0	43.2
31	575	0.5217	145.5	43.3
32	581	0.5164	147.0	43.3
33	587	0.5111	148.6	43.4
34	593	0.5059	150.1	43.5

Channel	Frequency (MHz)	Wavelength (m)	Field Strength (uV/m)	Field Strength (dBu)
35	599	0.5008	151.6	43.6
36	605	0.4959	153.1	43.7
37*	611	0.4910	154.6	43.8
38	617	0.4862	156.1	43.9
39	623	0.4815	157.7	44.0
40	629	0.4769	159.2	44.0
41	635	0.4724	160.7	44.1
42	641	0.4680	162.2	44.2
43	647	0.4637	163.7	44.3
44	653	0.4594	165.3	44.4
45	659	0.4552	166.8	44.4
46	665	0.4511	168.3	44.5
47	671	0.4471	169.8	44.6
48	677	0.4431	171.3	44.7
49	683	0.4392	172.8	44.8
50	689	0.4354	174.4	44.8
51	695	0.4317	175.9	44.9
52	701	0.4280	177.4	45.0
53	707	0.4243	178.9	45.1
54	713	0.4208	180.4	45.1
55	719	0.4172	182.0	45.2
56	725	0.4138	183.5	45.3
57	731	0.4104	185.0	45.3
58	737	0.4071	186.5	45.4
59	743	0.4038	188.0	45.5
60	749	0.4005	189.5	45.6
61	755	0.3974	191.1	45.6
62	761	0.3942	192.6	45.7
63	767	0.3911	194.1	45.8
64	773	0.3881	195.6	45.8
65	779	0.3851	197.1	45.9
66	785	0.3822	198.7	46.0
67	791	0.3793	200.2	46.0
68	797	0.3764	201.7	46.1
69	803	0.3736	203.2	46.2

* Radio Astronomy Frequency

THE ALL-DIGITAL RADIO STATION I: DIGITAL AUDIO PRODUCTION

Sunday, April 9, 1995

Session Chairperson:
Milford Smith, Greater Media, Inc., East Brunswick, NJ

***UPDATE ON USA DIGITAL'S FM1 AND AM IN-BAND, ON-CHANNEL DAB SYSTEMS**
A.J. Vigil
USA Digital Radio
Chicago, IL
Tony Masiello
CBS Radio
New York, NY
Glynn Walden
Group W Radio
Philadelphia, PA

***AT&T—DAR SYSTEMS**
Nikil Jayant
AT&T/Amati
Murray Hill, NJ

***S-BAND PROPAGATION**
Arvydas Vaisnys
JPL
Pasadena, CA

***EUREKA 147 IMPLEMENTATION**
Paul Ratliff
BBC
Tadworth, Surrey, England

****PANEL—DAB TESTING**
Panelists:

Thomas B. Keller
Consultant
Springfield, VA

Ralph Justus
EIA
Washington, DC

Robert Culver
Lohnes and Culver
Laurel, MD

Al Resnick
Capital Cities/ABC Inc.
New York, NY

Bert Goldman
Shamrock Broadcasting
Phoenix, AZ

Charlie Morgan
Susquehanna Radio Corporation
York, PA

*Papers not available at the time of publication
**Papers were not solicited from panelists

THE ALL-DIGITAL RADIO STATION II: DIGITAL AUDIO BROADCASTING

Sunday, April 9, 1995

Session Chairperson:
Jerry Whitaker, Technical Writer, Beaverton, OR

***MIDI SURVIVAL SKILLS**
Rick Kemp
Broadcast Supply Worldwide
Tacoma, WA

DIGITAL AUDIO TECHNICAL APPLICATIONS
James Hauptstueck
Harris Allied Systems
Richmond, IN

***A PRACTICAL ALL-DIGITAL AUDIO STUDIO**
Mark Yonge
Solid State Logic
Oxford, England

***THE DIGITAL RADIO STATION: AN OVERVIEW**
Skip Pizzi
Intertec
Overland Park, KS

***PLANNING, INSTALLING AND MAINTAINING LOCAL AREA NETWORKS**
Eugene Novacek
Enco Systems
Farmington Hill, MI

***LESSONS WE LEARNED IN GROWING A SOFTWARE DIVISION—A MANUFACTURER'S PERSPECTIVE ON DEVELOPING PRODUCTS FOR THE DIGITAL RADIO STATION**
Geoff Steadman
Orban Division, AKG Acoustics
San Leandro, CA

***DIGITAL TECHNOLOGY AT NATIONAL PUBLIC RADIO**
Mike Starling
NPR
Washington, DC

*Papers not available at the time of publication

DIGITAL AUDIO TECHNICAL APPLICATIONS

James Hauptstueck
Harris Allied Broadcast Equipment
Richmond, IN

Hard disk, Magneto Optical, Floptical, ISDN, Mini Disc, SW56... the list goes on. Technology continues to bring our industry many new types and styles of storage and communications equipment. The difficulty lies in deciding which technology is the right one for each of your applications. We will discuss each technology incorporating their strengths and weaknesses. Once we understand the basics of each technology, we will correlate them to applications. We will discuss applications where these technologies can give us the greatest benefits in efficiency, quality, and durability. In today's audio marketplace, we need to make use of every advantage at our disposal.

The audio arena is constantly changing. Ever evolving technologies and the companies which develop them continue to bring new devices to our door steps. As time goes on, the number of new products that are put before us grows at an ever increasing rate. Manufacturers take full use of the new capabilities afforded to them to speed the product development process, and decreasing the time it takes to bring these new products to market.

Our minds can begin to become cluttered with conflicting information about these new devices. Much of the information we get about new technology comes from manufacturer's advertisements, trade articles, and most importantly from our peers. Our level of understanding about the new technologies and how they relate to our businesses can become biased by the same influences that we depend on so deeply to bring them to us. The marketing and advertisements of manufacturers, the experiences (good or bad) of our peers, and often times our own preconceived ideas can cause us to bypass critical new technological breakthroughs.

These breakthroughs in audio storage and communications can often add tremendous new advantages to our workplace. We always want to make our audio sound the best we can with the resources we can afford. Audio quality is the first thing that comes to our mind when we mix the term digital with the word audio. However, there are often limits to the amount of money that we are willing, and capable of spending to achieve pure digital audio replication. We try to obtain the maximum benefit possible for the investments made in all of our equipment purchases. We can afford a newer, higher quality digital technology, if the technology itself offers other benefits that will help offset purchase cost. Equipment cost can be offset by many different features such as: higher longevity of media life, greater ease of usage for our staff, faster and cheeper communications, longer periods of time between breakdowns, and lower

maintenance cost for the equipment. A lot of times there are also additional benefits created that are only measurable by the new efficiencies and creativity developed within our production and air staffs.

Not all new ideas are good ones. If we miss the mark on a new idea or concept, it may not be seen immediately, if it is ever seen at all. It is our decision how profitable and efficient our organizations are going to be. Our people depend on us to make the right decisions. When we decide to try a new technology, we do take a risk. We take the risk of possible increase. Needless to say, the risk of decrease is always there too. The worst decision that can be made is to ignore new technology all together. It is too easy for our competition to bypass us when we ignore the tools that are at our disposal. If we do our homework and implement changes wisely, we will add capabilities and efficiency in many areas of the station. In the end, we will look back and see a huge increase the quality of our audio chain.

Let's take a look at some of the new technologies that have been developed in the last few years to try to get a better understanding of just what they are and how they can help us.

Communications

Communications equipment has come a long way. It gives us a lot more of the capabilities that we need, and some never before thought possible. Believe it or not , they are even more or less affordable. We can send real time digital audio and control data from one place to another over a single phone line. This can be accomplished using services such as Switched 56 and ISDN.

Switched 56 is a 56 Kilobyte per second data stream that has widespread availability through out the country. Duplex communications are standard with most equipment. To utilize this service, you must contact your local phone service provider to get costing and find out weather you will receive a four or two wire service. Once you have the service installed, you pay for the usage time (hence the term switched). The equipment that you will have to supply consist of a CSU/DSU which is the connection to the telephone service, and a codec, which does audio compression. You need a codec and a CSU/DSU on each end of the path that you wish to establish. There are several different manufacturers of SW56 equipment. Some of the compression and codec products will not interface to other types. That can be a serious problem unless you ask a few questions to the right people. There are guides available to lead you through the phone companies and to assist you in determining the right pieces for the application you have.

A telephone service known as ISDN is quickly surpassing SW56 in the locations where it is available. ISDN is a 64 Kbyte digital phone service and is generally cheeper than SW56 services. More for less...great concept. Here again, there is terminal adapter, codec, and a network terminal interface (nt1). You will find that the equipment prices are similar for both types of services. With ISDN you can have the ability on a single line to send 15Khz stereo audio with a extra 16KBs data line for control or for sending data files. There are many scenarios possible. You may want to send bi-directional mono audio or a variety of other audio and data combinations. ISDN provides you with two "B" channels (64Kbs) and one "D" channel (16Kbs). Most audio equipment manufacturers will utilize audio compression capabilities such as ISO/MPEG Layer II or Layer III to give you the greatest audio / time ratio while preserving digital quality. Depending on the type of audio compression used, you can get 20Hz - 15Khz mono audio on a single "D" channel. This type of speed allows real time transfer of audio and much faster transfer of data files vs. previous technologies.

Perhaps the actual send and receive locations constantly change. Instead of installing fixed equipment, you sometimes can order ISDN for a single day's usage in some locations. The cost is often times low enough to compete in many applications against fixed equipment such as STL's and even satellite services.

There are several other communication routes available for your usage including STL's, T1 services, and of course satellite. The best service to use in the transfer of digital audio depends totally on the amount of information to be transferred, your send and receive locations, and of course the cost factors relating to your needs. There are several types of places to turn to find out which best fits your needs without having to call 25 different people. Distributors, equipment manufacturers, and consultants generally can help guide you through the maze much faster than going it alone.

Storage Devices

As time has proceeded from the past to the present, we have experienced a wide variety of media for audio storage. Some have been successful, others not. The cost of the storage media, the quality of the audio itself, and the reliability of the associated equipment have all been major factors in their success. Records, open reel tape, cassettes, carts, and currently compact disc have all experienced great success in the professional audio arena.

One of the major driving factors not to be underestimated is cost. We generally use a considerable amount of storage for the mediums we embrace. If the cost is too high, we are less likely to accept that particular format. We have found that acceptance by the consumer industry greatly impacts the cost of a format. The mass manufacturing of millions of cassettes and it's associated lower cost have assisted in it's widespread acceptance through out the industry in a very wide variety of applications. As we look at the newer types of storage devices, we must also measure them against consumer acceptance in order to judge their future cost.

Hard drive storage falls into the same category in pricing theory. Hard drive prices have drastically been reduced due to it's mass appeal in virtually every type of business. Hard drives are even found in most homes in developed countries. They have been showing up in a huge variety of equipment in every aspect of life. This type of mass appeal and resultant mass manufacturing, competition for business, ease of use, and of course reliability, have kept the prices spiraling downward. We like those kinds of trends. Downward cost trends mean that we are able to benefit greatly due to a lower cost media that can offer high quality audio.

Some of the positive attributes of hard drive storage systems are their reliability and high performance. Hard drives offer very quick access times. Access times can be found as low as 10 milliseconds. Fast access time allows instant access of our audio. The faster we can read the data from the drive, the faster we can play or transport it. Maintenance of hard drives and associated computer systems are virtually nonexistent. We remove dust periodically, optimize the storage performance occasionally, and provide clean power feeds to keep them happy. There are virtually no moving parts to wear out, no bulk erasing or rewinding of audio tapes. The MTBF of a SCSI II drive can be as high as 15 years. How many cart decks will you repair and how many carts will you replace in a 15 year time frame? How many CD's will you clean, optics and bearings will you replace? As you can see, we must look seriously at technologies that offer serious savings for our endeavors.

Hard disk storage is not perfect. There are some potential pit falls to look at. One possible problem with hard drive storage is the fact that if a hard drive dies, you will probably lose a serious amount of audio. Backup or redundancy is more important than ever with this type of media. When your audio (commercials) is your income, loss can be devastating. There are businesses that specialize in removing data from bad drives, but the process tends to be expensive and time consuming. Up until recently, hard drives have been viewed and used primarily for audio that gets replaced or updated periodically. The increase in drive life span and lower cost now makes it worthy in applications for long term storage. Audio stored on drives must generally be recorded onto them in real time. Recording 1500 five minute songs in real time onto hard drives takes a while. Start up time of that magnitude for music storage purposes can result in a considerable start up cost. A cost much greater than several existing technologies such as CD's.

Most of the hundreds of hard disk storage systems in the world, also incorporate many different functions. Every feature from automation, to multi-track editing can be found in today's systems. It is critical to your business to incorporate a system that is easy to use and understand, as well as having the benefits and features that are needed today and growth capability for tomorrow. That kind of all encompassing system can be difficult to find if you do not fully understand the technical side and the applications side of your business. A lot of individuals have made tremendous strides in increasing their operations efficiency by using these systems. Others have made serious mistakes in choosing systems. The achievable benefits greatly out weigh the pitfalls. However, you must be willing to invest the time and resources to make an educated decision. The technology is changing faster than any one person can keep up with. Gain has never been easy or free. We must use the resources that are at our disposal to seek out the right companies to partner with when we decide on this type of technology. It is like a partnership with these manufacturers. You will want and need a company that has the capabilities to give you continued new features and the support you need for the future.

Compact disc have been around for quite a while now. Most of us understand the technology pretty well. We hear the great audio quality and know what is involved in the up keep of the equipment. More and more are finding benefit to a slant on this technology in recordable CDs. CD recorders have dropped dramatically in price in the last year. The blank recordable CDs themselves are about $15.00 each. That has become very affordable for a technology that is so reliable with such quality. The down side is that they are not re-recordable. Once they are finished... they are finished. You can get CD players that will play CDs with a temporary table of contents (orange book standard). When you encode a finalized table of contents on the disc (red book standard), it can be played in any CD player. If you think about long term backup of audio, condensing audio, or the promotional aspects to your customers, you may find this technology advantageous.

A relatively new technology that follows along this line is Magneto-optical (MO). Magneto optical disc give us the same quality and reliability as CDs, yet they are re-recordable. MOs can be rerecorded up to a million times. The MiniDisc is one type of MO. The small disc will hold as much audio as a standard CD (up to 74 minutes). They can do this due to a psycho-acoustic compression algorithm (ATRAC). The algorithm has a good quality playback, but you will not want to perform the algorithm more than once on a specific piece of audio. The degradation incurred is too high after multiple passes though the ATRAC algorithm. Sony developed this technology as a replacement for the audio cassette. For applications where you record once and playback many times, it works great. MiniDisc players also buffer the playback audio which eliminates skipping of the audio during playback. MiniDisc allows you to record all of your audio at once, then subdivide it into individually labeled audio files. Access time tends to be about the same as in CDs.

In the future we will see more of the non-data-reduction versions of MO disc. These disc are currently being used in many data applications in the computer industry. They are offered in several sizes with much more storage capacity than current CDs. The problem with them is an economic one. They are very expensive. Hopefully, they will come down in price to bring them within our reach.

Floptical disk are basically computer floppy disk used for commercial playback. These disk are offered in 2 MB and 13 MB sizes offering up to 5 minutes of 15 Khz stereo audio storage. The acceptance of the floppy disk in the computer industry has brought the disk down to a very reasonable price. They are easy to handle, but are susceptible to being erased by magnetic fields just like all other magnetic media. One advantage is that you can get them at any local office supply store. They store associated information such as title, artist, cut length, and etc. The playback and record machines are generally easy to learn and make an easy transition from cart machines to digital storage without going into more complex systems.

DAT tape has steadily increased in acceptance since its inception. DAT offers great digital storage for mastering, backup, and wide variety of audio recording and playback applications. DAT tapes are offered in a wide variety of sizes (10 to 120 minute tapes). While the audio quality is supreme, there are limitations for it's usage. The cue and search times are often too long for quick access in some applications. Fast paced on air commercial playback is one example where speed becomes an issue. Just like a lot of the technologies, there are moving parts. We must be sure to clean the heads occasionally. Tape wear and extreme environmental conditions can effect the DAT tape's reliability. Even with some of the same weaknesses as in other tape bases devices, DAT far surpasses tape in audio quality. We will continue to see DAT as a very successful storage media for digital audio.

DCC or Digital Compact Cassette is a tape based system designed to use standard audio cassettes and DCC tapes. DCC has achieved success in Europe while finding limited success to date in this country. DCC uses a psycho-acoustic algorithm for digital audio storage called PASC. Like the MiniDisc, you would not want to re-record audio through this algorithm. The DCC offers good playback capabilities and is an advantage when you have a substantial cassette library with the desire to move to digital. One concern about DCC has been the heads used in the system. The heads are made of a very strong yet very thin metal. Mixing usage of old cassettes and new DCC tapes will cause the need for periodic head cleaning. You will also have head wear like cassette decks. Another point to keep in mind, is to look at the access and search times when considering them for on air playback.

Conclusion

There are many different types and styles of audio storage and communication devices available on today's market. Many of them overlap with others in the areas where they are targeted for usage. It is important for you to take a serious look at your operation, and try to use technologies that let you cover as much territory as possible. Keep in mind the fact that growth in the development of these technologies is continuing forward. When you buy into a technology, make sure that it will grow and expand in it's capabilities as the future unfolds. Do not be afraid to ask questions of manufacturers, distributors, consultants, and of course your peers.

The following chart may assist you in determining which technologies are acceptable for each of your audio applications:

APPLICATION	CD	RECORDABLE CD	MD	MO	FLOPTICAL	DCC	DAT	HARD DRIVE
NEWS GATHERING			X	X		X	X	
PROD MASTERING		X	X		X		X	X
COMMERCIALS			X	X	X			X
AUDIO BACK-UP		X		X		X	X	X
LONG FORM STORAGE	X	X	X	X		X	X	X
QUICK AUDIO EDITING				X			X	X
MUSIC PLAYBACK	X	X	X	X		X	X	X

TV DATA BROADCASTING: TECHNOLOGY DEVELOPMENT

Monday, April 10, 1995

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USING ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING IN THE VERTICAL INTERVAL OF AN NTSC TV TRANSMISSION

Majid Chelehmal, Ph. D.
Tom Williams
CableLabs
Louisville, CO

ABSTRACT

This paper describes an efficient method for the transmission of digital data through a standard television channel using one or more horizontal lines in the vertical blanking interval (VBI). Using this technique, the raw data is first transformed using orthogonal functions, then the transformed data is transmitted. At the receive site, an inverse operation is performed to recover the original data. This technique is known as orthogonal frequency division multiplexing (OFDM). It offers the possibility of high immunity to ghosts (echos, or mulipath reflections). The use of a guard interval further extends the echo performance. When OFDM is combined with error-correcting codes, immunity to carrier wave interference can be obtained. This transform method offers advantages over conventional teletext, and may be implemented using less hardware complexity than single carrier modulation employing a time domain adaptive equalizer.

BACKGROUND

Orthogonal frequency division multiplexing (OFDM) is a technique for transmitting data. With OFDM, an inverse discrete Fourier transform (IDFT) of a block of original data is sent instead of the original data. OFDM is a frequency division multiplex of many synchronized low data rate orthogonal carriers instead of a single high-speed carrier, such as QPSK. Using the OFDM technique for transmitting data results in several advantages, which are based on the properties of the Fourier transform. At the receive site, the forward discrete Fourier transform (DFT) is used to recover the original data.

THE FOURIER TRANSFORM

Before launching into an example, it is valuable to examine the characteristics of the Fourier transform, the DFT, and the fast Fourier transform (FFT). The Fourier transform is a mathematical operator that performs conversions between the time and frequency domains.[1] The DFT is defined by:

$$G(k) = \sum_{n=0}^{N-1} g(n)\, e^{-j2\pi k\frac{n}{N}} \qquad k = 0, 1, 2, \ldots, N-1 \tag{1}$$

and the IDFT by:

$$g(n) = \frac{1}{N}\sum_{k=0}^{N-1} G(k)\, e^{j2\pi n\frac{k}{N}} \qquad n = 0, 1, 2, \ldots, N-1 \tag{2}$$

where g(n) denotes a discrete-time signal and G(k) is its DFT transform. N is the number of samples in the transform.

The Fourier transform and its inverse operate on complex (real and imaginary) numbers. What makes the Fourier transform desirable for digital signal processing (DSP) applications is the existence of several FFT algorithms that drastically reduce the number of computational operations required to perform the transform. Direct computation of the DFT requires on the order of N^2 operations, where N is the transform length. Using an FFT, the number of computations is proportional to $(N)Log_2(N)$. As a rough approximation, a 1024-point FFT can be done in about 100 μs by a dedicated FFT DSP chip, in about 3 ms by a high-end PC processor, and in slightly less than that by a general-purpose programmable DSP chip. These transform times depend on the exact FFT algorithm and accuracy. The Fourier transform is a linear mathematical operation. Therefore, the principal of superposition applies.

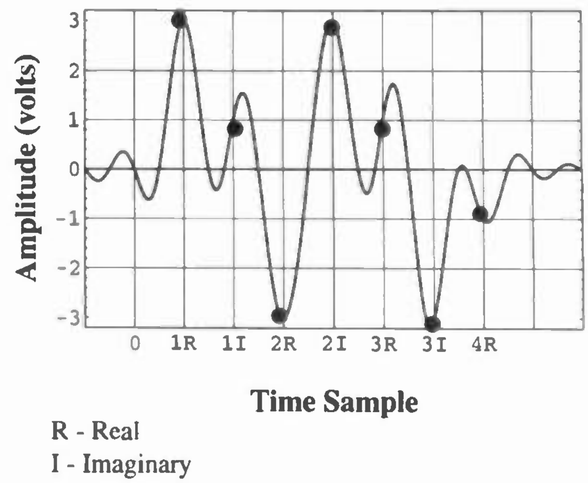


Fig. 1 A block of data in time domain.

A Simple Example

Figure 1 is a time domain waveform with 14 bits (7 symbols) of randomly chosen data in a block. The original data block is assumed to be an arbitrary sequence of {+3, +1, -3, +3, +1, -3, -1}. Two bits of data are mapped into each of the four different voltage levels. The data have been shaped by a low-pass Nyquist filter, so that the resulting pulses have a Nyquist response. This resembles conventional time domain baseband data, such as teletext, viewed on an oscilloscope. The Nyquist filtering band limits the data without any intersymbol interference between pulses at the sampling instants (providing, of course, that there are no echoes in the channel). Note the voltage sample's values at the sampling times, which are shown as dots. These voltage levels are also known as symbol values. Since two bits of data determine each sample voltage, this system is said to use two bits per symbol.

To perform an IDFT and force imaginary terms of the output data to zero, the real part of the input data must be even symmetric, and the imaginary part must be odd-symmetric about the N/2 sample. This requires the use of an 8-point transform for seven symbols of data. The reason for avoiding imaginary terms is that a VSB television transmitter does not normally contain a quadrature channel with which to send the imaginary information. The input data and the resulting transformed output data are shown in Table 1. The DC term was set to 0 so no DC shift will be produced on the active portion of the horizontal line. The seven symbols were alternated between the real and imaginary columns. The bottom trace of Figure 2 is a plot of the output data resulting from the transform (column 4). This waveform is transmitted. Note the table values are identical to the sample values. Column 5, the imaginary terms, have been forced to be zero and need not be sent.

TABLE 1. An 8-Point Discrete Fourier Transform Example

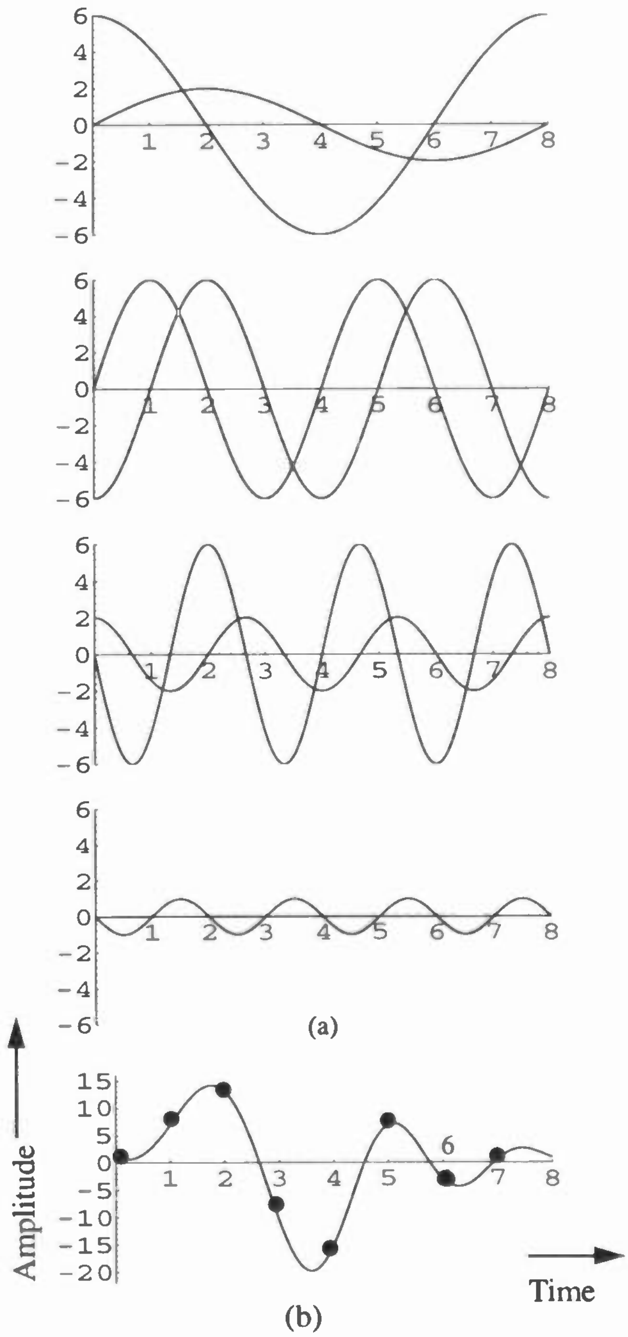
1	2	3		4	5
N	Real	Imag.		Real	Imag.
0	0.0	0.0		1.0	0.0
1	+3.0	+1.0		7.0	0.0
2	-3.0	+3.0	>IFFT>	13.0	0.0
3	+1.0	-3.0		-10.65	0.0
4	-1.0	0.0	<FFT<	-15.0	0.0
5	+1.0	+3.0		7.0	0.0
6	-3.0	-3.0		-3.0	0.0
7	+3.0	-1.0		0.66	0.0

If this waveform is decomposed into its various harmonic components, or viewed on a spectrum analyzer, it can be seen to contain energy at the 1st through the 4th harmonics. The four constituent harmonics are shown above the transmitted time signal trace in Figure 2. Each harmonic is complex, and may be viewed as containing a real (cosine) and imaginary (sine) term. Note that the amplitude of each sine and cosine term corresponds to the values found in columns 2 and 3 of Table 1. The first through the third terms are doubled because the data values were used twice symmetrically. Thus, frequency domain data has been transformed into the time domain.

Capturing these samples in a receiver and forward transforming them restores the original data block by the inverse process. This simple example was done only for purposes of illustration of the Fourier transform process. In a practical TV system, the number of samples will be much larger than eight.

The transform data may be viewed as multiple parallel low data rate streams, (in this simple example only four), each occupying its own narrow frequency band. The low data rate is equal to the block rate. In this example, the block rate is one-eighth of the original symbol rate.

Some immunity to echoes is obtained automatically by the low data transmission rate of the individual OFDM harmonics if the channel's echoes are short compared to the block rate. Additional immunity to echoes can be obtained by using a guard interval comprised of time domain samples copied from the end of the transmitted data block and appended to the front of the data block. The length or duration of the guard interval should be proportional to the delay of the severe echoes anticipated in the channel. A cable channel would be expected to have shorter echoes than a broadcast signal. If leading echoes are expected, a short leading guard interval may be used.



(a) Frequency components

(b) Resultant signal summation

Fig. 2 Decomposition of an OFDM signal.

As mentioned above, advantages of an OFDM data transmission are related to the properties of the Fourier transform. In particular:

1. An impulse in the time domain transforms to a flat energy spectrum in the frequency domain. This means that a large amplitude spike from impulsive noise in the channel shows up at a much lower level spread over all the samples of the transformed data.

2. A sine or cosine wave in the time domain transforms to a line, or impulse, in the frequency domain. This means that a co-channel interfering carrier would damage the data in one, or a few, of the transformed samples at the receive site. However, if error-correcting codes, such as Reed-Solomon block codes, are used, unimpaired data reception may be restored at a slightly lower data rate.

3. If the original data is random (i.e., noise-like) then the transform of the data will also be random. This implies that the transmitted spectral energy should be flat. This is easily accomplished with a data randomizer utilizing a pseudo-random generator.

APPLICATIONS TO NTSC OR PAL TRANSMISSIONS

OFDM transformed data may be inserted into the horizontal line structure of an analog TV signal. If one or more of the lines in the vertical interval are used, the data will not interfere with picture reception. Advantages, compared to conventional teletext, should be a higher data rate and/or greater data robustness to channel impairments with a relatively low receiver implementation cost. Although the instantaneous OFDM data transmission rate is high in the vertical interval, the voltage samples can be captured and later transformed during the active picture (about 16.7 ms) while analog video and sync are being transmitted. This provides sufficient time to perform the forward DFT using lower-cost digital components, such as DSP chips and general-purpose microprocessors.

VSB MODULATION OF OFDM

Figure 3 is an NTSC horizontal line carrying a proposed OFDM signal composed of 172 (complex valued) samples or frequency components in the frequency domain. The active line consists of 640 total samples (51.08 μs) in the time domain, with a leading guard interval of 120 samples, 512 useful samples (40.87 μs), and a trailing guard interval of 8 samples. The sampling rate is chosen to be at 12.528 MHz, and phase-locked to the chroma burst. The low-speed block symbol rate is 24.47 kHz. Only 172 components of the 255 are used to provide for simple post filtering, and limit the maximum frequency to 4.2 MHz, (i.e., 24.47 kHz * 172), thus avoiding interference with the sound carrier. The transformed data is biased on a pedestal of 40 IRE, with a maximum of 100 IRE and a minimum of -20 IRE enforced by clipping. If this data is captured and Fourier transformed, the resulting real and imaginary data samples may be displayed on a Real-Imaginary diagram with the real samples (i.e., cosine terms) on the X-axis and the imaginary samples (i.e., sine terms) on the Y-axis. This is illustrated in Figure 4. Each individual constellation point is the complex value of one frequency component representing two data values. The constellation points are spread very slightly as a result of quantizing the data to only eight bits of resolution.

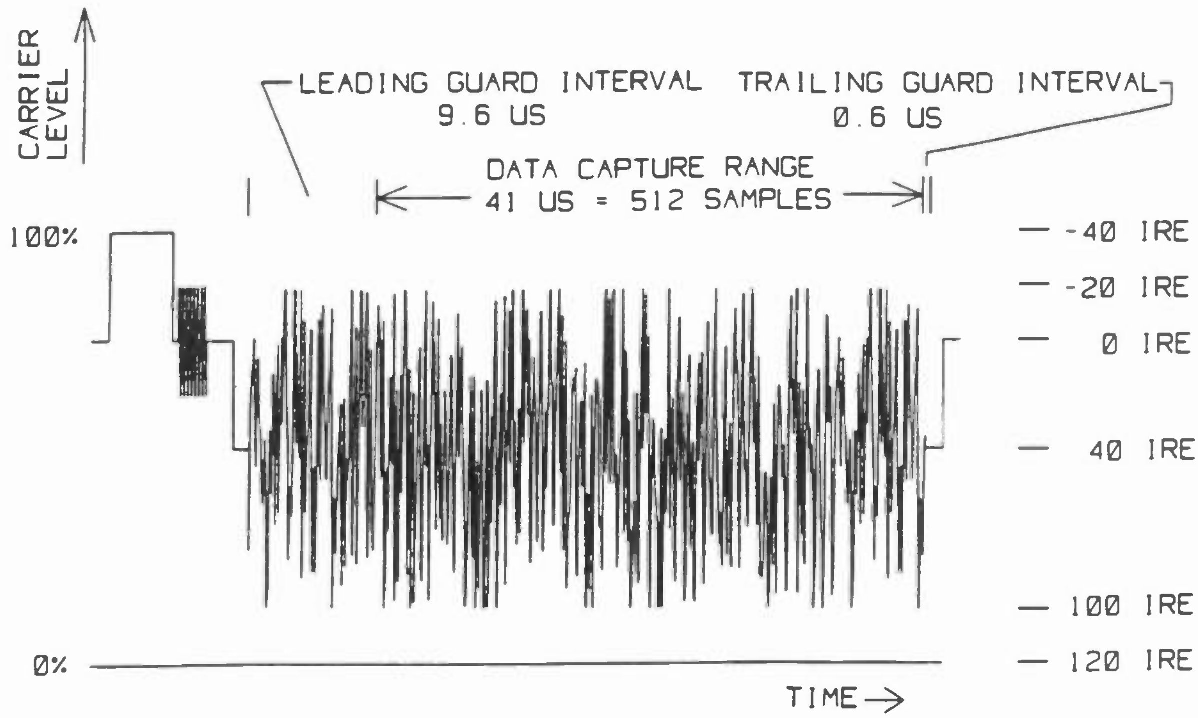


Fig. 3 An NTSC horizontal line carrying an OFDM signal.

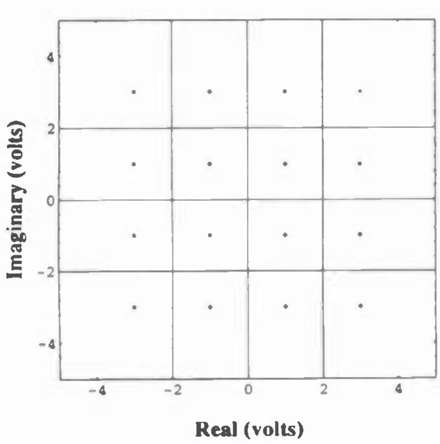


Fig. 4 Real-Imaginary diagram for an OFDM signal at the transmitter.

An OFDM transmission is a composition of many frequency components which occasionally line up in phase and produce large excursions. If random noise is encountered in the channel, it is useful to maximize signal-to-noise ratio (SNR) for the lowest error rate. However, with an NTSC transmission, it is necessary to limit both the peak positive and negative voltages by clipping. The challenge is to determine the correct amount of clipping that maximizes the resultant SNR, while minimizing the ill effects of excessive clipping.

Figure 5 is a Real-Imaginary diagram showing the constellation points spreading caused by clipping. The clipping process may be modeled as an unclipped signal summed with the clipped portion added out of phase. Thus, clipped energy resembles impulses, and energy is spread to all transformed symbols.

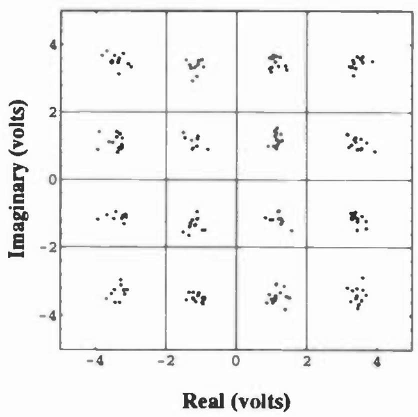


Fig. 5 Real-Imaginary diagram showing the effect of signal clipping at the transmitter.

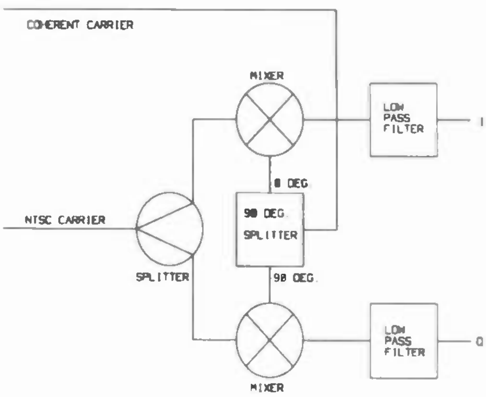


Fig. 6 A block diagram of a synchronous quadrature demodulator.

THE DEMODULATOR

In the example given above, OFDM is examined at baseband. VSB modulation and demodulation employing conventional Nyquist slope filtering at the receiver may be used to replicate such a baseband OFDM signal. However, it is informative to look at demodulation by a synchronous quadrature demodulator to examine the effects of real channel impairments, such as echoes, ICPM (incidental carrier phase modulation), phase noise, and residual FM on the recovered signal samples. Figure 6 is a block diagram of a conventional quadrature synchronous demodulator which produces I (inphase) and Q (quadrature) outputs from a coherent carrier reference and an NTSC carrier.

Figure 7 is an I-Q diagram of a transmitted NTSC signal showing phasor movement for the OFDM sample capture period. I-Q displays are not commonly used for NTSC modulation, but they are illustrative. The NTSC carrier is not filtered by the receiver IF Nyquist slope filter. Only the real part of the first OFDM harmonic is displayed. For reference, the sync, peak white, and black level points are illustrated. If no echo is present, and if only the upper sideband of the NTSC carrier is analyzed for the duration of the OFDM sample capture, the phasor will rotate 360 degrees around the axis point, as shown by the "main signal" solid line. This phasor takes about 41 μs to make the single 360-degree rotation, and 512 samples will be taken during this time. (Had the lower sideband been illustrated, it would have rotated in the opposite direction.) The radius of this first OFDM harmonic is 30 IRE, so all of the energy of the OFDM signal is devoted to this single harmonic. Had the second harmonic been illustrated, two rotations would have been observed. The demodulated signal, as recovered by the I channel of the synchronous demodulator, is shown below the phasor diagram as a projection on the I-axis versus time. If an echo signal (another solid line) is in the channel and is shorter in duration than the guard interval, its trajectory will be as shown by the smaller circle. In this example, the echo is at 135 degrees and half the amplitude of the main signal, with negligible delay. The received signal will be a vector addition of the two voltages,

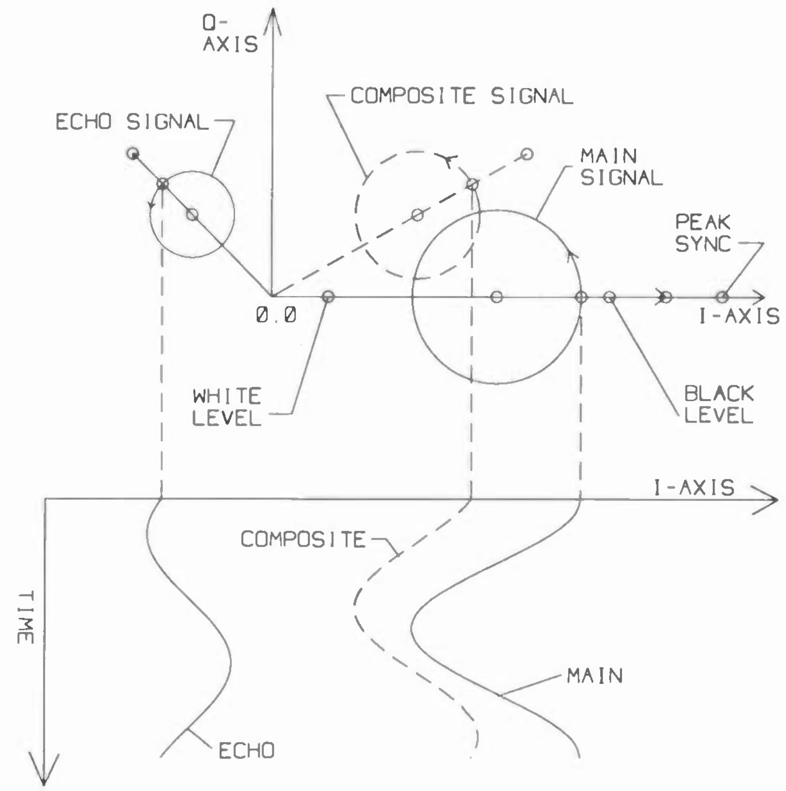


Fig. 7 I-Q diagram for an NTSC signal with echo.

shown as the "composite signal" (dashed circle) and its corresponding projection on the real axis. The echo has caused both an amplitude and phase shift in the composite signal. Thus, OFDM reception will require a simple single-tap frequency domain complex adaptive equalizer in the presence of strong echoes, as described in the following discussion.

It should be pointed out that, if the echo is long and the carrier frequency is high, the 135-degree echo starting point offset in this example may have been produced by many rotations, or spins, about the origin. The number of rotations is the echo delay distance divided by the carrier wavelength. A long echo delay will cause an additional phase shift in the demodulated echo due to the offset start point of the echo phasor. Moreover, the long delay will produce a greater relative phase shift on a higher harmonic than on a lower harmonic because higher harmonics rotate in less time.

Thus, the amplitude and phase shift of the composite signal will be a function of the echo delay, echo phase, echo amplitude, and harmonic number of the affected harmonic component. A periodic training, or reference, signal may be used to establish a correction phase and magnitude for each OFDM harmonic. If other phase-disturbing impairments such as residual FM, phase noise, and ICPM afflict the channel, the starting and ending points for the phasor will be rotated off of the I-axis. However, if the phase motion is slow compared to the capture time, the starting and ending points for the phasor will be nearly the same.

As a point of interest, if the 3.58 MHz chroma burst (which occupies only the upper sideband) of an NTSC signal is viewed on the I-Q diagram, it will make eight or nine circular rotations about the blanking point. In this respect, the burst is similar to one of the OFDM harmonics.

CAPTURED DATA

Figure 8 illustrates captured random OFDM data and its Fourier transform. The data was generated in the lab and sent through a cable channel A-1 modulator to an I-Q demodulator similar to the one illustrated in Figure 6. The upper two traces contain 512 real and 512 imaginary time-domain samples that were captured on a two-channel digital oscilloscope. Note the real data are biased on a pedestal and have a DC level offset. The imaginary data appear to have higher frequency energy content because low frequency cancellation in the Q channel occurs

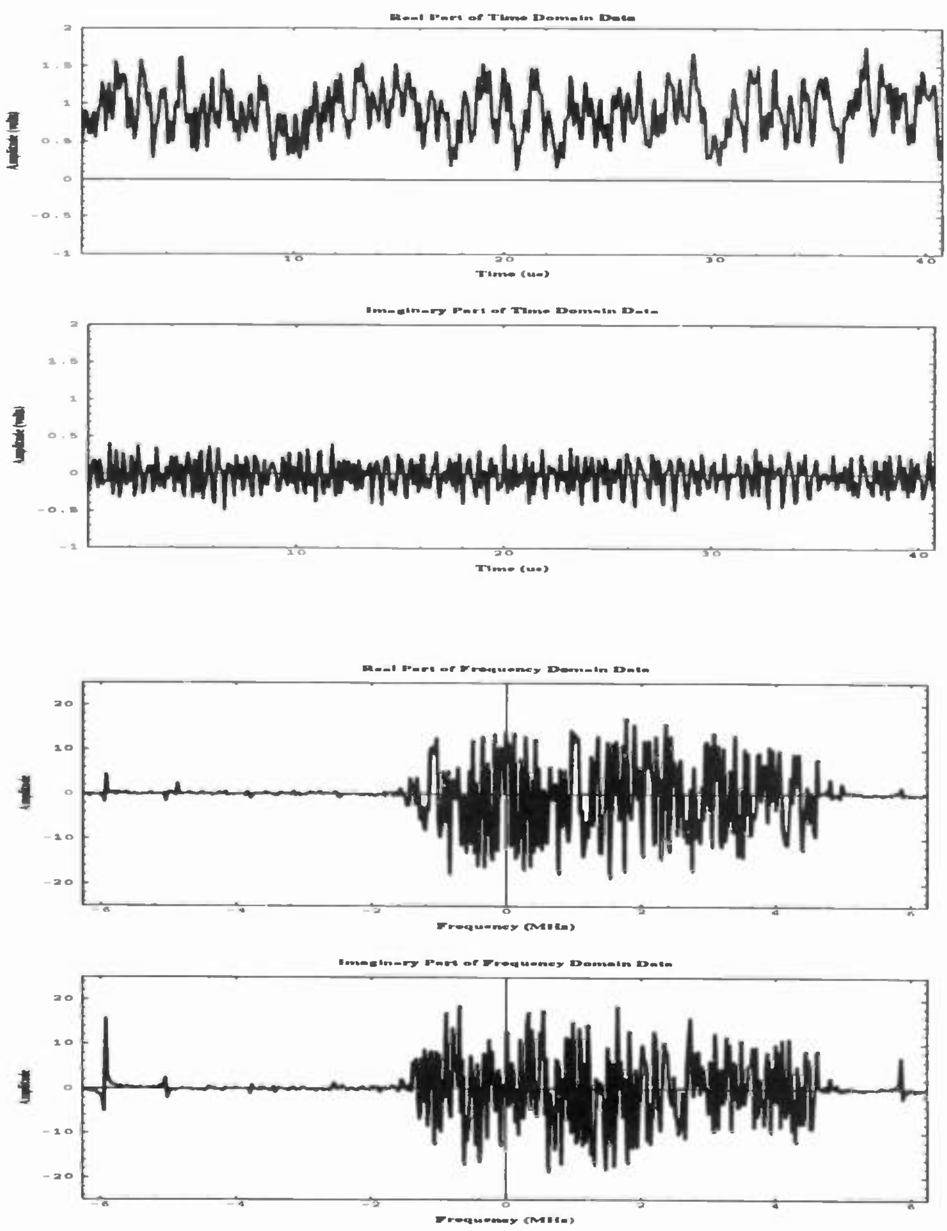


Fig. 8 Captured data from channel A-1 and its Fourier transform.

due to the presence of matching lower sideband in the double sideband portion of the AM-VSB signal. The frequency domain data displays the carrier (DC) at the origin in the center of the lower two traces, and the highest frequency (e.g., 6.2 MHz) is at the right of the trace. The highest frequency sample on the lower sideband with energy is found on the left, which is limited by the modulator's VSB (vestigial sideband) filter. The highest frequency sample with energy on the upper sideband is found on the right which is limited by only transmitting some (e.g., 172) of the possible 255 carriers. Note the spurious high frequency energy in the channel (caused by the removal of an IF filter that was too narrow for this test).

These data show that a VSB demodulator can be built to capture OFDM data without any Nyquist filtering on the IF carrier. The Fourier transform naturally separates phasors that are rotating clockwise (lower sideband) on the left side of the transform, and phasors that are rotating counterclockwise (upper sideband) on the right side of the transform. To reject the lower sideband, the receiver designer only has to ignore the half of the transform with energy from signals at negative frequencies (i.e., below the RF carrier frequency at the origin). In the case where a conventional IF Nyquist slope filter is used, only a real (inphase) signal is recovered. The resulting transform will have upper and lower sidebands which are symmetric.

TECHNICAL CHALLENGES IN BUILDING A SYSTEM

As a result of laboratory experiments and computer simulations, CableLabs has uncovered some of the implementation challenges. To some extent, the job of building this OFDM system is simplified by the presence of the NTSC RF signal, which provides a strong carrier for RF synchronization, and frequent 3.58-MHz chroma bursts which can be used for timing. On the negative side, the OFDM bursts will be relatively infrequent due to intervening picture information so that impairments, such as moving echoes, will have a relatively long time to change between blocks of data.

Timing error and timing jitter are two sources of time sampling error. Figure 9 illustrates the critical nature of the sampling time accuracy. The spreading of the constellation points occurs as a result of shifting the sample clock a half sampling period (about 40 ns). The lower frequency components are relatively unaffected, but the higher frequency components are severely rotated. Accurate timing is a greater challenge in the presence of strong echoes and dynamic echoes. Dynamic echoes represent another challenge besides just timing: an accurate update is continually needed for equalization.

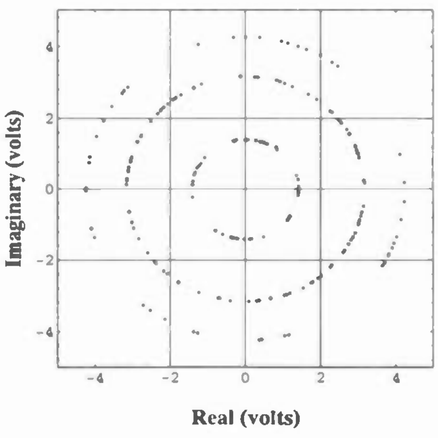


Fig. 9 Real-Imaginary diagram showing the effect of sampling error.

A receiver capturing a GCR (ghost cancelling reference) waveform faces a similar challenge. It is presumed that sampling frequency error between transmitter and receiver sampling clocks is insignificant.

Gledhill et al.[2] discuss some of the demodulation techniques that can be employed on an OFDM signal.

Table 2 list the time and frequency domain parameters for a possible NTSC/OFDM data transmission system utilizing a horizontal line VBI signal.

TABLE 2. Parameters for a possible NTSC/OFDM data transmission system in the VBI.

Frequency Domain:

Number of transmitted carriers:

172 out of 256 (complex carriers).

Last carrier at:

4.2 MHz

Spacing between individual carrier:

24.47 kHz

Number of FFT samples:

512

Time Domain:

Clock rate:

12.528 MHz (79.82 µs / sample)

Total samples:

640 samples / 51.08 µs

Captured FFT samples:

512 samples / 40.87 µs

Leading guard interval:

120 samples / 9.57 µs

Trailing guard interval:

8 samples / 0.638 µs

CONCLUSION

This paper introduces the idea of using an OFDM transformed data signal in the VBI of an NTSC or PAL transmission. One possible implementation using an OFDM-16QAM signal has been described. A demodulation model that may be used to explain the effects of channel impairments was presented. Some of the details associated with implementation have been discussed, along with lab data.

ACKNOWLEDGMENTS

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TELEVISION ON-LINE: INTERACTIVITY AND NEW MEDIA

Monday, April 10, 1995

Session Chairperson:
Doug Garlinger, Lesea Broadcasting, Noblesville, IN

***BENEFITS OF ONLINE SERVICES FOR THE BROADCAST INDUSTRY**
Harlan S. Levinson
UNET 2 Corporation
New York, NY

WIRELESS TECHNOLOGIES FOR INTERACTIVE VOICE AND DATA SERVICE IN THE 218-219 MHZ FREQUENCIES IN THE U.S.
Alex Calderon
Concepts to Operations
Annapolis, MD

***MHEG/MPEG2 INTEROPERABILITY: A KEY ISSUE FOR THE DEVELOPMENT OF MULTIMEDIA AUDIO-VISUAL SERVICES**
Pierre Jourdan
CCETT
Cesson Sevigne, France

REAL-TIME GENERATION OF DATA DEPENDENT GRAPHICS
Mark A. Harris
CBS
New York, NY
Chuck Molyneaux
Silicon Graphics
Maitland, FL
Michael Rich
Media Computing Inc.
Phoenix, AZ

***PRACTICAL STEPS TO ENTERING THE DIGITAL REVOLUTION**
John W. Kaufmann
Digital Equipment Corporation
Shrewsbury, MA

MULTIMEDIA SERVICES IN BROADCASTING
Tadashi Isobe
NHK
Tokyo, Japan

*Papers not available at the time of publication

WIRELESS TECHNOLOGIES FOR INTERACTIVE VIDEO AND DATA SERVICE IN THE 218-219 MHZ FREQUENCIES IN THE UNITED STATES

Stanley I. Cohn, Executive Vice-President
Alejandro A. Calderón, President
Concepts To Operations, Inc., Annapolis, Maryland

In 1992 the Federal Communications Commission established the Interactive Video and Data Service (IVDS) for use in the United States. This wireless service allows interaction with TV signals and also with various data systems. The frequency band chosen by the FCC was the 218-219 MHz band with two licenses in each market. The markets are the same markets that were used for Cellular Radio Systems in the United States.

In choosing the 218-219 MHz frequency band the FCC had a concern about interference to existing services that were in nearby frequency bands. In particular, the interference to TV Channel 13 and the Automated Maritime Telecommunications System was addressed in the rules published by the FCC. In order to avoid interference with TV Channel 13, the rules allowed for a cellular type of system which would consist of a central transmitter/receiver (CTS) unit in each cell and a number of home units which would be receiver/transmitter units at each subscribers home. The use of a cellular system allows the reuse of frequencies and is thought to be most spectrum efficient. The power of the central transmitters were allowed to be only a maximum of 20 watts, the antennas heights were also restricted. Based on the CTS location, with respect to the various contours of the TV Channel 13 service area, the height above average terrain (HAAT) and effective radiated power (ERP) limitations were set. These translate into approximate cell radii as shown in **TABLE I**.

The power of the home set top units (Remote Terminal Unit or RTU), were also limited to 20 watts, but less power is to be used where feasible. In particular, a control of the power was required to reduce the power automatically to that needed to

TABLE I - IVDS Coverage Limitations

TV Channel 13 Service Area	Maximum CTS ERP	Maximum HAAT	Approximate Cell Radius
City Grade	20 watts	120 feet (37m)	10.4 miles (16.6km)
Grade A	7 watts	120 feet (37m)	8.0 miles (12.8km)
Grade B	1 watt	120 feet (37m)	4.8 miles (7.7km)
Grade B +2 miles (3.2km)	1 watt	120 feet (37m)	4.8 miles (7.7km)
Grade B +3 miles (4.8km)	3 watts	120 feet (37m)	6.4 miles (10.2km)
Grade B +4 miles (6.4km)	10 watts	120 feet (37m)	8.7 miles (14.0km)
Grade B +5 miles (8.0km) and beyond	20 watts	120 feet (37m)	10.4 miles (16.6km)
Grade B +10 miles (16.0km) and beyond	20 watts	500 feet (150m)	20.6 miles (33.0km)

communicate with the CTS receiver. The home units are restricted to transmit 5 seconds per hour to avoid interference conditions.

An alternate system, which takes advantage of the horizontal and vertical blanking intervals of Channel 13 in order to avoid interference, was considered by the FCC. However, a waiver of the rules is required in order to use such a system.

In March 1994, licenses were awarded through a lottery process for the nine (9) largest Metropolitan Statistical Areas (MSA's); two licenses were awarded in each market area. In July 1994, the remaining MSA licenses were involved in an auction process whereby the two highest bidders in each market were to receive licenses. The FCC will be awarding these licenses shortly. All licenses will be awarded with the understanding that 10% of the area or population in each market should be covered by the end of the first year, 30% of the area or population in each market by the end of three years, and 50% or more of the population or area are to be covered at the end of five years.

Three companies in the US have developed, or are developing systems for IVDS use. These are e•on Corporation (EON) located in Reston, VA; Radio Telecom and Technology, Inc. (RTT) located in Riverside, CA; and Interactive Return Services, Inc. (IRS, Inc.) which is located in Reston, VA. The methodology used by each these companies are compared in **TABLE II**.

EON uses physical cells with the radii shown which correspond approximately to the radii allowed in the FCC rules. They use the IVDS frequencies both for transmission from the central CTS to the remote unit and from the remote RTU back to the CTS receiver.

RTT does not use physical cells; instead what are called virtual cells are used and require a waiver of the FCC rules. The RTT system, called T-Net, has a coverage radius of 20-30 miles (32-48km) for each CTS. The information from the CTS to the RTU is transmitted via IVDS frequencies plus a synchronization signal from Channel 13. The vertical blanking interval of a host TV station can also be used. Transmission returning from the RTU to the CTS is by IVDS frequencies.

Interactive Return Services, Inc. uses physical cells for receive only. They use a handheld unit at the subscribers' locations with a power of about 100mw which results in a coverage of 1-2 mile (1.6-3.2km) radius. There is no direct communication from the CTS to the RTU as IRS, Inc. relies on the advertiser or programmer to put an audio signal on the TV signal which activates the handheld unit. The transmission from the subscriber to the central cell location is via the IVDS frequencies.

TABLE II - IVDS Technology Comparison

Company	System	Coverage	CTS to RTU	RTU to CTS
e•on	Physical Cells	2-4 mile (3.2-6.4km) radius (Grade B) 4-7 mile (6.4-11.2km) radius (Grade A) 6-9 mile (9.6-14.4km) radius (City Grade) per cell	IVDS	IVDS
RTT	Virtual Cells	20-30 mile (32-48km) radius per CTS	IVDS + Channel 13 + Host VBI	IVDS
IRS, Inc.	Physical Cells (Receive Only)	1-2 mile (1.6-3.2km) radius per CTS	None, Beep on TV	IVDS

Figure 1 illustrates the EON IVDS System. Originally EON proposed CTS sites with RTU home units surrounding the sites. In that stage of their development the, RTU's were to have a maximum power of 20 watts. In order to avoid TV interference, EON decided to use remote receivers which would allow them to reduce the power of the RTU's and increase subscriber capacity. Each of their cells handle five thousand subscribers times the number of remote receiver units. A maximum of fourteen remote receiver units can be associated with each CTS. A cell in EON's system can therefore handle up to seventy thousand subscribers. **Figure 2** illustrates the relative size of the cells, depending on whether the CTS is located within the Grade A contour of the TV signal or City Grade coverage. Cell sites within the Grade B coverage are smaller and more cells are required for coverage of an area.

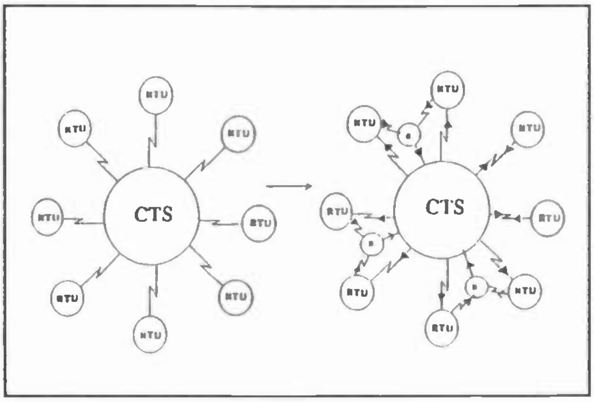

Figure 1
e•on IVDS System Diagram

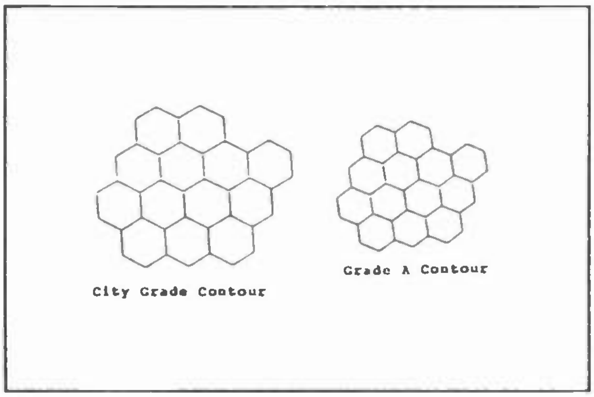

Figure 2
Relative Cell Sites

In the EON system, satellite transmission is used to transmit the information gathered at a cell site to the Hub location in the United States as shown in **Figure 3**. The satellite link is also used to transmit from the Hub to the various advertisers and service providers, and from the service providers to the central location. The Hub also returns information via the satellite link to the cell site which then returns information to the subscriber RTU.

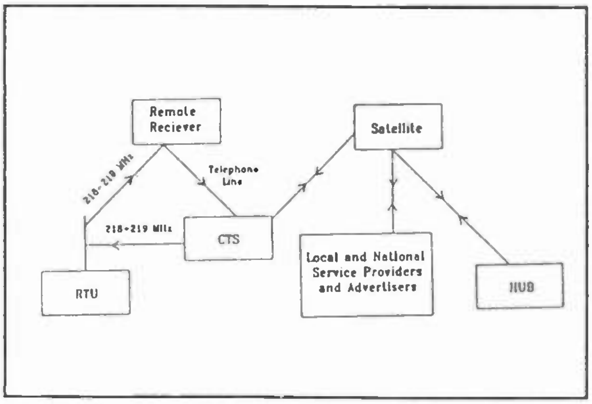

Figure 3
e•on System Interconnections

The RTT T-Net IVDS System is illustrated in **Figure 4**. RTT uses a central transmitter site and home RTU units.

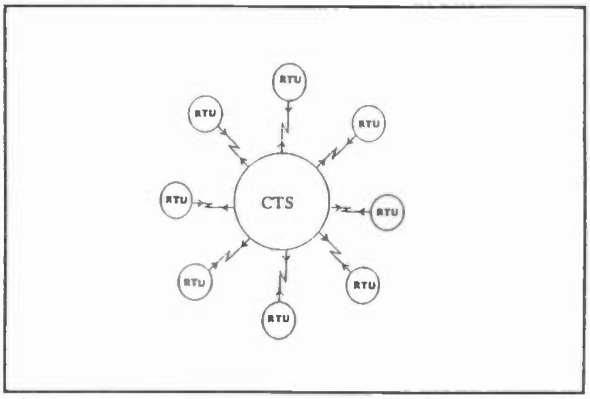

Figure 4
RTT IVDS System Diagram

Because of use of the horizontal blanking interval of TV Channel 13 to synchronize the transmissions of the RTU's, T-Net has what is called a virtual cell arrangement as illustrated in **Figure 5**.

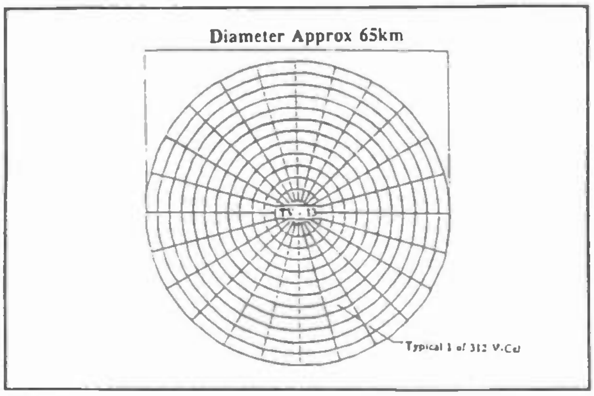

Figure 5
Typical Virtual Cellular Arrangement

With a cellular diameter of approximately 65km or 40 miles, T-Net can cover a considerably larger area with one transmitter than systems that use physical cells. Each transmitter/receiver unit is associated with an angular sector of coverage. Initially coverage can start with an omni-directional system which will allow for approximately 30,000 subscribers. An expansion would be to use four directional antennas to provide four sectors of coverage. This would cover 120,000 subscribers. Further division of the sectors can be achieved to cover more subscribers as more capacity is needed for the system. RTT uses a packet switched telephone network to link a subscriber via the CTS to national and local advertisers and service providers who are in the same packet switched network as shown in **Figure 6**.

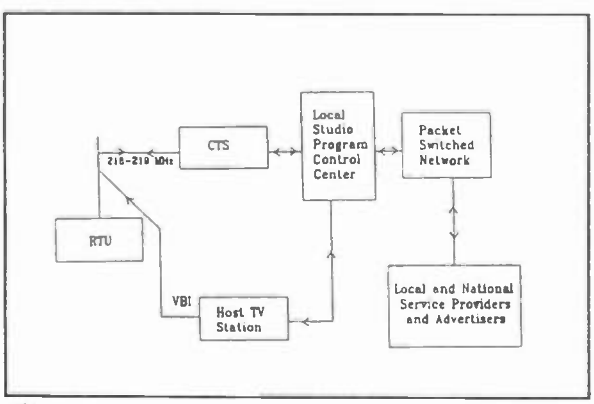

Figure 6
RTT System Interconnections

Figure 7 illustrates the IRS, Inc. System which consists of handheld RTU's and numerous cell sites of 1-2 mile radius. From each cell site telephone lines are used to return the signal to a central location and from there to local and national advertisers or service providers as shown in **Figure 8**.

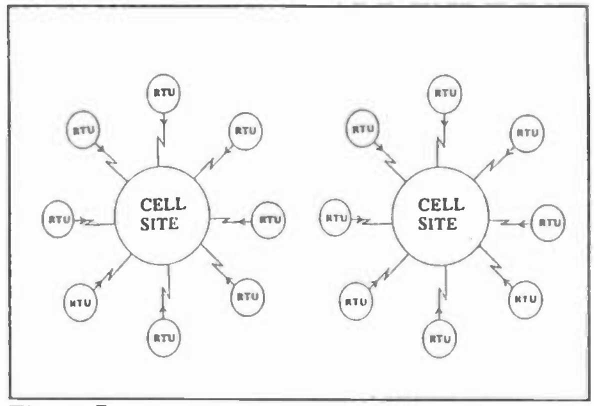

Figure 7
IRS, Inc. IVDS System Diagram

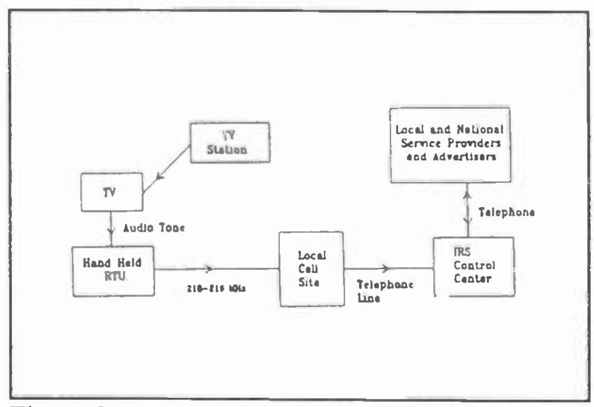

Figure 8
IRS, Inc. System Interconnections

The Federal Communications Commission was concerned with reducing the possibility of interference to Channel 13 viewers. In particular, if the service area of an IVDS system overlaps the Channel 13 Grade B contour, a notice to the public must be given and the IVDS licensee must respond to any complaints of interference from Channel 13 viewers and eliminate the interference. A waiver of this requirement can be obtained by getting written consent of the Channel 13 licensee in the area.

There are various interference sources and victims as summarized below:

- o CTS to Channel 13
- o RTU to Channel 13
- o IVDS to AMTS
- o IVDS to IVDS Neighbor
- o Other Sources of Interference to TV
  - Household Appliances
  - Automobile Ignition
  - Industrial Equipment, etc.

An interference complaint causes the IVDS licensee to send service personnel to determine the cause and eliminate objectional IVDS interference, or convince the viewer that the interference is due to other sources. The interference reduction techniques that can be used involve system design considerations and after-the-fact or operational corrections. Among the system design considerations are limitation on effective radiated power, antenna height, distances from CTS to residential facilities and duty cycle as well as certain emission standards. Coordination is required with the neighboring IVDS systems which operates on the same channel. TV blanking intervals, as used in the RTT system, and micro cells as used in the EON and IRS, Inc. systems are also used to reduce interference. After the fact operational correction of interference would include filters, shielding, change in the location of a CTS, change in location of RTU antennas, or proof of the source being other than IVDS system.

The three IVDS Systems have been designed to minimize the interference potential to Channel 13 and to the Automated Marine Telecommunication System. The Automated Marine Telecommunication System operates in the inland waterways of the United States and does not present a problem in most areas. Channel 13 appears to be the largest potential interference problem because it is used in many locations as shown in **Figure 9**.

Each of the manufacturers have designed set top boxes, except for IRS, Inc. which use a handheld unit. The basic set top boxes at the present time are of a simple design which allow for a minimum type reply and no display capability on the screen. More advanced units are available which allows for display on the screen, but are considerably more costly, and there is a question of public acceptance of the higher cost involved. As time goes on the cost of the set top units should be greatly reduced. It is also anticipated that these technologies can be combined with capabilities of cable set top boxes.

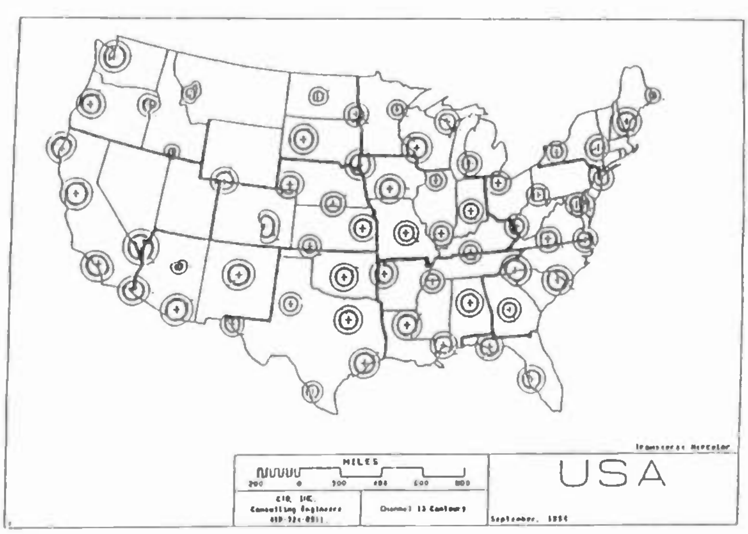

Figure 9
Channel 13 Locations and Contours

REAL-TIME GENERATION OF DATA DEPENDENT GRAPHICS

Mark Harris
CBS Engineering
New York, NY

Chuck Molyneaux
Silicon Graphics
Maitland, FL

Michael Rich
Media Computing, Inc.
Phoenix, AZ

Abstract: In 1994, CBS News decided to take a new approach to the on-air look for presentation of election data. A look was developed, independent of graphics hardware, that required a new concept in implementation. Data displays were to appear to be on surfaces of a star that would move in non-linear ways in 3-D space. In addition, it was desirable to light the object so the data displays would also be lighted. Several methods, using conventional broadcast hardware, were considered and rejected. A discussion with Silicon Graphics lead to the use of their hardware and the development of software that could provide the desired result. The star object was modeled, the animation created, the system constructed and the control software completed. The result closely matched the original concept and marked the first time that broadcast resolution 3-D graphics, incorporating live video, were created in real-time. This paper will discuss the design concept and the hardware and software used to implement that design. We will conclude with a discussion of the system used to control all of the devices involved.

Introduction: The nation-wide election, held every two years, provides the television networks with an opportunity to use state-of-the-art graphics equipment to display and explain results. CBS News has a history in this area that begins with the use of modified terminals in 1970 and extends though the first use of character generators and video disk recorders. During this history computers have always been used to collect the data required and control the various graphics devices to provide interesting and coordinated displays.

Two recent elections demonstrate how then state-of-the-art equipment can be pushed to generate displays that provide data to the public quickly and with visual interest.

Prior Systems: In 1988 the graphics design used a background that was a US map moving from state-to-state. Over that was the variable data from a character generator and pictures of the candidates with the winner above the loser. No device then existed that would air the pictures and text and provide the desired wipe on and off of all this information. As you see in figure 1, five devices and three video keyers were used. Video timing was difficult especially since many of the devices were used for other broadcasts as well as our election testing and rehearsals. Each of these devices was controlled from a VAX computer system that was also handling the database. In order to ensure that all elements of the displays were available simultaneously, some were actually controlled by others.

By 1992 the current compliment of graphics equipment was in place. Now the collection of equipment used in 1988 were combined into two devices. Figure 2 shows the system then used. In addition the old VAX computers were abandoned for a network of personal computers. Later in this paper there will be a description of this network.

1994 Design: In 1994 the design of the on-air graphics and the transition between displays required new technology. In the past any 3-D element to the graphics or transition had to be modeled and rendered in advance to be played back from a video disk recorder. Although some compositing within these devices was possible, and done by CBS News in 1986, this was time consuming. Since one of the system requirements has always been speed, these displays carried a tremendous penalty. CBS News desired to have displays mapped onto the flat surfaces of a star. To transition between displays the star would rotate, moving the current display off and the next one on. During this transition light sources would move across the faces of the star.

Several methods were considered. Standard digital effects devices could be used, however, this would have restricted the motion in some ways.

The lights on the faces also would have been difficult. Synchronization of the moving elements would have required very tight control to ensure that the illusion of this motion was preserved. The potential problems almost resulted in abandonment of this design. CBS News then contacted Silicon Graphics to see if any of their hardware could help.

It was determined that an Onyx workstation with the Sirius video system and a RealityEngine II, with special software, would be required. In the next section there will be a more detailed discussion of this hardware and software. The visual design was completed and modeled. The SGI software was written and the video system was conceived. Figure 3 shows the video system. Although three main devices were required, the on-air look created could not have been created in any other way.

1994 System: As a component to the integrated election results system, equipment from Silicon Graphics is required because of the real-time need for simultaneous live video in and out at 30 frames per second while placing the live video input on lighted 3D models under motion and lighting change each frame.

The hardware configuration includes: SGI 4 CPU Onyx with a RealityEngine II graphics subsystem and Sirius live video option, 128 MB RAM, 2 1.2 GB disk drives, DAT, and CDROM. The software configuration utilizes IRIX 5.2 with REACT real-time extensions, C compiler, GL Graphics Library, and custom real-time display software known as IRIS OnAIR (TM), written in C.

Overall, live video is continuously made available to the Onyx system via Sirius. Users are able to selectively control the model motion, video snapping on various sides of the model, live video displays, model shapes, etc. via either keyboard controls or separate RS-232 communication. The model is continuously rendered to the 1280x1024 resolution screen by the RealityEngine II graphics subsystem. Rendering includes placement of either live or snapped video frames on the sides of the model, motion and lighting of the model, and motion of the viewing eyepoint. Externally, the model is viewed within an NTSC sized window, while the content of the NTSC window is sent out of the system at 30 frames per second via Sirius. The video output includes an alpha channel, allowing downstream placement of the model over any background of the producer's choice. It is the combination of the model over background

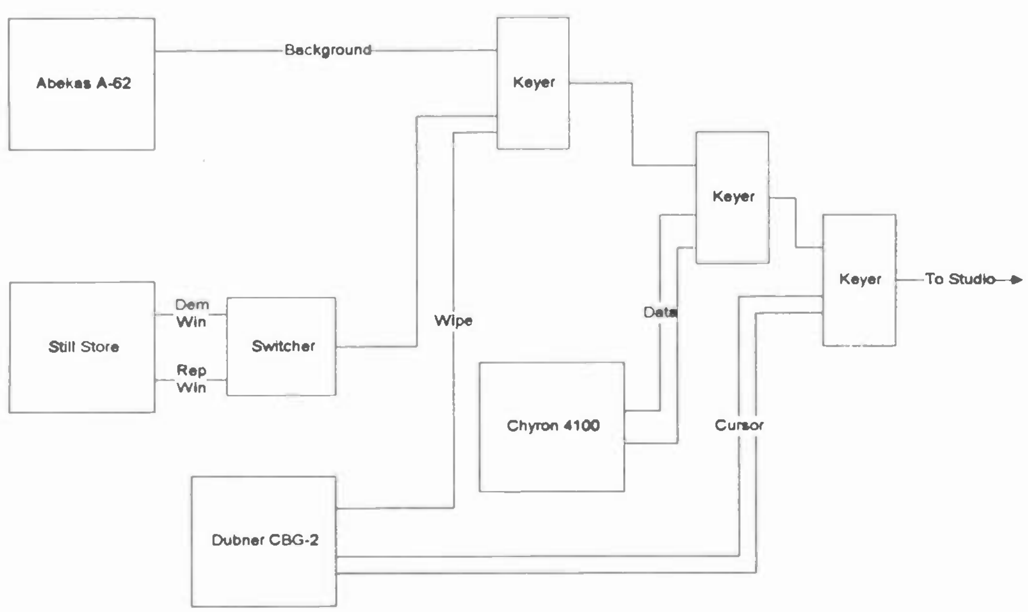

Figure 1

that is broadcast live with audio across the network to the home TV set.

Although video enters and exits the Onyx system at 30 frames per second via Sirius, there is a one frame delay latency. It takes one frame to capture the video input and place it on the model polygons, and a second frame to then get the rendered image out the system. Since there is no simultaneous audio to be coordinated with the graphics action at the frame-by-frame level, this latency is virtually impossible to detect by the human eye.

The quality of the overall presentation is such that the home viewer cannot tell that graphics are being displayed in real-time, marking a watershed breakthrough in flexibility for the broadcast Producer/Director.

Multiple model shapes, model motions, camera positions, light colors, light placements, light motions, as well as video placement panels are predetermined via Wavefront modeling tools in accordance with the look desired by the Producer. This allows for a wide range of artistic license on the part of the show designer.

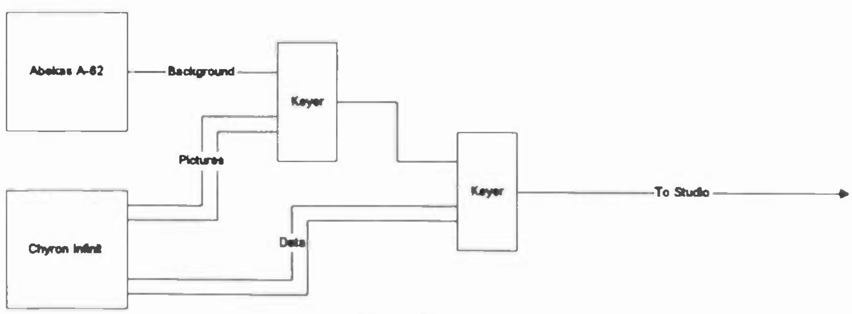

Figure 2

Various raw Wavefront files are then organized into a directory tree structure. A corresponding IRIS OnAIR (TM) data file is constructed with a text editor to coordinate the raw files with IRIS OnAIR's (TM) operational commands.

Before IRIS OnAIR (TM) is engaged, several techniques utilized in the construction of flight simulators are used to create an operating environment conducive to consistent displays without lost frames. Since IRIX is the Silicon Graphics Inc. version of the Unix multi-user operating system, Unix contains the inherent ability to swap out real-time tasks whether the user wants them to be or not. However, IRIX contains advantageous REACT real-time extensions to counter this behavior consistent with a typical Unix platform.

Specifically, two of the four CPU's within the Onyx system are isolated via a simple command, i.e. they cannot be used for normal tasks. Then the IRIS OnAIR (TM) software is enabled to run on one of them (which includes video input), while the video output software is enabled to run on the other. These two tasks will now run unimpeded in real-time. The remaining two CPU's engage in normal operating system activities.

Once IRIS OnAIR (TM) is operating, a communication program is engaged which allows for the control of the model via RS-232. This means external machine control equipment can operate the special effect model behavior in a similar manner to dedicated hardware, even though the look of the model is completely flexible. In essence, it is the best combination of dedicated hardware consistency with open system flexibility.

Once engaged, election results feeding in automatically to the election database generates accurate to-the-second stills on a character generator. Once the still page is complete, the command is sent to IRIS OnAIR (TM) via RS-232 to snap the still via Sirius live video input, and place it on the next available side of the model. Then the command is issued to move the model, and the viewer sees what would have been a static 2D still flying in space in real-time 3D over a pleasing background. After the viewer sees a computer generated list of stills is displayed in sequence, the command is give to return the model to the home position.

IRIS OnAIR (TM) commands include: motion from video panel to panel, return to a home position from any panel, snapping frames or displaying live video on the model video panels, etc.

Refer again to figure 3 for the following discussion. Sixty field per second video plus sync enters the Onyx system via Sirius. Upon user command, live video is either snapped to a texture in the raster manager as a still, or the texture is continuously updated frame-by-frame, hence live video. Essentially, live video becomes an NTSC-sized texture, either single frame or continuously updated frames at the behest of the user. The RM5 raster managers are able to hold quite a few of these, and so multiple stills are storable in texture memory. Version 1.9 allows for five video panels within the model.

Under either keyboard or optional RS-232 control, the Wavefront defined model is drawn to the screen automatically placing snapped video textures into the areas of the model defined as video panels numbered one through five. The model may be moving or stationary as the user directs. Either way the application window and display is updated at thirty frames per second Alpha information is simultaneously provided to the raster system at the time of model drawing and becomes a part of the output from this point onward.

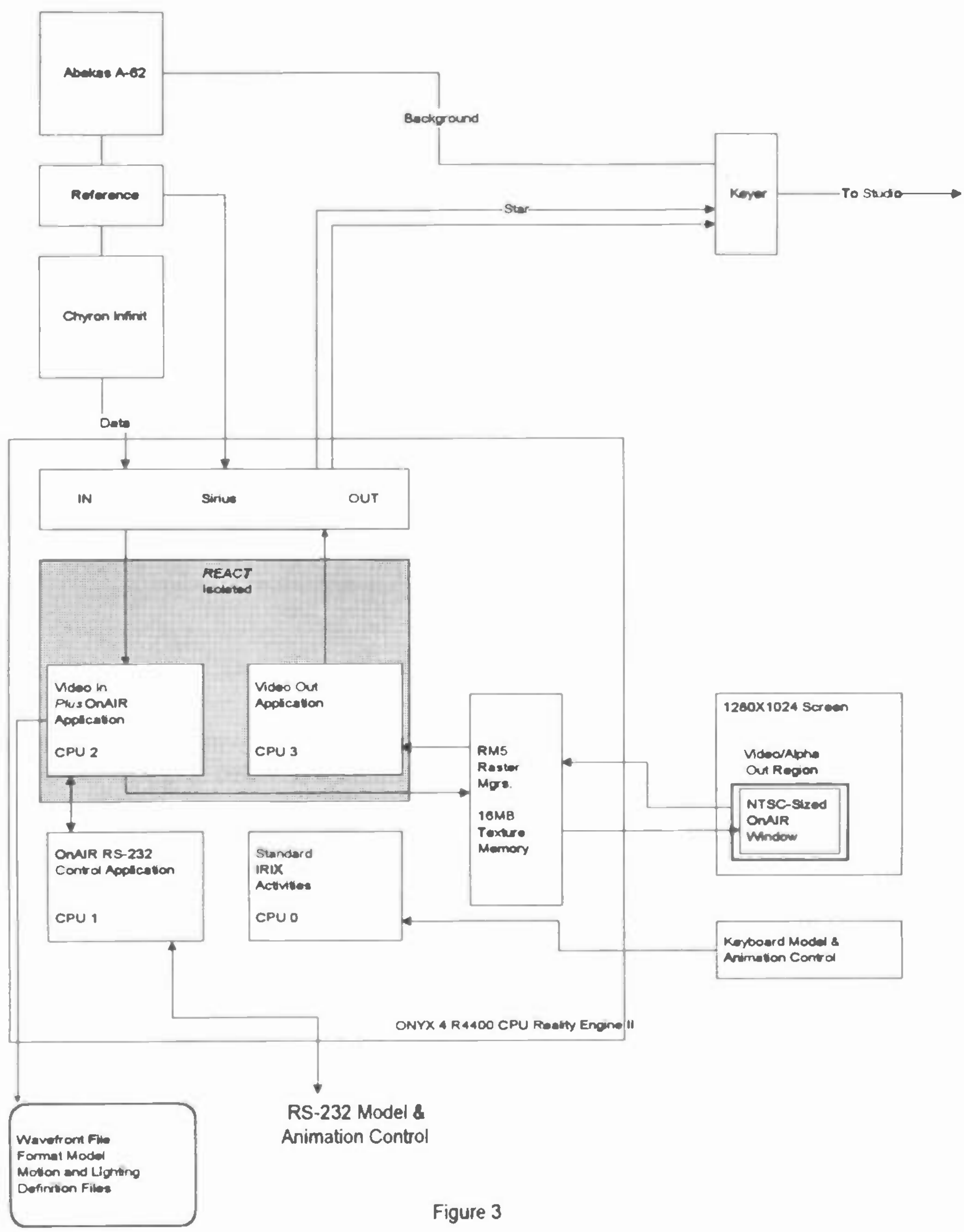

Figure 3

A second application, provided standard with the IRIX operating system, takes any screen-sized portion of the screen and sends it (plus Alpha) out the Sirius interface to external equipment. Since the screen portion is initialized to be the application window, video action occurs simultaneously at thirty frames per second in and out. External sync drives the precise timing of both.

To ensure dedicated CPU's, thereby avoiding lost frames, real-time REACT features typical of the flight simulation industry are enabled to isolate the two CPU's involved with video from the others. The others accomplish typical Unix activities, including the optional non-real-time RS-232 control application.

Data Acquisition and Control System: Control of the system is similar to the system used in 1992. A network of more than 50 personal computers (Figure 4) running under a standard operating system was used. The computers were segregated by function.

One group took the data from the information sources and entered it into the database. These used the ANGIS product from Media Computing, Inc. This is a standard product programmed as required for the on-air displays.

A second group were machine controllers. Some of these also ran ANGIS, others ProTEC, another Media Computing product specifically for machine control. It is a macro language allowing control of the equipment and access to the ANGIS database.

The final group of computers, programmed in ProTEC, were for operator control. These allowed producers and operators to create, manipulate and air lists of displays. The data to be displayed was not extracted from the database until absolutely required. In addition any display could be called to air at any time with the desired transition effect.

The system actually consisted of five sets of broadcast graphics equipment under the control of four operators. Status was available to the broadcast producers, corespondents and director coupled to the on-air graphics. Additional computers were used to monitor the system operation as well as the status of the database.

Conclusion: As has been demonstrated, the combination of design, hardware and software and Media Computing's ANGIS and ProTEC created a system that met the original goals. Displays were called to air almost instantly. The transition effect met all design requirements. In addition, the system was able to break new ground and originate, for the first time, full broadcast resolution, full motion 3-D graphics generated as they were aired. These graphics also included live video mapped on surfaces of this object. This combination provided the CBS News producers with the desired on-air look plus the speed required to support a demanding Election Night Broadcast.

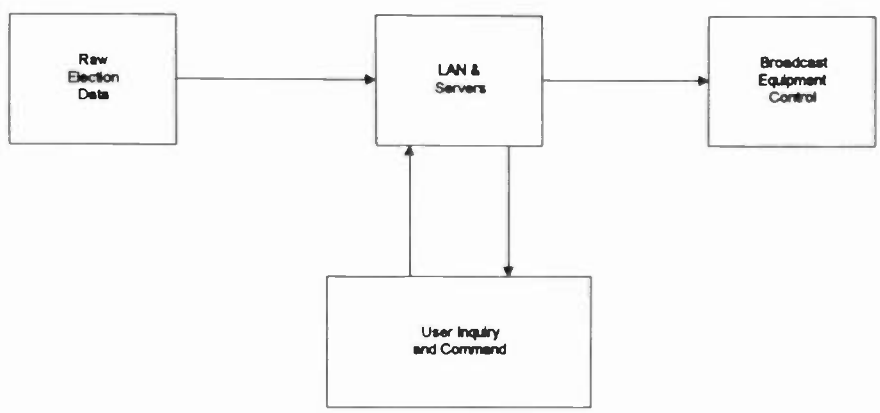

Figure 4

MULTIMEDIA SERVICES IN BROADCASTING

Tadashi Isobe, Hiroshi Seno and Kenjiro Kai
NHK Science and Technical Research Laboratories
Tokyo, Japan

Abstract

One-way transmission in broadcasting and interactive viewing in multimedia seem contradictory. However, the introduction of multimedia services into broadcasting is studied and its possibilities are discussed. An experimental system of multimedia broadcasting services, using data channel of HDTV broadcasting in Japan, was developed. The system provides a TV support service and a multimedia information service. These multimedia services are promising also as ISDB services in the near future.

INTRODUCTION

A main feature of multimedia services is user interaction with the program that is being presented. Interactive viewing is achieved by two way data transmission between the user and the center through telecommunication channels. Multimedia services can also be realized using computer systems with large capacity buffer memory.

A broadcasting system transmits a signal carrying the same contents to an unspecified number of receivers spread over a wide area. The transmission paths are basically one-way from the broadcasting station to the receiver. Here, we investigate making use of broadcasting features to introduce multimedia services, which depend on two-way data transfer and large capacity read-only memory (e.g. CD-ROM), into broadcasting which is basically one-way transmission. We clarify the possibility of stored reception and selective reception. As a specific example of a service, we describe a television support service and multimedia information service called PRESENT.

FEATURES OF BROADCASTING

Broadcasting is based on one way transmission. Thus it has various special features. Broadcasting can be received by any number of users at the same time, whereas in the case of telecommunications, users may lose their connection due to the limited capacity of the center that is providing the service. With broadcasting, it is also possible to share costs for program production and transmission, among a large number of users, making sufficient funds available to cover production and transmission costs and allowing low-cost operation. These are the basic features of broadcasting.

Furthermore, television has become part of the environment of our daily life, with many people having the TV on in the background as they go about their business. Comfortable and easy passive viewing without the need for operation is another feature of broadcasting.

Yet another feature is that, whether by terrestrial or by satellite TV broadcasting, radio waves can be used to immediately deliver programs produced in real time to the viewer or listener.

MULTIMEDIA AND BROADCASTING

The development of multimedia services in the fields of computers and telecommunications has been remarkable. Following are the most common features of multimedia:
-integration of multiple media for presentation,
-interactive viewing by user,
-digital technology for data processing.
In the following we compare these features with those of broadcasting.

Integration of multiple media

Television broadcasting has been from the beginning an integration of sound and video. The teletext system has also begun with the implementation of closed captioning (captions that can be viewed selectively) and teletext services. Television broadcasting thus involves a combination of video, sound and text. Television is available to households throughout Japan, and as one TV per person becomes the norm, it is common for a viewer to switch channels frequently to find a desired program. Television, with its appealing realistic moving images, has taken root in modern society as a powerful information medium and advertising medium. One objective of the multimedia services that have developed on computer and telecommunication systems is to approach the media representational quality of broadcast television. Multimedia presentation can be said to be an intrinsic element of broadcast television. Broadcasting is aiming for the areas of even higher quality presentation such as HDTV, 3-D images, and virtual reality where naturally, multimedia is naturally making progress as well.

Interactive viewing

Broadcast transmission paths are one-way; the implementation of interactive operation and viewing requires modification of the receiver and other measures. The configuration of an interactive reception system is shown in Fig. 1. The system includes the following functions.
(a) Stored reception: All broadcast data of the specified program is temporarily stored in the receiver's memory and users can view the program interactively.
(b) Selective reception. a number of content units are repeatedly broadcast and users can receive the program selectively.
(c) Two way transmission: Users requests and responses are transmitted to the broadcasting station using an other transmission line and users can receive the program interactively.

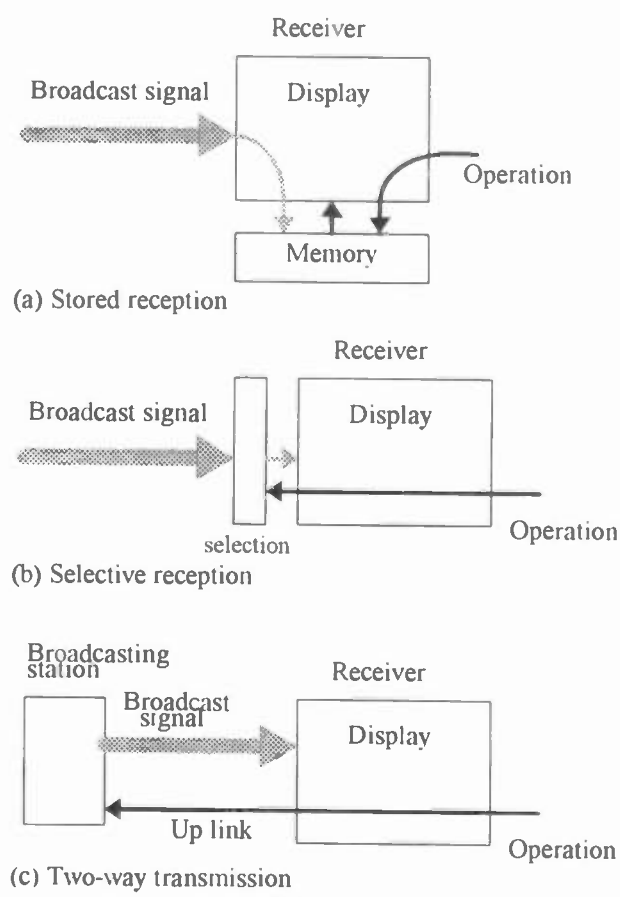

Fig.1 Configuration of an Interactive Viewing

Besides implementing such interactive viewing, it is possible to achieve passive and operation-free viewing that is a feature of broadcasting. To achieve this capability, it is necessary to transmit from the broadcasting station the data that defines the most common selection path, or according to the intentions of the program producers, the recommended selection path. The program is then played back according to these data.

Digital processing and transmission

Digital processing other than for teletext broadcasting and satellite broadcasting sound, and digitization of the transmission path in particular, are topics to be addressed from this time on. The broadcast transmission paths that can serve to deliver multimedia services to Japanese viewers in the near future are satellite broadcasting data channel, the HDTV MUSE data channel and the ISDB (Integrated Services Digital Broadcasting) channel.

In satellite broadcasting with digital sound, a area for transmission of digital data along with the sound was reserved from the beginning. The extra sound transmission capacity can also be used as part of this data channel. The HDTV MUSE system has a data channel like that mentioned above.

The recent progress in LSI technology and the remarkable advances in sound and video data compression techniques have spurred the development of an all-digital integrated broadcast format called ISDB. Going beyond digital television, ISDB will provide various forms of data presentation, including still images, text data, binary graphics, personal computer software, and game machine data, as well as indexing data for supporting the receivers of this data all over a single broadcast wave.

The features of an ISDB transmission path are

1) efficiency in using multiple services with a limited transmission capacity,

2) flexibility in integrating various services having different data transfer speeds and transfer characteristics,

3) expandability for adding new services that will be developed.

In the future, most of the broadcasting bands will be able to be used as those of ISDB. For instance they are the 12 GHz or 21 GHz satellite broadcasting channel. The transmission capacity of these channels are shown in Table 1. Multimedia services can be transmitted through these transmission paths.

Table 1 Transmission Capacities

Transmission line		Transmission capacity
Data channel	Digital subcarrier NTSC system	0.224 -1.76 Mb/sec.
	HDTV MUSE system	0.112 -1.12 Mb/sec.
ISDB	12GHz satellite	41 Mb/sec.
	21GHz satellite	up to 150 Mb/sec. (for example)

EXAMPLES OF MULTIMEDIA SERVICES

An experimental system of multimedia broadcasting services, using data channel of HDTV broadcasting in Japan, was developed. The system offers a TV support service and a multimedia information service. The TV support service provides multilingual closed captioning, detailed information related to TV programs and program schedules and guides, allowing users to fetch them when needed. The multimedia information service named PRESENT is a broadcasting service that allows users to view multimedia information, such as news, weather and stock market information, anytime interactively.

TV support multimedia services

Data can be transmitted through the data channels of television and HDTV, and also along with the many digital television and HDTV in ISDB. Accordingly, by transmitting information related to TV or HDTV programs and presenting the information along with the programs as needed by the viewer, TV support services can be provided. An outline of these services and examples of the required transmission capacities are shown in Table 2. Here, the data quantity is based on HDTV broadcasting. The data quantity is approximately 0.5% to 5% of that of HDTV; by providing information related to HDTV as a multimedia service, intelligence can be added to the HDTV service. Efficient production of programs is an important issue in these systems.

Multimedia information broadcasting service PRESENT

PRESENT(Personal REquest Service via ENhanced Teletext) is an information service that features good multimedia information retrieval and interactive viewing. It can be said to be a system that opens the way to personal use of broadcast services. The program contents are not related to television programs; basically, the data is stored in the memory of the receiver for viewing. One possible news-related service is the "electronic newspaper," which handles news story information. Each type of information can be presented in a multimedia format, consisting of text, still picture, video, and sound. The transmission of indexing data such as program schedules and keyword tables will allow program search and selection of the specific information required on the receiver side. Moreover, the viewer will be able to access to a more detailed explanation or other programs related to a particular term

Table 2 TV viewers support services

Service	Description	Examples	Transmission capacity
Caption	Caption can be selected to display or not display, language of caption is selectable.	Closed caption (multilingual) Subtitles for movies and dramas	0.05 - 0.2 kb/sec per language
Information	Together with main TV program, versatile program information can be viewed interactively as viewers, preference presentation style.	Detail explanation for review,exercise on education Outline of story in drama Various data during live sports program Audio for hearing impaired	0.3 - 5 kb/sec per item
Introduction (program guide, table)	Program table and guide are available on screen. They may be used for receiving reservation and recording reservation. Change of program start time causes no problem by using this function.	Program table with genre (2 weeks) Recording reservation for programs of specified genre.	3 - 50 kb/sec per ch (10sec guide)

that appears in the text presented. The number of information items to be provided and examples of their data transmission capacities and receiver memory sizes are shown in Fig. 2.

Future requirements will include portable terminals consisting of full-color liquid crystal displays, large-capacity and fast-access storage media, and information processing systems.

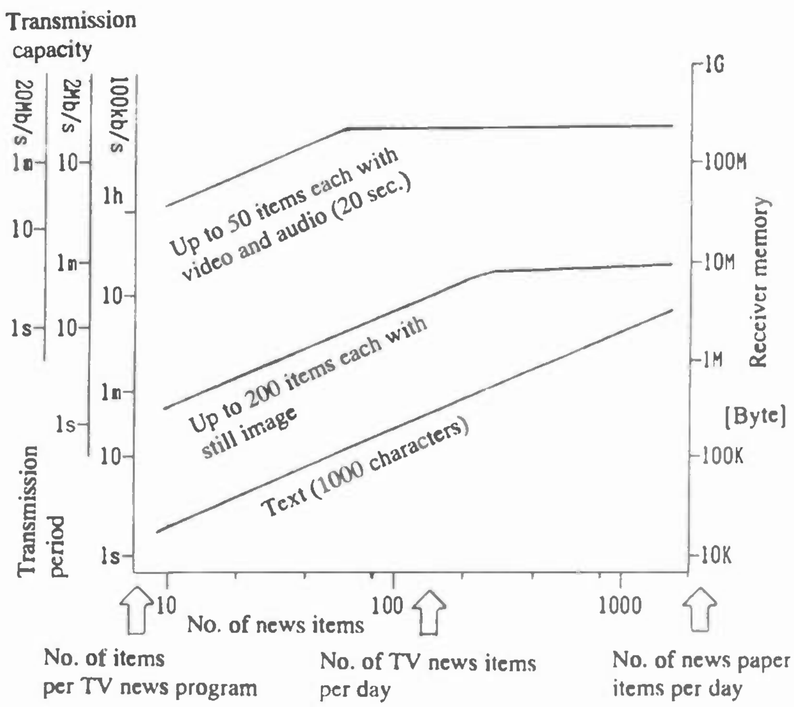

Fig. 2 Data Quantities for PRESENT

CONCLUSION

The introduction of multimedia into broadcasting has a major feature of incorporating interactive viewing. The stored reception and the selective reception will be useful for interactive viewing. There is a need for methods of evaluating the generation and optimization of indexing data to support such interaction. Although multimedia using two-way transmission may be implemented in the future broadcasting area, the one-way transmission will still play an important role in multimedia broadcasting as it forms part of the essential features of broadcasting.

Progress is being made to improvements in the quality of broadcasting, including such services as HDTV and 3-D television. Also in multimedia, there is a need for improvement in the quality of presentation.

The establishment of suitable functions to be used in various services ranging from passive viewing to interactive viewing and methods for evaluating the effectiveness of their implementation will be one of topics for further research.

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RADIO DATA BROADCASTING: PRESENT AND FUTURE TECHNOLOGIES

Monday, April 10, 1995

Session Chairperson:
Jerry Whitaker, Technical Writer, Beaverton, OR

FM RADIO, RBDS AND THE PERSONAL COMPUTER OPPORTUNITIES FOR CONSUMERS AND BROADCASTERS IN THE FUTURE OF RADIO DATACASTING
Mike McCoy
Advanced Digital Systems
Cerritos, CA

FMV-FM VIDEO SYSTEM INTRODUCTION
Ling-yuan Tseng
Panya Enterprises Co., Ltd.
Taipei, Taiwan

****PANEL—HIGH-SPEED DATA BROADCASTING**
Panelists:

Gary Gaskill
Seiko Telecommunication Systems
Beaverton, OR

David Kelley
Terrapin Corporation
Garden Grove, CA

Phil Moore
Digital DJ
San Jose, CA

Jim Marshall
Mitre Corporation
McLean, VA

*Papers not available at the time of publication
**Papers were not solicited from panelists

FM RADIO, RBDS AND THE PERSONAL COMPUTER OPPORTUNITIES FOR CONSUMERS AND BROADCASTERS IN THE FUTURE OF RADIO DATACASTING

Michael McCoy
Advanced Digital Systems
Cerritos, CA

ABSTRACT

RBDS (Radio Broadcast Data System) the technology of transmitting and receiving data over a 57Khz subcarrier on the FM band may best be exploited by putting radio and RBDS data into equipment that is designed to handle that data; the personal computer. By linking FM Radio and RBDS with the Personal computer we create new opportunities for both the listener and the broadcaster. This paper examines the state of RBDS technology today and the additional services available to the consumer by combining RBDS and the personal computer. RBDS receivers in computers offer unique applications and services that broadcasters can provide to the listener which will enhance the listeners radio experience and simultaneously increase station revenue.

INTRODUCTION

RBDS (Radio Broadcast Data System) data casting coupled with FM Radios in personal computers gives new power for the user and creates opportunity for the radio broadcaster to provide more choice and greater flexibility to their listening audience.

With all the hype about the information super highway, radio broadcasters and computer hardware/software developers are beginning to show how radio can make use of the Worldwide FM radio infrastructure to quickly build an information skyway. By making use of existing technology such as RBDS and the future standards for high speed data transfer, radio can move into the fast lane of the super information skyway.

In the very near future with a advent of high speed data transmission or DAR broadcasters can create subscription radio networks by sending highly compressed digital radio programs to personal receivers. Why not have ESPN radio or the Psychic hotline radio network. Radio broadcasters can serve specific market needs of the listening audience and advertisers will want to target to the specific demographic that the network attracts for greater return on their advertising dollar.

Interactive Information

By linking FM data casting with the personal computer, radio becomes a method for transmitting graphics, maps, text, data and possibly even video information to thousands of users/subscribers simultaneously. The computer lets the media become flexible and adaptable to individual user wants and needs. Interactivity means that the user has the ability to make choices. Most people think of interactivity in the form of game playing where the player takes and action and an interactive program will make some intelligent choice to represent the reaction. Video games be interactive but information and data is usually not interactive. Today, in fact, most people suffer from information overload. This overload is created because we receive information spuriously and unfiltered from the radio, television, newspapers and now computer On-line services. We receive more information than ever, but we really do not have a choice or an easy method of filtering out and receiving only the information that we are interested in. People like and want information but they also would like to be empowered with the ability to choose and control what types of information they receive. Today we hear so much about the future of television offering 500 channels of programming. Why? To give the user greater choice over the type of programming they want to watch. Why then doesn't radio create a system whereby the user/listener has the ability to customize the type of information they would like to receive/listen to. This can vary from selecting the type of music or even selecting the playlist of the music the user wants to hear to customizing the type of radio information programming, news or sports information that the user wants to receive. Radio can reduce the amount of information overload by allowing the user to sift through what is available and hear only the type of information or programming that they are interested in.

Most information that we receive today whether it is over the radio, newspaper or television is broadcasted information. Broadcasting or broadcasted information is a "from one to many" type of information disbursement. Even when using the much talked about Internet and other such on-line dial-up services such as America Online or Compuserve most of the information is a broadcasted type of information such as news, sports updates, weather information. However, with these types of services I must dial up and each time I want to receive specific information I must seek out the information that I desire. With an FM Radio data casting system the user can select the type of information that they wish to receive and therefore the computer/receiver can sift through the broadcasted information . The computer can capture only the information that the user wants to receive. This means greater ease of use and greater user flexibility and customization. Some people are calling this type of system "Radio on Demand". Today there is already a system on the market for the personal computer that allows the user to choose the radio program that they wish to capture. This early form of "Radio on Demand" is something like a VCR for your radio where you can select the start time, end time and the radio program(s) you want to capture, but in the future this can grow into a very robust system that allows the user greater freedom in selecting the type of programming they choose to listen to.

The Very Near Future

John Wilson rushes around the house in his normal morning routine. He wakes up after hitting the snooze button twice, showers, shaves, dresses, and tries to grab a quick bite before heading out for the morning commute to his downtown office. Once in the car he scans the various radio morning shows to find one who is broadcasting the traffic announcements so he can plan an alternate route if his usual route is jammed. He generally leaves earlier than needed because often times he doesn't hear the traffic report stating that the freeway is jammed until he finds himself stuck in that dreaded traffic jam.

This morning however, before leaving the house John clicks the traffic icon on his personal computer and he is greeted with both audio and text of the most recent traffic announcement. The traffic report was automatically captured by his RBDS FM radio receiver he installed in his computer. The RBDS receiver automatically scans for traffic announcements and automatically captures both the audio and the radio text of the traffic announcement. All John needs to do is click on the traffic icon for the most up to the minute report on traffic conditions. John plans his alternate route before starting the car and shaves several minutes from his normal commuting time.

Since John equipped his computer with an RBDS receiver, he has a few extra minutes each morning to check up on the latest sports updates, winning Lotto numbers and the replays the most recent morning news. By simply clicking the appropriate icons on screen he has instant information.

John's wife, Jane listens to the radio while getting the kids breakfast ready, then clicks the City icon to verify the time and location of the chamber of commerce luncheon she plans to attend and checks the city's recreation center schedule for today's after school activities for the children. Jane also enjoys the broadcasted daily newsletter on Health and Nutrition that she can access with just a click of her mouse. This afternoon Jane plans to replay the cooking show. The cooking show is broadcasted on Saturday afternoons, but Jane captured the show on the computer so she could replay it when she had a some time to herself so that she could try out the latest recipes.

Tammy, Johns teenage daughter, loves the new CD Magazine that her favorite station mailed to her. As each song plays she can see the broadcasted artist name, song title. The songs PIN (Program item number) is broadcasted and activates the CD to show a photo of the album cover, lyrics and a biography of the band! Tammy wonders why more people don't watch Radio!

This is not one of those AT&T commercials that talk about future technology to tease you with something that you cannot do today. "Did you Ever receive a Fax while sitting on the Beach......YOU WILL!, AT&T" John, Jane and Tammy can do all those things TODAY with an RBDS receiver installed in a personal computer. The Slogan for RBDS should be.....YOU CAN!

The personal computer is the perfect device to make use of FM radio data casting. The personal computer equipped with an RBDS capable FM radio receiver can act as the receiver to capture both audio and data for convenient listening and/or viewing of information. An RBDS receiver and personal computer can capture data 24 hours a day. The receiver can be customized by the user to automatically capture the type of information that they are most interested in and ignore the information that they do not want. Subscription services such as newsletters, stock quotes and special interest topics like horoscopes can be received only if the receiver has the proper subscription serial number.

The personal computer opens up a wide number of possibilities for the growth of FM radio uses both for audio as well as data broadcasting. The technology exists but it must be fully implemented for any of these new and exciting capabilities to take hold.

State of the Current Technology

After several years of work, the NRSC (National Radio Systems Committee) ratified the RBDS (Radio Broadcast Data System) on January 8, 1993. In the past two years both radio broadcasters and receiver manufacturers have been slow to implement the system. To date there are less than 200 stations broadcasting RBDS data and only a handful of receiver manufacturers shipping RBDS capable radios. For RBDS to become a universally implemented system many market factors must come together to create the catalyst for change. Below we examine new potential new markets, the listeners and the broadcasters and industry trends to help predict the eventual success of RBDS.

THE UNTAPPED MARKET FOR RBDS

Many of the benefits for RBDS relate to car radios and no doubt the automotive industry is an enormous market, but the growth in personal computers in the home and office creates another vast market for RBDS receivers. An RBDS receiver in a personal computer offers advantages over other types of receivers in the way it can store and display the RBDS data. In March of 1995 Advanced Digital Systems of Cerritos, California began shipping the Worlds first RBDS FM radio receiver in the form of an add-in card for the personal computer. Today there are more than 140 million computers Worldwide and more than 20 million of those personal computers are in homes across the United States. Nearly 8 million of these computers offer the latest multimedia capabilities for playing back sound files and CD-ROM/CD-Audio disks. These computers, if equipped with an FM RBDS radio, have the capability to receive data and text information of all types and variety such as news, weather, weather maps, sports updates and on and on.

The Listener

Do people want the type of information that RBDS can provide? The rapid growth of dial up on-line services such as Prodigy, America Online, Compuserve and the Internet shows that the users of personal computers indeed are interested in gaining information via their computer. The problem with these on-line services is that the user must have a modem, which in return requires a telephone line, phone usage charges and monthly or hourly access charges. Each time the user wishes to receive the information, they must dial into the service, provide user i.d. and password and then search for the information they require. The advantage to a data broadcasting service is that the user pre-selects the type of information that they wish to gather. The information is transmitted throughout the day and is captured by the RBDS receiver and computer and the audio or data is available when the user wishes to hear it or view it. The user simply touches an icon and the information appears or the audio plays, no dialing, no long distance phone bill and no secret passwords! If these types of information systems are to become universal they must be very simple, fast and easy enough for the novice to use.

If millions of computer users will pay to go through all the trouble of extra phone lines, dial up and search times, access fees, phone charges and the complicated steps to get information from an on-line service to gain access to the information superhighway, then just imagine how many people will want a system like RBDS that is so much easier and automatic to get the same information.

The EIA (Electronic Industries Association) conducted a survey performed by the Verity Group which revealed that RBDS features would change the way people listen to radio. The poll revealed the following:

- 60% reported interest in purchasing RBDS as an option on a new car.
- 70% of consumers would be willing to pay up to 10% more to purchase an RBDS radio.
- 30% surveyed said they considered the emergency broadcast feature to be among the most important features, and 20% indicated they would purchase the radio for this feature alone.
- 60% of those surveyed expressed interest in the potential to gain instant access to traffic and emergency broadcasts.
- 60% expressed interest in entertainment features such as the ability to receive text messages such as artist name and song title, or to search stations by program type.
- 55% reported that they would listen to their radio more if they were able to scan stations by format.

The poll also revealed that promotion and education will be important in unveiling this new technology as <u>80% of those surveyed were not aware of RBDS technology</u>.

From the survey results above we can see that radio consumers want the ability to tailor radio to their listening preferences. By using RBDS, receivers/listeners can scan the FM band for their favorite format such as country, jazz or rock or they can set their radio to scan for stations transmitting traffic announcements.

"The results of this survey reaffirm our belief that RBDS technology has a future in the U.S. as an integral broadcasting communications technology" said Gary Shapiro, vice president of the EIA/CEG group. "We're convinced that RBDS will positively change the way Americans listen to and feel about radio broadcasting, which until now has been overlooked as a potential medium for the information superhighway," said Shapiro. "RBDS technology fits the American lifestyle by providing news, entertainment, traffic and emergency broadcast features at the touch of a button, whether you're at home, or like many American, driving in your car," he added.[2]

From this we can see that it is obvious that if the RBDS standard of transmitting data over a 57KHz sub carrier is utilized to it's fullest extent there are many ways in which the broadcaster can create new revenue streams by optimizing the use of his bandwidth. What is the outlook for implementing RBDS and what are the key applications that will help this new technology grow?

Build it and they will come, or will they?

The NRSC came up with the technical specifications and a standard. The hardware engineers designed the RBDS encoders, but getting RBDS into full swing has taken a bit longer than some proponents expected. Many ascribe this delay in system implementation to the chicken and egg theory. Radio broadcasters claim that there is no need to transmit RBDS data if there are no receivers that can receive and decode the data. Receiver manufactures cite that there is no reason to build receivers if there are no stations broadcasting the data. Others say that for RBDS to come into nationwide usage somebody must come up with a way for the broadcaster to make money.

We have created the standard and now everything else will automatically fall into place, right? What will be the catalyst to make this technology take off? Is there interest among broadcasters? Market studies and market trends show that we may be closer than we think to having a nationwide RBDS system.

The NAB (National Association of Broadcasters) 1994 FM Subcarrier Market Report, shows that there is a high degree of interest among broadcasters to transmit RBDS data and as the EIA study above pointed out there is indeed pent up demand among listeners/users to receive the benefits that RBDS can offer.

According to the NAB 1994 FM Sub carrier Market report, more than 42% of all stations surveyed indicated that they plan to broadcast the RBDS signal. In the top ten markets this percentage increased to 47.5% and for markets 11-50 the plan to implement an RBDS broadcasting system climbs to more than 56% of the stations.

Traditionally, FM sub carriers have been a portion of the bandwidth that the broadcaster has leased to a service such as broadcasting financial data, radio paging or the transmission of Muzak. And although these type services have been around for many years, more than 70% of all FM stations reported that they were not currently leasing any FM sub carrier. This means that there is an enormous amount of underutilized sub carrier capacity. The NAB FM Subcarrier Market Report estimated that RBDS could conservatively generate $40,000,000.00 in additional revenue for broadcasters.

Of those stations surveyed when asked the reason that they have not leased their sub carriers in the past, more than 55% responded that no buyer had expressed an interest.

From the results of the NAB survey we can see that there is ample interest among broadcasters, all they need is market interest and viable services to offer.

Cracking the Egg

If all the surveys show that listeners want the benefits of RBDS and broadcasters are planning to transmit RBDS data then it sounds like this chicken and egg theory is just about to crack!

There are many market factors that are contributing to help create the synergy for the success of RBDS. These market factors must come together to create enough momentum to ensure that RBDS is fully implemented.

One major market force is that the EIA has allocated $500,000.00 for promoting RBDS if the industry; i.e. encoder and receiver manufacturers will match the funds with an additional $500,000.00 for a One Million dollar RBDS marketing war chest. An RBDS forum marketing working group is being formed to the program. One of the main uses for these funds will be to set up broadcasters in the top markets around the country with the equipment to transmit RBDS data. This means that by the end of 1995 more than 90% of the population will be covered. In exchange for the equipment the broadcaster would be obligated to make RBDS public service announcements to help educate the listeners. Thus creating user demand for RBDS.

The growth of RBDS encoder installations is almost inevitable as companies such as Differential Corrections, Inc. (DCI) install a nationwide infrastructure to satisfy their subscription based business. There is also renewed interest in RBDS since the FCC has released their new Emergency Alert System (EAS) recommendations.

The installation of RBDS encoders in radio stations across the country will go a long way to getting the benefits of RBDS to the listeners, but just installing encoders is not enough. Of the nearly 200 stations able to broadcast RBDS data only a fraction of the stations are using the technology to its fullest extent.

Building a technology and infrastructure for broadcasters to transmit RBDS is not enough. What every good technology needs are good applications to take advantage of the technology and interest the listener.

THE KILLER APPLICATION

When a new technology is presented to the market often times it takes just one successful application to create an entire new industry. The telephone and cable industries plan to create an information superhighway at the cost of billions of dollars, but the jury is still out on what will be the application that makes the technology blast off. What is the killer application for the super information highway? Will it be Video on Demand, the choice of 500 television channels, interactive TV, interactive shopping, no one knows.

In the RBDS industry we must be asking ourselves the same question. *What is the killer application for RBDS?* Which of the following applications will make RBDS data casting spread like wildfire. Will it be Radio on demand, Radio text, Artist name and Song title, radio paging, radio faxing, Air mail, or some other application not yet thought of.

Artist name and Song Title....who benefits

To find the likely killer application we might look for the application that has the widest appeal and offers the greatest benefit to one or more interest groups.

The EIA study mentioned above indicated that 60% of those surveyed expressed interest in the ability to receive text messages such as artist name and song title. Focus groups conducted by Advanced Digital Systems, show that radio listeners were frustrated by the fact that either the song title and artist name is rarely, if ever, mentioned by the disc jockey. Most of the time the listener must learn the artist name and song title through word of mouth or after listening to the song several times to finally catch the D.J. mention the song title and artists name.

Recording industry studies indicate that 70% of record sales can be directly attributed to radio play. Record companies know that the success of a song or artist depends on the amount of radio play a song gets. If 70% of record sales come from radio play then who is most likely to benefit from having the song title and artist name appear on radio's LCD display while the song is playing? ......The Recording Companies!

Another result of the EIA study that I have not mentioned before is that among listeners aged 18-26 seem to be most interested in the advantages that RBDS offers the listener. More than 85% of respondents in this age group expressed interest in RBDS transmission of song title and artist name. This statistic should be of utmost interest to the record companies as this is their primary target audience.

Remember another startling fact that the EIA study revealed? That 80% of those surveyed were not aware of RBDS technology. I wager that the recording industry is among this 80%. The industry that is most likely to benefit the most, benefit by increased record sales, barely even knows that the technology exists.

The Recording Industry Artists of America (RIAA) is actively looking for new media and new technologies to increase the sale of record albums. RBDS is one of the best and least expensive methods for the record companies to increase the listening audiences awareness of a recording of a new song or recording artist. The transmission of radio text displaying the song title, artist name and the album name would most likely have a direct and dramatic effect on record sales.

It is very possible that the recording industry would either pay the broadcaster to transmit this radio text information or at least subsidize the broadcasters expenses for the RBDS equipment and operating expenses. Representatives of the RIAA have already indicated a willingness to support RBDS with an education effort. Educating listeners about the benefits of RBDS will help to create a demand for the service.

According to the NAB 1994 FM Sub carrier Market report, the average revenue for leasing a subcarrier is $1,976.00. Recording companies may be willing to lease a portion of the RBDS bandwidth, for transmitting artist name and song title. If so, then each station might be able to receive $200-$500 per month for providing this service. Artist name and song title alone, based on just $300 per station each month, would generate nearly $20,000,000 of extra revenue for radio broadcasters annually.

APPLICATIONS TO GENERATE RBDS REVENUE

In addition to collecting revenues for transmitting artist name and song title, RBDS entrepreneurs have thought of many other ideas to generate revenue for the station owner.

We have already seen that by installing an FM radio in a personal computer gives the user an environment that is flexible enough to allow listening creativity and viewing of RBDS information. In fact, having an RBDS receiver in a computer offers several advantages over the conventional style of radio receiver. The computer allows radio to take on a graphical and visual aspect that has never been possible before. You can't view the radio stations program schedule on your Home Stereo System. RBDS enabled car stereos and Home receivers show radio text that scrolls across a small display like it were an old ticker tape machine. The computer removes the restraints of conventional stereo systems. Linking a personal computer with an RBDS receiver opens a whole new world of opportunities for the radio listener.

Let's take a look as some of the capabilities of RBDS receiver in a computer. These new services are just a few ideas of how the broadcaster can use RBDS to generate additional revenues and increase the benefits of the listener.

Radio text

As we have seen in the example above recording companies are interested in just about anything that makes the path from hearing the song to making the purchase at Tower Records shorter. Radio text of artist name and song title increases the listeners awareness level of the artist, the song and the album. This increased awareness level creates an easier path to purchasing the record will benefit the record company and help sell records.

Once we have someone like the record companies set up to subsidize the broadcaster for transmitting radio text, the broadcaster can use this medium to transmit additional information that will benefit the user such as sports, weather and news updates. With an FM radio in a personal computer such information can be captured and stored for later viewing. If I missed the news at the top of the hour, I can instantly retrieve the most recent text of the news update on my computer screen.

In addition to Song title the broadcaster can use radio text to promote the station, help to define that stations image and notify the listener of what is coming up next!

Radio text can also be sold as advertising space. Additional revenues can be generated by inserting advertising text. Radio text can accompany a radio spot to help reinforce the ad or radio text can be sold as separate ad space to create new ad revenue for the station.

Navigation

Companies such as Differential Corrections, Inc. (DCI) and Personal Travel Technologies, Inc. are helping to create both the RBDS national infrastructure but offering new services to users while generating income for the broadcaster.

DCI has over 145 stations up now with plans to have nearly 400 stations on line broadcasting RBDS data by the end of 1995. These 400 stations will provide coverage of 95% of the U.S. population. DCI offers GPS satellite correction information to subscribers and in the future plans to transmit real-time traffic updates. Users of this data range from agricultural & marine applications to golf courses, enhanced 911 dispatch, traffic navigation, dispatching and tracking of vehicles and traffic management.
Personal Travel Technologies offers a software/hardware solution that monitors RBDS GPS correction data to notify the user that their current or future planned travel route is affected. The software will then suggest an alternative route and show the new route on a computer generated map.

Navigation systems are already beginning to show up in automobiles. RBDS GPS correction data is also being integrated into some of these systems. In the future a user will have navigation charts in their car but they can also have this technology in their notebook computer. If the business traveler has a notebook computer that includes a navigation system, then where ever the user goes he will have his navigation system with him. When arriving in a new city he will not have to worry that the rent-a-car may nor may not be properly equipped. Travel routes can be easily input into the computer and the best route mapped out. Even the most formidable cities will be easily navigable without the worry of getting lost or missing an important business meeting.

The broadcaster benefits through revenue sharing with the DGPS correction data provider. Companies such as DCI will provide the RBDS encoder for the station and then split the subscription revenue with the station. This is a terrific opportunity for the stations that DCI selects for their coverage areas. As the use of real time traffic updates, navigation and intelligent highway systems grows the opportunities and revenues for broadcasters will increase.

Transparent data channel

All types of data can be sent to the listener via the transparent data channel such as program information, computer files, faxes and even newsletters. The personal computer is the perfect recipient for this type of data as great amounts of data can be received and stored in the computer and be displayed graphically.

Today many companies and associations publish newsletters via the fax machine. The problem that these publishers encounter is enormous. The time and costs involved in sending faxing out the information to thousands of subscribers. Each subscriber must be individually dialed and the newsletter transmitted. This can involve an entire bank of fax machines, many hours each day, hundreds of phone lines and one whopping phone bill! RBDS can be used to transmit the newsletter simultaneously to every subscriber and the publisher gets the word out with just one phone call! Although RBDS allows for a data rate of only about 1,200 bps, a three page newsletter would take just 3 minutes to be received in the PC. Each new subscriber would receive serialized, addressable software with their subscription so that only qualified subscribers would receive the newsletter. Just imagine the savings of time and money! IF RBDS were used to transmit newsletters at least two things would happen. 1.) Publishers would be willing to pay handsomely for the convenience. 2.) More newsletters would be published in this manner because it is faster, simpler and the investment for starting such a newsletter would be greatly reduced since there would be no investment in hundreds of fax machines and phone lines.

In addition to newsletters, I am sure that you can imagine other types of information that listeners would be willing to pay for such as stock quotes, the latest odds from Las Vegas Sports gambling and special news services. The best thing for the broadcaster is that with this type of system the listener must stay tuned to the station which is broadcasting the information. What a way to gain revenues and maintain loyal listeners!

Radio guide

For programming such as NPR or other non-competitive stations program information or actual programming schedules can be transmitted via RBDS. This "Radio Guide" could be used by the listener to map out their listening schedule based on the stations program schedule, days or even weeks in advance. The listener can program their computer radio to automatically turn on at selected times and programs that air at inconvenient times can be captured by the computer for later listening. The listener would receive program updates via RBDS and the data can be displayed on the computer screen in a grid type format. The user can select the station and programs that he/she wishes to listen to and the radio will automatically turn on and switch to the desired station for the programs selected.

Radio on demand

Radio listeners today with an FM RBDS receiver in their PC can capture radio programs to their computer hard disk. We have virtually created the VCR for Radio. The listener can map out the listening schedule and either listen to the music or capture the audio to the computer hard drive for later listening. Radio text can be captured along with the audio portion of the program so that both the audio and radio text can be replayed at a later time that is more convenient to the listener. Radio on Demand is the ability to listen to the type of music or radio program desired but with the flexibility to listen at a time that is convenient to the listener, not necessarily when the program or song is aired. Radio on Demand provides new and greater flexibility to the listener, never imaginable before.

P. I. N.
Having an FM radio in a personal computer allows us to take this flexibility a step or two further. RBDS allows for the use of a PIN (Program Item Number) number. Just as a song is about to be played the PIN can be simultaneously transmitted. Today many radio stations publish magazines for their regular listeners. These magazines promote the stations civic activities, the radio personalities, and provide program information. With the explosion of the multimedia computer in homes, a large percentage of each stations listening audience own multimedia PC's . A magazine on CD-ROM disks can be inexpensively produced with much of the same information as the typical magazine, but with additional features and benefits. The CD-ROM can contain the PIN number of every song that might play over the next month. When the song is played and the PIN transmitted, this can cue the CD-ROM to display the album cover where the song can be found, song lyrics, artist biography, and other album's produced by the artist.

Just imagine the opportunities for radio station promotions. Listeners are notified that next Saturday night at 8:00pm they should load the KROC CD-ROM in the PC for a special surprise. At the appointed hour a special PIN is transmitted and a secret file is opened which plays video clips of the upcoming hot new album music video. Interactive radio promotions such as games, contests and record previews are just a few examples of the power and opportunity that RBDS equipped computers presents.

We can see from the examples above that combining the personal computer and RBDS offers new flexibility in the way the radio and radio data can be used to create new opportunities for the broadcasters and greater benefits for the listener. RBDS allows the broadcaster to offer new and innovative services to the listener while generating incremental revenue for the station. The listener benefits through the newly added visual aspects of radio and the ability to use data transmitted via RBDS by the broadcaster to add greater value and flexibility to the listener.

Conclusion

RBDS is a technology that is uniquely suited to be used with personal computers and by linking FM Radio and the computer, RBDS can change the way we all think of radio. The RBDS industry is very close to taking off. Many market forces such as the EIA, EAS and receiver manufacturers, service providers such as DCI and the recording industry can work together to create a catalyst for full implementation of the RBDS standard. RBDS has the capacity to generate more than $40 million in incremental revenue for the broadcasters by offering new services to the listening audience. Many of the benefits of RBDS can best be exploited by integrating RBDS receivers in personal computers so that the data can be displayed in text and graphics.

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[3]Gary Shapiro, EIA/CEG Group Vice President, "I want my RBDS "SMART" Radio", EIA/CEG Press release, Washington, D.C. June 27, 1994

Recommended Reading on RBDS

Scott Wright, Delco Electronics, "RBDS: The American Outlook"

Miles Beam, Milestone Technologies, "A Summary of Data Broadcasting technologies and potential applications in today's market"

FMV—FM VIDEO SYSTEM INTRODUCTION

Ling-yuan Tseng
Panya Enterprises Co., Ltd
Taipei, Taiwan

ABSTRACT

For a long time, FM SCA has been used to broadcast analog background music and audio programs, or provide digital data transmission services such as paging, stock market and weather or headline news updates. Some demonstrations have been offered in the past to broadcast fax messages and address to individual fax numbers. Due to the nature of SCA channel's narrow bandwidth, its almost impossible to transmit motion video programs over the SCA channels. However, technology evolves. The recently developed technologies of channel bandwidth compression, video data compression and some others will make the SCA video delivery possible. This paper is trying to explain on a system level how and why it is possible.

INTRODUCTION

Video broadcasting has been dominated for a long time by TV technologies, this was later shared with satellite direct broadcasting and followed by cable technologies.

All of these video delivery technologies occupied very broad bandwidth. Nowadays, the radio frequency, a very valuable public asset, is getting scarce and its very difficult to allocate available ones. For any new services, it will be almost impossible to access the already too crowded air slot. The desire of easy access of video broadcasting channel becomes higher and higher. Especially, for those programs which are not entertainment in nature.

This paper will introduce a new method to deliver the video programs. It uses the FM subcarrier channels as the media, then applying the video compression techniques, channel bandwidth compression techniques and channel bundling techniques onto those SCA channels. In this paper, the description of this new method will be only presented at the system level. Prototypes are under construction, and related technologies are already filed patents with the US Patent Office.

SYSTEM DESCRIPTION

The whole FM video system will provide two services, one is the video broadcasting, and the other is video communications. For regular customers, only a set-top VCC box attached to the regular TV set will be able to access or use those services easily.

Video broadcasting service will involve four parties i.e.,
(1) video program provider(s)
(2) service center
(3) FM radio stations
(4) recipients/subscribers/customers

Depending on the complexity of the operation and the area served, the FMV could be implemented in closed environments such as school campus, private communities, parks, small townships, or it can be scaled up to a county wide, state wide or even nation wide operation.

The whole FMV services will work as follows:

A program provider will call up the service center to reserve an air time slot for broadcasting his/her video program live. At the studio, which could be at home, kitchen, study, garden, or places with access to the Public Switched Telephone Network (PSTN) services, a VCC box will be hooked to the PSTN. Depending on the high speed data transmission service he/she can get from the local phone company, one line or multiple lines will be needed.

On the VCC, there are ports available for various I/O ports including a video camera port. Once the reserved time comes, he/she will start the camera. The captured motion image frames will be fed into VCC first for compression, then depending on the data speed or channel bandwidth provided, the compressed video data file will be split into sub-frames and transferred to the proper channel port(s). There will be a "video splitter" to handle this job.

On the receiving end of the service center, a counterpart of the frames merger will concentrate those sub-frames and merge into the original compressed video frames. It will then be fed into the VCC for video de-compression.

Again, depending on the complexity of the incoming video file the service center's video processor will determine how many SCA channels are needed for broadcasting. For some not too active motion video programs, 3 SCA channels will be enough. In some cases, it might need five or six channels for the full motion image delivery. Of course, when the technologies of video compression and channel bandwidth compression are improved, the number of SCA channels to be bundled will be less and less.

The video processor will split the whole video file into sub-frames, and assign them to the available SCA channels. Maybe more than one FM station will be needed. The transmission between the service center and FM stations shall be the leased high speed data line.

Before sending out the split video file, the service center might put in some address codes in each file to activate only those valid VCCs. Data encryption can also be performed by using the stream encryption techniques to minimize the time delay.

At the recipient site, a VCC set-top box will be attached to a regular TV set. The VCC will auto scan the SCA channels and lock the channels in a bundle for a specific program. The VCC will merge and decompress the video frames and then display on the TV screen.

As for video communications, the media will be PSTN. Basically, only two parties will be involved, the calling party and the receiving party.

SYSTEM COMPONENTS

VCC: Video Communication Controller

The Video Communication Controller is an adapter attached to a regular TV set and associated audio and video peripherals, such as video camera/camcorder, VCR, videodisk player, telephone, and PC/FAX. VCC transmits or receives video signals via communication networks, which could be narrowband analog RF or wideband digital RF channels.

VCC is the key component in the whole FMV system. The system will offer customers the video program delivery services as well as interactive video communication services.

Since the video communication in most cases only involves two parties, and doesn't involve other operations or algorithms, this paper will only concentrate on the FMV broadcasting system.

Program providers (parties that generate the source of video programs), VCC will accept video signals from the attached video camera, VCR, or video disk player, then process and transmit it via the communication network to a remote site which could be a FMV service center or an FM station for the scheduling of broadcasting.

As FMV subscribers, the VCC will receive video signals from narrowband FM SCA channels, then process and display it on the TV screen or store it in VCR, or PC.

The main functions for the VCC to perform are:
(1) compress/decompress motion video signals
(2) merge video sub-frames
(3) provide I/O ports for various A/V peripherals
(4) establish and switch communication channels
(5) detect and demodulate the FM SCA signals
(6) handle the address verification and data security

FM Transmitter

Any FM radio station, either commercial or public, will have three subcarrier channels available for other usage. Those subcarrier channels which have been verified to not interfere with regular FM broadcasting are 57 kHz, 67 kHz, and 92 kHz.

At FM stations, a SCA modulator will be needed to accept the video signals from FMV service center or directly from program providers and then modulated onto the main carrier of the FM station. The physical dimensions of the modulator will not be larger than a desk top PC.

CCM: Conference Controller Module

This module is an enhanced version of VCC. Normally, it will be only needed when a live video conference is in operation. In a FMV service scenario, one of the most attractive services will be the telecoursing. Teachers give lectures at remote places, students scattered over the area will be able to participate in the live discussion, raise questions while others are watching or there could be group discussion involved. Then, the CCM will be installed at the teacher's site.

A CCM has multiple video input ports, and each will individually accept compressed video signals from the VCC which accepts the video communication calls from the conference participants.

Each CCM will have a master port which will hook to the teacher's VCC.

When the live video presentation is given students/recipients will view the live program from the TV screen just like the normal FMV program. When the student has a question and would like to interact with the teacher, he/she can switch to video comm mode on his/her VCC, place the video call and start the discussion.

This video call will go to one of the teacher's CCM incoming video call ports. The number of video calls that can be handled by a CCM depends on the system requirements.

The CCM will determine the pattern of the screen, the screen partition, and the space arrangement. For example, the screen pattern can be designed so that the teacher's portion takes 2/3, while the remaining 1/3 will be divided and shared by the incoming callers. The subframes arrangement is dynamically allocated, and it requires a very sophisticated algorithm.

The mixed screen signals will go through the normal video compression algorithm, and/or frame splitting algorithm and be sent to the service center. So, the students will see the live discussion over the screen, just like what's happening in the regular classroom.

The students who initiated the video comm will see the whole "classroom" over the video camera at the teacher's site.

Video splitter

This module will boost the video signal transmission through put over the point-to-point communication link. In the whole FMV communication network, the signal transmission bottleneck will mostly occur at the link between the program providers and FMV service centers.

For most FMV program providers, it will never be justified to install a high speed data line between their office/home to the FMV service center. This is unless, they can accept the time delay by sending the video tape to be broadcast later.

In the cases that live, real time broadcasting is desired, the question of how to efficiently use those already existing communication channels becomes an attractive issue.

Video splitter module will cut the regular video frame into several subframes, and then transmit each subframe via separate, independent, slower, analog communication channels such as the regular twisted copper wire subscriber loops. Depending upon the data volume, two such channels would perfectly do the whole job, or three or four channels might be needed.

The hook up of regular subscriber loop services is a very affordable investment for most people. Thus the huge amount of video data, after it is compressed, can be transmitted over the several slower analog channels.

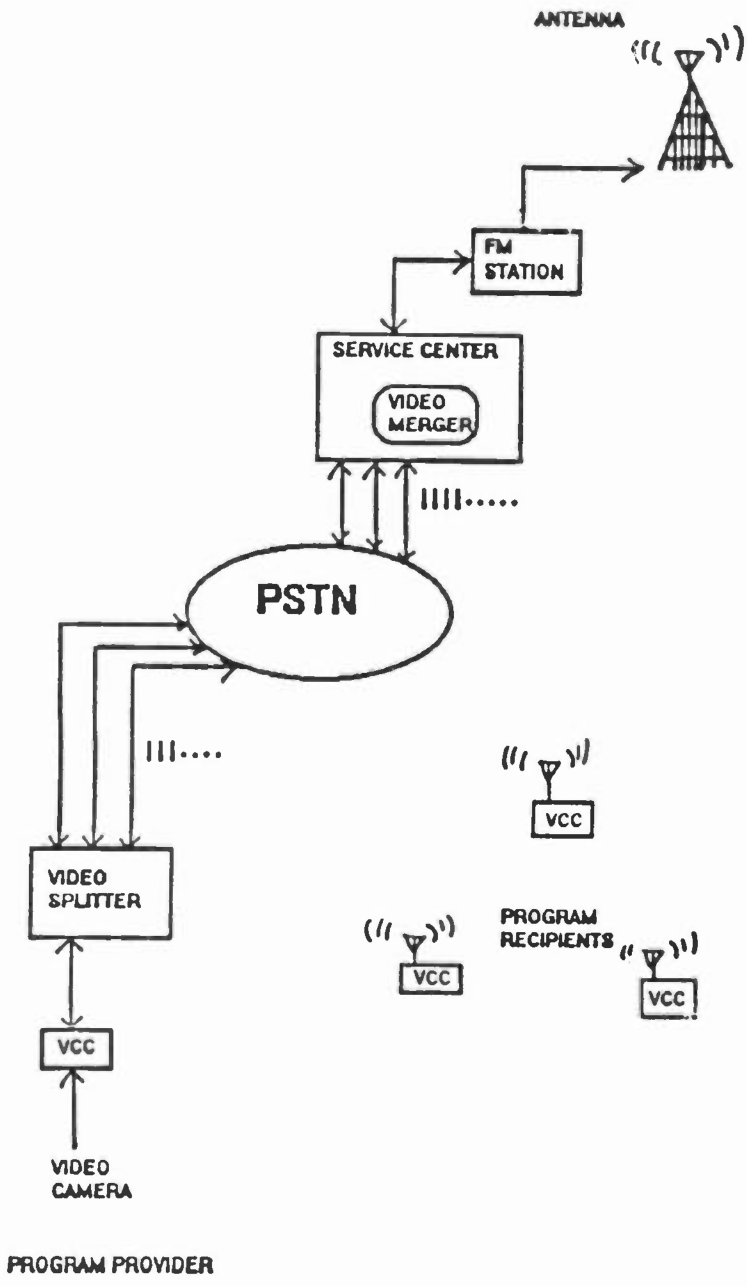
Video merger

This module will reverse the function of "video splitter." It will reassemble the "subframes" received from several incoming slower communication ports, then construct them into the whole picture frame.

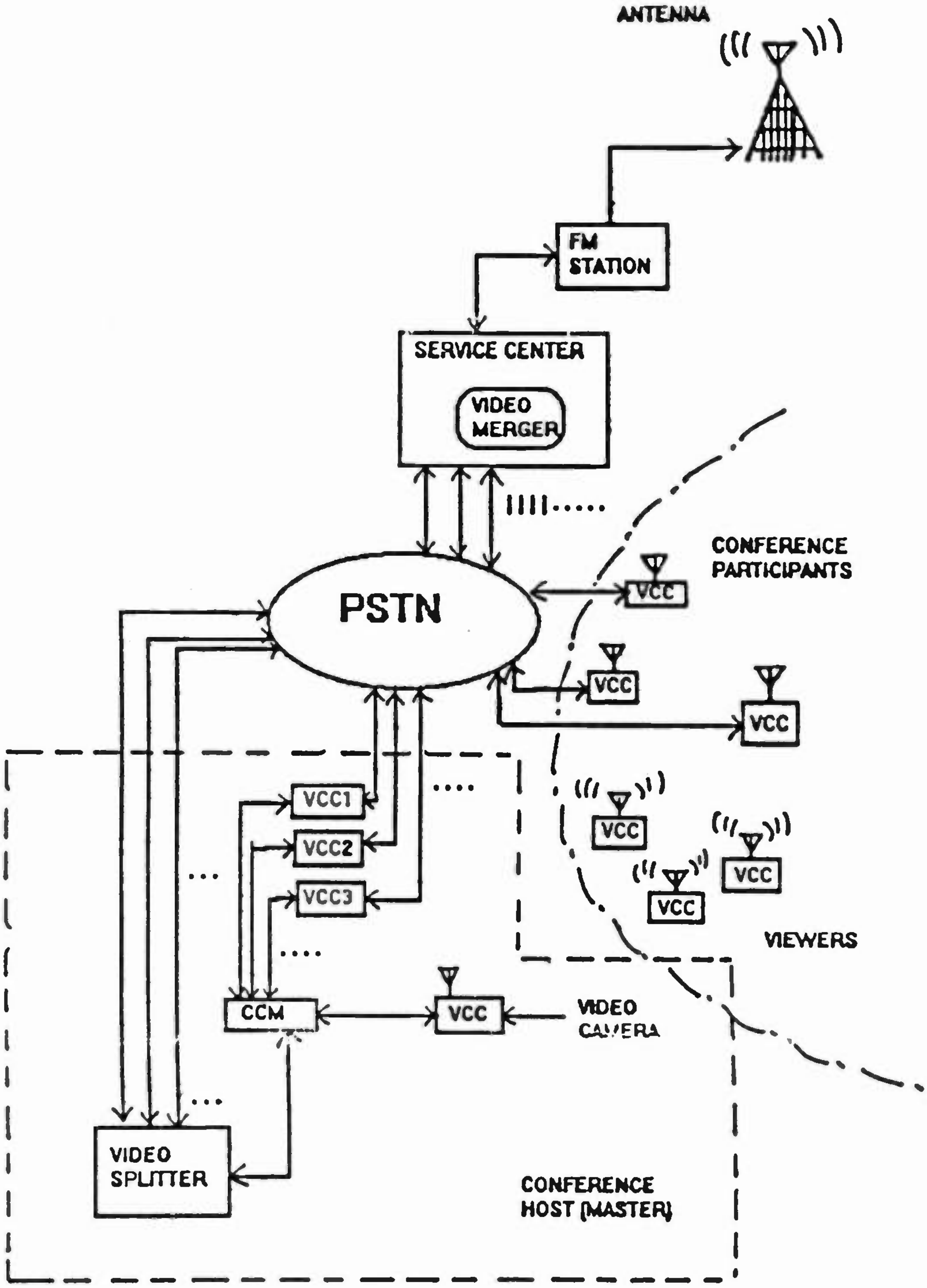
The number of slower communication channels i.e., the PSTN subscriber loops, in most cases, will be determined by the communication protocol prior the start of the transmission.

For those that are not full time program providers, the use of the "video splitter" paired with the "video merger" at FMV service center will be the most efficient, affordable, and effective tool.

4.1 A program provider on-line, real-time FMV broadcasting



4.2 Tele-coursing



COMPUTER TECHNOLOGY FOR BROADCAST SUPPORT: BBSS, LANS, WANS AND THE INTERNET

Monday, April 9, 1995

Session Chairperson:
Bill Ruck, KNBR-AM/KFOG-FM, San Francisco, CA

***RADIO LAN**
William F. Bakker
ITC
Bloomington, IL

INTERNET AND ITS USE FOR BROADCAST FACILITIES
Tim Pozar
TLGnet and KKSF/KDFC
San Francisco, CA

***INTERACTIVE VOICE RESPONSE SYSTEMS**
Vic Jester
WNNX
Atlanta, GA

*Papers not available at the time of publication

INTERNET AND ITS USE FOR BROADCAST FACILITIES

Tim Pozar
TLGnet & KKSF/KDFC
San Francisco, CA

Abstract

The Internet has proven to be a valuable tool for reaching the listeners and viewers of radio and television stations. It is also useful for accessing a wide variety of on-line materials. With the recent development of such tools as the Hyper Text Transfer Protocol (HTTP), Mosaic, low-cost access, and high-speed modems, the Internet has become more intuitive and accessible to millions of people.

This paper will provide an introduction to the basics of the Internet and some of its resources. It will also focus on opportunities for the use of the Internet that relate to broadcast programming and engineering.

1. INTRODUCTION TO THE INTERNET

Where can you get only 1 hour old weather satellite images for your area, current state and federal legislation, and track your FedEx®[1] package? How can your audience get information about your station like programming times, event directions, and sound and video clips from your shows any time of the day? Via the Internet . By having your station plugged in to this global data network you can all of this and plenty more at a cost ranging from free to ~$1000 a month.

1.1 Definition of the Internet

Simply, the Internet is a group of thousands of data or computer networks that are tied together via leased lines, or radio (shortwave through light) that share a common protocol called the Internet Protocol or IP. IP was born out of some pretty crude and slow hardware and has had 25 years of development behind it. It was developed so that sections could be severed and the network will self-heal in a matter of minutes. It also scales very well to the current and future fast network technology like ATM and SONET. Because of it's flexibility and speed, the Internet provides all the tools to tie local computer networks to others.

1.2 Explosive Growth

The Internet has grown exponentially since its development by the Defense Department's (D)ARPA division just over 25 years ago. In October of '84 there were 1024 hosts or computers directly connected to the net. Nine years later there were 2,056,000 hosts. This January the Internet had an estimated 4,851,000[i] hosts connected (See Fig. 1). The Internet Society estimates that the Internet will reach 100 million hosts by the 1st quarter of 1999[ii].

There is some debate on how many people have access through these hosts. Estimates range that there are on average 3[iii] to 10[iv] users per host. This would give a number between 15 to 50 million people on the Internet. Each one can use the resources available on the Internet 24 hours a day.

Access to the Internet is available in almost every point on the globe. At last count there were 159 countries (and other entities) out of 238 that had conductivity[v].

[1] FedEx is a registered trademark of "Federal Express".

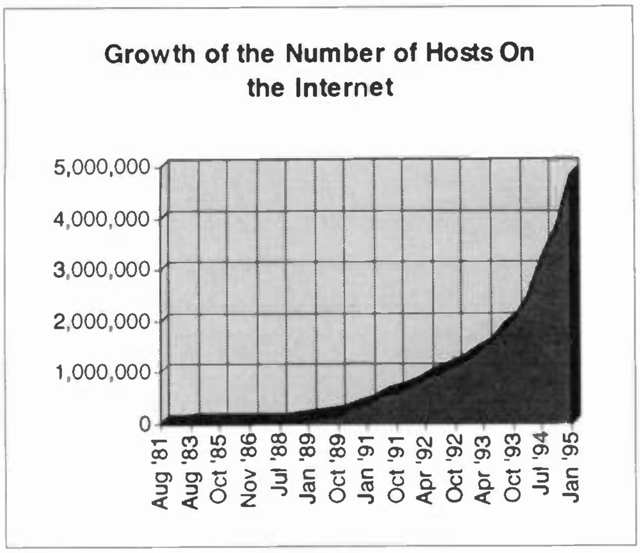


Fig. 1

1.3 New Tools

Up till recently one of the problems with the Internet was that you needed to know the arcane "language" of UNIX®[2]. This was due that most of the hosts on the Internet ran UNIX. You would also need to know how to use very unfriendly Internet tools like FTP (File Transfer Protocol) and Telnet. There was also the fact that as shown above, just a few years ago there were few sites on the Internet that you could gain access to.

Several new tools have made the Internet easier to navigate and access. About two years ago the concept of a Uniform Resource Locator (or URL) was developed. A URL would contain information such as the protocol, the site and the directory and file name to retrieve a document. A sample URL would look something like:

`http://www.tbo.com/index.html`

This URL defines that a document is available via the HTTP protocol, from the site "www.tbo.com" and the file is called "index.html". In fact this URL points to the KKSF and KDFC server where you can find out all about us. More sample URLs that point to Internet references in this paper can be found in the endnote section.

With the URL a new protocol was developed called Hyper-Text Transfer Protocol (HTTP). HTTP with a mark-up language called Hyper-Text Markup Language (HTML) created documents that would have pointers to other documents embedded in them. If a reader of a HTML document was interested in knowing more about microwaves, and that word was attached to another document, the reader could select it and be seamlessly transferred to an essay on microwave theory.

The second major development was a graphical front-end to the Internet called Mosaic. Mosaic was developed at the National Center for Supercomputing Applications (NCSA) department at the University of Illinois. It is an application that spoke a number of the main Internet protocols, including HTTP, to retrieve documents via URLs and can display HTML documents. A user of Mosaic would just need to use their cursor to point to a highlighted word or graphic to bring up another document that would be related. Mosaic has popularized HTTP traffic to be one of the most used on the Internet in the last year.

Recently there has been substantial interest in creating commercial versions of Mosaic. Spry Incorporated has taken the Mosaic software, added some bells and whistles and debugged it and is now selling it commercially. Netscape Communications Corp. hired the main programmers from the Mosaic project at the NCSA and created a new "Mosaic" called Netscape. Netscape has added a number of major improvements to this HTML browser that it is the application of choice now.

1.4 Ease of Access

Since the Internet was started by the DoD, there was tight restrictions on who could connect and what sort of "traffic" would be allowed on the Internet. With the DoD's departure, hundreds of Internet Service Providers (ISPs) have stepped in to provided the on-ramps to the Internet. Due to large amount of ISPs competing to be your provider the competition has dropped the cost of connecting substantially. Depending on the speed and the services you want, you can end up paying

[2] UNIX is a registered trademark of "X/Open".

nothing on the low end to about $1000 a month for a fast connection to the Internet.

2. RESOURCES

With this tremendous growth and easy of access there has been an explosion of wide range of resources. Your news department will be aided by news wires from the Voice of America[vi], and sources like the New York Times and the Wall Street Journal[vii]. Press releases are available from the White House[viii], FBI[ix], FCC[x] and many other government agencies and companies.

Federal and State government are starting to make legislation available. California's Legislative Data Center[xi] has put up a server that offers current bills, statues, and codes. It is updated every night so you can track the bills as they go through the process of becoming law. Recently, The Library of Congress has made available a service they call "Thomas"[xii] (after Thomas Jefferson) where current House and Senate bills can be tracked and downloaded.

Writing a paper for the NAB[xiii] and just don't have your dictionary around? You can look up those two dollar words with dictionaries[xiv] and thesauruses[xv] available. Forget the ZIP+4 code of the station? You can query the USPS's "ZIP+4 Lookup"[xvi] server.

3. STATION PROMOTION

One of the basic advantages of the Internet is that it supports the bi-directional flow of information. Anyone can put up a server and provide information to the networked community. This is where your Promotions, Programming and possibly Engineering Departments can get into the act.

There are a number of ways to self-promote your station. It just depends on how much time and money you want to throw at it.

3.1 Mailing Lists

One of the least costly ways to promote your company is with an electronic distribution of a station "newsletter". In the Internet this is called a mailing list. A mailing list would be a list of listeners/viewers that have contacted you that they want to receive promotion material from you. Once a week you would put together a letter that would talk about upcoming events, programming, or related information about your station and send this to your list.

The least expensive way to do this is to get a "shell" account with an ISP. Shell accounts may run from $0[3] to about $20 a month. A shell account will let you access Internet e-mail and the conferencing software known as USENET.

As soon as you get your account setup, you will want to post a message to the appropriate conference areas on USENET that your station has an e-mail list that announces station events and if folks are interested they should drop you a line. You can also plug the station's email address on the air and collect addresses this way. Be prepared to be inundated with requests to be on your list. KKSF's mailing list is currently over 1000 addresses that we send our weekly electronic newsletter to.

3.2 HTTP or WWW Servers

The next step in information distribution is a World Wide Web (or WWW) server. WWW servers can deliver text, pictures graphics, audio, movies, and animation via HTTP. A well developed WWW server can have the same impact as a well designed listener newsletter to entice or remind the user to "tune-in".

Starting up and maintaining a WWW sever will take a bit more effort and cost than a mailing list. You can either setup a WWW server in-house or by renting space from a provider. I would suggest

[3] You may be able to get the account for free for mentions on the air. By using the ISP's Internet e-mail address for your own, it indirectly plugs the company. Say if you end up with an address like "kxxx@isp.com", the ISP gets their plug.

that if you don't already have the expertise on-site that you look for a provider that can run and design the server for you. By going outside you will need to pay for renting the "space" on the server, and in some cases, some providers charge by the download. Costs can range from $0[4] a month to $500 a month depending on how much material you make available or how often you change the site.

Running a WWW server in-house is much more complicated. You will end up paying for a leased-line to an ISP and the ISP's monthly costs. You will also need to have a computer that will be the server. This could be a '486 loaded with the memory and hard disk space needed to run UNIX or WindowsNT[5]. There is also the labor and talent needed to maintain the system.

So, now you have this nifty WWW server, what can you do with it? You can start by just putting up your logos and some short description of the station. This will get a bit old in a hurry. By putting up some information that is updated on some periodical, or adding interesting pointers or features to the server, you will have a better chance of repeat business. Let's look at some examples.

KKSF/KDFC's server (See Fig. 2) contains pointers to electronic versions of our paper newsletters, documents of current events and concerts, and we try to constantly change and features so there is something new each time a user queries our server.

Since this we are a radio station, pictures and graphics play an important part in giving some image to the company. Logos, portraits of the announcers, and even pictures of the tower can help listener connection to the station.

Our server averages about 8,000 "hits" per week. With an average figure of 10 hits per person it ends up about 800 folks per week may check out our site. As the Internet grows this number will only grow too.

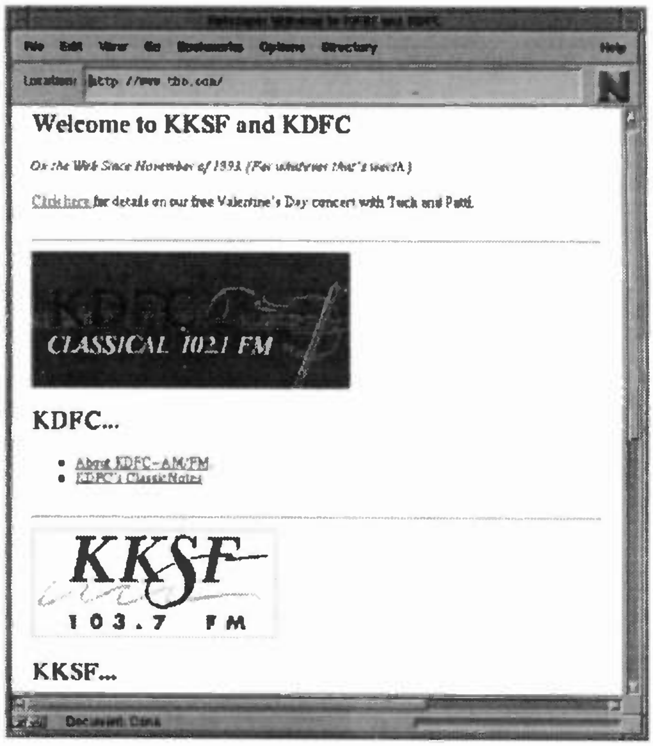


Fig. 2

The Canadian Broadcasting Corporation (see Fig. 3), with the help of the Communication Research Centre, has been experimenting the last couple of years of distribution of programming via the Internet. Folks on the Internet can download recent shows and play them back on their workstations in entirely.

The CBC has even setup merchandising via their WWW server. You can order audio tapes and transcripts of shows, clothing, books and other accessories. There is instructions on how to order. New developments by companies like Netscape will enable radio stations to sell directly over the Internet by taking credit card numbers and automating the ordering process.

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[4] Again, you may be able to trade the service to lower the cost.

[5] WindowsNT is a registered trademark of Microsoft Corporation.

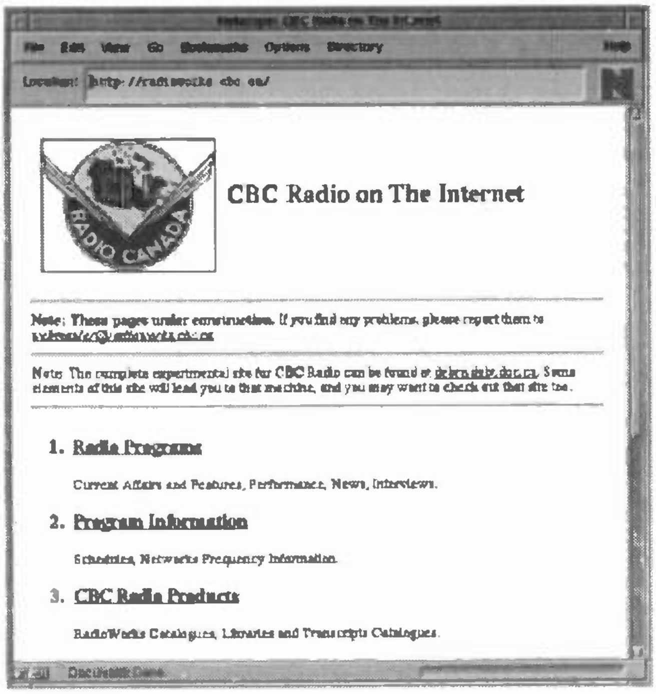

Fig. 3

3.3 FTP Servers

Although WWW servers are fast becoming the "defacto" way to distribute information on the Internet, there is still a large set of the Internet population that can't display graphics, or audio. A File Transfer Protocol or FTP server can serve this "underprivileged" set of Internet users out there. The same text, graphics, and sound files can be then "hand" downloaded and played back on the user's workstation. It isn't quite as elegant, but it goes a long way from having nothing for them.

3.4 Politics of the Internet

Since the Internet was developed as a non-commercial network and many folks out there still don't see the need for unsolicited advertisements, you need to be sensitive in the design and delivery of your materials.

Advertisements should not be forced on a user. They are paying for the time to download the ad. A better way of handling it would be to have a small pointer to an ad and let the user decide if they want to see it or not. This may mean that you will need to come up with some creative ways to entice the user. "cool" designs, games, or contests may be the way you get folks to push that button.

4. INTERNAL STATION USE OF THE INTERNET PROTOCOLS AND APPLICATIONS

The Internet is built on the concept of "Open Protocols". The standards for the Internet are well known and published in documents called RFCs. Many of the applications like Mosaic and the WWW servers are distributed as Freeware or Shareware, where the cost to use the application is either free or a reasonable fee if you find the application useful.

Many of these free application are powerful enough to use in the corporate setting. At KKSF/KDFC we are using applications like Gopher and FreeWAIS as our Associated Press wire server. There was no cost to set up this server (besides the labor) and we ended up with a much more powerful piece of software suite than what AP was offering. The down side to this is the support. You just can't call anyone in particular on the Internet at 3am for some help. Support comes in the form of posting something to USENET and hope that someone has an answer for you.

As mentioned in the introduction, the Internet was designed for Wide Area Networking (WAN). That fact and that the Internet protocols have become a widely accepted industry standard, this makes the Internet the perfect "glue" to connect stations in your group. (Even Novell has supported IP since it's version 3.11 of Netware.) With the appropriate security designed into your networks, you can use the Internet to distribute digital audio, video, copy, accounting data, sales orders and even e-mail. Internal mailing lists that may share ideas between the engineering or sales departments can easily be created. Specialized data like audio or video is just another chunk of data to the Internet. One station may get a buy and produce the spot and it can be quickly distributed to the other stations.

5. CONCLUSION

The Internet is flexible, and cost effective. Our recurring cost for the server, connection and labor ends up running about $400 a month. It is probably the most effective promotional device that we support.

6. CREDITS AND ENDNOTES

This paper and associated materials are available in electronic form via anonymous FTP at kumr.lns.com [140.174.7.1] in /pub/nab95/.

I would like to thank my wife, Sue Olivier, for the editing of this document.

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INSURING THAT YOUR STATION WILL PASS INSPECTION: ASK THE FCC

Monday, April 10, 1995

Session Chairperson:
David Wilson, NAB, Washington, DC

****Panelists:**

Richard Breen
FCC
Powder Springs, GA

William Borgman
FCC
Allergan, MI

James Higgins
FCC
Laurel, MD

Laurence Jones
FCC
Ferndale, WA

Clark Poole
FCC
Grand Island, NE

William Zears, Jr.
FCC
Livermore, CA

**Papers were not solicited from panelists

TAPELESS VIDEO PRODUCTION: THE EVOLUTION

Tuesday, April 11, 1995

Session Chairperson:
Bill Beckner, W*USA-TV, Washington, DC

THE TRANSITION TO SERVER-CENTERED BROADCASTING
Stevan Vigneaux
Avid Technology, Inc.
Tewksbury, MA

CONTROL OF MULTI-CHANNEL A/V DISK SERVERS FOR ON-AIR PRESENTATION
Stanley Becker
Louth Automation
Menlo Park, CA

BENEFITS OF UTILIZING NEXT GENERATION SCSI INTERFACES WITH DISK ARRAYS
Robert Fine
Ciprico, Inc.
Plymouth, MN

***INTEGRATING NON-LINEAR DEVICES INTO THE BROADCASTING ENVIRONMENT**
Donald E. DeCesare
CBS Inc.
New York, NY

***TAPELESS IN SEATTLE AND HONOLULU, TOO.**
Brian Lay
KING-TV
Honolulu, HI

*Papers not available at the time of publication

THE TRANSITION TO SERVER-CENTERED BROADCASTING

Stevan Vigneaux
Avid Technology
Tewksbury, MA

INTRODUCTION

The events and developments of the past two years can leave little doubt in the mind of the thoughtful observer that the era of server-centered broadcasting is upon us. It began with disk-based editing and playback systems which started entering broadcast technical facilities in early 1993. Since then the introduction of a range of nonlinear production and playback tools from several suppliers has transformed what was once seen as a mere trend into a torrent. As the unquestioned value of disk-based playback and editing systems became evident, the next logical step was equally apparent - linking the separate production workstations to a central library. Hence, the introduction of the video production server at NAB 1993.

This NAB has finally witnessed the entry of some of the industry's behemoths who are, at this fairly late date, acknowledging what the rest of us have known for several years, the age of broadcasting from disks connected to a central server has surely and securely arrived. It would now require a true Luddite to suggest that the majority of broadcasters will not be using server-centered production and playback systems within a few years. Virtually everyone in this room already has a vision for the future of the technical facility for which they are responsible. A vision which is certainly awash in disk-based systems connected to a server with a central library and archive.

A famous comedian is reputed to have said, "I'm not afraid of dying, I just don't want to be there when it happens." Most of us have had similar thoughts about disk-based technology. We're not afraid of being there. It's the process of getting there that bothers us.

No matter how sharp and clear a vision each of us has for the future, there is that "fuzzy" area, the phase between where we are today and where we're going to be. It's somewhat like standing on one side of a chasm spanned by a great bridge. Each side of the chasm is sharp and clear. We've enjoyed being where we are, yet we look forward to getting to the other side. But the bridge is cloaked in fog and mist so we're a bit uneasy about crossing over.

Even though video servers dominate the trade press and the "trend" to disk-based systems for editing and playback has become a torrent one must still ask, "Why should my station, network or production center make the change?" No one wants to risk getting caught up in a fad and ending up as a technological and professional lemming. The reason to make the change is the best possible one, server-centered disk-based production systems make the production process faster, easier and more efficient, and enable the production of higher quality broadcasts, both creatively and technically. Having decided to make the change and embrace a server-centered disk-based production system, the next question is, "How?"

The purpose of this paper is to walk through the process raised by these two key questions. This paper will briefly review why one would want to make the transition, then speak about some of the transitional planning issues, and conclude by discussing the transition process itself.

THE BENEFITS OF DISK-BASED SYSTEMS

Disk-based systems first appeared as off-line pre-production editors in post houses. They were restricted to off-line use because early compression systems gravely limited their image quality. Despite their poor image quality, disk-based editing systems were quickly adopted into wide use because they provided substantial increases in editing speed which rolled immediately to the production's bottom line. Programs and commercials were off-lined in twenty to fifty percent less time. Further, the random access capability of the disk drives allowed the production team genuinely revolutionary creative freedom. Changing an edit or modifying a sequence no longer meant going back and recutting daily rushes from the sound stage or changing several tapes and waiting for them to shuttle to the right point so the edit could be performed.

Broadcasters who have already adopted disk-based editing systems have found the same benefits of editing speed, flexibility and creative freedom the nonlinear pioneers discovered just a few years ago. The big difference is that today's disk-based nonlinear systems have on-line quality. Broadcasters around the world are going to air daily with news, programming, and commercials stored, edited and played on disk. Disk-based playback systems for commercials and/or news stories are also in constant and rapidly increasing use. It is overwhelmingly evident that disk-based editing and playback systems have already become the hottest technology in broadcasting and that servers will be the single most important enhancement to broadcaster's production toolkit for the late 1990s and beyond.

EDITING WORKSTATIONS

As mentioned previously, editing on disk is faster, more flexible, and provides increased creative freedom.

Speed

Disk-based editing is faster because editing, by its very nature, is a constantly changing process. It's faster because there is no need to wait for tape machines to shuttle or tapes to be changed. It's faster because any "mistake" can be fixed with a single click on the "undo" button. It's faster because it replaces the complexity of time code numbers and obtuse commands with an easy to understand and use graphical interface. The speed derived from a disk-based editor can translate into greater productivity, more stories coming out of the edit room each day, or better stories from a creative point of view because the system's speed allows operators the extra time to try things differently.

Flexibility

Those of us who remember typewriters and carbon paper need no convincing about the benefits of word processors and laser printers. These new tools brought us more than just faster work flow, they also gave us the freedom to change, the chance to rework a sentence, the opportunity to delete that line we put in and later thought better of. We may call it word processing rather than nonlinear writing but that's just what it is, nonlinear writing.

There are a wealth of parallels between the flexibility of the word processor versus the typewriter and disk-based editing systems versus linear technologies. Nonlinear video and audio editors provide the same freedom to change, "the freedom to change your mind without losing it," as one advertisement reads. Nonlinear editors allow us to go back, in an instant, and change a transition from a cut to a dissolve, and then change it back again if we prefer. Disk-based editors allow us to make one version of a story for the six o-clock newscast and quickly produce an enhanced one for the eleven o'clock show without being forced to completely recut the story.

Creative Freedom - Story Quality

The speed and flexibility of disk-based systems enables editors to produce better stories, better programs, better commercials, better promos. It is true that even the best word processor can not make a good writer out of a bad one. But, it gives the good writer the tools to become a better, more productive writer. It is equally true that even the best disk-based editing system won't turn a slice-and-dice editor into a video artist. However, in the hands of a skilled user the speed and flexibility of disk-based editors frees their creative abilities. Suddenly the hardware is out of their way for the very first time. No worrying about drop-frame calculations, no thought given to match–frame errors. Instead, all the operator's energy and interest can go directly to where it was always supposed to be going, the piece being edited. The net result of this new creative freedom is better results that provide the edge broadcasters need in today's increasingly competitive market.

PLAYBACK SYSTEMS

Playback systems are the lifeblood of any broadcast facility. It doesn't matter how brilliantly the news stories have been edited if they can't get to air reliably. Even more important is the playback of commercials, the "cash register" for every station and network. Disk–based playback systems have surged into broadcast plants because they provide:

Reliability

Today's disk drives have mean time between failures in excess of five hundred thousand hours, well over fifty years. The introduction of RAID technology has enhanced even that stellar capability by producing virtually absolute reliability. Heads do not clog, tapes do not misthread, drop-outs do not occur. Disk-based playback systems are so reliable that some vendors have tried extending the lives of antiquated videotape jukeboxes a few extra years by adding "front end" disk caches to provide the reliability tape-based playback islands have never offered.

Flexibility
As has often been said, the only constant in broadcasting is change. Change in the rundown for the newscast, change in the commercials to be played, change in the program log, and then more change in the news rundown and the commercial playlist. Disk-based players excel at change because they provide the same nonlinear random access as a disk-based editor. Rundowns can be changed seconds prior to air with no concern that the change will not make it to air. It will, every time.

Ease of Use
The better disk-based playback systems have gone beyond merely replacing tape machines and jukeboxes. They have made work easier for the operator and in doing so have increased both human reliability as well as the system's. The more innovative disk-based playback systems have added features such as on-screen video reference frames so there's more than just a line of text to describe which spot is about to run next. They've also added true multi-channel capability, multiple playlists or rundowns, instant access emergency clips, and status displays which can be customized to each operator or station's particular needs.

Disk-based editing and playback systems have brought great speed, flexibility and reliability to broadcast use. But, what if they were able to all work from a central library with shared simultaneous access?

THE BENEFITS OF SERVER–CENTERED SYSTEMS

The next step in the evolution of disk-based systems is networking to a central library, a media server. The server takes each of the benefits mentioned previously to a higher level by integrating all of the individual production and playback workstations, the disk-based recorders, editors, and playback systems, into a complete and coherent whole. Perhaps the best analogy is to build on the comparison to the word processor. If disk-based editing and playback is to broadcasting what the word processor is to writing, then adding the server is comparable to desktop publishing.

The presence of a central library introduces many new capabilities and efficiencies to the production process, in addition to those already listed for disk-based editing and playback systems:

Shared Media
In a well-implemented server-centered production system multiple users are able to simultaneously access the same media. That means one edit bay cutting a story on the governor resigning, another creating a story on the likely successor, a third building a promo for the upcoming newscast, and all three of them using material from the same video clip of the resignation speech.

Speed
Speed is as much a benefit of networked workstations as it is for disk-based production islands. Some of the speed comes from being able to share the media. There is no need

to wait because it's all instantly available to multiple users. Speed also comes from directly recording incoming feeds into the server thereby providing instant access. No more waiting for tapes to be ejected from the feed recorders and running them down the hall to the edit bay. In fact, at least one currently available server allows editing to begin while the feed is still being recorded, eliminating even that time delay.

Media Management
Perhaps the single most valuable asset any broadcaster owns is the media. Yet, despite its phenomenal value, it is not usually managed very well. Tapes containing the only copies of the day's major events move from place to place with little if any control. Many times the media management system consists of a harried producer screaming into the intercom, "Who has the tape with the resignation speech?"

In server-centered production systems, all the media is in one place, the server's redundant RAIDed drives. Having the media centrally located, and knowing it will not be leaving there, makes it truly manageable for the very first time. Every incoming feed can be named and cataloged by date, time, source name, and any other relevant data. The system's database allows searches on any portion of the catalog data to provide fast retrieval.

Having reviewed why the benefits make it important for broadcasters to move with all due haste to disk-based, server-centered production and playback systems it is time to examine the question of how to make the transition.

THE TRANSITION

Based on observations at dozens of broadcast sites around the world there are several key principles which aid the transition to server-centered broadcast systems.

DEVELOP A VISION

The first stage in any major transition is developing a vision. That's business school speak for figuring out what the benefits are expected to be and how the station will be transformed by the time the transition is complete.

In the world of broadcasting, developing a vision mandates a team approach. The chief engineer who tries to develop the vision without genuine input from news, traffic, sales, and the general manager will almost surely fail. This applies to news directors and general managers as well, of course. The transition to server-centered production is a major change which will affect everyone from the news producers to the editors to the master control operator, the traffic department and even the sales force. Everyone needs to be part of developing the vision. That does not mean that one person can not lead the process, that is probably essential. But it does mean that no one person or department can force the process or control it.

What is the right vision for your plant? Is it a collection of disk-based editing islands for news which dub the finished product back to tape for playback in the traditional manner? Or is it a server-centered production system where all the users can access and share a common central library? Does the right vision for your facility go all the way to putting video on journalists' desktops so they can browse, screen, and perhaps even rough cut or edit stories? Does the vision include wide-area production so users can browse and then share material with other stations and even access the massive video databases being brought on-line in the next few years?

Does the right vision for your plant start and stop at a disk-based commercial playback island so there is no need for networking? Or does the right vision for your facility start with a disk-based commercial playback system and extend to networked program and promo editing workstations? Does it include the traffic department having direct access to the media library so they can verify and manage its content or will they still have to walk to engineering just to screen a spot?

One key step in defining the vision includes reading the available literature. There have been dozens of articles in the trade press this past year alone on disk-based editing, playback, servers, networks, and even the disk-based field recorder being introduced at this NAB. Another step is to use that literature to cull key vendors and then meet with them. Have them present their view of the present and the future, making clear what is already real versus what is purely vision, and then select those vendors whose vision meshes best with yours for second stage consideration.

Then go back and re-examine the vision. Is it realistic? Is it reasonable? Is the timetable and budget within your reach? After adjusting the vision and further refining its details it is time to move forward.

MAKE A COMMITMENT

Once the vision has been defined, and it need not be overly exhaustive in detail, the next critical step is to make a commitment. A real commitment. The best prescription for failure in introducing any new technology is to treat it as an option, something the staff and management can either use or not use based solely on whim.

One station put a nonlinear editor into their news editing area and trained all the editors. There was a lot of excitement for a couple days. A few weeks later the unit lay ignored and essentially unused. Why? Because neither news nor engineering management made it a priority. They didn't treat the system as if it were important to the station so it wasn't important to their staffs. So, when the daily crunch came, the staff usually dropped back to their tape-based editing bay to cut the next story. The project failed and the unit was withdrawn.

Another station, in the same town, put the same disk-based editor into their news department. After a few weeks it became an editing mainstay for promotions, sports, features, and series. The news director has told the director of engineering he wants all his bays converted to disk-based systems. Why such a different result? Because the technology was made a priority rather than an option. Two editors, not the whole staff, were trained and then told that this was their edit bay where they would edit all their stories. The commitment from management was clearly understood and, along with their own personal interest and vision of the future, motivated the editors to work through the learning curve and master the product.

Making the commitment, making the technology mandatory, clearly explaining the management vision and making sure that vision is also the staff's vision, these are keys to making disk-based technology a success.

START SOMEWHERE BUT DO START

The most successful transitions to server-centered production are likely to occur in stations that jump in all the way. There are a number of "greenfield" sites around the world building server-centered facilities right now. These broadcasters have had the luxury of building completely new facilities or major enhancements to existing plants. They have done much more than just begin their transition, they have arrived. However, the majority of the world's broadcasters will not have this great privilege and will instead have to transition their existing facilities to server-centered production systems. In most instances, the transition will begin in one of four "islands" within the plant.

There are four areas of the broadcast plant which will benefit greatly and quickly from the features of disk-based systems and are therefore ideal candidates to start the transition to disk-based systems:

Promo Production

The repetitive, though usually sophisticated editing required by promotion departments makes them one of the best places to initiate the change to nonlinear editing. In most broadcast facilities the promotion department generates the heaviest editing workload outside of news. During ratings periods the amount of promos to be cut and their sophistication climbs even higher. The speed, flexibility, and repeatability of disk-based editing makes promotion production an excellent choice for a first step into disk-based systems.

News Editing

There is a tendency to think of news editing as being all "crash and burn" production. Anyone truly familiar with contemporary news broadcasting knows this is not the case at all. A significant, and growing, percentage of the newscast is comprised of sophisticated stories. Virtually every station has one "Super Suite" and many have more than one. These are the rooms used to edit features, series, investigative reports, and the like. Until the advent of disk-based technology, capital cost combined with the reluctance to commit every story to the slower pace of such a complex room prevented broadcasters from making every room a super suite. Nonlinear editing breaks both barriers by providing a fast, easy–to–use editing system with the power of a super suite and the speed of disks.

Sports editing

Sports is a major element in most newscasts and places a great demand on editing time and capabilities. Many stations have made their sports segments major attractions by producing "play of the day" or "blooper of the day" features. These stories are ideally suited to disk-based editing systems because they make great use of wipes, dissolves, DVE, and titling. Sports stories usually contain many separate short clips and often can not be completed until right before the newscast, or even during it, because the events being covered tend to run late. Disk-based editing provides the speed and flexibility to produce better stories in less time.

Commercial Playback

Commercial playback was earlier referred to as the station's "cash register." Perhaps a somewhat blunt term for us trustees of the public airwaves. However, there's no escaping the need to pay the bills and that's precisely what the commercial playback system does. Considering its importance, and the well known reliability problems associated with alternative technologies, the advantages of disk-based playback systems make this another obvious starting point.

As the first of these applications become successful, another can easily be added. And, the systems chosen for these areas can easily be enhanced when linked to the server. For instance, once promotion production and commercial playback are linked through the server, the completed promos will be instantly available for playback to air without the burden of manually transferring them into the player. Alternatively, a single sports editing workstation could be the starting point followed by a second and perhaps a third and then by the server which would allow them all to share the media in the central library. Then connect the playback system, or a second one dedicated to news playback, to the same server and the result is a seamless flow of raw media through the editing systems and into the player.

REMEMBER THE VISION

A caution, make sure the products and application areas selected both match the vision. If the vision is for unconnected islands there are many possible choices. If the vision is for multiple workstations linked to the central server, the choices narrow considerably. A critical element of making this crucial first purchase is to make sure it fits the overall vision. Consider developing a checklist of key features and then stick to it. Don't be swayed by the latest exciting new feature from any vendor unless it fits the vision.

Also, when selecting products, it is wise to obtain clear distinctions between what is real today and what may be real someday and what may never become real. For example, there is a lot of talk today about MPEG and there is no doubt that MPEG holds great promise. However, since MPEG encoders remain in the fifteen thousand dollar range, this is not the year MPEG becomes the affordable format of choice for a production system which will require somewhere between six and twenty encoders.

THINK THROUGH THE DETAILS

Input, output, composite, component, analog, digital, control, network, interfaces, all of these belong on the list of issues to be carefully thought through prior to making a commitment.

Does the system easily interface to the existing plant? If the station is wired for analog composite video and analog audio yet the system under consideration only provides serial component digital video and AES/EBU digital audio, this is a serious problem which can only be resolved with extra-cost converters. If the plant is all digital and the candidate product is analog-only that's the opposite problem, yet just as costly and complex to resolve. If the system being looked at offers both interfaces then the present is addressed as well as the future.

What about control? As anyone who has ever built an edit suite using machines from different manufacturers and an edit controller from a third can attest, just because each device has an RS-422 port does not necessarily mean they will all communicate properly. RS-422 is an electrical specification which does not define a data protocol, a communication language, or even basic commands. Before making a system commitment it would be wise to make sure which devices the system must truly control and then to make sure the system will do so.

Then there's networking. One of the most common questions vendors receive these days is, "Does it have an Ethernet port?" The answer is often a glib "yes" which seems to satisfy many. The more experienced know that this isn't much of an answer. Because having an Ethernet or some other specific type of network port does not do any good unless the two devices in question "speak" each other's language. As everyone who has ever networked Macs and PCs together knows full well, once the network gets going the users quickly find out that a memo written on their Mac in ClarisWorks may not be readable on their PC in Microsoft Word and vice versa. Ask what is important about having networking in this product? Is it to link it to the station's e-mail system? Is it to exchange files with another product? If so, what product? Can the system under consideration read and write the file format required by that product?

GO A LITTLE SLOWLY, GO GENTLY

Other than those few who will be building completely new facilities with new staffs, most broadcasters will making a transition for their people as well as the equipment.

There will probably be some in your shop who are afraid of new technology. That's a real and genuine problem which must be honestly faced. Many of the best technical people in broadcasting have never held a mouse or used a computer keyboard. Telling one of these people to "double click on that folder" doesn't communicate a thing, instead it makes them feel inadequate and out of touch. It increases their fears. Does that mean the transition to disk-based systems cannot go forward? Not at all, these are the same people who took us from film to tape, from black and white to color, from mono to stereo, and from microwave trucks to SNG trucks. What it does mean is that training must be part of the process.

It also means that while people have to know that management is committed to making this transition they also need to know that management is committed to them personally making the transition as well. This is actually an element of the vision. If the vision includes everyone from the beginning, even though there may be significant changes in how work is done and even who does what, the process will be surrounded by allies rather than intentional or accidental saboteurs.

CONCLUSION

As stated at the beginning of this presentation, there is no doubt that broadcasting has entered the age of server-centered disk-based recording, editing and playback. Disk drives, servers and networking are all here to stay and bring with them enormous potential. Just as most of us have managed previous technology-driven transitions before, we will manage this one as well. To successfully manage this transition it is essential to develop a clear and coherent vision shared by the whole team of players, make a solid and visible commitment, and take the time and make the effort to implement it well.

Those who first make the transition to server-centered production systems will be the first to reap their benefits, benefits every bit as great as those gained in the move from film to tape, and the move from black and white to color, and the one from ENG to SNG. Each one of these transitions opened new golden ages for broadcasters, this one will too. Welcome to server-centered disk-based broadcasting.

About the author: Stevan Vigneaux is Senior Product Marketing Manager for the Broadcast Group within Avid Technology, Inc. of Tewksbury, Massachusetts USA. His responsibilities include: Product Development, Product Management, and Marketing for the Broadcast Group's editor (NewsCutter) and the networking and library systems (MediaServer and AvidNet). Prior to Joining Avid, Stevan was Product Marketing Manager for Production Systems Products (digital switchers, effects, stillstore, editor, router, etc.) for Sony Broadcast's U.S. operations. Stevan has also been Chief Engineer for two television stations and has served on several SMPTE and NAB committees including chairing the Time and Control Code Working Group. He holds a Bachelor of Science Degree in Electrical Engineering from Boston's Northeastern University.

CONTROL OF MULTI-CHANNEL A/V DISK SERVERS FOR ON-AIR PRESENTATION

Stanley Becker
Louth Automation
Menlo Park, CA

ABSTRACT

The introduction of random access multi-channel A/V disk servers will have a dramatic effect on the methods for on air presentation.

Tape library with disk caching and all disk commercial storage systems will become the presentation methods of choice over the next several years.

To enhance the use of random access video disks in the automation environment, Louth Automation in concert with disk manufacturers has developed a new communications protocol.

Unlike a VTR protocol which uses linear addressing (time code), the disk protocol introduces a file naming convention for ease of random access and storage space management. In addition the protocol provides a mechanism to address multiple input and output ports.

The protocol is concise and direct allowing reliable status reporting from the controlled device and frame accuracy with real time commands.

This paper will discuss the implementation of this new disk protocol and control architecture in the emerging video disk environment.

INTRODUCTION

Because an understanding of the past is important for dealing with the future, we will begin by detailing the current tape presentation environment and its control mechanisms. Next, we will examine transition architecture and finally a model for the future "on air" presentation systems.

CURRENT TOPOLOGY

Today a typical system (figure 1) consists of a mixture of media sources, VTRs, Cart machines, Still Stores, Character Generators, etc. and a number of media manipulators, Master Control Switcher, Router, DVE, etc. These elements are controlled and coordinated by a "presentation device server." In addition a control sub-system is required for media preparation. Media "tape" identification and locations of spots and programs on the tape are required for automating on air presentation of program elements, commercial spots, promos, etc.

Currently the communication from the presentation and preparation server to the devices is a diverse conglomeration of electrical interconnects and protocols. The dominant interconnect is RS-422 or the SMPTE variant ANSI/SMPTE 207M. The dominant protocols are Sony remote for VTRs and the Grass Valley Group's serial interface for switchers. However, RS-232 and ASCII protocols are also used. The user selects devices based on his needs and budget, and the burden of interconnect falls to the automation controller.

The devices are typically connected in a point to point or star configuration. This was necessitated by the need to provide real time frame accuracy over a low baud rate interconnect.

As business pressures dictate, more and more facilities are moving to multi-channel operation further complicating media preparation and presentation management, and necessitating the need to automate.

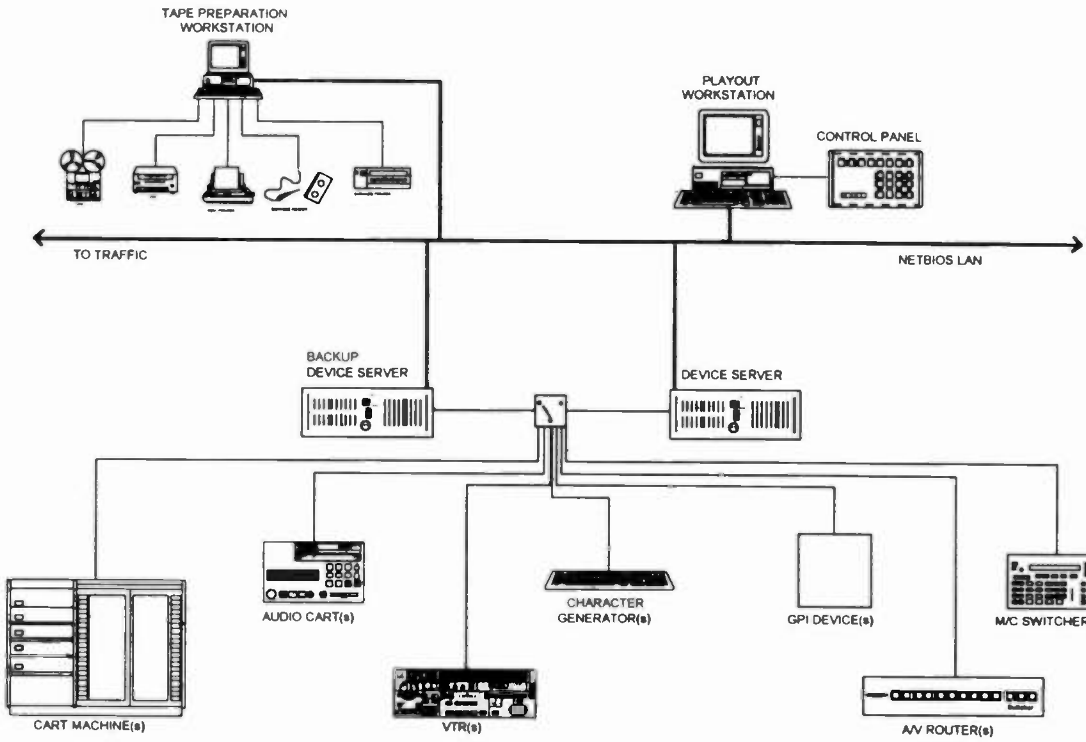

FIGURE 1 CURRENT TYPICAL BROADCAST CONFIGURATION

TRANSITION ARCHITECTURE and A/V DISK SERVERS

The introduction of the video disk server has afforded us an opportunity to change the style of on air presentation. A popular initial implementation of the disk will be as an output buffer (figure 2A). A cart machine may be used as a media library and the needed A/V material cached to the output buffer disk. This caching would be controlled from the playout list with a set look ahead with the transfer being performed in the background from the on air presentation. The next step will be to add large capacity "near on line" storage to supply the media to the output buffers in advance of air time (figure 2B). In this scenario some of the traditional A/V devices are used to input material into the archive store for later transfer to the presentation I/O disks. Cost, transfer speed, and operational capabilities are the most important factors in determining the size of the presentation disks, and the size and media of the archive storage system.

How does control of these new A/V disk servers differ from control of traditional media devices? A disk control protocol must allow full utilization of the random access, and multi-channel capabilities of the new audio/video disk servers. Back to back playout of spots must be supported to allow a continuous video stream from a single output. Louth Automation, in concert with disk manufacturers, has developed a non-proprietary disk control protocol to address these needs.

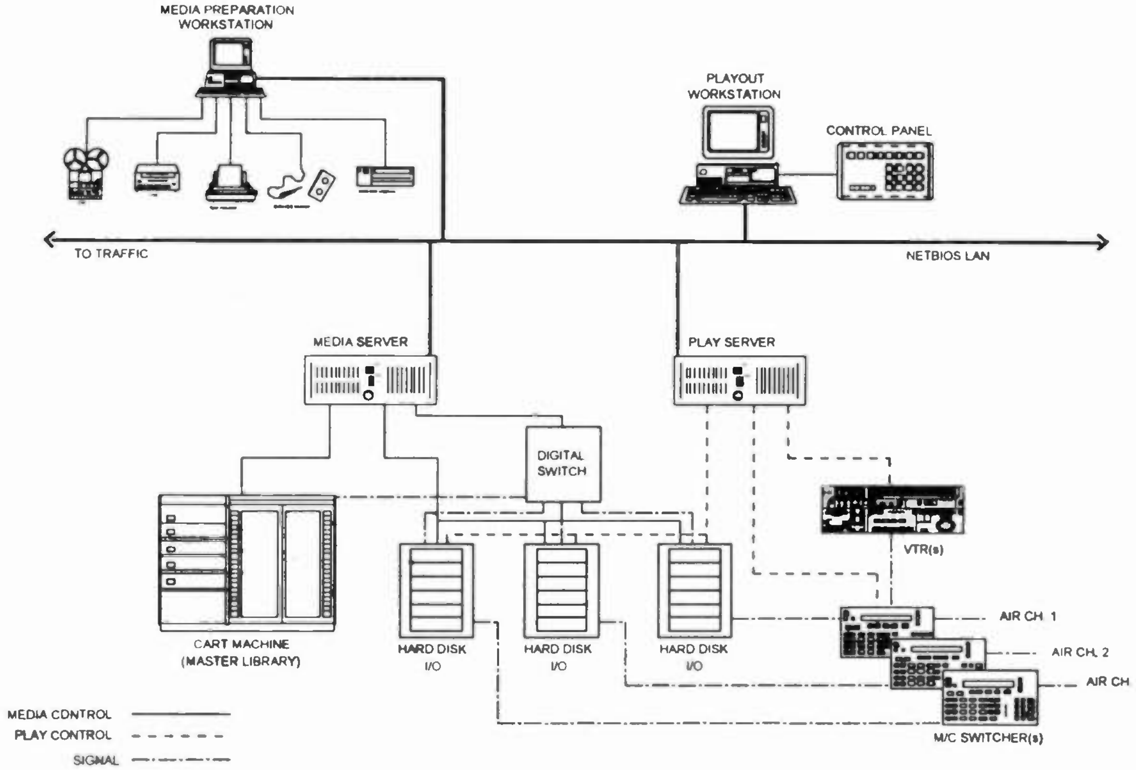

FIGURE 2A TYPICAL DISK CACHING CONFIGURATION USING EXISTING CART MACHINES

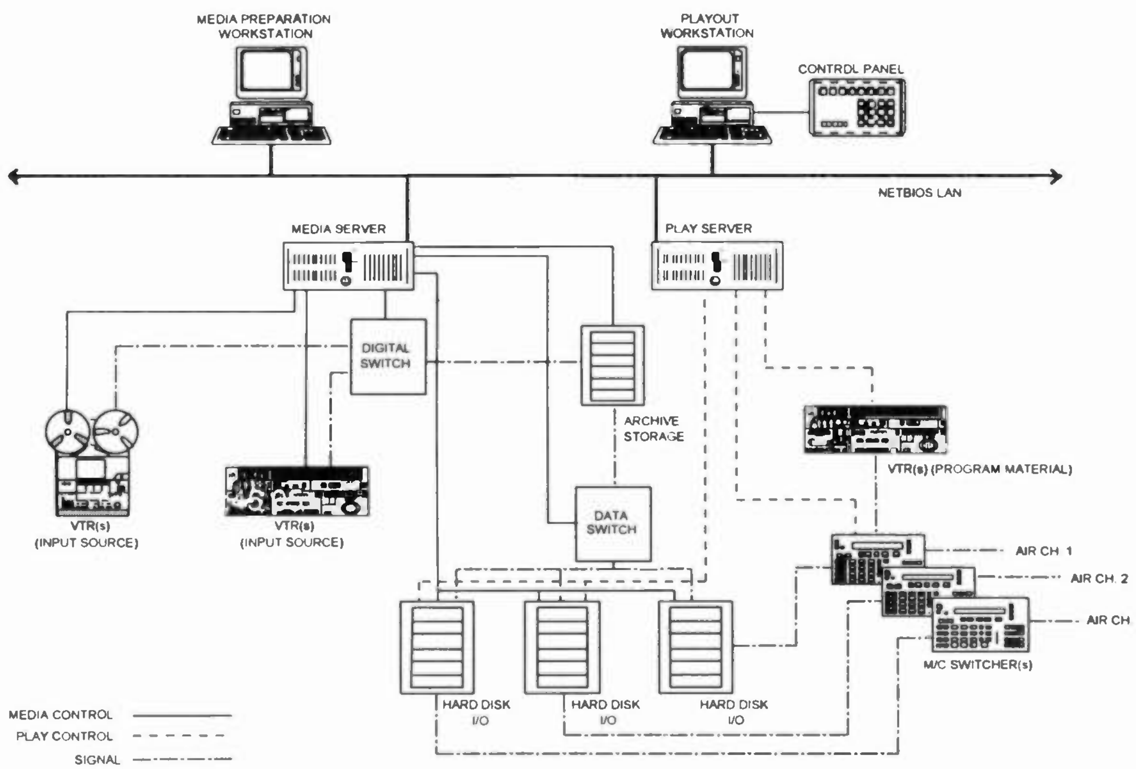

FIGURE 2B NEAR FUTURE DISK/TAPE COMBINATION WITH ARCHIVE STORAGE

Media Identification

Unlike a VTR protocol which uses linear addressing (time code), the disk protocol introduces a file naming convention (ID) for ease of random access and storage space management.

The disk control system identifies media for record and playback by a simple ID and duration. One of the largest advantages to an ID based system is that the automation system can query if an ID is available. If the response to the ID query is positive, then the automation system is guaranteed to be able to playout that material (unless there is a hardware failure). A recorded ID may be played back in its entirety by just requesting the ID. If a portion of the ID is to be played back, an offset start time and duration may be specified. The concept of cueing an ID for play or record is used to allow a video disk to setup its buffers, prepare its files, etc., for reading or writing. File, ID, and disk space checks are made upon a cue command prior to air time to ensure the media will be played or recorded at the required time.

For time sense, the protocol supports requests for the time remaining in the ID, or the elapsed time from the start of the ID.

Multiple Channels

The disk protocol command structure must address the complexities of multiple input and output channels and multiple controllers.

The Louth protocol allows a control port to "open" multiple I/O channels. It may open these channels as "locked"; i.e., another controller may not take control, or "unlocked." Once a controller has opened multiple I/O ports, a given port is issued commands when "selected."

When multiple control ports are used by different controllers; e.g., a controller recording into the disk while another is playing, the protocol must provide a mechanism to update the controller with changes to the disk's contents; the Louth disk protocol provides this mechanism with the ID's added and ID's deleted syntax. This keeps the automation controller informed of any last minute media additions or deletions.

The multiple port capability from a single disk allows multiple output feeds and permits previewing of any material without concern of interfering with the air playout.

Delete Protect

Preventing accidental deletion of material is crucial on a large shared system where media management and preparation are working on the same disk that is on air. A delete protect command prevents an operator or application from removing material until it is specified unprotected.

Disk Parameters

The protocol allows the user to set specific disk parameters such as video compression rates and audio sample rates. These commands are useful for systems that wish to provide different performance for different programs.

Time Line

The Louth protocol allows for commands to be deferred or issued on a time line. This concept was introduced for instances when the communications interface is indeterminate; e.g., Ethernet, or when multiple ports are controlled simultaneously on a single communication interface.

Archive

The command structure makes provision for archival storage by providing a sequence of archive commands, "send to archive," "get from archive" and "delete from archive." Archive systems may use any media including tape, optical disk, magnetic disk or other media all with the same control function.

Editing

An ID can be edited by using the new copy command. The protocol provides a mechanism for identifying an SOM and duration within an existing ID to create a new ID. This command may be implemented by the disk by issuing pointers to the locations within the file so that no new physical copy is required. This simple editing command allows for greater media management and control while conserving storage space and image quality.

Format

The Louth disc protocol uses a format similar to the Sony VTR protocol. The Sony serial VTR protocol format has two significant limitations; 1) the byte count is limited to a nibble (0-15) which restricts the command and response size. This is especially limiting when requesting a list of ID's. The disk control protocol introduces a byte size byte count. 2) The Louth format introduces a "unit address" nibble that allows the user to specify a subsystem within the disk, e.g., an internal switcher. The Louth system uses the command type nibble with much more precision and has introduced a type for "deferred (timeline)" commands.

The new disk protocol is based on the best of previous protocols with a few new features that increase its flexibility and capabilities while maintaining its efficiency as well as addressing the needs of current and future disk servers.

THE FUTURE CONFIGURATION

Emerging hardware will make a new broadcast configuration (figure 3) possible. As the cost of storage decreases, compression technology improves and data transfer rates increase, all digital systems will emerge. The system could be simplified to four major components; Audio/Video I/O disk buffers, a data switch, an archive, and a control system.
Let's analyze some numbers and current scenarios. Uncompressed CCIR 601 4:2:2 sampled video requires about 24 Mbytes/second (rough number); an eight to one motion JPEG compressed signal uses about 3 Mbytes/second and an MPEG compressed signal 1 Mbytes/second.

If we use the JPEG signal as a reference, we can compute that a thirty (30) second spot requires about 90 megabytes. At today's storage price of between fifty cents and one dollar per megabyte (use $.75), the cost for 30 seconds of storage is $67.50 or $135.00 per minute. In prime time, if we run 16 minutes of spots per hour and would like the output buffer to have the next 2.5 hours of spots ready to go, then the storage cost would equal (40 minutes X $135/minute) $5400. If the total inventory was 3000 thirty second spots (1500 minutes), the inventory storage cost is over $200,000. These are high but not impossible numbers, however add program media and the numbers will get quite large.

These large cost figures, not to mention the size of disks to be on line, suggest an off line or near on line archive storage system will become an important sub-system in the near future. Tape archive systems currently used in other industries are available with only a small investment in interface software. With a large tape archive system feeding the required media to several input/output disks, a powerful flexible and reliable system could be assembled to meet almost any broadcast requirement.

Conclusion

The control system does not care about storage size, cost, or media distribution. As long as the media can be identified in a device under automation control and can be transferred between the I/O disks and the archive, the system will work. The new disk control protocol will provide the tools to facilitate random access, multi-channel automation. The protocol is simple and reliable promoting efficiency and flexibility in development and use.

The protocol provides general commands and is extensible so it will accommodate or adapt as new features, capabilities and sub-systems are added to broadcast video disk servers.

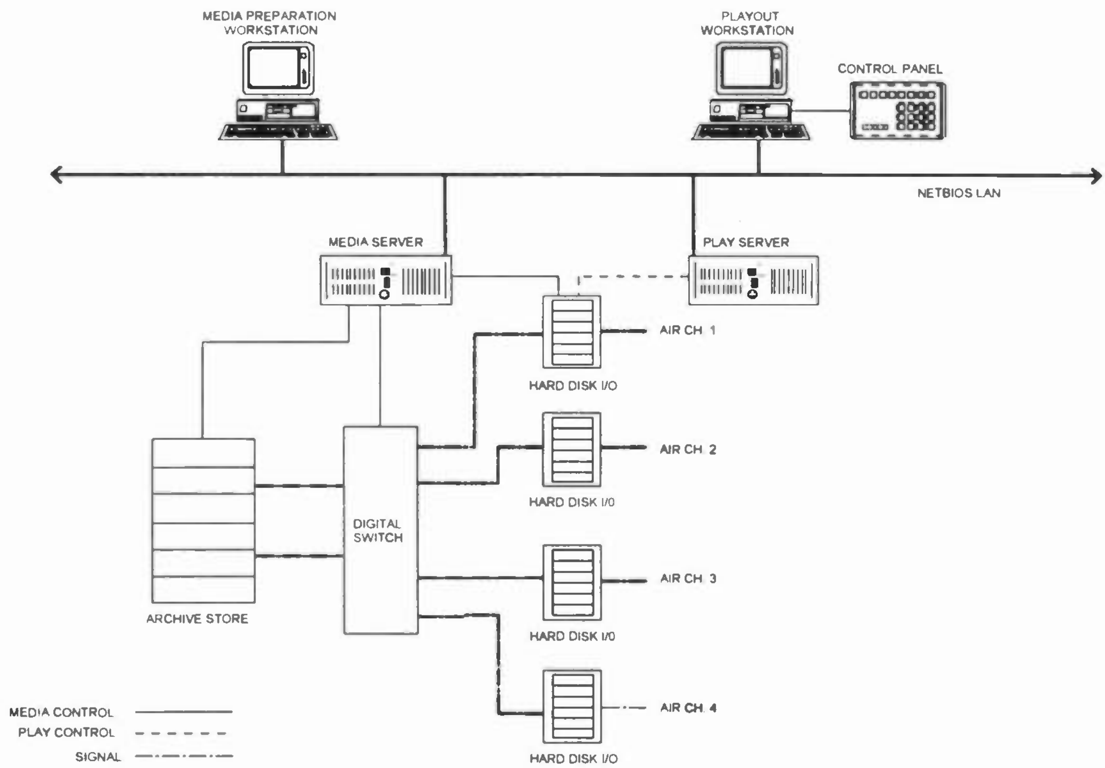

FIGURE 3 FUTURE BROADCAST CONFIGURATION (ARCHIVE AND DISK I/O)

BENEFITS OF UTILIZING NEXT GENERATION SCSI INTERFACES WITH DISK ARRAYS

Robert B. Fine
Ciprico, Inc.
Plymouth, MN

ABSTRACT

Over the last decade, computers have revolutionized the film/video industry to create new special effects that previously had to be created by hand, one frame at a time. As technology expands, so have the capabilities of the computer. Even with this progression, the performance of the disk drive interface has lagged behind. While CPUs have increased in performance by a factor of 100, disk drive transfer rates have increased only four times. One result of this differential is that uncompressed images cannot be retrieved and displayed from a single disk in real time. While RAID (Redundant Array of Independent Drives) disk arrays have improved this condition, they still depend on the performance of the particular peripheral interface standard used with the storage system. This paper will describe the benefits for the film/video industry of using the next generation of the SCSI (Small Computer Systems Interface) peripheral standard with disk array technology.

FILM/VIDEO APPLICATIONS

All of the different application software used in the film/video industry, such as animation, editing, compositing and paint, have a common element. They all need to store and retrieve image files in the shortest time possible. This becomes difficult since each frame created by these application programs is quite large.

The requirements of a disk storage system can be described in the following terms: file size, capacity, availability and image quality.

File size It is important to first understand the size of a typical image file, and the performance needed from the storage subsystem to retrieve the image from the disk in real time. The calculation for the data storage needed per frame is based on image size, frame rate and color density.

Using NTSC size images as a starting point with 3 bytes (24 bits) of color:

Each frame = 640 x 480 pixel x 3 bytes color
= 9.21 Mbytes

Displaying these frames at standard video rates of 30 frames/sec requires a bandwidth of 27.6 Mbytes/sec. This is the minimum rate required for NTSC size images. Other formats and resolutions require even higher transfer rates.

Capacity A 15 second effect requires nearly .5 GB of storage. With most production facilities working on multiple projects simultaneously, and with many versions of each effect kept on-line, disk based storage requirements can easily reach hundreds of gigabytes and even terabytes of on-line storage.

Availability In addition to the large amounts of storage required, these storage systems must be *available* for the production staff nearly 24 hours a day. As the number of disks increases to reach the needed capacity level, so does the potential for loss of data due to either human error or mechanical problems with the disk drives. The impact of system downtime can be significant on a project with a tight production schedule. Waiting hours or days to re-create lost images can have detrimental effects to a production team in terms of both cost and schedule.

Image Quality Another requirement for many post-production environments is the need for the highest resolution images possible. Since many special effects involve complex compositing of images, image quality often cannot be compromised through compression technology.

LIMITATIONS OF SINGLE DISKS

Digital images on a computer system are typically stored on disk drives. These devices have become the de-facto standard because they are inexpensive and easily installed by even novice computer users. While drive capacity and performance have increased dramatically over the last few years, these two areas have not kept pace with the needs of the computer systems in the film/video industry.

The most common size for disk drives is the 3.5" form factor. In this size, the largest capacity drive currently shipping in volume is 2 GB; 4 GB is just starting to ship in production quantities. However, even in these capacities, a single drive is just enough to hold a couple of special effects sequences. Post production facilities require much larger amounts of storage.

In addition to capacity, the performance of single drives is also below the needs of the application software. Single drives provide performance of 4-8 Mbytes/sec. Some drives with parallel transfer capability provide transfer rates of 9-12 Mbytes/sec, but still below real-time transfer rates of 27.6 Mbytes/sec. Most standard drives will provide playback about 1/4 the rate required for full-speed uncompressed video, preventing the display of computer generated images in real-time as they should appear naturally.

Since single drives cannot provide real-time playback, various techniques are used to alter the images to fit within the available bandwidth. These compromises are usually made in one or more of the following areas simultaneously: reducing the image size, skipping frames, or compression.

First, the image size can be reduced to a sufficiently small image that can be played in real time. With a NTSC image requiring 27.6 Mbytes/sec, each image (frame) would have to be reduced by a factor of 9 from the original image. [Reducing an image by a factor of 2 in both horizontal and vertical axis reduces the image by 1/4 of the original size. An image 1/4 NTSC size would require a bandwidth of 6.9 Mbytes/sec, slightly above the performance of a single drive. Moving to a factor of 3 in each dimension would reduce the image by 1/9 the original, requiring 3.06 Mbytes/sec- within the limits of most drives. Although this is the amount images would have to be reduced to display in real-time, this would result in images too small to be effective. Note that many low to mid-range computers only allow integer multiples for image size reduction].

Second, frames can be skipped. Skipping enough frames (only showing 1 out of every 6) to provide a transfer rate within the limits of a disk drive would result in very poor representation of the original images.

Compression is the third option. Since most compression implementations on high-end systems provide variable rates, the original image would require approximately 6:1 compression. Depending on a number of factors, including the speed of movement and the amount of light in the original image, this may or may not be an acceptable option.

Disk drives, as mechanical devices, are prone to failure. While disk drive manufacturers specify their products as having MTBF (Mean Time Between Failures) rates of over 750,000 hours (about 85 years), these numbers represent statistical data based on optimal conditions and are not representative of actual results. As any production facility has experienced, disk drives do occasionally fail.

When a drive failure does occur, the system administrator has two choices. Reload the files from backup, if a backup of the file exists, or tell the animator that they have to re-create or re-render the images; both options are expensive and could put an already tight production schedule in jeopardy.

SOLUTIONS

Two solutions are currently available to display images from a disk subsystem in real time. Either compress the images or use a RAID system with a peripheral standard that offers performance beyond standard SCSI. For many production facilities, compression is not feasible due to loss of image quality. RAID systems will be discussed in the next section, followed by an introduction to the next generation of peripheral standards.

RAID

RAID systems solve many of the limitations of single disks. These storage systems combine multiple drives into one enclosure, providing greater capacity, performance and availability features. The maximum performance of a RAID system is limited by the disk interface standard used to connect the combined drives to the host computer.

Definitions RAID was defined in a technical paper from the University of California at Berkeley in 1988 by Patterson, Gibson and Katz. The original Berkeley paper provided a definition for RAID as well as a definition for the five RAID levels. The different RAID levels are implemented by different manufacturers as either hardware or software based. Software based systems are usually easier to configure, but typically provide much lower performance than hardware based systems.

Refer to Table 1 for the definition of the different RAID levels.

Since the original paper, an additional RAID level (level 0) was defined. This level provides improved performance yet offers no protection in the event of a drive failure. For this reason, it is not included in most traditional references to RAID.

BENEFITS OF RAID

The different RAID levels are designed to provide three key features: capacity, performance and redundancy. Each of these features is very important to the film/video industry.

Added *capacity* through the use of multiple drives: By combining drives in a RAID system, the capacity requirements of a production facility can be met.

Increased *performance* by splitting the data into smaller chunks, with a chunk for each drive: Use of a RAID system can provide much greater performance than a single drive. With that level of performance, storage and retrieval of images takes a fraction of the time compared to a single disk. Since the average rate for a qualified animator is approximately $50/hour, the additional cost of a RAID system can quickly be recovered, because work can be completed much faster.

Improved *redundancy* by providing an extra drive to be used in the event of a drive failure: Even though disk drive failures occur infrequently, the results can be disastrous when they do occur. With a RAID 3 system, when a disk drive fails, the RAID storage system will continue to operate at full speed. With the current financial pressures on production facilities to turn out projects on time, this feature will quickly pay for itself.

RAID systems can be implemented on any standard storage system interface. One of the most common peripheral standards used for RAID is through the SCSI standard. Even though these RAID systems can provide performance very close to the SCSI limit of 20 Mbytes/sec, this is still only 70% of the performance needed for real-time video.

Level 0	RAID level 0 stripes data across multiple drives. No redundancy is provided.
Level 1	Mirroring. Automatically copies data on a second set of drives providing an exact copy of all files. While being the easiest RAID level to implement, it results in a large overhead cost as all information is duplicated.
Level 2	High-performance parallel array. Uses Hamming code to determine which drive failed. This scheme typically uses multiple parity drives, and is therefore most expensive to implement than other RAID systems.
Level 3	High-performance parallel array. Offers the highest performance for large, sequential files. RAID 3 is best suited for imaging applications.
Level 4	Independent access array. Similar to RAID 5, however this version dedicates parity to a single drive. In an independent access array, placing the parity on a single drive results in a significant performance penalty as write operations contend for the same parity drive.
Level 5	An independent access array, with parity distributed among all drives. Provides the highest performance for small, random access files. RAID 5 works best for multiple users accessing small records, such as database applications.

Table 1

INTRODUCTION TO ULTRASCSI

A new peripheral interface standard has recently been announced that provides the ideal solution. This new standard is an extension of the existing SCSI standard and is being developed through various standard committees. The official name of the specification is called ANSI X3T10/1071D. This extension of SCSI is called UltraSCSI and doubles SCSI's maximum transfer rate from 20 Mbytes/sec to 40 Mbytes/sec. The name of this new standard is also sometimes referred to as *double-speed* or *Fast-20 SCSI*.

UltraSCSI is based on the SCSI standard and provides a cost effective method for computer systems to migrate to higher levels of performance. UltraSCSI will follow the same progression that the SCSI interface has had, from fast (10 Mbytes/sec) to fast/wide (20 Mbytes/sec). It is expected that UltraSCSI will be endorsed as the next stage in this progression.

ULTRASCSI BENEFITS

Even though the UltraSCSI standard defines transfer rates of 40 Mbytes/sec, single disk drives are still currently limited to 4-8 Mbytes/sec, far short of UltraSCSI limit. It will be a few years before drive technology has advanced enough to provide this level of performance from a single drive. The easiest way to use UltraSCSI standard today and achieve performance of nearly 40 Mbytes/sec from a storage subsystem is to use a RAID system based on UltraSCSI. Such a RAID system can internally combine low-cost SCSI drives (with the current SCSI standard of 20 Mbytes/sec) and provide an UltraSCSI external connection. This system could easily provide bandwidth of almost 40 Mbytes/sec to the host computer.

The UltraSCSI interface equates to a breakthrough in technology for the film and video industry. With a maximum transfer rate of 40 Mbytes/sec, well above the 27.6 Mbytes/sec required for real time video playback, animators can see their work displayed on the computer system at full speed. This level of performance is achieved through a cost-effective interface on a single peripheral channel.

In the near future, with improved transfer rates from single drives, uncompressed video will be retrieved from single disks. Until then, disk arrays implementing the UltraSCSI interface are required to provide this level of performance.

FUTURE OF DISK INTERFACES

Interfaces to disk-based storage will continue to evolve. Some of the new standards being implemented are Fibre channel, SSA (Serial SCSI Architecture), and P1394. These interfaces have one fundamental difference from the SCSI standards. Unlike SCSI, which is a parallel interface, the other interfaces are serial. These serial interfaces provide performance up to 150 Mbytes/sec. At these speeds, higher density images such as feature films and HDTV can be transmitted in real-time. For applications that require lower resolution NTSC sized images, hundreds and even thousands of simultaneous compressed images can be sent in real time over a single channel. This would provide the ideal architecture for a video on demand system or high definition video conferencing system.

CONCLUSIONS

Technology has firmly established its presence in the film/video industry. Computers have been instrumental in the creation of new effects that previously were too costly or were simply not possible to create. While these computers have developed extensive graphics capability and powerful CPUs, they still lag in disk drive performance. Current SCSI disk drives are limited to 4-8 Mbytes/sec, about 25% of the speed required for full speed uncompressed video. While SCSI-based RAID systems can provide performance of nearly 20 MBytes/sec, this is still 70% of the performance needed for real-time playback. Use of new advances, such as the UltraSCSI version of the SCSI interface which provides throughput of 40 MBytes/sec, coupled with a high-speed RAID 3 subsystem, will provide full speed uncompressed video playback from a storage system in the very near term, all in a cost-effective package.

Other new emerging peripheral standards such as fibre channel, P1394 and SSA will provide even higher levels of performance. These technologies will enable capabilities such as real-time transmission of movies, HDTV and high resolution video conferencing.

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DESIGNING THE ALL-DIGITAL VIDEO FACILITY: BROADCAST AND PRODUCTION

Tuesday, April 11, 1995

Session Chairperson:
Jerry Butler, WETA-TV, Washington, DC

***BUILDING A BROADCAST FACILITY: BEFORE THE MEGABITS**
Richard W. Stephen
Stephen F. Pumple
IMMAD Broadcast Services
Markham, ON, Canada

DESIGNING FUTURE-PROOF SERIAL DIGITAL TELEVISION PLANTS
Bob Paulson
OmniMedia Communication
Westborough, MA

DESIGNING THE ALL DIGITAL PRODUCTION CENTER: BROADCAST AND PRODUCTION
Bob Pank
Quantel Ltd.
Berkshire, England

***DESIGN REQUIREMENTS FOR NEWSROOMS AND TECHNICAL OPERATIONS IN THE DIGITAL FUTURE**
Frank Rees
Ralph S. Blackman
Leroy James
Rees Associates, Inc.
Irving, TX
Stevan Vigneaux
Avid
Tewksbury, MA

***VIDEO NETWORKING IN SUPPORT OF THE VIDEO PRODUCTION PROCESS**
Jim Long
Starlight Networks
Mountain View, CA

THE TELEVISION LAN
Ken Jones
TV3 Broadcasting Group Limited
Middlesex, England

THE IMPLEMENTATION OF A FULL-DIGITAL TRANSMISSION SYSTEM IN THE TBS BROADCAST CENER
Shigetoshi Kobayashi
Tokyo Broadcasting System, Inc.
Tokyo, Japan

*Papers not available at the time of publication

DESIGNING *FUTURE-PROOF* SERIAL DIGITAL TELEVISION PLANTS

C. Robert Paulson
OmniMedia Communication
Westborough, MA

ABSTRACT

Speed and sophistication of digital television products now doubles every 12 to 18 months. Size and cost of serial digital signal processing, storage and transmission devices now halves every 12 to 18 months. "Future-proofing" is therefore the mandatory goal of the now endless task of upgrading existing hybrid analog/digital video/audio plants to *multiplexed, serial digital, format independent,* production and broadcasting operations versatility. Technology must be the servant rather than the driver of the adaptive planning and design process, whose goal is acquiring diverse new creative assets to exploit diverse new opportunities for generating sales and profits.

THE WORLD WE LIVE IN

Time is Now Non-Linear Too! [1]

Three distinct eras mark the precession of time in the world television production and broadcasting industry over the last 25 years. But, as opposed to "equinoctial precession," the slow, predictable *earlier* occurrences of the equinoxes in each successive sidereal year, since 1970 the television industry time periods associated with *Past, Present* and *Future* have shortened unpredictably in each era.

Television's *All-Analog (AA) Era* spanned 25 definitely linear-time years from its birth pains in 1945, following the cessation of World War II shooting hostilities, to the NAB Show in Washington DC in March 1973 (Fig.1A A). In a suite in a far corner of the Wardman Park Hotel, a struggling high-speed contact videotape duplicator developer, CVS (Consolidated Video Systems), debuted the CVS-500 digital video time base error corrector. The television industry's ***Hybrid Analog/Digital (HAD) Era*** had begun (Fig. 1 HAD).

THE PAST	THE PRESENT	THE FUTURE
LINEAR TIME		
AA - The "good old days" of the 1970s.		
Three to ten years back, its products still in use	Now through the next couple of years	Five years or more down the road
NON-LINEAR TIME		
HAD - Here and now in the mid 1990s		
Yesterday back to last year's NAB; anything earlier is useless or irrelevant	It's endless, unsettled; decision-making is a guessing game	Any minute now, brought on by a new legislative action or consumer demand
AD - In the hereafter, arriving any day -		
This morning thru the last software rev issuance	This noon thru the next software rev issuance	A near-term tomorrow, reported at 0001 by CNN

Fig. 1. Time: The non-linear rushing river.

We have been living in the Second Era Present's endless, unsettled, enervating environment for the past several years. We are awaiting a future that will have arrived on some completely unnoticed yesterday, which fact we will discover upon arriving at the office the next morning.

What will trigger the future transitions? In the Global Village, positive forces such as the expansion of the EU and the forming of APEC will lessen national political egoism and techno-political bickering, . In the US, long-awaited issuance of and HDTV broadcasting will generate new creative energy and upgrading fund infusion in the television production industry. Worldwide nascent consumer demand for already technically feasible products and intercommunication services may suddenly expand to critical mass justifying production startups.

(Why? Only hindsight will be able to tell us!)

The third and final era, the *All-Digital Era* (Fig. 1-AD) will similarly arrive unpredictably. The actual moments of occurrence of these blurred *Past/Present/Future* transition times, marked now by NAB Show dates, but soon marked approximately by software rev issuances, will be unimportant. It is highly probable that the *All-Digital Era* will sneak up on us as an extension of the current Endless Present, overtaking and tumultuously ending the Second Era before its Future arrives..

That's a terrible environment to contemplate as the milieu for future television production and broadcast operations! Won't the good old days of the All-Analog early 1970s return when the All-Digital Era has arrived?

Emphatically not! Why not? There are two technology-driven reasons.

(1) Moore's Law Governs Us, and There's No Repeal in Sight (Fig. 2)

Dr. Gordon Moore was the late 1960s co-founder of Intel Corporation, one of the first integrated circuit (IC) developers and manufacturers. Today the company sets the pace in new IC development by introducing a faster smaller X86 chip every couple of years. The "Pentium" (586) chip has started to overshadow the still-sold 386 and 486 chips (Pentium jokes on Internet notwithstanding).. Already in development are 686 and still faster successors.

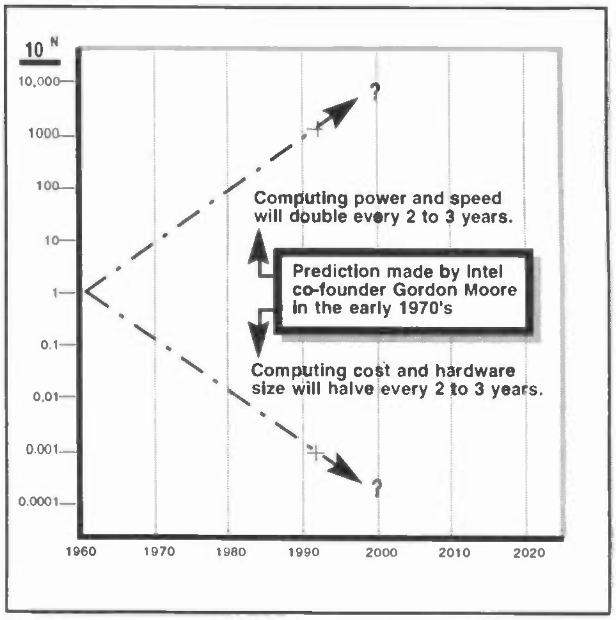

Fig. 2. Moore's Law is ***the*** Technology driver! [2]

In the early 1970s Dr. Moore was asked to speak on trends in chip development at a technical conference. To arm himself with facts, he checked back on the processing speed and cost trends Intel had established since its founding. Plotted on a logarithmic vertical axis against time, he found that Intel's product successes were doubling the speed and sophistication of computing every two to three years, while halving the cost and size of the microprocessor chips. His extrapolation of that graph into the indefinite future has become known as "Moore's Law", and every successful computer industry device maker's price/performance record since then has proved the reliability that mind-boggling prediction.

Applied to the development of other hardware products, such as an automobile, Moore's Law has a mind-numbing impact. Suppose you had bought a Cadillac in 1964 for $10,000, and it traveled 10 miles on a gallon of gas. Today's approximately eleventh generation successor to that design would cost less than $10.00, and run over 10,000 miles on a gallon!

(2) Technology Convergence Is Proceeding Asymptotically Toward Concentricity (Fig. 3) [3]

Communications, Computer and Television technologies were born independently of each other approximately 50 years apart. The common drive that moved them from accidentally discovered physical facts of life ("new technology") to commercial enterprise is the same drive that began their convergence in 1973 -- latent user demand for a product/service that was better/faster/cheaper/smaller than what was then in existence.

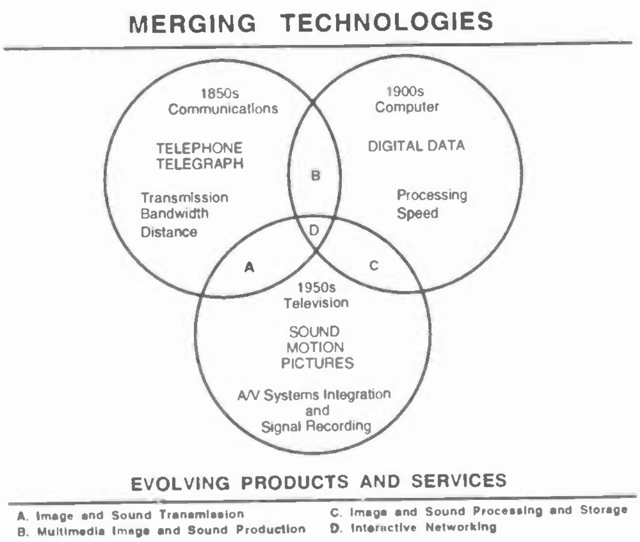

Fig. 3. Convergence breeds emergence

In reality, television industry engineers lost what they assumed was a birthright -- controlling the industry's destiny by introducing new hardware products every few years -- when television engineers Bill Hendershot and Mike Tallent installed crude first generation AD/DA signal conversion chips in their CVS-500 TBC.

The subsequent pervasion of computer chips into television product design was unstoppable. The crude, slow, expensive 1970s ICs have been steadily succeeded by LSI and VLSI designs following the Moore's Law curve. ULSI and VHSIC chips are under development. Trace widths have passed below 1 micron, and will be approaching 0.1 micron within the decade. Operating voltages are falling to and through the single 3 VDC level as shrinking chip sizes and trace lengths shrink power requirements.

Do television engineers have to become experts in telecommunications and computer technologies to remain useful to their employers? "Yes," sort of, for the near future, but "No," sort of, for the farther-out future. There's little to gain from acquiring telecommunications systems engineering expertise. Its R&D is driven to reduce hardware costs and eliminate labor in the processes of transporting voice and computer data traffic to and from anyplace on the planet. Television industry signal transmission represents a "niche market" too small to consider.

Fortunately, three product price/performance results are harmonious with the television industry's high-bit-rate video and audio signal transportation and storage needs: [4]

- Optical transmission link devices operating in the 1 to 10 Gbps order of magnitude;
- Magnetic/optical storage with capacities measured in TeraBytes with I/O transfer rates already at 270 Mbps and moving higher;
- Network operations management hardware and software permitting the ATM multiplexing of asynchronous video and audio data streams into SONET transmission circuits operating at upwards of 155 Mbps.

Television engineers' needs to understand the workings of these products will end once they accept the telecommunications industry's popular "Fuzzy Cloud" concept as a technically sufficient representation of both the complex network architectures within it, and the capabilities of the operations software which identifies, multiplexes, switches, transmits and de-multiplexes traffic transported on its satellite and fiber infrastructure.

The cables of copper wires and glass fibers appearing at the "demarc point" will deliver serial bit streams which were formatted somewhere else by an allied television industry organization, per the "in plant" interface standards established by professional associations of television and computer industry technical experts.

Convergence rate of these core technologies toward concentricity might soon become asymptotic, except that convergence breeds emergence of new products and services (cf Fig. 2 bottom). Products and services for (A) Image and sound transmission, (B) Multimedia image and sound creation, (C) Image and sound processing and storage and (D) Interactive networking will inexorably technically obsolete and competitively out-price predecessor generations every few months by New Year's Eve 2000!.

The Television Industry's Future -- An Extension of the Endless Present

Both the performance/price trend in microprocessor development and technology convergence will continue unendingly into the Third Millenium. Desktop computing has already been one-upped by laptop computing, followed by palmtop computing. Next in sight -- Dick Tracy wrist watch computers complete with cellular phones and connections to pocket wallet sized fax displays?

It is especially important to realize that strategic marketing is changing in the same manner as technology. Occurrences of the following examples of change "just happen," however, probably based as much on impulsive whims and intuitions of execs and marketers as by extrapolation of historical trend data, analyses of market research questionnaire returns, interpretation of focus group statements, or crystal ball gazing.

- Computer products marketing strategy has returned to "bundling" a hardware system and already-loaded software at competitively incomparable price points - the marketing strategy for which IBM was reviled by competitors and punished by courts in the 1960s.

- Discount computer store chains sell PC products with three generations of sequentially better/faster/cheaper/smaller Intel chips by price/features differentiation.

- Apple has finally begun to attack the PC's unit sales dominance by licensing its operating system to third parties.

- Firmware-driven single-function computers with wireless ports are now being marketed in minuscule packaging such as wrist watch cases, PCMCIA cards (now mercifully called "PC Cards), and sound output greeting cards.

Does this computer industry turmoil really have any relevance in the television Industry??

Answer -- Does any electronic television product *not* contain one to several computer chips and associated RAM?

What about the Future after the next Future's Endless Present? How about direct biofeedback picture and sound inputs into the human brain, bypassing the eyes, ears, nose and tongue (PsESP -- Pseudo Extrasensory Perception), and "HCSI" (Human Computer Serial Interface) input/output ports become standard on computers, interfaced to Alpha and Beta brain wave amplifier PC board?

Now there is a Hobson's choice! If such technological breakthroughs *never* happen, the television production and broadcast industries face a continuance of today's endless "Endless Present" in the All-Digital Future.

But what if PsESP and HCSI do happen? The need for most television production and broadcasting plants and creative technical people to run them might well cease.

By the time one of these options wins, anyone now working in the television industry will be long retired, and probably transmigrated to other realms. But that's no consolation!

In either case, for the rest of their careers industry executives and engineers must resign themselves to working in an environment which is an unbroken continuation of the current Endless Present.

This fact mandates establishment of a new concept in facilities planning - *Future-Proofing.*

FUTURE-PROOFING: MANAGING CORPORATE SURVIVAL

The Mechanics of "Future-Proofing"

Is Future-Proofing for real? Yes. Is it easy to achieve? Yes and No. **No**, positively, if your entire organization doesn't accept the truth of the attention-grabbing direct mail piece announcing an October 1993 MIT Enterprise Forum™:

IF
YOU'RE DOING
BUSINESS
AS USUAL TODAY,
YOU MAY NOT
BE IN BUSINESS
TOMORROW.

Yes, possibly, even *probably*, if you

THIMK FUTURE-PROOFING!

It must become the marching cry for brainstorming and assets management efforts that begin immediately.

"Thimk" is misspelled purposefully, to jog you into a reflection on the current problems of the company chided by the "Thimk" cartoons. Sloganeering is never the key to success in any kind of planning.

"Brainstorming" and "assets management" are also used purposefully. "Brainstorming" must be the first focus of the mechanical process, replacing endless Planning Committee meetings consisting mainly of negative pontificating about the ridiculousness of others' far-out ideas.

"Assets management" must replace "facilities planning." The most important asset in every organization today is its **People**, not facilities. This truth is obviously not shared by the majority of today's corporate managements. Planning for future survival precipitates "downsizing," which, to most of corporate America, means laying off skilled people in large numbers.

Organizing the Future-Proofing Team

Since people are an organization's most important, ***all*** the organization's people should be notified immediately about the urgent need to begin future-proofing the existing business operation. It is beyond the scope of this paper to define how the focusing of all the organization's people on future-proofing is translated into a small task force which consolidates the brainstorming ideas and begins the planning work. Hopefully it's obvious that the task force must have a representative from every functional department and P&L center in the organization. That individual should *not* be the top manager or necessarily the senior employee; the representative should be the best and most energetic future-thinker in that department.

It will be prudent to have more than one representative from marketing with sales promotion, advertising and personal selling expertise, imagination and enthusiasm. Future-proofing begins with the tapping of multiple revenue streams. Good marketing people already know where the first ones are located. Typically, however, their ideas never are brought up in engineering dominated by managers thinking only about this quarter's "bottom line" and engineers begging for money for "facilities upgrading."

Future Proofing Planning Rules

(1) Loyal, skilled. motivated creative and technical PEOPLE are the biggest asset.

(2) What the business accomplished in sales and profits last year is more irrelevant than important.

(3) Whatever the business is doing today is a shaky foundation for long term survival.

(4) "Downsizing" is ***NOT*** a viable option -- it is a red-ink-forced catastrophe erroneously seen as a one-time cure-all; in reality it is a people blood bath that must be repeated to correct the first effort's mistakes, and if repeated regularly will destroy the organization.

(5) "Rightsizing" should be an assets management technique repeated regularly, evaluating all near-future assets as a group.

(6) The grass is ***NOT*** always greener in somebody else's back yard (market niche).

(7) Analog equipment and tweaker tool maintenance expertise are both depreciating assets.

Living in the "Endless Present"

Seize the Day! (Carpe diem)

The "good old days" will never return. That's the fact created by the operation of Moore's Law. And assuming that some hoped-for future event will some day make choices more apparent, make decision making easier, is also wishful thinking. Moore's Law again. Therefore, if all the endless tomorrows dawn just like today's, why not start future-proofing activities by noon today?

Tapping New Market Opportunities

Market development opportunities are never in short supply. It's just that it's very difficult to perceive them when all your concentration is on (1) achieving sales and profits growth by conducting "business as usual;" (2) Viewing the bottom line numbers and ink color and comparison to a year ago as a barometer of corporate health.

Your first brainstorming efforts will identify new sales opportunities that are attractive. They have probably existed for some time within your best clients' organizations. Many others probably exist in similar organizations which are not your clients. Other sales opportunities could be tapped if you modified your present business operation just a little bit.

How do you turn these into immediate revenue streams with near-term promises of profits? By modifying (re-training) your most adaptable, versatile asset -

Motivated *PEOPLE!*

Management doesn't need to devise plans for motivation. People motivate themselves once *their* ideas for future-proofing are considered.

Assets identification What are *all* the current assets that *might* have future value? How must they be changed to become assets with continuing value in generating new revenue streams? There are four major categories, with interestingly different requirements for change:

People with new technology know-how
- Computer-base Digital Signal Processing (DSP)
- Video and audio signal compression
- Serial digital coding, multiplexing & transmission
- Fiber optics signal transmission and switching
- System, facility and network automation

Capital equipment
- Smaller, all-digital, self-calibrating, PC controlled

Facilities
- Smaller, open architecture, fiber/Cat 5 cabled

Financial staying power
- Investing in new sales/cash flow development
- Partnering with competitors, suppliers, clients
- "Right sizing" *all* the assets regularly, in balance

Developing "Business Plan A"

Immediately adopt the operating philosophy that

Success is learning to deal with Plan B

The Plan A document identifies all the assets needed to tap the first new revenue stream. All the assets may already exist. More probably, however, People and Capital Equipment assets will require some upgrading. Only minor facilities modifications may be required to make room for some new equipment. Financial staying power can come from creative financing or sharing sales promotion costs with new partners.

Plan A should not cover a period longer than six months of thereabouts. In television production and broadcasting, in multimedia production and distribution, and in the segments of the telecommunications and computer industries serving these business operations activities, an obviously justifiable time span will be:

From today through the next NAB.

Assets Acquisition

People: Technology Know-how Needs

Firing/forcibly retiring old loyal employees and hiring computer whiz kids to acquire new technology expertise is stupid. Even yesterday's graduates put on the payroll today have obsolete knowledge in another six months. Furthermore, this crash policy of sudden people asset downsizing followed by upsizing with whiz kids has well-reported after effects in lowered morale, lower production, and inevitable further downsizings.

From years of close association, managers know the current technology know-how assets of their employees. They know who is already acquiring technology know-how capabilities listed above. They know which employees are at the bottom ranking in educatability, willingness to be motivated and adaptability to change. Even those people, however, should be given the opportunity to join the future-proofing team before they are summarily fired.

"Continuing education" must become a line item in each department's budget under Personnel Costs. A "degree" in a person's bio indicates just what it means: "A step or stage in a process, course of action, scale or classificatory order.) (The Living Webster)

Continuing Education does not imply extended absences to "go to school." All levels of academic institutions from high school to graduate schools offer continuing education courses for both skills upgrading and attainment of next "degrees." Many professional societies offer training and skills accreditation programs. Manufacturers anxious to sell the products of their newest technologies offer know-how upgrading in cassettes and publications, "Help" services on public computer networks, one day and evening local open workshops and on-site seminars, and extended schoolroom courses.

Motivated employees will invest their own time and money to acquire new creative and technical skills, with or without employer reimbursement. Needed skills may also be acquired by construction of innovative, precisely focused alliances, as described in the next section.

Equipment, Facilities and Capital

Acquisition of these assets must be considered in parallel with the assessment of people skills needs described above. If the needed technology know-how can not be put "on staff" immediately, it must be added to the equipment/ facilities/ capital needs assessment and search.

Once, equipment needed was equipment bought, frequently paid for in total when delivered. Today, equipment is leased, rented and bartered for finite periods. A cash outlay is nevertheless usually required.

In the 1990s, ***Partnering*** with competitors, suppliers or clients to create new markets and new revenue has in the become an effective and cost-attractive means for equipment, facilities and financial staying power.

These are not legally negotiated mergers of assets. Alternatively, they are finite length "alliances" or "consortiums," committing parts of each Partner's output product and marketing assets to a new market development effort which benefits all of them. These agreements are backed by people, facilities and financial resources.

As the trade press delights in reporting, the bigger the companies entering into the partnerships, the more likely and more quickly they seem destined to disintegrate -- spectacularly! There are purportedly different eternal reasons for each of these failure. However, the common cause may well be the aggrandizing ambitions of the seemingly cooperative, affable, mutually flattering deal makers!

Boutique-ing Several years ago the author advanced the idea that "Boutique-ing" was the most profitable and perhaps the only course toward long-term survival for 1990s "full service" production and postproduction houses.[5]

The logic of this conviction becomes more convincing with each passing year.

Does this imply downsizing by firing bunches of employees in P&L centers that are losers or marginal net cash generators, and mothballing all their suites till "things get better"?

Absolutely not! Mothballing an already obsolescent asset makes no sense. Instead, talk to your compatriots and erstwhile competitors around town. Persevering discussions will find ways in which relocation of people and their capital equipment asset tools will benefit everybody.

Include all your local right of way owners in these discussions. Additional perseverance will uncover allies ready to invest in the needed dark fiber circuits needed to tie all the boutiques into a network which operates at any source-selected bit rate from 1.5 Mbps to 1.5 Gbps, and analog too! Remember while negotiating that the fibers don't necessarily have to be dark. ATM switches allowing access to SONET circuits at "reasonable" rates are equally acceptable.

Playing the OmniMedia CSC Game (Corporate Survival Checkers)

The vast majority of organizations ready to start creating a future-proofing will be faced with the same old management dictums at the first meeting: "We absolutely cannot consider solving our problems by moving! We don't have any money to spend on buying new equipment, hiring more people, and kicking off flashy new marketing programs."

"We should be talking about laying off people. We have to get healthy at the bottom line before we do anything else."

If that is management's absolute and unyielding response to the idea of future-proofing, it's time to update the old resume!

But suppose management says, "Let's put some good ideas on the table." Then it's time to begin playing the "CSC Game" -- Corporate survival Checkers (Fig. 4).

***CSC* (Corporate Survival Checkers) *Game* ©**

Vendor ____________ Product ____________________ Played by ____________ Date ____________

<table>
<tr><td>New product
(Next generation of either Current product or Modified product)</td><td colspan="2">4 Debut date- ___/___</td><td>5 Debut date- ___/___</td></tr>
<tr><td>Modified product or New application for Current product</td><td>2c Debut date- ___/___</td><td>2d Debut date- ___/___</td><td>3 Debut date- ___/___</td></tr>
<tr><td>Current product</td><td>1 Analysis date- ___/___</td><td>2a Debut date ___/___</td><td>2b Debut date- ___/___</td></tr>
<tr><td>Engineering axis ↑</td><td colspan="2">Current market</td><td>New Market(s)</td></tr>
<tr><td>Marketing axis →</td><td>Current customers</td><td>New customers</td><td>New customers</td></tr>
</table>

How to play the game

1 Make up separate sets of game boards for each product and the competitors threatening its survival Writing reference-numbered "bullets" to point to detailed commentaries on five numbered support documents,
2 Plot your current strategic plan for upgrading product and developing new sales opportunities
3 Plot your competitors' anticipated product/market development moves to improve their market positions
4 Compare the game boards -- When, where and why does your plan lose out to the competition?
5 Plot a modified game plan for your product which makes your company a winner

Plotting rules

1 List each current product's features, capabilities, applications and competitive advantages
2 Describe and schedule one move at a time to occupy a "2" square -- Sub "a" is the fastest and least costly
3 Plan a move to Square 3 only if it's low risk and potentially high profit
4 Plot your Square 4 arrival before the competition -- If you don't obsolete your own product, they will!
5 Don't move to Square 5 without a *full* "Resources Survival Kit" (people, cash, technology, marketing savvy)

Fig. 4. Corporate Survival Checkers (CSC) Game

From all the potential near-term output products, and all the potential new customers in current and new markets, the task is to find *the* one combination that has the highest probability of rapidly generating new revenue streams followed quickly by operations in the black.

There are four optional "checkerboard moves" shown in Fig. 4, moving outward from "Square 1" (lower left box). A separate game must be played for "current product."

A move to Square 2a and then to 2b is the fastest and most economical to implement. It requires no new equipment or people retraining, just innovative sales promotion.

A move to Square 2c is more expensive and time consuming. It probably requires acquiring equipment and re-training people. A diagonal move to Square 2d cost money for both new product development and marketing.

Observing the old New England farmer's reply to a question on driving directions, "Yew cain't git theyuh frum heah!", Square's 3, 4 and 5 are impossible jumps from Square 1. In fact Square 5 will never be reachable via any combination of moves through Squares 2 and 3. By the time it's supposed to be in sight, Moore's Law's operation will have replaced it with new and different opportunities.

Playing the CSC Game is a process of struggling to stay profitable while moving through the "2" Squares to Square 3 or 4 in one game, and then playing new Games next year.

Playing the CSC Game will also immediately establish the need for new engineering thinking. It is easy to define equipment needs for upgrading the existing plant to produce *technically* acceptable new output products. But they won't sell if they're not priced right! And few organizations can justify a move to a new plant to produce at lower costs.

DIGITAL PLANT DESIGN: ACQUIRING ADAPTABLE ASSETS TO EXPLOIT FLEETING SALES OPPORTUNITIES

Facilities Upgrading Rules

It is mandatory to make the first facilities upgrade a step along an individual and custom-designed Future-Proofing road. To accomplish that challenging task, every organization must write a mission statement which will guide its continuing Plan B issuances.

Not to survey the long-term landscape before starting on the Future-Proofing journey is like reaching into your desk drawer for one paper clip, only to discover that some joker has strung them all together. The only way to obtain one paper clip, or to re-direct the effort to design a Future-Proof facility is to drop the string, and start the planning process all over again. In a fast-moving competitive marketplace, that step may well lead down the road to nowhere.

Consider the following caveats in your planning effort::

(1) Anticipate the eventual demise of uncompressed single-channel analog NTSC/PAL mastering, distribution and/or broadcasting;

(2) Prepare for both 4:3 and 16:9 compressed digital components production and postproduction;

(3) Prepare for both 4:3 and 16:9 analog, multiple channel, backward compatible NTSC/PAL broadcasting;

(4) Prepare for common image HDTV digital components production and postproduction;

(5) Prepare for mastering, distribution and/or broadcasting of the above programming at various MPEG-2 compression ratios;

(6) Prepare for producing and mastering "intellectual property" in myriad "Interactive Multimedia" formats.

Obviously, preparing for all those output products at once *would* require moving to a new facility. Since that's not economically prudent, the first (Plan A) upgrade must focus on one or two of the options. Succeeding Plan Bs will later be written to improve Plan A profitability and/or to pursue new market opportunities.

Equipment Upgrade Decisions

Choosing Technology or Standards

When you hear the phrases "state of the *art,*" or *"proprietary* design" applied to any hardware, software or service you encounter at a trade show, you're generally accurate in interpreting the statement as, "It hasn't been invented yet." Watch out! Caveat emptor! If, however, you are also given firm price and delivery dates, you know by the operation of Moore's Law that whatever it is will be nearing design obsolescence by the time it's delivered. Your next step -- look for the "road sign" which is assurance that its acquisition is a Future-Proofing move. That is a guarantee of compatibility with either existing or in-process de jure or de facto standards.

When you later discover you need more "bells and whistles," the vendor will more likely be around to satisfy your needs. If you suddenly don't like your first-choice vendor, there are others you can turn to for help.

Equipment Acquisition Priorities

Adoption in your mission statement of the caveats listed at the left results in two fiats:

(1) Your television/multimedia production, postproduction and/or broadcasting plant will be all-digital when the last Plan B project ends;

(2) The digital audio/video "data" signals originating and/or flowing through your plant will have individual bit rates ranging from 64 kbps (digitized intercom voice) to 1.5 Gbps (uncompressed HDTV digital component video and eight channels of 20 Hz to 20 kHz digitized program audio).

These fiats must result in the inclusion of a "Capital equipment acquisition priority schedule" in Plan A. These categories are:

(1) Multiple small, digital, fiber and hybrid fiber/copper, field re-configurable routers;

(2) SMPTE 259M video signal converters - composite/component - analog/digital;

(3) AES/EBU audio signal converters and serial multiplexers;

(4) Digital disk storage arrays and non-linear video and audio editing workstations;

(5) Bit-rate independent master control switchers;

(6) Operator-programmable operations automation software;

(7) Motion JPEG and MPEG-2 compression systems.

Getting Started

Step 1: Routing System Master Plan All of this equipment is of course needed at once. Establishment of a time-phased upgrading plan for the existing analog copper routing and distribution system must be completed, however, before any shopping for other equipment is begun.

For obvious economic and operations reasons, base this document on continuing use of the existing Routing and Distribution Switcher. Its video cross points and coax cables will be adequate for routing up to 270 Mbps video and lower-rate multiplexed digital audio to and from many existing equipment locations. Where 16:9 digital video component (360 to 1,500 Mbps) runs requiring more than about 100 meters of cable are required, fiber transmission links, small fiber or hybrid fiber/copper switchers and/or fiber patch panels must be added.

Switchers and patch panels can be located at the Router location or in the video component suite, depending on expansion needs defined in future Plan Bs. Two-fiber links from Router coax outputs to individual equipment may be the first fiber upgrade step. As equipment is added, 4 by 4 fiber in/coax out routers can be installed at the equipment locations. Digital audio signals can be time-multiplexed and transported on the freed coax circuits.

Serial digital fiber interface standards for both SMPTE 259M and serial HDTV (1.3 - 1.5 Gbps) signals, now in final stages of drafting in SMPTE Technology Committees, are scheduled for 1995 publication. The routing system master planner is therefore assured that a commitment to use fiber in system upgrading will be a step along the Future-Proofing road.

Another SMPTE Working Group is moving toward publishing a standard for a hybrid fiber/copper cable in 1996. Camera manufacturers and users are working in concert to ensure that the first production runs of all-digital 16:9/4:3 HDTV cameras will interface standard hybrid camera cables available at the same time from cable and connector vendors.

Step 2: Acquiring everything else Acquisition of equipment in the other six categories will be on a timetable in which the need for equipment to produce new output products is balanced against the bank account.

Vendors of all the categories now stand ready to work with users, and to cooperate with each other and hybrid routing system vendors, to satisfy individual upgrading needs on user-established timetables and budgets.

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THE ALL-DIGITAL PRODUCTION CENTRE

Ken Brindley
Quantel, Ltd.
Newbury, Berkshire, England

Abstract

All-digital production centres have already been built around tape-based storage but now, with the advent of affordable large scale disk stores, future centres will be disk-based. For successful performance the configuration of the system is critical. More than that, the design of the edit suites and the performance of the central store/server, as well as their integration, are all vital. This involves designs that take full advantage of the flexibility disks can offer rather than attempting to reproduce existing tape performance.

Introduction

For some 20 years digital television equipment has been increasing in both scope and power. At first the products never showed their digital signals to the outside world as they floated in an analogue sea. Now not only is virtually all new equipment digital but the connections between them are digital too. The sea has become digital.

All-digital production centres comprising editing, graphics, inputting and playout/transmission, already exist but, up to now, have been broadly based on the designs of their analogue predecessors. But rather than just replacing analogue machinery the digital era has also brought a host of new facilities and approaches to meet the challenges of today's television industry - which any all-digital centre should incorporate.

One of the most significant and recent changes has been the combined effects of declining prices, greater storage capacities and increased speed for computer disks, heralding their wide use for digital video storage.

Already there are many areas where they show important advantages over tape, so clearly disks should play a major part in future all-digital production centres.

Aims

Technology itself cannot be the sole measure of the quality, power, or suitability of equipment for any particular application. It is essential to look beyond and consider what needs to be achieved and what gains new systems bring. In building the all-digital production centre the aims are:-

1) Improvement in signal quality with no loss through the system.

2) Improvements in distribution and availability of programme material to all users.

3) Better reliability and flexibility - especially in the playout process.

4) Integration with new technology.

This paper measures the success of four solutions for the all-digital production centre against these aims, concentrating on the editing, graphics and transmission playout areas. The first three solutions are only partially successful but logically lead to the fourth, based on Clipbox, which meets all the aims. This illustrates the technological changes needed to reap the potential benefits of a fully integrated system.

Solution 1: Tape-based Centre

All-digital centres built to date have been based on tape technology. Their configuration owes much to the analogue layouts already used for many years (figure 1).

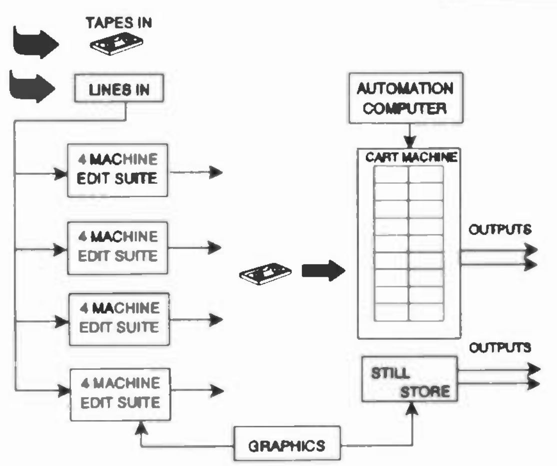

FIG.1 TAPE-BASED PRODUCTION CENTRE

Editing is based around multi-VTR suites with edit controllers, DVEs, digital switchers, character generators and graphics, the edited tape being delivered to the transmission system cart machine for playout to air. The machines are connected using the serial digital interface (SDI), feeding the digital signal over a single coax cable, and switched via serial digital routers. As this replaces the three cables needed for analogue components, plus there is the possibility for embedding the audio, cabling can be reduced.

The digital tape-based production centre can achieve the first aim of improved signal quality, especially if using component digital recorders. Being digital, connecting to other digital equipment is made straightforward, although this does not go as far as full integration. With programme material still distributed in the same way, by cassettes, and system reliability continuing to be governed by tape and complex electro-mechanical cart machines, the remaining two aims are not met.

The Rise and Rise of Disk-based Systems

Disks are now offering viable alternatives to the total reliance on tape - especially in the areas of editing and playout - but there are great differences in operation as well as in their relative costs. Finding the best way to apply the new medium is essential to bring the maximum benefits from the technology and to fulfil the aims set above.

It is since the late '80s that the supremacy of the tape-based linear edit suite has been increasingly challenged through the introduction of non-linear disk systems. As direct one-for-one replacements for digital VTRs, digital disk recorders (DDR) are used as video caches. There has also been the emergence of integrated edit suites where a single disk store is used to supply all required sources and record destinations. These suites range from those for off-line which use heavy video compression, to on-line suites using little or no compression.

The recent development of redundant disk arrays has introduced not only much longer storage but also more reliable operation - any faulty disk drive can be replaced without loss of data. With cost effective storage time running up to several hours, these have now been applied not only to editing but also to playout systems. Non-linear video access can greatly speed operation and the absence of highly complex cassette and tape handling mechanisms promise much improved reliability and reduced maintenance. Such potent benefits show a bright future for disks - and a reduced role for tape.

Future production centres will be disk-based but how should the system be configured? With the disks used today differing from tapes in that they are not removable, distribution is by copying rather than physical transfer - leading to new methods of system layout and operation. The following solutions 2-4 describe disk-based all-digital production centres mainly from the point of system configuration but also, in 3 and 4 bring the central store, or server, specification into discussion.

Solution 2: Video Server Networks - Linear

A digital production centre can be built comprising both editing/graphics and playout facilities connected via a network to a video server central store (figure 2).

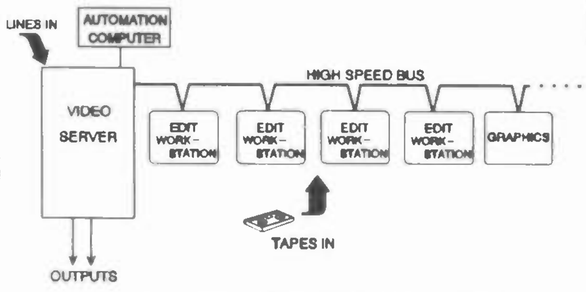

FIG.2 VIDEO SERVER NETWORK – LINEAR

The server connects its outstations via a 'linear' network which can be expanded simply by adding extra stations. In operation audio, video and stills can be input to the server for central storage and hence despatched to any graphics and editing stations as required, via the network. Work prepared in the outstations can be sent back to the server for storage or for playout.

Experience with computer systems tells us that network expansion can never be infinite - there is always a practical limit beyond which the network becomes slow or stops altogether. Although some computer users may not be too concerned at occasionally having to wait a few seconds, for broadcast this situation is usually unacceptable.

A further change from the computer world is the sheer volume of data involved with digital television pictures. Using the ITU 601 digital coding standard a single 8 bit 525 line digital television channel will produce a data stream of 168 megabits per second. Even before allowances for error checking and correction as well as other network overheads this, in computer terms, is a very high data rate demanding state-of-the-art technology in the server and for the network. In practice this is a serious bottle-neck as multiple channels are required to serve the network. One way out is to greatly reduce the data through heavy compression of the images. This compromises picture quality and effectively limits flexibility as the outstations' use becomes restricted to off-line.

The aims are only met in part. Provided there is no contention on the net the system can score by offering improvements in the distribution of programme material. The disk-based server should be reliable and offer good access for playout. However signal quality is sacrificed for compression and flexibility is limited as the edit workstations are only off-line quality.

Solution 3: Video Server Networks - Star

An alternative is to connect the server in a star configuration (figure 3).

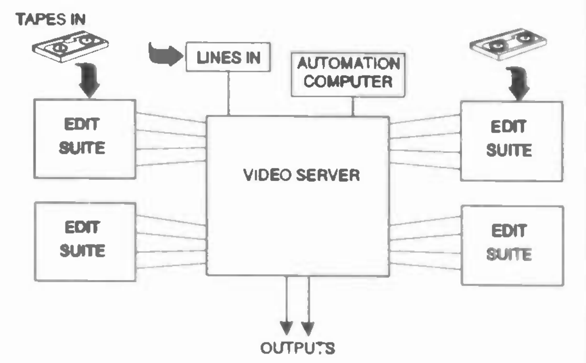

FIG.3 VIDEO SERVER NETWORK – STAR

This way each interface need only operate at video rate with any requirements for multi-channel bandwidth being kept internal to the server. The connections can use the tried and tested television industry standard SDI - capable of operating up to 270 megabits per second and over 600 ft of coax. With routing switchers readily available and much TV equipment able to accept the signal directly, this looks like a suitable solution.

Perhaps the most obvious configuration is to use each srever channel as a video/audio source and record facility. This way the server channels replace VTRs in an edit suite as well as simultaneously providing record input and playout facities. By storing all footage in the server it can be available to all users for editing, graphics and playout.This places the server at the hub of the production facility and, given sufficient performance, could succeed in achieving all four of our aims. However, assuming an average of four VTRs are used in each of four edit suites, this uses 16 server channels. Adding one each for playout and direct input, means 18 channels are needed - far beyond any server on offer today. Once again an escape route is to compress the pictures, so compromising signal quality.

Solution 4: Integrated editing and playout system

Solutions 2 and 3 point out a lack of network and server bandwidth to allow quality performance.

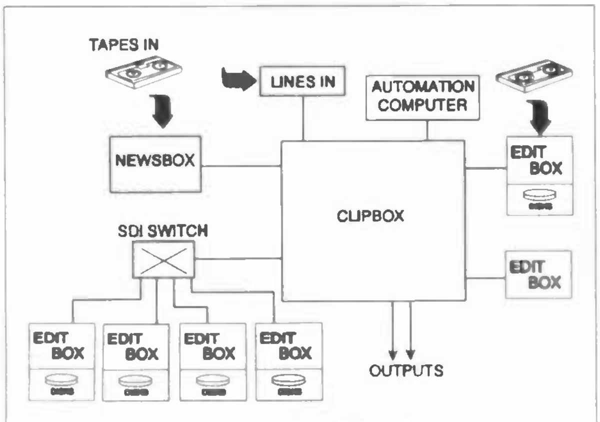

FIG.4 INTEGRATED EDIT & PLAYOUT SYSTEM

Figure 4 shows a solution which does meet the aims and depends on an equitable division of tasks and the application of established technology working closely with new developments. In solution 3, much of the channel capacity is used to provide sources in the edit suites. So far it has been assumed these are based on the traditional multi-VTR theme, with each server channel substituting for a VTR, so that footage held in the server can be edited and stored back ready for replay. With more modern methods disks can be used to much greater effect.

Success depends not only on the server and its network but also on the design of its outstations. Within the last two years integrated disk based edit suites, such as Newsbox and Edit Box, have been developed for on-line operation. These depend on real-time true random access (the ability to read any frame in any order, at or above video rate) from their stores to provide effective non-linear editing systems. Although direct comparisons are not totally valid, these can offer the facilities of suites using up to six VTRs, and because of the speed and access of the stores, the editing process involves little, if any, dubbing. In effect the editing process produces a set of replay instructions rather than a new video recording. This is of major importance as it drastically cuts the need to copy video data, saving disk space, copying time and minimising video transfers around the system.

By designing a server able to provide true random access for its channels each one can substitute for the edit suite's disk store. This is included in the specification of Clipbox. This true random access channel is far removed from the traditional 'linear' understanding of channel. When interfaced to a true random access edit system, such as an Edit Box, it can offer the equivalent of many VTR channels - or rather sources with non-linear access.

Clearly the operation of the edit suite with the Clipbox store requires a very high degree of integration to achieve the necessary video rate frame-by-frame control. The capability of the SDI, already adopted to carry the video and embedded audio, has also been extended to carry the necessary control commands as embedded signals. The whole server to outstation connection is completed with just two coax cables (input and output).

Using SDI also means that standard routing switchers can be used to re-configure the system so that edit suites could be on-line or off-line to the server. Since the suite described above would be inoperable if disconnected from the server, it has been arranged for suites complete with their own disk store also to be connected. These are autonomous units that have the flexibility to operate on their own or with the server. This has several advantages - providing a degree of security by removing the absolute dependency on the continuous operation of the central store and, given that not all suites need to operate with the server all the time, allowing more suites to be connected by the simple addition of a SDI switch.

System management

The task of designing a whole production centre has to include system management. The required facilities and footage must be available at the right place at the right time - a task traditionally assigned to scheduling. The internal administration of the true random access video store is highly complex - not least because the pictures of any clip may be scattered about the store. One task of the store's internal management system is to give direct access to all clips without needing any knowledge of where the frames are held. Another is to eliminate contention so that any channel is free to access any frame at any time. It is possible for all channels to simultaneously play the same footage. Although this may not always be an operational requirement, such flexibility greatly simplifies the task of external control, such as the automation computer. Regardless of any other activity, all footage is always available for play on a next frame basis.

In the case of Edit Box and Newsbox operating with Clipbox, control of the Clipbox store is integrated into the suites' menus. This way the task of using the Clipbox store becomes a simple extension of their normal operation. As with any good management system, the power or complexity of the operations is hidden from the operator.

Conclusions

Several designs for an all-digital production centre have been described but all except the last fail to meet the original aims. The tape based solution can give good quality but lacks the speed and flexibility of today's disk based operation. The open ring style of connection based on computer networking has limited appeal as it has to operate with compressed video. Operating a server in a star configuration network eases the networking bandwidth requirements but quickly runs short of channels for quality work. Only the integrated editing and playout approach can extend to embrace the whole production centre while meeting the aims of quality, programme availability, flexibility and operation with the new disk technology.

With the future of editing and playout systems becoming disk-based it is important to realise the full advantages that working with the new medium can offer. Blindly following networking ideas originally developed in the computer industry and edit suite designs from the tape era of the TV industry, do not give the best results. The aims can be met by using new ideas developed for the disk-based age - both for the server store and edit suites - and building them into an integrated system. While this may seem a big step from current practices it gives the clearest vision of the future of all-digital production centre.

THE TELEVISION LAN

Ken Jones
TV3 Broadcasting Group Limited
London, England

Abstract

Digital television allows broadcasters to treat programmes as computer files. Files can be accessed via a Local Area Network by different users who previously needed physical videocassettes. Computer storage is cheaper and more robust than television-specific storage media. Time-accuracy is required only at the point of transmission. The TV-LAN replaces the central routing matrix with a more flexible tool. Transforming today's linear station to tomorrow's TV-LAN station can be achieved in a series of cost-effective steps without committing broadcasters to a specific digital standard.

1. Introduction

Television engineering and operations are complex and expensive; they are major cost-centres. Every dollar saved in the technical department translates directly on to a broadcasting company's bottom line.

In an increasingly competitive world it will be the companies that successfully embrace the new ideas that prosper, while those that don't go to the wall.

The TV-LAN is both a quantum leap and a plateau; once it is established there'll be no more fundamental changes for a generation.

2. Development of Digital Television

2.1 Origins

Analogue television grew directly from established cinema techniques, transmitting a series of electronic still pictures in real time. All the information for each picture was transmitted afresh, resulting in very high levels of information redundancy.

Digitising an analogue signal involves sampling the signal at specific points to obtain a numeric value for each point. If the sampling is frequent enough, reproducing the sample values in sequence results in a picture indistinguishable from the analogue original.

Transmitting a rapid series of numbers instead of a varying signal occupies more bandwidth, but numbers are easier to manipulate and don't degrade on copying.

Early digital television mimicked analogue; all the information for each picture was distributed, and the digital domain was exploited for complex picture manipulation and degradation-free copying. For more than a decade digital television was marooned on a string of digital islands in an otherwise-analogue sea.

2.2 Storage

Storage of early digital television pictures was not practical with computer systems then available because of the read/write speeds required and the volume of date involved. Uncompressed video requires a data rate of over 200 Mb/s, roughly equivalent to 100 GBytes of storage per hour.

Instead, television-specific "black boxes" were developed for both on-line and tape storage. The tape machines were designed to be as functionally-similar to their analogue predecessors as possible, recording discrete frames on individual head passes. While this approach was essential for compatibility with analogue equipment in hybrid television installations, it greatly increased the cost of the machines.

Two developments have transformed the position; data compression has reduced the bit rate to around 24Mb/s without apparent artefacts, and the cost of data storage on computer industry standard hardware has fallen dramatically. The industry's rule of thumb is that data storage costs are currently halving every eighteen months.

Together these two advances move television away from bespoke solutions with sales in the hundreds, and into the mainstream computer environment, with sales in hundreds of thousands and unit prices correspondingly lower.

2.3 Compression

Frame compression analyses an individual picture and identifies areas carrying the same information; it transmits the single value and the block identifier rather than sending each bit of data. The data rate and hence the bandwidth come tumbling down.

More advanced systems look at changes between neighbouring pictures, and reduce the data rate further by only sending change information.

The result is a dramatic reduction in transmitted data and hence the storage needed to hold a given sequence of images.

2.4 Compression Artefacts

Eliminating redundant data for transmission and regenerating it on reception is not a `no-loss' process. The skill of the mathematicians writing the algorithms lies in making the best compromise between preserving the perceived original scene detail and reducing the data actually transmitted. At the limits of their skills, artefacts (elements not in the original scene) begin to appear.

Three common artefacts identified so far are block-edging, contour-ringing and marbling.

The effect of degradation produced at the margins is very subjective; unlike analogue degradation which tends to be constant, digital degradation is transient.

As yet there is no method of objectively measuring compression artefacts, although work is in progress.

2.5 Timing

Analogue television operates in real time; there is a fixed time relationship between the scanning mechanism in the camera and the scanning mechanism in customers' tv sets.
In particular, signals arriving at switches have to be in the same time plane. Conventionally, this is achieved by delaying all signals to match the latest, and the earliest applications of digital techniques to television involved compensating for variable mechanical delays in tape transports by the use of digital buffers.

The buffer, or temporary store, is endemic to all digital systems; data is stored on receipt, processed and then stored pending disposal. Transfer to other systems occurs when it's convenient for the two systems to communicate.

In a fully-digital world this process will be end-to-end, from the camera to the customer's tv set. In practise, television station's will retain output switchers requiring timed inputs for many years to come. However data transfer up to this point will not be time-critical. This has profound implications for the cost and complexity of the digital station of the future.

2.6 TV Files

Today, most digital television programmes are regarded as timed streams of data, with buffering used to compensate for processing delays. In future, programmes will be treated as files, with their transfer time totally independent of their real time playback rates. When considering the Television LAN, it is important to remember that the data involved is not being handled in real time, except perhaps at the station's output.

3. Local Area Networks

3.1 Basic Principles

A LAN consists of a series of individual computers connected together via a transmission medium. The computers on the LAN perform different functions; some act as input devices, some as storage devices, some as processing devices and some as output devices. While the total amount of data in the system may be vast - almost limitless - the data being handled by individual computers is limited and hence small, cheap computers can be used for each application.

3.2 Data Tranfer

The LAN transfers data between the different computers, but does so according to network rules, not rules dictated by the data.

4. A Practical Television LAN

4.1 Data Rate

Existing computer networks operate at speeds of from 4Mb/s to 100Mb/s. Uncompressed digital video data requires a network running in the hundreds of Mb/s if the pictures are to be reproduced in real time at the ouput point.

However an Asynchronous Transfer Mode (ATM) network running at 155Mb/s will support compressed video at 24Mb/s and such systems are on the point of commercial launch. In the longer term networks running on fibre optic links with speeds of 600Mb/s have been canvassed by industry leaders.

Control software and switching parameters will take time to develop, especially in the absence of agreed industry standards, but given the pace of computer-industry development it is reasonable to anticipate the arrival of the practical broadcast television LAN within the next year.

Control versions of television material can be compressed to 500Kb/s, and these can be accommodated on networks available today.

4.2 Operational Requirements

The television system described here assumes that it must input material, store it for programme and control purposes, process it for presentation/promotion/transmission, and output it to air.

Note that this description does not require that transmission-ready material be delivered to the system - the material could equally be in "rushes" form needing editing and dubbing (post production).

The material should only be physically handled twice - once when it is transferred into the system and again when it is finally purged, the assumption being that videotape will remain the archive storage medium for the immediate future.

All other processing should happen electronically at workstations.

4.3 System design principles

The station's operations should centre on a broadcast LAN supported by linked ancillary networks. The backbone or core should support input devices (videotape machines, line feeds, modems, etc), storage (files servers and robotic tape streamers/CD's), processing systems (edit suites, graphics, etc) and output devices (airplay PC's or caches), all operating at the chosen broadcast data rate or faster.

Control of the core LAN resides in the output and processing machines. These devices receive instructions from the scheduling network and then command the storage devices to make the appropriate data available. Only data immediately required for output or processing is held on-line; the vast majority is held in robotic systems and ultimately on shelving.

The output devices are constantly looking ahead and ordering data to be brought on-line. They are also regularly purging the active storage of expired material.

Back-up consists of emergency material residing on the local hard discs of the output devices.

4.4 Cascaded storage

Output devices have limited storage but sophisticated control systems to ensure timing accuracy on playback.

Input to these devices is accomplished over the LAN from larger near-on-line stores. These stores are supported by robotic devices loading bulk storage media into an array of transports from storage bins, analogous to the videocart machines in use today.

Backing up the robotic server is, as always, shelf storage.

Data storage at each level of the LAN environment involves a trade-off with LAN activity.

For example, a small output store will involve heavy LAN activity as every programme element will have to be downloaded each time it is due for transmission. A larger output store will hold high-frequency material for as long as it's current, and so reduce activity on the LAN.

Analysis must be performed station by station, but some of the criteria will be:

4.4.1 OUTPUT LEVEL:
- "permanent" material like station idents;
- "semi-permanent" material like series bumpers and seasonal promotions;
- "campaign" material, commercial or promotional;
- emergency stand-by material;
- buffer for "tape-delayed" live events;
- buffer for advance downloading.

4.4.2 ON-LINE LEVEL:
- number of channels to support;
- number of post-production suites to support;
- acceptable delays in downloading to post-production suites;
- size of current commercial inventory;
- size of current promotional inventory;
- substitute programming requirements;
- buffer for saving live events;
- buffer for advance downloading.

4.4.3 ROBOTIC LEVEL:
- transport data rates;
- volume of unique material in given period;
- staffing levels for load/purge of storage bins.

4.5 Integrated software

In the same way that a modern office environment uses common platforms to support different applications, broadcasters need integrated software solutions.

The same platform has to support sales, acquisitions, commissioning, storage, scheduling, traffic, post-production, news, playback, presentation, and a host of ancillary functions like mail, word processing and accounting.

It should be at least theoretically possible to perform any of these activities on any station on the LAN, although in practise there will be limits to this flexibility.

In parallel with the development of the television LAN hard, firm and software, integration of the best applications software is urgently needed.

5. Advantages of the TV LAN

5.1 System Design

The core of an analogue station is its Central Routing Matrix, switching signals to and from all points in the system. As channels have multiplied, these devices have become bigger and bigger until their complexity and cost has dwarfed all other elements in the station's design.

Matrices are inefficient; a high proportion of crosspoints are never made, but there is no financial benefit in inhibiting them. As matrices grow bigger, controlling them becomes ever more expensive, and worst of all, expansion can only be accomplished by adding extra input or output tiers.

The LAN works on different principles; all elements of the system are connected to a common network. Data is sent from one point to another along this "common carrier".

The network "slows down" or "speeds up" according to the level of activity and its own capacity, but as data is being transferred from buffer to buffer, the actual transfer time is irrelevant, within wide margins.

Activity is restricted to required data instead of tying up say 256 crosspoints because information is required from two of them. Traffic on the LAN can be prioritised, with transmission material taking precedence. Additional stations can be added at minimal cost as long as overall network activity remains within design parameters.

5.2 Input

Material arriving at the input of an analogue system is edited at this stage to meet station-specific standards.

Most stations will insist their own clocks appear at the head of the material, and that programme start-of-message occurs at a conventional point, say 10:00:00:00. There are other requirements like audio conventions, the use of user bits, etc.

The practical result is that resources are devoted to copying the whole programme in order to effect a few relatively minor changes to control parameters.

This is an expensive process, requiring continuous human monitoring and taking at least one and a half times the material running time to complete.

Digital material stored on a LAN is non-linear; any element can be accessed in any order. Editing at the input stage is eliminated in a LAN environment - the material is simply copied into the store in whatever state it arrives, and the control parameters are subsequently edited in the non-linear world.

Continuous monitoring is unnecessary so a single operator can perform multiple real-time transfers to store simultaneously. The practical effect will be to reduce labour input to this process from 1.5 to around 0.5 times the material running time.

5.3 Store of Broadcast Material

In conventional systems, storage is by means of edited linear tapes. If simultaneous access to the material is required, multiple copies have to be made in real time.

Associated material - like completed subtitle files - has to be stored on separate systems because the only way of combining the material is by copying the associated material together in real time.

Further, any individual element of the material can only be accessed by spooling the tape to the appropriate point. With material of significant duration - ie over a couple of minutes - the spooling time is a major inefficiency. Staff working twelve-hour shifts in a Beta SP dubbing environment waste around ninety minutes per shift spooling tapes.

In a LAN non-linear environment the material in the on-line store can be accessed by several independent users simultaneously without copying or spooling; recognisable pictures can be displayed at any speed the operator requires.

Associated material - subtitles, format files, access parameters, etc - is combined with the original file in the computer domain, making subsequent output to transmission much more robust.

5.4 Store of Control Material

As well as storing material for eventual transmission, a television station needs the same material in sub-broadcast form for control purposes. Viewing copies, subtitle copies, logging copies etc are conventionally produced on VHS tapes.

Stations are awash with these copies; although individually cheap to make and store, they add up to a significant overhead.

The material can be made available on any work station and upstream staff can call up any part of the station's inventory on their desktop computers.

Similarly control material can be distributed to suppliers such as salesman and subtitlers in data form. Viewing rooms and off-line suites are eliminated along with a whole tier of material handling, with significant operational savings.

5.5 Processing

Conventional edit suites use either analogue or digital videotapes; these tapes offer restricted access to the material, and editing can only take place in real time by copying material from one tape to another. Complex manipulation requires either expensive machinery or time-consuming multiple copying.

A LAN-based system solves the access problem. Non-linear edit suites contain local storage. A "rushes" list of material required for editing is prepared by production staff using desktop access to the control material in the store.

This list commands the broadcast network to download the broadcast version of the material to the edit store.

Once editing is complete, the finished product is loaded back to the store, ready for playback under schedule control.

5.6 Output

All modern transmission systems are governed by a computer-generated schedule.

When preparing the final version of the transmission schedule, staff frequently need to check fine detail - credit durations, audio outs, etc - and this is another operational overhead on an analogue station. Either every conceivable detail is logged and stored for reference, or the physical tape material has to be re-examined. Both procedures are time-consuming and therefore expensive.

In engineering terms the major expense and frailty of current output systems is translating the computer schedule into control of the mechanical systems needed to play the tapes and operate the discreet switching devices.

With LAN-based playout, the schedule lists the files to be played, together with ancillary transitional functions. Fine detail is checked by the scheduling staff on their own work stations, and a large area of interfacing is eliminated, saving both capital expenditure and operational costs.

6. Operational overview

6.1 Input

Input processing is reduced to downloading data and ensuring it is correctly named. A single operator can run several downloading systems simultaneously because once line-up is complete, no further processing at the input stage is necessary.

Checking and preparation for output together with promotion planning are performed on the compressed control versions of the material. Because edited files are stored back to the core, scheduling and output have the amended data immediately available.

External processing, particularly subtitling, can occur via modem.

6.2 Elimination of Stages

It will be seen that several stages of current material handling have been eliminated.

Because all events take place on the core, or in emergency from the linked local discs, record keeping is greatly simplified. The scheduling and ratings systems can receive near real time reports of activities, if required.

In physical terms, transmission suites no longer need arrays of monitors and desks full of processors and switchers. The output units work in a windows-type environment and need only a keyboard, mouse, high resolution screen and check monitors. Significant savings can be made on space, power, environment and of course capital cost.

7. Operational Cost Implications

In the recent past, transmission was performed by a team of people who worked together intensively for a few minutes every hour. The rest of the time they were watching and waiting.

Cart machines and automation systems had the effect of time-shifting many of these team functions, so that one or two staff, working continuously, performed the work of the team.

The television LAN takes this process back up the supply chain; once raw material has entered the store, subsequent processing is non-linear. Staff do not have to wait for real-time copying to be completed before moving on to the next task.

8. Implementation of the Television LAN

8.1 Incremental Steps

Even if the television LAN were available as a complete package today, introducing it overnight to an existing station would pose spectacular problems. However the means are readily to hand to switch over to LAN-based broadcasting in incremental stages.

8.2 Output

Digital cache technology is already in operational use at the output stage - the first operational station to use the technology was in fact TV3 with its new subscription service TV1000 Cinema. Interstitial material is manually fed into the cache, edited digitally and played to air on a manual cue. The next step is to feed the cache from a cart machine under schedule control.

8.3 Post-Production Network

Once all a station's outputs are cache driven, the next stage is to use cache outputs to feed edit lists to on-line suites. Multi-channel stations will possess several caches and will need to feed several post-production areas. This is the point at which the network can be introduced. The network software will identify which cache holds the required material, and then copy it to the suite's local store. Similarly completed post-production items will be routed to the appropriate cache for playback.

8.4 Control Copies

The next development stage will be to give the station's office network access to heavily compressed versions of the programme files. Cache technology allows specification of different compression rates for different outputs, and the control system, analagous to the edit list, will direct these files across a bridge to the office network.

8.5 File Servers

Once the LAN is running reliably in a non-critical environment, transmission cart machines can be replaced with central file servers, and the cart machines re-employed as servers for the on-line stores. Input sources will be fed directly into the servers, and operational decisions will determine if the material is archived to tape.

8.6 Completion of the LAN

The remaining matrix-routed sources, probably live feeds, can then be transferred to the LAN and the system is complete.

9. Conclusion

Most television stations are still equipped with obselescent analogue equipment which is nearing the end of its useful life. It will have to be replaced in the near future, and specialist television manufacturers are engaged in cut-throat competition to establish bespoke products as the new industry standards.

There is an alternative. Computer industry hardware is far cheaper than broadcast television equipment for similar functionality.

PC networking in the office environment revolutionised administration throughout the world. Information is disseminated faster, more accurately and in far larger quantities than in the paper environment of only a few years ago.

Crucially, this revolution has been accomplished with a fraction of the staff previously needed. Literally tens of thousands of clerks and middle managers have been displaced as whole tiers of administration have been eliminated. The cost savings have been enormous.

The television LAN offers the prospect of similar productivity gains in broadcasting.

K.E.L. Jones
Langston Associates
January 1995

THE IMPLEMENTATION OF A FULL-DIGITAL TRANSMISSION SYSTEM IN THE TBS BROADCAST CENTER

Shigetoshi Kobayashi
Tokyo Broadcasting System, Inc.
Tokyo, Japan

ABSTRACT

The TBS Broadcast Center went into full operation on October 3, 1994, in which total digitalization was achieved in regard to both radio and television divisions. In Japan, we are the first broadcaster who has experienced such a large digitalization in a "key-station" scale. We employed the SMPTE 259M composite digital serial format for video signal transmission and adopted the AES 3-1992 format for audio signal transmission. This presentation provides a brief description of our transmission system, with the primary emphasis being on video signals.

INTRODUCTION

Construction of TBS's (Tokyo Broadcasting System) new building, The TBS Broadcast Center, was begun in May 1991 and completed at the end of April 1994, with the approximately five months following devoted to installation and adjustment of equipment. On October 3, the Center went into full operation as a central broadcasting facility.

The Center occupies a land area of about 5 acres and provides a floor space of some 28 acres. The building has a height of roughly 312 ft. and contains 20 stories aboveground and two basement levels. Six studios are available for live TV broadcasting and eight for radio broadcasting.

EXTENT OF DIGITALIZATION

A block diagram of the main video lines for the entire station is given in Fig.1. Inter-room (between blocks surrounded by two dotted lines in the figure) signal transmission is thoroughly serial digital. On the other hand, intra-room facilities were also digitalized as much as possible. As a matter of course, after analog signal undergoes digital conversion once, the signal is processed and transmitted to the master output solely in digital form, as long as no analog processing is done within a block.

Figure 1 has been simplified, with the sections directly connected to on-air left out. Accordingly, closed work sites such as the CM bank and editing rooms do not appear in the figure, although these also have been digitalized as much as possible. Component digitalization has also been employed in some areas, such as rooms named "Atelier," "Design Room" and "CG Room" those are concerning computer graphics.

After all, the following areas remain analog:

(1)Reference signals distributed inside the whole station
(2)Signals for simple monitoring
(3)Emergency transmission system
(alternate system for major disasters)
(4)Interface sections with analog equipments recovered and installed from the old building

SIGNAL FORMAT

A) ADOPTION OF SMPTE 259M

The SMPTE 259M standard was adopted for the serial video signal format instead of the 10B1C standard for the following reasons.

1) Signal Input/Output Compatibility with Broadcast Equipment

Most production equipments with serial I/O such as VTRs and production switchers follow the 259M format. Simplifying signal connections is extremely important considering the large quantity of such equipment.

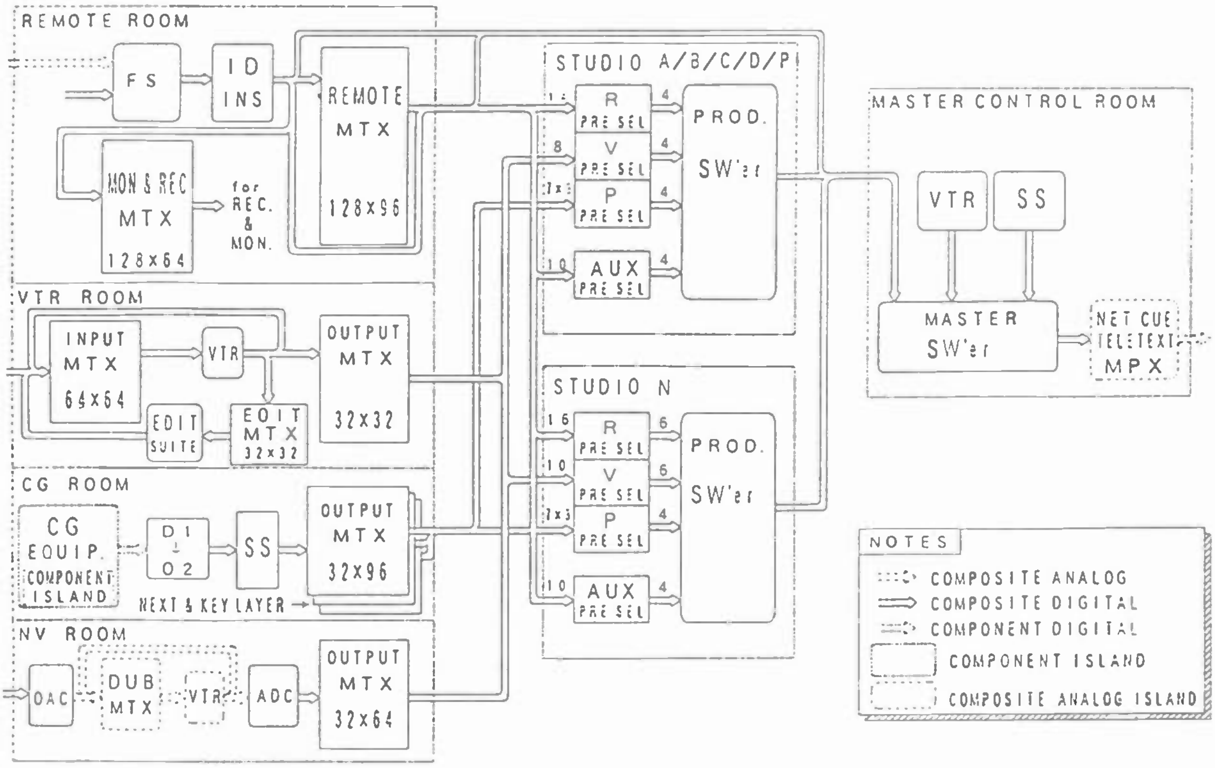

Fig. 1 TBS Broadcast Centre Video Block Diagram

2) Likelihood of Transmission Monitoring Other Than by C-bit Inversion

Assuming long-distance transmissions such as handled by common carriers, monitoring of transmissions by complementary bit (C-bit) inversion is probably effective. However, for transmission of three to four hundred meters at maximum via coaxial cable, as in this case, C-bit monitoring has little effect. In addition, C-bit monitoring alone is not sufficient for truly grasping the transmission situation. Methods such as EDH monitoring[1] and SDI stress tests[2] should therefore be adopted.

3) Importance of Video Synchronization

Concerning signal synchronization, the only benefit brought by C-bit is rapidity of word synchronization. For synchronization as video signals both methods mentioned above require waiting for Time Reference Signal (TRS). In addition, for the usage as a pre-select switcher, there are no problems upon practical use, even if ,in the worst case, the whole succeeding line would be sacrificed because of the time relation between the switching point and TRS.

4) Longer Transmission Distance

Because the transmission bit rate is low without the C-bit, the transmission distance of the 259M format can be extended 10% compared with the 10B1C format.

B) TEMPORARY ADOPTION OF COMPOSITE DIGITAL

For the reasons stated above, the decision to use the SMPTE 259M format was made early on. However, the decision whether to go with composite or component signals was put off until the spring of 1993. Composite signals are clearly a Y/C multiplex technique from analog era, and today, when another multiplex technique has been achieved in the digital domain, the concept of composite digital contains an intrinsic contradiction.

Component signals have the following benefits, as opposed to composite signals:

(1)High picture quality with no interference like cross color.

(2)Particularly advantageous for iteration of processing such as resizing, chroma-keying, and so on.

(3)Without a subcarrier peak, thus the spectral distribution is concentrated on direct current, making it also suitable for bit compression.

(4)Good compatibility with next-generation TV standard like HDTV.

Despite these advantages, the outcome was that composite serial was put into use from the outset for inter-room transmission, as can be seen from Fig.1. The reasons for this are as follows.

1) Interface with Analog Composite Equipment Recovered

A great deal of analog composite equipments were brought over from the old building and recovered. Connecting these to a digital component system would require signal conversion. Taking into account the need to accommodate live broadcasts and the huge number of their installations, the converter requires adequate performance in terms of picture quality, reliability, size and cost. At the time of our decision, there began to appear several new types of signal converter which could directly intermediate between digital component and analog composite. However, serious doubts remained regarding the question of whether "a satisfying product could be supplied by the required time at a reasonable cost," particularly from the viewpoints of picture quality and reliability.

2) Interface with Digital Composite Equipment

At the time, the number of D2-VTRs being used at TBS and associated companies was already close to 100. Not to mention the cost of component/composite format conversion in the digital domain, there are a lot of problems from the aspect of signal delay for real-time use, especially live broadcasts. Moreover, the merit of total digitalization is lessened and the same problem described in the preceding item appears if signals are combined via analog composite to avoid signal delay.

3) Differences in Jitter Countermeasures Among System-Integrators

Most serial digital equipment that does not perform parallel processing internally, such as routing switchers (RS) and distribution amplifiers (DA), handle at least NTSC composite (143Mbps), PAL composite (177Mbps) and 422 component (270Mbps). Among them there are also those that, according to their specifications, can handle 360Mbps, the serial rate of EDTV signal sampled at 18MHz, and higher bit rates. On the other hand, reclocking ability degradation is seen in much of the equipment that handles multi-rates within a fixed cost. This trade-off between multi-rate accommodation and reclocking ability is a serious problem when building a large-scale serial transmission system.

There is a distinct trend to excessively adopt countermeasures just to be safe, particularly with regard to jitter, because much remains quantitatively unknown about its real influence. In this case as well, a system-integration company requested to adopt a particular type of DA with extreme jitter-suppressing function at each receiving point of inter-room transmission. The DA was able to handle only single rate of 143Mbps. It seemed to be impossible to improve them for 270Mbps by the required time. The requirement was accepted to go with the safety measure.

4) Problem with Transmission Distance

The maximum length of the cable in the new broadcasting center is 350m. It was concluded from a variety of transmission tests that by using 5C-FB cable, no-repeater transmission of a 143Mbps signal was possible up to 350m, even taking into account the difference of input return-loss and cable compensation ability of receiving equipment. However, we could not say the same for cases when the transmission bit rate was 270Mbps. (There was several equipments indeed, that could not accept 270Mbps signal fed via 5C-FB cable more than 300m long.)

5) Problem with Dynamic Range

It is generally known that in ITU-R Recommendation 601, only around 7～8 IRE is acceptable as headroom and footroom when quantizing the luminance signal. On the other hand, SMPTE 244M has a dynamic range of -42.1 to +138.6 IRE, targeting composite signals. Of course, considering VHF/UHF transmitters and analog transmission systems of common carriers, it is indispensable to avoid extremely excessive amplitude. However, because the white clip level of cameras operated in our studios is adjusted to 105 IRE, white characters superimposed on a bright base picture requires considerable level. There seemed to remain enough time for us to shift the operating amplitude of the whole system by the required day.

6) Problem with Equipment Development Schedule

Setting aside the judgment of advantages or disadvantages from the viewpoint of operator management, our workplace somehow places importance on "an environment in which many people can operate with as little training as possible." Particularly in live broadcasting facilities, there are few cases where ready-made equipment has begun to be operated without any modification of its man-machine interface. For the new broadcast center, a variety of equipments were therefore developed, including a production switchers for studio use, but some of these would not have met the development deadline if component signals were used.

7) Problem with Operation Education

For those of us accustomed to an analog composite environment for many years, just beginning to deal with digital composite signal requires a lot of effort. Moreover, there would not have been time to hold thorough training activities with regards to the handling of component signals.

The center went into operation with composite format for the above reasons; however, most of RS and fairly amount of DA can support bit rates up to 270Mbps as our infrastructure for broadcasting. This is to ensure flexibility to allow multi-rate, multi-format operation in the future.

C) CONCERNING ANCILLARY DATA

Serial digital signals allow for the multiplexing of ancillary data with the video signal, such as 4 channels of digital audio or the transmission of ID signals, etc. with video signals. However, any ancillary data for substantial purpose are not transmitted between rooms in the center at present, for the following reasons:

(1)In order to use ancillary data, the audio data must usually be multiplexed onto the video signal prior to transmission and separated again after transmission to allow processing of audio signal received--thereby an enormous number of multiplexer and de-multiplexer will be needed;

(2)ID signals can also be multiplexed into a single line of the video-vertical-interval, and these ID information data are desired to be recorded by VTRs and fed even by analog equipment with active picture.

Consequently, for inter-room audio transmission, independent coaxial cables are laid apart from those for video transmission.

Regarding intra-room transmission, however, there exists a certain room where a main operation is simple dubbing of programs between VTRs with no signal processing, therefore embedded audio technique was adopted.

For both intra-room and inter-room, and both TV and Radio division, The AES 3-1992 format (sometimes called the AES/EBU format) was employed as a logical data format of digital audio.

CABLES

The cables, which are laid out in a star configuration, do not connect blocks directly, but always go through a connection room. Even so, the maximum length a cable was projected to be roughly 350m. From the perspective of cost, it was more desirable to use coaxial cable for distances of this order, than to use optical fiber which would require large numbers of O/E and E/O converters, thereby increasing costs considerably.

However, according to digital equipment manufacturers, the guaranteed transmission range of the coaxial cables (the 5C-2V (similar to the Belden 8281 in the U.S.) or the 5C-2W) currently under use was only 200m to 250m, and the projected distance of 350m was thus outside of the guaranteed range. In fact, through performance tests on the 5C-2V-type coaxial cable, it was found that it would be dangerous to transmit over distances exceeding 300m because the cable-compensation ability and return-loss varied depending on the equipment being used, and because of other factors such as the number of BNC connection points or the jack boards inserted in the transmission path.

Based on these considerations, low-cost 5C-FB cables with low-attenuation (approximately 70% compared to the conventional 5C-2V type) at high frequencies was employed for inter-room transmission. As a result of their transmission trial, it was concluded that the 5C-FB cables seemed to provide stable and efficient conductibility for composite serial digital signals over transmission distances exceeding 350m.

An experiment was also made, that 110:75-ohm impedance conversion and balanced-to-unbalanced conversion transformer was applied to 110-ohm I/O impedance equipment for audio transmission via 75-ohm coaxial cables. As a result of this trail, stable transmissions were achieved even over distances of 500m. Thus, in view of cable reusability and cost performance, it was decided that the same 5C-FB cable used for video would also be used for audio transmission within the TV division. In the radio division, however, as distances were much shorter, AES balanced cable was selected for use.

Finally, it was decided that for transmissions from adjacent buildings in distances exceeding 400m optical-fiber cable would be used to transmit the composite serial signals. Optical-fiber cables were also laid in a portion of the transmission path for HDTV signals.

CONNECTORS

A connector panel is installed at the input/output of each room, so the intra-room and inter-room domains can be separated. Because of this, there are a maximum of 14 connecting points (including the jack board) where the signal route is connected by BNC connectors. Here the characteristic impedances of all connectors are kept equal to 75 ohms.

SIGNAL TIMING

An outline of delay diagram is shown in Fig.2. The reference signal shared by all of the devices, as usual, is an analog black burst. Fluctuations in the delay in the signal output from each resource room -"Remote Room," "VTR Room," "CG Room," and "NV Room"- with respect to the reference is between -1.3 and +3 μ sec. When these arrive at a sub-room, phase correction occurs at the line synchronizer at the input to the production switcher, but the absolute delay at the correction point differs from +6 to +8 μ sec depending on the sub-room. The absolute delay at the sub-rooms varies greatly depending on whether the switcher is digital or analog. The absolute delay is corrected about +47 μ sec by the M/E amp input-stage line synchronizer at the master control room. After passing through the master M/E amp and DSK, the final absolute delay is around +70 μ sec.

ROUTING SWITCHERS

Early discussions actually focused more on whether to employ a centralized system for video distribution (all switchers located together in one place) or a de-centralized system (multi-location switchers), rather than on the question of analog or digital with regard to inter-room transmission.

Though the reduction of cost that would result from a centralized arrangement for the digital distribution switcher was attractive, in the end, the de-centralized system was selected for the freedom it provides to the various departments in which the switchers are located and the possibility for expansion it would allow as might be necessary in the future.

Consequently, seven different types of routing-switcher-systems were developed and installed. They are briefly described below:

1) Remote matrix

This is mainly concerned with distributing the various signals from within and without the station to the sub-rooms, master, and VTR rooms. It is self-controlled, based on scheduling data stored in "the traffic control system", one of the TBS core data systems.

2) Monitoring and recording matrix

This distributes the various signals from within and without the station to the recording VTR, editing VTR, and monitoring equipment installed in the news video and other rooms. As a control method, the desired source is manually selected by receiving person. Approximately 45 controlling units located in various part of the Center are connected in a multi-drop configuration by coaxial cables.

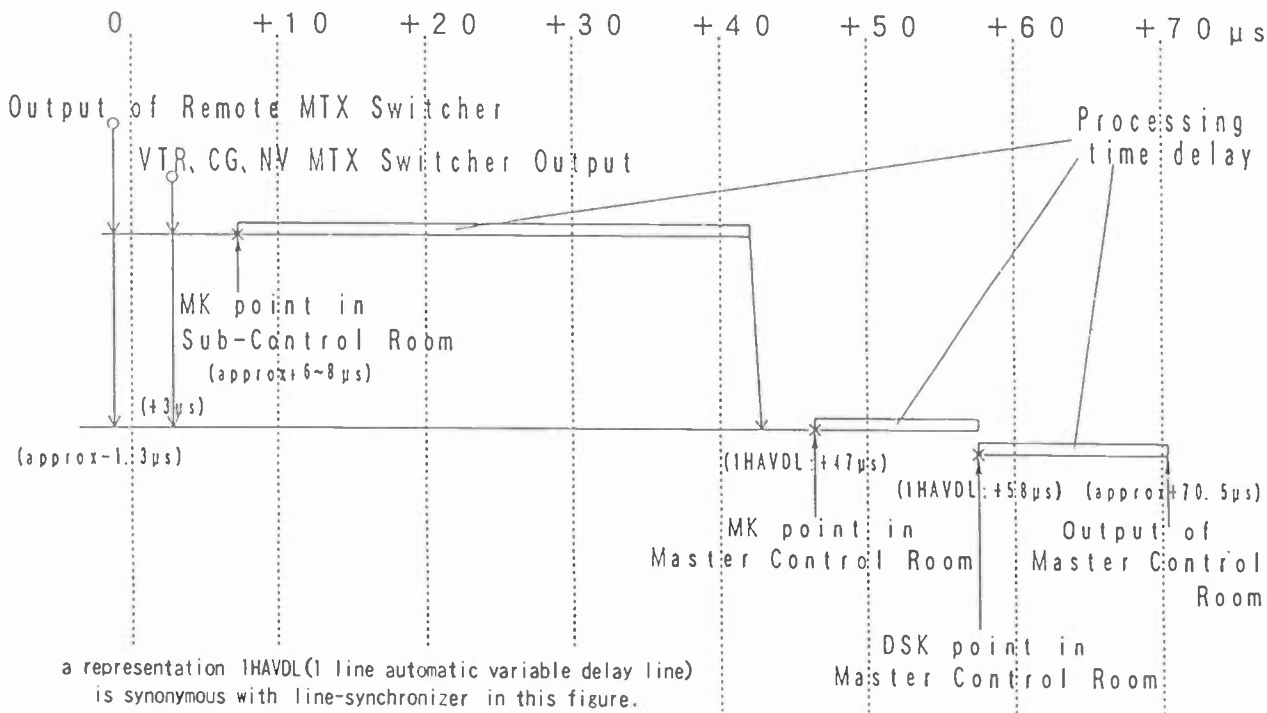

Fig.2 TBS Broadcast Center Delay Diagram

3) CG room output matrix

This distributes output signals from the various still-image file equipment in the CG room to the sub-rooms. Consisting of three layers of unequal size, the three signals (on-air material, key, and next material) can be switched with a single action using a virtual cross-point function. In addition, using the grouping function, multiple still-file equipment can be combined and distributed to the sub-rooms with a single action.

4) NV room output matrix

This distributes the signal output from a VTR that is playing back in the NV room to the sub-rooms with a single action. With the grouping function, many VTR outputs can be switched and distributed to the sub-rooms. It also has the capability to distribute other news materials to network stations during live news program broadcasts.

5) VTR room output matrix

This distributes the output signal from each of the VTRs in the VTR room to the sub-rooms in the same way as the NV room output matrix. New control software for items **3)**, **4)** and **5)** has been developed and designed along common specifications for each control, expecting cost, reliability, and ease of operation.

6) VTR room input matrix

This switcher distributes external signals coming into the VTR room, to VTRs in the room. Control, as with the monitoring and recording matrix, is done by manual selection at the receiving end.

7) Studio pre-select switcher

These switchers select from the various signals within and without the sub-rooms before they are input to the main sub-room switcher. They are broadly classified into four types, the R, V, P, and AUX pre-selects, supporting four categories of material (remote, video tape, still, and miscellaneous).

These seven types of routing matrix switchers are distributed among all the operating sites, and the individual operators of various sections are also expected to perform maintenance.

In addition to the above, there are local routing switchers for intra-room use, performing specialized operations. For example, the intra-room routing switchers in "the CG Room," "Design Room" and "Atelier" operate on digital components and have two-layer construction, including a key layer.

EXAMPLES OF PROBLEMS

The year before the building was completed, we gathered typical equipments of several manufacturers and conducted serial composite signal feeding tests supposing inter-room transmission. We encountered various problems at these preceding trial, acceptance test of facilities to be installed and during actual installation operations. They are presented here, including those related to intra-room systems. At present, we have countermeasures in place for almost all.

A) A VARIETY OF STANDARDS IN ANALOG COMPONENT SIGNAL AMPLITUDE

From the viewpoint of input/output signal amplitude, some of the equipment can only handle the analog component signals of EBU-N10 standard. In addition, several devices can only handle (so-called) Betacam amplitude with set-up level, but not handle the amplitude without set-up level, frequently used in Japan.

B) NON-CONFORMITY WITH ITU-R RECOMMENDATION 601

Several types of equipments exhibited phenomenon like those listed below.

(1)Analyzing the data in the output signal, it was found that the fourth word of SAV and EAV data did not follow ITU-R Recommendation 601. This signal was not accepted at all by some of other equipment.

(2)Because of SAV and EAV data insertion timing error in the output signal, the vertical phase was off by several lines at the equipment receiving its output.

(3)A certain equipment can only support luminance data values of up to $3F8_H$ within active picture area of input signal, thus the pixels whose luminance data values equal $3F9_H \sim 3FB_H$ are not accepted normally and inverted to black pixels.

C) NON-CONFORMITY WITH SMPTE 259M

We came across equipment that showed the following phenomenon.

(1)Upon observation the output eye pattern is non-symmetrical; there is severe overshoot and undershoot and the zero cross point is off-center. As a result, other devices cannot receive the signal properly.

(2)Because the input return-loss is not less than -15 dB, equipment used as a receiver cannot achieve the prescribed transport distance.

D) JITTER

After observation with a waveform monitor offering an up-to-date jitter measurement function, we came across several devices whose output was suspected to contain more jitter than the recommended value. However, we did not receive any reports of actual negative effects due to jitter itself. From the trial measurement(3) of jitter susceptibility at a input stage of several types of equipments, jitter tolerance was approximately resulted 2 nsec with component and 4 nsec with composite at jitter frequency of 600KHz.

E) OTHER

The following, while not examples of non-conformity with standards, are actual examples of problems.

(1)There was a device with weak equalizing ability which limited the component signal to 270m. Because this was used for transmission of about the same distance, it did not receive normally.

(2)10-bit data value within horizontal blanking period in serial output of a certain equipment was created simply by adding 2 bits of "0" under the LSB of 8-bit value. Of course, such blanking data value does not meet the recommended value of SMPTE 244M.

(3)There was a device that could not accept any signals, unless their receiving data value within the horizontal blanking period completely agreed with recommended value of SMPTE 244M.

(4)Because of excessive overshoot by the parallel ECL output, the following serializer did not perform correctly.

CONCLUSION

We have introduced here one example of a station-wide digital transmission system on the scale of a major broadcasting station. Looking back now, with the majority of work completed to a degree, we feel that total digitalization has provided us with real benefits such as simplification of adjustment work, improvement and uniformity of picture quality, and noise resistance.

In the future, we will look into effective use of EDH signals and ancillary data as the need arises. In addition, multi-rate, multi-format operation in excess of 143Mbps will come to be considered as a flexible infrastructure for future TV standards.

Transmission of still-image files by Ethernet LAN is going to be installed and used between several rooms concerning computer graphics as a method of image transmission that dose not depend on television standard. However, a detailed description has been omitted here.

Finally, we would like to sincerely thank all the manufacturers and all other concerned parties whose assistance made this system possible.

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DIGITAL AUDIO ENCODING: CONCEPTS AND REALITIES

Tuesday, April 11, 1995

Session Chairperson:
Milford Smith, Greater Media, Inc., East Brunswick, NJ

***DIGITAL AUDIO ENCODING & DECODING**
Larry Hinderks
CCS
Holmdel, NJ

***A HORSES FOR COURSES APPROACH TO BIT-RATE REDUCTION**
Fred Wiley
APT
Belfast, Northern Ireland

STATUS REPORT ON PAC AND MPAC PERCEPTUAL AUDIO CODERS FROM AT&T
Nikil Jayant
AT&T
Murray Hill, NJ

***FEATURES AND CHARACTERISTICS OF THE AC-3 CODING SYSTEM**
Louis Fielder
Dolby Laboratories
San Francisco, CA

***CASCADING CODING SYSTEMS - POTHOLES ON THE SUPERHIGHWAY**
Herb Squire
WQEW/WQXR Radio
New York, NY

*Papers not available at the time of publication

STATUS REPORT OF PAC AND MPAC: PERCEPTUAL AUDIO CODERS FROM AT&T

Nikil Jayant
AT&T Bell Laboratories
Murray Hill, NJ

ABSTRACT

The perceptual audio coder (PAC) is a powerful psychoacoustic algorithm that provides high-quality CD stereo at compression ratios exceeding 10:1. This capability of the PAC algorithm is critically needed for providing high-quality audio services in bandwidth-limited applications such as ISDN music delivery, digital audio broadcasting and multichannel sound for advanced television. Currently, the PAC algorithm addresses these applications with respective transmission rates of 64 kbps (stereo), 128 kbps (stereo) and 320 kbps(five channels). This paper provides a status report on PAC and its current applications.

INTRODUCTION

Following its contribution to the MPEG-1 Audio Standard [1,2], in particular to its lowest bit rate version (Layer 3), AT\&T Bell Laboratories proceeded with the creation of a new coding algorithm that was particularly suited for compression ratios on the order of 10:1 or higher -- for example, coding of the 1411 kbps CD-stereo signal at rates on the order of 128 kbps. The fundamental needs of such a design, as dictated by considerations of signal processing psychoacoustics and coding, caused an inevitable divergence from the MPEG-1 audio format.

Recently, following the successful implementation and application of the stereo PAC algorithm in DAB experiments in the United States, the PAC algorithm was brought back into the MPEG standardization process as a non-backward-compatible (NBC) system in the MPEG-2 process for the coding of 5-channel audio. A rigorous subjective test of various backward-compatible (BC) and NBC systems was undertaken as part of the MPEG-2 work. In this test, the multichannel PAC algorithm (MPAC) emerged as the leading contender for a new MPEG-2 standard. This paper is a status report on the stereo PAC coder (as applied to the DAB standard process in the United States), and the MPAC coder (as used in the ongoing MPEG-2 process).

Section 1 describes the stereo PAC algorithm. Section 2 summarizes its rate in the DAB process. Section 3 reviews the still-evolving MPAC algorithm. Section 4 comments on future work on PAC, MPAC and their extensions.

THE STEREO PAC ALGORITHM

The PAC algorithm [3,4] is based on transform coding of audio signals using perceptual noise criteria, a technique that was pioneered at AT\&T Bell Laboratories [5]. The perceptual audio coder is a psychoacoustically driven system based on empirical, but well-calibrated rules for utilizing the phenomenon of noise-masking. The principle of *simultaneous* or *frequency-domain* masking defines a just- *noticeable*-distortion (JND) profile (Figure 1) below which quantization noise (say, due to compression) cannot be perceived. The JND profile is a reflection of the fact that a signal can mask a weaker signal in its *frequency vicinity*, even when the difference between the levels of the two signals is not substantial. The principle of *non-simultaneous*, or *time-domain* masking (Figure 2a) utilizes the masking of the weaker signal in the *time-vicinity* of the stronger signal. All psychoacoustic coders attempt to utilize the above phenomenon, but the effective use of masking depends on the accuracy of the psychoacoustic model and on how well the signal-analysis framework facilitates the application of that model for coding.

The JND model in the PAC algorithm is currently based on an input-dependent interpolation between well-known models for *noise-masking-tone* and *tone-masking-noise*, combined with additional, masking terms which reflect the spread of masking beyond the critical band (staircase tread in Figure 1) that contains the masker.

The phenomenon of temporal masking is maximized in PAC by means of input-dependent switching between long and short blocklengths for frequency-analysis (Figure 2b). Transitional segments tend to be analyzed with a shorter blocklength in the MDCT (modified discrete cosine transform). As mentioned, block switching is input-adaptive, and it is based on a carefully designed psychoacoustic criterion.

Another unique feature of PAC is the method used for the joint-coding of the left (L) and right (R) channels in a stereo pair. The PAC algorithm provides both for the independent coding of these channels (L and R) and for composite coding that uses the sum and difference signals (L+R and L-R) as coder inputs. The decision of stereo-coding mode is flexible, time- and frequency-dependent, and based on psychoacoustic principles that avoid pychoacoustic artifacts such as *noise-unmasking*.

The PAC algorithm finally includes an adaptive entropy coder that further reduces the total bit rate. Entropy coding and psychoacoustic quantization are jointly performed in an iterative operation.

A block diagram of the stereo PAC coder appears in Figure 3. Although the stereo encoder is fairly sophisticated, its design is guided by the need for robust implementation in current signal processing technology. The stereo decoder is quite simple, and it is currently implemented on a single general-purpose microprocessor.

THE APPLICATION OF PAC TO DAB TECHNOLOGY

The United States has begun the process for defining standards for digital audio broadcasting (DAB), also referred to as digital audio radio (DAR). The process includes testing of the wideband *Eureka* system, an S-band satellite system, and a number of *In-Band* systems that are matched to the basic 200 kHz subdivision in terrestrial FM broadcasting. The In-Band systems are classified into the categories of *On-Channel* (IBOC), *Adjacent Channel* (IBAC) and *Reserved-Channel* (IBRC). Figure 4 provides simplified descriptions of In-Band DAR and FM spectra, and Figure 5 provides an illustration of how the In-Band technologies may evolve in a system where the space-frequency plan is currently based on fairly well-separated FM stations.

The performance of the stereo PAC coder at compression ratios on the order of 10:1 makes it an ideal candidate for the audio subsystem of DAR technology. In the USA-DAR contest, the AT\&T systems for IBAC and IBRC broadcasting use PAC at a rate of 160 kbps, while the AT\&T-Amati system for IBOC broadcasting uses PAC at two alternative bit rates: 160 kbps for the double-sidelobe operation (as in Figure 4), and 128 kbps for single-sidelobe operation. The satellite system being developed by the Voice of America -- NASA -- JPL consortium uses PAC at 160 kbps. Outside of the contest, an experiment satellite system developed by CD-Radio uses PAC at 128 kbps.

The MPEG-Layer 2 coder is also being tested in the DAR contest, as part of the systems offered by Eureka and USA-Digital Radio. This coder operates at higher bit rates, up to 256 kbps for the stereo pair.

The USA-DAR contest is being administered jointly by the Electronics Industries Association (EIA) and the National Radio Systems Committee (NRSC). Laboratory tests at the NASA--Lewis Research Center, with subjective tests at the CRC (Communications Research Centre, Canada) are expected to last through the end of 1994. Field testing of candidate DAR systems are planned for 1995.

The low bit rate capability of the stereo PAC coder is extremely well-matched to the needs of DAR technology for two fundamental reasons: it permits the use of a grater part of the 200 kHz capacity for transmission error protection, and it permits the use of a significant portion of the capacity for the transmission of additional data services.

In the AT\&T--IBAC and AT\&T--IBRC systems, the 200 kHz channel carries 360 kbps, permitting a very powerful rate-1/2 code for protecting the PAC bit stream. The DAR system actually has three levels of error-protection: an initial protection of a few very critical bits in the initial PAC bit stream, the rate-1/2 protection of the final PAC bit stream, and a proprietary error-concealment procedure at the receiver. The concealment algorithm addresses occasional block-error failures (audio mutes) which are caused when the transmission channel is poor enough to defeat the combined capability of the error protection-interleaving-channel equalization system.

The additional data capacity in the DAR system is on the order of 10 to 20 kbps. This includes synchronous data that are multiplexed to the PAC bit stream as well as asynchronous data that can be added when the (constant-quality, variable-rate) PAC algorithm does not need the allocated constant coding rate (say 160 kbps) for providing high-quality reproduction of an audio segment (which is typically about 10 ms long).

THE MULTICHANNEL PERCEPTUAL AUDIO CODER (MPAC)

The 5-channel MPAC coder at 320 kbps is a natural extension of the 2-channel PAC algorithm at bit rates on the order of 128~kbps.

In a simple version of MPAC, the signal-dependent composite coding algorithm in the stereo PAC coder is repeatedly applied to pairwise combinations of the five channels (L, R, C, LS, and RS) at the input of the MPAC algorithm. This results in various sets of JND thresholds which are either specific to an individual channel or to a channel-pair. Simple subalgorithms provide coding of 3-channels (L, R, C) or of stereo (L, R).

The MPAC decoder is designed for simple implementation, and the 5-channel decoder for MPEG-2 testing in 1993 has been implemented on a single microprocessor.

Table 1 is an excerpt from the subjective tests conducted by Deutsche Telekom and the BBC in support of an initial phase of the MPEG-NBC process. The purpose of this test was to demonstrate the need for an NBC part of the MPEG-2 process. The results of Table 1 indeed demonstrated such a need, and this has led to the decision to begin a formal contest for an NBC standard for multichannel audio. A second result, also clear from Table 1, is that the MPAC coder provided the overall best performance at 320 kbps, with a significant margin over the second best system tested. One of the detailed results in the test, not apparent in Table 1, is that the MPAC system performed conspicuously poorly on one of the 10 audio stimuli tested *(fountain-music)*. This has been addressed subsequent to the test, and the current version of the MPAC coder has been observed to be more robust across different stimuli. Recent modifications of the MPAC algorithm have in fact resulted in an even simpler algorithm for encoding and decoding.

FUTURE WORK

Recent work has shown that PAC and PAC-like algorithms degrade extremely gracefully as the compression ratio is increased beyond the level of about 10:1 discussed in this paper. In particular, compression ratios on the order of 20:1 will be very significant for emerging applications such as MPEG4 audio and the next generation of FM-band and AM-band broadcasting. Work on these extensions of PAC are in progress and will be reported in due course. [At that time, we also plan to provide reports on real-time implementations of the MPAC codec.]

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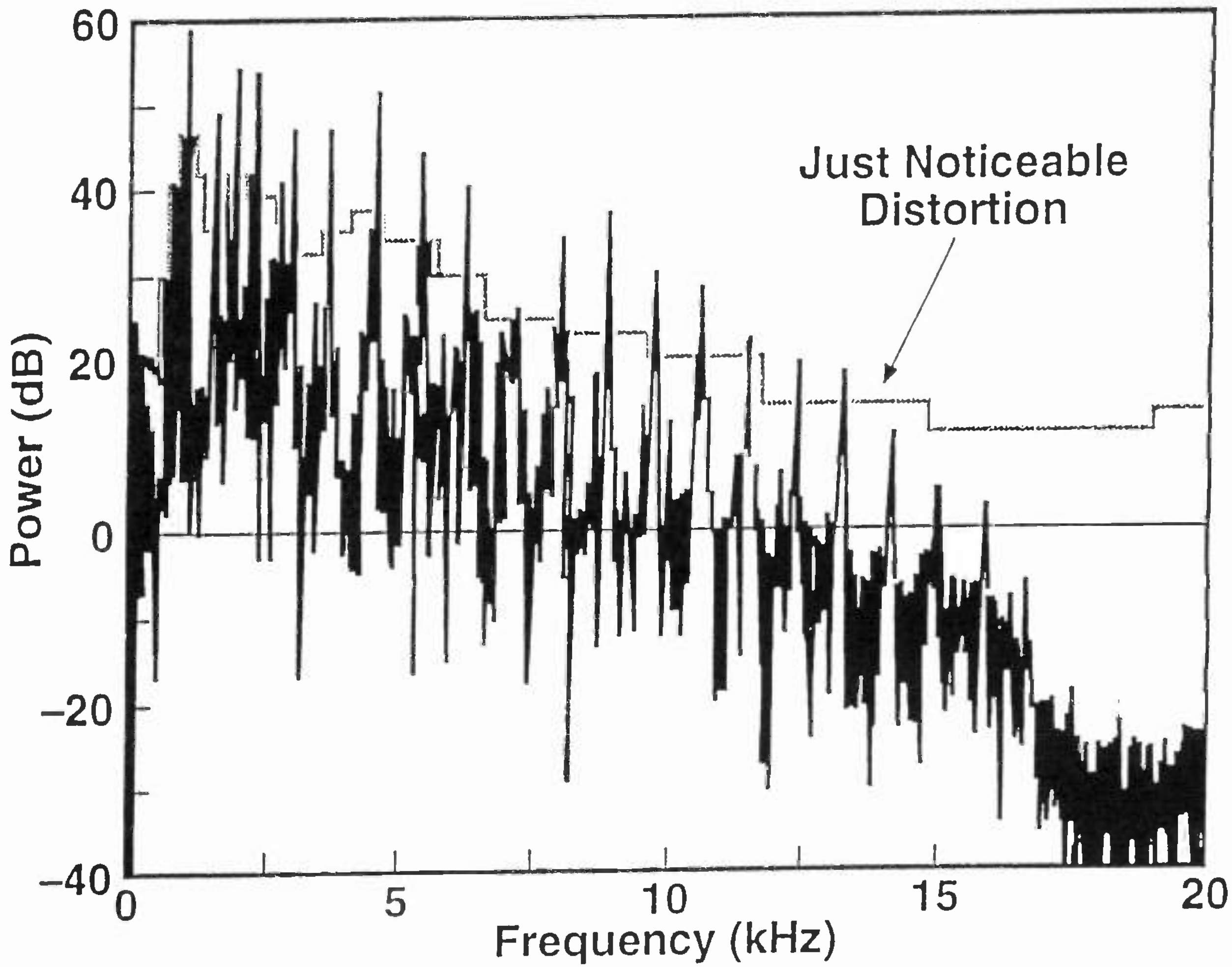
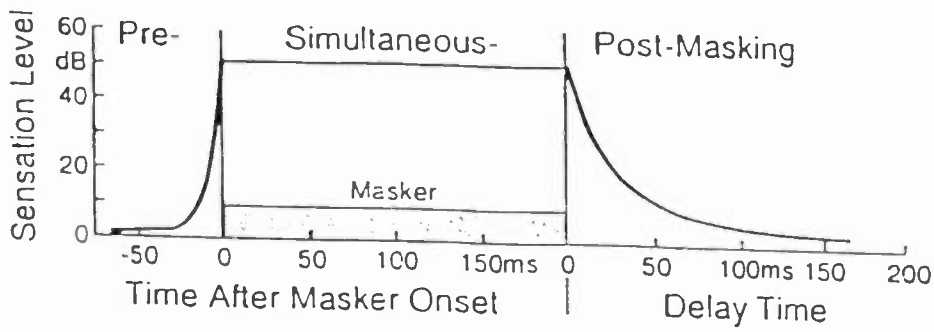
Digital Audio Compression
Perceptual Audio Coding



AT&T

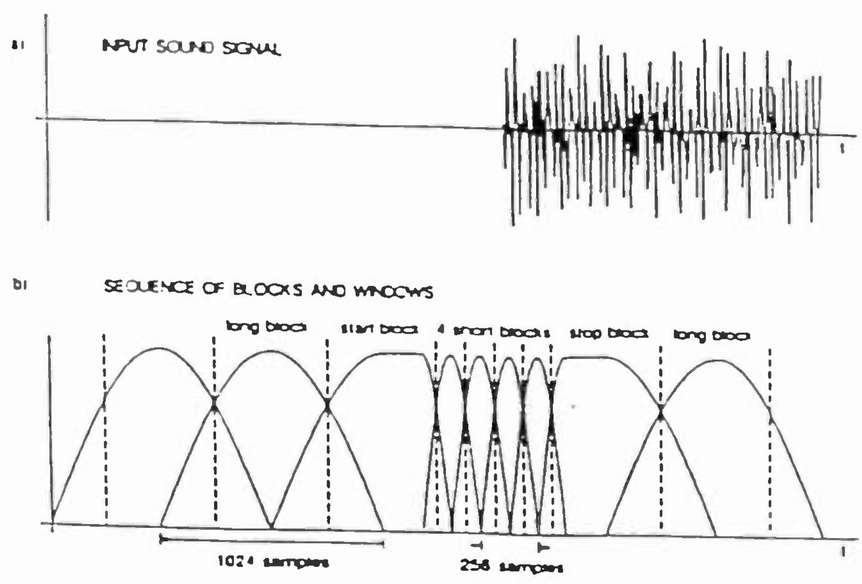
SH94-055OTH-006

Fig. 1



Masking of distortion by signal, in the time-domain.

Fig. 2A

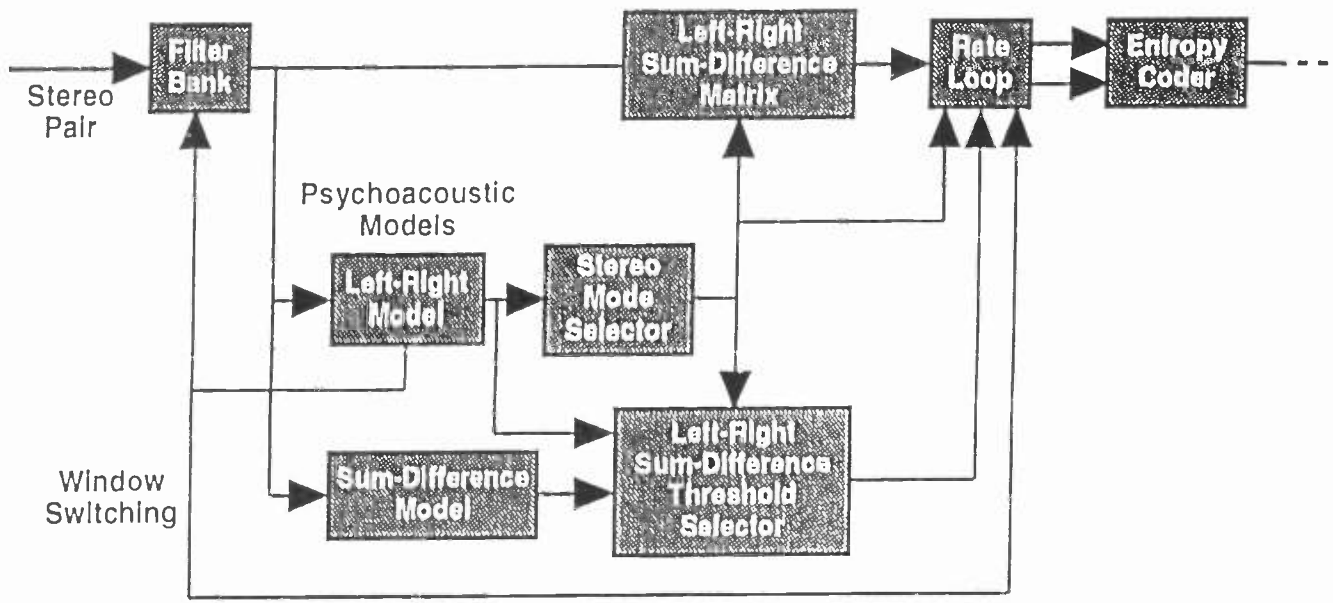


Adaptation of window length in transform coding.

Fig. 2B

The PAC Codec

Encoder



Decoder

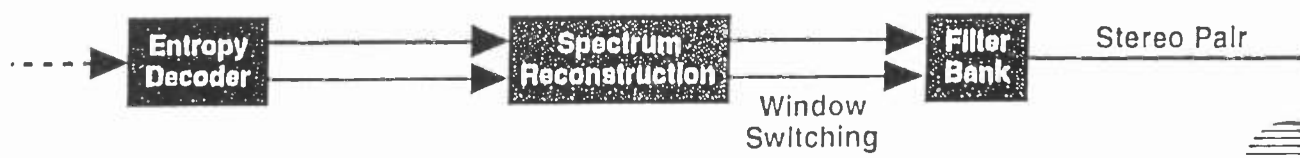


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Fig. 3

Audio Broadcasting in the FM-Band

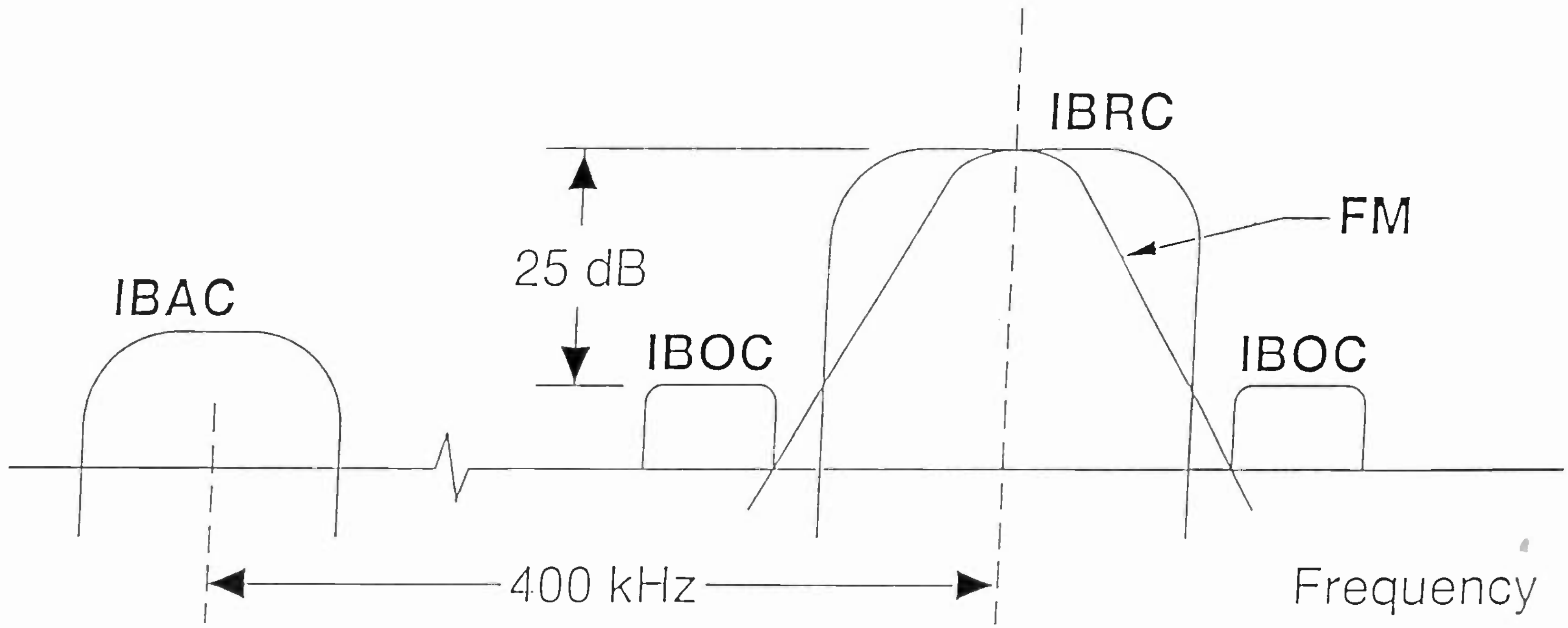

Fig. 4

MH4P866Y03

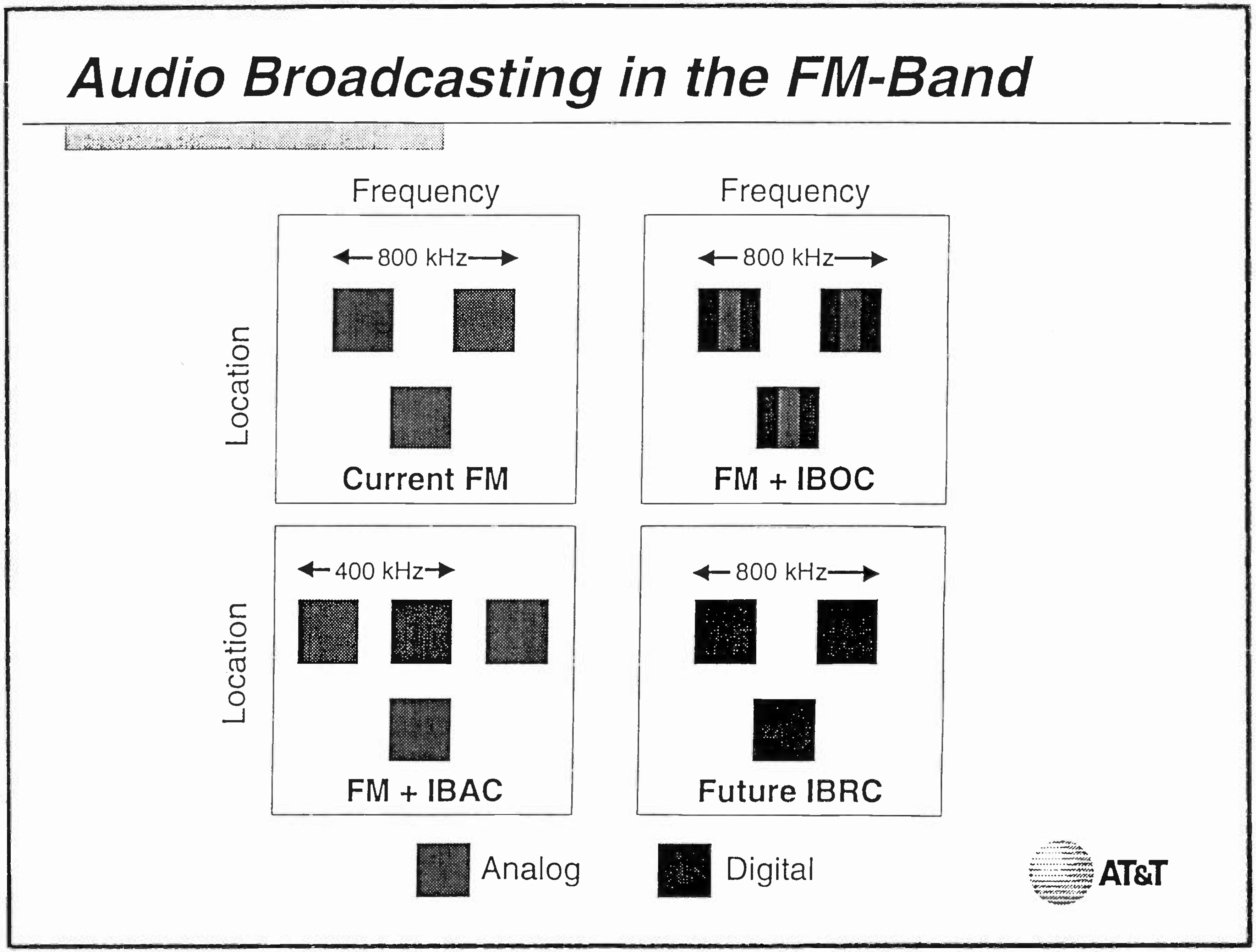

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Fig. 5

MPEG2 Results (5-Channel Audio)

Comparison of 5-channel audio codecs at 320kbps
Number of Signals (out of 10) that are transparently coded*

		Testing Laboratory	
		Deutsche Telekom	BBC
Philips	(MPEG-Layer 2)	1	0
Dolby	(AC3)	2	1
AT&T	(MPAC)	6	5

*Average quality loss of less than 0.5 on a 5-point scale
Based on the opinions of 45 expert listeners

Excerpted from MPEG data NSJ 3.28.94

AT&T

SH94-055OTH-016

Table 1

RADIO REMOTE BROADCASTING: THE LATEST DIGITAL TECHNOLOGIES

Tuesday, April 11, 1995

Session Chairman:
Bill Ruck, KNBR-AM/KFOG-FM, San Francisco, CA

***SPREAD SPECTRUM AND ITS APPLICATION FOR REMOTE BROADCASTING**

Eric Eckstein
QEI Corporation
Williamstown, NJ

***EFFICIENT REMOTE BROAOCASTING FOR RADIO**

Lynn Distler
Comrex
Acton, MA
Steve Church
Telos
Cleveland,OH
Jack Kelly
Intraplex
Westford, MA
Larry Hinderks
CCS
Holmdel, NJ
Mike Simpson
Midcom
Irving, TX
Jerry Nowicki
ESI
Danville, CA
Kevinn Tam
Dolby Laboratories
San Francisco, CA
Angela De Pascale
Global Digital Datacom Services
East Farmingdale, NY

*Papers not available at the time of publication

AUDIO AND VIDEO TESTING: NEW TECHNOLOGIES

Wednesday, April 12, 1995

Session Chairperson:
David Carr, KHOU-TV, Houston, TX

TESTING IN THE DIGITAL ERA
Jason Job
AAVS
Sioux Falls, SD

CUSTOMER SERVICE: NEW OPPORTUNITIES AND CHALLENGES
Steve Epstein
Broadcast Engineering Magazine
Overland Park, KS

SIGNAL MONITORING IN THE TRANSITION FROM ANALOG TO DIGITAL
Mark Everett
Videotek
Pottstown, PA

***YOU THOUGHT IT WAS WORKING**
Sandy Sandberg
Howard Ranen
Current Technology
Dallas, TX

***MEETING THE NEED FOR ERROR DETECTION AND HANDLING (EDH) IN SERIAL DIGITAL INSTALLATION**
Paul Moore
Gennum Corporation
Burlington, Ontario, Canada

*Papers not available at the time of publication

TESTING IN THE DIGITAL ERA

Jason Job
Advanced Audio Visual Systems
Sioux Falls, SD

ABSTRACT

The Digital Era is here to stay. We are becoming accustomed to the many digital "advantages". Engineers, however, have seen the darker side of digital video. They have seen incompatibilities between equipment, unexplainable loss of synchronization, "sparkles" in the image, even complete loss of image. Lack of proper test equipment and testing knowledge have led some engineers to conclude that digital video has much in common with voodoo and black magic.

In contrast, this paper will show how the same good engineering practices that have produced excellent analog television can also be applied to digital television. Practical, easy to understand test methods and equipment will be studied and explained. Real-world examples of problems that have been discovered in digital video installations will be discussed and the test methods that allowed their diagnosis and correction will be illustrated.

INTRODUCTION

It was noted, in a review of the 1994 NAB show, that there were no new analog tape formats introduced at the show. The decision in Japan to scrap analog HDTV this year is also notable. We are indeed well engaged in the digital era.

These marvelous new installations are not being born without labor-pains, however. Our world is still, and always will be, to some degree, analog. Most new digital installations are islands of digital, admittedly growing larger and larger, in an analog sea. In addition, since this revolution is less than ten years old, most of our test equipment, technicians, and engineers are still analog. None of us, from design engineers to repair technicians, majored in digital video in college. We now find ourselves, ill equipped as we might be, coping with a rapidly growing new technology.[1]

We must not, however, throw out everything we learned in our analog video schools. The same principles that we learned at school can be effectively applied to digital video, if we understand the various parameters and elements of the signal.

Two basic philosophical problems arise when we analyze the reasons for failure in a digital installation. The first is a problem of equipment that never met the specifications at its manufacture. The second is a problem of misunderstanding or ignoring the operating specifications and limits.

Normally, when analog equipment is purchased from a reputable video equipment manufacturer, one can be reasonably sure that the design is good and that the equipment design functions as advertised. For example, equipment with baseband composite video inputs and outputs can be interconnected without concern for unexpected results. The interface and specifications are well understood.

In digital video, however, one cannot currently assume that the design of a particular piece of equipment, even from a reputable manufacturer, is good or even standard. This is due, in some cases, to an incomplete understanding of the technology. In other cases, the specifications are vague and leave areas of uncertainty. Intelligent engineers, with good intentions, design equipment that is incompatible with other equipment because of misinterpretation of the standards.

Thus, when troubleshooting new equipment, or troubleshooting problems that arise when equipment is connected in new ways, it is important not to assume that the equipment is responding according to the standards.

The second problem arises when engineers misunderstand, or incompletely understand the significance of some specifications. This is sometimes due to a lack of education in understanding the technology.

When specifications for a standard are established, the various parameters of the interface, the signal, or whatever is being specified, are examined and a determination is made as to the tolerance that can be allowed. These limits are established with the philosophy that variations less than those specified will not cause any degradation in the quality of operation.

Thus in the analog world, for example, when RS 170 A specifies that the horizontal sync pulse should be 4.7 microseconds in duration, it also specifies a tolerance of $\pm 0.1\mu S$. The assumption is that a sync pulse that ranges in length from $4.6\mu S$ ($4.7\mu S$ - $0.1\mu S$) to $4.8\mu S$ ($4.7\mu S$ + $0.1\mu S$) will not cause any improper operation.

It is further assumed that all equipment that is intended to operate in this standard environment will produce signals that meet this specification, and that all equipment that receives this signal will operate correctly if the signal meets the standards set out in the specification.

Specifications for digital video signals are likewise established with the purpose of setting limits for deviation that will not cause improper operation. Like analog signal specifications, digital signal specifications also establish the limits in which the sending equipment must operate and the receiving equipment must accept.

In the analog environment, any violations of the specified limits may cause gradual degradation of the resulting image. The degree of degradation may depend on the receiving equipment tolerance. The acceptability of the degraded signal (image) will depend on the viewer, his/her expectations, training and personality. Minor violations of the specified limits occur regularly and are often viewed as unimportant. The amount of tolerated variation will often vary with the type of facility, corresponding to the type of end user for the product. Signals with enormous variations from standards are commonly used in products destined for small groups of end-users. Videotapes of weddings, school concerts, and other "family" events often violate nearly every standard established for NTSC video and yet are deemed acceptable by the buyer.

In the digital environment, small violations of the specified limits will usually show no effect at all in the resultant image. Both the trained and untrained viewer will see no image degradation. This is due to the nature of digital information transfer.

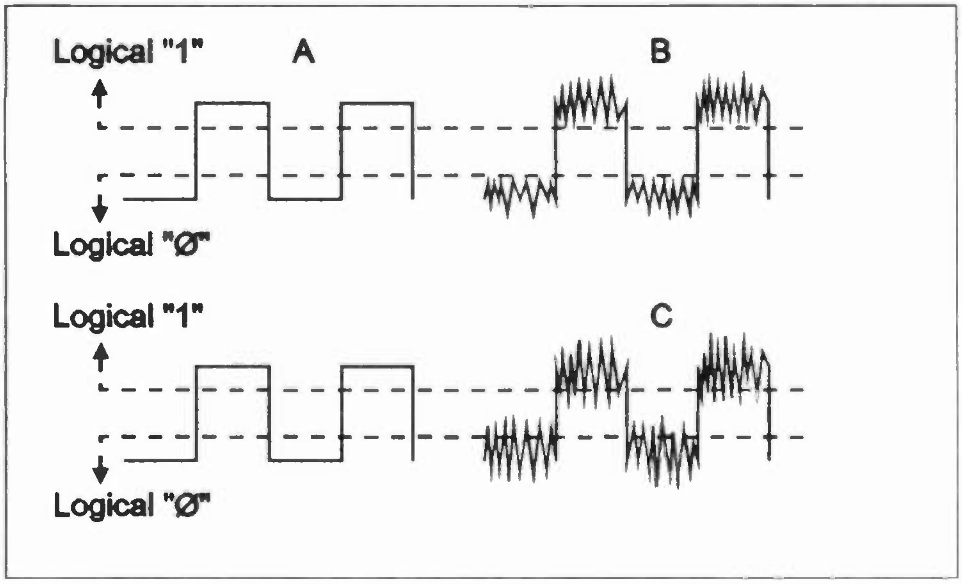

Figure 1 - Effect of noise on data decoding.

Figure 1 illustrates clean data signals and noisy data signals. The signal at A is clean and noise-free. The positive level is well above the threshold that is interpreted as a logical "1", and the negative level is well below the logical "0" level. This signal will be correctly interpreted 100% of the time.

The signal at B has superimposed noise. Actually the signal to noise ratio is quite low, well below what would be acceptable if this were an analog video signal. However, examination will show that the excursions on the positive levels are still always greater than the logical one decision point, and the excursions on the negative levels are always below the logical zero decision point. This signal will also be correctly interpreted 100% of the time. There will be no data errors and thus no degradation in the image (in the case of a digital video signal).

The signal at C also has superimposed noise. This time, however, the noise causes the excursions on the positive levels of the signal to randomly drop below the logical one decision point, and above the logical zero point on the negative levels of the signal. If the data were validated during the brief time when the signal was in an indeterminate state, an error could occur. Unlike analog noise, digital errors are usually very visible, since they can drastically change the value of the digital sample being sent. They often show up as sparkles in the image.

It can be similarly shown that jitter in the digital video signal will show no effect on the image up to a point where data errors occur, and will be abundantly evident when the signal slips over the "digital cliff. It is essential, therefore, to monitor levels, noise, and jitter in a digital circuit regularly. In critical parts of an installation, the monitoring should be done continuously with alarms set at critical thresholds. Sound operating practice would insist on establishing proof-of-performance records that would document the levels existing at installation and their evolution over time. This will aid in early warning of poor connections, damaged cable, etc. Operating levels should also be verified and documented whenever repairs or changes to the system occur.

Let's examine some other parameters of a digital video signal to illustrate how this philosophy can be valuable in the real world.

All examples given will assume a video signal conforming to SMPTE 125M (Bit parallel component (4:2:2) digital video) and SMPTE 259M (10 bit 4:2:2 component digital video). Composite (4fsc NTSC and PAL) video has very similar parameters and in many cases the examples also apply to these signals as well.

A bit parallel digital video signal is specified as having peak to peak amplitude of 0.8 to 2.0 V at the transmitter. The average voltage (the midpoint between the "high" and "low" data states) is specified as -1.29 V ±15%. Inputs must accept and correctly interpret signals in the range of 2.0 V p-p maximum, to a minimum of 185 mV. Signals having a peak to peak amplitude less than 185 mV may not be correctly interpreted.

The amplitude of a serial digital video signal at the output of the transmitter is specified as 0.8 V ±10% into a 75Ω unbalanced load.

The most common source of low voltage levels at receivers is long cable lengths. One hundred meters of commonly used coaxial video cables will exhibit losses of about 12 - 15 dB. It is generally acknowledged that greatest usable length of cable for serial transmission is about 300 meters.

It is well known that the bit error rate in a well designed system will be quite low when using short cable lengths. As cable length is increased, the bit error rate will increase very slowly up to a point at which the receiver is no longer able to reliably decode the data. The error rate will jump up significantly at that point.[2] The graph in Figure 2 shows the "knee" in the bit error rate curve.

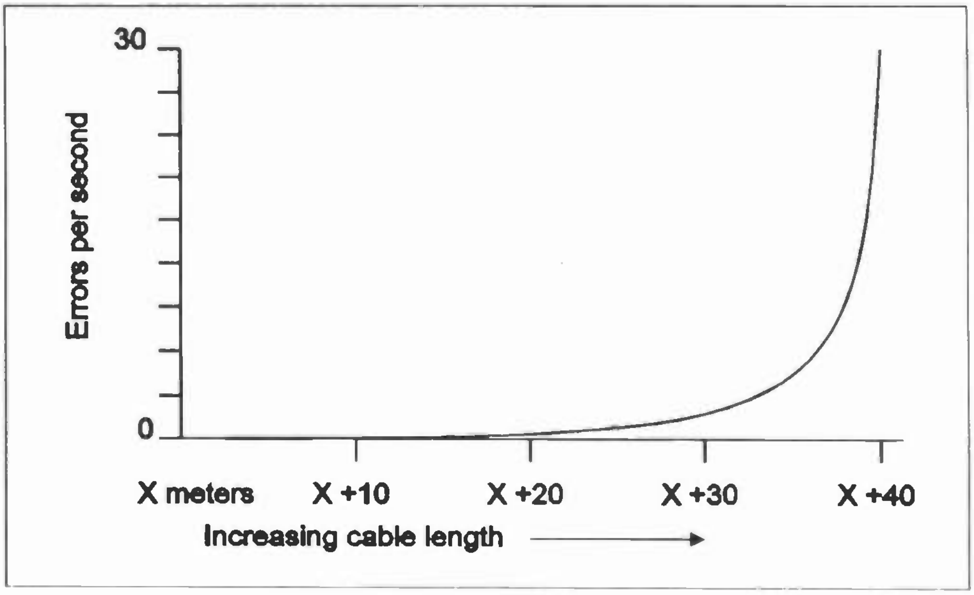

Figure 2 - Error rate as a function of cable length.

In the system illustrated here, operating with X meters of cable gives an unmeasureably low error rate. Adding ten, or even twenty meters of cable would show an undetectable increase in errors. Adding thirty meters still shows only a slight increase in errors, which would still be difficult to detect with the naked eye. However, adding forty meters of cable causes the error rate to jump to a rate of one error per frame. This would be quite objectionable.

It has been suggested that temporarily adding 50 meters of cable to a link that is operating without visible errors can be a way to test the margin of safety in the system. If the addition of 50 meters of cable causes no discernible increase in visible errors, one can be reasonably sure that the edge of the digital cliff is some ways off when operating normally without the additional cable. Such a test has interest, but it should not be substituted for measurement, documentation and careful review of operating levels and jitter at frequent intervals.

It is normal for signal level to decrease with long cable lengths and for high frequency roll-off to occur. This will round the edges of the data transitions and make decoding the data more difficult. Serial receivers are designed to counteract this loss of level and high frequencies by applying equalization to the signal to restore its level and to restore lost high frequency information. The amount of high frequency equalization that is applied is calculated from the level of signal arriving at the receiver, since there is a known relationship between the losses at different frequencies in common coaxial cables.

It is important that the losses of level be derived from cable losses since equalization is calculated and applied by the receiver as a function of the input level. Losses due to other factors will cause incorrect equalization to be applied. Levels that are lower than can logically be expected due to cable length need to be investigated to discover their source. Poor connections due to dirty or damaged connectors, patch panels, etc. can be sources of low levels.

Low digital signal levels, whether in a parallel or serial interface, can result in data errors. The errors will occur at statistically random times, resulting in "sparkles" in the video image at best or more seriously, in loss of sync.

It is important to remember that the picture information in a digital signal is not inherently protected by any error checking or correcting method. This is in contrast to most digital data transfers where checksums and handshaking procedures allow errors to be detected and the data re-sent if necessary until perfect transfer is achieved. The data rates involved in digital video, as well as the desire for a simple, inexpensive interface, make this currently impossible. Thus, in a quality installation, error rates must be exceedingly low or picture quality will by negatively affected.

Another parameter critical to proper data decoding is the jitter present on the signal. Jitter is the difference in timing between where the data transition "should" be and the actual location of the transition. It is a pulse position modulation, the instantaneous difference in the phase of a signal under test compared to a stable and jitter-free primary clock. The actual transition of the signal under test may occur before or after its correct position.

Jitter is particularly critical for signals being transmitted in serial form, since the signal is sent without an accompanying clock signal. In order to be able to decode the logical levels of the incoming serial signal, a clock is recovered from the data stream. This recovered clock is used to decode data.

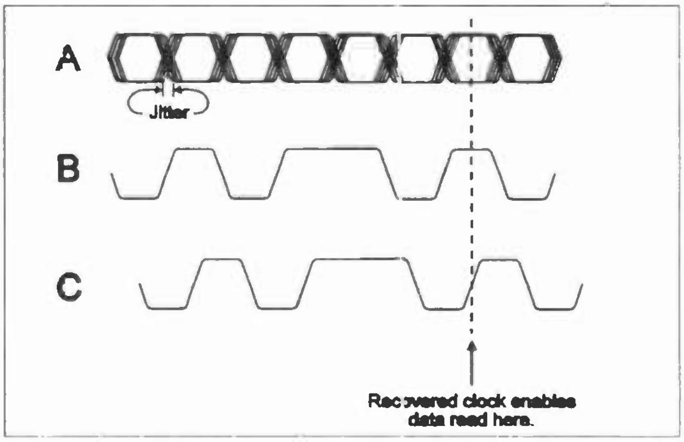

Figure 3 - Serial jitter.

In Figure 3 we see a representation of a serial signal with jitter present. Waveform A represents many periods of the serial bitstream as it would appear overlaid on an oscilloscope. Some of the transitions would occur earlier than the average and some later. We see that the zero crossings of a large number of transitions are spread out in time. Their maximum deviation in time is the peak-to-peak jitter. Jitter is expressed in nanoseconds or picoseconds of maximum deviation.

If we could freeze the data stream at a moment in time we would see the instantaneous position of the waveform in relation to the recovered clock. At time B, the data is well centered on the recovered clock and will be correctly interpreted. At time C, the signal is instantaneously advanced, due to jitter. The data is now no longer properly centered on the recovered clock when it validates the reading of the data, and an error will occur.

A small amount of jitter is not dangerous to proper data decoding, but if the amount of jitter becomes significant with regard to the period of the data cycle, errors can occur.

The jitter present on a serial signal becomes more serious as cable lengths increase. The attenuation of the cable causes the amplitude to decrease, as we discussed in the section on levels, and since the attenuation is greater as the frequency increases, the rise time of the waveform increases and rounds off the waveform. The period of time during which the level can be accurately determined is shorter, since the "flat" part of the waveform, the part where the data level is detected, is now shorter. Cable equalizers in receiving equipment can correct for much of this loss, but jitter may become a significant factor in data errors.

Since the data transfer is asynchronous, variations in time (jitter), if sufficiently large, can cause the data to be incorrectly interpreted since the synchronism is lost. The data then becomes "garbage" since the correct bit order (or word framing) is lost. Loss of one bit means that the boundary between the digital words is no longer correct. Thus, for example, the least significant bit of the following word becomes the most significant bit of the current word. (The words in a serial data stream are sent least significant bit first.) Figure 4 illustrates word framing.

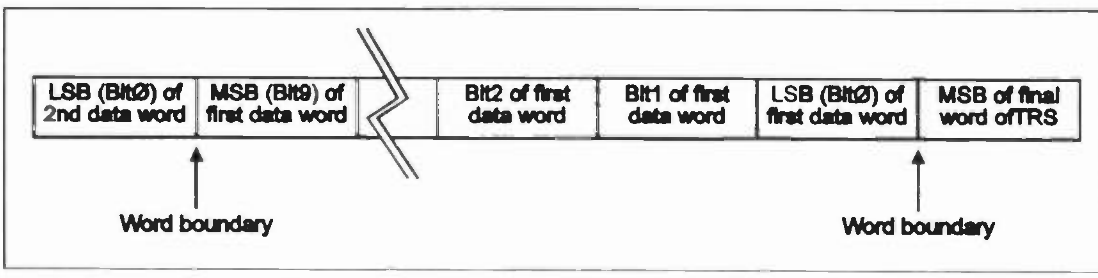

Figure 4 - Word framing in a serial digital signal.

This will have a disastrous effect on data being transmitted by the affected word. Furthermore, all words following the affected word will also be similarly corrupted until the deserializer realizes the error and re-synchronizes the word boundaries. This only occurs at the end of the line, at the timing reference signal (TRS).

According to SMPTE proposed standard 259M, which is currently under revision, "The timing of the rising edges of the data signal shall be within ±0.25 ns of the average timing of the rising edges, as determined over the period of one line."

The frequency of the jitter present on a serial signal is important since the effects of different jitter frequencies will be different.

Low frequency jitter will not affect the deserializing and decoding of data since the phase locked loop in the receiver of the deserializer can track frequency variations up to a certain frequency point. This frequency varies according to the manufacturer of the receiver, and is typically between 1 kHz and 10 kHz. Jitter at frequencies below this range will not affect data recovery. It will appear in the deserialized parallel clock. High frequency jitter, that can cause data recovery errors, is called alignment jitter.

It is imperative to measure the amount of jitter present at the output of each transmitter in a new installation, and to periodically check to see that the level has not changed. Once more, the operator needs to be able to determine how close to the edge of the "cliff" he/she is operating.

Jitter in a serial data signal is commonly caused by equipment problems in the serialization circuitry. These problems are sometimes design problems. Some equipment manufacturers have lacked adequate test equipment to sufficiently test their serializer circuits, and thus have manufactured equipment that does not meet the SMPTE specifications. Also, equipment failures can cause jitter levels to rise in equipment that was meeting specs when originally manufactured.

Poor decoupling of power supplies, and noise in power supplies can cause increased serial jitter. High levels of relatively high frequency jitter (above 1 kHz) on the parallel clock being serialized can translate into increased serial jitter levels. Special attention must be given to equipment (distribution amplifiers, routers, etc.) that re-clocks the data stream since these can add jitter to the signal. Their performance should be verified at installation and proof of performance should be carried out at regular intervals to catch degraded performance before bit errors cause serious image flaws.

When testing serial jitter, it is wise to use a gray pattern in which all of the data bits in the parallel interface are constantly changing state. This results in a concentration of high frequency energy (at multiples of 13.5 MHz). Experience has shown that this stresses serializer circuitry and often causes increased jitter in poorly designed serializers. The digital values for this pattern are: Y = 127 (8 bits) or 511 (10 bits), C_R & C_B = 128 (8 bits) or 512 (10 bits).

Voltage levels and jitter are two parameters that relate to the electrical waveform that is used to transfer the data. In addition to the electrical "carrier" of the data, the actual data stream can contain errors that will adversely affect quality.

One such parameter is the Timing Reference Signal, or TRS. You will recall that the TRS in a component digital video signal begins with a preamble, which is a special combination of digital words consisting of FF, ØØ, ØØhex in 8 bit format, or 3FF, ØØØ, ØØØhex in 10 bit format. The digital values FFhex and ØØ are called reserved codes, since they are reserved for use as preambles to the TRS only.

Reserved codes that are allowed to occur in the active video period can "fool" certain equipment into believing that the sync time has arrived and may cause false sync triggering. This is a very serious error which will destroy the integrity of the image.

If reserved codes are detected in active video, it is important first of all to determine if the errors are occurring randomly or at a specific position in each field of video. If the reserved code is appearing to move about the screen, it is a random error. Random errors are generally related to levels or jitter. On the other hand, reserved codes that occur at the same place in each frame usually indicate a failure in the equipment. Improper setup or adjustment of equipment can also lead to reserved codes appearing in the active picture area. By analyzing the location and behavior of the reserved code on the monitor, the cause of the error can usually be determined.

As mentioned earlier, errors in the TRS are quite serious since they can cause loss of synchronization in the receiving equipment. Using the Hamming code, which protects the data in the TRS, it is possible to decode which bit of the TRS is in error.

Not all of the digital values from Ø to 255 (or 1023) are recommended for use. Instead, a buffer zone is defined in the specifications. This buffer zone protects the digital video from clipping that would occur if the values reached Ø or 255. The zone also makes it less likely that valid video signals would produce the reserved code values of ØØ and FFhex (3FFhex).
Valid video values range from 16 to 235 for luminance (64 to 940 in 10 bit format), and 16 to 240 for chrominance (64 to 960 in 10 bit format).

Values outside of this range are not recommended for use. Equipment should normally be set up to exclude these values from regular use.

It is important to monitor the video data values continually and signal any excursions into these non-recommended areas. If range errors are being produced, the cause must be examined. In certain cases it is permissible to use the non-recommended values, but it is essential to understand the implications of doing so. It is essential to determine the cause of any range errors that are not generated expressly. It is crucial that equipment that manipulates the digital video data not change values so that non-recommended values are produced. It is important, in trying to determine the cause of these errors, to monitor the input and output of such equipment to determine if such changes are taking place within the suspected device.

Often obscure problems arise that cannot be traced to any of the above parameters. In these cases it is invaluable to analyze the actual data values present at the output of a unit under test. By passing a test pattern with known digital values through the unit under test and analyzing the data at the output of the unit, valuable clues as to the cause of the malfunction will be found.

The analysis might show values that were changed. Such analysis of actual equipment has also detected TRSs in the wrong position of the digital television line. A correct TRS in the wrong position may seem to operate correctly with some equipment, but not with others. A careful analysis of the sample positions and values is indicated.[3]

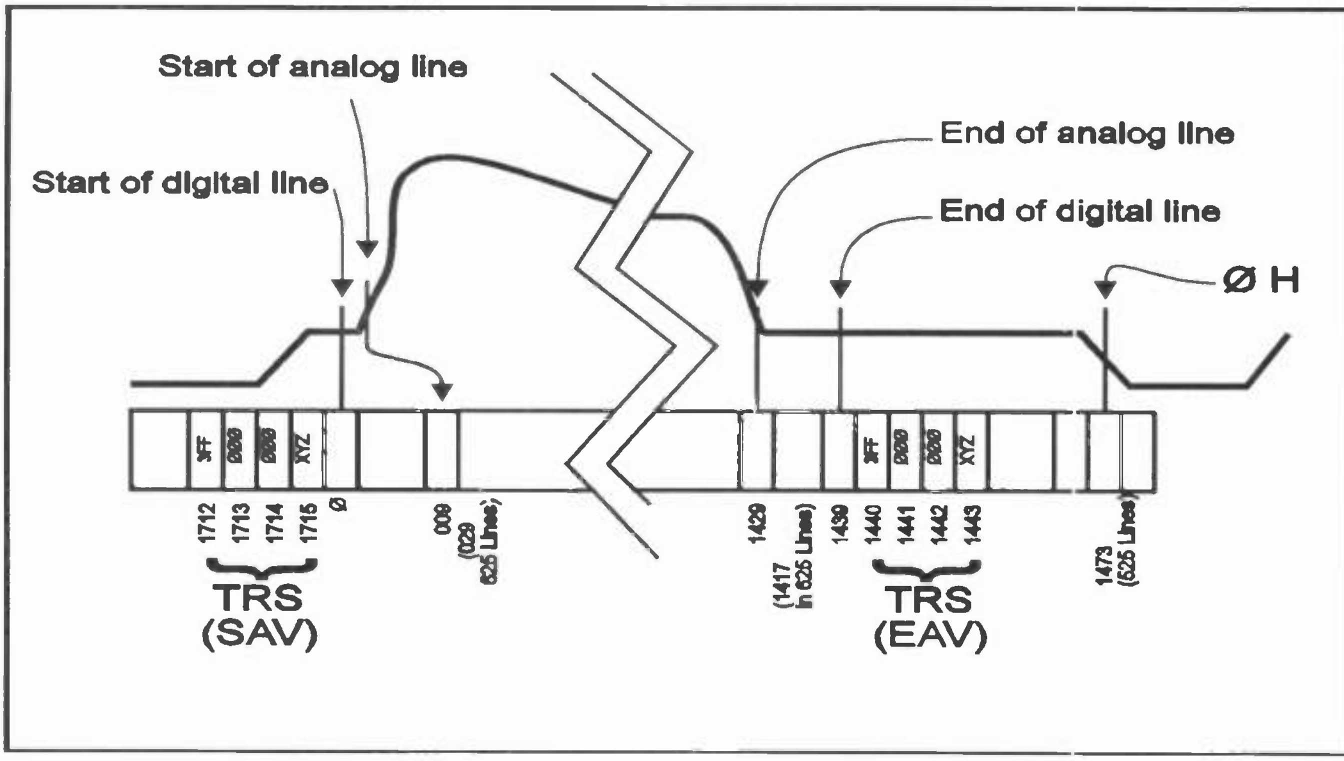

Figure 5 - Sample positions in digital video data stream.

Figure 5 shows the position of samples in the data stream. Troubleshooting synchronization problems should always include an analysis of the position of the samples to insure that the TRSs are in their proper location. Digital video technology is new technology and manufacturers occasionally misinterpret specifications, in spite of the best of intentions. European documents often number the samples beginning at sample one instead of sample zero. This can lead to confusion. In addition, since all digital video equipment is microprocessor based, software bugs creep into designs and can cause problems like we have been discussing.

If all parameters are held within specifications, there is an excellent chance that digital video signal transfers will occur without error. In the case where visible faults are occurring in the video image, an analysis of these parameters will almost always reveal a deviation from the specification that is causing the visible fault. Thus, detailed analysis of the video signal offers valuable insurance against problems in digital video, plus allows the operator to effectively troubleshoot any problems that arise.

In cases of incompatibility between units, it is indispensable to be able to verify the conformity of outputs and the ability of inputs to accept standard signals. Problems of incompatibility are almost always traced to failure to observe the rules (standards) of technology.

The road to an all digital future is not a superhighway. There are still many potholes, and at times the road goes very close to the edge of the cliff. Troubleshooting digital video systems calls for an open mind, a clear thought processes, and a cool head. An educated, equipped engineer will find many rewards in the digital future.

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CUSTOMER SERVICE: NEW OPPORTUNITIES AND CHALLENGES

Steve Epstein
Intertec Publishing, Inc.
Overland Park, KS

ABSTRACT

Providing quality customer service to broadcasters and video professionals has always been a challenge. Part of the reason is that this industry operates 24 hours a day, 7 days a week, 365 days a year. Downtime can be extremely costly, even when it is as short as 30 seconds. System redundancy can provide some protection against downtime. However, when a portion of a redundant system fails, it must be returned to service as quickly as possible to maintain the security that redundant systems offer. Both manufactures and their customers have a responsibility to each other when determining and providing for customer service needs. With today's technology, new problems and solutions come in many forms, some of which did not exist until recently.

INTRODUCTION:

As a former Chief Engineer I have spent many years on the customer side of the line. As a freelance service provider I have also seen the other side -- the person the customer turns to when the system fails. Recently, one of my clients, a post-production facility, lost its character generator. It occurred during the weekend and luckily the unit was not needed for several days. First thing Monday morning the manufacturer was contacted so that a replacement could be obtained.

After contacting the company, it was determined that the board was out of warranty. Under the circumstances, replacement loaner boards are not offered. The only options available were to return the board for repair or buy a new one. At the time, turnaround for board repair was running 6-8 weeks. To be completely fair to the company, these products are sold through dealers, and the company expects the local dealers to provide for their customers. However, the local dealer, like many dealers today, did not stock replacement parts. This is not the type of service that video professionals have come to expect. Making matters even worse, obtaining an return authorization from the company involved exchanging multiple faxes over a period of more than a week. This process should be as easy as picking up the phone.

As an experiment, I placed a call to the Grass Valley Group, who had manufactured the facility's analog switcher. This particular switcher, a 1600 series, was manufactured nearly twenty years ago. When I asked, "How long would it take to get a replacement 1620 mix/effects module?" The reply was; "Tomorrow; and if you're close enough, we can get it to you this afternoon". *That* is the type of service video professionals require, and have come to expect!

THE REALITIES OF CUSTOMER SERVICE:

For manufacturers, quality customer service is expensive. Unfortunately, the lack of a sufficient level of customer service can be even more costly. Dissatisfied customers can prevent potential customers from even considering companies, regardless of the features and price point offered. To a manufacturer, the loss of current customers as well as a potentially significant percentage of new customers can spell disaster. If allowed to continue unchecked, loss of market share and an eroding customer base will eventually cause the business to fail. Under these circumstances, regaining old customers can be nearly impossible. Once this scenario has begun, the company's only hope is to attract new customers and avoid repeating the same mistake.

Providing customer service to the consumer markets can be overwhelming. Consumer products usually have much smaller margins and the customer's level of technical expertise is much lower. Professional level products may be sold by the hundreds, while consumer products tend to be sold by the millions. When millions of units are sold, the number of customer service inquiries can be enormous. Compounding the problem, the average consumer may be such that the calls can be unnecessarily long. Service representatives may waste considerable time simply determining the customer's level of understanding. At the consumer level, costs can be addressed by committing a predetermined amount of resources to customer service, say 30 operators, each on duty for 8 hours a day. Based on customer calling patterns, the operators can be deployed at appropriate times. Effective management can keep busy signals and the customer's "hold" time to a minimum, thereby minimizing customer dissatisfaction.

For video professionals, this level of service is generally less than acceptable. When a transmitter or production switcher has gone down, the engineer needs accurate information quickly and near immediate access to parts, rather than "minimum hold time." There is a distinct difference between consumer and professional service requirements. For professionals, equipment downtime usually means revenue loss; for consumers it is just an inconvenience. When equipment used in professional applications fails, the real cost of the failure falls into two categories: repair costs and revenue lost because the unit is out of service. Outside contract engineers or even the in-house engineer can cost several hundred dollars an hour plus expenses. Parts' costs are at a level few consumers can even fathom: $3,000 for a replacement head, or $60,000 for a replacement klystron, plus in many cases same- or next-day delivery. For broadcasters, transmitter or STL failure can renders the majority of the facility useless. In a post production facility, losing a switcher or electronic editor can mean an entire suite is out of commission.

Under these circumstances, the repair costs are overshadowed by the amount of revenue being lost. Since the actual numbers vary, this may not always be the case. However, it has been my experience that the first question asked is "When will it be repaired?" not "How much will it cost?" The cost factor enters into the equation only later, usually in the form of "Was it worth it?" Based on this, what the customer needs is access to assistance. This can take on many forms. The fax machine allows orders to be sent in anytime, but it is little more than a convenience under these circumstances. Automatic fax-back services and bulletin boards offer 24 hour access to technical information if they are maintained and have the desired information. On-call service personnel are even better. Having someone on the other end of a crisis goes a long way toward its solution. As an example, years ago I was working at a Wichita TV station. We had been using VPR-80s with a parallel editor and were installing the ACE editor for serial operation. Everything was installed properly, but the system would not work. To no one's surprise, the production department had a client scheduled for the next day to show-off the new capabilities.

Calls to Ampex eventually got me in touch with the Product Manager. He was at the LA Olympics, watching over machines that were in use for the broadcast. As it turned out, the machine configurations were similar, and they had also discovered the problem. Software experts had located the software bug and burned new PROMs. Unfortunately those PROMs were the only ones that existed and were still considered experimental. Luckily, the Olympics were over that evening. At the conclusion of the broadcast, the Product Manager pulled the PROMs from the machines and overnighted them to me. They arrived at my home the next morning. I went to work and installed them. They worked perfectly, and the editing session went off without a hitch.

WHAT MANUFACTURERS SHOULD OFFER:

In a perfect world, everything would last forever, including the comprehensive replacement warranty. However, this is not a perfect world. Many of the parts inventory regulations for consumer products do not apply to professional equipment because of limited production runs. As stated before, service expectations vary as well. Ideally, the manufacturer's service and warranty policy should be brought up early in the investigative stage, long before the sale is closed. Unfortunately, professionals in this industry have come to expect a level of service and simply assume that every company will provide it. Companies that do provide that level of service are more than happy to discuss their policy with potential customers. On the other hand, companies that do not are not about to advertise the fact. Because of this, it is up to the customer to investigate the matter and determine what level of service is offered. In most cases, professionals in the broadcast and post-production industries require the following:

- **Telephone access:** 24 hours a day, 7 days a week. At the low end, this could be a message on an answering machine that provides a number for after hours emergency service. At the high end, a direct dial number to a service technician is provided.
- **Timely parts delivery:** To most engineers this means overnight delivery. Anything longer is not acceptable. Same-day service would be great.

However, the logistics are such that this is not always possible.

- **Quick turnaround:** When equipment is returned to the factory for service, "rush" service (less than a week) must be an option.
- **Loaner equipment:** Depending on the situation and the equipment, some level of exchange or loaner equipment should be available. This allows the customer to get back in operation while their equipment is being repaired. This may be preferable to "rush" service, as it allows the customer to be fully operational almost immediately.

As you can see, the list is rather short, but providing this type of access can be expensive. From a company's point of view, the costs can be handled in one of two ways. The first is by charging the customer directly. This option is used by many of today's software providers such as Aldus and Corel. Customers can call in with credit card in hand and register. Once registered, they are put through to a service provider. Charges are based on a per minute as well as per call basis. A slight variation is to provide each registered software owner with 15 or so free minutes. Once the free minutes are used, billing is begun. Microsoft offers another variation: 90 days free support for developers. Rather than starting when the software is purchased, the 90 days start when the first call is placed. During the 90 days, there is no limit to the number of minutes allowed.

The second method is to view customer service as overhead, and figure the estimated cost into the equipment price. This method is widely used in the broadcast industry, and is one of the reasons professional equipment costs so much. Many times when this method is used, replacement board sets, parts inventories and full-time service technicians are figured into the equation. All of these items increase the manufacturer's costs, and all contribute to higher initial prices for the equipment due to the overhead involved.

There are several ways manufacturers can provide for the needs of their customers. Fax-on-demand can be very helpful during initial installation. Setting up a fax-on-demand system may be costly initially, but, ongoing costs are considerably less. I have utilized these systems many times on service calls. A client may need a new board installed in a PC, but does not have any of the original system documentation. Being able to obtain jumper settings and pinouts for undocumented equipment via fax-on-demand is extremely helpful. Along these same lines are the manufacturer BBSs. As systems become more and more software dependent, obtaining upgrades via modem can be very convenient. PROM coding (firmware) could be sent out in this manner, as well.

Complete documentation is also very helpful. Being able to look at a schematic or block diagram can simplify the troubleshooting process. Most manufacturers in this industry provide relatively good documentation, but many times it is incomplete. Part of the documentation should detail the process of obtaining help. Direct numbers to parts, service and sales should all be specified, as it can be difficult to obtain the emergency service number from the main number after hours. Among the things that can be done from the manufacturers standpoint are having voice mail or answering messages that contain the necessary information. For example, the main number should have a message that gives direct numbers for service, parts and emergency service if available. Having a fax number included in this message is also helpful. The service department message should also have the emergency service number and fax-on-demand and BBS numbers. By setting the answering messages up in this manner, technicians can call in at 2 AM and obtain help, even though no one is available. Many times I have installed new software only to find the monitor, printer or network drivers are not up to date. By calling the tech support line, I have obtained the BBS or fax-on-demand numbers. Subsequent calls to those have provided me with the information and software I needed. As often as not, these calls take place on the weekend when service personnel are not available. Despite this, I have been able to obtain the information quickly and easily. With today's technology, I am amazed at how many companies do not provide these services.

Another avenue for companies to explore is the information that is available on hold. Most of the time it is music, which may be nice to listen to, but not very informative. Recently I received a two-program software package. Each program had its own install disk, but, the documentation stated that a master install disk was included and should be used. After two failed attempts to install the software, I contacted the company. First, I had to register this copy since I was not a registered user. The registration process was automatic, but was the last step in the install sequence. Once I made it through that process, I was put on hold to wait for a technician. It was a ten minute wait, listening to elevator music. Once the technician answered, his first question was if I was having trouble installing from the master disk. I answered that I was, and he said that it was a known bug and the solution was to simply use the install disk of each program, instead of the master disk. Ten to fifteen minutes wasted to find out they knew about the problem! Why that information was not part of the hold message along with the elevator music, I don't know. It would have saved both the technician's and my time along with the company's money.

WHAT CUSTOMERS SHOULD PROVIDE:

Now that we have looked at the manufacturers, let's turn to the customers, who also have a responsibility to the manufacturers. In general, this means responsibly using the services offered. Specifically, don't waste their time. All engineers and technicians have gaps in their knowledge, and therefore may not know the specifics of a system. They should be able to admit that and take time to learn the system instead of expecting a short training course over the phone. Operators and some management, however, may not be technically inclined and should not call a service department unless it is absolutely necessary. Regardless of who makes the call, there are several things that should be done beforehand, among them:

- **Read the manual:** Unfortunately, too many pieces of documentation go unread until a problem occurs. At that point the pressure is increased and critical points can be easily overlooked. Read and become familiar with the manual before there is a problem. Understand the problem as well as possible before placing the call.
- **Equipment specifics:** Model and serial number should be handy. In addition, the approximate age of the equipment, the software and firmware versions and any installed options should be known.
- **Problem specifics:** Have ready an exact description of the problem, including whether it has happened before, what was happening when it occurred and is it repeatable. Any and all unusual symptoms that may be related to the problem should be relayed to the manufacturer's service representative.
- **Have access to the problem equipment, and have a phone nearby:** When the call is placed, have the equipment powered up and in front of you. If the technician needs specific information, it can be accessed immediately.
- **Have an operator nearby:** Many technicians can repair equipment they cannot operate. If that is the case, have a skilled operator nearby to assist in the troubleshooting process and verify that proper operation has been restored.

As you can see, there is considerable work that needs to be done prior to calling the manufacturer. In a crisis much of this is overlooked and should not be. If you work in the facility on a daily basis, most of the work above can and should be done long before problems occur. Being prepared can make it much easier to locate the needed information in the manual and troubleshoot the problem yourself. When you do call, be patient. Even though the technician at the other end may be familiar with the equipment, some problems just don't make sense. Explain the details and allow the technician some time to think. Try not to interrupt the thought process; and be prepared to answer questions. Many technicians compare this type of troubleshooting to doing brain surgery over the phone. It is not easy, and the technician is entirely dependent on the eyes and ears of the person in front of the equipment. It has happened to me many times: If I get an accurate description over the phone, the solution becomes obvious quickly. Poor descriptions usually result in long, unproductive phone calls and many times require an on-site service call.

CONCLUSION

Quality customer service, like equipment downtime, is an expensive proposition. Reducing the costs while providing the required level of service is a challenge that lies in the hands of both manufacturers and their customers. For the broadcast and post-production industry, the level of service required is substantial. Video professionals have unique requirements that manufacturers marketing to this industry should be aware of and address. At the same time, video professionals must use those resources in a manner that makes it possible for the manufacturer to continue to provide those services and remain in business. The next time you consider buying consumer equipment for professional use, check into the customer support being offered and make sure you can afford the lower-priced consumer equipment. Depending on the equipment, and its intended use, you may find that it is far more cost-effective to spend double or triple up front, knowing that if there is a problem, the manufacturer is ready, willing and able to stand behind the product and keep your losses to a minimum.

SIGNAL MONITORING IN THE TRANSITION FROM ANALOG TO DIGITAL

Mark J. Everett
Videotek, Inc.
Pottstown, PA

ABSTRACT

There is a great challenge in the presentation of signal monitoring information for digital video. User surveys revealed that most operators and some engineers have difficulty understanding the presentation of purely digital information. The relation of a set of eight or ten bit numbers to reality of the video presentation was lost to many. It became apparent that most operators and engineers depend upon picture monitor displays and then on transcoded analog outputs to determine picture quality. This paper presents a concept which takes a serial component digital input and develops a analog component waveform or analog composite waveform for display on analog component or serial digital component picture monitors.

INTRODUCTION

Television, in both the original picture and in the final presentation, is analog. We have been going through and, to some degree, are still in a long transition expanding the use of digital representations of this analog picture. One of the most significant advances in the last decade was the development and implementation of component serial digital production and recording equipment. While this concept (digital video) does not have the resolution of the original analog, it's extreme advantage is the near perfect reproduction over multiple generations of recording and processing. The problem is the evaluation of the process. As many of the users of digital video come from the analog domain, and since the skills of many operators and technicians do not include an in depth understanding of the purely digital representation of video, measurement of video signals presents a challenge to the equipment designer.

The first, and obvious, solution which most equipment designers came up with was a measurement instrument which functions in a fashion similar to that of a logic analyzer. The best known method currently available to determine the content of a digital video bit stream is via logic analyzers which have been around for quite a long time. This method has some distinct positives and negatives. The first positive is that the results are exact. There are no on screen estimations which are subject to variable interpretations. Then there are trigger points. When you set a logic analyzer to trigger on a certain sequence of data, it does just that. No almost points, no missed points, just exactly what you want.

Much of the composition of a digital video bit stream lends itself very well to these logic analyzer functions. In serial ITU-R 601 and component serial SMPTE 259 data, there are many events which are ideal for data interpretation and display type of function. Events like SAV (Start of Active Video), EAV (End of Active Video), line length, valid video data, valid checksums and many others are easily, accurately and correctly evaluated by these type of units. Operators can easily get information when there is a problem or error in their video signal data or data format.

VIDEO MEASUREMENTS WHEN THE DATA IS CORRECT

I interviewed a large group of users of serial digital equipment to determine their wants and needs with respect to the traditional signal evaluation most operators and technicians are required to complete. I was surprised to learn that the large majority of these users were trusting the presentation on a high quality analog component monitor. There were measurement scopes and logic analyzers available, but the far majority of evaluation was based upon the presentation on the picture monitor. The tougher question was related to what they feel they really need to do their job. Let's look at some of the obstacles.

First, digital video is great, but component analog is better. At least if you don't have to make a tenth generation copy in analog. Lots of users have significant investments in analog monitors, many of which are very good and many of which have component analog capabilities. I was surprised to see component analog monitors in the master monitoring positions in these suites, but the economics are tough to argue with. A CAV presentation on a monitor is capable of much wider bandwidth than digital, and without the hard frequency limitations of 601/259 digital video.

Next, they are very happy with looking at a picture monitor as the main source of picture quality judgement, with the assumption that there is a means available to view a waveform display. It became fairly clear that camera automatics (gain, black, iris, etc.) work very well. On the subject of waveform displays, it was equally clear that some users want displays in RGB format, some want displays in Y, Cr, Cb format and still others want waveform displays in an encoded composite analog format.

Then, answers also indicated the desire for alarm indications when obvious, and not so obvious, digital parameters are violated. The anticipated parameters included gamut errors, EAV and SAV errors, absolute high and low video level errors, loss of data, invalid line length and invalid line count, plus others.

The sum total of the requests resulted in a concept which accepts a serial component digital video input, is video screen based, capable of various analog raster displays, capable of reporting digital rule violation alarms and output the display on either component analog or component serial formats. Quite an order, and surprising in the simplicity of the concept. The not too often stated, but obvious other requirement is that the output picture must not be impaired by the process. The operators and technicians want a serial digital monitoring device which is essentially passive. It should monitor the digital stream constantly, while the user simply views the input serial digital picture either in the analog or serial state.

The requests for control options were many, but all boiled down to three basic needs. Local front panel control, with easy access to common display functions, extended local control with the same ease of access and operation, and remote control. The reason for remote control is to allow for the potential use of automation to call certain specific function of the display device under unique external conditions.

IMPLEMENTATION OF THE SOLUTION

We set about to design a display device which would impress display information over input video. We had already had experience in the design of an analog display device for composite and component 525/60 and 625/50 analog video. Much of the basic concept would be held, and some new features would be added. The concept of a waveform display over video on a picture monitor is not new, but the addition of digital component video into the mix is innovative.

Input treatment is fairly straight forward. The two inputs to the instrument are both immediately de-serialized for ease of processing internal to the unit. The next step is an input multiplexer which is controlled by the main system controller unit. The multiplexer selects from input A or B or an internal calibration signal. At this point in the process, all characteristics of the signal remain completely in place, just de-serialized. From this input selection, the parallel digital signal has three main paths.

The primary path is to the control and timing section. The requirement of an input of 601 or SMPTE 259 Serial Digital Video set some very strict boundaries, and left only the detection of 525/60 or 625/50 source material. The definition of this digital signal allows for either 8 or 10 bit encoding, but the display is only enhanced where 10-bit is used rather than 8-bit. The control and timing detector therefore only looks at the line count, and has a window of ±10 lines to determine 525 or 625 format input. We considered counting line elements, as there is a difference here also, but you notice we left a large margin for error in the basic line count detection so we could be sure that we are in the correct ballpark before making more exact judgements. This control and timing block has more functions which will become obvious. After the line count determines the format of the source, some finer quality judgements and "measurements" can then be made. Since it is apparent that we have to do some data examination, certain other data elements can be examined for conformance to the rules of the definition of the signal. We look at the data and check SAV, EAV, line length (525 and 625 video have different line lengths, but both are defined), number of lines (here we do an exact count), legal video limits (there are reserved data values at either end of the range where video is excluded), blanking length and protection bits. All of this data is checked and an error count is maintained for use in notification of the operator of any error, if requested. From this point, the parallel data is fed to three digital to analog converters for the next step in the display processing.

A second path out of the input multiplexer is fed to a fairly elegant circuit which accepts a parallel 601 data stream and develops a composite analog (either PAL or NTSC) video signal. The developed display has two distinct uses: First, the encoded video provides an alternately encoded waveform display which is available as a user choice in the selection of display formats. Secondly, the encoder delivers a composite signal to the rear panel of the unit for simple viewing. This confidence and monitoring feed is not intended as a fully reconstructed encoded output.

A third path out of the input multiplexer directs video to the final output serial option for use in bypass and 100% picture mix. Bypass is a mode where the signal is not processed, yet passes through the instrument. It is still evaluated for all of the digital errors (as well as analog errors like gamut and sync reference) and yet the user expects a clean and unmodified signal at the output. To make things slightly more complicated, a picture mix and picture key mode are available in the unit to mix or key between the input video and the display information. In cases where the user selects 100% picture, we again want to present a clean picture. The parallel video from the multiplexer is therefore routed to the output serializer and switched in those cases where full input video warrants.

Returning to the main signal path, the next function is to prepare for the display mixing. We evaluated mixing in the digital domain and in the analog domain. Cost factors were considered and display requirements were also considered. It might be argued that mixing a 601 signal in a purely digital environment is desirable, but we had to factor the user requirement of a primarily analog display. We also determined that an analog display signal impressed on an analog background simply looks better than the same set done in a 601 environment. The choice to work the display function in analog being made, then required the signal be converted from serial to analog and filtered to comply with the 601 suggestions. Three sets of DACs and filters are employed and now the input is in the analog format.

Once in the analog form, the signals can be transcoded, as the user requires from one color space to another. Some of the users want to view the 601/259 signals in their native Y, Cr, Cb formats and some prefer RGB displays. While looking at the color space, gamut violations can be determined for additional information to the error and alarms group. Here also, speaking of alarms, is the place where the input serial digital is compared to a reference analog signal, if present, to determine if the input is synchronous with the reference. The transcoders also provide required gains and offsets for the remainder of the analog processing portion of the system.

From this point on in the analog processing portion of the concept, the unit works in a fashion similar to any raster based analog display system. Some features have been added to this portion of the system to comply with user requests based on experience with analog instruments. There is a small debate among users as to which type of picture and display combination is best, mixed or keyed. We decided to allow the choice of either in the digital implementation, and have included a menu choice to select mix or key and the percentage of the background mixed into either choice. The display presentation was also an issue. The choice of full screen and partial screen displays left open the discussion of how much of a partial screen is partial. Two reduced screen formats were considered and both a half and a quarter screen display, (which are truly quarter and sixteenth in total screen space) were selected. It is here, in the display generation section, where the converted analog composite waveform generated by the parallel to composite converter mentioned earlier, is available for use as an alternate display format as a waveform display over the component video. The encoder is controlled by the 525/625 detector to produce PAL or NTSC as dictated by the detected input.

The display board output will take the generated display and again transcode the component analog video with the added display into a user selected format to suit the display monitor: color difference or RGB. At this point the user connects to an analog component monitor to view the process. The reason for this approach, again, is because the requirements of the users was for a display of serial digital on an analog component monitor.

There is also provisions for a serial output. This output has an A to D converter to take the component analog video with the added display information and develop a 601/259 signal for viewing on a serial component digital monitor. As mentioned earlier, this serial output is the third portion of the system which receives the selected parallel input from the input multiplexer. In cases where the unit is selected to bypass or 100% picture modes, this input is switched directly to the output serializer to minimize processing errors to an otherwise straight through digital input. The 601/259 signal is simply de-serialized and then serialized without any other processing in the bypass mode.

CONCLUSIONS

Signal quality measurements and judgements in today's systems require both qualitative and quantitative measurements. One of the main problems in the transition from analog to digital is that the qualitative judgements are made via analog waveforms, vector and picture displays. Digital instruments are ideal for the quantitative judgements, and the user of video equipment in the digital world needs both analog and digital tools to judge the performance of his system. Since our original sources and final display are analog in nature, it is not too surprising that we still have to use some amount of analog representations to judge performance of a system. Our goal is to determine purely digital means of determining that the output looks just like the input, and maybe one day we have that means in the digital world.

Until that time, we will have to rely on some human judgement by looking at analog representations of the original. We certainly today have some purely digital judgements we can make, and very accurately, so the real answer for today is somewhere in between. We can use the best of both worlds as we strive towards the ultimate solution for assurance of video quality.

DIGITAL VIDEO: NEW TECHNOLOGIES FOR THE 1996 OLYMPICS

Wednesday, April 12, 1995

Session Chairperson:
Charles Jablonski, NBC, Inc., New York, NY

***BELLSOUTH'S BUILDING OF THE BROADCAST TECHNOLOGY FOR THE ATLANTA 1996 OLYMPIC GAMES**
Manolo Romero
Atlanta Olympic Broadcasting 1996
Atlanta, GA
Paul Harman, Marc Hayes, Bill Smith
BellSouth
Atlanta, GA

***NEW BROADCAST TECHNOLOGIES FOR TELEVISING THE 1996 OLYMPICS**
Kenneth Fuller, Philip Paully
NBC, Inc.
New York, NY
George Wensel
NEP
Pittsburgh, PA

***ALLOCATING SPECTRUM FOR THE OLYMPICS**
Louis Libin
NBC, Inc.
New York, NY

*Papers not available at the time of publication

TECHNICAL REGULATORY ISSUES PART I: RADIO AND TELEVISION

Wednesday, April 12, 1995

Session Chairperson:
Dane Ericksen, P.E., Hammett & Edison, San Francisco, CA

FCC TOWER REGISTRATION—PROGRESS REPORT
Robert D. Greenberg
Federal Communications Commission
Washington, DC

FM AND TV BROADCASTING IN THE MEXICAN AND CANADIAN BORDER AREAS—COMPLYING WITH THE NEW AGREEMENTS
Robert D. Weller P.E.
Hammett & Edison
San Francisco, CA

***OSHA REQUIREMENTS FOR BROADCASTERS**
Robert Curtis
OSHA
Salt Lake City, UT

****PANEL—BROADCAST AUXILIARY ISSUES**

Richard Smith
FCC
Washington, DC

Richard Rudman
KFWB
Los Angeles, CA

Howard Fine
FCC

Gary Patrick
NTIA
Washington, DC

Chris Imlay
Booth, Ferret & Imlay
Washington, DC

PANEL—RFR ISSUES

Robert Cleveland
FCC
Washington, DC

Robert Greenberg
FCC
Washington, DC

William F. Hammett
Hammett & Edison
San Francisco, CA
Washington, DC

Jules Cohen
Jules Cohen & Associates
Washington, DC

Robert Curtis
OSHA
Salt Lake City, UT

Barry Umansky
NAB
Washington, DC

*Papers not available at the time of publication
**Papers were not solicited from panelists

FCC TOWER REGISTRATION PROGRESS REPORT

Robert D. Greenberg
Federal Communications Commission
Washington, DC

ABSTRACT

This paper will review the Federal Communications Commission's (FCC) current practices in authorizing towers, problems the Commission and its licensees have had over the years, and a Commission proposal which will streamline the tower authorization process. For the purpose of this paper, the terms antenna structure and tower are interchangeable. These terms refer to any structure that is itself an antenna, or has an antenna on it, and is subject to FCC rules.

INTRODUCTION

On January 12, 1995, the Commission adopted a Notice Of Proposed Rule Making (NPRM), WT Docket No. 95-5, which proposes to streamline the Commission's antenna structure clearance process. The proposed process will replace the current clearance procedures, which apply to licensees and permitees, with a uniform registration process for structure owners. As part of this proceeding and in keeping with updated recommendations by the Federal Aviation Administration (FAA), the Commission proposes to revise Part 17 of the Commission's rules entitled "Construction, Marking, and Lighting Of Antenna Structures." The Commission further proposes to revise applicable sections of the Commission's rules making antenna structure owners primarily responsible for the maintenance of obstruction marking and lighting. The Commission believes that these proposals will simplify and expedite the processing of authorizations involving FAA coordination.

It is anticipated that a Report and Order will be adopted in 1995.

WHERE DID THE TOWER STANDARDIZATION IDEA COME FROM?

In processing thousands of applications over the years, there were parts of the processing system I thought could be improved. For example, I did not understand why there were so many different forms and procedures, depending on which service and Bureau you were dealing with, for getting a tower approved by the FCC. It seems to me a tower is a tower, whether there is a broadcast antenna or a cellular antenna on it! Also, today if a tower owner increases the height of a multi-use tower, all broadcast licensees on the tower must file construction permit and license applications to reflect the increased height of the tower even though there is no change to their transmitting facilities. See 47 C.F.R. Section 73.1690(b)(1) entitled "Modification Of Transmission Systems." This seemed very bureaucratic to me.

So when the call came from the Chairman in 1992 for ideas for Total Quality Management ("TQM") teams, I suggested this one. My idea for a Tower Standardization Team was selected and I was chosen to assemble a TQM team to look for a solution to the problems. I chose two people from each of the following Bureaus: the Private Radio Bureau; the Common Carrier Bureau; the Field Operations Bureau; and the Mass Media Bureau. The eight members of the team had over 153 years of FCC experience. These people were selected because they knew the processes and system, and would be willing to identify pieces of the puzzle that could be improved. For a year and a half, the team met once every two to three weeks for 2 hours.

The team members chose me as their team leader and, with a facilitator, we started down the road to reinvent the tower process, even before it became fashionable. I must say it has been an interesting trip.

OBJECTIVE / OPPORTUNITY STATEMENT

Part of the FCC's Total Quality Management movement included the formation of quality teams to solve problems throughout the agency. The quality teams use a problem solving process developed by the FCC to:

(a) find permanent solutions to problems rather than "band-aid" fixes;
(b) build quality into FCC processes; and
(c) improve customer service.

The first step of the problem solving process is to create an opportunity statement. An opportunity statement basically focuses a quality team on a specific goal by describing exactly what results a process is producing now and what it should be.

In achieving our goal with respect to improving the antenna clearance procedures, our team developed the following opportunity statement:

"Reduce the additional time to process requests for changes in coordinates, height, and obstruction marking and lighting ("OML") involving existing antenna structures from **32** to **10** days."

MAGNITUDE OF REQUESTS

At the outset, it is important to note the number of requests the Commission receives. These requests are both applications and notifications. For instance, in the Mass Media Bureau, changes in coordinates or height require an application, while a change in obstruction marking and lighting requires a notification. In either case, an authorization should be issued. In 1993 the Mass Media Bureau received 3,468 such applications and 540 notifications. In the Common Carrier Bureau, there were 1,404 applications, while in the Private Radio Bureau, there were 11,496 applications. The Field Operations Bureau conducted 1,296 investigations in 1993 involving existing antenna structures.

COST OF POOR QUALITY

Due to the proliferation of antenna structures in the United States in the last ten years, methods and procedures at the FCC that were once workable have become inefficient and cumbersome. One of the text book definitions of the cost of poor quality ("COPQ") is that it can cause a significant drain on resources and can have a strong negative impact on how customers view the services or products of the organization. The COPQ can also demonstrate the potential for savings or redirection of effort to more productive tasks.[1]

The team assessed the cost of poor quality involving these four Bureaus. This cost was calculated at the rate of one worker hour per request multiplied by the number of requests times the average salary of the worker. In the Field Operations Bureau, the cost was calculated at the rate of eight wasted hours per investigation involving antenna structure data. The "worker hour" consists of finding the correct coordinates in the tower query data base if it exists. If not, coordination with the Support Services Branch in Gettysburg is required to confirm whether they have the antenna structure information, whether this information is correct, and whether the FAA responded with the correct coordinates, height and obstruction marking and lighting. The internal cost is approximately $500,000 per year. The staff also informally surveyed six engineering consulting firms, who estimate that their total expenditures for preparing multiple application filings involving the same antenna structure exceed $320,000 per year.

ROOT CAUSES

The team initially considered 24 possible root causes. This number was eventually reduced to the following six:

1. Different coordination methods between the Bureaus and the Support Services Branch (SSB) in Gettysburg.

2. The method for modifying FCC tower data and advising (multiple) licensees is inefficient.

3. Rules differ from Bureau to Bureau for accepting tower information changes.

4. Any redefinition of coordinates or increase in tower height at multiple use sites results in multiple applications.

5. Tower data is sometimes inconsistent; difficult or sometimes unable to access different FCC data bases.

6. All tower authorizations do not contain uniform information (e.g., coordinates, height and OML).

PRIMARY ROOT CAUSE

Eventually, one primary root cause was identified. Specifically, each Bureau has a different method regarding coordination with the Support Services Branch (SSB) in Gettysburg. For example, the team found that different forms, procedures, and even different units of measure (e.g., meters vs. feet) are used. To address this root cause, the team recommended that the agency adopt a Commission-wide uniform procedure for authorizing changes in tower height, coordinates, and obstruction marking and lighting involving existing antenna structures.

MULTIPLE USE ANTENNA STRUCTURE

We have determined that there is an average of 12 licensees per antenna structure. What happens to each of these licensees when the owner raises the tower 20 feet, **or** the location is actually different than what is shown on the authorization, **or** the owner changes from red lights to strobe lighting? In each case, every licensee's authorization must be modified.

The Commission, however, is not consistent in how it processes these changes. Some licensees will automatically receive a modified authorization without submitting an application; others will receive a notification indicating that their tower parameters have changed and they must file an application to modify their authorization; still others will receive nothing at all but are none the less responsible for obtaining a modified license. The end result is licensees on the same tower sometimes have different marking and lighting specifications on their authorizations.

We believe that instead of modifying each licensee's authorization, it would be better to make one person - the tower owner - responsible for tower information and obstruction marking and lighting. To give you a better understanding of our proposal, let me briefly explain the current process.

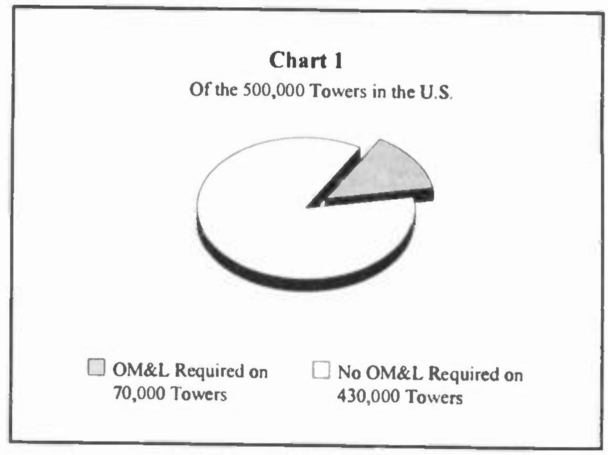
The FAA requires notification prior to construction for all structures over 200 feet above ground **or** if they intrude into airspace, posing a hazard to air navigation. These structures include tall buildings, water towers, silos and antenna towers.

The FAA then conducts an air hazard study or determination for the proposal and **recommends** steps such as painting and lighting to prevent airspace obstructions from threatening the safety of flight. Legally, the FAA determinations are non-binding recommendations.

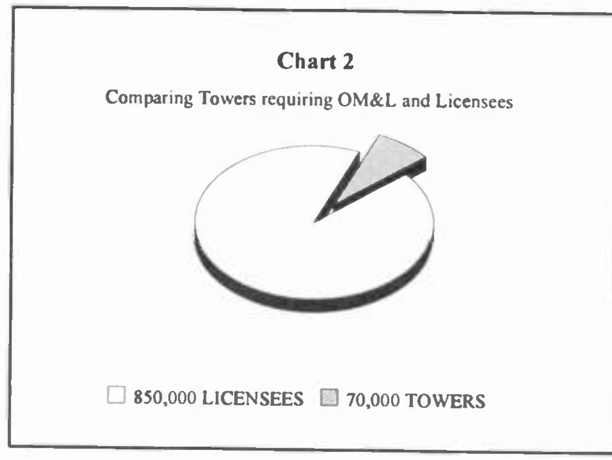
Statutory authority, on the other hand, has been given only to the FCC to enact and enforce regulations relating to antenna towers. The Communications Act directs the FCC to ensure that antenna towers are properly lighted and marked. The FCC relies heavily on the FAA's recommendations and normally issues obstruction marking and lighting **requirements** to its licensees accordingly.

The following two charts should give you some idea of the magnitude of our problem.

There are approximately 500,000 antenna towers in the United States. About 70,000 or 14% require obstruction marking and/or lighting.



As stated previously, we have determined that there is an average of 12 licensees per structure. So while on the surface this appears to represent a managable number, the present rules and procedures actually effect some 850,000 licensees.



Now that you have a general idea how the current process works, I will explain the team's proposed solution, which the Commission adopted in the NPRM.

RECOMMENDATIONS OF THE TOWER STANDARDIZATION TEAM

We proposed a unified, Commission-wide process for antenna structure registration because it will provide standardized information on towers and tower owners.

The FCC's Support Services Branch in Gettysburg will create a data base of towers and owners that can be used as a cross reference for all licensees on that tower. Each tower required to have obstruction marking and lighting will receive a unique registration number. This is in keeping with changes to Section 303(q) of the Comunications Act, which makes tower owners equally responsible for tower painting and lighting. This new procedure will reduce the number of responsible parties from 850,000 licensees to 70,000 tower owners.

What does this mean for tower owners? It means that they will be responsible for tower painting and lighting. They will have to do the initial coordination with the FAA by filing FAA Form 7460-1. Once they have a determination from the FAA, the tower owners would then file revised FCC Form 854 (Application For Antenna Structure Registration) with the FCC's Support Services Branch in Gettysburg. After the Support Services Branch clears the tower, they will issue FCC Form 854R (Antenna Structure Registration). This document will contain the unique antenna structure registration number, which will be good for the life of the tower. The tower owner will be required to provide a copy of the registration, FCC Form 854R, to all prospective and existing tenant licensees. Applicants needing FAA clearance for a new license on an existing tower will only have to refer to the registration number when submitting an application.

This new process will reduce the number of filings and expedite both routine clearances and minor change applications. For example, corrections to coordinates, changes in the tower height or changes to the obstruction marking and lighting will not require that each licensee on the tower submit a license modification to incorporate the changes.

This new process will also improve reliability and consistency of the data. Numerous entries for the same tower lead to errors. Because we will now collect information from one source - the owner - there will be less likelihood of errors than the present system of collecting information from multiple sources.

The new process will improve consistency of obstruction marking and lighting at multiple use tower sites. In addition, FCC rules for changing antenna structure information will be consistent. The new process will improve service to our customers through one-stop shopping!

For the first time we will provide access to a unified database for all to use. Ownership information will be available to the public, FCC field inspectors, and the FAA. And for structures previously cleared, applications will not be delayed due to hold-ups in antenna clearance procedures. The main improvement will be increased savings to the Commission and to the private sector.

COMMISSION PROPOSAL

The Notice Of Proposed Rule Making proposes to:

1. Encompass a whole new system for registering antenna structures;

2. Implement one Commission wide procedure;

3. Eliminate the filing of applications at multiple use sites when the only change to the structure is height or OML;

4. Create a new tower database accessible to all Commission staff, including Compliance

and Information Bureau field offices, other government agencies, for example the FAA, and the public.

5. Adopt a revised FCC Form 854 entitled "Application For Antenna Structure Registration." Tower owners will be required to file this form;

6. Adopt a new FCC Form 854R entitled "Antenna Structure Registration." The Commission will issue the registration. This form will include a new "Notification Of Antenna Structure Completion Or Disposal." This notification will be mailed back to the FCC so the FCC's database remains accurate.

7. Revise all bureau application forms;

8. Create a phase-in period for the new system.

BENEFITS

1. The Commission will save a half million dollars per year and private industry will save at least 321,000 dollars per year.

2. There will be less delay when processing routine minor changes; therefore, there will be better service to our customers.

3. This new system will streamline the coordination between Support Services Branch and the application processing branches.

Author's note: I would like to thank the members of the Tower Standardization Team for their efforts and insights over a two year period. The Tower Standardization Team members are as follows: Lisa Stover, Steve Markendorff, and Sid Briggs of the Wireless Telecommunications Bureau; Jim Voigt, Jeff Young, and George Dillon of the Compliance and Information Bureau (formally the Field Operations Bureau); and Robert Greenberg and Robert Hayne of the Mass Media Bureau. Special thanks go to Roger Noel of the Wireless Telecommunications Bureau for the help he has given the team and Sharon Bertelsen of the Mass Media Bureau for her role as facilitator. (Some members of the team worked in the Common Carrier Bureau and the Field Operations Bureau previously.)

Editor's note: The opinions expressed by the author are not necessarily those of the Federal Communications Commission.

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1. Take Charge Consultants, Inc., Downingtown, PA

FM AND TV BROADCASTING IN THE CANADIAN AND MEXICAN BORDER AREAS—COMPLYING WITH THE NEW AGREEMENTS

Robert D. Weller, P.E.
Hammett & Edison, Inc.
Consulting Engineers
San Francisco, CA

Abstract

New agreements between the United States and Mexico concerning FM Broadcasting and between the U.S. and Canada concerning TV Broadcasting went into force in 1994. Changes to other existing agreements and treaties between the U.S., Canada, and Mexico have occurred in the past several years. Failure of U.S. stations to consider the implications of the various treaties often results in applications being returned or processing delayed. The most current requirements of these various documents are reviewed and compared with FCC requirements.

INTRODUCTION

Broadcasters near the Canadian and Mexican borders are subject to bilateral or multilateral treaties, in addition to the rules of their own nation's regulatory agencies. The technical provisions of these treaties are often different from those specified in either of the respective government's regulations. Proposals that are not in compliance with applicable treaties may require special handling, such as notification or coordination between the governments concerned.

In the U.S., applications requiring international notification or coordination are to be avoided, since such applications are typically held by the FCC until a threshold quantity is reached, before being forwarded to the other administration for consideration. This procedure can tie up applications literally for years. An understanding of the various agreements is important to ensure expedient processing of applications.

TERMINOLOGY

The term "treaty" is both generic and specific. As a generic term, it refers to an international agreement "governed by international law, whether embodied in a single instrument or in two or more related instruments and whatever its particular designation."[1] In the United States, its restricted (specific) meaning denotes "international agreements made by the President with the advice and consent of the Senate."[2]

Most treaties affecting U.S. broadcasters are not treaties under the restricted definition. They are actually "Executive Agreements," meaning that they have been concluded by the Executive branch of the U.S. Government pursuant to or in accordance with existing legislation or a prior treaty, in accordance with the President's Constitutional powers. Agreements are typically signed by the ambassadors of the countries involved or, on behalf of the U.S., by an Office Director within the Department of State.

The details of the agreement or treaty are implemented in non-binding documents known as "working arrangements." These are typically negotiated and approved at the staff level. A list of treaties, agreements, and working arrangements related to FM and TV broadcasting that are presently binding on the U.S. appears as Figure 1.

Agreements with Canada

Agreement Relating to the FM Broadcasting Service and the Associated Working Arrangement (1991)

Agreement Relating to the TV Broadcasting Service (1994)

Agreements with Mexico

Agreement Relating to the FM Broadcasting Service in the Band 88-108 MHz (1994)

Agreement Relating to the Assignment and Use of Television Channels (1962)
Amended 1975, 1979, 1980, 1982, 1984, and 1988

Agreement Relating to Assignments and Usage of Television Broadcasting Channels in the Frequency Range 470-806 MHz (Channels 14-69) (1982)
Amended 1985 and 1988

Figure 1. Listing of Agreements relating to FM or TV Broadcasting between the United States and Canada or Mexico.

THE FM AGREEMENTS

U.S.-Canada

The "Agreement between the Government of Canada and the Government of the United States of America Relating to the FM Broadcasting Service and the Associated Working Arrangement" became effective in February 1991, replacing an earlier agreement that had been in force since 1947. It is expected that some stations, which had been authorized under the original 1947 agreement (and before the 1984 working arrangement that amended it) would be able to improve their coverage under the 1991 agreement.

The working arrangement for the 1991 agreement is virtually identical to the 1984 working arrangement and applies to allotments and assignments within 320 km of the mutual border, affecting the 22 states of Alaska, Connecticut, Idaho, Indiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, Montana, New Hampshire, New Jersey, New York, North Dakota, Ohio, Oregon, Pennsylvania, Rhode Island, Vermont, Washington, West Virginia and Wisconsin Five station classes are specified, as shown in Figure 2.

Spacing between stations is calculated using spherical Earth calculations, which express the number of kilometers as a function of latitude and longitude. The calculations reduce the spherical trigonometric functions to their power series identities, using the now obsolete Clarke ellipsoid of 1866, truncating the power series at two terms and introducing a "fudge" factor to define conversion of miles to kilometers. These calculations yield approximate, but incorrect, values.[3]

For stations exceeding the maximum height above average terrain specified for their station class, coverage equivalence is obtained by power reduction to prevent extension of the distance both to the 60 dBu F(50,50) class contour and to the appropriate interfering F(50,10) contour.

Limited (*i.e.*, short-spaced) assignments are permitted, provided there is no prohibited contour overlap. As in the FCC's Rules, the determination of prohibited overlap involves projection of protected and interfering contours from the existing and proposed stations, respectively. Unlike FCC Rules, the median (F(50,50)) field strength value for the protected contour is always 54 dBu, except for Class C stations, where it is 58 dBu. The interfering contour is projected with the F(50,10) curves, using desired-to-undesired ("D/U") ratios of 20, 6, -20, and -40 dB for co-channel, first-, second-, and third-adjacent channel assignments, respectively. The -20 dB D/U ratio required for second-adjacencies is considerably more restrictive than the present FCC requirement of -40 dB for commercial stations,[4] but identical to the present requirement for non-commercial educational stations.[5] Contour overlap need only be considered for land areas on the side of the border where the proposed station is located. That is, trans-border interference potential need not be considered. Additionally, zones lying entirely over water

Station Class	U.S.-Canada FM Agreement ERP	HAAT	Equivalent Distance	FCC Regulations ERP	HAAT	Equivalent Distance	U.S.-Mexico FM Agreement ERP	HAAT	Equivalent Distance
A (Mex)/A1 (Can)	3 kW	100 m	24 km	not defined			3 kW	100 m	24 km
A (U.S.)/AA (Mex)	not defined			6 kW	100 m	28 km	6	100	28
B1/C3 (U.S. & Mex)	25	100	39	25	100	39	25	100	45*
B/C2 (U.S.)	50	100	45	50	150	52	50	150	65†
C1	100	300	72	100	299	72	100	300	72
C	100	600	92	100	600	92	100	600	92

* distance to 57 dBu contour

† distance to 54 dBu contour

Figure 2. Summary of FM Station class definitions under FCC Rules, and the U.S.-Canada and U.S.-Mexico Agreements. Equivalent contour distances are 60 dBu F(50,50) except as noted. FM translators, with effective radiated powers not exceeding 50 watts, are permitted under the Agreements as Secondary, Low Power FM stations

need not be considered. While the procedure for calculating the interference area is specific with regard to the D/U ratios to used, the method of contour projection is somewhat non-specific. The number of radials (3 to 16 km) used to define the average terrain is not specified, nor is the number of radials on which contours must be projected.

Translators. FM translators are treated as Low Power FM ("LPFM") facilities, which are authorized on a secondary, non-interference basis. Effective radiated powers of up to 50 watts are permitted, provided the 34 dBu F(50,10) contour does not exceed 32 km in any direction. This is a significant limitation for translators at high sites, since a LPFM proposal 319 km from the border at 500 meters above average terrain (HAAT) would be limited to 0.7 watt, even though a full-service FM station would be considered fully spaced at that distance. All LPFM proposals within 32 km of the border require international concurrence.

U.S.-Mexico

The FCC is now accepting and processing applications for FM broadcast stations within 320 km of the Mexican border, subject to a new "Agreement between The United States of America and the Government of The United Mexican States Relating to the FM Broadcasting Service in the Band 88–108 MHz." The major change in the new Agreement is the inclusion of a method for developing allotments based on contour protection. There are a number of other changes in the new Agreement; many of these changes eliminate ambiguities and more closely align it with the current FCC Rules and with the U.S.-Canada Agreement.

New Station Class Definitions. The new Agreement recognizes and defines seven station classes, including the sub-classes AA, B1, C1, C2, and C3. The class definitions found in the new Agreement are generally the same as those presently contained in Part 73. The only differences are that "Class AA" in the new Agreement is equivalent to Class A under Part 73, and the reference height for Class C1 in the Agreement is 300 meters, rather than the 299 meters specified Part 73. The Class A defined in the new Agreement is equivalent to the old (3 kW) FCC definition of Class A.

Interestingly, class contour distances are not defined in the new Agreement; protected contour distances are, however, specified. For station Classes B1 and B, the class and protected contour distances are different, since class contours are always based on 60 dBu field strength. For Class B1 stations, the protected contour is based on 57 dBu field strength; for Class B stations, the protected contour is based on 54 dBu. Since the family of F(50,50) curves is not equally spaced, this may lead to slightly different permitted ERP values.

Class Relation	Canada Co-Channel 0 kHz	Canada Adjacent Channels 200 kHz	Canada Adjacent Channels 400 kHz	Canada Adjacent Channels 600 kHz	Canada I.F. 10.6/10.8	Mexico Co-Channel 0 kHz	Mexico Adjacent Channels 200 kHz	Mexico Adjacent Channels 400/600 kHz	Mexico I.F. 10.6/10.8
A - A	132 km*	85 km	45 km	37 km	8 km	100 km*	61 km*	25 km	8 km
A - AA	not applicable					111	68	31	9
A - B1	180	113	62	54	16	138	88	48	11
A - B	206*	132*	76	69	16	163*	105	65	14*
A - C1	239*	164	98*	90*	32	196	129	74	21
A - C	242	177*	108*	100*	32	210	161*	94*	28*
AA - AA	not applicable					115†	72†	31†	10
AA - B1	not applicable					143†	96†	48†	12
AA - B	not applicable					178†	125†	69†	15
AA - C1	not applicable					200†	133†	75†	22
AA - C	not applicable					226†	165†	95†	29
B1 - B1	197†	131†	70†	57†	24†	175†	114†	50†	14
B1 - B	223†	149†	84†	71	24†	211†	145†	71†	17
B1 - C1	256†	181†	106†	92†	40†	233†	161†	77†	24
B1 - C	259	195†	116†	103	40†	259†	193†	96†	31
B - B	237*	164*	94†*	74*	24†	237†*	164†*	65†	20*
B - C1	271†*	195*	115†*	95†*	40†	270†	195†	79†	27
B - C	274	209*	125†*	106†*	40†	270	215†	98†*	35*
C1 - C1	292†*	217†*	134†*	101†*	48†	245	177	82	34
C1 - C	302†*	230†*	144†*	111†*	48†	270	209	102	41
C - C	306†	241*	153†*	113†*	48	290†	228†*	105	48

* separation distance less than required in old Agreements. † separation distance greater than required in Part 73

Figure 3. Summary of FM Station spacing requirements under the U.S.-Canada and U.S.-Mexico Agreements.

Contour Protection for Short-Spaced Assignments. The most significant change associated with the new Agreement is the provision of "restricted allotments," which do not meet the spacing requirements. Power reductions and/or directional antennas can now be used to afford equivalent interference protection to existing facilities or allotments, in much the same way as Section 73.215 of the FCC Rules. This provision should allow many stations in the border area to increase their coverage.

In determining the required contour protection, field strength values are calculated in a manner similar to that specified in FCC Rules. Protected and interfering contours are projected at field strength levels appropriate for the classes of station involved. The protected contour is based on an F(50,50) value; interfering contours are based on F(50,10) values. The protected and interfering contour field strength values to be used are the same as those specified in Section 73.215.

Only the eight standard radials may be used for determining HAAT. When it is necessary to protect an assignment that is not along one of those radials, one must interpolate linearly between the two standard radials adjacent to the actual azimuth. Azimuths and distances are reported to the nearest degree and kilometer, respectively, but rules for rounding are not given. F(50,10) values resulting in distances of less than 15 km default to F(50,50) values. Values of HAAT less than 30 meters are replaced with 30 meters.

Translators. As with the Canadian Agreement, translators in the Mexican border area are considered LPFM stations. Although detailed technical requirements are specified, international notification is always required for FM translators within 320 km of the border.

THE TV AGREEMENTS

U.S.-Canada

The current "Working Arrangement for Allotment and Assignment of VHF and UHF Television Broadcast Channels under the Agreement between the Government of the United States of America and the Government of Canada Relating to the TV Broadcasting Service" is dated March 1, 1989, but did not become effective until January 5, 1994. Allocations and assignments within 400 km of the border are affected. Two zones are defined: "Zone I," which is identical to the Zone I defined in Section 73.609(a)(1) of the FCC Rules, plus a portion of Canada, which includes the major cities of Ottawa, Montréal, and Québec, and "Zone II," which includes all border areas outside of Zone I.

This and the previous agreements define "standard parameters," which are similar to the FCC maximum parameters at VHF within Zone I, but are significantly different at UHF and outside of Zone I. The limitations imposed by the standard parameters limited many UHF TV stations in the border area to 1,000 kW ERP. The new Agreement defines "maximum parameters," which are nearly identical to the maximum ERPs specified in the FCC Rules, but derating equivalence is determined from the distance between allotments and assignments, rather than the formulas involving HAAT used in FCC Rules.

Average terrain is calculated using the standard eight radials, at distances from 3 to 16 km from the antenna, rather than the 3.2-16.1 km specified in the FCC Rules. Channel protection (including adjacencies and the UHF "taboos," where appropriate) is based on distance separations, which are generally slightly less than those required under FCC Rules. In addition to the minimum mileage separations, lack of prohibited contour overlap must also be demonstrated for stations separated by less than a specified distance. As with the FM Agreement, trans-border interference potential is not considered, since protected contours are assumed to stop at the border.

Maximum distances to the protected contour are specified but do not apply for LPTV assignments. Specification of the maximum distance often has the effect of truncating the contour. Low Power Television ("LPTV") operation is permitted on a secondary (non-interference) basis.

U.S.-Mexico

TV stations operating near the Mexican border are subject to different agreements and working arrangements, depending upon whether they are VHF or UHF, full-service or low-power.

VHF Stations. The current "United States-Mexico VHF Television Agreement" became effective April 18, 1962. As with Canada, allocations and assignments with 400 km of the border are affected. Maximum parameters are identical to the maximum ERP specified in the FCC Rules for VHF low-band channels (*i.e.*, 100 kW), but are 0.1 dB higher for VHF high-band channels (*i.e.*, 325 kW vs. 316 kW). ERPs are calculated in the horizontal plane, rather than toward the radio horizon or in the plane of maximum radiation.

VHF TV Stations

Maximum ERP	Maximum HAAT	Minimum Distance* from Border	Equivalent 52 dBu† Service Radius
10 W	600 m	60 km	26.5 km
20	300	60	20.9
50	200	60	21.5
50	600	90	38.9
200	400	90	41.4
500	300	90	43.3
1,000	200	90	42.3
500	1,000	140	70.8
1,000	500	140	61.3

* 52 dBu is the average Grade B signal level for VHF TV stations.
† Distance is average of F(50,50) values for low and high-VHF curves.

UHF TV Stations

Maximum ERP	Minimum Distance from Border	Equivalent HAAT* for 36 dBu interfering signal
0.1 kW	40 km	100 m
1	60	100
10	100	100

* 36 dBu is the appropriate F(50.10) field strength to preclude interference to full-service UHF TV stations, assuming offset operation.

Figures 4A and 4B. Summary of operating parameter limits versus distance from the U.S.-Mexico border.

There is no power derating requirement for VHF stations at high sites. Assignments are based strictly on distance separation criteria. For the area along the border with West Texas shown in Figure 5, co-channel assignments must be 355 km apart. In all other areas, 305 km is required. For adjacent-channel operation 100 km is required in all cases.

For LPTV operation on VHF channels, the September 14, 1988 amendment applies. LPTV operations are on a secondary, non-interference basis. Operation can be authorized without international negotiation if the proposal is at least 60 km from the border, subject to height and ERP limitations. Permitted operations (not requiring international coordination) are summarized in Figure 4A.

HAAT is calculated along radials from 3 to 16 km, but the number radials is not specified. ERP is calculated in the horizontal plane along the azimuths toward the border area, so judicious choice of azimuth and elevation antenna patterns can yield very effective LPTV facilities that still comply with the agreement.

UHF Stations. At UHF, a 1982 Agreement replaced the former 1958 Agreement. Assignments within 320 kilometers of the border are affected. As with the Canadian Agreement, ERP is limited to 5,000 kW, but only power in the horizontal plane is considered. Maximum power facilities are permitted at locations up to 610 meters above average terrain, with the average terrain calculated along radials from 3.2 to 16 km. A chart is used to determine the maximum ERP at greater heights, but the results are virtually identical to the power derating formula given in Section 73.614(b)(5) of the FCC Rules.

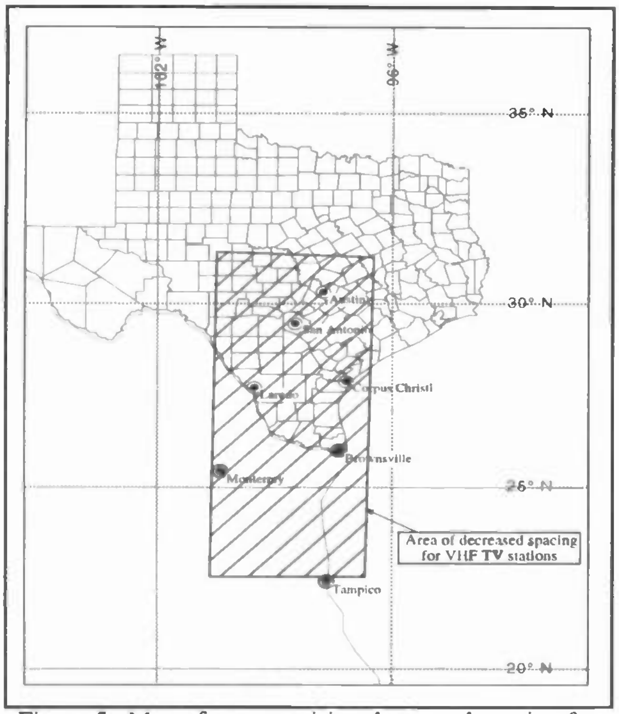

Figure 5. Map of area requiring decreased spacing for full-service VHF TV Stations.

For LPTV operation, both the 1982 Agreement and the October 19, 1988, amendment apply. Interference to full-service stations or land mobile assignments is not permitted. Operation can be authorized without international negotiation if the proposal is at least 40 km from the border, subject to ERP and HAAT limitations. Permitted operations (not requiring international coordination) are also shown in Figure 4B.

Unlike full-service stations, HAAT for UHF LPTV stations is calculated along radials from 3 to 16 km, but the number radials is not specified. ERP is calculated in the horizontal plane along the azimuths toward the border area, so judicious choice of azimuth and elevation antenna patterns can also yield very effective LPTV facilities that still comply with the Agreement.

SUMMARY

FM and TV broadcasters in the Canadian and Mexican border areas are subject to the requirements of various bilateral treaties. FM stations within 320 km of either border are affected. TV stations within 400 km of either border are affected, except that this distance is decreased to 320 km for UHF TV stations near the Mexico border.

The technical definitions used in the treaties vary, and an in-depth understanding of them can frequently allow coverage improvements.

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1 U.S. Department of State, Treaties in Force
2 *ibid.*
3 Comments of Hammett & Edison, FCC Mass Media Docket 86-144, June 6, 1986.
4 47 CFR §73.215(a)(2).
5 47 CFR §73.509(a).

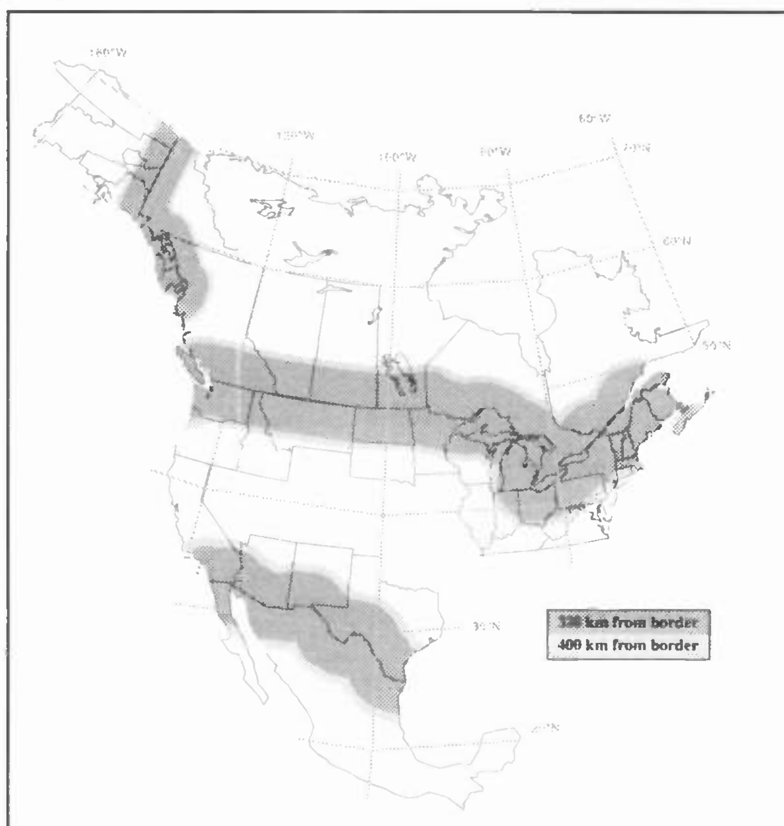

Figure 6. Map of areas affected by Canadian and Mexican FM and TV Agreements.

TECHNICAL REGULATORY ISSUES PART II: RADIO AND TELEVISION

Wednesday, April 12, 1995

Session Chairperson:
Dane Ericksen, P.E., Hammett & Edison, San Francisco, CA

**PANEL—UNATTENDED BROADCAST OPERATION

Richard Smith
FCC
Washington, DC

Harold Hallikainen
Hallikainen & Friends
San Luis Obispo, CA

Peter Burk
Burk Technology
Pepperell, MA

Muffy Montemayor
National Supervisory Network
Avon, CO

William Hassinger
FCC
Washington, DC

John Garziglia
Pepper & Corrazini
Washington, DC

**PANEL—EMERGENCY ALERT SYSTEM

Helena Mitchell
FCC
Washington, DC

Richard Rudman
KFWB
Los Angeles, CA

Frederick Baumgartner
KDVR-TV
Denver, CO

Gerald LeBow
SAGE Alerting System
Stamford, CT

Darryl Parker
TFT
Santa Clara, CA

Gregg Skall
Pepper & Corrazini
Washington, DC

**PANEL—FCC ROUNDTABLE

William Hassinger
FCC
Washington, DC

Richard Smith
FCC
Washington, DC

Larry Eads
FCC
Washington, DC

Beverly Baker
FCC
Washington, DC

**Papers were not solicited from panelists

TELEVISION RF WORKSHOP: MAINTAINING THE SIGNAL

Thursday, April 13, 1995

Session Chairperson:
Doug Garlinger, Lesea Broadcasting, Noblesville, IN

***SINGLE TUBE 60 KW UHF TV TRANSMITTER USING NEW DIACRODE TECHNOLOGY**
Timothy P. Hulick Ph.D.
Acrodyne Industries
Blue Bell, PA

***CIRCULARLY AND ELLIPTICALLY POLARIZED BAND IV/V UHF TELEVISION TRANSMITTING ANTENNAS FOR BROADCAST**
Geza Dienes
Andrew Corporation
Ontario, CA

A NEW TECHNOLOGY FOR ENERGY MANAGEMENT AND TUBE PROTECTION IN IOT TRANSMITTERS
Nat S. Ostroff
Comark Communications, Inc.
Colmar, PA
Wolfram Schminke
Thomcast A.G.

AN EXPANSION OF THE OUTPUT POWER RANGE OF ANALOGUE TELEVISION IOT SYSTEMS AND THEIR APPLICATION TO DIGITAL ATV
Geoffrey T. Clayworth
EEV Ltd.
Chelmsford, Essex, England

DUAL-CHANNEL COMMON LINE COUPLER
Dennis Heymans
Micro Communications, Inc.
Manchester, NH

MSDC KLYSTRON FIELD EXPERIENCE— 5 YEAR REPORT
Earl W. McCune
Varian Microwave Power Tube Products
Palo Alto, CA

*Papers not available at the time of publication

A NEW TECHNOLOGY FOR ENERGY MANAGEMENT AND TUBE PROTECTION IN IOT TRANSMITTERS

Nat S. Ostroff
Comark Communications, Inc.
Colmar, PA

Dr. Wolfram Schminke
Thomcast A.G.

ABSTRACT

This paper will describe a new approach to the control and management of the high d.c. energy associated with IOT transmitters. Traditional wisdom and manufacturers' specifications require that the IOT tube be protected from internal high voltage failures (arcs).

This paper will detail a new system of protection that increases overall reliability of the entire transmitter while simplifying the hardware and improving tube life.

I. INTRODUCTION

When Comark developed the world's first IOT transmitter in 1986[1], we were concerned about the tube manufacturer's requirement that the tube be protected by a fast acting crowbar device across the high voltage beam supply.

The first solution to the crowbar requirement was a triggered spark gap. While the triggered spark gap was proven to meet all of the tube manufacturer's requirements, as measured by the standard melted wire test, it was not a perfect solution. Several years after the introduction of IOT technology, EEV developed a dual gap thyratron which is now the standard crowbar device in current manufactured IOT transmitters today.

While both triggered spark gaps and thyratron tubes meet the protection requirements of the tube manufacturer, Comark never fully accepted a solution that required the dumping of high amounts of energy in order to protect the IOT.

This paper will describe an adaptation of a proven technology, currently employed in super power shortwave AM transmitters that completely eliminates the crowbar functions from the transmitter system while fully meeting tube manufacturer's protection requirements. This paper will also describe several significant additional benefits of this solution.

The no crowbar system solution is called a Pulse Step Power Supply or $(PS)^2$ for short.

II. A CROWBARLESS SOLUTION TO IOT SYSTEM REQUIREMENTS - $(PS)^2$

A. The Crowbar Solution

The IOT tube must be protected from high energy discharges inside its vacuum[2]. There are several reasons for this requirement. One reason is the obvious need to protect the pyrolytic graphite grid. The other reason is to minimize gas release inside the relatively small vacuum envelope. Unlike the klystron that the IOT replaces, the vacuum volume inside the IOT is small enough to be significantly degraded, on a short term basis, by gases that are released during a high energy discharge.

The classic solution to the IOT protection problem has been to use a device like a triggered spark gap or Thyratron to shunt the high voltage beam supply to ground during an arc event and thus minimizing the energy released by the arc.

The problem with the classic crowbar is that it must be capable of handling the power supply's full output until a fast a.c. line breaker trips and the stored energy in the power supply's transformer core and filter sections is discharged. The instantaneous peak level of the total discharged energy is huge, approaching as much as several hundred kilowatts[3].

The transients generated by a fully functioning crowbar must be managed to avoid collateral damage to other components in the transmitter's system caused by the RF and electromagnetic pulse from the crowbar.

Comark was forced to address the transient effects of crowbar circuits in its first "S" series IOT transmitter and, of course, in its current IOX generation. Without proper design precautions, the effects of the crowbar transients will cause either immediate peripheral component failure or a random failure history that seems to have no obvious explanation.

Besides the transient protection requirement, the use of a crowbar system adds cost and complexity to both the manufacturing process and the operating maintenance requirements of the system.

Finally, a crowbar protection solution is simply not aesthetically pleasing in an engineering sense.

Thus, Comark set out to eliminate the crowbar entirely from its IOT transmitters and still meet tube manufacturer's requirements. The result of this effort has yielded considerably more than just the elimination of the crowbar.

B. Eliminate the Crowbar

The ideal solution to tube protection would be to be able to disconnect the beam power supply from the tube at the first evidence of a developing arc event. By disconnecting the tube, the power supply does not discharge into the arc and the arc is quenched. Further, large energy transients are avoided.

Unfortunately, a series switch that will interrupt 32 kv and several dozen amps in a microsecond is not easily implemented. Thus, an equivalent solution to disconnection needed to be found.

The characteristics of a non-crowbar power supply would be to have the ability to shut the power supply off in microseconds with the supply having low stored and follow on energy.

Comark has developed such a power supply in cooperation with our sister Thomcast company, Thomcast A.G. in Turgi, Switzerland. The crowbarless power supply solution is named Pulse Step Power Supply or $(PS)^2$ for short. The $(PS)^2$ solution draws heavily on the design of Pulse Step Modulators (PSM) used in 100 kW to 1000 kW shortwave AM transmitters, as well as large RF sources for scientific applications. In fact, the needs of the $(PS)^2$ solution are a significant relaxation of the requirements that have been reliably met by PSM equipment for ten years in the field world wide.

C. History of PSM

In 1982, BBC (Brown Boveri, Switzerland, the forerunner of Thomcast AG), introduced the first high power, high voltage, solid state modulator, known by the term PSM, Pulse Step Modulator[4]. The principal idea was to feed a vacuum tube amplifier by a modulated solid state voltage source.

The revolutionary solution of putting a number of individually controllable switching power supplies in series changed the world of high power AM sound broadcasting transmitters forever. An important revolution in broadcast transmitter design resulted, and today most customers insist on solid state modulators, not accepting the earlier, conventional tubed class B or series switch-tube solutions.

In Thomcast, several generations of pulse step modulators have been developed. Whereas, the first prototype was using high voltage bipolar switch-mode transistors in combined half-bridges[4], the next very successful model was using frequency GTOs (gate turn-off thyristor), described in [6]. This type has been sold and produced more than 120 times, and can be found with customers all over the world, for power classes from 100 kW up to 1000 kW carrier power.

The latest development of the PSM for AM transmitters is based on a new switching element, the IGBT (insulated gate bipolar transistor)[5], which allows higher switching frequencies compared to the former GTO, and leads to a simpler switch module design. Since its introduction, this type is available and had been installed throughout the whole power range, from 100 kW to 1000 kW.

For the circuit diagram of a typical PSM system see figure 1.

D. Principle of Operation

Modulators for high power amplitude modulated transmitters have to provide a relatively high carrier voltage (12 to 15 kV), with a superimposed AF-signal with peak values reaching at maximum (100% modulation) carrier value, following the AF modulation-signal or 24 kv to 30 kv. This value is similar to the d.c. requirements of the IOT.

For the sake of simplicity, only two of a larger number, depending on output voltage and power, of equal switch modules are shown in figure 1. The switch module is depicted in figure 2. It consists in principle of a 6-pulse rectifier with storage capacitor-bank C and soft charge circuit (relay S), the switching element (IGBT), and the free-wheeling diode FD, as well as the module's control circuit (Control).

The output voltages of said modules are added up to reach the maximum modulator output voltage in case all modules are in switched-on status (IGBT "S" conducting). Depending on how many modules are switched on, any voltage between zero and the maximum voltage can be reached.

$V_{out} = nV_s$, with n number of modules, in "switched-on" status V_s = capacitor voltage of single module

Furthermore, it can be shown that the effective overall switching frequency for the PSM is:

$$nf_s$$

where n is the number of modules and f_s is the switching frequency of 1 module

This property of the PSM is one of the secrets behind the low energy storage inherent in PSM technology.

Superimposed pulse duration modulation using all modules in a specific, patented way allows the output voltage Vout to reach values between the steps, typically with a dynamic (S/N) of better than 60 dB[5].

A central, fully digital control unit is controlling and supervising all the modules via fiberoptics links. This allows floating of the modules from ground, and also ensures optimum isolation in terms of EMC.

The main technical advantages of this design are:
- highest efficiency (above 97%)
- inherently very good power factor
- high bandwidth, up to 10 kHz (low energy storage, fast shut off)
- high redundancy, since operation will continue even if some modules do not function properly (soft failure mode)
- totally digital signal treatment, allowing most flexible modulation enhancements including low cost implementation of filters, stabilizing functions and output voltage regulation. This minimizes the need for energy storage for low frequency video components.
- no crowbar needed in case of arcing in tube or circuit because of negligible stored energy
- built in test equipment (BITE), leading to extremely safe operation

E. PSM as a Power Supply

The major requirement for AM transmitters is the generation of the carrier voltage with superimposed AF voltage. This evidently was the principal design goal when PSM was first developed. The pulse step modulator, at the beginning, was designed to fulfill, at best, this requirement. The other above mentioned features, such as, no need for a crowbar, were achieved as supplementary advantages.

By 1984, PSM was applied as a power supply for neutral beam injectors, where only the switch-off characteristics were of importance[7], as well as the limited stored energy dissipated in short circuits. The technology available at that time (GTO) allowed relatively low cost (in terms of Watt per $) for high nominal powers (60 kV, 100A), but asked for much higher specific cost (W/$) for lower design powers. Hence, pure power supply applications for lower powers, or lower currents could not be considered, until new switching elements, like IGBTs were available on the market.

Now, powers from several kW up to 1 Megawatt can be provided using Pulse Step Modulators as power supplies. One of the most recent applications is described in (8) and (9), a power supply for gyrotrons, a MW microwave tube, operating at 100 Ghz and more. This type of tube needs a very stable collector voltage (better than 1%), and supports only a few Joules in internal arcs, without damage, a perfect case for PSM.

The mentioned supply delivers up to 85 kV at 80 A or 6.8 Megawatts, with stabilities much better than 1%. The well known wire test has proven the unique switch-off characteristics of PSM even at these power and voltage levels.

It can be shown that the high equivalent switching frequency of PSM (i.e. nf_s) is one reason why this technology has such low energy storage. An equivalent single switching power supply that could achieve these high power levels would be forced to operate at relatively low switching frequencies, thus, it could not achieve the necessary low energy storage needed to protect the microwave tube.

PSM is now a very interesting solution for all high frequency tubes, running at high voltages that are sensitive to high energy discharges, like the IOT.

F. PSM as IOT Power Source $(PS)^2$

For the $(PS)^2$, stability and low energy switch-off, small size and low weight are important requirements. Here PSM offers further possibilities, compared to conventional designs. Going back to the first designs (1982), and replacing the combined halfbridges by IGBT-equipped full H-bridges, leads to a small, light weight solution with primarily switched step up transformers. Via the transformation ratio of those transformers, the individual output voltage of the modules is determined. This allows relatively high $(PS)^2$ voltages even with a rather low number of modules.

In addition, $(PS)^2$ preserves all of the features of PSM which include:

- no crowbar required
- regulation of output d.c.
- modular design
- adjustable beam voltage
- redundancy
- low a.c. line transients
- high efficiency

III. BENEFITS OF $(PS)^2$

The unique features of $(PS)^2$ change the way a UHF TV IOT transmitter can be configured. New system designs reduce the complexity of installation and improve overall reliability and signal performance.

A. Elimination of crowbar circuits

No crowbar implies no induced high energy transients on the a.c. line and 100% certainty of tube protection by the very nature of the $(PS)^2$ technology.

B. Regulation of beam voltage

Regulation of the beam voltage by the $(PS)^2$ system eliminates external voltage regulators and improves specification stability. Linearity specifications are particularly improved by tight regulation of the beam voltage, as is the reduction of filter requirements for low frequency video components.

C. $(PS)^2$ package

$(PS)^2$ is packaged in a single air-cooled rack mounted inside the transmitter footprint. The usual heavy, oil filled, outdoor beam supplies are eliminated. All high voltage and a.c. primary distribution wiring can be contained inside the transmitter cabinet. This increases safety and reduces installation costs.

D. Adjustable beam voltage

Continuously variable beam voltage settings allows for optimizing systems efficiency at the actual transmitter operating power and eliminates the need for step start or SCR a.c. switchgear.

E. Soft failure modes

Multiple d.c. voltage sources in $(PS)^2$ allow for soft failure instead of complete loss of beam voltage.

F. Low a.c. line induced transients

The rapid turn off nature of $(PS)^2$ reduces induced a.c. transients on the power line and eliminates the need for remotely resettable circuit breakers.

IV. CONCLUSIONS

Comark and Thomcast A.G. have jointly developed a new approach to IOT transmitter power supply design and tube protection systems. The $(PS)^2$ technology introduced by this paper draws heavily on the well known PSM (Pulse Step Modulator) designs used successfully throughout the high power short wave AM industry.

$(PS)^2$ eliminates the high voltage crowbar now included in all IOT transmitters. It also changes the fundamental way an IOT transmitter system is configured, by eliminating external oil filled outdoor beam supplies, external a.c. voltage regulations, a.c. step start or SCR a.c. switch gear and remotely resettable a.c. circuit breakers. $(PS)^2$ also improves overall signal quality and reliability by offering continuously variable regulated beam voltage to optimize signal performance and efficiency, while also providing soft failure modes.

Finally, the elimination of the high energy crowbar system from the IOT transmitter makes the overall system more aesthetically pleasing from an engineering viewpoint.

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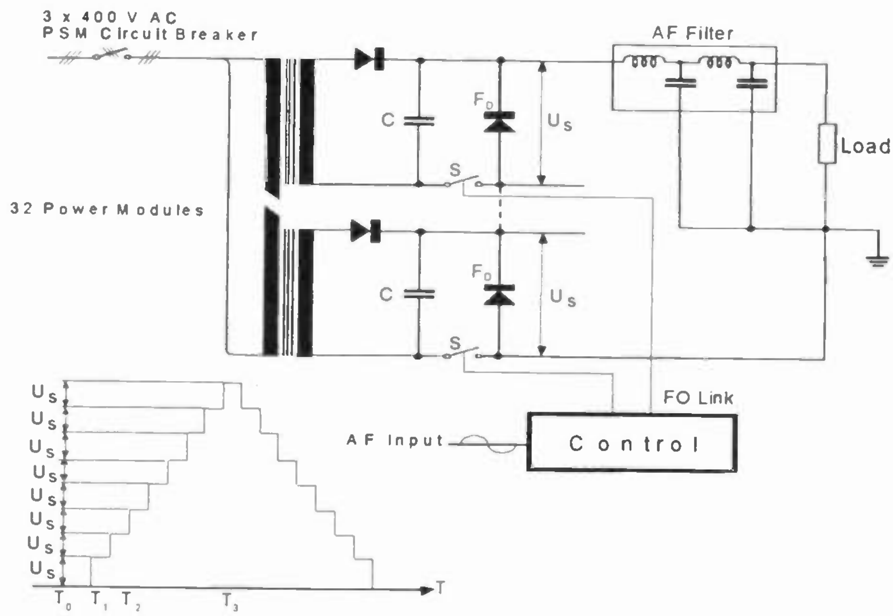

Fig. 1: 100kW SW-Standard THOMCAST Modulator. Block diagram showing the principal building blocks, characteristic for any power class - modulator.

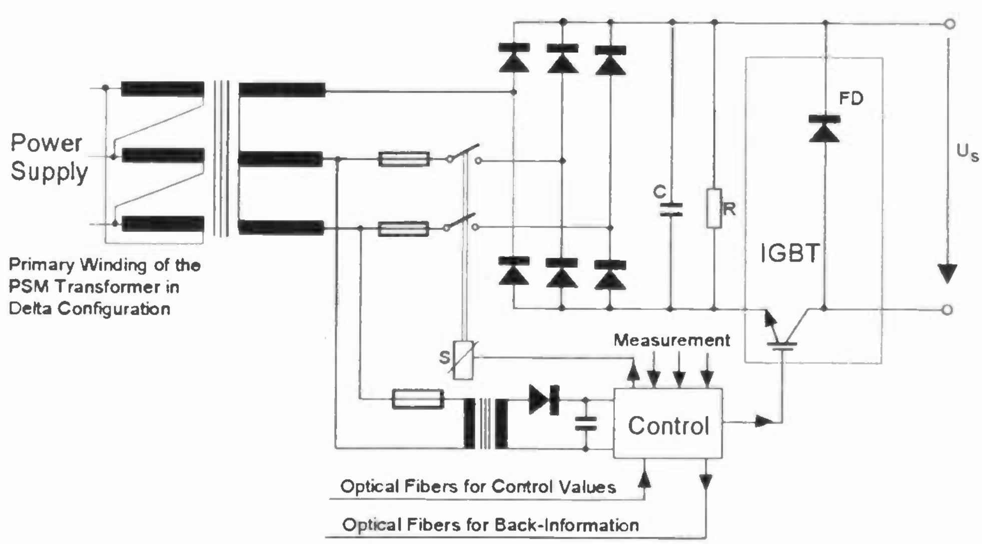

Fig. 2: Standard switching module, comprising the related control circuits

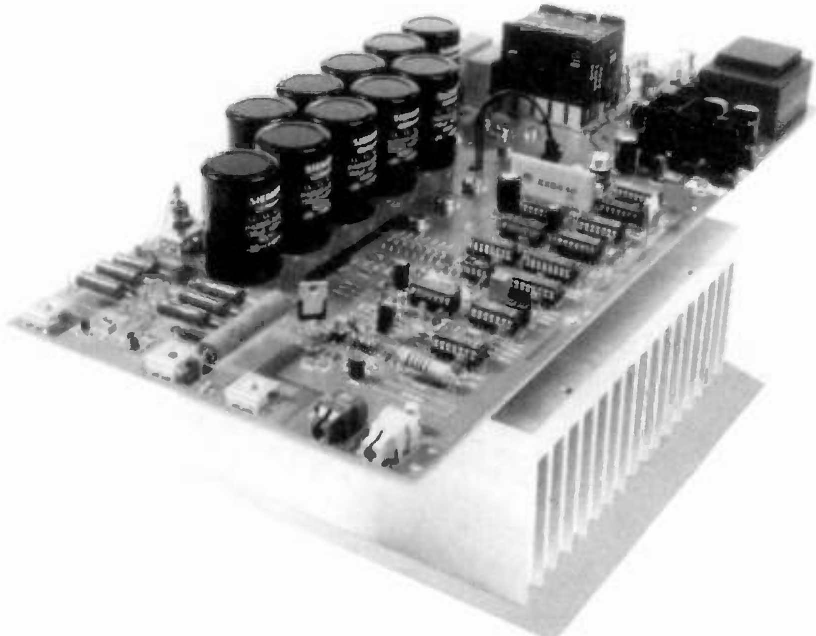

Figure 3 - Typical air-cooled $(PS)^2$ module

AN EXPANSION OF THE OUTPUT POWER RANGE OF ANALOGUE TELEVISION IOT SYSTEMS AND THEIR APPLICATION TO DIGITAL ATV

Stephen Bardell, David W. Carr, Geoffffrey T. Clayworth, Timothy A. Crompton,
Dr. Roy Heppinstall, Dr. Alan H. Pickering, Dr. Edward Sobieradzki
EEV Ltd.
Chelmsford, England

ABSTRACT

EEV IOT technology has been outstandingly successful in cutting energy costs and reducing the size of high power UHF Television transmitters since its introduction during 1991.

This paper reviews the achievements (and the problems which have had to be solved) of the IOT technology in high power transmitters and sets out those factors which have led to the demand to extend the technology to a wider range of powers.

The design features of a highly innovative, compact IOT system for use at lower powers are described in detail, with emphasis given to a novel input cavity which reduces the weight and bulk whilst maintaining ease of tuning and avoiding the difficulties of earlier types of IOT input cavity.

Performance test results are presented, together with some predictions of cost of ownership for the new IOT system.

Finally, the way in which the new system will be used for transmission of digital ATV is explained.

THE IOT – THE PREFERRED TECHNOLOGY FOR HIGH POWER UHF TV

Since the first high power UHF TV transmitters using IOTs went into service in 1991, a total of some 300 tubes and circuits has been installed. Many countries where UHF TV is transmitted have installed operating IOT systems and the attraction of the technology is undeniable. Why do so many broadcasters in so many countries find the IOT to be their preferred technology?

There are two features of an IOT which are important in making it outstandingly successful. Both are responsible for greatly reducing the energy costs of the UHF TV transmitter.

Firstly, the IOT has an exceptionally high Figure of Merit (FOM) - a parameter which has been adopted as the industry standard and is a measure of the beam power consumed by a TV amplifier tube. For a tube amplifying only the vision signal it is defined as:

$$FOM = \frac{P_V}{P_B} \times 100\%$$

where P_V is the r.f. peak sync. output power and P_B is the average beam power - the beam power consumed by the amplifier when a mid-grey luminance signal is being transmitted. For the IOT, Figures of Merit significantly in excess of 120% are obtained - a factor of three higher than is typically obtained with conventional unpulsed klystrons, the tubes used in early UHF TV transmitters. The importance of achieving a high FOM can be clearly seen in Figure 1, which shows the average beam power consumption for various combinations of peak sync. output power and FOM.

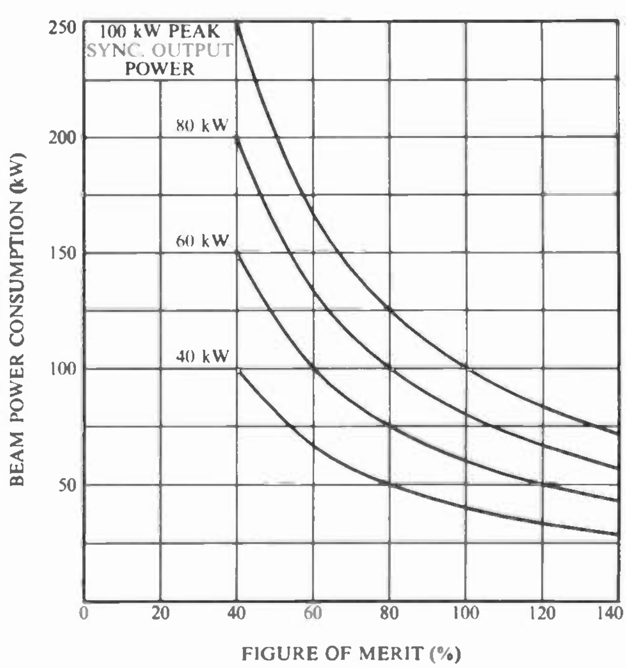

Figure 1. Beam power consumption versus FOM for vision-only service.

Test results for a typical IOT7360 operating as a vision amplifier are given in Table 1. Since a FOM of 131% is achieved, the IOT consumes only 50 kW, whereas a typical pulsed klystron would have consumed about 105 kW for the same output power.

Beam voltage	32.0	kV
Mean beam current	1.56	A
Peak beam current	3.3	A
Grid bias voltage	−98	V
Grid current	−1	mA
Body current	23	mA
Input power	387	W
Output power	65.5	kW
FOM	131	%

Table 1. Typical vision-only performance of IOT7360

The second feature of importance is the extremely linear power transfer characteristic of the IOT. This makes it possible to operate an IOT efficiently in a common amplifier mode, in which both the vision and aural signals are amplified in a single tube. Suitable pre-correction systems are readily available and a FOM of about 100% can be obtained when a tube is operated in accordance with the system M (NTSC) standard. For a tube operating in the common amplifier mode the FOM is defined as

$$\text{FOM} = \frac{P_V + P_A}{P_B} \times 100\%$$

where P_A is the aural power and P_V and P_B are as defined earlier. Typical common amplifier results are given in Table 2.

Beam voltage	31.9	kV
Beam current (mid-grey, syncs. and aural)	1.47	A
Grid bias voltage	−77	V
Grid current	−12	mA
Output power (peak sync.)	42	kW
Output power (aural)	4.2	kW
Drive power (peak sync.)	202	W
FOM	99	%
Level of intermodulation product*	−44	dB

Table 2. Typical Common Amplifier performance of the IOT7360 (*without pre-correction)

A major advantage of operating in this mode is that the extra size, weight and capital cost associated with having separate vision and aural amplifier tubes is avoided.

Typical costs of ownership for transmitters operating at a sync. power of 40 kW are shown in Table 3. It has been assumed that the IOT is operating in common amplifier mode, whereas for the conventional pulsed klystron or the Energy Saving Collector klystron two tubes are required – one each for the vision and aural signals.

The figures clearly indicate the lower cost of the IOT.

	IOT	ESC	Klystron	Solid-State	
Transmitter peak sync. power (V + A)	40+4	40+4	40+4	40+4	kW
Transmitter power consumption	52	60	108	128	kW
Power cost per kilowatt (yr 1)	0.07	0.07	0.07	0.07	$
Cost of replacement tube (yr 1)	37,175	54,000	33,000	N/A	$
Maintenance cost per annum	1,000	1,000	1,000	500	$
On-air time per day	20	20	20	20	hours
Average inflation per annum	4	4	4	4	%
Average life of tube 1 (** see below)	20,000	35,000	35,000	N/A	hours
Average life of tube 2 (sound)	N/A	45,000	45,000	N/A	hours
Replacement solid-state modules (year 1 per annum)	N/A	N/A	N/A	500	$
Tube/module cost over 20 years	287,167	419,693	310,965	15,403	$
Power cost over 20 years	818,551	944,482	1,700,069	2,014,894	$
Maintenance cost over 20 years	30,969	30,969	30,969	15,485	$
Transmitter cost	350,000	550,000	360,000	750,000	$
Total cost	1,486,687	1,945,144	2,402,003	2,795,782	$
Relative cost	100	131	162	188	%

Table 3. Typical cost of ownership calculations for IOT, ESC, Klystron and solid-state transmitters.

**Average life stated is life that is reasonably expected, not guaranteed for any particular sample.

THE ACHIEVEMENTS AND PROBLEMS (AND THEIR SOLUTIONS) OF THE IOT SYSTEMS CURRENTLY IN SERVICE

The IOT7360 entered service for the first time in the US in 1991 with an innovative and unusual 250 kW transmitter at WSTR, Cincinnati, Ohio. This transmitter had four vision-only IOTs supported by a klystron in the aural socket. Almost all subsequent IOT transmitters, however, use the tube in the common amplifier mode.

As of mid-January 1995, some 200 IOTs have been put into operation in the Americas, and another 100 tubes are expected to enter service there by mid-1995. Elsewhere in the world, sizeable networks using the IOT have been installed in Sweden, Finland and Indonesia with other transmitters soon to be operational in Slovenia and Poland.

There have been problems with the service lives of some of the early tubes. Some stations experienced a few tubes with grid to cathode short-circuits which were caused by problems in the electron gun support structure.

The operational lives of the tubes have been analysed using the well known Weibull statistical technique[1]. The analysis shows that, as a result of the modifications, the characteristic life of the IOT7360 tubes has been increased from about 13,000 hours to 24,000 hours. Individual service lives in excess of 17,000 hours for the IOT7360 and 25,000 hours for the IOT7340 have now been achieved, the total service life for all tubes being in excess of 1,700,000 hours.

Problems with the IOT itself have, over the last two-and-a-half years, been relatively few. However, early build standards of the input cavity system exhibited a number of early life failure modes.

The main features of the input cavity design used on the high power IOTs are shown in Figure 2. A cylindrical resonant cavity incorporating an annular sliding tuning door is connected between cathode and grid of the IOT. R.F. energy excites the cavity via an input loop attached to the tuning door. The resulting r.f. input voltage between the cathode and grid density modulates the electron beam drawn from the cathode and the beam is then passed onto the klystron-like r.f. output interaction region of the tube. It is necessary to maintain the body of the cavity and its tuning mechanism at ground potential by using r.f. chokes to prevent the leakage of r.f. energy, whilst holding off the full beam voltage.

The early cavities had a semi-flexible resin insulator moulded between the metal plates of the folded waveguide type chokes. This resin is rigid at ambient temperature but is flexible enough at expected operating temperature to avoid mechanical stresses appearing

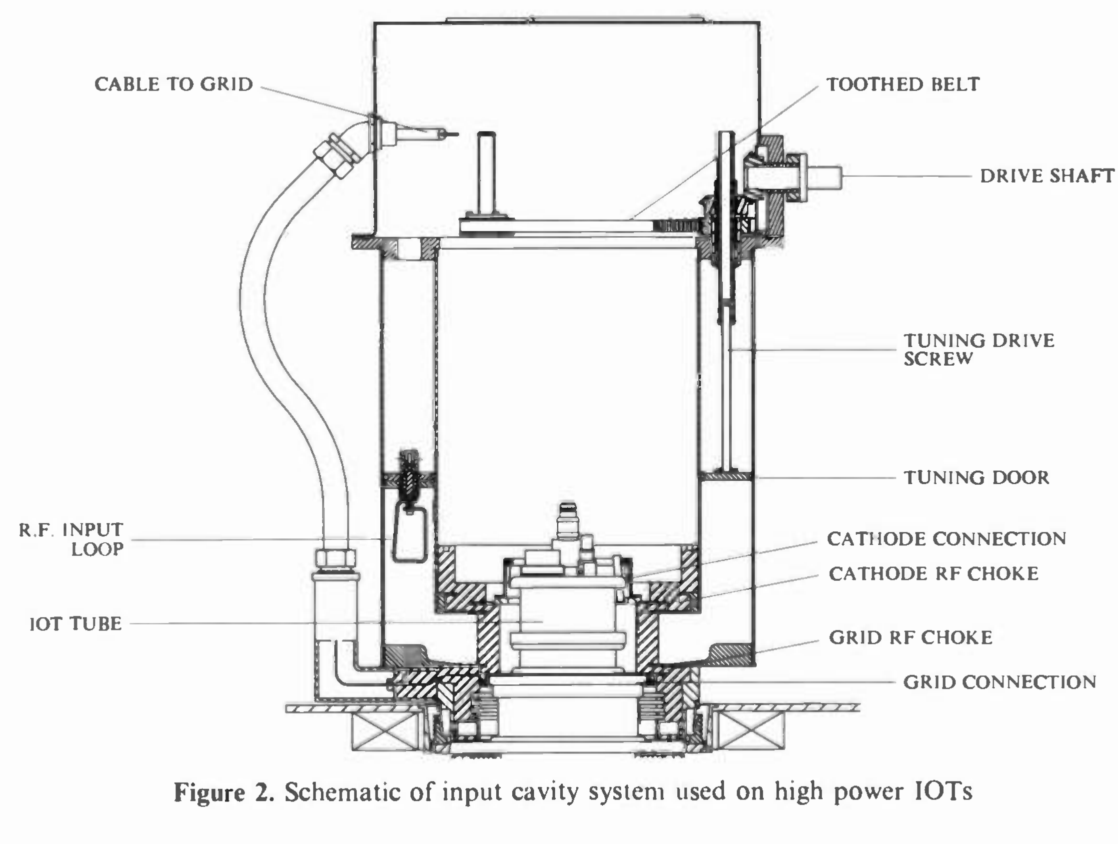

Figure 2. Schematic of input cavity system used on high power IOTs

within the insulation. The temperature of the chokes was to be reduced by blowing air between the chokes and the IOT gun. The r.f. performance of these cavities was excellent but a number suffered voltage breakdown in the resin when the inlet temperature of the cooling air was higher than that anticipated in the original design specification.

Alternative insulating materials were evaluated in order to improve the choke reliability at higher temperatures. Silicone rubber or a hard resin formulation (specially modified to match the expected expansion characteristics of the metal components of the chokes) were found to be the best high temperature insulators for the chokes.

At the same time, enhanced computer modelling became available and was used to assist with the design of choke structures to provide significantly lower electric stresses both within the chokes and between the cavity and the IOT.

The Weibull statistical analysis technique has been used to assess the performance of cavities in service, and demonstrates the improvement which has been achieved. The characteristic life has changed from 7,000 hours for cavities of the early design to 20,000 hours (and continues to increase as the operating lives of the population increase without further failures) for later cavities.

EEV has supported users by replacing early cavities and is convinced that input cavity reliability will meet the expectations of the industry.

In spite of the problems, IOT users have continued to promote the technology. Indeed, both they and transmitter manufacturers have encouraged EEV to extend the IOT technology to lower power levels. This led EEV to develop a novel IOT system for use in the 10 to 20 kW power range.

Figure 3. The IOT7320R low power air-cooled IOT

A COMPLETELY NEW IOT SYSTEM FOR LOWER POWER TRANSMITTERS

Designated IOT7320R, the new tube is a fully air-cooled IOT capable of common amplifier, analogue TV service at a power output of up to 22 kW + 2.2 kW (for a transmitter power output of 20 kW + 2.0 kW). The tube will be useful and remains very efficient at transmitter power outputs down to 10 kW + 1.0 kW. A single tube covers the frequency range 470 MHz to 860 MHz. Gain is at least 20 dB and at best 23 dB, depending on operating frequency. A completely new ceramic-insulated input cavity system, for which a patent application[2] has been filed, is incorporated.

The tube which is shown in Figure 3 and diagrammatically in Figure 4 plugs (very much in the same way as an air-cooled UHF tetrode) into its fixed r.f. circuit (Figure 5), which owes much to the experience gained with the output circuits of earlier IOT types, but has been redesigned to improve ease of installation and minimise size and weight.

In contrast to current IOT systems the circuit (shown schematically in Figure 6), which is designated IM7320R, does not include a support trolley. It is intended that the circuit shall be semi-permanently incorporated into the transmitter cubicle.

Since the tube needs only a small magnetic field, the size of the focus coil has been considerably reduced.

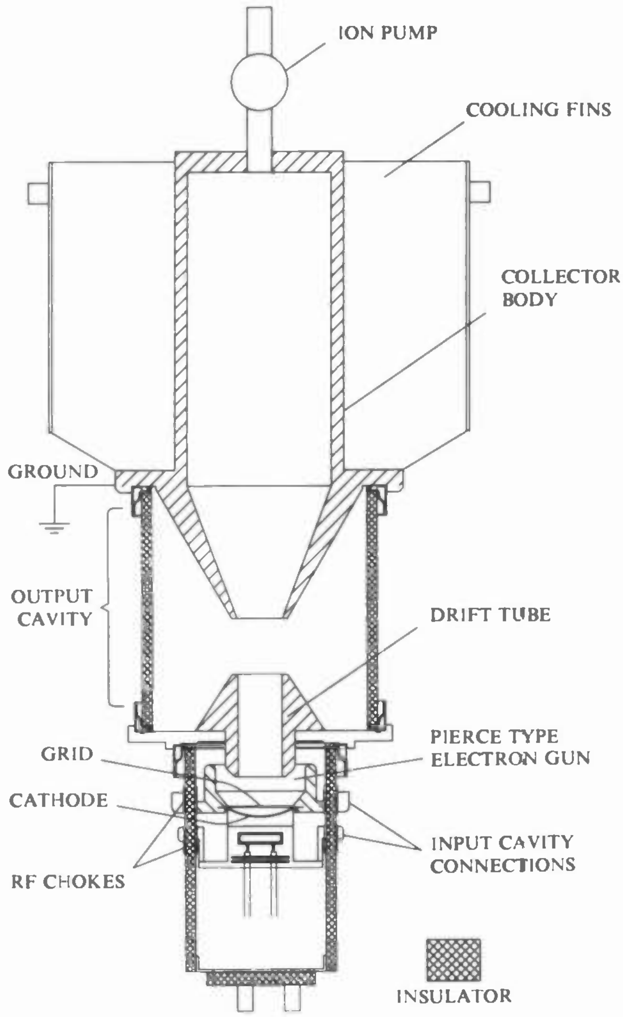

Figure 4. Schematic of IOT7320R

Figure 5. Manual installation of IOT7320R into operating circuit IM7320R

The design features of the IOT7320R

The IOT7320R tube differs in concept from the current IOT types but makes use of the operational experience gained with them. It consists (Figure 4) of a Pierce-type electron gun with a non-intercepting grid, a short drift tube, an output cavity gap and a collector at earth potential. The grid voltage is modulated, typically between −100 V and 0 V with respect to cathode, by making the cathode and grid form the 'extremities' of an r.f. input cavity. A system of ceramic insulated r.f. chokes, for which a patent application[2] has been made, is used to isolate the tuning mechanism of the input cavity from the high voltage on the cathode and grid. The current-modulated beam is accelerated through the anode and passes an output gap, exciting the output cavity. The remaining energy in the beam is dissipated by the collector, which is held at ground potential and carries an appendage ion pump.

A very compact IOT system for lower power transmitters has been developed. This features a small, lightweight, air-cooled IOT and a compact circuit which is designed to be mounted in a standard 27-inch rack. The circuit is shipped and installed as a complete unit with no on-site assembly. The tube plugs into the circuit with the collector end up to minimise the space occupied by the cooling air output pipe.

The cathode, the grid and the focus electrode are all assembled inside a single ceramic cylinder, which is the vacuum envelope of the tube. The r.f. chokes are formed by conducting metal cylinders on the inner and outer walls of the ceramic cylinder.

This has the advantage that **all** the external circuit is at earth potential with **all** the high voltage components completely contained **inside** the vacuum envelope and fed via flying leads at the electron gun end of the tube.

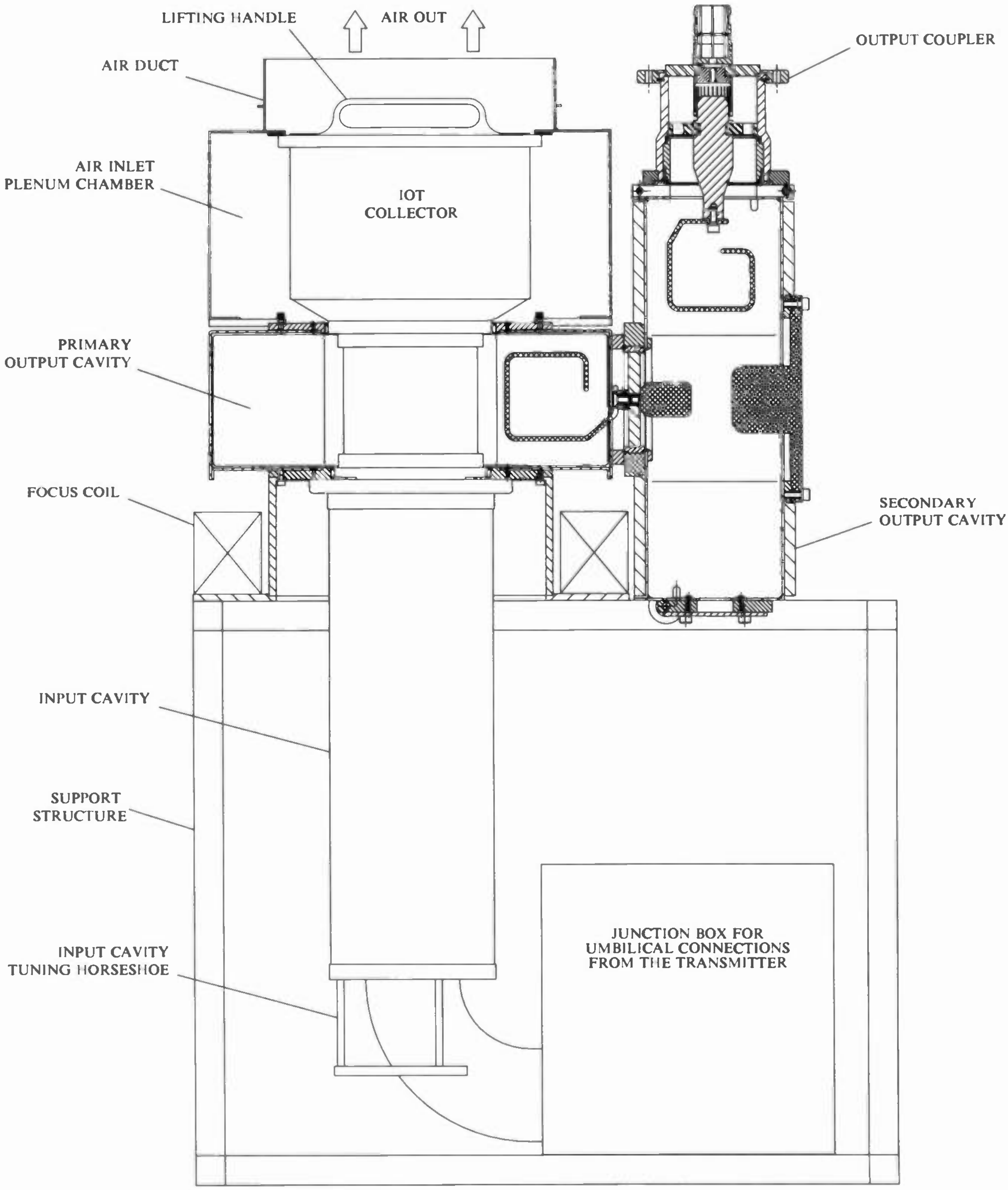

Figure 6. Schematic of IOT7320R in circuit type IM7320R

Because the r.f. chokes are incorporated into the tube envelope, we have been able to design a smaller, lighter and less complex input cavity than that used by current IOTs. This input cavity (Figure 6), which is permanently assembled on the circuit but can easily be removed if necessary, is continuously tunable over the whole US and European UHF TV bands without the need to remove the tube or any other parts of the circuit.

The output cavities are to EEV's well proven double-tuned design used on the higher power IOTs, but suitably modified to enable the tube to plug easily into the primary cavity.

The magnetic circuit was designed with extensive use of newly available computer modelling techniques. This enables the use of a small size collector which considerably reduces the weight of the tube, and a small focus coil which reduces the size and weight of the circuit assembly.

Ease of use of the IOT7320R/IM7320R IOT system

The fully air-cooled IM7320R circuit (Figures 5 and 6) has been designed to give greater ease of assembly compared with the existing higher power IOT circuits. The primary output cavity is not split (as it is on the high power IOT circuits) and so has been pre-assembled onto the magnet frame along with the secondary output cavity and the input cavity. Only the air exhaust pipe needs to be removed to give access to install the tube.

On the tube, the r.f. output contacts and the grid and cathode r.f. input contacts are stepped in diameter so that the tube can be plugged into four matching spring-fingered cavity contact rings in one movement. The flying leads for heater, cathode and grid drop easily through the centre of the input cavity and can then be plugged into the junction box under an interlocked safety cover. The time for assembly of the IOT into its circuit has been reduced by at least an hour compared with current 40 kW and 60 kW types.

The IM7320R circuit may be mounted on drawer slides to allow it to be pulled forward for tube changes. Alternatively, the circuit may be built into the transmitter cubicle and a lightweight hoist, on drawer slides, provided to lift the tube in or out when needed.

PERFORMANCE TEST RESULTS ON THE IOT7320R

Testing of pre-production systems has been on-going since October 1994 with very encouraging results. Figures of Merit in excess of 95% have been recorded at 22 kW with gain of more than 21 dB during common amplifier tests. Cost of ownership comparisons at the 20 kW level for solid-state, klystron, tetrode and IOT7320R transmitters have been calculated and plotted as Figure 7. The attraction of the IOT transmitter is then clear.

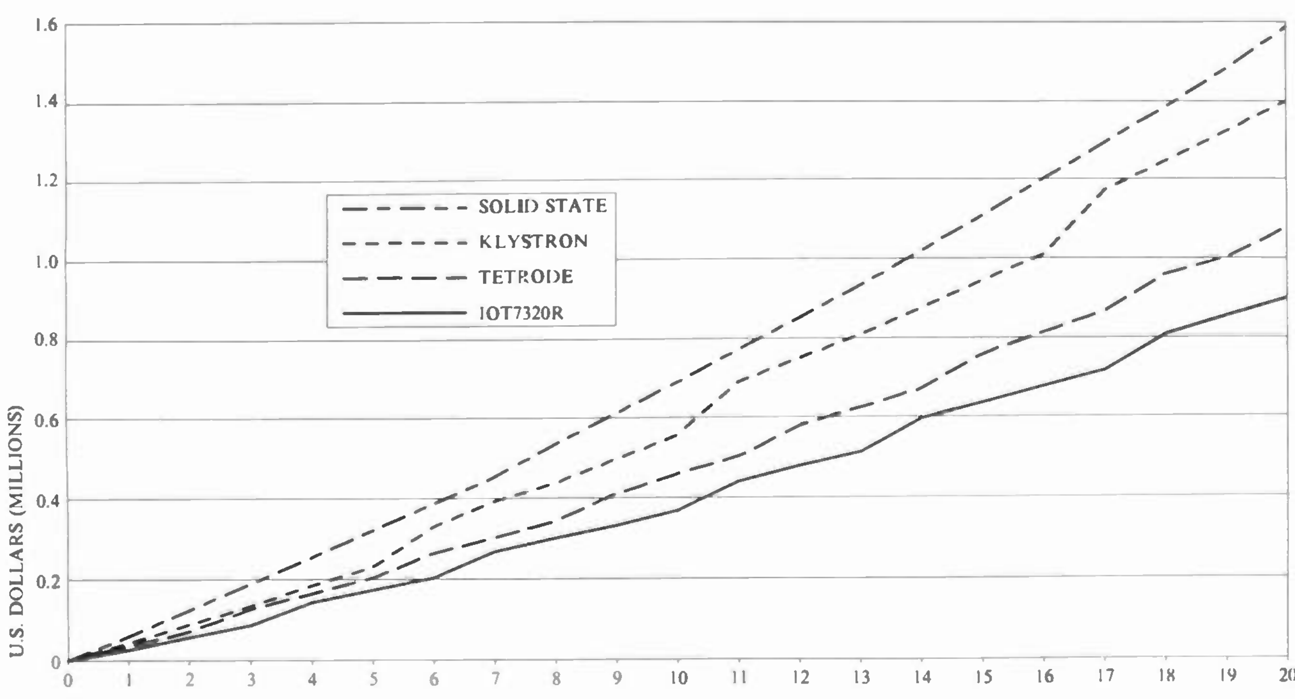

Figure 7. Predicted cost of ownership for IOT7320R transmitter at 20 kW, compared with alternative technologies

SUITABILITY FOR DIGITAL ATV TRANSMISSION

In establishing the design requirement for the IOT7320R, special consideration was given to the likely performance requirements of digital ATV.

The 8-VSB digital ATV signal may be regarded as white noise with occasional peaks of much higher amplitudes, the ratio of peak to average power being about 6 dB. The IOT7320R has been designed so that the cathode is capable of providing peak currents well in excess of those required for analogue TV at a peak sync. level of 22 kW. Its collector is capable of dissipating mean powers of up to 19 kW.

The electron gun, the r.f. structure and the collector have all been designed to provide a tube operating at peak envelope power levels of up to 42 kW without the grid voltage going positive with respect to the cathode. Also, the tube is quite capable of operating at c.w. power levels in excess of 15 kW.

It is anticipated that the tube will be capable of operating as a digital ATV tube at power levels sufficient to give the same service area coverage as that given by an amplifier delivering 60 kW of sync. power in an analogue TV transmission.

CONCLUSION

The performance of the IOT technology in high power analogue UHF TV service since 1991 has been reviewed. The solutions to some problems which arose have been described, together with performance data which shows that the IOT will remain the preferred technology for high power analogue transmitters for some years to come.

The new air-cooled IOT7320R, for lower power transmitters, incorporates features which will make it attractive in analogue transmitter markets where at present the choice of amplifier technology is limited to the UHF tetrode or to solid-state.

The potential of the new IOT in the digital ATV transmitters of the near future, where small size, ease of operation and low cost of ownership will be of paramount importance, is obvious.

ACKNOWLEDGEMENTS

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The views expressed are those of the authors and not necessarily those of the General Electric Company of England.

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DUAL-CHANNEL COMMON LINE COUPLER

Dennis Heymans
Micro Communications, Inc.
Manchester, NH

ABSTRACT

Many techniques have been proposed for sending a broadcast signal(s) to the top of the tower without adding another transmission line. This is specially important when a tower is stress limited and the broadcaster would like to add a LPTV or HDTV antenna. He will quickly discover that the stress limiting factor is the transmission line and not the antenna. Many solutions have been proposed, (a) re-configure the tower and remove some of the lines and antenna, (b) locate the power amplifier at the top of the tower feeding the signal either by microwave or at IF, through a small fiber optic cable. A practical solution for many stations is to "couple" the new signal into an existing transmission line and "de-couple" the two signals at the tower top.

MCI has developed a dual channel coupler that accomplishes this with no interference between the two signals. The Grand Alliance is using one of these new devices at the field test facility in Charlotte, NC. This paper will discuss the design aspects of this coupler and look at examples of its present and future applications.

BACKGROUND

Limitations of existing tower. The biggest question the broadcaster faces is can a new tower be built . Surveys show that the existing tower will have to be used because of the cost [1]. The time required to get FCC and FAA approval compounded by delays associated with complying to all local regulations will put the design construction and installation outside the FCC specified time scale. Aside from this it will be very difficult to find a new tower location that will service the same market.

Another factor to consider is the tower lease. If a station is leasing space we can assume that they are not the owner. Their line may have to be removed to make room for the owners new HDTV channel. When considering using an existing structure you must also deal with the problems of aerodynamics. Some solutions would be to share a common antenna using a multi-channel panel.[2] Another is to share the existing VHF or FM line by using the Dual Channel coupler.

SYSTEM CONSIDERATIONS

The HDTV system will require a separate antenna since the HDTV band is UHF and there are no antennas available that will radiate both VHF and UHF channels.

The new antenna will require it's own feeder line. As mentioned previously in most installations the feeder line has a higher wind load than the antenna.

Typical Antenna*	Wind Area
Type A	6 ft^2
Type B	13 ft^2
* length 10 ft.	

Feeder Line*	Wind Area
3 1/8	260 ft^2
6 1/8	520 ft^2
* 1000 ft. tower	

Considerable reduction in wind load can be obtained if the new HDTV signal can be fed to the antenna in the same line as the existing NTSC signal. With the "Dual-Channel Common Line coupler" it is possible to combine LoV and UHF, HiV and UHF or FM and UHF signals.

DESIGN CONSIDERATIONS

Coupler/Decoupler. A block diagram of a typical system is Figure 1.

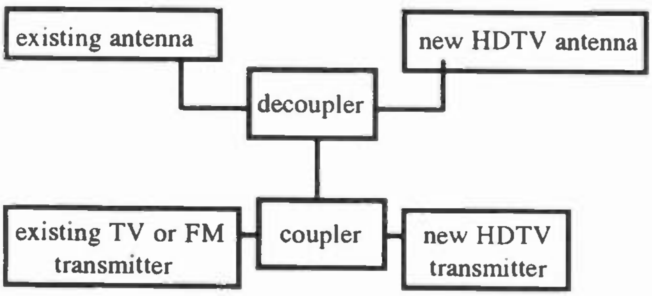


Figure 1

Design Problem. The design is a combination of a low pass filter (pass low-reject high) Figure 2 , and a hi pass filter, (pass hi-reject low) Figure 2a.

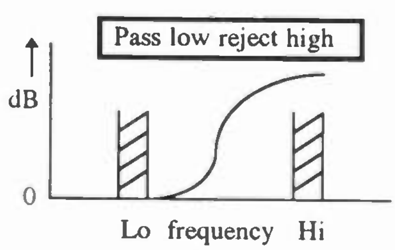


Figure 2

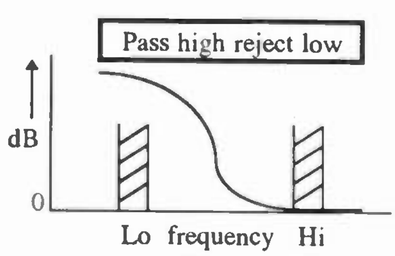


Figure 2a

The filter chosen to pass low and reject high was a low pass device commonly used as a harmonic filter. The high pass filter required a unique solution. It was resolved by using waveguide. Waveguide is an excellent high pass filter above cut-off and it rejects all frequencies below cut-off. The cut-off frequencies and usable channel range of the common waveguide sizes is shown in Figure 3 .

Waveguide	WR1800	WR1500	WR1150
CH. range	14-39	25-54	43-69
Cut-off	328 MHz	394 Mhz	514 MHz

Figure 3

Combining. Coupling/decoupling of the two channels was solved by applying the method used in star point combiners. Each filter is connected to a common output coax "T". The lines connecting each filter to the coax junction are phase matched to each other, as well as to the junction. This allows both channels to combine to the common output and be isolated from each other. The lines should be kept as close to 1/2 wavelength as possible. Figure 4 shows this arrangement.

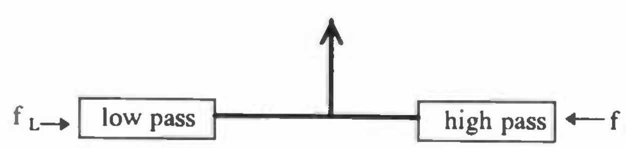


Figure 4

TRANSMISSION LINE

The next step is to determine the usable frequency range and power level for the existing line.

Rigid Coax. Rigid coax transmission line has a specific line length for different channels. Before considering the use of the dual-channel common line coupler, two very important aspects must be looked at:

1. Flange reflections
2. Power consideration

Flange reflections. The usable range of channels for different line lengths shows the limitations for UHF channels when compared to VHF channels. We can see from Figures 5, 5a and 5b the line lengths of coax and the respective channels of use.

TV Channels requiring 20 foot sections

2	3	4	5	6	7	8	11	12	14
15	18	19	22	23	27	31	35	39	43
44	47	48	51	52	55	56	60	64	68

Figure 5

TV Channels requiring 19 3/4 foot sections

16	20	24	28	32	36	40	41
45	49	53	57	61	65	66	69

Figure 5a

TV Channels requiring 19 foot sections

9	10	13	17	21	25	26	29	30	33	34
37	38	42	46	50	54	58	59	62	63	67

Figure 5b

Each flange connection has an inherent VSWR. Flange reflections result whenever a large number of sections of any type of transmission line are put together. These reflections will add in phase when the periodic reflections are an equal number of half-wavelengths apart.

$$\mathbf{VSWR_{max} = (VSWR\ flange)^n}$$

n = number of sections

Say we have a 1000 feet of coax with each line section set at 20 feet. We have 51 flange connections, not counting elbows and field cuts. If the VSWR of each flange connection is 1.005 we will have:

$$\mathbf{VSWR_{max} = (1.005)^{51} = 1.29:1}$$

This VSWR is not acceptable for TV broadcasting.

The semi-rigid or flex line has an advantage because it has no flanges. It typically has a connection at the bottom and at the top. This eliminates the flange reflections and allows the line to be used over the broadcast bandwidth. This type of line does have a lower power rating when compared to rigid line. Figures 6 and 6a provide information on line size and power rating at different bands.

	Lo V	**Hi V**	**Lo U**	**Mid U**	**Hi U**
Size	**88 MHz**	**200MHz**	**470MHz**	**650MHz**	**800MHz**
1 5/8	16 kW	10kW	6.6kW	5.6kW	5 kW
3 1/8	64	40	26	22	20
4 1/16	95	64	40	35	32
6 1/8	185	130	80	68	62
*6 1/8	175	120	70	58	55
*8 3/16	300	180	125	100	-----
*9 3/16	350	190	150	120	-----

Figure 6

Average Power rating for single channel rigid line.

	Lo V	**Hi V**	**Lo U**	**Mid U**	**Hi U**
Size	88 MHz	200MHz	470MHz	650MHz	800MHz
2 1/4	25kW	15kW	10 kW	9 kW	7 kW
3	46	28	19	14	12
3 1/2	60	35	22	17	15
4	69	44	27	23	19
4 1/2	80	50	32	28	24
5	90	58	37	31	26
5 1/2	120	78	48	40	36
6 1/8	160	100	64	55	48

Figure 6a

Average Power rating for single channel semi-flex line.

Power Considerations for dual channel use. Power rating of line is dictated by the temperature on the inner conductor and the sum of the peak voltages [3]. The temperature rise of the sum of the two powers should not exceed the EIA rating of 100 °C [4]. The sum of the two peak voltages must not exceed the allowed peak voltage rating of the line. An example of this would be if we had a CH 6 operating at 60kW average power into a 6 1/8 - 50 ohm line. The temperature rise on the inner conductor is 29°C, at 20°C ambient (or 49°C total). Choosing a UHF channel 35 (compatible line length with CH 6) we can operate at 26kW. The temperature rise on the inner for CH 35 at 28kW is 28°C, at 20°C ambient (or 48°C total). The sum of these is < 100°C.

SUMMARY

ATV Dual-Channel Common Line Coupler. The ATV Field Test facilities in Charlotte use Channel 6 and Channel 53. During some of the testing phase it was necessary to use a single feed line to feed the energy to each antenna. The elbow complex at the tower top had to be reconnected manually each time field strength measurements were to made on one channel or the other. This required a rigger to climb the tower and make the change. The connection to the line at the base of the tower was easier to accomplish through a patch panel.
The ATV asked MCI to design a Dual-Channel Common line coupler to be located at the tower top so a permanent connection to the antennas could be made.
The performance over each 6 MHz band of the coupler is shown in Figure 7.

	Channel 6	Channel 53
VSWR	1.04:1	1.05:1
Insertion loss	0.05 dB	0.04 dB
Group Delay	0.05 ns	0.05 ns
Isolation to each	95 dB	58 dB

Figure 7

The following Figures show mechanical information (Fig.8) and tower location (Fig.8a) of the Dual-Channel Line coupler. Also included are typical top and side mount antenna locations for ATV. (Figs 9 & 10)

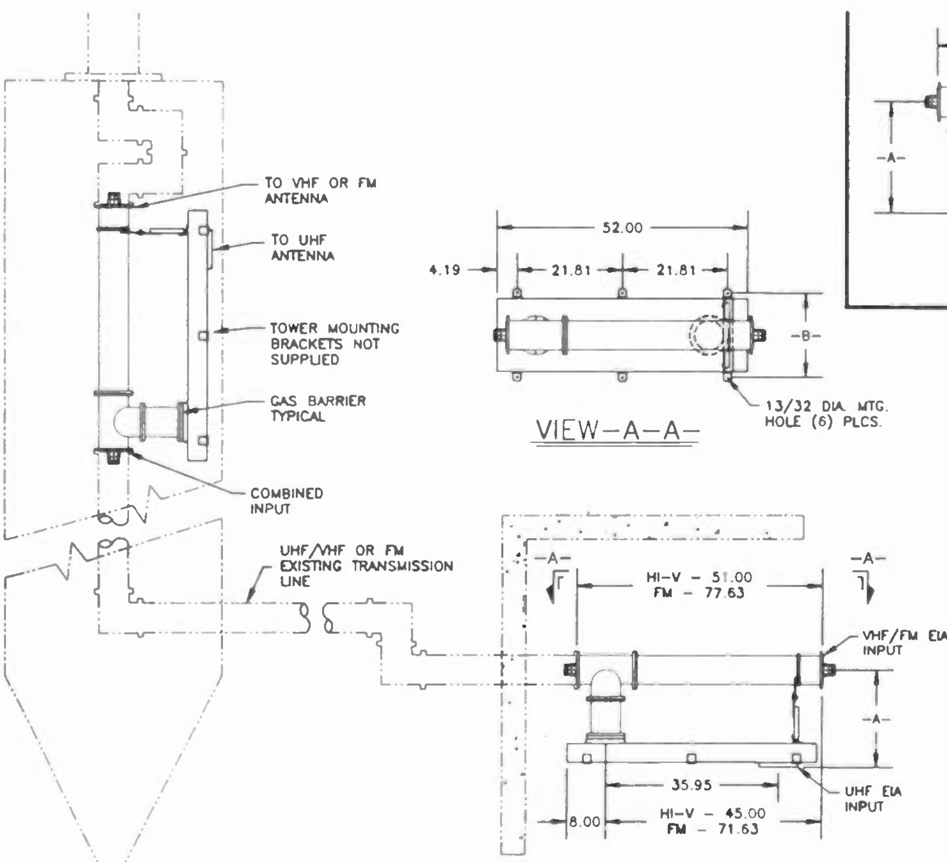
REFERENCES

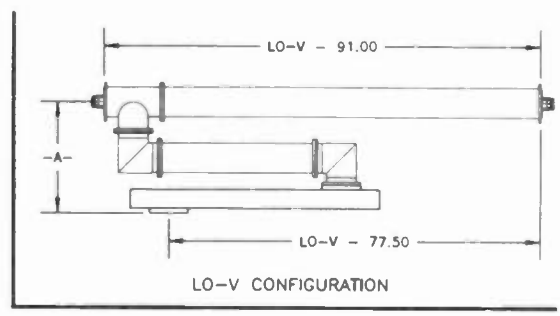
[1] T.J. Vaughan," Effect on Tower Stress due to the selection of Antenna and Transmission Line for HDTV", HDTV World Symposium,April 1993

[2] J. Banker and T.J. Vaughan, " Antenna and Transmission Line for the Simulcast Period", HDTV World Conference, March 1992

[3] T.J. Vaughan and Associates, "High Power Considerations in Coax Line", Report 1273, 1981

[4] Electronic Industries Association, "Rigid Coaxial Transmission Lines ans Connectors", EIA RS-259, RS-258, March 1962.





UHF	VHF/FM	-A-	-B-	WIND AREA	WT.(lbs.)
14-17	2-6	23.75	20.50	936 SQ/IN	235
	7-13	21.13			150
	FM	34.50			155
18-42	2-6	23.00	17.50	780 SQ/IN	225
	7-13	20.38			145
	FM	33.75			150
43-69	2-6	25.00	14.00	598 SQ/IN	215
	7-13	22.38			140
	FM	35.75			145

NOTES: 1)CONNECTORS SHOWN 6 1/8 EIA. OTHER SIZES AVAILABLE.

2)DIMENSIONS ARE MAXIMUM

Figure 8
Mechanical specifications

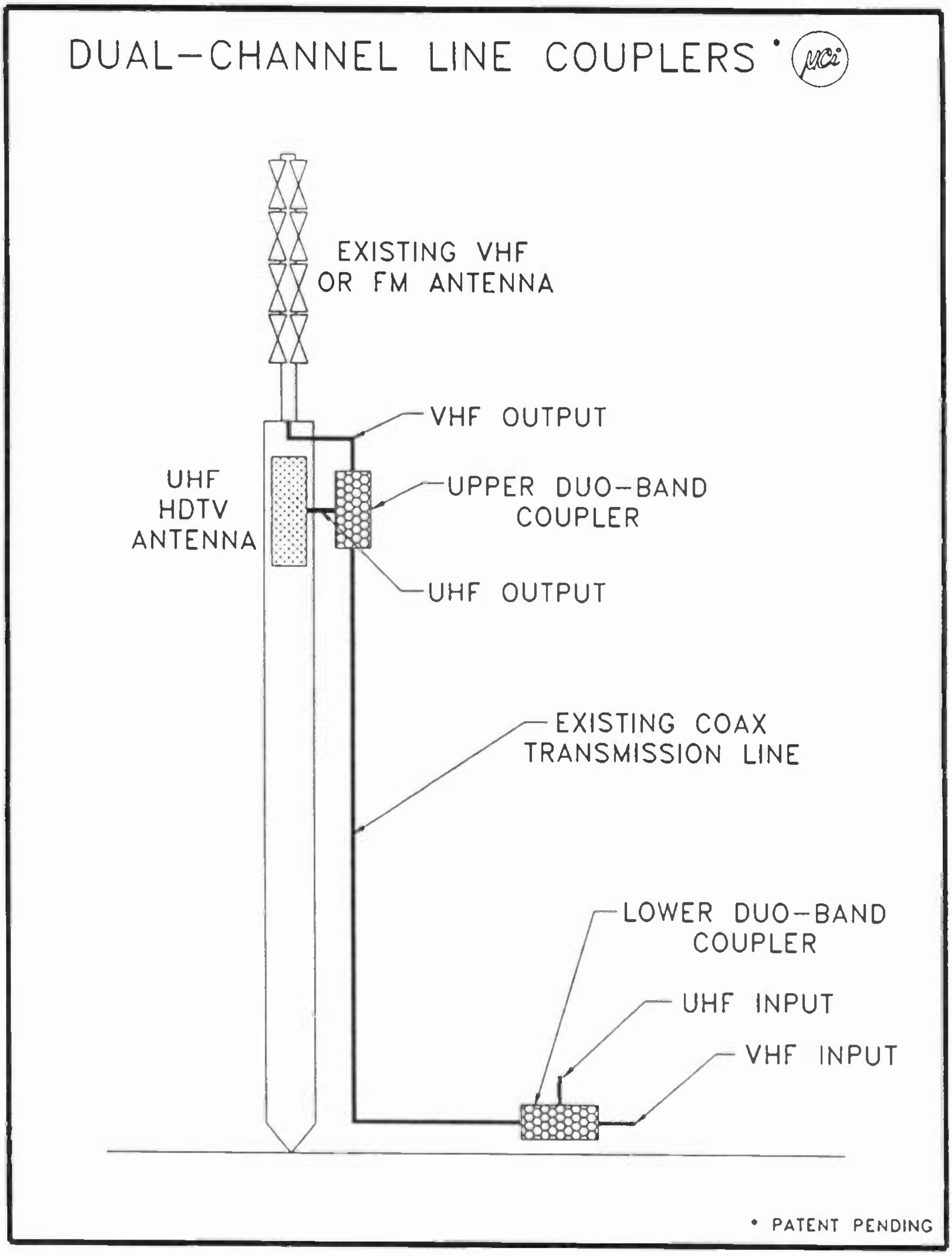


Figure 8a
Line Coupler Location

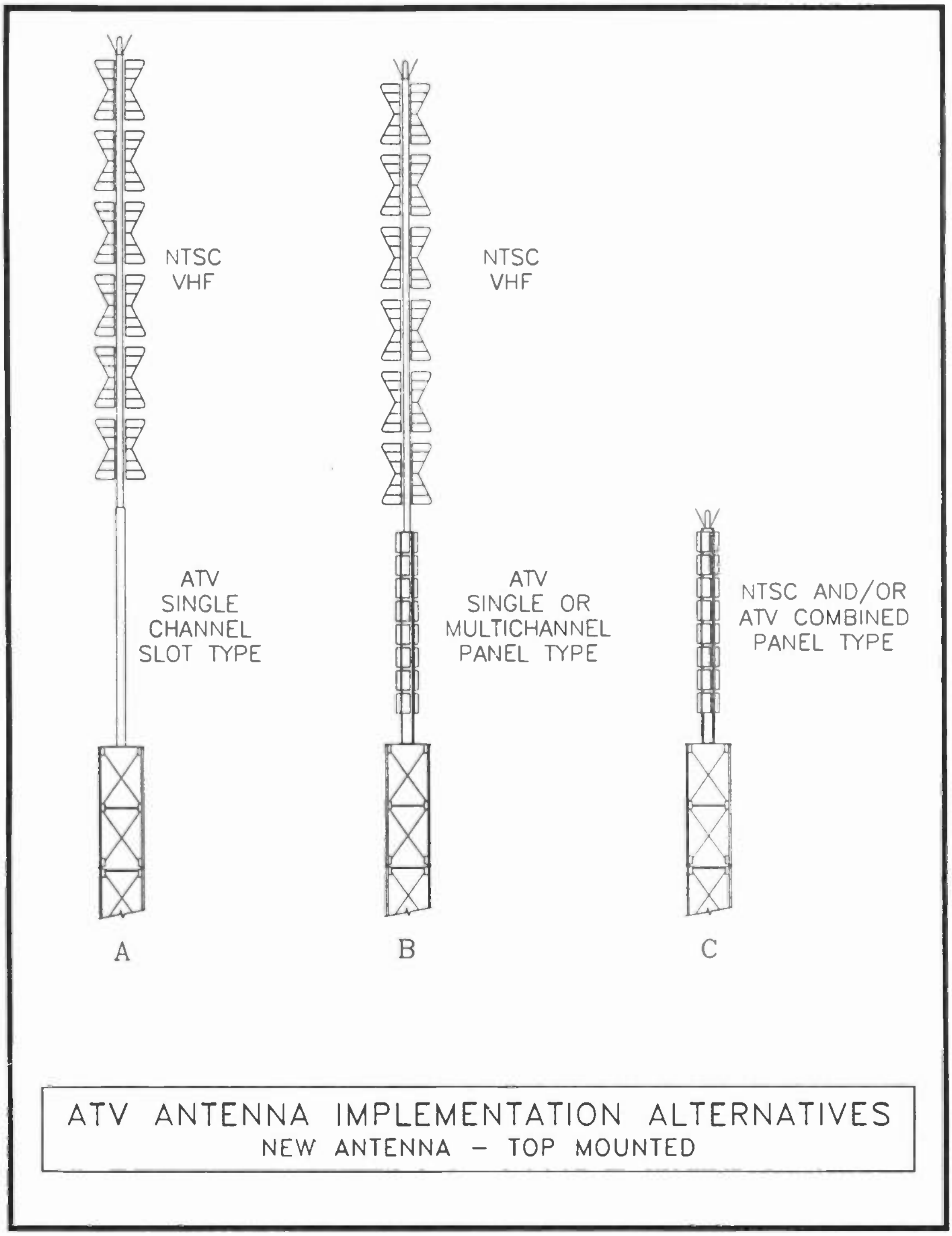


Figure 9
Possible Top Mount Arrangement

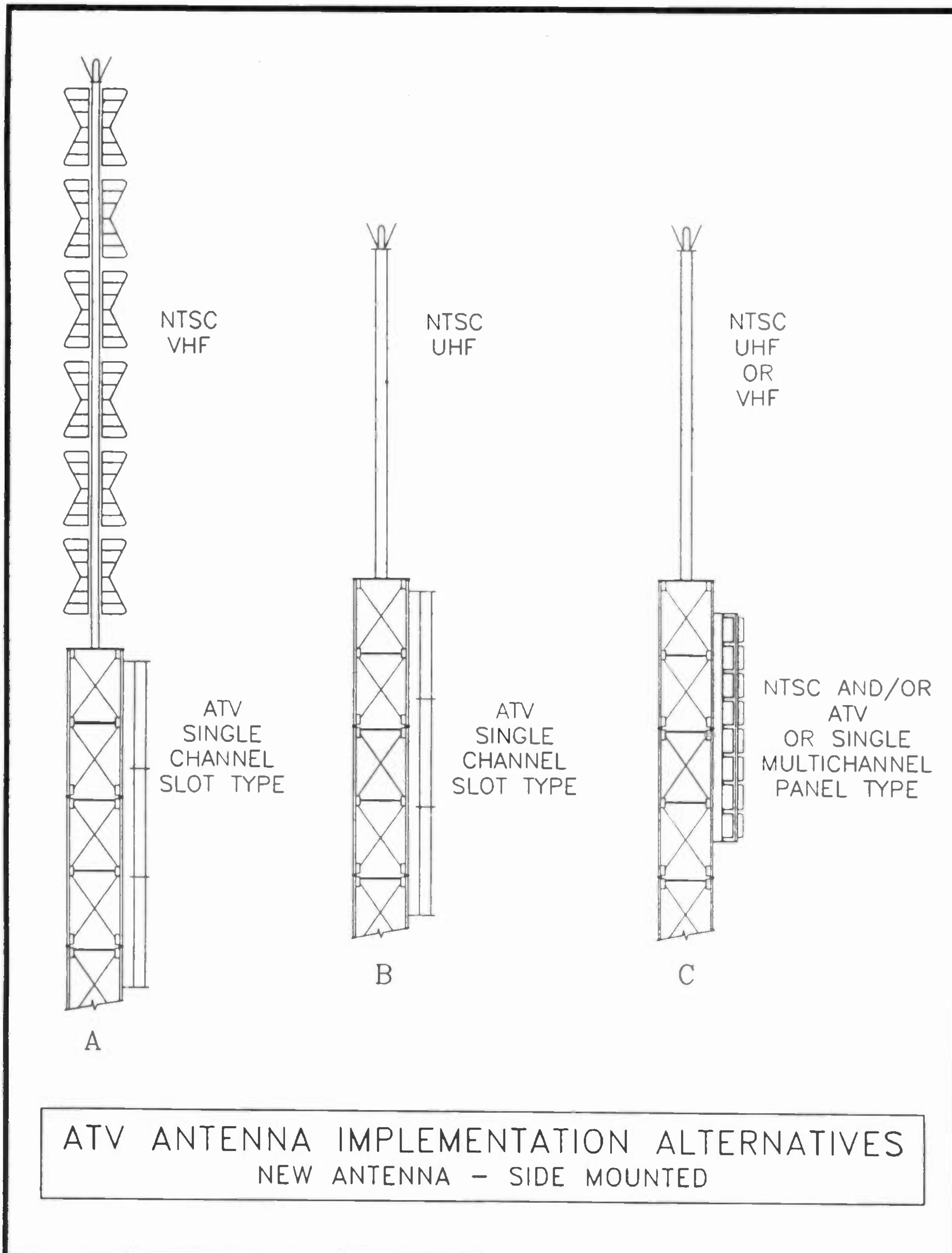


Figure 10
Possible Side- Mount Arrangement

MSDC KLYSTRON FIELD EXPERIENCE—5 YEAR REPORT

E.W. McCune, R. Batra, D. Sharrah
Varian Microwave Power Tube Products
Palo Alto, CA

ABSTRACT

The high-efficiency Multistage Depressed Collector klystron for UHF-TV service has been operational for over 5 years. Varian has 90 tubes operating at 36 stations; these tubes have accumulated over 2 million hours of service. Fifty-nine tubes have logged over 20,000 hours and 21 tubes over 30,000 hours. There have been 14 failures, most due to external causes. This report reviews the performance characteristics of the MSDC klystron and presents the field performance. The tube failures are described in detail. A statistical analysis of life performance is presented that indicates a projected MTBF of 60,000 hours. The MSDC life performance compares favorably with other high-power klystrons and shows no significant adverse effects from the MSDC energy-saving feature.

INTRODUCTION

The multistage depressed collector (MSDC) klystron is the result of a cooperative development program with NASA utilizing NASA-developed technology to achieve very efficient operation for microwave amplifiers. The Varian VKP-7990 klystron incorporates this technology, with performance as noted in Figure 1. A photograph of the klystron and its associated circuit and magnet is shown in Figure 2. The development effort was completed in 1989 and was reported at NAB at that time.[1] The klystron was incorporated into UHF-TV transmitters by Harris Broadcast in their UM design and by TVT, now a division of Harris, in their VISTA design. Transmitters of these types using Varian MSDC klystrons have been installed at 36 stations (30 Harris UM and 6 VISTA), starting in February 1990. Varian has continuously monitored the performance of the klystrons installed in these transmitters as part of our quality-improvement program. A preliminary report on field performance was provided at NAB[2] in 1992; however, we can now provide a more comprehensive report with 5 years of data.

Description

- Four External Cavities
- Tunable, 470 to 810 MHz
- Water and Air Cooling
- Includes: MSDC Collector, Modulating Anode, Beam-Control Electrode

Performance

• Output Power	64 kW saturated
• Drive Power	20 W
• 1-dB Bandwidth	6 MHz
• Figure of Merit	130 in Typical TV Service

Figure 1
VKP-7990 Multistage-Depressed-Collector Klystron Performance Characteristics

As of January 1995, 113 klystrons have been produced; 90 are in service at the 36 UHF-TV stations, with nine additional in standby as spares. Fourteen tubes have failed in operational transmitters for a variety of reasons. The total operating time for the tubes in service now exceeds 2 million hours. The longest operating klystron is at 38,000 hours, with 21 tubes over 30,000 hours and 59 tubes over 20,000 hours. The average life of the tubes in service now exceeds 24,000 hours. The 14 failures occurred at seven stations; it is worth noting that 29 stations have experienced no tube failures and are operating with their original tubes. This report focuses on the tube failures to describe the operational problems and to derive an expected performance life.

KLYSTRON FAILURE ANALYSIS

A detailed list of the failed klystrons is shown in Figure 3. The failures can be categorized in four areas. The largest group, with six incidents, failed due to breakage of the output-cavity ceramic. Four of the cases of output-ceramic

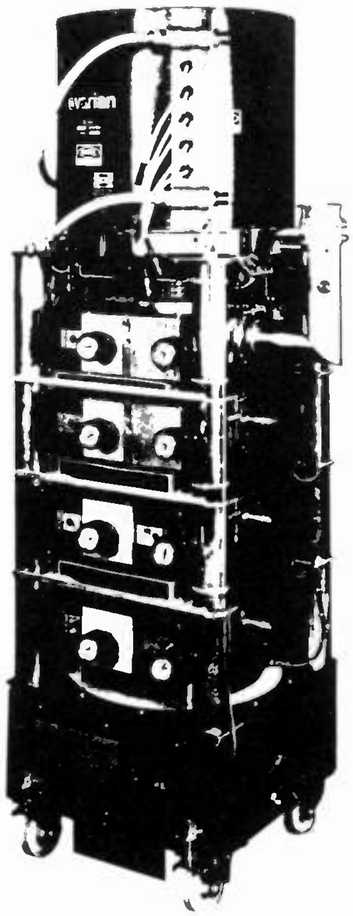


Figure 2
The VKP-7990 MSDC Klystron with Circuit Assembly

failure occurred very early in MSDC deployment. Corrective actions at that time resolved most of the problems. However, over the past 4 years there have been two additional cases. Both cases showed arc damage at the output cavity, indicative of an output-transmission-line fault.

The second failure category, "Collector Arc," lists three incidents. In two cases, an arc occurred at a collector insulator, causing breakage and loss of vacuum. One case was traced to improper installation, while the other was due to a voltage surge. The third case was due to internal voltage breakdown in the collector and was an early failure. Subsequent corrective actions have resolved the problem.

There were three incidents of the third failure category, listed as "Gassy." These klystrons developed excessive gas pressure that adversely affected their performance. We have revised our vacuum processing procedures to resolve the problem.

Two incidents of "Drift Tube Damage," the fourth failure category, were recorded. These klystrons both suffered extensive melting of the input cavity drift tube due to loss of focusing magnetic field during operation. These events occurred at one station due to faulty control logic, which has been corrected.

It is important to note that there are no cases of normal klystron end-of-life, such as loss of cathode emission, or any evidence of the "coppering phenomenon" that is observed in some other external-cavity klystrons. Cathode emission failure would not be expected this early in life, since the cathode design is similar to that used on our internal-cavity klystrons, which commonly achieve 100,000-hour lifetimes.

LIFE-EXPECTANCY PROJECTION

A statistical analysis technique is available to project a value for mean time between failures (MTBF) as described by Nelson.[3] As of January 10, 1995, 104 klystrons have provided 2,162,000 hours of operation, with 14 failures. This represents a set of incomplete failure data that can be analyzed using a hazard plot appropriate for multiply censored failure data. The failed tubes are listed in Figure 3; for each tube there is a sequence number showing the order in service hours, a hazard value in percent, and the cumulative hazard value. The hazard value is determined by dividing into 100 the number of tubes with longer operating life (104 less the sequence number). The cumulative hazard values associated with the failure time are then plotted on a log-log chart to form a Weibull Hazard Plot, shown in Figure 4. A best-fit line with a slope of 1 is drawn through the data points to indicate the most likely life performance expectation. The value of 1 for the slope of the curve is appropriate for constant failure rate due to random failures and fits the data reasonably well. The projected failure rate in Figure 4 indicates an expected MTBF of 60,000 hours. It is interesting to note that this is the same value predicted in the preliminary report in 1992.

We have noted that many early failures occurred during the first year of operation of the MSDC transmitters. Consequently, it would be appropriate to evaluate the life performance after the first year to arrive at a better life prediction. We have reevaluated the hazard data deleting the six early failures and have derived a modified Weibull Plot. The data points are more closely aligned along the 45-degree slope representing random failures. Also, the curve is shifted slightly, leading to a higher predicted value for MTBF (approaching 100,000 hours).

An Operational Problem Noted

Two stations reported a water-leak problem inside the collector enclosure of their klystron. The leak was determined to be due to erosion of the upper coolant connector caused by electrolytic action. Replacement connectors were provided, which solved the immediate problem. However, the basic problem was electrolysis caused by excessive conductivity of the cooling water. In order to provide advance warning of erosion problems, we have developed an independent means of monitoring electrolytic action, an easily installed replacement coolant connector that incorporates a sacrificial element calibrated to indicate the degree of erosion. By design, electrolytic erosion is concentrated at the replaceable coolant connector so we can monitor the effect. Consequently, the new connector design provides an effective solution to the problem. New connectors are being provided to all stations to upgrade their tubes.

CONCLUSIONS

An analysis of the field experience resulting from 104 MSDC klystrons over a 5-year period indicates an expected MTBF of at least 60,000 hours. Our experience with other similar klystrons would suggest a similar value, so it is likely that the depressed-collector feature has not degraded the life performance. The observed failures are random in nature and do not indicate any impending end-of-life mechanism. So far, the MSDC klystron life performance proceeds on track; however,we will continue to monitor the tube operation to verify unchanged performance.

REFERENCES

1. E.W. McCune. "Final Report: The Multistage Depressed Collector Project." NAB Engineering Conference, Las Vegas, NV, April 1988.

2. E.W. McCune. "MSDC Klystron Field Experience." NAB Engineering Conference, Las Vegas, NV, April 1992.

3. Wayne Nelson. "Hazard Plotting for Incomplete Failure Data." Journal of Quality Technology, January 1969.

Sequence Number	Serial Number	Operating Hours	Failure Date	Hazard %	Cumulative Hazard	Failure Description
1	L9-10	500	6/90	0.97	0.97	Output Ceramic
2	F2-313	1364	12/92	0.98	1.95	Gassy
4	G2-315	1900	1/93	1.00	2.95	Gassy
5	H0-02	2929	3/91	1.01	3.96	Collector Arc
6	G9-03	3000	5/90	1.02	4.98	Output Ceramic
7	B3-325	3237	10/93	1.03	6.01	Output Ceramic
8	H9-03	3275	9/90	1.04	7.05	Output Ceramic
13	J2-319	4008	8/93	1.10	8.15	Output Ceramic
14	L1-11	4158	4/93	1.11	9.26	Drift Tube Damage
15	F1-14	4728	8/92	1.12	10.38	Gassy
16	E9-152	6204	3/91	1.14	11.52	Output Ceramic
17	F9-170	7620	3/91	1.15	12.67	Collector Arc
18	C2-302	10168	3/94	1.16	13.83	Drift Tube Damage
98	A0-08	35968	11/94	16.67	30.50	Collector Arc

Figure 3
MSDC Klystron Failure Data

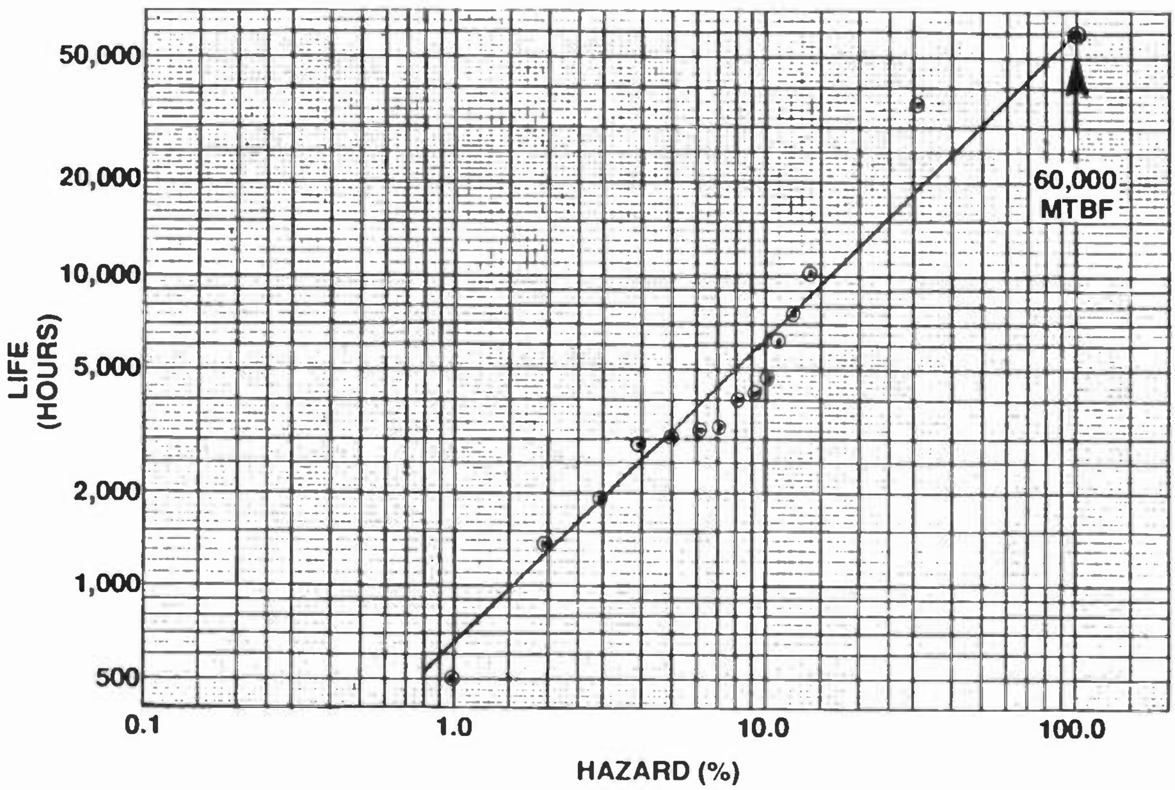


Figure 4
Weibull Hazard Plot

RADIO RF WORKSHOP: MAINTAINING THE SIGNAL

Thursday, April 13, 1995

Session Chairperson:
Fred Greaves, Susquehanna Radio Corp., York, PA

*Papers not available at the time of publication

SIGNAL STRENGTH SURVEY OF FM BROADCAST STATIONS

Charles A. Cooper
du Treil, Lundin & Rackley, Inc.
Sarasota, FL

ABSTRACT

This paper will present a procedure to measure the signal strengths of FM broadcast stations encountered by an automobile type receiver. Using a signal level meter, a GPS receiver and a notebook computer, signal level samples and associated location data are automatically acquired as an automobile traverses an area. This data is then assessed to produce a signal level survey coverage map. Multiple stations can also be measured and compared.

INTRODUCTION

Predicting the actual radiofrequency environment encountered by an automobile receiver in limited urban environs using traditional methods often produces ambiguous results. Traditional propagation methods include the FCC "curve" method and discrete point-to-point methods. The FCC propagation model predicts the median field strength over a radial extending from the transmitter site. Only the average terrain from a distance of 2 to 10 miles is employed to determine to predicted field intensity, with no consideration given to obstructions or terrain shadowing.

While point-to-point advanced propagation methods, such as Longley-Rice (Tech Note 101 method) provide improved predictions of received field strength, many localized variables are not considered. These variables include signal multipath, vegetation attenuation and non-circular transmitting antenna radiation patterns. However, by sampling the signal strength and associated geographic location, the actual signal level distribution over portions of a station's predicted coverage area can be determined.

SIGNAL ACQUISITION PROCEDURE

Employing a computer controlled signal strength meter, a global positioning system (GPS) receiver, a notebook computer and a "typical" automobile vertical whip antenna, the radiofrequency environment encountered by a mobile automobile can be surveyed. The specific equipment used by this firm includes a Z-Technology signal strength meter, a vertical whip antenna and a Trimble GPS receiver. A common "off-the-shelf" notebook computer is used to acquire data from the signal strength meter and GPS receiver.

The Z-Technology R-501P meter is a portable precision signal strength meter providing a measurement accuracy of 2 dB or better. With computer control of all functions including changing frequency and sampling the signal strength value, multiple stations can be measured automatically, permitting a ready comparison of signal strengths. The signal strength for each station, measured in units of dBμV at the receiver input terminals, is sampled by the notebook computer for every measured frequency.

The signal strength for each frequency is sampled every three seconds by the signal strength meter as the automobile travels around the survey area. Each acquired signal strength is the averaged value of four samples periodically acquired over a time duration of 160 milliseconds. These time periods were set to compensate for the data acquisition hardware constants of the system.

Using a GPS receiver in the signal strength survey allows the sampled signal value to be associated with a specific geographic location. A Trimble ScoutMaster GPS receiver, with a digital output, provides a geographic location defined by latitude and longitude with a worst-case accuracy of ±300 feet. For each sampled signal strength, the location is acquired by the GPS receiver and immediately noted.

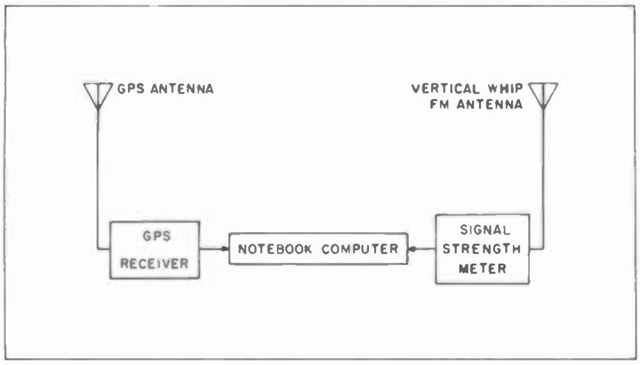


Fig. 1 FM Survey Equipment Block Diagram

To simulate the FM band radiofrequency environment of an automobile, a vertical whip antenna magnetically mounted on the automobile roof is employed. The antenna used is a Radio Shack "gutter-mount" 29.5 inch whip antenna and is connected to the signal strength meter. At 100 MHz, this antenna is ¼ wavelength long.

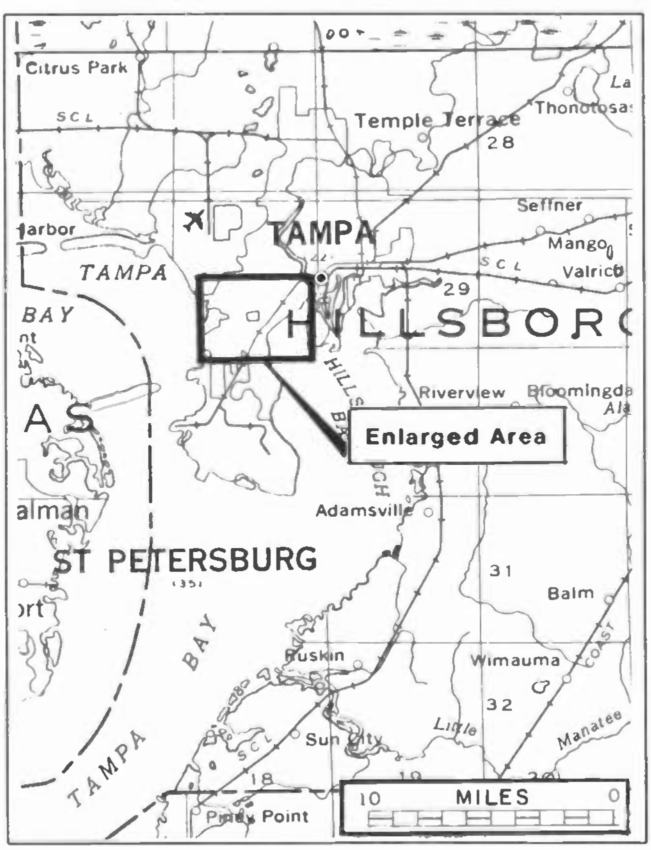


Fig. 2 Expanded FM Survey Test Area

A vertical whip which is ¼ wavelength long at 100 MHz has a relationship of induced voltage to incident field strength which is uniform to within approximately ±1.0 dB between 88 MHz and 108 MHz, when terminated into a 50 ohm load. If this variation is deemed important, correction factors may be applied individually for the various frequencies measured in the signal analysis software.

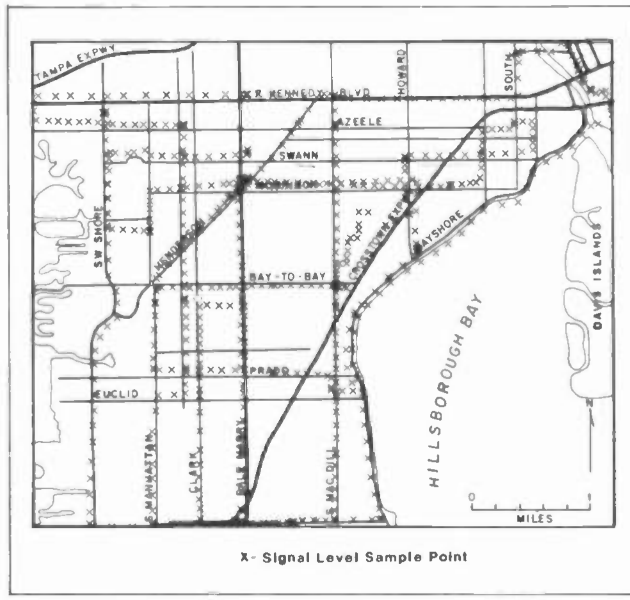


Fig. 3 Locations of Sampled Signal Levels

As shown by Figure 1, with the signal strength meter, GPS receiver, whip antenna and notebook computer assembled in a mobile test platform, the signal strengths of multiple stations can be acquired. A computer program has been developed to acquire the location and sampled signal level value for each station surveyed. The acquired data is stored for later analysis.

The resolution of the signal levels is dependent upon the size of the area under question. Typically, the more sampled data values, the greater the precision of the analyzed results. As an example, a signal strength survey was conducted in the Tampa, Florida market for two FM stations. The area in question was the southern section of Tampa as shown on Figure 2. Figure 3 is an enlarged map illustrating the survey area. Also noted on the map are the locations where the signal levels where sampled. The major thoroughfares of the area were traversed to acquire the data.

DATA ANALYSIS

To analyze the data, an area of regularly spaced discrete points is developed. At each point, or node, an estimate is calculated based on weighed linear combinations of the sampled signal levels lying within a search window. This analytical estimation method, termed Kriging, attempts to calculate "unbiased" estimates at each grid node.[1] These regularly spaced estimates are then employed to determine the coverage contours. A contouring mapping software program, such as Surfer,[2] can aid in Kriging estimation and subsequent data plotting.

The Kriging estimation method is considered "unbiased" since it tries to have the mean (average) residual or error, m_r, equal to zero. It also attempts to minimize the variance of the errors, σ_r^2. The residual is considered to be the difference between the estimated value and the actual sampled value at a specific geographic location. The variance of errors is the average squared difference of the residual from their mean. Since the acquired data is only a sample set and not an exhaustive set, m_r and σ_r^2 are always unknown. However, by modeling the sampled data by employing an estimation method such as Kriging, the errors can be minimized.

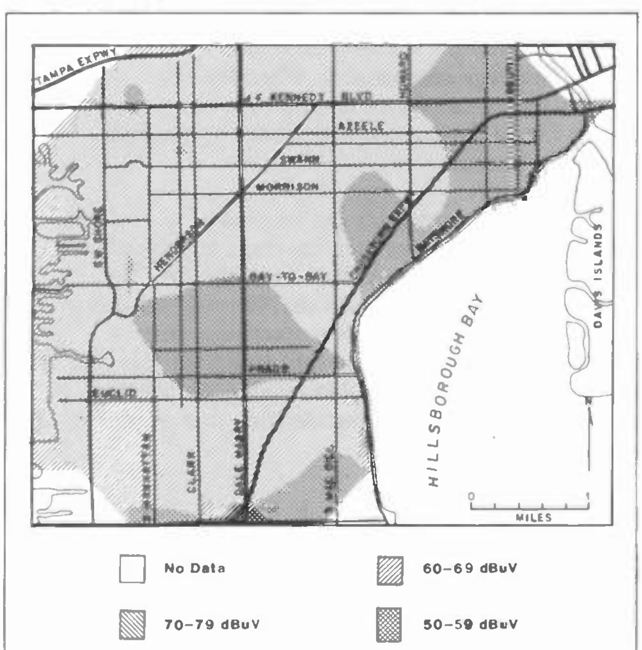


Fig. 4 WUSA Actual Signal Voltage Coverage Map

In the survey of the Tampa area, a grid was developed with at least 12 data samples encompassing a search window at each node as suggested by Isaaks.[3] The search window employed in the noted survey is an ellipse centered on the node. The grid structure and search window specifications were empirically developed to show the desired signal strength detail while minimizing the mean residual, m_r and the variance of errors, σ_r^2.

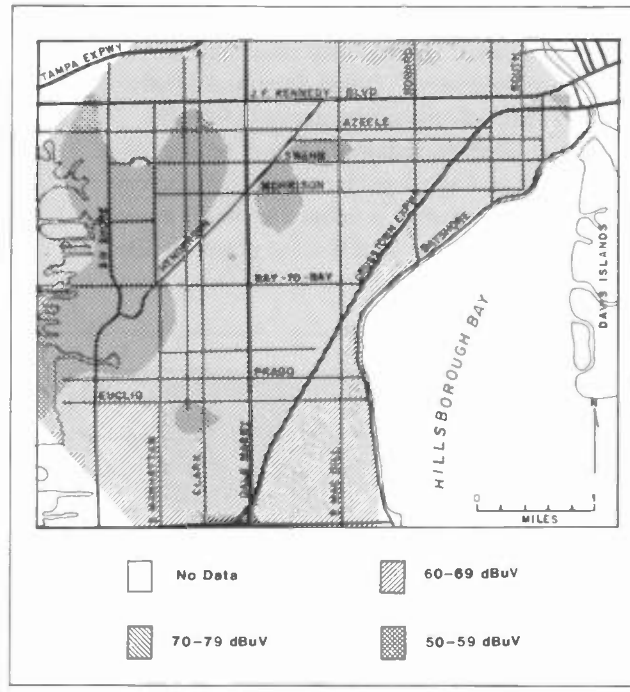


Fig. 5 WKES Actual Signal Voltage Coverage Map

To determine the mean residual and the variance of errors, the estimated and actual values are compared in a technique called cross validation. In cross validation, the sample value at a particular location is temporarily discarded from the sample data set. The value at the same location is then estimated using the remaining samples. Once the estimate is calculated, it can be compared to the actual sample that was initially removed from the sample data set. This procedure is repeated for all available samples. The residual data sample mean and variance can then be calculated.

Using the above methods, the data from a signal strength survey for two FM stations in the Tampa market were plotted. Figure 4 is an actual coverage map for station WUSA on 100.7 MHz. WUSA is a class C1 FM station with an effective radiated power 100 kilowatts and an antenna radiation center height above average terrain of 183 meters. From the center of the coverage map, the WUSA antenna is located 12.7 miles away on a northwest bearing. On Figure 5 is WKES, a class C on 101.5 MHz.

With an effective radiated power of 100 kilowatts and an antenna radiation center of 412 meters, the transmitter is located 15.4 miles east-southeast from the center of the coverage map.

From a recent paper concerning the establishment of effective radiated power and antenna heights for various station classes, Karl Lahm summarized receiver performance information on a range of specific car receivers.[4] It was determined that satisfactory stereophonic performance in 90% of evaluated car receivers required a power sensitivity of 43.5 dBf at the receiver input terminals. Satisfactory stereophonic performance is defined as 50 dB audio output quieting. The unit of dBf is the power in dB (decibels) relative to one femtowatt (10^{-15}).

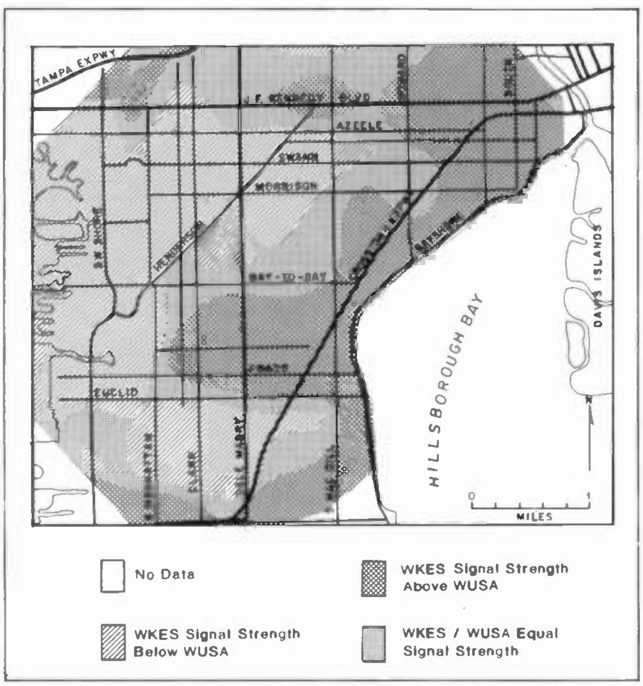


Fig. 6 WUSA/WKES Signal Comparison

To convert the units from power (dBf) to signal voltage (dBμV), the receiver is assumed to have a 50 ohm antenna termination impedance. Therefore, a signal voltage of 33.5 dBμV at the receive input terminals is required to achieve satisfactory stereophonic performance. A 3 dB derating figure to cover antenna cable mismatch, connectors and antenna deficiencies is included in the 33.5 dBμV value.

Again referring to Figures 4 and 5, it can be determined that satisfactory stereophonic service is available in the south Tampa vicinity from the two FM stations. As noted above, the receiver signal voltage threshold is 33.5 dBμV. The lowest range of signal level values is between 50-59 dBμV for both WUSA and WKES. However, it can also be seen that WKES (Figure 5) provides a greater signal strength over a larger area than WUSA (Figure 4); as to be expected from a class C facility with respect to a class C1 facility.

It must be remembered when viewing the signal level maps of Figures 4 and 5 that receive input voltages are shown, not the incident signal levels with which broadcasters are so thoroughly familiar because of the FCC's reliance on them.

A signal level comparison between the radio stations can also be accomplished by simply calculating the signal level difference at each grid node. Figure 6 illustrates the signal level difference of WKES with respect to WUSA. Along Hillsborough Bay, WKES provides a greater signal than WUSA; along SW Shore road, WUSA provides a greater signal level than WKES. Close comparison of the individual station coverage maps can also disclose the approximate difference in signal strength over areas of question.

CONCLUSION

By using an automated test platform to periodically sample the receive signal level of FM stations and the geographic location, a coverage survey map can be generated illustrating the actual signal level distribution. Multiple stations can also be sampled to provide a coverage comparison. When receiver sensitivity specifications are compared to the survey results, it can be determined where poor or marginal reception will occur.

Such measurements can be used by the owners of FM stations to evaluate their coverage areas relative to the other stations in their markets and, with the measurements repeated periodically, to track changes in coverage which might indicate corrective measures. Prospective buyers should also find measurements such as those described herein helpful in ranking the coverage areas of the stations under consideration in a desired market.

[1] Isaaks, Edward H., Srivastava, R. Mohan, "An Introduction to Applied Geostatistics"; Oxford University Press; 1989; p. 278,

[2] "Surfer for Windows"; Golden Software, Inc.; 1994.

[3] Isaaks, Edward H.; Srivastava, R. Mohan, "An Introduction to Applied Geostatistics"; Oxford University Press; 1989; p. 341.

[4] Lahm, Karl D., "Optimization of VHF Effective Radiated Power and Antenna Height Combinations"; *1992 Proceedings, 46th Annual Broadcast Engineering Conference Proceedings*; 1992; p.286.

PARASITIC DIRECTIONAL ANTENNAS: AN INEXPENSIVE EXAMPLE

Karl D. Lahm, P.E.
Voice of America[1]
Washington, D.C.

Abstract

In the fall of 1993, the Voice of America completed construction of a temporary 100 kW medium wave (AM) station located in Kuwait, which was to serve until a permanent 600 kW station could be built. It became apparent that the temporary station, which used an omnidirectional antenna, would have to serve much longer than originally anticipated due to delays in authorization to construct the permanent station. Nevertheless, an increase of signal strength in the primary service areas was desired. That was accomplished by the installation of a parasitic antenna element configured as a reflector, creating a two tower directional antenna system that doubled the power radiated in the directions of interest. Cost was limited to installation and setup labor, since almost all system components were available from inventory. Operating on 1548 kHz, this antenna is a practical example of how such configurations might be exploited by domestic broadcasters in the expanded portion of the AM band.

I. Background

In the early 1990s, the Voice of America (VOA) obtained authority to construct and operate a broadcast relay (transmitting) station in Kuwait to enhance VOA broadcast service to that region of the world. The permanent facility envisioned by VOA is to operate at a transmitter power of 600 kW on 1548 kilohertz (kHz), with a multimode directional antenna to concentrate radiation toward different target service areas during different portions of the broadcast day.

The construction of a complete, permanent station consumes a lot of time. The service objectives at this site required operation at an earlier date, if such was at all feasible. An "interim" station, operating with a nondirectional antenna at a power of 100 kW, commenced operation in October of 1993. It was equipped with a nondirectional antenna created out of components existing in VOA relay station network inventory. The transmitting equipment was comprised of two 50 kW transmitters housed in transportable shelters and a combiner circuit created by rebuilding a surplus directional antenna tuning unit cabinet.

In the summer of 1993, the possiblility of converting the Interim Station to directional operation was examined in detail by VOA RF engineering and project management staff. Theoretical modeling and cost estimates showed that such a conversion would be practical, inexpensive, and effective.

II. Antenna Design

The parasitic directional antenna system is comprised of the original nondirectional antenna, associated equipment, a second antenna tower and monopole imaging (ground) screen, and a terminating circuit for the latter radiating element. The second tower was obtained from an abandoned communications installation at the same site. The tower was dismantled, relocated, erected, and repainted by a local contractor. The terminating network was fabricated in the U.S. to a design by VOA, once again making use of components available from VOA network inventory. New ground system components were procured domestically and installed by the local contractor. Figure 1, attached, illustrates the antenna site layout with the new tower added.

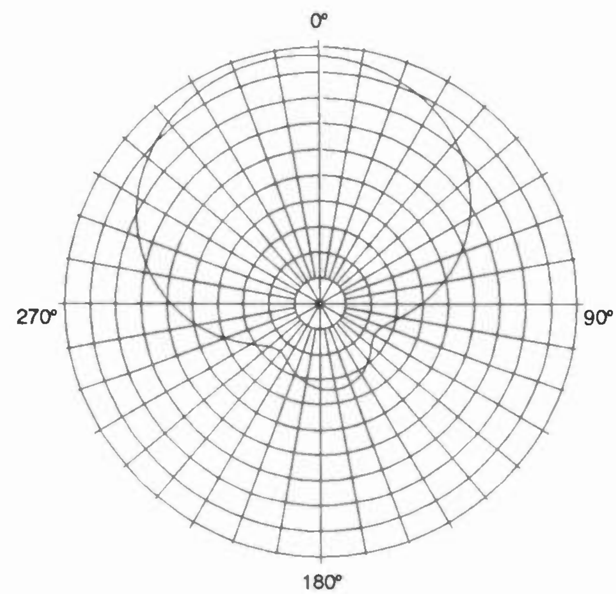
The primary objectives for the directionalization of the antenna at the Interim Station were (a) gain of 3dB from the northwest through the northeast, (b) minimum radiation southeastward, toward an adjacent channel station, and southwestward, over sparsely populated areas, (c) minimization of cost, and (d) simplicity of implementation. It was determined that these objectives would best be met by installation of a second mast to be used as a parasitic reflector.

Any parasitic antenna element is adjustable only by varying its terminating impedance. The resistive component of this impedance must be as low as possible in order to maximize efficiency. Since only one operating condition (terminating reactance) is variable electronically, independent control of field magnitude ratio and phase difference cannot be achieved. For field phase differences corresponding to a specified pattern minimum radiation bearing, magnitude ratio is determined by the spacing between the driven element and the reflector. The spacing thereby determines array gain and suppression. With the radiator line positioned at 350° True and the pattern minimum oriented toward 120° True, it was determined that an interelement spacing of 38 meters (70.6 electrical degrees) would produce the desired gain toward the primary service areas (each approximately 30 degrees off the element bearing).

A. Prediction of Operating Conditions

The MININEC3 moment method electromagnetic computation program was used to model all pertinent characteristics of the modified antenna system. Figure 2 is a polar plot of the desired radiation pattern.

Figure 2



This pattern has a maximum gain of 4.1 decibels (dB) at the center of the main lobe (350° True), a 3 dB beamwidth of approximately 135°, -7.9 dB gain at the pattern minimum (120° and 220° True), and -4.9 dB gain at the pattern "tail" (170° True), yielding a front-to-back ratio of 9 dB and a front-to-minimum ratio of 12 dB. All gain figures are referenced to nondirectional operation with the south tower detuned.

The ideal base operating parameters computed using MININEC3 or similar programs are not those likely to be present at the output jacks of the antenna terminating networks. The parameters present at those locations are dependent upon the shunt capacitance of the base insulator (and lighting transformer at the north tower), series inductance of the radiator feed pipe, and shunt capacitance of the terminating network cabinet output feed-through bowl, all of which form a lagging pi-network. Measurements taken during construction of the nondirectional antenna showed the base insulator capacitance to be 25 pF, a feed pipe inductance as 3.3 μH, and feed-through bowl and stray capacitance to be 61 pF. Applying these factors to the MININEC3 data and presuming that they would be identical at the new tower's base, the antenna operating parameters expected at the tower bases for operation of the new system are shown in Table I.

B. Measured Operating Conditions

Also shown in Table I are the actual measured values of antenna input impedances and currents. The south/north tower current ratios deviate 4% for directional operation and 3% for the nondirectional case with respect to predicted values. This correlation is further evidence that the desired operating conditions have been achieved.

III. Input and Terminating Networks

The existing omnidirectional antenna was already fed through a conventional "Tee" matching network. Table I shows that a considerable increase in load reactance and slight reduction in load resistance was expected to result during directional operation. This matching network had to be modified to accommodate both loads.

This was not difficult to do. Figure 3 is a schematic diagram of the modified input network for the driven tower. The output arm of this matching circuit is comprised of four variable vacuum capacitors arranged in series-parallel. A jack was placed in the paralleling path so that one series pair of capacitors is in the circuit for the higher-reactance directional mode

Table I
TOWER BASE INPUT PARAMETERS

	Directional		Non-Directional	
Parameter	**North Tower #1**	**South Tower #2**	**North Tower #1**	**South Tower #2**
Predicted Input Impedance, Ohms	81.5 + j170	0.5 - j80.6	86 + j124	2.8 + j329
Measured Input Impedance, Ohms	78 + j177	3 - j99	80 + j136	4 + j341
Predicted Input Current, Amps	35.0	30.0	34.1	4.4
Measured Input Current, Amps	35.8	29.4	35.4	3.5
Predicted Input Current Ratio	0.86		0.13	
Measured Input Current Ratio	0.82		0.10	
Predicted Radiated Field Ratio	0.647 /+135.0°		< 0.001	

Figure 3 - North Tower ATU

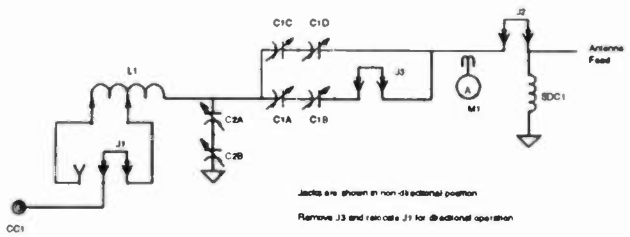
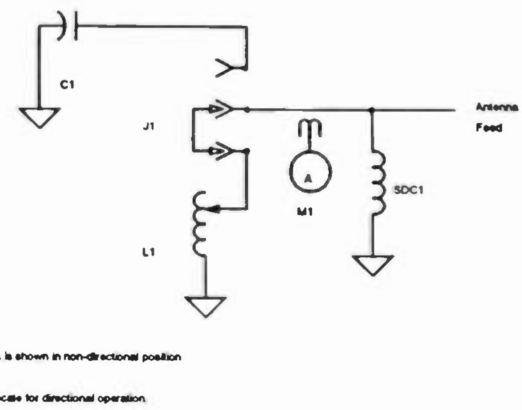


Figure 4 - South Tower ATU



and the second series pair is paralleled in by plug insertion when nondirectional operation is desired. The input arm, which is comprised of a coil, was provided with two taps selected by another jack-and-plug arrangement. One tap is used for directional operation, the other for nondirectional. The shunt arm of this matching network retains the same adjustment for both modes.

The new radiator also required two terminations, of reactances very different not only in sign but also in magnitude. Figure 4 illustrates the topology of the circuit connected at the south tower. In its final form, a coil is selected by jack-and-plug for nondirectional operation, while a fixed vacuum capacitor is selected for the directional case.

This was not the original circuit topology. A series coil and fixed vacuum capacitor were installed for antenna termination during directional operation. However, an error was made in sizing the current rating of the coil. During the first night of test operation, several VSWR trips were observed on the transmitters. Inspection of the circuit revealed that the coil had been overheated and it also showed signs of arcing from its roller to its ribbon turns. Luck prevailed, as the series reactance of the coil and capacitor, as finally adjusted, was virtually identical to the reactance of a fixed vacuum capacitor available from station stock, without reducing supplies of critical spares. Accordingly, the coil was retired and the fixed capacitor changed to the one having the necessary reactance.

IV. Antenna System Adjustment

The modified antenna system was adjusted and made ready for service (commissioned) in three days, commencing on a Monday and concluding on a Thursday. This rapid commissioning time was made possible by (1) the inherent simplicity of the design, (2) the consideration of practical effects in network design, (3) having no need to perform a Proof of Performance in the manner specified by the FCC, and (4) good luck, despite one overheated coil.

A. Initial Efforts

Shortly after arrival at the site, the terminating reactances at the south tower were set to theoretical values using the station's operating impedance bridge.

A field strength meter was placed approximately one kilometer from the antenna system and near a bearing of 120° True, determined by sighting of the tower line and vehicle transporting the meter. Operating at low power (approximately 8 kW), the directional terminating reactance was adjusted at the south tower to produce a minimum field strength reading at the sighted survey location. Then the input and output branches of the Tee matching network at the north tower were adjusted to provide a match of the transmission line to the resulting directional and nondirectional load impedances. This action was intended to establish the proper phase relationship between the fields of the driven and reflecting antenna elements. With the proper phase relationship established, the ratio of the fields should approximate the correct value, because there is no independent adjustment of the two parameters.

B. Precise Adjustment

More precise adjustments of the reactances terminating the south tower took place the next day. This effort yielded measured terminating impedances (at the network output J-plug) of 4+j341 for nondirectional operation and 3-j99 for directional operation. Both values are reasonably close to the predicted values described in Table I.

The objective of adjustment related to the nondirectional operating mode was to precisely detune the new antenna element so as to produce minimum reradiation in the horizontal plane. This results when a current minimum is positioned along the radiator length such that the sum of currents above and below is equal. For radiators less than 125 electrical degrees tall, the position of the detuned current minimum relative to the total radiator height is defined by the equation $P = 0.322 + 0.00484\ e^{(G'/80)}$, where P is the position and G' is the effective tower height in electrical degrees (generally, the height in degrees divided by 0.95).

To establish this current minimum position, a station staff member experienced in tower rigging climbed the south tower to a height of 17 meters above the base insulator, where he used the Potomac field strength meter to detect radiator current. A block of wood had been affixed to the side of the meter in order to separate it from the tower leg by a uniform distance. Minimum current at this location corresponds to minimum reradiated field in the horizontal plane. Nondirectional detuning coil L1 was then adjusted to produce a minimum indication on the meter with the north tower driven by a signal generator. This current was 2½% of the current flowing at the same location with the radiator base open-circuited.

Precise adjustment of the terminating reactance for directional operation was then conducted. VOA engineers again drove across the site to a position approximately 1½ kilometers distant, where they used a compass to position themselves such that the array center was located at a bearing of 300° True away, the reciprocal of 120°. The station was operated with one transmitter, at low power, in the combined mode. Field strength was read for the nondirectional mode. Then the directional mode was activated and the South tower terminating was again varied to obtain the minimum field strength. The north tower matching network was then retuned to achieve a better match of the transmission line. North tower input impedances were then measured over a range of frequencies. Field strengths were measured as described below.

Table II
ANTENNA INPUT VSWR

Frequency kHz	Omni	DA
1533	1.12:1	1.22:1
1538	1.08:1	1.13:1
1543	1.03:1	1.07:1
1548	1.00:1	1.00:1
1553	1.03:1	1.04:1
1558	1.06:1	1.10:1
1563	1.10:1	1.15:1

V. Input Impedance Measurements

The antenna input impedance was measured at a range of frequencies using the Delta OIB-3 and its companion RG-4 receiver/generator. The resulting data was converted to VSWR figures relative to the carrier frequency condition and is shown in Table II. These data indicate that the sideband VSWR characteristic of the nondirectional antenna is degraded significantly with the parasitic reflector added. This is not surprising, expecially given the close spacing (70.6 degrees) between elements. It has been long recognized that the substantial coupling between closely spaced directional elements restricts impedance bandwidth significantly. An antenna having lower gain and suppression requirements would employ wider interelement spacing, which would result in less bandwidth degradation between nondirectional and directional modes.

VI. Field Strength Measurements

Limited groundwave field strength measurements were undertaken to further verify the adjustment of the antenna system. Because proper positioning of the pattern minimum inherently establishes the field phase and field ratio for this type of array, the gain and suppression are virtually assured to be correct. Field strength measurements are subject to variations caused by local conditions in the immediate vicinity of the measurement location. When measurement count is limited, such data should not be relied on as a conclusive and sole indication of antenna performance. However, where other indications of performance infer the same conclusion, such data helps confirm the performance achieved.

Measurements were taken at locations uniformly spaced along readily accessible roads close to the transmitter site. Two sets of measurements were performed, one for nondirectional and the other for directional operation, both with 100 kW of antenna input power.

Distances and bearings to each measurement location were determined by plotting those points on an accurate topographic map of the area and then extending radial lines from the site center through each such point. These data are presented in Table III.

The directional/nondirectional field strength ratio was computed for each measurement location. The theoretical far-field directional/nondirectional ratio was computed for azimuthal bearings matching those determined for each measurement location. These ratios were compared and the difference computed.

Inspection of Table III reveals that measured directional/nondirectional ratios are within ±2 dB of theoretical ratios at all but one measurement location. Given the limitations inherent in single-point-per-bearing data and its analysis, this is excellent correlation. Multiple measurement locations were available at or near the 192° and 351° bearings. Averaging the ratio differences within those respective point groups, the data suggest that directional radiation is 1 dB above theoretical toward 192° True and approximately

Table III

FIELD STRENGTH MEASUREMENTS

Bearing (°T.)	Distance (km)	Theoretical DA/ND Ratio (dB)	ND Field Strength (mV/m)	DA Field Strength (mV/m)	Measured DA/ND Ratio (dB)	Measured-Theoretical Difference (dB)
1	12.1	+4.1	210	300	+3.1	-1.0
3	9	+4.0	380	540	+3.1	-1.0
32.5	1	+3.1	2180	3000	+2.8	-0.3
47.5	2	+2.1	1600	1980	+1.9	-0.3
54	3.1	+1.6	1000	1250	+1.9	+0.4
57.5	4.5	+1.2		280		-1.2
69.5	1	-0.3	1000	940	-0.5	-0.3
87.5	2	-3.3	1200	820	-3.3	-0.0
105.5	2.9	-6.7	980	470	-6.4	+0.3
124.5	4	-7.7	1000	345	-9.2	-1.5
137.5	5	-6.6	900	295	-9.7	-3.1
153	7	-5.4	560	350	-4.1	+1.3
190	12	-5.6	280	168	-4.4	+1.1
191	15	-5.6	215	130	-4.4	+1.3
192.5	7	-5.8	560	290	-5.7	+0.1
192.5	9	-5.8	360	200	-5.1	+0.7
195.5	5	-6.4	770	470	-4.3	+1.7
196.5	3	-6.1	1150	640	-5.1	+1.0
205	2	-6.9	1720	960	-5.1	+1.8
221	1	-7.9	3100	1450	-6.6	+1.3
351	1	+4.1	3000	4850	+4.2	+0.1
351	5	+4.1	650	920	+3.0	-1.1
351.5	3	+4.1	960	1680	+4.9	+0.8
353	2	+4.1	1620	2350	+3.2	-0.9
358.5	7	+4.1	360	540	+3.5	-0.6

¼ dB below theoretical toward 351° True. The latter bearing is one degree off the center of the main radiation lobe (350° T.). The small apparent deficiency in radiation (3.1% low) is beyond the resolution of the measurement apparatus and techniques used. It could easily arise from a slight error in transmitter output power or drift in the calibration of the field strength meter.

VII. Conclusion

The analysis of measured data and setup procedure used in the field establish that the parasitic directional antenna system constructed at the Kuwait Interim Relay Station meet all design objectives. Antenna input currents and impedances are remarkably close to predicted values. Main lobe (northward) gain is as expected. Suppression (southward) is also in accordance with expectations. Feed network components readily accommodated the change in operating conditions that results from directionalization. The station has operated successfully since September of 1994 using this parasitic directional antenna.

Note:

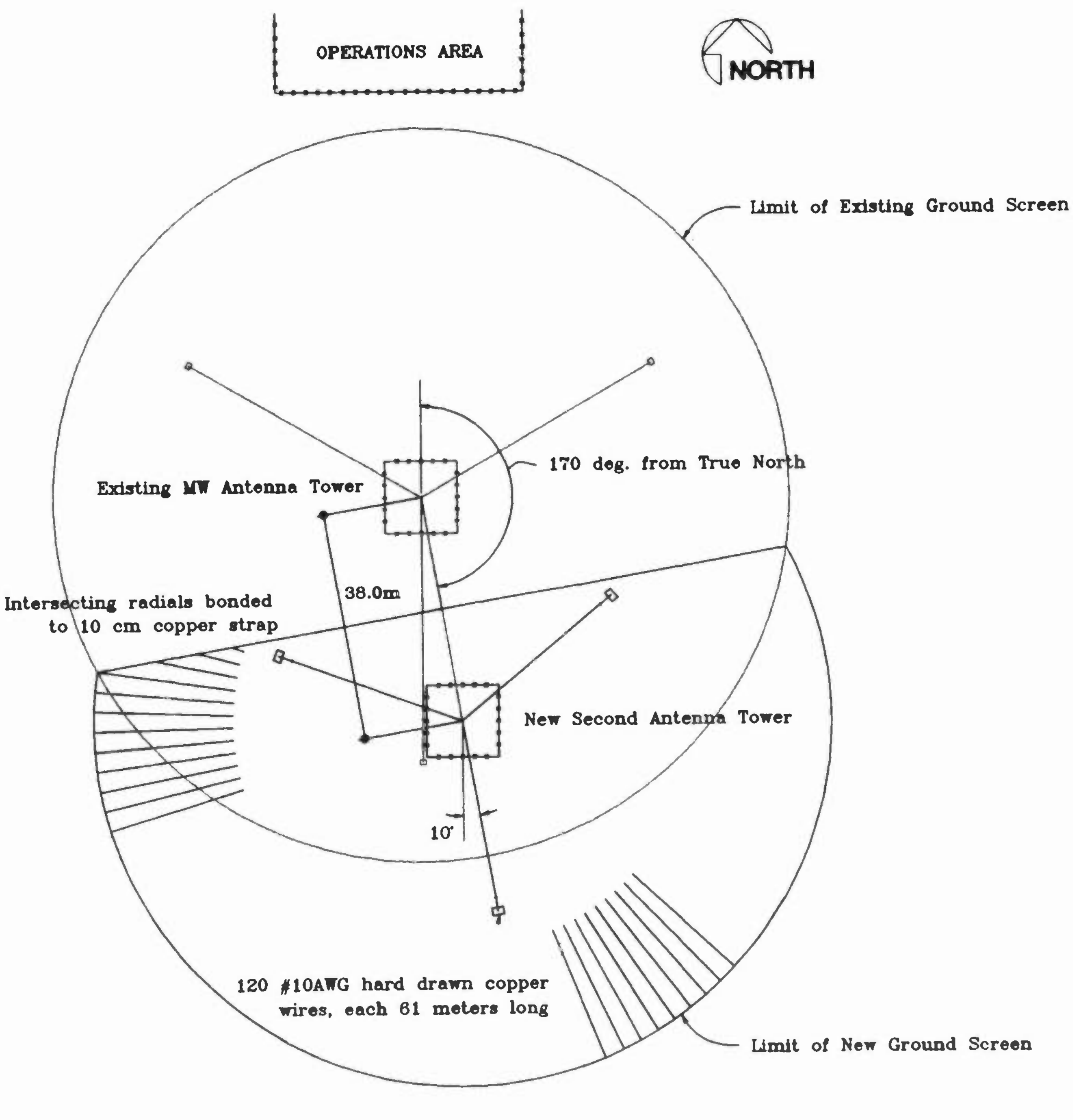
1. The opinions expressed in this paper are those of its author and do not reflect any official positions of the U.S. Information Agency or the government of the United States of America.

Acknowledgements:

A project like this is not conducted by one person alone. The efforts of Robert Koeberlein, P.E., the project manager, Robert Walton, the on-site construction manager, and RF engineer Gregory Gibbs, who assisted in adjustment and measurement of this antenna system, all deserve recognition.

Figure 1

Antenna Site Plan



NEW AM BROADCAST ANTENNA DESIGNS HAVING FIELD VALIDATED PERFORMANCE

Clarence M. Beverage
Communications Technologies, Inc.
Marlton, NJ

ABSTRACT

During the last five years, North American Broadcasters have implemented, on a limited basis, several variations on the traditional vertical radiator with 120 buried radials with significant success. These innovations are described in this paper and include elevated radial ground systems in place of traditional buried ground systems, use of a single internal cable to excite a self supporting grounded tower rather than a multi wire external skirt and the use of a guy wire or other sloping radiator to achieve a directional antenna pattern. We discuss the practical aspects of each system, information drawn from field experiences, and the FCC's view of these antenna types.

ELEVATED RADIAL GROUND SYSTEMS -BACKGROUND

In June of 1937, the classic paper by Brown, Lewis, and Epstein, "Ground Systems as a Factor in Antenna Efficiency" was published in the Proceedings of the Institute of Radio Engineers (now the IEEE). For the next five generations, ground systems for AM towers have been based on the original measured data in that paper. In the March, 1988 issue of the IEEE Transactions On Broadcasting, a group of authors described a new type of ground system for AM towers in a paper titled "AM Broadcast Antennas with Elevated Radial Ground Systems". The authors were Al Christman and Roger Radcliff of Ohio State University, Richard Adler from the Naval Post Graduate School, Jim Breakhall from the Lawrence Livermore Lab, and Al Resnick from Cap Cities/ABC. The elevated system described at that time consisted of a single quarter wave tower with four elevated radials, also one quarter wave in length, spaced evenly around the tower.

The efficiency of the elevated radials was compared to a system of 120 buried radials using the "Method of Moments" computer code NEC-GS. The published results showed that four elevated radials gave essentially the same antenna efficiency as the standard 120 buried radial system over the full range of modeled soil conductivities. At the time that the paper was published, no one had validated the theoretical calculations by constructing a full size antenna system in the 540 kHz to 1600 kHz band. The elevated radial concept sparked a great deal of interest within the engineering community which was tempered with questions such as, "will it work in the real world", "how stable will it be" and "will the FCC accept its use"?

INSTALLED ELEVATED SYSTEMS

In November of 1988, our firm supervised the construction of a temporary antenna system in Newburgh, New York under FCC Special Field Test Authority using call sign KPI-204. The antenna system consisted of a lightweight, 15 inch face tower, 120 feet in height, with a base insulator at the 15 foot elevation and six elevated radials, a quarter wave in length, spaced evenly around the tower and elevated 15 feet above the ground. The radials were fully insulated from ground and supported at the ends by wooden tripods. Approximately ten feet above ground, a T network for matching the antenna was mounted on a piece of marine plywood to isolate the components from contact with the lower section of the tower which was grounded. Power was fed to the system through a 200 foot length of coaxial cable with the cable shield connected to the shunt element of the T network and to the elevated radials. A balun or RF choke on the feedline was not employed and the feedline was isolated from the lower section of the tower. The system operated on 1580 kHz at a power of 750 watts.

The efficiency of the antenna was determined by radial field intensity measurements along 12 radials extending out to a distance of up to 85 kilometers. The measured RMS efficiency was 287 mV/m for 1 kW, at one kilometer, which is the same measured value as would be expected for a 0.17 wave tower above 120 buried radials.

The Newburgh tests gave empirical proof that the elevated system worked although, in an abundance of caution, we used six radials instead of four. For the limited time that the system was operational, the system was stable as determined by monitoring the field intensity at selected locations each day. The measured base impedance was in general agreement with a tower of this height above a standard, buried, ground system. Results of the KPI-204 tests were submitted to the FCC in January of 1989.

The first permanent use of an elevated radial ground system appears to be at WPCI, 1490 kHz in Greenville, South Carolina. This installation, designed by William A. Culpepper, involved replacing a standard buried system with a four wire elevated system consisting of #10 solid copper wire, one quarter wave in length, and supported on treated wooden posts which keep the radials 4.9 meters above ground. The antenna radiation efficiency, based on field strength readings on the eight cardinal radials, was 302 mV/m at 1 kilometer versus the predicted FCC value of 307 mV/m. The WPCI installation was unique in that the tower was base insulated but the radials came right up to the tower, 4.9 meters above ground, and terminated in insulators. The tower was fed from the tuning unit, through a piece of coax to the 5 meter point on the tower where the center conductor of the coax was attached to the tower and the shield to the elevated radials. This feed system resulted in a higher feed resistance than would normally be expected. Data on this facility was taken from the FCC files.

Directional antenna applications were the next obvious application area for elevated radials. The FCC granted construction permits to several stations in the early 90's including KXKW, 680 kHz, Tioga, Louisiana, WNJO, 1550 kHz, Seaside Park, New Jersey and WGNY, 1200 kHz, Newburgh, New York. The first four tower directional array to be built and licensed in the United States was WWJZ, 640 kHz, Mount Holly, New Jersey with a daytime power of 50 kW. This system, designed by Ted Schoeber, employed six elevated, quarter wave radials per tower with the radials 15 feet above ground, made of 1/4 inch steel guy cable and supported at each end through an insulator tied to a telephone pole. Data on this facility was obtained by review of the FCC files and inspection of the transmitting complex.

In the spring of 1993, CTI began to oversee the installation of a four tower directional array in Oakland, New Jersey, on 1160 kHz. The WVNJ installation took advantage of experiences gained at earlier installations and became the basis for a standard design. (Figure 1 is a side view of the standard design). The advantage of this design is mechanical rigidity for stability while being easy for a tower rigger to implement. In a new installation such as this, the base piers are poured with eye hooks to terminate the elevated radials. Three foot fiberglass rods are connected to the hooks to provide safe worker access to the area around the tower base. Each radial is connected to an insulator, run up to the support post, fifteen feet from the tower base, and then horizontally out to the terminating insulator and end support post. All radials are 1/4 inch steel guy cable interconnected with guy cable and the cable brought down to the ATU copper ground strap. The tower is fed directly above the base insulator through a lightning isolation loop as in any standard base insulated arrangement.

The WVNJ site was selected to meet restrictive land use and allocation restrictions. Consequently, the site was built in a rocky area where a buried system could not be installed. Since the feedlines, sampling line, control and AC cable could not be buried they were installed in 4" PVC pipe for protection and layed on the surface of the ground. Four inch strap was run between each tower and the transmitter building. All coaxial cables were bonded to the four inch strap at 50 foot intervals to prevent stray RF currents.

The WVNJ system provided additional insights into the use of elevated radials due to problems encountered. In a typical buried ground system, it is not uncommon to truncate the ground system in some directions due to natural obstructions or property restrictions. In this case, several elevated radials had to be shortened to approximately 70% of the full quarter wavelength. A shortfall in antenna efficiency did not show up in the nondirectional antenna proof since the ND tower was on the SW side of the array and the truncated radials were on the east side of the array, in the direction of the major lobe of radiation.

Our first test was to disconnect the 7/8 inch feedline from the ATU input to the ND tower and install an RF choke, or balun, made up of toroid cores around the outer conductor. This resulted in a modest change in base impedance and slight heating of the cores indicating that an RF current path did exist along the shield. However, when the power level was set up to match the new impedance, and several field monitoring points checked, it was realized that there was no change in measured field intensity.

The other cause of anticipated low efficiency was the truncated radials. Modeling of the array using the measured soil conductivity with NEC-2 confirmed the shortfall. Extending the truncated radials to a full quarter wavelength brought up the measured antenna efficiency. This taught us a valuable lesson; elevated radial ground systems cannot be truncated when used in combination with towers near a quarter wave or less. The use of truncated radials under a half wave tower are discussed in another section of this paper.

PRACTICAL APPLICATIONS

Elevated radials are an inexpensive and practical solution where there is sufficient property to install a minimum of four equally spaced radials a full quarter wave in length. They may be used to replace damaged buried systems or for new installations. In new installations, these systems allow continued farm use of the land, installation in rocky areas where a buried system would not normally be employed, and implementation of a station in environmentally sensitive areas where the land disturbance associated with buried systems would be prohibited. Based on the experience base to date, concerns about stability in varying weather conditions or efficiency problems are unfounded when systems are properly designed and installed.

SHUNT FED TOWER INNOVATIONS

Sometimes necessity is the mother of invention. Broadcasters have been using unipoles or wire skirts as a method to excite a grounded tower. As new uses for the RF spectrum proliferate, tower space is at a greater premium and opportunities for Broadcasters to lease tower space are constantly increasing. Unfortunately, AM towers are generally shunned due to potential contact with either the hot tower, in the base insulated case, or the hot skirt wires, in the case of grounded towers. A method has been devised to excite a self supporting tower which is totally internal to the tower structure.

In mid 1993, Douglas Broadcasting, Inc., licensee of KOBO, Yuba City, California, became interested in expanding the utility of its self supporting tower for rental use and was also involved in the design and implementation of a multi tower directional array in an area with significant environmental problems. The DA site problems were so extensive that guy wires were deemed a hazard to the endangered bird species and the thought of skirt wires on the tower was unpalatable. The concept of a single vertical cable, running up the middle of the tower, was proposed by the KOBO engineering staff as a possible solution. Initial computer modeling with minninec gave ball park numbers that looked promising enough that DBI went forward to fund the research project.

In the spring of 1994, the internal feed system was implemented. Local engineers chose a length of 1 5/8" heliax which was on hand as the center feed. Copper straps were used to jump across each base insulator to ground the tower and the initial shorting point inside the tower set. Initially, the system proved to be unstable. This problem was traced to poor bonding in the tower sections and was subsequently resolved by brazing at the appropriate locations. Efficiency of the feed was checked by setting base current to the proper value for the base insulated case and then taking field strength readings at selected monitoring points. The system was then set up for the shunt feed described above and the field strength at each monitoring point checked. All readings were within 1 to 2 percent of the original value.

A note concerning computer modeling should be inserted at this point. It was possible to obtain a general idea of the tower feed impedance using several different versions of minninec. Once the system was built and measured impedance data was available, attempts at modeling with minninec were not productive in terms of approaching the measured value. NECAM, a version of NEC-2, written by David Pinion, PE, was then tried. When actual soil conductivity and dielectric constant data was employed, the NEC-2 implementation gave an answer that is close enough to the measured value to rely upon for future predictions. The reason for the difference in accuracy is believed to lie in the difference in the codes. Minninec does not have the ability to take ground conditions into account when computing impedance. This is a critical difference and should be taken into account in cases where more accurate impedance or antenna efficiency values are needed.

In late 1994, CTI began working with WJRZ radio in Toms River, New Jersey to design a nondirectional antenna system for 1550 kHz using an existing 300 foot communications tower. NECAM computer modeling studies of this tower compared favorably with measured results. In this case, a 1/4" EHS steel guy cable was attached to a three foot fiberglass rod and terminated in a concrete block placed in the center of the tower. The guy cable was then run vertically to the 250 foot level on the tower and bonded to a cross brace. Shorting jumpers were attached to the vertical cable at the 100 foot and 150 foot AGL levels on the guy cable. During final installation, impedance measurements were made at both shorting points to provide more data to use in calibrating the computer model.

This tower employed a unique elevated radial ground system. Four radials, 1/8 wavelength, were employed in the expectation that a tower near one half wave in height would achieve good efficiency with a shorter radial. This, in fact, did not prove to be totally true and a lower than expected radiation efficiency was assigned to the radiator. Computer modeling studies have shown, what we believe is the answer. The current distribution on a base insulated half wave tower is different than it is on the shunt fed tower. There is a greater current distribution in the lower half of the shunt fed version which would tend to increase ground losses. It is important to be aware of the possibility of a variation between design and measured values and to allow sufficient margin for error in the original design to compensate for real world variations.

On November 22, 1994, the FCC granted WJRZ Special Field Test Authority, under call sign KPK-251 to test the antenna system on 1550 kHz. Tests were completed in December of 1994 and results are now on file with the Commission.

SHUNT FEED BENEFITS

We discussed previously the benefits which AM broadcasters could derive by using an internal feed wire in terms of increased rental income. There are other benefits as well. In this age of increased real estate prices, some AM stations are looking at the possibility of selling their property and going to a single tower, nondirectional, operation. The internal feed system can make existing self supporting towers available as rental sites to a broadcaster where the owner would have previously been against this use. It is possible that future refinement, computer analysis, and empirical studies will show that uniform cross section towers can be excited in this way as well.

SLANT WIRE RADIATORS

Slant wire radiators have been in use for a number of years. A slant wire radiator, in the context used within this paper, is either a guy cable or sloping steel cable, insulated from, and supported by, a single tower or other vertical radiator. Grant Bingeman of Continental Electronics most recently introduced the broadcast engineering community to the concept at the 41st Annual Broadcast Engineering Conference with his paper "An Economical Directional Antenna For AM Stations". Grant published the results of a parasitic directional antenna system installation at XEWB in Mexico in the July, 1994 issue of BE Radio. In discussion with Canadian consulting engineer Gordon Elder, he indicated that he has installed a daytime directional antenna system in Canada for daytime hours of operation.

One of the more exhaustive studies on the use of slant wire radiators was written by E.T. Ford of the Independent Broadcasting Authority. Mr. Ford's paper, "A Directional Medium-Frequency Transmitting Antenna Comprising A Single Guyed Mast And A Sloping-Wire Parasitic Reflector" describes extensive tests run between 1972 and 1982 on 40 different systems. The Ford paper was very extensive and thorough and gave both theoretical and empirical data concluding that the systems did perform as calculated.

Slant wire radiator development is still in the early stages of being explored in this country. The concept, within proper limitations, holds great promise for many broadcasters. Currently a number of stations are limited to low nighttime power or less than desired daytime power. In some of these cases, the broadcaster is unable to construct another tower but could obtain significant relaxation of the power restrictions if a DA could be implemented.

FCC POLICIES

The FCC employs Rules and Policies to regulate the AM Broadcast service, in part, to assure service and prevent interference. To that end, elevated radial ground systems are a permitted use at this time for directional AM stations as system performance is validated as part of the proof of performance and licensing process. It is recommended that stations wishing to install an elevated system on a nondirectional tower check with the AM Branch of the FCC Mass Media Bureau to determine the current procedure. It is possible that a proof of performance would be required to confirm antenna efficiency.

The internal shunt feed system described herein is believed to be new to the FCC and to the industry. As in the case of elevated radials for nondirectional towers, one should describe their proposed implementation with the FCC before proceeding.

Currently, the FCC has a policy which prohibits the use of parasitic arrays. In August of 1994, Milstar Broadcasting Corp. filed a Petition For Rule Making, with the FCC "To Allow the Use of Slant Wire Radiators". Implicit in that Rule Making was a request to allow parasitic arrays as well. Due to an apparent lack of input from Broadcasters, the FCC has not moved forward to implement a Notice of Inquiry in this area. However, the AM Branch has indicated to the author a willingness to authorize slant wire radiators which would be fed, for daytime only use, on an STA basis.

CONCLUSION

The antenna systems described herein are all potentially profitable for AM Broadcasters. When properly designed and implemented, they can be cost saving and revenue producing. Possibly even more important, they open up site locations which might previously have been thought of as unusable. Elevated radials are now a mature technology with an established user base. The internal shunt feed has proved to be predictable in the cases studied. Parasitic radiators need FCC endorsement before significant development can occur. However, this methodology holds great design potential for directionalization of signals as well as for diplexing.

NORTH LATITUDE: 41° 31' 30"
WEST LONGITUDE: 74° 06' 03"

A = 2'

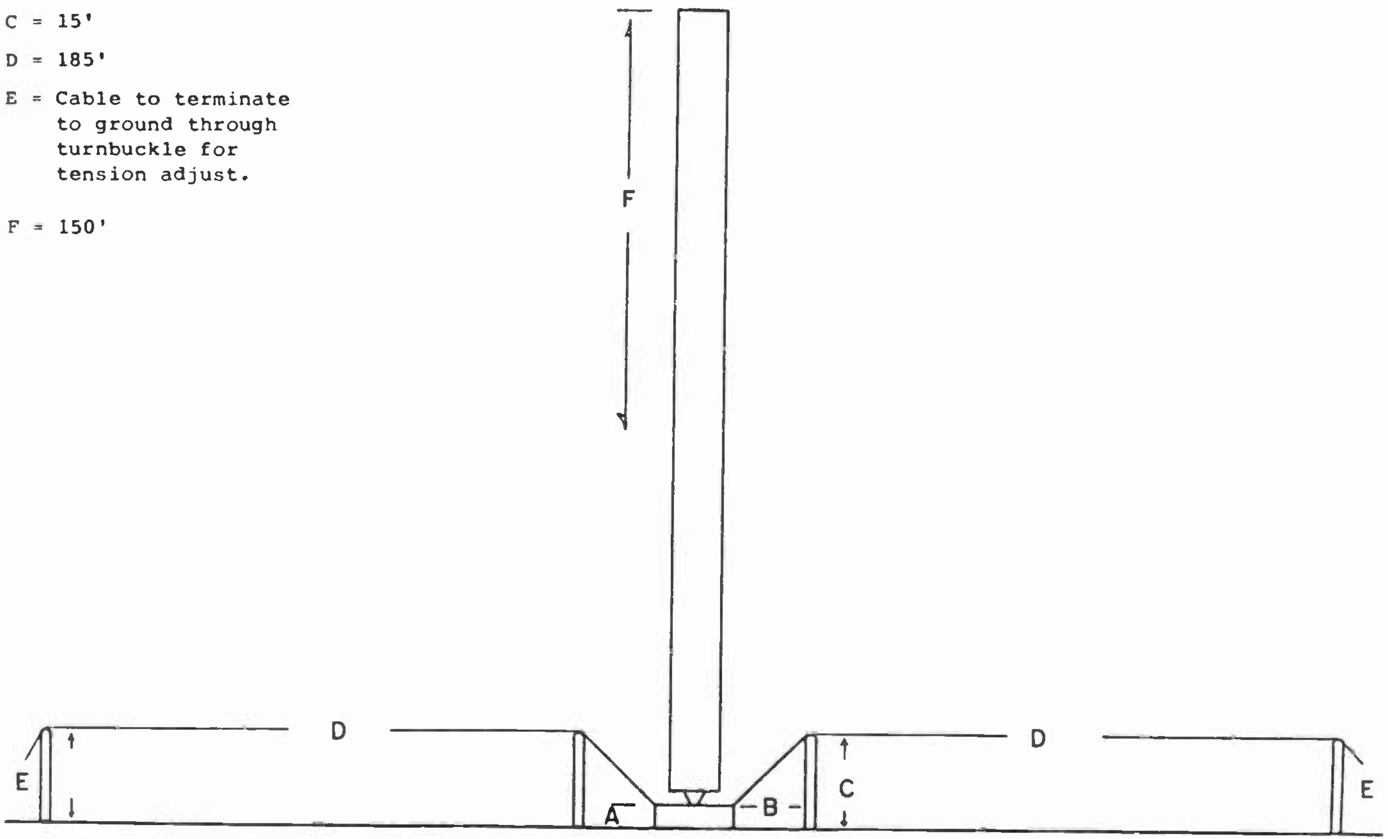
B = 20'

C = 15'

D = 185'

E = Cable to terminate
to ground through
turnbuckle for
tension adjust.

F = 150'



GRADE LEVEL 515 FEET AMSL

FIGURE 1

TYPICAL ELEVATED RADIAL SYSTEM - SIDE VIEW

DIMENSIONS FOR 1200 kHz
WGNY-AM NEWBURGH, NEW YORK 8/93

RF PHASE RESPONSE VERSUS SOUND QUALITY IN AM BROADCASTING

Timothy C. Cutforth, P.E.
Vir James Engineers—Broadcast Engineering Consultants
Denver, CO

ABSTRACT

The match between the antenna and the transmitter has long been known to limit the performance of AM systems. Some AM systems do not perform well despite a good impedance match at the sideband frequencies. This paper reviews the conclusions of past studies of the effects of impedance matching on performance and then explores the sideband phase response of the system and its ramifications. Performance limitations resulting from the phase response characteristics of the transmitting system are defined and demonstrated. Methods of correction of both amplitude response and phase response characteristics are explored. Correction of phase and amplitude response at the exciter level using the Kahn Flatterer system will be evaluated and compared to brute force correction methods. Listening tests of on air systems with and without correction are presented for demonstration of system performance before and after correction of sideband response.

HISTORICAL PERSPECTIVE

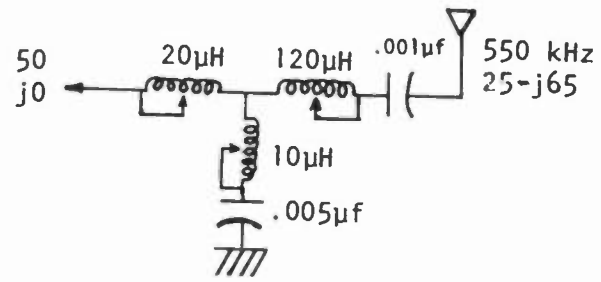
W.H. Doherty presented a definitive analysis of the "Operation of AM Broadcast Transmitters into Sharply Tuned Antenna Systems" at the IRE convention September 30, 1948. Because of the serious effects on transmitter performance, the paper recommended adoption of a standard load for AM transmitters. That standard was adopted and is still in use today. The paper discussed phase shifting as a method for optimizing the impedance match at the plate of the transmitter final amplifier. That method of using phase shifters to improve transmitter performance is still regularly used today and is commonly called line stretching.

EXPERIMENTAL EVIDENCE

The Doherty paper included photographs of oscilloscope traces that clearly demonstrated the degradation possible with a real transmitter and several specific loads. Note that the sine wave is altered in all cases. The least waveform alteration is the case where the amplitude of the modulation is reduced significantly at high frequencies. We obviously can not afford to overlook the distortions and loss of response such mismatches cause. Amplitude affects are obvious. If we don't broadcast full modulation power in the sidebands, the listener will receive less than full modulation and signal to noise will suffer as will frequency response. Even when the waveform distortion is minimized through line stretching, the modulation is still reduced and there is still some increase in distortion.

WHAT ABOUT PHASE RESPONSE?

Despite the fact that the previous studies and conclusions have been stated in terms of impedance match there is always a change in phase response when there is a change in impedance. Take for instance a simple T network. The simplest three component T network will exhibit a very small but measurable change in phase shift over a +/- 10 kHz operating window. When that same T network is made up of conveniently available parts the result may be quite different. The T network shown will itself exhibit a 17 degree shift in phase over the +/- 10 kHz operating window. The VSWR is only 1.4 to 1 so this is not a particularly bad impedance match. Clearly there are worse networks and the phase shifts in an older design directional array common point will often be worse...especially when the sideband impedances are grossly nonsymmetrical.



Typical ATU Network

WHY IS PHASE RESPONSE IMPORTANT

The audio envelope detected in an ordinary AM radio is derived from the vector addition of the carrier, and the two sidebands. When the phase relationships are altered between the two sidebands and the carrier, the detected audio envelope is reduced significantly. It is in fact quite possible to broadcast full maximum allowable power in the two sidebands and then not be able to properly reassemble the audio at the receiver. When you listen to a stereo cassette or stereo cart in monaural it is abundantly clear what happens when two high frequency components are assembled at any thing other than the correct phase. It is therefore imperative that both the impedance match and the phase response be perfect to guarantee that the listener gets low distortion, good frequency response, and best signal to noise ratio.

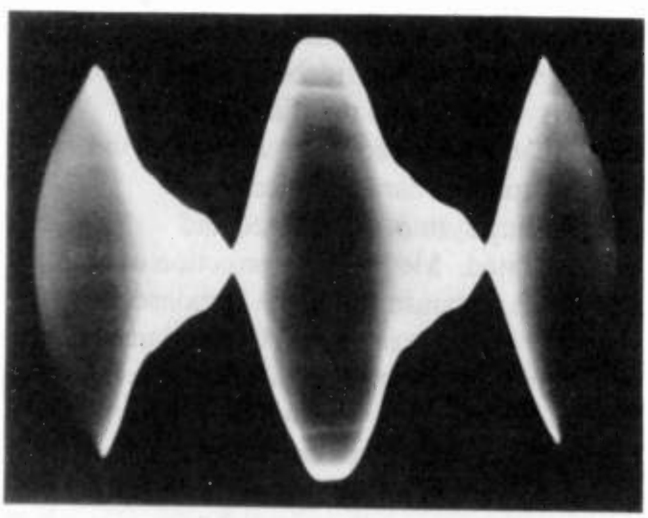
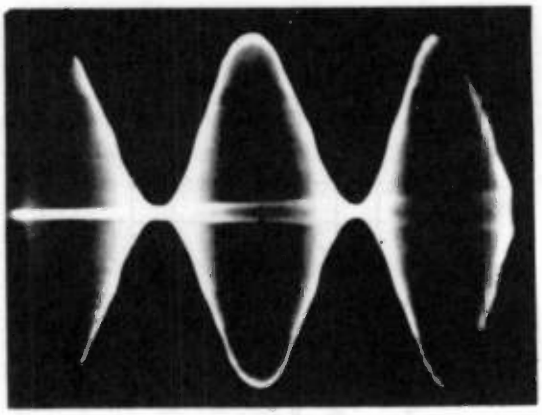


FIGURE 5

Figure 5 from the September 1948 IRE paper "Operation of AM Broadcast Transmitters into Sharply Tuned Antenna Systems" by W. H. Doherty clearly showed the serious modulation envelope distortion caused by some transmitter loads.



A

D

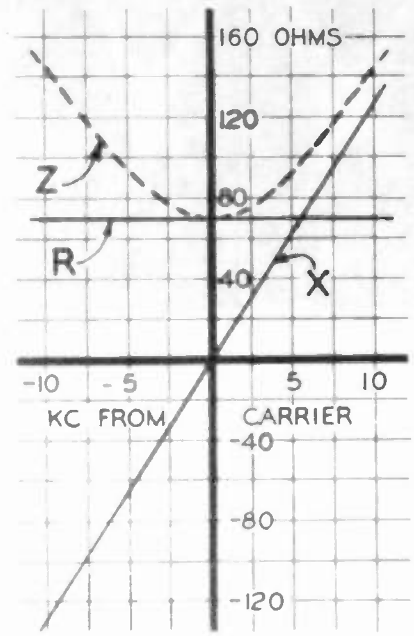
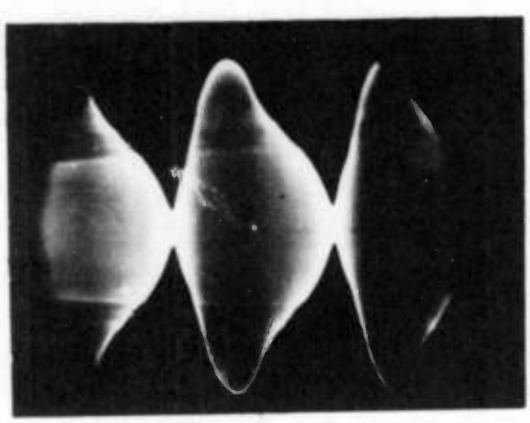


Figure A shows the modulation envelope for the load impedance characteristic shown in figure D



B

E

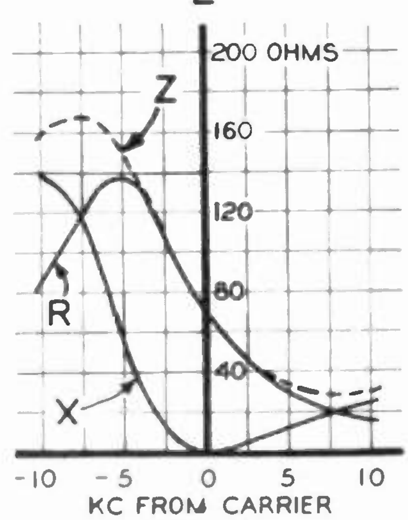
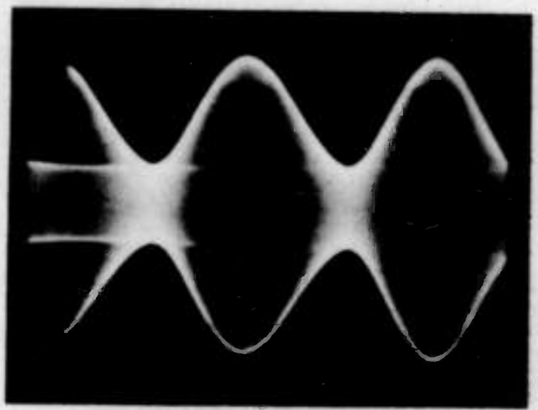


Figure B shows the modulation envelope for the load impedance characteristic shown in figure E



C

F

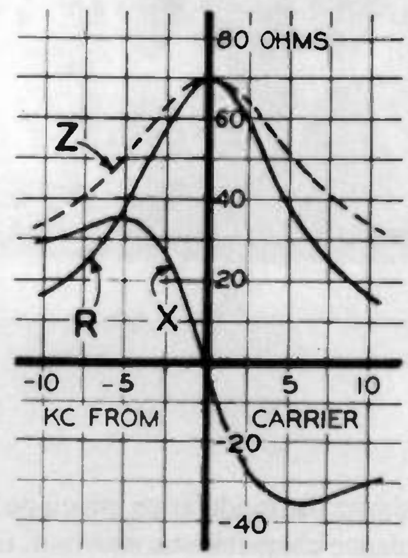


Figure C shows the modulation envelope for the load impedance characteristic shown in figure F

NRSC AM-BAND RF EMISSIONS COMPLIANCE

Gregory J. Buchwald
Motorola, Inc.
Schaumburg, IL

ABSTRACT

The National Radio Systems Committee (NRSC), during the mid -- 1980's, proposed voluntary standards concerning pre-emphasis, transmitted audio bandwidth specifications, and RF emission limitations. The resulting standards were powerful in reducing interference. The FCC acted quickly to adopt the RF emissions mask as a replacement of Rule 73.44. At the time of adoption, stations were presumed to comply with the rule if they incorporated NRSC audio processing in their broadcast chain. Presumptive compliance ended on June 30, 1994. Commensurate with that date, all AM broadcast stations in the United States are required to maintain proof that compliance with the RF emissions mask has been met. The purpose of this paper is to briefly discuss the history and evolution of the standard, measurement techniques that can be used to insure compliance and causes of non-compliance.

Historical Perspective

During the period starting in the early 1960's through the mid 1970's and once again in the early 1980's, the commercial AM broadcast band went through periods of high growth with respect to the number of licensed stations. Regulations were relaxed with regard to interference protection ratios on clear channels and power levels were raised to 1kW full time on the "local channels." Access to AM broadcasting frequencies was at an all time high during the mid 1980's, and so were interference problems. In addition, during this time frame, a vicious circle of events began to unfold which, ultimately, led to narrow bandwidth, low fidelity radios. As the number of broadcast stations increased, the art of audio processing also matured to the point that the current occupied bandwidth rules were no longer sufficient for proper protection of adjacent and second adjacent channel stations. Receiver manufacturers answered the problem by simply reducing the bandwidth of the AM sections of receivers until the average AM radio had an audio response of about 100Hz to 2.4kHz. With a desire to reverse this trend and once again restore the manufacture of high quality, wideband radios, the National Radio System Committee (NRSC) took on the task of studying the then-current situation and proposing solutions in the form of voluntary standards. The work involved interference studies, tests of various pre-emphasis and audio limiting proposals, and contracting the firm of B. Angell and Associates to perform a survey which would yield necessary information on what the general public felt represented an acceptable received signal in terms of acceptable interference levels and fidelity.

The results of the NRSC work yielded three voluntary standards:

1) Standardized pre-emphasis which insured adequate compatibility with narrow band radios, yet controlled levels of potential spectrum spreading high frequency information. The adopted curve is known as the "modified 75uSec." curve and is shown in Figure 1.[1,2]

2) Standardized audio low pass filtering for audio limiters or the input section of broadcast transmitters. After considerable study and debate, a 10kHz response was chosen based on the then-current allocations table. The low pass response of this standard is shown in Figure 2.[3,4,5]

3) A new RF emissions mask, later proposed to and adopted by the FCC to limit the transmitted spectrum from an AM broadcast facility. This last standard insures protection ratios to all broadcasters and is inclusive of all equipment in the broadcast chain.[6]

In addition, further standards were adopted which affect the receiver industry. These will not be discussed as they are beyond the scope of this paper.

Early trials of the voluntary standards indicated that the impact of incorporating the standardized pre-emphasis and audio filtering at a broadcast facility reduced interference levels dramatically. In addition, many stations were finding that their own signal sounded better;

particularly on narrow band radios. The latter was due to a subsequent reduction of transmitted difference frequency inter-modulation distortion products when the NRSC 10kHz audio low pass filters were installed. It was also apparent that, unless all broadcasters complied, the full impact of the new standards would not be enjoyed. Thus, the NRSC asked the Commission to adopt the RF emissions standard as a replacement for the current Rule 73.44. The Commission acted quickly to adopt the revised occupied bandwidth standard, further indicating that until June 30, 1994, all broadcasters utilizing the voluntary standards listed in 1 and 2 above, were presumed to comply with 73.44. Thus, no measurements were required to prove compliance. This period of "presumptive compliance" drew to a close on June 30, 1994. From that day forth all broadcasters are required to secure proof that their station does indeed comply with Rule 73.44.

To understand the impact of this rule change, one need only compare the allowable occupied bandwidth of the pre-NRSC rule with that of the post-NRSC rule as indicated in Figure 3. In the earlier rule, spectra need only be reduced 35dB with reference to the carrier over a 150kHz bandwidth! In the current version, a steep skirt response replaces this wide bandwidth spectrum. In particular, second and third adjacent stations are offered substantial increases in protection from interference. In Figure 4, one can see that two second adjacent stations could not be received with a receiver bandwidth greater than 5kHz due to the mutual ±15kHz response of each. In Figure 5 the NRSC version indicates that both stations should be able to enjoy 10kHz reception within their respective licensed coverage areas. Indeed in the Chicago area, when WMAQ (50kW, 670kHz) installed the filter, WSM (50kW, 650kHz, Nashville, TN) was once again heard each night, nearly interference free, in the Chicagoland area! Similar reports were reported across the United States. It is also worth noting that to receive NRSC Certification, broadcast transmitters and transmission systems as well as audio limiters must individually also comply with a second, more stringent test which has its roots based in CCIR standards. This test requires that a known noise source (pulsed USASI) modulates a broadcast system component to a peak level of 100% and an average level of 30% modulation.[7] The spectral limits are also indicated in Figure 3. This strict test procedure insures that newly designed equipment will easily meet the requirements of 73.44.

Compliance Testing

The June 30, 1994 deadline has passed and compliance with 73.44 must now be verifiable by all stations. The testing is not necessarily difficult, however, due to the current methods approved by the Commission, it may be tedious, particularly for broadcast stations located in major metropolitan areas. Proposals to simplify the procedure will be discussed elsewhere in this paper.

There are essentially two mainstream methods which can be used to document compliance. These methods utilize either a spectrum analyzer or a "Splatter Monitor" such as that which is manufactured by Delta Electronics (Alexandria, VA.). In each case, equipment must be purchased or rented. Alternatively, it may be wise for local groups (such as SBE chapters, etc.) to mutually acquire the equipment through rental or other means thus reducing per-station expenses. Measurements should be taken on an annual basis or, preferably, whenever changes in the broadcast chain (transmitter, stereo exciter, or final audio limiter) are incorporated.

The spectrum analyzer is currently the most popular method of compliance testing. The Commissions rules indicated that the occupied bandwidth must be measured at a point approximately 1kM from the broadcast site. Furthermore, specific measurement techniques are presented indicating that spectral recording of the close-in spectra (±20 or 30kHz removed from carrier) should have a resolution bandwidth of 300Hz or less to insure proper recording of the shape of the attenuation response at ±10kHz. Wider filter bandwidths may be used for wideband (±80 to 100Khz) spectral recordings. In addition, a peak hold function must be used and the spectra must be recorded for at least 10 minutes under normal program conditions. The RF emissions mask is then compared to the recorded photos or plots; Rule 73.44 is considered a Go-NoGo gauge. In practice, two photographs are generally recorded with one indicating close in spectra as described above, and the other recording wideband spectra. The author also recommends a third recording of wideband spectra be taken at the transmitter sample for reasons indicated below.

A typical wideband photograph is shown in Figure 6. It can be clearly seen that other broadcast stations confuse the recording of the station's own spectral signature. Ultimate suppression is difficult, if not impossible, to define due to the abundance of spectral components from other broadcast stations. For this reason, a third measurement should be taken at the transmitter sample, perhaps with the transmitter operated into a dummy load, to prove the purity of the transmission. All other stations in the wideband field photo should be identified and all unknown spurs should be investigated. If the spurs are generated by your facility, they must be dealt with.

Probably the most difficult problem encountered in using the spectrum analyzer to record the occupied bandwidth of the broadcast facility is to achieve ample signal at the input of the spectrum analyzer 1kM from the site. The author has had good success using an untuned, multi-turn loop antenna approximately 4 feet in diameter. The shielded loop reduces susceptibility to some forms of interference and has considerable directionality which can be used advantageously to reduce the levels of neighboring stations which may otherwise interfere with the measurement procedure.

A second problem is that of limited dynamic range of the spectrum analyzer itself. Some analyzers, such the older Tektronix 7L5 plug-in, have a front panel display range of 70dB and can be overloaded by the carrier component of the station if care is not taken. To counteract this problem, a carrier notch filter, consisting of a high-Q filter, can be constructed or purchased which will reduce the carrier level by a pre-determined level. The resulting carrier attenuation is noted on the spectral photograph or plot. Spectrum below -80dB, referenced to carrier level, can therefore be read without error.

Most spectrum analyzers do not operate from battery supply voltages. Therefore, power must be supplied in the field at the monitor point. A desirable solution is to make arrangements with a local home owner in the area, allowing measurements to made on his or her property using his AC mains supply. A residential setting is desirable over a business since the likelihood of interference from computers and other office equipment acting to corrupt the spectral analysis are less likely. If a gasoline generator must be used, care should be taken to insure that commutating noise from the alternator set or ignition noise from the gasoline engine is not allowed to impact the recorded spectral display.

Measurements using the Splatter Monitor are somewhat different than those using the spectrum analyzer. The splatter is essentially a "homodyne" direct to baseband demodulator. The baseband signal has the same characteristics of the radiated RF signal and thus may be similarly analyzed. In the most direct usage of the Splatter Monitor, the baseband signal is applied to a mask filter network identical to that described in 73.44 (see Figure 3). A peak hold meter circuit indicates the degree of compliance of the radiated signal, and a comparator circuit resolves the signal into a Go-NoGo indication. After the RF signal is converted to baseband, narrow filters can be selected which allow the signal to be dissected into narrow frequency band components. In this fashion, spurs may be identified with approximately 1kHz resolution. Many stations will find the splatter monitor to be the easiest form of compliance certification since it can be rack mounted at the transmitter site thus allowing simple verification of compliance at each maintenance interval. The Go-NoGo alarm indication makes the instrument as easy to read as the station modulation monitor.

In addition to the two methods listed above, a somewhat cruder, yet quite effective method may also be employed by stations which otherwise contract once-per-year measurements. It is possible to use a Field Intensity Meter (FIM) such as the FIM 21 or 41 from Potomac Instruments to take rough measurements. Absolute accuracy is difficult to establish since the RF / IF filter bandwidths are not narrow enough to insure complete compliance; however, armed with the knowledge of the selectivity of the FIM, the FIM may be tuned off channel by a known increment such as 15 or 20kHz either side of assigned carrier frequency, and the meter switch can be down ranged to assess the amount of out-of-band radiation generated. Each step counterclockwise of the field strength meter switch indicates a step of -20dB. Thus, a carrier reference can be chosen on channel, then tuned off channel, and the meter switch down ranged to read approximate spectral level. In addition, a chart recorder can be connected to most FIMs which would register the peak voltage received within the bandwidth of the FIM. Such measurements should not be relied upon as proof of compliance. However, once compliance has been established through other means, the FIM method can be "calibrated". Subsequent changes in reading would then indicate a need for further study. The RF / IF selectivity of an FIM 21 meter, measured at 1000kHz is indicated in Figure 7.

As a final note on measurement techniques, each time the radiated spectrum is measured to indicate compliance of 73.44, it is also a good time to check the signal for harmonic radiation (harmonics of the carrier frequency) and spurs caused by transmitter inter-modulation products or instabilities. Broadcasters should not lose sight that these measurements are integral part of compliance certification.

Sources of Spectral Problems

In most cases, measurements using either the spectrum analyzer or the Splatter Monitor will indicate compliance. In those rare cases that excessive occupied bandwidth are indicated, there are a number of areas which should be investigated. Common causes of excessive spectra are:

1) Unfiltered audio clipping after NRSC filtering; i.e. modulation enhancers or simple diode limiters;

2) Non-linear envelope modulation of the transmitter due to peak or trough of modulation limiting caused by improperly biased modulators and power amplifiers (in particular transmitter which utilize progressive modulation techniques) or flat (end of life) electron tubes;

3) Incidental Phase Modulation (IPM) caused by improperly neutralized RF power amplifiers and / or RF feedback;

4) Damaged elements in the audio / RF feedback ladders of older, plate modulated transmitters; and

5) Simple misadjustment of the audio processing system (incorrect bandwidth selection or excessive audio drive to the transmitter.

The above listed items may be used as a check list. The effects of unfiltered audio limiting are obvious: Unfiltered clipping generates non-linear products which cause rapid spectrum spreading. Steep-skirted audio filters with integral overshoot control, generally located in the final audio limiter, remove these undesirable products prior to transmission. It should be clear that simple clippers do not afford this protection and can not, therefore, be legally used in most cases.

In a similar fashion, many broadcast transmitters can not be modulated to +125% in a linear fashion. In some cases, the transmitter can not be modulated to -100% as well. It is therefore wise to first check the linear modulation capabilities of the transmitter, and then limit the audio drive to the transmitter to stay within the measured constraints. It is worth noting that some transmitters will produce short burst-like peaks of 125%, but sustained modulation can not be supported at these levels. Such transmitters should not be operated above their sustainable modulation limits to avoid excessive spectral product generation.

IPM can also cause excessive spectral components. A spectrum analyzer can be used to determine the level of IPM generated by a broadcast transmitter. A transmitter which produces 1% THD envelope distortion should have higher order spectral products that are at least 40dB below the level of the fundamental modulation product (not the carrier level). Additional products are usually caused by IPM components. In Figure 8, the spectrum of a poorly neutralized transmitter can be observed. While the transmitter produced envelope distortion levels of about 1%, it is clear that the spectral components indicate a much higher level which manifests itself as IPM. In Figure 9, the transmitter has been properly adjusted to reduce the IPM to an acceptable level. Direct measurement of IPM can also be performed using a stereo modulation monitor. If the transmitter is momentarily switched to monaural operation and the pilot is disabled, IPM can be directly read on the L-R meter. As a general rule of thumb, IPM should be reduced to at least -25dB with respect to the fundamental component at 85% envelope modulation. Clearly, a figure of -35 to -40dB is desirable.

Feedback ladders in older transmitters are often overlooked. Since considerable dissipation can occur in plate modulated feedback ladders, resistor values can change over time, or components can be damaged. Resisters should be carefully measured for value and replaced if found to be out of tolerance by ±10% or more. This is an often overlooked problem which, when corrected, will also yield substantially lower on-air distortion as well as reduction of out-of-band radiation components.

Finally, most audio processors can be programmed for NRSC (9.5 or 10kHz) response as well as pre-NRSC bandwidths of 11 or 12kHz. The author has measured more than one station which indicated non-compliance only to find that the filter was improperly selected or bypassed!

Modifications of the Present Rules

While the author, having participated in the NRSC efforts, is in complete support of the NRSC rules and the subsequent change in 73.44, he also feels that some modifications can be incorporated in the measurement techniques thus simplifying the measurement criteria for broadcasters. Probably the most glaring area of difficulty is in recording of spectral components 1kM from the transmitter site. Worst case spectra generally occurs at the transmitter output since the Phasor and ATU components generality act as a bandpass or low pass filter to reduce these components upon transmission. Since the -80dB points are difficult, if not impossible to measure in the field due to the presence of other broadcast stations, it is felt that the spectral measurements should be taken at the transmitter sample point. This is not unlike measurement techniques which are already in use for FM and Television broadcasting. Harmonic and RF inter-modulation measurements should, of course, still be performed in the field with an FIM or calibrated receiver.

Secondly, the current rules do not allow the use of video filtering on a spectrum analyzer. Many of the newer analyzers do not allow the video filter to be completely disabled. The response of the combined video and RF/IF filtering is taken into account in the final display. Consideration should be given to allowing the use of some video filtering, thus widening the list of analyzers which can be used. Experiments performed by the author indicate that if the video bandwidth is at least 7 to 10 times the RF / IF bandwidth (i.e. 3kHz video bandwidth for 300Hz resolution), the accuracy of the spectrum analysis is not compromised. In addition, wideband noise levels of the analyzer itself are reduced.

Third, consideration should be given to the fact that the current ATS rules indicate that up to 10 times per minute a transmitter can be envelope modulated to -100%. Such modulation could cause infrequent peaks in the spectral signature of the station which would otherwise indicate non-compliance with 73.44. Consideration should be given to allowing such infrequent peaks to occur, or the ATS rules should be reviewed. The author favors the former since the largest impact is at the -80dB points where infrequent peaks will have no effect on the protection of neighboring stations.

Concluding Statements

In conclusion, the impact of the NRSC standards and the subsequent adoption of the RF emission limitation by the FCC into Rule 73.44 has had a dramatic effect on interference reduction in the AM broadcast band. Just as the increase in the number of automobiles on our highways and in our cities have led us to require that automobiles are tested for exhaust emissions, the increase in AM broadcast stations over the past thirty years has also brought about the requirement of emission testing for the AM broadcast band. While the compliance measurements may be a bitter pill, the net result is extremely positive. Measurement techniques are not simple, yet they are within the reach of each station, either by using the methods listed above or through the contracting of services. In any event, a compliant transmitter should be certifiable in 1 to 2 hours and even less once experience is gained. But the NAB (through the NRSC) and the FCC should also not be content to allow the rules to stand as they currently exist. Subtle, yet effective modifications of the rules should be considered which would simplify the testing procedure and further define the current Go-NoGo gauge described in 73.44. The means for interference reduction are in place. It is time to consider fine tuning procedures to insure ease of compliance for all broadcasters.

References:

[1]Electronics Industries Association, "NRSC AM Pre-emphasis / De-emphasis and Broadcast Audio Transmission Bandwidth Specifications", Publication EIA-549, June 24, 1988.

[2]G. Buchwald, "NRSC Pre-emphasis Proposal", Submitted to the National Radio Systems Committee, March 4, 1986.

[3]R. Orban, "NRSC Active Lowpass Filter Design", Submitted to the National Radio Systems Committee, October 3, 1986.

[4]S. Salek, "Considerations For a 10kHz. Transmission Bandwidth in AM Broadcasting", Submitted to the National Radio Systems Committee, November 20, 1986. Also Published in the IREE Proceedings (Australia), September, 1987.

[5]Electronics Industries Association, "NRSC AM Pre-emphasis / De-emphasis and Broadcast Audio Transmission Bandwidth Specifications", Publication EIA-549, June 24, 1988.

[6]G. Buchwald, "RF Emissions Mask Proposal", Submitted to the National Radio Systems Committee, March, 1987.

[7]D. Tyrie, DOC - Canada, "RF Emission Mask Proposal", Submitted to the National Radio Systems Committee, July 8, 1987. (CCIR-based test specification for broadcast equipment.)

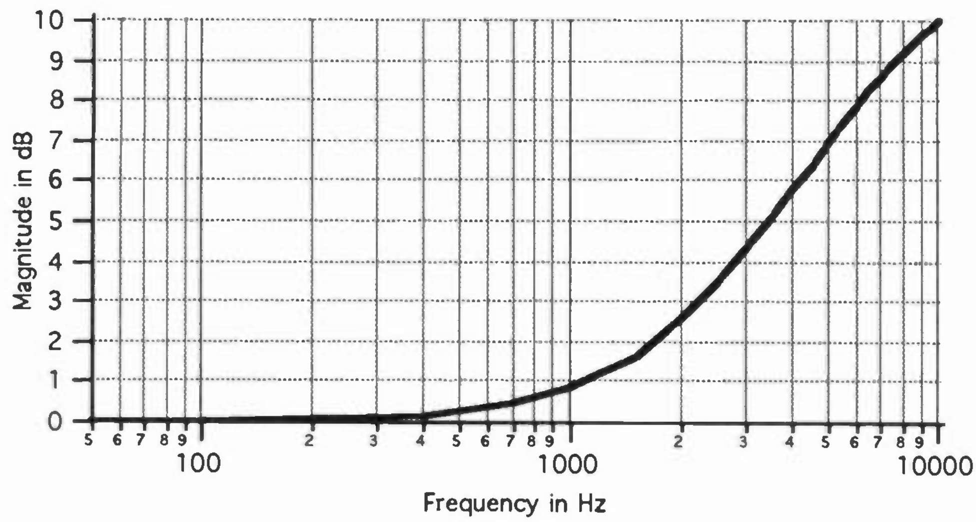


Figure 1 - MODIFIED 75 μS AM STANDARD PRE-EMPHASIS CURVE

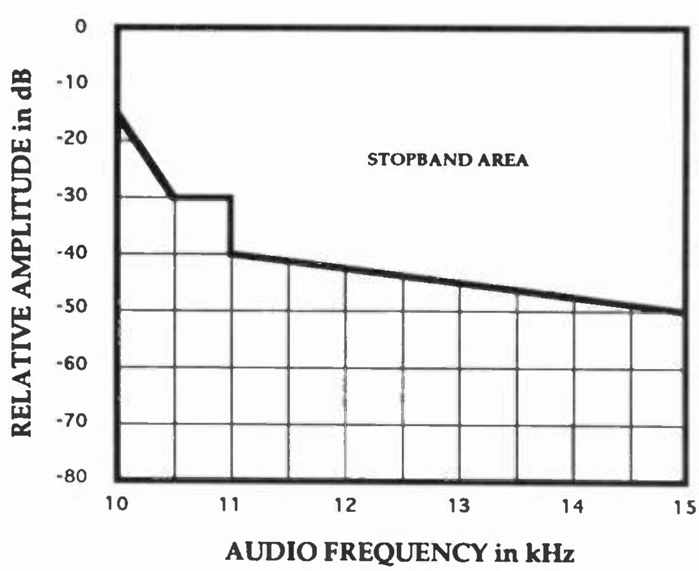


Figure 2 - NRSC STOPBAND SPECIFICATION
(Audio Envelope Input Spectrum To AM Transmitter)

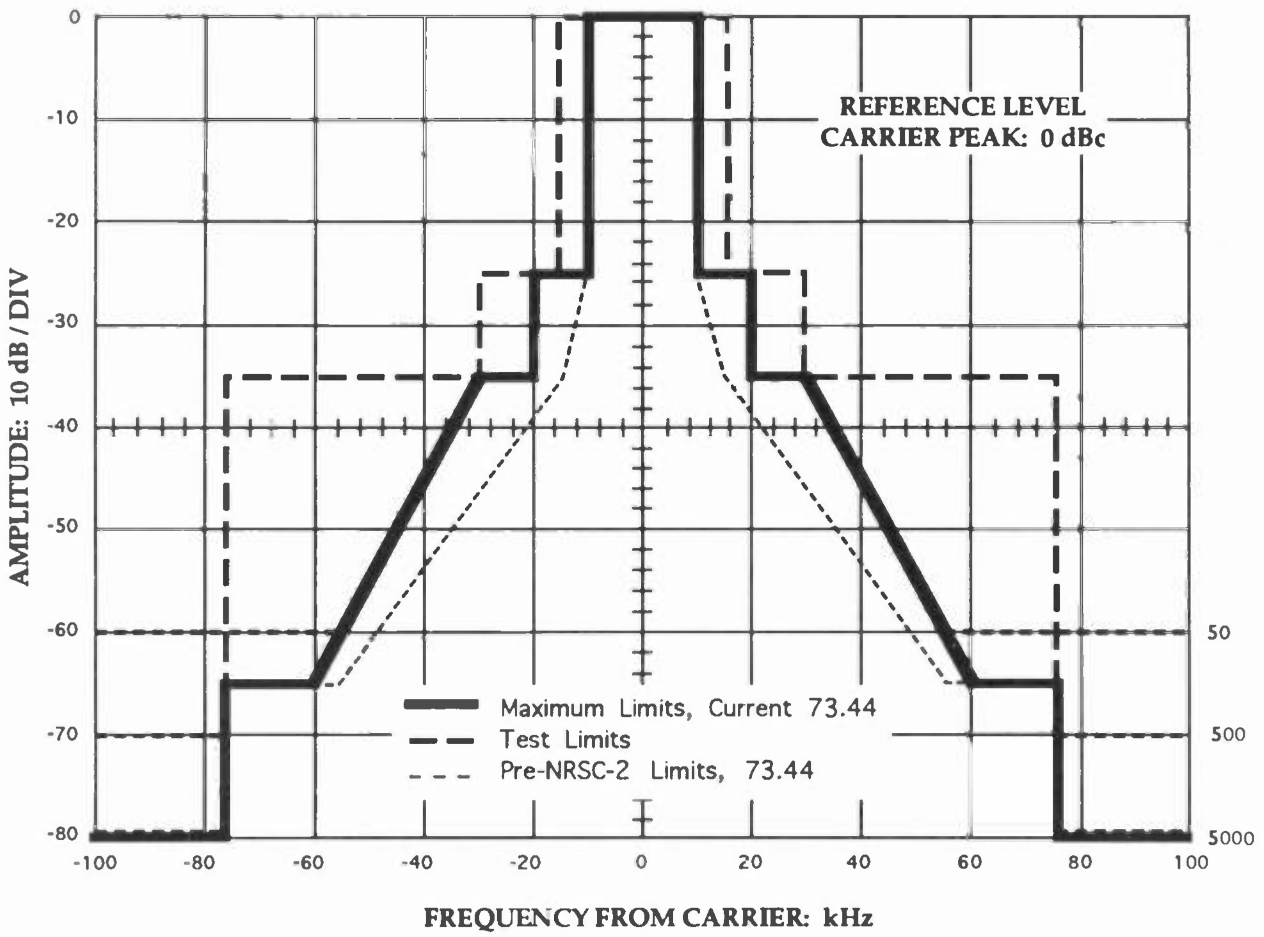


Figure 3 - AM BROADCAST RF EMISSION LIMITS

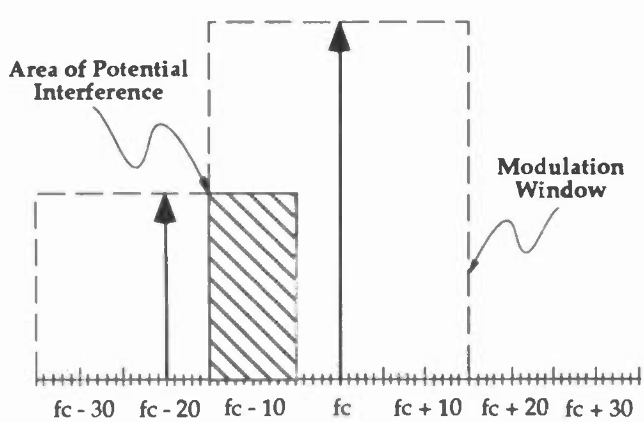


Figure 4 - PRE-NRSC ±15 kHz TRANSMISSION BANDWIDTH

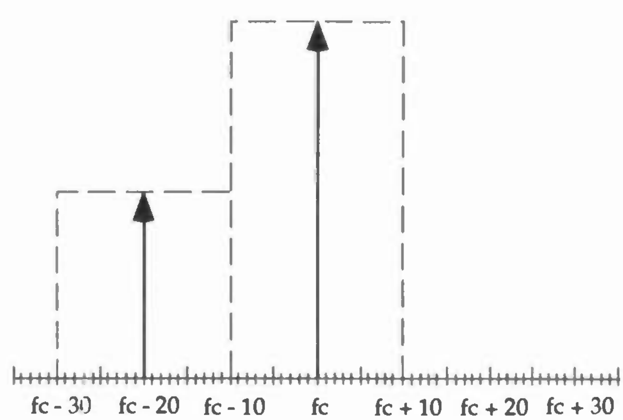


Figure 5- POST-NRSC ±10 kHz TRANSMISSION BANDWIDTH

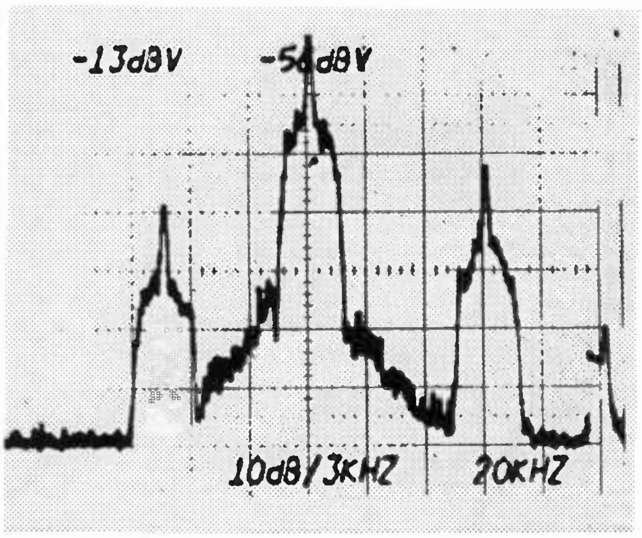


Figure 6 - WIDEBAND SPECTRAL SIGNATURE, DESIRED STATION PLUS NEIGHBORING SIGNALS.

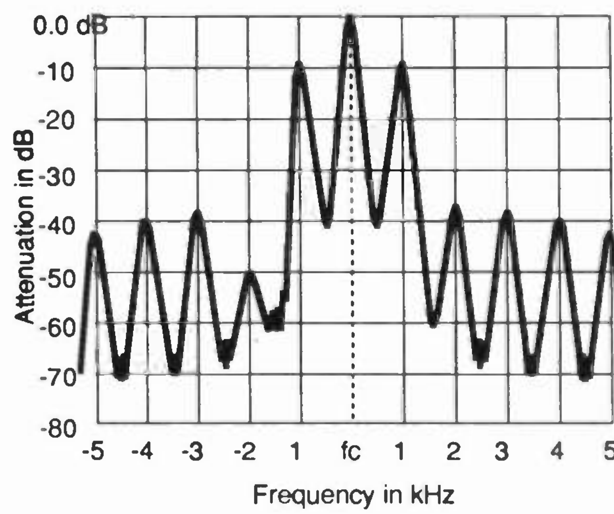


Figure 7 - IPM PRIOR TO REDUCTION TECHNIQUE.

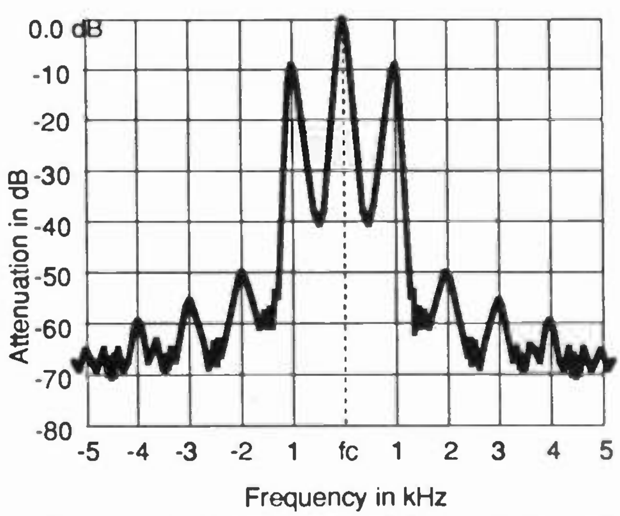
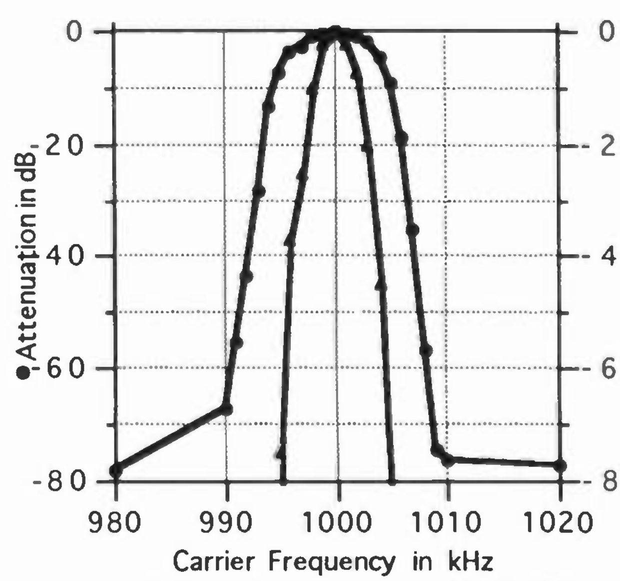


Figure 8 - TRANSMITTER HARMONIC DISTORTION PLUS RESIDUAL IPM AFTER CORRECTION ACTION.



The 0.0 dB level is referenced to a 100 mV/M field.

Figure 9 - FIM SELECTIVITY CURVE

FM BLANKETING INTERFERENCE: A CASE STUDY OF PROBLEMS AND SOLUTIONS FOR A TYPICAL HIGH POWER FM STATION

Thomas M. Eckels, P.E.
Hatfield & Dawson Consulting Engineers, Inc.
Seattle, WA

ABSTRACT

FM broadcast stations in urban areas often operate from transmitter sites which are either surrounded by residential development or are being encroached upon by residences. Within the area close to a high power FM transmitting facility blanketing interference is very likely, affecting radios, television sets, and other consumer electronic devices exposed to the high field strength levels produced by the transmitter. This paper describes the FCC's rules and policies with respect to blanketing interference, the kinds of consumer electronic equipment typically affected by blanketing interference, the types of interference produced within the blanketing contour, and the technical and "public relations" measures which have been effective in ameliorating the effects of blanketing interference.

INTRODUCTION

Blanketing interference is a general term which refers to the interfering effects of very strong AM, FM or TV signals produced in the vicinity of a high power transmitter. One of the symptoms of blanketing interference is the disruption of the normal operation of radio and television receivers by a strong signal, which blocks the reception of other signals--hence the term "blanketing". As the term has come to be applied in specific cases, it actually describes several specific types of interference mechanisms which occur in the presence of a high level of radio frequency energy. These include: receiver front-end desensitization, production of intermodulation and other spurious products in receiver front-ends or in non-linear junctions (power and phone lines, chain link fences, tower members, etc.) near the transmitter; and rectification and detection of radio frequency signals in audio circuitry. The interference produced in the blanketing area can affect a wide range of electronic devices normally found in residences, including television receivers; AM, FM and shortwave radios; stereo and "home theater" equipment; intercoms; telephones (both wired and wireless), and computer equipment. Blanketing interference can both prevent the reception of desired radio and TV signals and cause undesired signals to be introduced into home electronic equipment (e.g. broadcast audio on a homeowner's telephone).

The typical blanketing interference problems and solutions described in this case study were drawn from the author's experiences in resolving blanketing interference complaints for Non-Commercial FM station KVTI(FM), Tacoma, Washington.

FCC RULES AND POLICIES

The FM Blanketing Rule

The present FM blanketing rule, §73.318, was adopted in October 1984, by Commission action in Docket 82-186; the rule became effective January 1, 1985. The pertinent part of the §73.318 reads as follows:

> *(b) After January 1, 1985, permittees or licensees who either (1) commence program tests, or (2) replace their antennas, or (3) request facilities modifications and are issued a new construction permit must satisfy all complaints of blanketing interference which are received by the station during a one year period. The period begins with the commencement of program test, or commencement of programming utilizing the new antenna. Resolution of complaints shall be at no cost to the complainant. These requirements specifically do not include interference complaints resulting from malfunctioning or mistuned receivers, improperly installed antenna systems, or the use of high gain antennas or antenna booster amplifiers. Mobile receivers and non-RF devices such as tape recorders or hi-fi amplifiers (phonographs) are also excluded.*

For purposes of administrative convenience, §73.318 (a) defines the area within which blanketing interference will be assumed to occur as the area within the 115 dBu/m contour. A licensee's financial responsibility for the resolution of complaints applies only to those complainants who reside within the 115 dBu/m blanketing contour. Following the one year period, and for complainants who reside outside the blanketing contour, station licensees are obligated to provide "technical information or assistance to complainants on remedies for blanketing interference".

FCC Response to Blanketing Complaints

Over the past several years, the Commission has become increasingly assertive in its enforcement of the FM blanketing rule, largely in response to complaints from neighbors who have been affected by the operation of new FM facilities in locations where high power transmitters did not previously exist. In at least one case, the neighbors retained legal counsel in Washington to represent their interests before the FCC.

Two recent cases illustrate the importance of resolving blanketing interference problems and the potential consequences of an inadequate response to blanketing interference complaints. In Calvary Educational Broadcasting Network, Inc., an FCC Administrative Law Judge imposed a one-year license renewal term, accompanied with strict compliance and reporting requirements, on KOKS(FM), Poplar Bluff, Missouri. This action was later affirmed by the Review Board (9 FCC Rcd, 6412, 11/2/94). In the case of WRQI(FM), South Bristol Township, NY, the Commission staff ordered the station to abandon its construction permit site and to move back to its original licensed site. The station had operated from the CP site for four years and had not resolved all blanketing interference complaints to the satisfaction of either the neighbors or the FCC during that time.

Consumer Equipment Covered by §73.318

There are ambiguities in the language of §73.318 which leave open to question the specific types of consumer electronic equipment included in the blanketing station's area of responsibility. "Mobile receivers and non-RF devices" are specifically excluded by §73.318, but one must look to the Commission staff's actions in specific cases to determine how these exclusions will actually be applied. Based on the record in the KOKS(FM) case and on the Commission's official correspondence with WRQI and KVTI, it appears that any piece of equipment which contains a radio or television tuner and which is capable of being plugged into an AC outlet is considered to be covered by §73.318. This includes "boom boxes" and other portable stereo systems which may also operate from battery power supplies.

Telephones - Telephones, both hard-wired and wireless, are not protected under §73.318. In a letter to the legal counsel for WRQI (1800B#-MJF/RDG, July 14, 1994), the Commission staff's position with respect to telephones is very clearly stated:

> *Hard-wired telephones are considered non-RF devices under §73.318 and as such are not covered by this rule. Cordless telephones are covered by Part 15 of the Commission's Rules. Section 15.5(b) states, in pertinent part, that cordless telephones may not cause harmful interference and that interference to cordless telephones caused by the operation of an authorized radio station must be accepted. (P. 16)*

RF Devices with Non-RF Components - With respect to devices which contain both a radio receiver and a tape recorder (a common configuration for "boom-boxes" and modern component stereo systems) it is not clear from the record what the requirements of §73.318 are with respect to the tape recorder. Has the station satisfied the requirements of the rule if the radio portion of the unit functions normally? As a practical and "political" matter, apart from the question of compliance with the rule, it is clearly in the station's interest to resolve the interference to both the radio and the tape player.

VCRs and Camcorders - According to the current edition of FOB Bulletin No. 16, FM Interference to TV and FM Radio Reception, March 1991, VCRs are not subject to the requirements of §73.318:

> *You can sometimes hear FM radio signals on telephones and other home electronic entertainment equipment, such as Video Cassette Recorders (VCRs), stereos, and recording devices. The Commission offers no interference protection for these devices. Therefore, you should contact your dealer or manufacturer for assistance. (Page 4)*

However, in both the WRQI and KVTI cases, the Commission staff has considered VCRs to be protected under §73.318. Therefore, based on the more recent interpretations of §73.318 by the Commission staff, VCRs are subject to protection. Camcorders are specifically excluded from protection under §73.318, according to the Commission's correspondence with KVTI.

Technical Information and Assistance

The technical information and assistance provided to residents outside the blanketing contour and those who complain after the one-year period must be specific enough to allow the complainant to understand how to resolve blanketing interference problems to specific equipment (i.e., how to install filters, ferrite cores, etc.). In the event that the corrective measures are not successful, the station must recommend replacement equipment which is less subject to interference.

A CASE STUDY: KVTI(FM)

KVTI(FM), Tacoma, Washington, is a Class C1 non-commercial FM station licensed to Clover Park Technical College. It operates with an effective radiated power of 51 Kilowatts (H & V). Its antenna (a 4-bay Jampro JSCP) is side-mounted on a uniform cross-section guyed tower with its radiation center 70 meters above ground level. The KVTI transmitter site is located in a residential neighborhood, at the south end of the campus of Lakes High School in Lakewood, Washington. There are residences located within 150 feet of the base of the KVTI tower. The KVTI 115 dBu/m blanketing contour extends 1.75 miles from the base of the tower.

The KVTI tower is located about 55 kilometers from the Seattle area FM and TV transmitter sites on Cougar Mountain, Queen Anne Hill, and Capitol Hill; about 60 kilometers from the FM broadcast site on West Tiger Mountain; and about 46 kilometers from the Channel 13 and Channel 20 transmitter sites on Gold Mountain. The majority of the off-the-air FM and TV signals available in Lakewood are from the Seattle area transmitter sites.

The station began operating from this transmitter site in May of 1991. Even before going on the air, the station initiated a program designed to resolve interference complaints, using the services of a local TV-radio service shop. Since the station initially went on the air, more than 100 complaints related to blanketing interference in the vicinity of the KVTI site have been resolved. In April of 1994, a group of neighbors living in the vicinity of the KVTI site filed a petition with the FCC, complaining of blanketing interference from KVTI.

In response to the petition, the Commission sent a letter (1800B3-MJF, dated August 22, 1994) to KVTI requiring the station to resolve 20 "previously referred" unresolved complaints and to provide "effective technical assistance" to 46 new complainants whose names were listed in the petition. The letter also required KVTI to submit a detailed report regarding the resolution of the complaints, including maps showing the locations of all the affected residences. The majority of the new complainants listed in the petition had never contacted KVTI prior to signing the petition.

Clover Park Technical college retained Hatfield and Dawson as project manager to help resolve the interference complaints and to prepare the report to the FCC. Mr. Joseph N. (Nick) Winter, Jr. of Broadcast Services Northwest was also retained by the College to assist with the field work and to carry out the station's program of continuing assistance for neighbors with interference problems. The author, Mr. Winter, and Mr. Stephen Lockwood, P.E. of Hatfield & Dawson performed all the site visits and equipment tests required for the project.

The blanketing interference symptoms described in this paper and the techniques used to ameliorate them are based on what we learned in our visits with the residents of Lakewood.

Affected Equipment, Symptoms of Blanketing Interference, and Measures Employed to Ameliorate Interference

Described below are the types of equipment found to be susceptible to various forms of blanketing interference and the corrective measures which were successfully used to ameliorate the interference:

- **Television Receivers** - A wide range of television receivers were affected by blanketing interference, ranging from 5" portable models to 48" projection TVs. Many households had a number of affected TV's; some households had as many as 12 affected receivers, often with accompanying VCR's. TVs connected to off the air receiving antennas or using "rabbit ears" were usually most severely affected when tuned to channels 4, 5, and 7. The effects of the interference ranged from very slight "fuzziness" in the picture to a "herringbone" pattern in the video. In the most extreme cases, the herringbone pattern completely obliterated the picture. In some cases, audio from the radio station could be heard on the TV speakers. The severity of the interference depended upon the D/U ratio between the desired TV signal and the undesired blanketing signal.

TVs connected to the cable system often exhibited similar symptoms to those connected to off-the-air antennas, depending upon the level of the blanketing signal leaking into the cable distribution system. In addition, TVs connected to home cable systems used to feed multiple sets from a single CATV drop often exhibited mild to moderate herringbone patterns on cable channels 8 and 34 (corresponding to the frequency of the 2nd harmonic and 3rd harmonic of the FM station). Measurements at the FM transmitter demonstrated that the signals producing this interference were not being radiated directly by the transmitter. This type of interference appeared to be produced by spurious products produced in non-linear junctions in the cable feed systems, in external metallic junctions (power lines, phone lines, metal fences, etc.), or in the front ends of other TV receivers connected to the cable feed system. The only effective techniques we found to correct these problems were to increase the level of the desired signals on channels 8 and 32 and/or to replace the television set with a model less susceptible to this type of interference.

In nearly all cases, the installation of a Microwave Filter Company 5KFM-90.9 notch filter at the RF input connector of the TV and a Fair-Rite 04433164151 "clip-on" ferrite core or a Fair-Rite 5943003801 toroid core on the AC power cord eliminated the interference. (This technique was not effective for the channel 8 and channel 32 interference, since it was produced by a spurious signal on a frequency far outside the range of the notch filter, and because the use of a notch at the channel 8 or channel 32 frequencies would have eliminated the desired signals as well.) In some cases, the interference could not be eliminated using these techniques, and the TV had to be replaced with a new model known to be less susceptible to interference. Most of the TV's which had to be replaced were older models without an "F" connector integral to the tuner module. These TV's were usually overloaded by the FM radio frequency energy entering the tuner directly through the TV's case.

Figure 3 shows the installation details for the filters and toroid cores. Drawings similar to those in Figure 3, along with detailed written instructions were provided to complainants as part of a "handbook" prepared by our firm, which describes how to resolve common blanketing interference problems.

- **VCRs**-The interference effects observed in VCR tuners were very similar to those observed in TVs. The same remedial measures used for TVs were successfully used for VCRs. In many cases, the VCR tuners were less susceptible to interference and produced better picture quality than TV receivers of the same vintage. It was not necessary to replace any VCRs in the blanketing area.

- **Home CATV Cabling** - Many of the households we visited had extensive internal cable distribution systems, often using a single feed from the cable company and multiple splitters to feed as many as 10 TV receivers. This resulted in very low TV signal levels at the "downstream" end of these systems, which made the receivers connected to the cable much more susceptible to interference from the strong FM signal. In many cases, even replacing the cable in these systems with double-shielded coax did not reduce the level of the FM signal leaking into the system to eliminate the interference. In these cases, powered splitters were installed to increase the level of the desired TV signals at the downstream receivers. Notch filters were installed at the input of the powered splitter to prevent amplifier overload by the strong FM signal, as shown in Figure 3.

- **Rooftop Antennas** - In a several cases, rooftop antenna systems had to be modified to increase the level of desired TV signals and/or to reduce the level of the interfering FM signal entering FM and TV receivers. 300 ohm twinlead downlead connections were replaced with double-shielded coax and splitters were added in place of parallel-connected downleads. These modifications both helped to reduce the interference and improved the signal quality at the TV receivers.

- **AM/FM/Shortwave Radios and Boomboxes** - The strong FM signal did not affect the operation of the Broadcast Band AM tuners in most radios; a significant level of 60 Hz power line noise in the neighborhood tended to limit the availability of AM signals to those with high signal strength. The FM tuners in many boomboxes, inexpensive "all-in-one" component stereo systems, and a significant number of quite expensive FM component receivers exhibited symptoms of receiver desensitization, intermodulation, and the production of multiple images of the blanketing station. On most receivers, these effects were observed below about 93 MHz on the FM band, but in some cases, the entire FM band was wiped out.

On receivers with coaxial antenna connectors, the installation of a notch filter usually eliminated the interference effects. Receivers with 300 ohm twinlead antenna connectors proved to be more of a problem, though it was frequently possible to use a combination of two 300/75 ohm baluns and a notch filter to restore the normal operation of the receiver with a 300 ohm twinlead antenna.

In many cases, even after the FM tuner section of a system was restored to normal operation, the FM station's detected audio could still be heard in the tape player output or in the power amplifier of a component system. These problems could usually be solved by the installation of ferrite cores on the AC power lead, the speaker leads, and all the audio interconnections in a component system. Figure 4, also taken from the "handbook", shows the installation details for the ferrite cores. In some cases, even these measures were unsuccessful, and the receiver or compact component system had to be replaced with a unit less susceptible to interference.

Boomboxes were an especially difficult problem, since many models have either a telescoping monopole external antenna or use the AC power cord as an antenna. Also, most boomboxes have plastic cases which provide little or no shielding against unwanted RF signals. In some cases, where the tuner section of the boombox functioned normally, but the tape player or the amplifier section suffered from RF rectification, it was possible to restore normal operation by installing ferrite cores on the speaker leads and the AC power cord, as shown in Figure 4.

We encountered several boomboxes with AM/FM/Shortwave tuners (there are many retired military residents of Lakewood, and these receivers had all been imported from overseas). The shortwave sections of these tuners were universally obliterated by the strong FM signal. These units were replaced with separate shortwave radios and AM/FM boomboxes.

- **Intercoms** - These units tended to suffer mainly from RF detection in their amplifier sections, which was relatively easy to eliminate by the installation of ferrite cores on the speaker and remote unit leads. One unit which included an integral radio was more difficult to deal with because it did not have any kind of external antenna, and did not have any obvious connection between the tuner circuit board and the outside world. This unit required some custom modification.

- **Clock Radios** - Surprisingly, some clock radios functioned normally in the high ambient RF field, and others had severe problems. Since these units all had plastic cases and most did not have external antenna connectors, the only available remedial measure for affected radios was to replace them.

- **Telephones** - Although telephones are specifically excluded from protection under §73.318, complaints about telephone interference comprise the single largest category in blanketing interference areas. Because the telephone is used often on a daily basis, the presence of a radio station's audio in the background on the phone is a constant irritant which will generate ill will in the neighborhood surrounding an FM transmitter site. In all cases we encountered it was possible to eliminate audio rectification in telephones by installing filters fitted with the appropriate modular connectors at the line cord and the handset cord of the telephone. We used filters custom manufactured by Coilcraft. In some cases, it was also necessary to install a clip-on ferrite core on the line cord or headset cord of the phone close to the body of the phone in order to eliminate the interference.

Some cases of telephone interference were produced by the 1 kW daytime AM station which operates from a transmitter site at the north end of the Lakes High School campus. Because residents did not tend to distinguish one form of radio interference from another, the most expedient solution to this problem, was the installation of appropriate filters designed to attenuate medium wave frequencies.

Most cordless telephones did not suffer from blanketing interference. The majority of the cordless phones in the Lakewood area were models manufactured by GE and Southwestern Bell.

Other Sources of Interference

Several other sources of interference to radios and TVs were identified during the site visits. It is important to identify and categorize the effects of these other sources because residents affected by blanketing interference do not have the technical background or any means of distinguishing various forms of interference, and tend to attribute all interference to the FM station.

- **AM Radio Stations** - On some AM tuners, the strong local signal from the daytime AM station produced intermodulation products which appeared at several locations on the dial. Turning the FM transmitter on and off had no effect on these products.

- **Power Line Noise** - Some residents lived adjacent to a power utility substation in an area which was located behind a small hill and was shadowed from all the Seattle area TV transmitter sites. The 60 Hz noise level in this neighborhood was especially severe in this neighborhood, especially after long periods with no rain increased the level of corona discharge across high voltage insulators in the power distribution system. The low-band VHF TV signals received off-the-air in this neighborhood were very noisy; even after on/off tests were used to demonstrate that this interference was not caused by the FM station, complaints were still received about this type of interference.

- **Touch Lamps and Light Dimmers** - One residence had several "touch lamps" which used a capacitive touch switch in the base of the lamp as an on/off switch. When these lamps were turned on they produced fairly high level noise pulses spaced about 100-150 KHz intervals from the VLF band up through 20 MHz. The noise produced by these lamps severely disrupted reception on medium wave and shortwave radios, showing up as a loud buzz at regular intervals across the operating band of the receiver. At first, this interference appeared to be produced by the FM station, because when a shortwave radio was tuned to a frequency occupied by one of the noise pulses, turning off the FM station appeared to cause the interference to go away. Further investigation using a spectrum analyzer revealed that turning the FM transmitter on and off merely shifted the frequency of the entire noise pulse spectrum generated by the touch lamps, but that it did not affect the amplitude of the RF noise these devices produced. With the FM transmitter turned off, it was possible to retune the affected receiver and to find the interference at its new frequency.

SCR light dimmers produced a similar noise pattern, but it was much less severe than the noise produced by the touch lamps.

Signal Measurement Procedure Used During Site Visits

At each household, detailed note sheets were made for each piece of equipment, and, for the majority of the households, spectrum analyzer measurements were made showing the received television signal strength levels and the FM signal levels provided by outdoor receiving antennas or by the local cable system. The signal level measurements were made in as many cases as possible to provide data regarding the level of television signal strength required at typical television sets to overcome the effects of interference from the strong FM signal. In many cases a measurement was made of the ambient KVTI field strength in the vicinity of the equipment affected by blanketing interference. The measured KVTI (FM) field intensity inside homes in the blanketing area ranged from 100 mV/m in houses located more than a few thousand feet from the transmitter site to more than 1 V/m in houses located immediately adjacent to the KVTI tower.

Quality of Off-the-Air TV Signals in Lakewood

Our measurements and site visits showed that off-the-air television reception in the absence of FM blanketing interference from was adequate (though generally not what one would call a high quality signal) in some areas of Lakewood using a pair of "rabbit ears" mounted on top of the TV set. In other areas, reception was sometimes poor to totally unusable, even with a rooftop antenna.

Both the measurements and the observations of the quality of received TV signals showed that there was a very pronounced diurnal (day-to-night) variation in the strength of both the TV and the FM signals from the Seattle broadcast transmitter sites on Queen Anne Hill, Capitol Hill, Cougar Mountain, and West Tiger Mountain. Given the distances between the transmitter sites and the receiver locations, the nature of the intervening terrain, and the fact that none of the receiver locations had adequate Fresnel zone clearance from the Seattle FM and TV transmitter sites, these variations were not entirely surprising.

At some locations, the change in propagation conditions from mid-day (when the air near the surface was well mixed) to early morning or late afternoon or evening (when the air tended to be more stratified) was significant to change the video and audio signal quality of the TV signals from good quality typical of a line-of-sight path to very noisy and "ghosty" poor quality typical of a diffraction path. This type of variation even caused all but a few of the available Seattle FM station signals to drop below the muting threshold of one FM receiver as day changed to night.

Notch Filter Characteristics

Microwave Filter Company 5KFM-90.9 notch filters were used to attenuate the KVTI signal at the input to TV and FM receivers. These filters have a 60 dB notch and a 3 dB bandwidth of +/- 3 MHz, so they can be used with minimal detrimental effect on the other off-the-air FM signals or on the Channel 6 aural carrier in cable systems. A spectrum analyzer plot of the frequency response of this filter is shown shown in Figure 1:

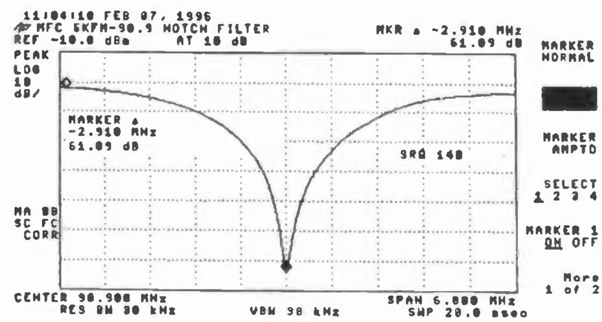


Figure 1 - MFC 5KFM-90.1 Filter Response

For purposes of comparison, the frequency response of a Radio Shack FM Trap (Part # 15-577), which has sometimes been used (often unsuccessfully) to attempt to mitigate blanketing interference is shown in Figure 2:

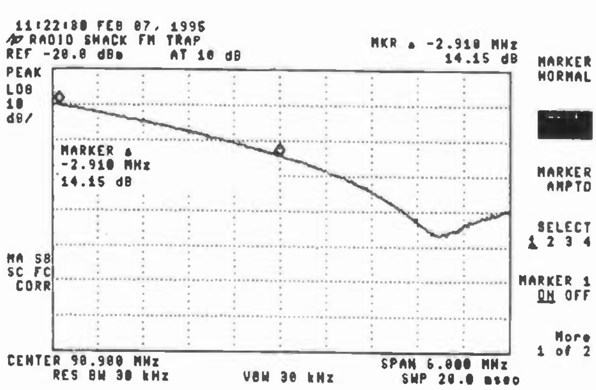


Figure 2 - RS FM Trap Frequency Response

As shown in Figure 2, the Radio Shack FM trap has less than 15 dB of rejection relative to the 3 dB point of the MFC notch filter, while the MFC notch provides more than 60 dB. The RS FM trap also has a relatively high insertion loss, has nearly 10 dB of amplitude response variation over the band occupied by Channel 6, and tends to degrade the quality of TV signals in low signal environments.

Tests of TV and Radio Receivers

Prior to making site visits with replacement equipment, a number of TV and radio receivers were tested at or near the KVTI transmitter site to determine which units were likely to function well in the high level RF field environment of the blanketing area.

The results of the TV receiver tests are shown in Tables 1 and 2. Table 1 shows the interference caused to each receiver when connected directly (with no filters) to a test receiving antenna at the KVTI transmitter site. Table 2 shows the reduction in interference for each receiver which resulted from the installation of an MFC 5KFM-90.9 notch filter between the antenna downlead and the antenna input connector on the TV. Based on these measurements, the best four out of six receivers were selected for use as replacement TVs in households in the blanketing area. Although it is not shown in the data, a further reduction in interference caused to some of the TVs resulted from winding several turns of the antenna downlead through a toroid core before connecting the downlead to the MFC filter. This reduced the level of RF energy conducted along the coax cable shield, which eliminated some residual interference effects in some cases. Even though two out of the six TVs had some problems at the KVTI transmitter site, we found in general that most modern TV receivers can be made to function correctly in the blanketing environment if appropriate filters and toroids are used and if a desired signal of adequate level is provided at the receiver antenna input.

Several AM/FM boomboxes and micro and mini component stereo systems were also tested in advance of installation in households. All the radios tested had digital tuning indicators and synthesized tuners. The following units were found to operate well in the blanketing environment:

- JVC PC-X105 AM/FM/Dual Cassette/CD
- JVC RC-QS11 AM/FM/Cassette/CD
- JVC UX-T1 AM/FM/CD/Cassette Micro Component System
- Sony MHC-450 AM/FM/CD/Cassette Micro Component System
- Samsung SCM-8300 AM/FM/CD/Cassette Mini Component System (with RIAA phono inputs)

The Samsung unit was used in cases where a system with a turntable needed to be replaced. Shortwave receivers were replaced with a Grundig YB-400 "Yachtboy" portable model. A larger and more expensive Grundig model did not function adequately in the blanketing environment.

Establishing and Maintaining Good Public Relations

Efforts to resolve blanketing interference complaints can be most successful if the following general guidelines are followed:

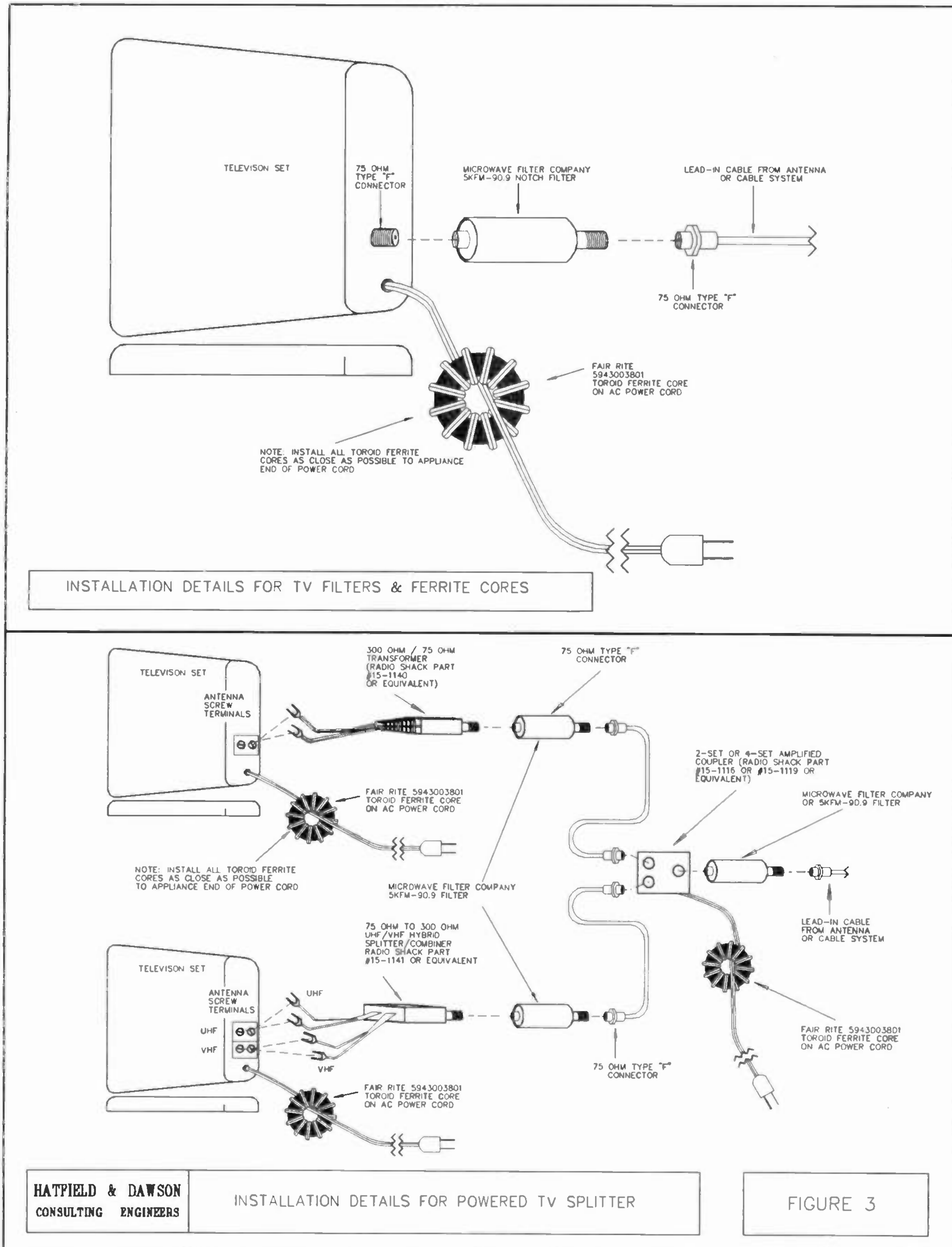
- Set up a system for receiving and tracking complaints before you turn on the transmitter at a new site.
- Retain experienced and competent technical help; sending out inexperienced people who do not know how to resolve interference problems will only cause more problems later.
- Document everything you do.
- Communicate with the neighbors; let them know what you are doing to resolve their problems; follow up after site visits.
- Don't minimize your complainants problems or attempt to blame them on the equipment they are using. Put yourself in their shoes.
- Go the extra mile; even if you are not required by the Commission's Rules to solve every problem, the more problems you actually do solve, the more good will you will generate among your neighbors.

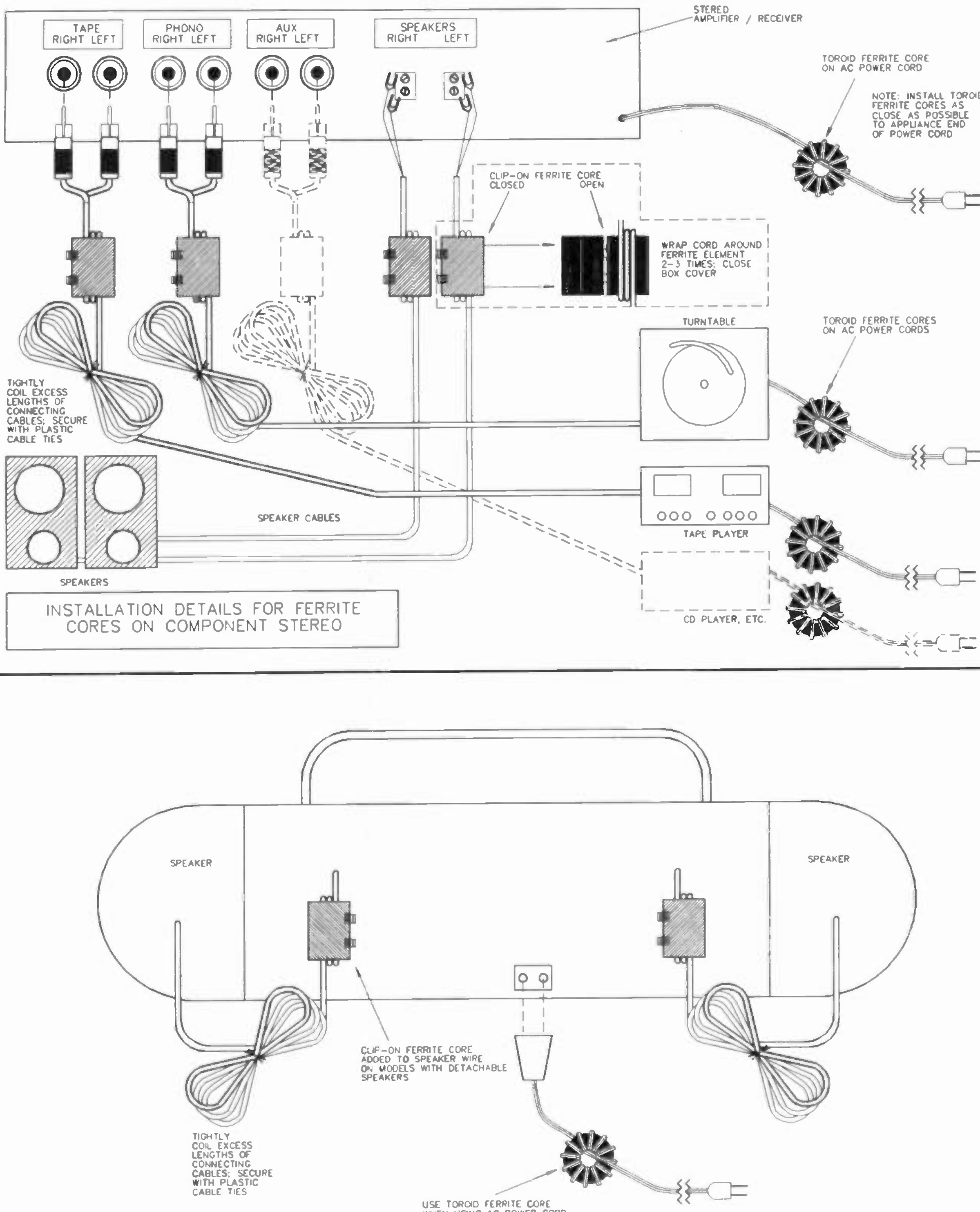
Received Signal			Television Receiver Manufacturer and Model Number					
Off-the Air TV Channel	Measured TV Signal Strength at Receiver (dBmV)	TV/FM D/U Ratio (dB)	Toshiba CF19C20 20 inch TV (August 1993)	JVC C-20CL5 20 inch TV (May 1994)	Hitachi 20MA1B 20 inch TV (October 1993)	Mitsubish CS-20101 20 inch TV (October 1993)	Samsung TTB2012 20 inch TV (April 1994)	Panasonic CF20S2S 20 inch TV (June 1994)
Channel 4	-12.4	-64.6	Good quality video and audio	Severe herringbone on video; audio OK	Severe herringbone on video; audio OK	Picture completely obliterated; audio OK	Severe herring-bone on video; audio OK	Moderate herring-bone on video; audio OK
Channel 5	-11.9	-64.1	Severe herring-bone on video; audio cuts in/out	Severe herring-bone on video; no color; audio OK	Severe herringbone on video; audio OK	Picture completely obliterated; audio OK	Severe herring-bone - no picture; audio OK	Very slight "fuzzi-ness on video; audio OK; ghosts
Channel 7	-10.8	-63.0	Excellent video & audio quality	Moderate herringbone on video; audio OK	Slight herringbone on video; audio OK	Severe herring-bone on video; audio OK	Slight herringbone on video; audio OK	Very slight herringbone on video; audio OK
Channel 9	-5.1	-57.3	Slight herring-bone on video	Severe herringbone on video; color on/off; audio OK	Moderate herringbone on video; audio OK	Severe herring-bone on video—no picture; audio OK	Severe herring-bone - picture just visible in noise; audio OK	Moderate herring-bone; picture at noise level; audio OK
Channel 11	-3.0	-55.2	Excellent video and audio quality	Slight herringbone on video; audio OK	Excellent video and audio quality **(Ch. 12 also OK)**	Moderate herring-bone on video; audio OK	Very slight herringbone on video; audio OK	Very good quality video and audio
Channel 13	0.0	-52.2	Excellent video and audio quality	Slight "fuzziness" on video; audio OK	Excellent video and audio quality	Slight herringbone on video; audio OK	Good quality video and audio	Excellent quality video and audio
Channel 20	-8.0	-60.2	Not tested	Not tested	Not tested	Not tested	Good quality video and audio	Very good quality video and audio
Channel 22	-13.6	-65.8	Excellent video and audio quality	Slight "fuzziness" on video; audio OK	Excellent video and audio quality	No signal; below RX squelch level	Slight herringbone on video; audio OK	Very good quality video and audio
Channel 28	16.9	-35.3	Not tested	Not tested	Not tested	Not tested	Very good quality video and audio	Excellent quality video and audio
KVTI (90.9 MHz)	52.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table 1 - FM Interference to Representative TV Receivers (Direct Connection to Receiving Antenna)

Received Signal			Television Receiver Manufacturer and Model Number					
Off-the Air TV Channel	Measured TV Signal Strength at Receiver (dBmV)	TV/FM D/U Ratio (dB)	Toshiba CF19C20 20 inch TV (August 1993)	JVC C-20CL5 20 inch TV (May 1994)	Hitachi 20MA1B 20 inch TV (October 1993)	Mitsubishi CS-20101 20 inch TV (October 1993)	Samsung TTB2012 20 inch TV (April 1994)	Panasonic CF20S2S 20 inch TV (June 1994)
Channel 4	-12.4	-3.0	Good quality video and audio; some noise on video	Noisy signal; no difference with FM on or off	Good quality video and audio; just perceptible change with FM on	Good quality audio and video; "fuzziness" on video; audio OK	Moderate herring-bone on video; audio OK	Very slight herringbone on video; audio OK
Channel 5	-11.9	-2.5	Excellent video and audio quality	Very high quality video and audio	Very slight "fuzziness" in video	Slight "fuzziness" on video; audio OK	Slight herringbone on video; audio OK	Very slight herringbone on video; audio OK
Channel 7	-10.8	-1.4	Excellent video and audio quality	Good quality video and audio	Very good quality video and audio	Slight "fuzziness" on video; audio OK	Slight herringbone on video; audio OK	Very slight "fuzzi-ness" on video; audio OK
Channel 9	-5.1	4.3	Excellent video and audio quality	Slight herringbone in video; audio OK	Good quality video and audio	Very good quality video and audio	Very slight herring-bone on video; audio OK	Excellent quality video and audio
Channel 11	-3.0	6.4	Excellent video and audio quality	Slight "fuzziness" in video; entering set through case	Very good quality video and audio	Very slight herring-bone in video; audio OK	Good quality video and audio	Excellent quality video and audio
Channel 13	0.0	9.4	Excellent video and audio quality	Slight "fuzziness" in video; entering set through case	Excellent quality video and audio	Very slight herring-bone in video; audio OK	Very good quality video and audio	Excellent quality video and audio
Channel 20	-8.0	1.4	Not tested	Not tested	Not tested	Not tested	Very good quality video and audio	Excellent quality video and audio
Channel 22	-13.6	-4.2	Excellent video and audio quality	Slight "fuzziness" on video; entering set through case	Excellent quality video and audio	No signal; below RX squelch level	Good quality video and audio	Excellent quality video and audio
Channel 28	16.9	26.3	Not tested	Not tested	Not tested	Not tested	Excellent quality video and audio	Excellent quality video and audio
KVTI (90.9 MHz)	-9.4 (with MFC notch filter)	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table 2- FM Interference to Representative TV Receivers (MFC 5KFM-90.9 Notch Filter)


TELEVISON SET
75 OHM TYPE "F" CONNECTOR
MICROWAVE FILTER COMPANY 5KFM-90.9 NOTCH FILTER
LEAD-IN CABLE FROM ANTENNA OR CABLE SYSTEM
75 OHM TYPE "F" CONNECTOR
FAIR RITE 5943003801 TOROID FERRITE CORE ON AC POWER CORD
NOTE: INSTALL ALL TOROID FERRITE CORES AS CLOSE AS POSSIBLE TO APPLIANCE END OF POWER CORD
INSTALLATION DETAILS FOR TV FILTERS & FERRITE CORES
TELEVISON SET
ANTENNA SCREW TERMINALS
300 OHM / 75 OHM TRANSFORMER (RADIO SHACK PART #15-1140 OR EQUIVALENT)
75 OHM TYPE "F" CONNECTOR
2-SET OR 4-SET AMPLIFIED COUPLER (RADIO SHACK PART #15-1116 OR #15-1119 OR EQUIVALENT)
MICROWAVE FILTER COMPANY OR 5KFM-90.9 FILTER
FAIR RITE 5943003801 TOROID FERRITE CORE ON AC POWER CORD
NOTE: INSTALL ALL TOROID FERRITE CORES AS CLOSE AS POSSIBLE TO APPLIANCE END OF POWER CORD
MICROWAVE FILTER COMPANY 5KFM-90.9 FILTER
LEAD-IN CABLE FROM ANTENNA OR CABLE SYSTEM
75 OHM TO 300 OHM UHF/VHF HYBRID SPLITTER/COMBINER RADIO SHACK PART #15-1141 OR EQUIVALENT
TELEVISON SET
ANTENNA SCREW TERMINALS
UHF
VHF
UHF
VHF
75 OHM TYPE "F" CONNECTOR
FAIR RITE 5943003801 TOROID FERRITE CORE ON AC POWER CORD
FAIR RITE 5943003801 TOROID FERRITE CORE ON AC POWER CORD
HATFIELD & DAWSON CONSULTING ENGINEERS
INSTALLATION DETAILS FOR POWERED TV SPLITTER
FIGURE 3



HATFIELD & DAWSON CONSULTING ENGINEERS

FERRITE CORES AND TOROID FILTER ON PORTABLE STEREO "BOOMBOX"

FIGURE 4

KDKA—A HISTORY OF INNOVATION CONTINUES

J.M. Bixby and Michael D. Rhodes
Moffet, Larson & Johnson, Inc.
Falls Church, VA

Charles J. Fagan, III
KDKA, Group W Radio
Pittsburgh, PA

INTRODUCTION

The old KDKA tower was built for the first time in 1938, at Saxonburg some 25 miles from the center of Pittsburgh, PA. The completion of the tower was accompanied by a wave of promotion and publicity. However, when it was actually turned on, it "didn't work". The antenna's high angle radiation came back down in the groundwave service area causing "self-fading" and the station could not be heard in Pittsburgh at night. Following a period of planning and evaluation, the tower was disassembled, moved and re-erected on the present site in Allison Park, PA, about 11 miles from the center of the city. Until the summer of 1994, KDKA operated from that site and with that tower. But, as the suburban population grew, the antenna's self-fading eventually became a problem even from the Allison Park site.

In the summer of 1994, the old KDKA "Franklin" antenna was toppled and a new tower was erected in its place. The new antenna was specifically designed to retain the excellent groundwave performance of the older Franklin, while dramatically reducing the high angle radiation to reduce or eliminate the "self fading." To accomplish this, and to provide a practical antenna, a number of proven techniques were combined to produce what we believe to be a unique and modern AM antenna design.

THE ORIGINAL KDKA FRANKLIN

By common definition, a Franklin antenna is a full wavelength over ground, insulated from ground, and fed at the center. By that definition, the original KDKA antenna was not a true Franklin, since it was only about 3/4 of a wavelength in overall height. It was, however, insulated at ground and was fed at the center across sectionalizing insulators. The feed assembly was composed of a ground mounted balun feeding a balanced open wire transmission line which ran up the inside of the tower to the center. The balun was fed by a tuning unit which provided an impedance match to the transmission line from the building. In that configuration the base feed apparatus also constituted a load across the base insulator between the base of the tower and ground. Each time the base tuning and feed apparatus was replaced or reconfigured, the load across the base insulator changed, causing a change in the relative current distribution between the upper and lower sections. This caused changes in the vertical radiation pattern of the antenna, some more favorable than others with respect to self-fading, but none was ideal. Since the base loading function was incidental to tuning and impedance matching, no effective vertical pattern control was feasible.

Over the more than 50 years the tower had been standing, despite good maintenance procedures, there had been substantial deterioration of the steel, to the point that its structural integrity was in question. Based upon a detailed inspection of the tower, it was concluded that it could not be economically restored. A new tower was required, and it seemed pointless to re-build the old Franklin which "didn't work". The choices were to build a simple conventional base fed vertical or a modified Franklin with greatly reduced high angle radiation.

An analysis of the physical configuration of the old antenna, that is, 720' overall, fed in the center, was conducted in MININEC. That study confirmed that even if an optimum adjustment could be achieved, there would be substantial high angle radiation. Even though the optimum adjustment of the old Franklin may never have been achieved, it was theoretically possible, and, therefore, it was the standard against which new designs would be judged.

THE NEW FRANKLIN

For a modified Franklin to be practical, the following design criteria would have to be met:

1. Groundwave performance essentially equal to the old Franklin to retain the present daytime (groundwave) service area.

2. High angle radiation (60° to 80°) substantially lower than the old Franklin (optimized) to minimize self-fading.

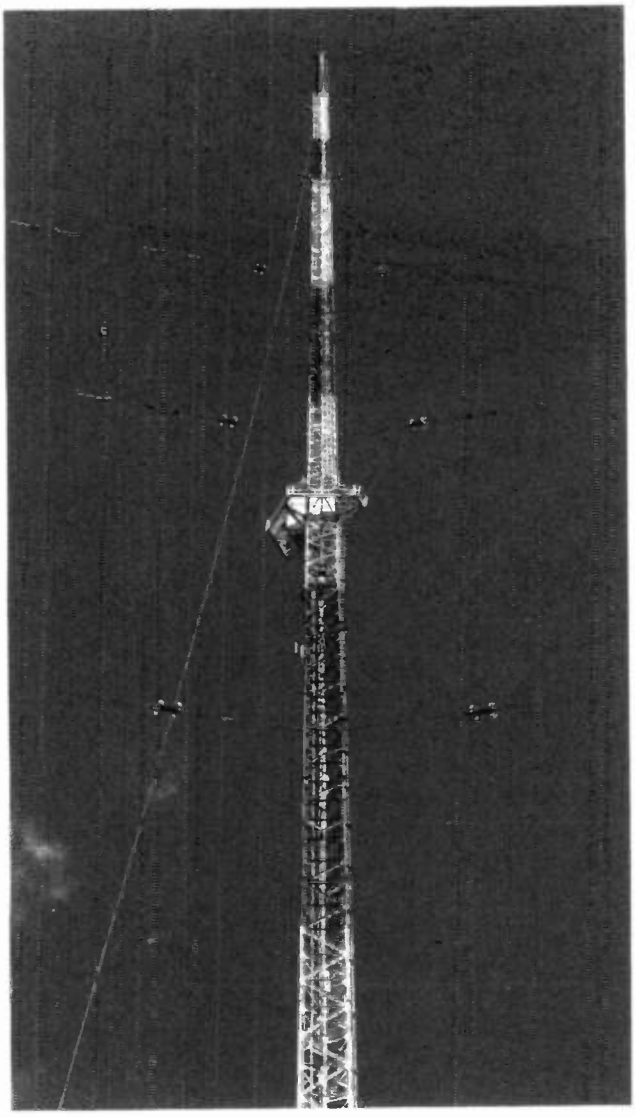
3. Overall height no greater than the old tower to minimize local zoning and FAA problems.

4. A simplified feed apparatus.

5. Isolation of the functions of impedance matching and base loading so that one could be adjusted independently of the other.

Other considerations, principally cost, entered the picture as well, but these were the primary engineering criteria.

The new "Franklin", if we can call it that, is also some 720' in height, just as the old one was. Like the old one, it is insulated at the base and at the feed point, several hundred feet above ground. However, the feed point was lowered some 90' to the 270' level, making the portion of the tower above the feed point essentially ½ wavelength. By adding reactive loading at the tower's base, the current distribution in the lower segment can be adjusted with respect to that in the upper section to modify the antenna's vertical radiation pattern.



New KDKA modified Franklin Antenna

In an ideal Franklin, the currents in the upper and lower sections are in phase, the points of maximum current (the "current loops") are 180° apart, and the integrated areas under the curve in the upper and lower sections are equal and in phase. As shown in Figures 2 and 3, the final model met these requirements, producing a vertical pattern, Figure 4, with dramatically reduced high angle radiation, and with groundwave radiation similar to the old Franklin. Thus, the first three criteria were satisfied.

The antenna is fed at the sectionalizing insulator by coaxial cable, eliminating the need for the balun. Since the impedance matching network is also located here, adjustments to it do not change the load at the base, thereby isolating the impedance matching and base load functions. Base loading is accomplished by a parallel resonant circuit between the base of the tower and ground. The impedance of this circuit can be adjusted over a wide range to provide the desired current distribution. Both the center tuning unit and the base loading assembly are equipped with motor driven components so the complete adjustment can be accomplished by remote control from the transmitter building. An antenna monitor and two RF sampling loops, one in the upper section and one in the lower, provide real time monitoring of the ratio and phase of the current in the two sections.

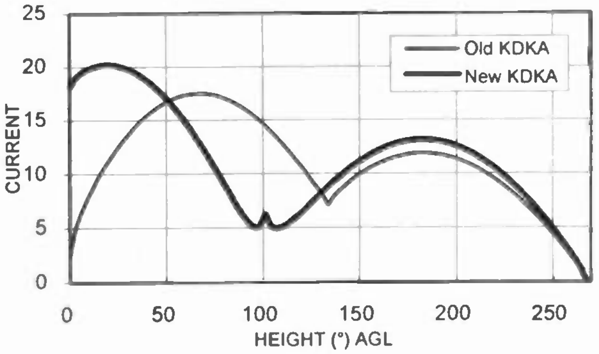


Figure 2

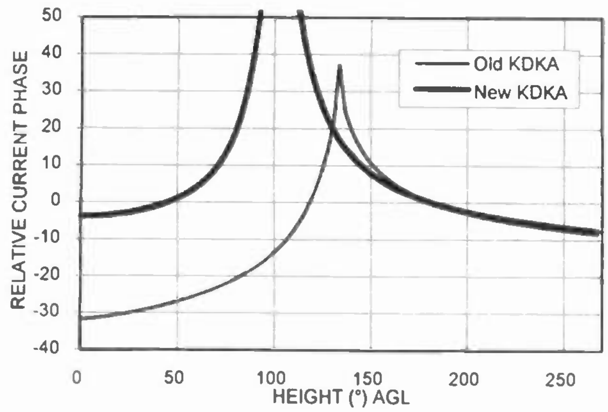


Figure 3

LINE ISOLATION AND GROUNDING

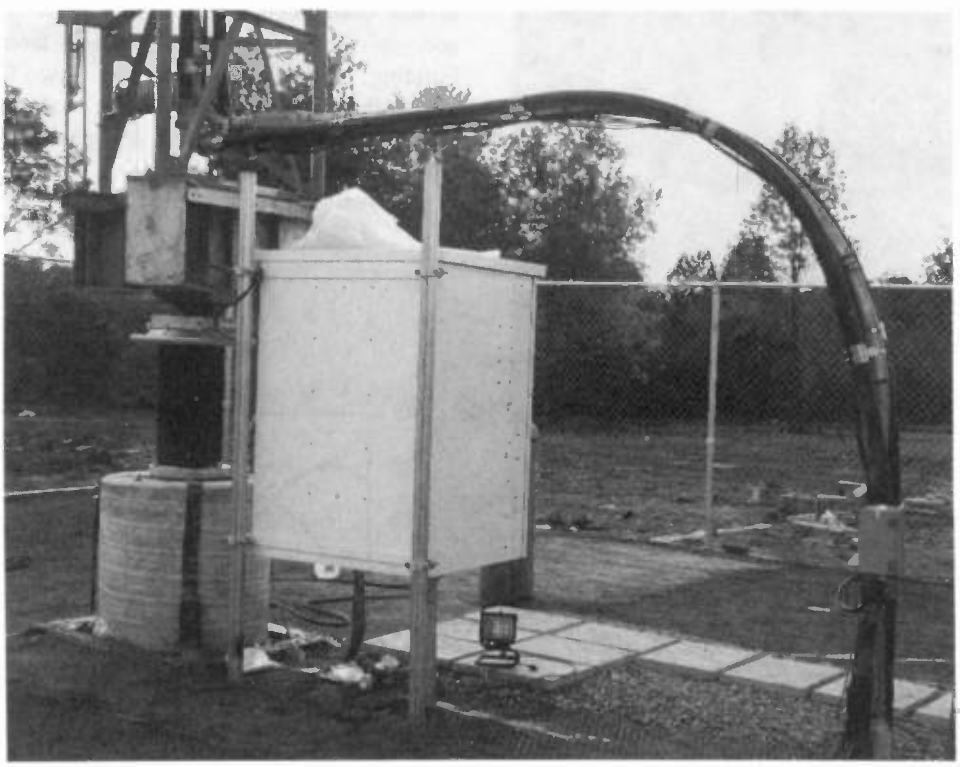
Since the tower is insulated at the base and 270' above ground, it was necessary to provide a means of isolating tower lighting and one sample line across both sets of insulators, and all lines across the base insulator. Since the transmission line was to be 3" semi-rigid, it seemed impractical to wind a length of it into an isolation coil. It was decided that the transmission line should be installed as a quarter-wave stub or "bazooka" section across the base insulator. The line would be insulated from the tower from ground level to a point about 90° above the base insulator where it would be bonded to the tower. From there, it would remain at tower potential to the sectionalizing insulator. This forms a quarter wavelength shorted stub across the base insulator so that the transmission line could be grounded at the base. Conventional chokes and ring transformers were considered for tower lighting, and rejected in favor of conduit also installed as a "bazooka" section across each set of insulators.

In the final configuration, the lighting conduit was fabricated of 3" thick wall galvanized steel. The conduit runs down the center of the tower from the top plate to near the base in a straight line. It is supported with insulated hangers in the bazooka section portions of the tower, and with conductive hangers in the remaining portions. Tower lighting and control wiring run within the conduit, which also serves as a support foı both transmission lines (main and spare) and the sample lincs. About 10' above the base of the tower, the conduit and lines exit the tower and make a smooth, large radius curve downward to ground. This arrangement accomplishes a number of things:

1. It places the entire tower at DC ground with a large diameter, robust conductor for lightning protection.

2. It isolates all lines and cables across both sets of insulators without the need for ring transformers, chokes, and the like.

3. It provides a suitable support for the transmission lines.



Base loading circuit showing transmission line and conduit.

ANTENNA PERFORMANCE

As Figure 4 shows, the high angle radiation from this antenna is much lower, both in absolute terms, and as a ratio to the radiation at the horizontal, than the best performance that could have been achieved with the old Franklin. The improvement varies with the elevation angle, but over the range of interest, the improvement is generally 10 dB or more.

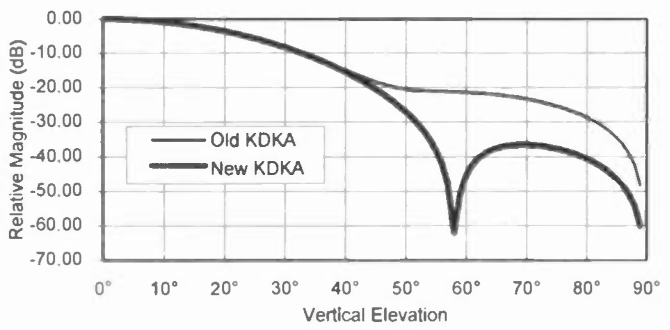


Figure 4

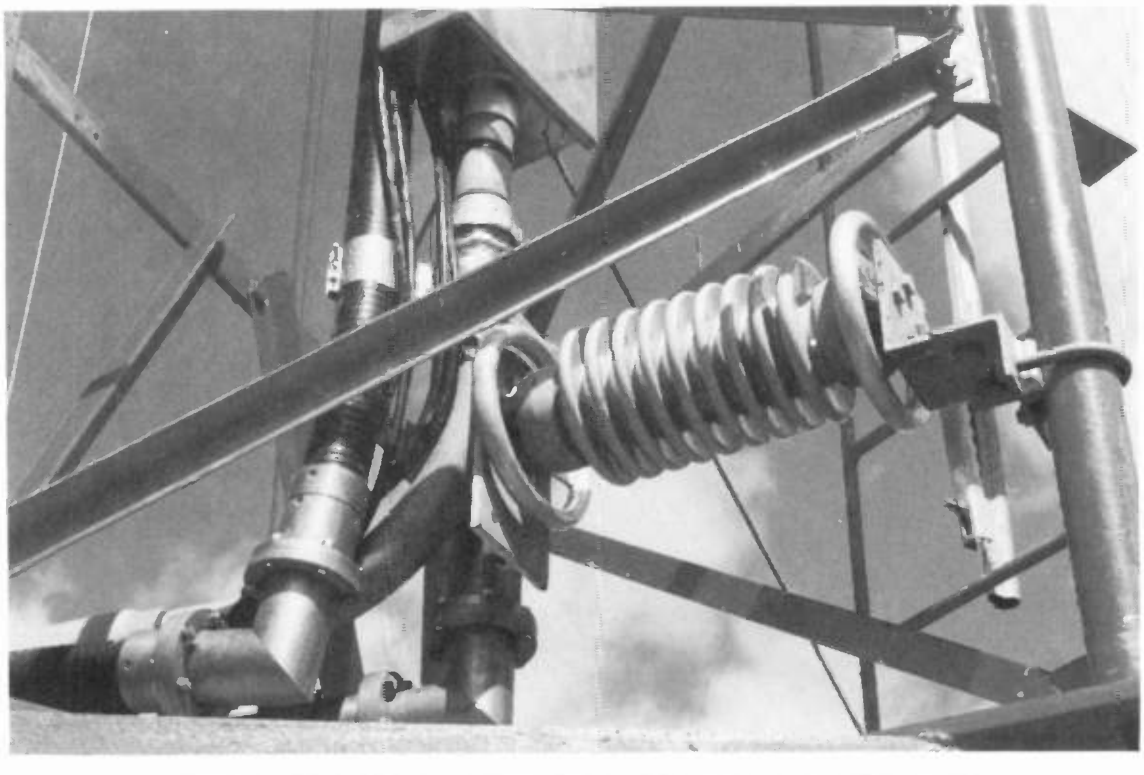
Destructive self fading is difficult to measure, and varies with time of day, season, sun spot cycle, and so on. To our knowledge, there were no quantifiable data taken on the old antenna, so no direct comparison is possible. However, the anecdotal evidence, based on listener reports and spot listening tests by the KDKA engineering staff universally agree that the self fading in the areas of concern is gone.

Standard non-directional proof measurements, as required by the Construction Permit, established the antenna efficiency at about 431 mV/m/kW @ 1 km or about 3050 mV/m @ 1 km for 50 kilowatts. This efficiency is essentially the same as predicted by the MININEC model.

CONCLUSION

With careful MININEC modeling, it was possible to evaluate the old KDKA Franklin antenna and to calculate its vertical pattern. With that as a benchmark, new designs for a modified Franklin could be evaluated and optimized in MININEC. The location of the feed point and the load at the base were varied until a combination was found which offered the most favorable ratio of high angle radiation to radiation at the horizontal, and, therefore, the best anti-fading performance. When compared to the original antenna's vertical pattern, as shown in Figure 4, the improvement was substantial.

The separated functions of impedance matching and loading at the base allow for independence of adjustment. Adjustments to the base loading network change the feed point impedance, but the matching network can be adjusted to compensate for those changes without altering the current distribution.



Conduit and transmission line on insulated hangers at base of the tower.

The use of bazooka sections to cross the two sets of insulators places the entire tower at DC ground for lightning protection. It also allows the various transmission, power and sample lines to cross the insulators without specific isolation components such as isolation coils, lighting chokes or ring transformers, and it provides a supporting structure for the transmission lines.

The authors, and in particular, J. M. Bixby, would be remiss if they did not acknowledge the contributions of Ogden Prestholdt to the success of this project. In addition to being a friend and mentor, Oggie planted the seeds of this approach in an earlier project. He also provided "sanity checks" at various stages, and was a source of encouragement overall.

Thanks are also due the management of KDKA and Group W for their confidence in the project.

SPECIAL SECTION

NAB / ITS ADVANCED TELEPRODUCTION CONFERENCE

INTERNATIONAL TELEPRODUCTION SOCIETY

HDTV PRODUCTION REPORT OF WORLD CUP SOCCER IN USA

Yasuaki Itou
NHK
Tokyo, Japan

ABSTRACT

World Cup Soccer '94 was held at nine cities in the U.S. during a month. NHK covered almost all games by means of two HDTV OB vans and one HD-ENG crew.
In Japan, HDTV productions have been generalized in these days and we have been aiming at effective video expression by making the most of the special quality of HDTV.

SUMMARY OF OPERATION

NHK arranged two HDTV OB vans . One was shipped from Tokyo to the west coast of the U.S. in order to cover eleven games from preliminaries to finals at Stanford Stadium in San Francisco and Rose Ball in Los Angeles. This OB van was equipped with 5 cameras, 2 VTRs and 1 slow VCR.
The other, usually based on NHK New York, was stationed in the east coast to cover six games from preliminaries to semifinals at Soldier Field in Chicago and Giants Stadium in New York. It was equipped with 3 cameras, 2 VTRs and 1 slow VCR.
HD-ENG system (1 camera and 1 VTR) was also used for recording twelve games which couldn't be covered by OB vans.
All video tapes of programs recorded at each venue were carried by air and car to South Mountain earth station where is one hundred and fifty kilometers away from Los Angeles, and after some editing these programs were transmitted to Japan by means of digital-MUSE.

CAMERA LOCATIONS

For the production in the west coast, for instance, five cameras ; 3 CCD cameras (HDC-500) and 2 tube cameras (HDC-300), three pieces of 40 times zoom lens and two pieces of 22 times zoom lens were used.
The cameras were installed at the slightly higher positions than usual in order that 'offside position' might be shot clearly.
As it is said that the wider picture is suitable for HD because of its 16:9 aspect ratio, one of the cameras was installed at the back of goal in the stands to get effective 'wide shot' . On the other hand, 'close-up' shot is also effective on HD, so that cameramen tried to get close shot of players without hesitation.
It is a matter for regret that NHK could get fewer strong impressions on the picture than host broadcaster did, because no camera was allowed on the ground. It will be better for us to set up some cameras on ground next time.

AUDIO

The audio planning was executed to aim at reporting livery atmosphere of whole stadium. Though the International Sound was provided by host broadcaster, especially remixed audio for HD program was needed. As NHK was not host but unilateral, our microphones and cables were not installed in the stadiums freely. To get original sound sources, the microphones were installed next to each camera and the sounds were fed to OB van via digital audio circuits contained in optic fiber camera cables. The best sweetened and synchronized sound for HD program was made by mixing IS and our original sources.

HDTV TRANSMISSION

HD program was encoded to the digital MUSE signal and transmitted to Japan via satellite circuit. The circuit was not only for HD production but also for NHK's conventional TV production. At South Mountain earth station, the signal to the satellite transmitter was directly changed from the digital MUSE to NTSC and vice versa. It was necessary for us to modify MUSE FM modulator which had been designed to modulate at 140 MHz. Satellite exciter was to accept 70 MHz in South Mountain.
The quality of the satellite circuit was quite superior during the whole operation. C/N at Tokyo was 22.1dB and could keep 5 dB of margin.

EXHIBITION IN USA AND EUROPE

HDTV program was exhibited in Los Angels and various places in Europe. The program was encoded to 45Mbps signal and transmitted from OB van to the convention center in Los Angeles by an optic fiber link. The encoder had been developed in the US.
The program was also transmitted to France via IOR satellite. In Europe, the HD program was converted in EUREKA's HDTV Standard (1250/50) and distributed to 40 cities around Europe by HD-MAC.

WORLD CUP '94 HDTV SYSTEM DIAGRAM

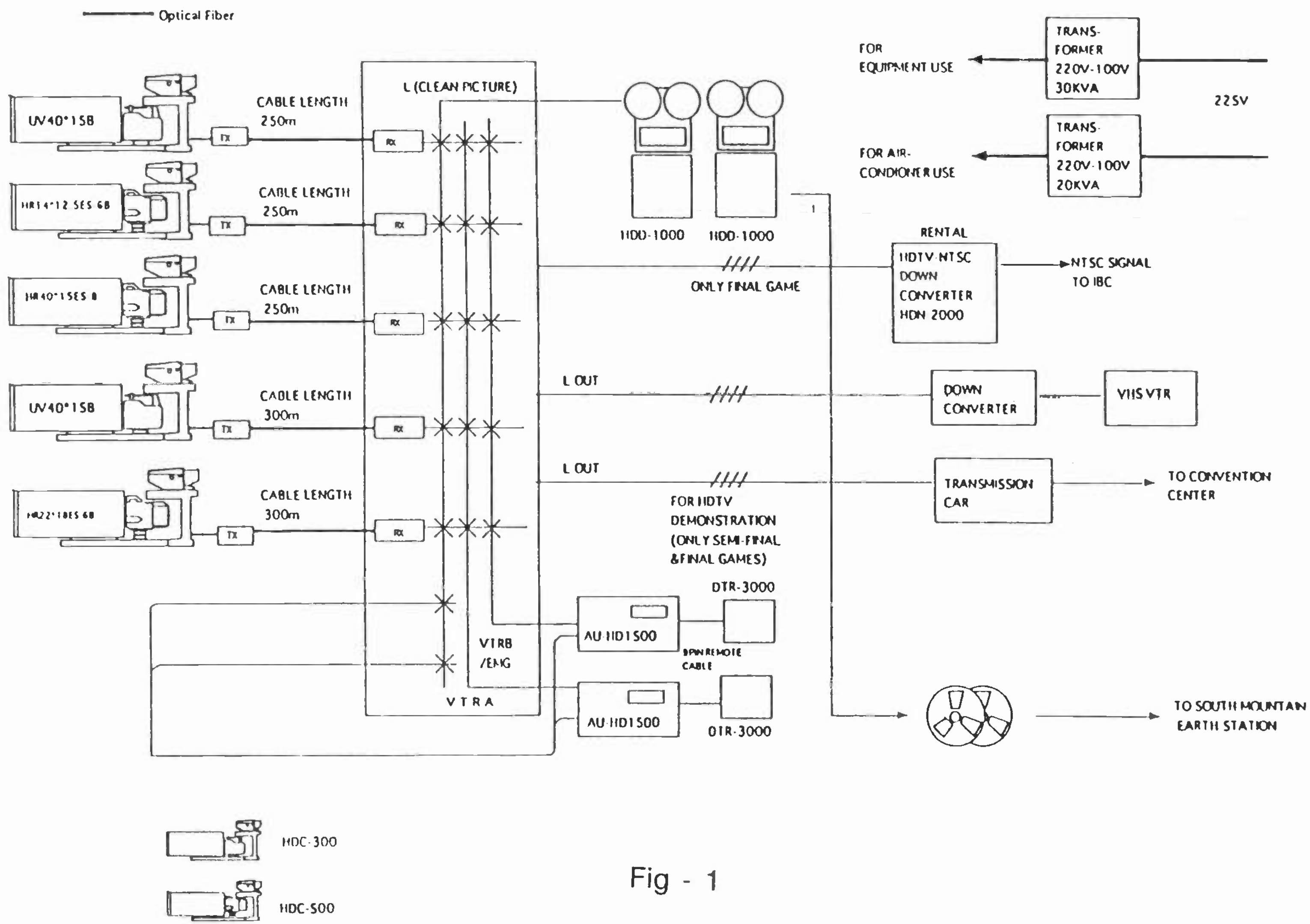


Fig - 1

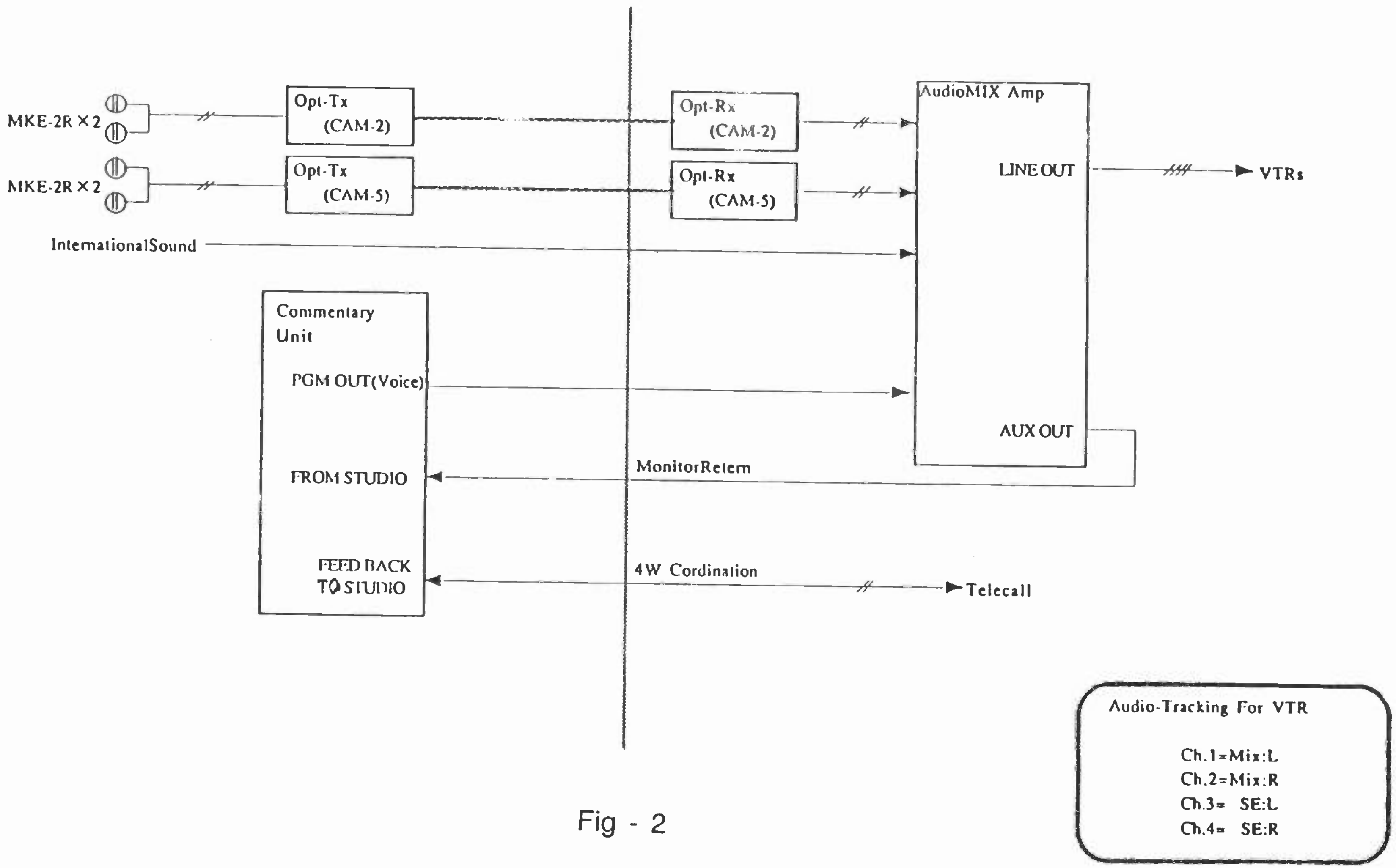


Fig - 2

HV-2 Audio-Diagram

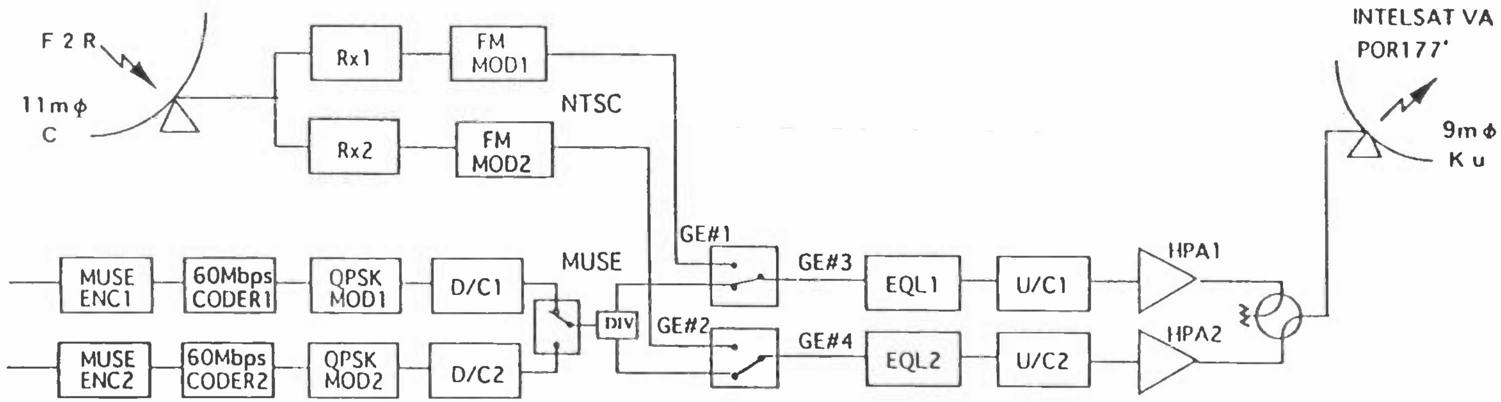


Fig -3

Transmission System Diagram of South Mountain Earth Station

CREATIVE APPLICATION OF TECHNOLOGIES: THE PRODUCTION OF "ON THE FAR SIDE OF TWILIGHT"

Noriko T. Mukai and Kohei Ando
Tokyo Broadcasting System, Inc.
Tokyo, Japan

Abstract

This paper focuses on the creative application of technologies in the production of a 40-minute short film originated and post-produced in HDTV, "On the Far Side of Twilight." Areas discussed include: financing, cost-cutting technological choices (film-to-HDTV transfers, upconversion, computer painting, nonlinear offline editing), exploration of new technologies (tapeless post-production), marketing efforts (multi-version, multi-lingual production, HDTV-to-film transfers) and interactive media development (CD-ROM). The intention of the authors is to demonstrate that technical knowledge and creativity can greatly reduce production cost without compromising creative quality.

*"On the Far Side of Twilight" is the recipient of the following awards:
- 1994 Hawaii International Film Festival, The Silver Maile Award
- 1994 International Electronic Cinema Festival, Astrolabium Award of Dramas
- 1994 Hi-Vision Award, Special Jury Award

Introduction

Production in HDTV is a costly process. As is the case with many productions, the production of "On the Far Side of Twilight" took place under demanding budgetary restraints. Needless to say, cost-cutting considerations began at the planning stage, but it was discovered that the majority of costs saved were to be found during post-production. Through creative use of technologies, it was found that it was possible produce quality results at a relatively low cost. In the end, the total cost of the production was roughly $650,000, including all in-house costs and transfers to film and other forms of linear media.

This paper discusses pre-production and financing, various cost-cutting measures used throughout the production and post-production of this film with particular focus on creative applications of technology, marketing ideas explored and interactive applications currently being developed.

The objective of this paper is to show that with careful planning, cost-conscious production and post-production procedures and creative marketing plans, films can be created in HDTV at a reasonable cost, with room to explore other creative applications as well.

Pre-Production and Financing

(1) Necessity for HDTV Quality

Based on the prior experience of having had produced a shorter version of the story in standard NTSC, the producers were aware from the very beginning that the film needed to be originated in a higher definition imaging quality, either 35 mm or HDTV, in order to satisfactorily express the subtle nuances of color, texture and variation required by the story.

Based on a consideration of various creative, budgetary and practical factors, the authors chose HDTV as the primary medium for originating material for this production, in view particularly of the following technical characteristics of HDTV:

- high resolution imaging of roughly 5 times the quality of conventional video;
- ease of image compositing for special effects;
- 16:9 wide aspect ratio;
- improved color rendition;
- multi-channel high fidelity sound.

(2) Financing

In fall of 1993, news of an HDTV software competition being sponsored by a local city government, Chiba City, prompted the producer and director to make changes to the original screenplay in order to meet the competition's requirements. The city wanted to co-produce a 15-minute film that would promote the city's image, and could be shown to citizens at HDTV screening sites across the city. The other requirement was that an English version of the production be created and entered in an HDTV software festival that the city was hosting the following year, the International Electronic Cinema Festival.

Out of entries from six participating organizations, "On the Far Side of Twilight" was chosen for *'its unique approach toward the concept of promotion and its potential for providing a dream to local citizens.'* *(Chiba City official)* The screenplay was modified to have a story within a story--each story capable of existing as a stand-alone piece. The city and TBS decided that following production of the full original, changes would be made to the outer story (such as including more Chiba vicinity footage) to make it into a promotional piece for Chiba City.

The producer and director then proposed a co-production idea to a major Japanese advertising firm which had for some time, expressed an interest in the possibility of a working creatively with TBS, for the objective of acquiring experience in the development of HDTV software. Based on the proposal, the firm agreed to finance a portion of the project in exchange for participation in its development.

Finally, a cooperative relationship was worked out with a post-production facility with extensive experience in the processing of standard video, HDTV and film. The facility became particularly interested when told of the wide variety of technological-artistic challenges posed by this production and offered its creative and technical cooperation.

(3) Flexibility of Screenplay

Needless to say, it was essential that the screenplay be flexible, as financing requirements had made it necessary for the creators to produce four versions in the end, the full original film in both Japanese and English, and two shorter, promotional and demonstration software versions. (A more detailed description of all versions created has been provided below in the Section titled, "Completed Versions/Formats.")

Production Schedule

Budgetary restrictions entailed that

production and post-production adhere to a rigorous but carefully-planned-out schedule. Production and post-production of all versions and all languages was carried out in the six month period between October 1993 and March 1994.

Aerial shooting (HDTV only) ... 2 days
Outdoor shooting (HDTV and film) ... 7 days total
Studio shooting (HDTV only) ... 2 days
SFX shooting for Main Title ... 1 day
HDTV Paintbox ... 1 day
Online editing ... 9 days
Music Recording ... 3 days
Audio Remix ... 3 days

Creative Applications of Technology

(1) Aerial Shooting

Aerial footage was shot in HDTV from a Sikorsky S76 helicopter, using a CCD camera (Sony HDC-500) and a 1/2-inch UNIHI VCR (Sony HDV-10). Following the shoot, all master tapes were immediately dubbed onto 1-inch digital tapes to preserve technical quality during editing. During the dubbing process, color correction was performed on the footage to attain the desired color and to match textures more closely to the 35 mm film aerial footage.

(2) Converging Sources

One cost-cutting consideration that was discussed in depth at an early stage of production was making effective use of footage from a variety of sources--'effective' referring to the process of weighing the most appropriate definition for the particular scene against the time, effort and cost of generating the scene in that format.

"On the Far Side of Twilight" was particularly conducive to the choice of mixing sources due to the creative nature of the screenplay--one that entailed frequent changes among real, imaginary, flashback and dream worlds.

Origination of footage took place in four formats other than HDTV, where roughly 75% of shooting took place: (a) 35 mm film (15%), (b) 16 mm film (7%), (c) Betacam (1%) and (d) HD Paintbox (2%). Transfers and conversions to HDTV were carried out at different stages depending on the type of processing and effects desired on the footage, prior to final post-production editing in HDTV.

The telecine system used for all film-to-HDTV transfers during the post-production of this film was a custom-developed original by IMAGICA, a high-quality movie-tone "wet-gate" system that deals with dust and scratches effectively. Use of a high-definition CCD camera (Sony HDC-500) is an another feature of this system that contributes to its high telecine quality.

Multiple-source origination was the result of largely artistic choices; but the choices were always weighed against economic factors in an attempt to find the best origination format in the most time- and cost-efficient manner. In the end, 16 mm film was chosen for dream sequences, 35 mm for background scenery in several composite scenes, component betacam for one scene that required fixed-point-observation-style shooting. Through this experience, the producers realized how important it is to keep an open, flexible and practical mind when facing such choices.

(a) 35 mm telecine to HDTV

Roughly 15 percent of the footage shot for the production was originated in 35 mm film. One question that the producers addressed early on, was what to do with the explicit expressiveness, the "hard" edged look of HDTV images. A major concern was that the too-clear images of HDTV might make the 'flying cube' appear as if it were pasted onto its background.

After much discussion, it was decided that certain sections should be shot in 35 mm and later transferred to HDTV. The film-to-HDTV transfer would give the backgrounds a dreamy "film-look," which would allow a more natural blend for the flying cube.

One imaginary sequence was shot using a 35 mm film camera, with the iris widened to create a high-key picture. The shutter speed was decreased from 1/60 sec. to 1/15 sec. to create a flowing decay of images. This was a relatively simple process in film, but would have been extremely time-consuming in HDTV. In another sequence, drop-frame shooting was carried out on film to shorten online HD editing time. Composite scenery for placing in windows of the flying train was also shot on film for the soft, dreamy effect it would have, and also because HDTV shooting from a moving train was impractical from a logistical point of view.

Lastly, perhaps it should briefly be mentioned that the pre-production of this film actually took place over a period of several years, while the producers searched unsuccessfully for financing. A considerable amount of scenery footage was, in fact, accumulated during this time (clouds, skies, sunsets, waves, etc.), showing how persistence toward goals and pre-production strategies can sometimes be surprisingly helpful. Shooting everything from scratch would have been an expensive and massive effort, due to the vast amounts of scenery required by the story to serve as the background of the boy's imaginary travels.

(b) 16 mm telecine to HDTV

Dream sequences were originated in 16 mm for its grainy texture, and were blown-up and telecined to HDTV. 16 mm film was chosen over 35 mm film in these sequences because the director's intention was to reproduce the sensitive and 'personal' touch found in private and experimental films. Naturally, the choice to shoot on 16 mm simplified shooting considerably, in addition to enabling reverse motion and slow-motion effects that would have been a much more complex process in HDTV.

(c) Component betacam to HDTV

One important sequence in the story needed to be shot in a fixed-point-observation style to convey passage of time and seasons. Needless to say, shooting in HDTV was out of the question.

Making note of the fact that the look that the sequence required was a soft, dreamy image, the producers decided to shoot the footage on 35 mm film, with the exception of one particular occasion on which this could not be arranged. In this particular instance, the alternative choice was to shoot on component analog betacam (digital betacam was not yet readily available), upconverting and blowing it up later to fit the 16:9 aspect ratio of HDTV.

This choice was based on results of tests conducted at TBS comparing the degradation in picture quality during upconversion from D-2 composite-to-HDTV and betacam component-to-HDTV, with the latter producing slightly superior results.

(d) HDTV Paintbox

Though HDTV paintbox work was carried out in only a few sequences in the production and for only a few hours, the aesthetic effects that it was able to produce in this particular production were incredible. The producers were made to realize that the notion that "HDTV paintbox is expensive" is not always accurate; and that the paintbox can be used as a powerful creative tool, capable also of cutting production costs significantly.

Because budgetary restraints entailed that the shooting schedule be adhered to rigorously, it was not possible to wait for ideal weather conditions for shooting. In one of the important early scenes of the film, the paintbox (Shimaseki SDS 480SGX) was used to turn a pallid sky in the background of the boy's arm as he cuts the sky, into a magical pink and purple sunset by brushing and blending colors into the sky.

In the last and probably one of the most important scenes of the production, the HD paintbox turned a late afternoon sky covered with heavy clouds into a beautiful sunset, by pasting shimmering waves and a sunset from other material and blending them into the scene. The paintbox was also used to create a mysterious sky background for the imaginary flying train.

The total amount of paintbox work performed for this production was less than ten hours. Yet the costs saved were immense; one need only imagine the cost of a possible re-shoot, with the need to call all crew members and cast back to the scene.

(3) Special Effects for Main Title

The special effects used for the creation of the main title were actually a derivation from an age-old, classical technique that was probably used for the opening of the Jean Cocteau film "Le Testament d'Orphée." Smoke inhaled from a cigarette was simply blown into a soap bubble, and the bubble was followed with the camera until it burst. This was shot on HDTV and later reversed using a hard-disk frame store system (Toshiba Frame Store TFS-800) during editing. Creation of the main title was also through an application of a simple technique--that of simply shooting the reflection of the title card in a pool of water, and reversing left and right during editing.

The special effects sequence for the opening was thus a classic example of a combination of low technology with the latest high technology, in order to fulfill the director's aesthetic intention to create a premonitory feeling of mysteriousness at the onset of the piece.

(4) Nonlinear Offline Editing

It is a known fact that online editing in HDTV is a highly expensive process. The key to cutting down online costs is to conduct offline editing in a way in which the final data is frame-by-frame accurate, and can be transferred to the HDTV editing with little additional effort.

The producers chose to conduct offline editing on a nonlinear system, in view of the fact particularly, that multiple versions of the production needed to be created out of common footage. The nonlinear system used was the Lightworks III. Digitizing of footage was conducted at a quality of 40 minutes/ gigabyte. With a hard disk capacity of 13 gigabytes, this allowed up to roughly 9 hours of footage to be digitized into the system for editing purposes.

The advantages of this nonlinear editing system were found to be as follows:

(a) Inserting additional cuts and scenes, re-combining or reversing order of blocks and scenes was easy;

(b) Convenient for multi-version productions using common footage;

(c) Software was user-friendly, and interface was designed to be easy to use by user with a film editing background; hardware design based on and similar to Steenbeck film editing system;

(d) Director could edit on his own until satisfied;

(e) Compact size of system allowed editing to take place on director's desk;

(f) Data could be transferred to floppy disk, and inserted into HDTV online editing system with data intact, reducing online editing time significantly.

However, there were a number of disadvantages to the system as well:

(a) Limited hard disk capacity;

(b) Systematic labeling of digitized video bits was not always easy, and caused occasional confusion;

(c) Digitizing quality of 40 minutes/ gigabyte was somewhat insufficient for HDTV (could not identify out-of-focus shots, and other visual defects) (Developments since the offline of this production have now made it possible to digitize at a higher quality of 10 minutes/gigabyte, although 20 minutes/gigabyte would probably be sufficient from a practical point of view.);

(d) Dissolves and multiple mixes of three or more sources, double exposure editing not possible;

(e) Not all online editing systems or operators are capable of handling nonlinear data.

As the bulk of HDTV production grows, more producers will undoubtedly look into the efficiency potential of nonlinear offline editing systems with interest. It is hoped that developments in video compression technology in the near future will enable digitizing of footage at a higher quality and in larger quantity, and that online editing suites will train their operators to be familiar with nonlinear editing data formats.

(5) Use of Digital Effectors

HDTV digital effectors have extremely limited capabilities as compared to those of NTSC. However, the digital effector was found to be a convenient tool, not only for the purpose of "digital effects" per se, but also for reducing studio shooting time, and leading ultimately to cost-reduction.

The most noteworthy use in this regard of the semi-three-dimensional digital effector (Toshiba HPE-8000) in "On the Far Side of Twilight" was the creation of the flying cube containing the boy--an important composite scene throughout the film.

To create this scene, the digital effector was used to adjust the size of the character inside the box, and then to fly the character across the background scenery. The path of the flying character was recorded in the memory of the digital effector. Meanwhile, the flying cube was created separately by pasting the different sides of the cube together. Once these materials were completed, the cube was then laid on top in a half dissolve* over the character flying over the background scenery, and by using the data in the memory, the movement of the cube was made to follow the trace made by the character.

(*This made it possible for the cube to appear transparent, while the character inside was solid.)

Because the digital effector enabled size decisions to be made at the post-production stage, blue-matte shooting of the boy, teenage boy and older man was carried out with relative ease, paying attention only to angles and rotations, and disregarding size.

(6) Color Correction Techniques

'Creative intent' was the most important determining factor behind color correction objectives: Did the particular sequence require that colors and textures match the two converging sources of visual material, or did it require an intentional variation in quality?

One of the largest problems faced by the producers throughout production was the fact that HD imaging is too explicit and defined for the purposes of certain sequences in the film, as the world depicted by the screenplay of "On the Far Side of Twilight" exists in an imaginary realm beyond reality. The director's intention was to use color correction as a method to move the expressive parameters of HDTV into those of film.

Processing was performed to create a "film-look"--colors were added and decay was added to background scenery to create an afterimage effect. Decay was added, in particular, to the backgrounds for composite scenes on which the flying cube would be pasted. When the scenery was too real and defined, the synthesized picture looked too flat, artificial and two-dimensional. The addition of decay created a "film-look," making the edges of the compositing less sharp, thus enabling a more natural synthesis and blend.

Color correction was performed on almost all material, either adding or adjusting to create, amber or purple tones expressing this imaginary world. Color tone was found to have a larger role in making the footage blend naturally in the final production than anticipated, and to be a cost-effective way of fulfilling aesthetic intentions at a lower cost.

Completed Versions/Formats

The following versions and formats of "On the Far Side of Twilight" have been completed as of February 1995:

(1) Full, original version (39 minutes)

Languages:
- Japanese
- English (English voice-over for narration, subtitles for dialogue)
- French (35 mm, PAL formats only)

Formats:
- HDTV videotape (1-inch, UNIHI, W-VHS)
- NTSC, PAL
- 35 mm/16 mm film

(2) Two shorter versions (15 minutes)

Language:
- Japanese only

Formats:
- 2 sets of 10 HD baseband laser discs for playback demonstration

Marketing Efforts

(1) Demonstration software

Noting that the screenplay required large amounts of aerial footage that would have great value as demonstration software for HDTV electronic products, the producers approached, at an early stage of the production, a major Japanese electronics manufacturer to pursue the possibility of using the program as demonstration software. After a viewing of the offline, it was decided that the manufacturer would finance a portion of the project in exchange for the right to use a shorter version of the film as demonstration software (in baseband laser disc format) for its HDTV projection system.

(2) Educational film market

"On the Far Side of Twilight" is currently being distributed on 16 mm film through educational film market channels to schools and educational-cultural facilities throughout Japan. The poetry that intertwines through the various sequences of the film was by renowned poet and playwright Shuji Terayama, and the film has been recognized by educators for its literary value as well.

The educational film market in Japan has a tendency to start out slowly, but once a film has acquired a reputation, maintains a steady pace. As of February 1995, roughly half a year after the film had been placed on the market, inquiries and sales had begun to increase in number.

Awards, Festivals and Venues

"On the Far Side of Twilight" has been recognized and highly acclaimed at numerous prestigious international film festivals throughout the U.S., Europe and Japan. Below, a list of major participating film festivals:

(Bold-face type denotes awards)

- **1994 International Electronic Cinema Festival, Astrolabium Award of Dramas**
- 1994 New York Film Festival
- 1994 Vancouver International Film Festival
- 1994 Maisons-Laffitte International Short Film Festival
- 1994 Vienna International Film Festival
- **1994 Hawaii International Film Festival, The Silver Maile Award**
- 1994 Dallas Video Festival
- **1994 Hi-Vision Award, Special Jury Award**
- 1995 Palm Springs International Film Festival
- 1995 Japan Society Madame Kawakita Memorial Film Festival (New York)
- 1995 NETPAC/USA Asian Film Tour (3-month U.S. tour)

Applications to Interactive Media

CD-ROM development plans for "On the Far Side of Twilight" are underway, although sample material was not available at the time of publication. The authors are working closely with a major personal computer manufacturer which has expressed an interest in the unique non-linear aesthetic and poetic nature of this production, and the interesting possibilities it offers to the development of a new genre of interactive software. Development plans target completion for fall of 1995.

Technical and creative issues currently under discussion and of possible interest to interactive software developers are: (1) finding a creative and practical balance between high quality wide-screen video and still images; (2) MPEG1 video compression software development; (3) finding the most interesting combination of text (story and poetry), video, still images, music and computer graphics; (4) multilingual software development.

Conclusions

It is widely known that HDTV has 5 times the visual information of standard NTSC. However, it is not as known that creative and technical defects are also 5 times more obvious in the HDTV medium.

The key to success and cost effective production in a project that requires a variety and multitude of technical applications is a close mutual understanding of creative objectives among producer, director and technical producer. Needless to say, based on this mutual understanding, careful pre-production planning, project development, financing, production, SFX shooting, editing, multi-version editing and marketing efforts are essential.

The production of the high definition film "On the Far Side of Twilight" was originated and carried out under extremely limited budgetary constraints. The authors hope that this presentation discussing the creative-technical choices made throughout its production will be of value to other producers, and that the production will serve as a case study for future productions.

Special Thanks

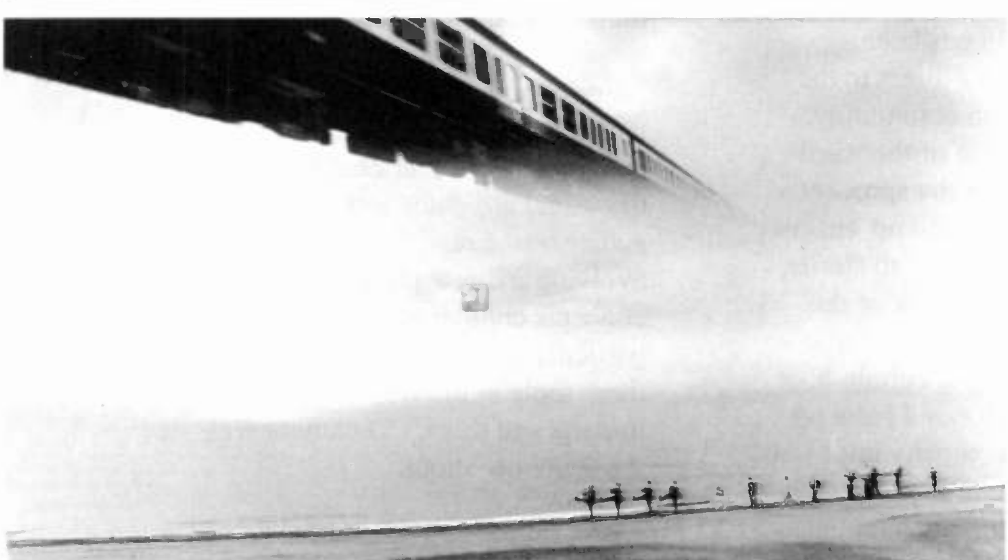
The authors wish to express their deep gratitude to Chiba City, Dentsu and IMAGICA for their involvement and cooperation in the production of this film. They would also like to thank the Toshiba Corporation, Sony PCL and Lightworks for their assistance in making this film possible.

(1) Flying through the sky...

35 mm film background, HDTV cube created with DVE in foreground.

(2) The sky slips out...

All HDTV. Slipping sky created with DVE.



(3) The Flying Train

HDTV background, DVE cube and paintbox sunset.

HDVS GOES TO THE MOVIES

J.A. West
Sony Broadcast & Professional Europe
Baskingstoke, England

HDVS goes to the movies

" Shooting a motion picture on digital motion picture stock for release in the cinemas on film is a viable proposition from both the financial and operational points of view. HDVS was used on the recent Winchester Pictures production Rainbow. This paper will describe the practical issues from the working practice to the equipment flexibility and supported with interviews from Bob Hoskins and Robert Sidaway and other crew members."

INTRODUCTION

Using High Definition Video System for motion picture production has been frowned upon by many as a threat to the traditional film production community. Similarly, the mere mention of the word television to supporters of the sprocket hole has immediately conjured up images of lower quality pictures shot with sterile, flat lighting and an apparent lack of the "film look". Although various motion pictures have used HDVS for certain blue screen effects, such as "Honey I blew up the kid", no production company until last September believed enough in the possibilities of the medium to shoot the entire movie in high definition. Why?

Well for years, broadcast engineering jargon has baffled many film people and manufacturers have not adapted film equipment to match the working practice of film makers.

The more traditional medium for movies namely film, celebrates 100 years this year and has a proven track record but practically speaking film or tape are simply just media on which to create images, tell stories and provide an illusion of reality to an audience. What makes the programme result impressive and memorable has much more to do with the content, the lighting, the filtering and the careful eye of the director of photography rather than the medium employed.

In trying to create perfect images and undetectable illusions, production companies are ever challenged to satisfy the visual appetites and expectations of audiences. Creative ideas are constantly evolving as new production tools and concepts come into use. HDVS and in particular the HDC-500 camera is one of these tools in the workshop of program making and this CCD camera was used for the Rainbow shoot.

In the next fifteen minutes I would like to describe how the HDC-500 was put through its paces with Rainbow and the reasons why the camera proved that it can work well in the traditional movie making industry.

Firstly, it must be understood that High Definition Video System is unique. We all know it is neither film nor conventional video yet it can be made to look like either. Once video and the inherent technology stopped implying difficult and complicated the more the film crew accepted it as just another movie stock. HDVS was described to the users as a digital motion picture stock with properties similar to a very low grain film stock. HDVS digital stock is rated at an equivalent ASA rating of 575 for tungsten (3200°) or rated at 650 ASA equivalent for daylight (5400°) shooting. Furthermore, like film it can be boosted by three stops.

Why Rainbow decided to use HDVS for their production was therefore more a decision on the most appropriate tool from the toolbox of image making rather than sticking with the traditional Hollywood tools.

We are often asked if Sony sponsored this movie well we didn't. It was a combination of events. World War II was shot last year on HDVS and demonstrated to John Alonzo, the Director of Photography and the crew that if the camera and CCU are used to create the "look" desired by the cinematographer and not used to match the specifications of the manufacturer or produce an exact reproduction of the scene in view, then the artform so well known in the film world can be adapted to the video world with success. Experience on the NBC production convinced Bob Hoskins who played Churchill in the NBC production, that to make Rainbow HDVS was the only option.

Just about a year ago, when Freddie Frances first came to our facility in the UK his first words to me were" Don't expect to convince me that I'll start shooting in high definition, and by the way I'm not an engineer!" I simply had to show him some examples of cinematic style photography on HDVS and some transfers to film and after a few tests using his own accessories that he uses with film, he was sold on the idea. Seeing was believing rather than swamping him with technical specifications. Freddie subsequently gained some more experience with HDVS at a hands-on seminar at Pinewood last April where he re-created some dimly-lit scenes similar to his film the Innocents.

With over three decades of experience, Oscar winning Freddie Frances has made an enormous contribution to motion picture production on both sides of the Atlantic with such hits as French Lieutenant's Woman and Cape Fear. Freddie approached HDVS with caution but after testing HDVS for himself he was heard to say : ..."When I saw high definition recently, I couldn't believe that a video format could look that good or that close to film. As a cinematographer who has always tried to keep head of technological change in our industry, I am very excited about the creative possibilities that HDVS offers. I see HDVS not only as a production medium in its own right but as a complimentary medium to film. It demonstrates flexibility namely, the way it can be used for special effects, yet it can still capture the mood of a candlelit romantic drama".......

Winchester Pictures realised as do most producers that when it comes down to the bottom line in movie making, it is the success at the box office with a good story line, the visual interpretation of that story and the quality of the final image that counts. The public doesn't really care what was used to record the images. Winchester had an ambitious project and yet they did not have unlimited funds so they needed the right medium to do the job.

We did some initial tests with HDVS equipment at Ealing Studios last July and Sony assisted the pre-production stage with its technical expertise and practical experience. It was rather strange also to find some of the crew of the CBC and Northern Light and Pictures first HDTV series Chasing Rainbows shot on the first generation camera, back together to shoot Rainbow.

Shooting started in September and in Robert Sidaway's words the film experienced crew took about twice as long to prepare for shooting with HDVS than with film but 48 hours instead of 24 was not a problem. Shooting ratios on Rainbow were lower than with film since what they knew that what they saw on the monitor was what they would get on the film and an unacceptable take could have been erased or over-recorded. Scene to scene matching was done on the set with Richard Lewis - the HD visionist - that's more acceptable than Chief engineer afterall that implies television. He acted in some ways similar to a film grader in the laboratory. However he offered much more, as the on-the-set tweaking possibilities allowed him to interpret the required effect that Freddie wanted within seconds such as using the ability to independently change the different parts of the transfer characteristics e.g. rather than waiting for an additional batch of lights, Freddie would ask Richard to "give me some fill".

Rainbow used two cameras. The A-unit was permanently in the truck with a studio configured HDC-500 and HDD-1000, digital VTR. The HDVS truck was the smallest truck on the set and housed the CCU, two digital VTR's, an NTSC down-converter and Freddie actually spent more of his time in the truck than on the set. In addition to the first camera there was the B-unit that operated either with a CCU alongside the A-unit or the HDC-500 was configured in the portable mode feeding a UNIHI analogue recorder. The portable unit and recorder were housed in a small Land Rover style vehicle. On several occasions both cameras were used together recording different camera angles with the B-unit sometimes recording cut-a-ways. David Snyder, production designer for Rainbow also directed the B-unit and you'll here his comments a little later.

For audio recording the soundman used a centre track Nagra fed with time-code from the digital VTR. However the audio was simultaneously recorded on the 1" HD tape which is capable of eight digital audio tracks.

Another reason for choosing HDVS was that Ultimatte work with HDVS could be achieved in real-time. By taking the elements onto the set and ensuring the accurate perspectives, the matte could be tested and paint or lighting changes made in real-time. The green screen effects were shot in eight days whereas in film could have taken up to six weeks.

Rainbow is a story about children finding gold at the end of a rainbow. They get absorbed into the rainbow and travel from New Jersey to Kansas. After stealing that gold and they have to cope with the subsequent deterioration to their world. Much of the story is a race against time to return the gold to the rainbow in order to save the world.

From that brief description you can see that there was a requirement for a considerable number of special effects, over 100 in fact. In particular, effects were created showing the kids inside the rainbow and to do this a green screen was used. The spectral response of the green screen closely matches the response of the green in the CCD chip or most film stocks and provides a much cleaner matte. Several scenes were shot under water in a pool and all traces of the water had to be eliminated.

Lighting the scenes did not pose any problems in fact there were times that little if any lighting was used such as the riot scene where just a few key lights were employed. Lighting set-ups were usually quicker and involved less equipment due to the high sensitivity of the HDC-500 camera.

Now like any motion picture production there were some problems during production but no more so with HDVS than had the recording medium been film. Firstly, working in Montreal also means you are working with a bilingual and mixed unilingual crew, and there were minor language hiccups as well as the inherent cultural differences.

From an equipment standpoint however, the communication system employed on the high def set needed improvement. On a conventional film shoot, the Director of Photography is usually found on the set close by the Director and his camera operator. With Freddie in the truck, it was not always possible to see why the action had not started when the recorder was ready. Alternatively, with the talent poised and the Director and camera operator ready to shoot, there was a five second delay while the recorder achieved speed, however if minor tweaking was required in the truck it was not easily seen by the crew on the set who could not understand the delay. However, after a few days the HD VTR was often ready within five seconds and usually before the clapperboy was ready.

The solution was to provide key crew members with wireless microphones and assign a "spokesman" for the set who controlled the direction of communication. Other perceived problems such as working with an umbilical cord did not prove to be a problem.

Shooting the TV station with many monitors all running on 525 at 59.94 Hz was solved by feeding the monitors in the TV station with a 60Hz signal.

As with any film shoot with live action on vehicles and shooting under non-studio conditions, the camera was subjected to fairly rough treatment as Bob will describe. Bitingly cold winds and heavy rain gave the camera no problem, in fact, the crew took no additional precautions than had they been working with film. The camera was handled in fairly hostile conditions such as in some scenes shot by John Palmer, Freddies operator. He hand held the camera on the back of a motor bike for a quick 30 metre dash. More hand holding was used to follow the dog.

The special effects opportunities with HDVS, add to the creative interpretation of the program at the same time reduce production costs to an acceptable level. Non real-time effects generated after scanning film in and out of the digital domain is not only a time consuming experience but costly as well. The Rainbow effects are currently being completed at the Sony Pictures High Definition Facility in Culver City where Steve Robiner a whiz of a computer brain has been inputting graphic data into the Silicon Graphics work station producing some interesting results.

Off- line editing of Rainbow has been done using Avid and the fact that the HD truck was able to provide a reel for reel down-converted U-matic tape meant that Ashley Sidaway, Rainbow's writer was able to start the off-line editing right away. Master dubs were made on 1" tape for ship back protection to Culver City. These were digital clones and once checked the protection tape could be erased. Three VHS tapes were made each day for rushes viewing back at the hotel.

The final HDVS master will be transferred to film using the Sony EBR - Electron Beam Recorder. Unlike other transfer systems to film the electron beam exposes the image directly onto fine grain black and white stock. A sequential exposure of red, green and blue on the same film is passed through an optical step printer to produce a negative from which prints can be pulled.

I mentioned that many advantages of HDVS recording were discovered on the set of World War II well the crew also found more on the set of Rainbow. as David Snyder will describe later.

So in summary why did this British/Canadian co-production choose HDVS? Well for feature movies like Rainbow, HDVS production is now a proven viable alternative to film acquisition when the distribution format is film. The image results are what Robert Sidaway looked for and as the producer he had no choice other than to stay within a fixed budget This combined with the need to stick to rigid production schedules with little contingency for extra shooting days were reasons enough to consider the HD digital stock for its production medium.

HDVS has transparent recording and multi-generation recording capability. In addition in post production there are many tools available for the creative mind. Colour correction, rectification of set defects, up conversion, down conversion, transfer to film, film telecine or film scanner to HDVS.

With a digital HD colour corrector, primary colour correction treats overall colour balance at black, gamma and white level but in addition secondary colour correction allows independent treatment of other colours.

The choice for producers to go to the movies with film, HDVS or a combination of HDVS and film is there. HDVS, in particular the capabilities of the HDC-500 CCD camera offers future productions a new dimension and increased creative possibilities for motion picture productions today.

I would like to show you a sequence from Rainbow followed by a short interview sequence shot last October during production.

Thank you for your attention.

A COMPACT, HIGH-PERFORMANCE HDTV CAMERA WITH FOUR-CCD CHIPS

Toshinori Saitoh, Masayuki Sugaware, Kohji Mitani and Yoshihiro Fujita
NHK Science and Technical Research Laboratories
Tokyo, Japan

ABSTRACT

A compact, high-performance and yet less-expensive camera is urgently needed to create more diverse and flexible HDTV program productions at a low cost. In order to meet the demand, we propose a new image acquisition system with four CCDs, two for green light, one for red, and the other for blue. The major purpose of our system is to obtain high-quality pictures with less pixel-number CCDs. The reduction in the number of pixels results in wider dynamic range, higher aperture ratio and better yield. The resolution power is secured by increasing the number of sensor chips. The HDTV camera with this system is appreciated because we can not only use it in the studio or electric field production (EFP), but also in news gathering.

The prototype camera has fully satisfied HDTV quality requirements (limiting resolution 1200 TV lines, sensitivity F5 at 2000lux, dynamic range 500%, SNR 52dB). And its weight is about 5kg. As a result, it is suitable as an HDTV hand-held camera. This camera also demonstrated the validity of the system by showing that high-quality pictures can be reproduced even with 2/3-inch CCDs.

INTRODUCTION

Hi-Vision test broadcasting started in Japan in November 1991. It was the first high definition television (HDTV) programming of this kind anywhere in the world. Since then, the broadcasting time has increased from the initial eight hours a day to ten hours, totaling more than 9,000 hours over the past three years. This Hi-Vision test broadcasting captured and telecast in very fine resolution such major events as the three Olympic Games held at Albertville, Barcelona, and Lillehammer, and the wedding of the Crown Prince.

Since November 25, 1994, the test broadcasting has been upgraded to regular Hi-Vision programs in response to the growing popularity of and demands for Hi-Vision. The broadcasting time remains the same at ten hours a day, but NHK (Japan Broadcasting Corporation) and seven private stations now provide a variety of dramas, music programs, documentaries, and news on a par with conventional TV.

As the demand rises for a greater variety of HDTV programs, so does the need for more sophisticated HDTV cameras to provide not only high quality pictures, but also compactness and low price. Most HDTV cameras in use today have built-in CCDs each with 2 million pixels (the number of pixels is equivalent to the digital sampling frequency) in 1-inch optical format. The problem with 2 million pixels in 2/3-inch optical format is that the more pixels the camera has, the smaller each pixel area becomes, creating a number of problems such as a narrower dynamic range, a reduced aperture ratio, impaired highlight characteristics, and a lower yield.

To make the camera smaller in size, the image size must be necessarily smaller. With this in mind, we have developed a 2/3-inch CCD camera[1]. It has a CCD with 1.3 million pixels, not the usual 2 million pixels, in order to keep the pixel from getting too small. A reduction in the number of pixels causes a deterioration in the resolution, but this is compensated for by a special method--the combination of dual green and spatial pixel offset imaging. With this method, priority is given to the resolution of the luminance signal rather than that to the chromatic signal so as to efficiently reproduce pictures' compatible with human visual sensitivity. Compact and easy to carry, this camera is being widely used in the production of HDTV programs.

The newly developed four-CCD camera system uses a total of four CCDs--two for the green light and one each for red and blue. It is basically a RGB imaging method with 3 CCDs, and combines the advantages of the dual green method. The four-CCD system has CCDs with fewer pixels, but this shortcoming is well compensated for by the higher resolution, a wider dynamic range and other improved image pickup characteristics. Its small size opens the way for the development of compact HDTV cameras for commercial use. This paper reports on the design, prototype development and evaluation of a four-CCD imaging pickup system that is compact and can provide enough high-quality pictures for HDTV.

FOUR-CCD IMAGING PICKUP SYSTEM

Fig. 1 shows the structure of the color separation prism developed for the four-CCD imaging system. It is essentially a conventional RGB prism with the addition of a half mirror in order to separate the green light into two portions. These two green lights are exactly the same. The four-CCD system we are proposing has two CCDs for the green light and one each for blue and red and they are arranged in relation to the optical image in such a way as to maximize the effects of spatial-offset imaging (see Fig. 2).

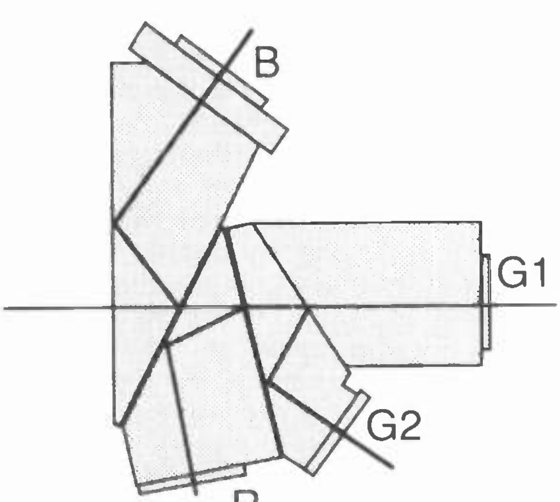


Fig. 1 Structure of the newly developed 4-CCD prism

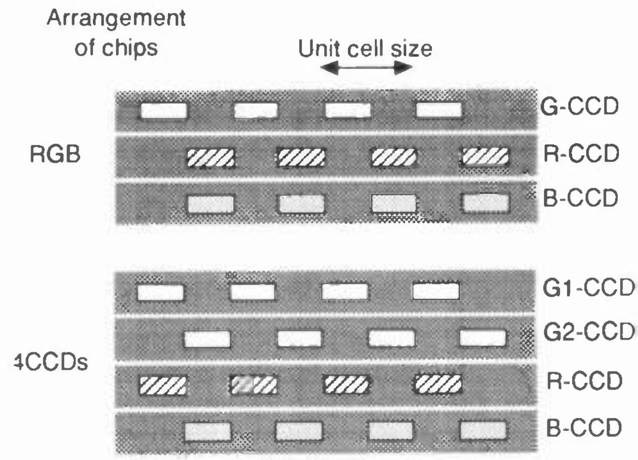


Fig. 2 Spatial pixel offset imaging

This imaging system using four CCDs provides the following advantages.
(1) High resolution.
(2) Wider dynamic range.
(3) Improved resistance to highlight (blooming).
(4) Prevents chromatic aberration of the lens.
(5) Less alias signal over a wide chromatic range.

To make the camera more compact, it is necessary to reduce the size of the optical image. The reduced pixel area, however, impairs the image pickup capacity. The four-CCD imaging system overcomes this problem using four CCDs as explained in (1) above, and this use of image pickup devices with fewer pixels but with a relatively large pixel area creates the following advantages.
(i) Higher sensitivity because the aperture ratio can be increased.
(ii) Ease in producing a shield structure improves the smear characteristics.
(iii) Image pickup devices with a relatively large pixel size improve the yield, which can be expected to help reduce the pickup device cost.

As explained above, many advantages are created by simply increasing the number of CCDs by just one. But why? In the Hi-Vision system, the luminance signal Y is expressed by the following formula[2].

$$Y = 0.701G + 0.087B + 0.212R$$

This luminance signal is considered to be intimately related to the resolution of the human eye. We learn from this equation that green light makes up as much as 70% of this important signal. It follows that by improving the resolution of the green component, it is possible to effectively improve the resolution of color pictures. With this four-CCD imaging system, two CCDs sample green light while spatial-offset imaging is in effect between them. In this way, we can obtain high picture resolution because the number of sampling points is actually twice that of the pixels of the CCDs, although each CCD has relatively fewer pixels.

Further, the use of two CCDs for green, which easily gets saturated in the RGB method, increases the transfer capacity, widens the dynamic range and improves the blooming characteristics. Another advantage is high resolution for the whole area of the image plane. This is because the system is more resistant to the effects of chromatic aberration which occurs at the edge of the lens thanks to the spatial-offset imaging carried out for monochromatic green. This can be verified by examining the simple calculation and measurement we show later. The CCDs for the blue and red are arranged as shown in Fig.2 in order to benefit also from spatial pixel offset imaging over a wide range of chromatic signals as we describe later.

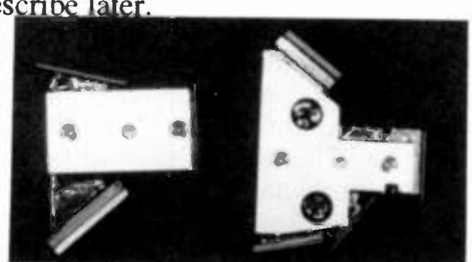


Photo 1 Comparison between
RGB prism (left) and 4CCD prism (right)

Despite these advantages, the four-CCD imaging system is not without shortcomings with the most prominent one being the problem of noise. Unremovable random noise that occurs in the image pickup device is more evident in this new system than in the RGB method because the former has one more CCD. With the addition of non-correlative noise, the noise level worsens by 3 dB for the green signal. The use of one more pickup device can also increase power consumption and the size of the camera itself, but, as it turned out, they are not as serious a problem as had been originally thought. Power consumption increases by one CCD, but each of these four pickup devices has fewer pixels, which means less overall power consumption, and their drive frequency can be held to a low level. Also, as shown in Photo 1, the prism for the four-CCD system can be made as small as the conventional RGB prism. The size of the camera itself can be designed so that it is not very much larger than a RGB camera because the extra circuits, one CCD drive and one head amplifier are very small considering the overall circuit size.

As explained above, the four-CCD imaging system has a noise problem, but the increase in power consumption and camera size is negligible. All in all, its benefits such as a wider dynamic range and improved highlight characteristics which were previously shortcomings in conventional HDTV CCDs outweigh the noise problem.

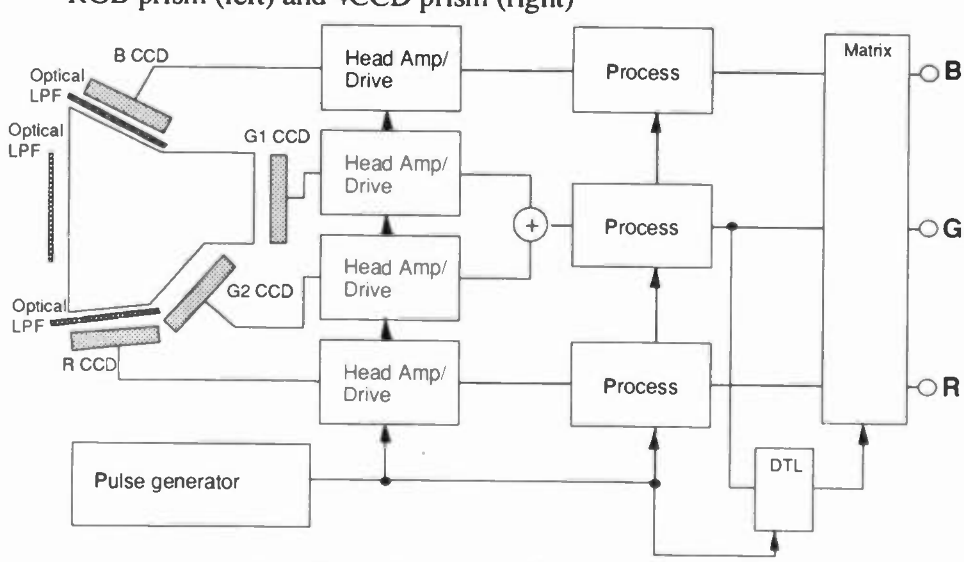


Fig.3 Block diagram of the prototype camera

PROTOTYPE CAMERA

Fig. 3 shows a block diagram of the prototype camera. The camera uses four 2/3-inch CCDs each with 1.3 million pixels pickup imaging[3]. It differs from a conventional RGB camera in that there is a new color separation prism, an extra CCD drive circuit and head amplifier. The signal processing, however, is virtually the same as that of an RGB camera after the two green components are combined.

The number of sampling points differs between green and blue or red which requires special consideration when designing the optical LPF. For green with two CCDs, we placed an optical LPF with the null point at 4fn in front of the prism in order to secure responses up to 2fn (fn: Nyquist frequency of the CCD) and hold down visible DC elements of the alias signal. For blue and red, there are two cases; to set the null point at 4fn by taking into consideration the pixel offset imaging between blue and red, and to set the null point at 2fn by placing priority on the suppression of the alias of monochromatic colors. We chose the one with its null points at 2fn, as we want to prevent the alias component near the DC area of the chromatic signal from visually impairing the picture. We placed these LPFs between the CCD for blue and the prism and between the CCD for red and the prism. The frequency characteristics of the optical LPFs are shown in Fig.4.

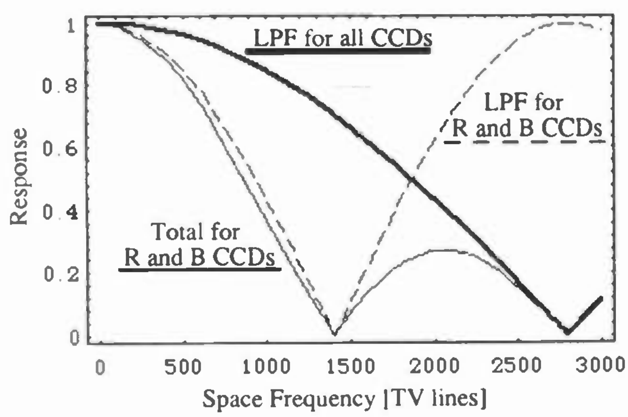


Fig. 4 Characteristics of optical LPFs

Photo 2 External view of 4-CCD prototype camera

Photo 2 shows the appearance of the prototype. It houses a camera head measuring only 11W x 22H x 36D cm, with a built-in vertical DTL circuit using small glass delay lines[4] that consume only small amounts of electricity. This arrangement has opened the way for developing an easy-to-carry version. The camera is capable of very high performance, as shown in Table 1 and Fig. 5, almost on a par with that of 1-inch HDTV cameras with CCDs each having 2 million pixels.

Table 1 Specifications of the system

Pickup method	4-CCD (GGRB)
Horizontal resolution	1200TV lines
Sensitivity	2000lx F5.0
SNR	52dB

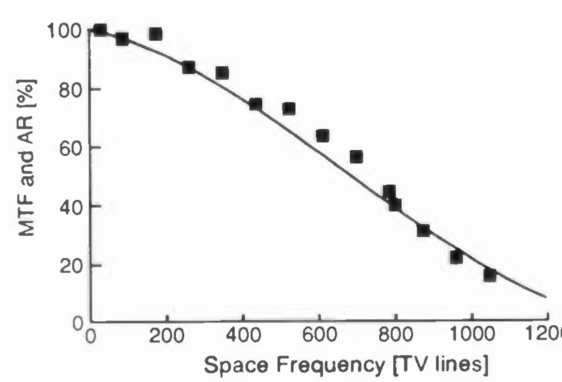


Fig. 5 Measured amplitude response (plotted) and calculated MTF (solid line)

INFLUENCE OF CHROMATIC ABERRATION

The four-CCD imaging system is an image pickup method less troubled by the chromatic aberration that occurs in the lens. As the demand grows for greater picture resolution, chromatic aberration of the lens is emerging as a problem that deserves serious consideration. The image pickup tube absorbs lateral chromatic aberration by registration correction, but this cannot be done with the CCD. Another difficulty is that as the

CCD provides uniform resolution from the center to the periphery of the image it is necessary to fully utilize this point. The target figure is one half or less the scanning line width for the entire screen[5]. With the 2/3-inch optical system, this goal seems very difficult to achieve considering the condition that the lens cannot be made heavier.

Lateral chromatic aberration occurs because the magnification of the image differs with the wavelength. In a TV camera it causes registration error. And it significantly worsens the resolution when spatial-offset imaging is in effect. We examined how the four-CCD system and the RGB system are affected differently by chromatic aberration. The RGB system has a CCD for green aligned by one half pitch of a pixel from CCDs for blue and red, which make it susceptible to the effects of lateral chromatic aberration. In the four-CCD system, on the other hand, the effects are lessened as pixel offsetting takes place between the two green channels.

We calculated the MTF (modulation transfer function) for white light using lateral chromatic aberration d as a parameter[6]. The results are shown in Fig.6. In this calculation, we used a 2/3-inch CCD with 1.3 million pixels (scanning line width of about 5 microns) and with an aperture ratio of 50%. The following luminance signal equations were adopted.

RGB method:

$$Y = 0.50G + 0.25B + 0.25R$$

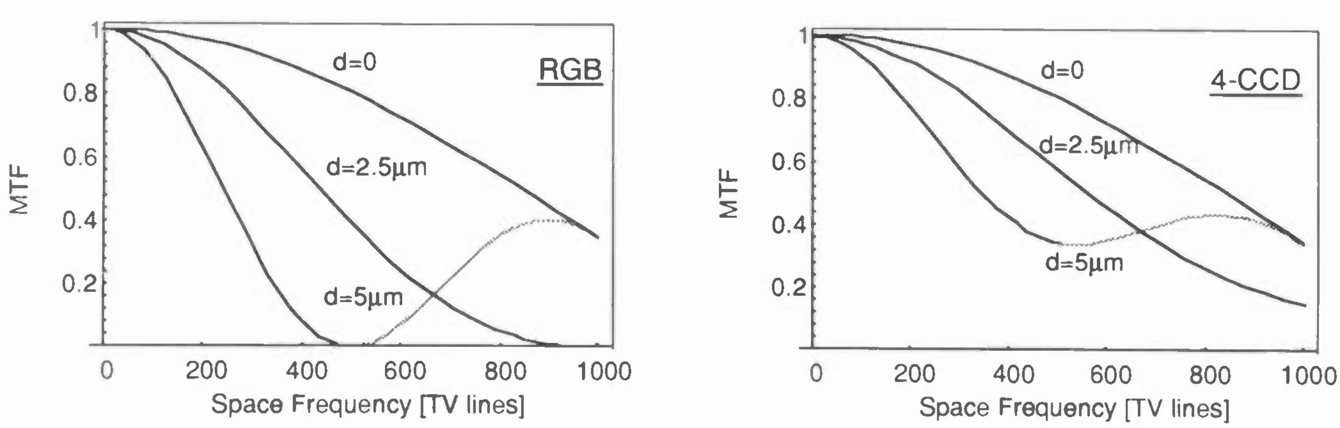
four-CCD system:

$$Y = 0.35G1 + 0.35G2 + 0.15B + 0.15R$$

Where, the intensities of the green, blue and red element of the incident light were G, B and R, respectively.

The calculation results show that, with the RGB method, MTF rapidly falls as the lateral chromatic aberration d increases. When d is 5 microns, about the same as the scanning line width, in particular, the effects of offset imaging are almost entirely canceled out. With the four-CCD system, on the other hand, spatial offset is in effect for green, which accounts for about 70% of the luminance signal, securing enough responses even if there is phase shifting between blue and red caused by chromatic aberration.

It is difficult to measure MTF by actually varying the lateral chromatic aberration d. It is known, however, that the degree of aberration is greater in the peripheral area of the lens than at the center. With this knowledge, we were able to measure how lateral chromatic aberration affects the RGB and four-CCD systems differently. These measured cameras have the same CCDs and circuit.



(a) RGB system

(b) 4-CCD system

Fig. 6 Calculated MTF

Fig. 7 shows how the measurement was carried out. We focused on the vertical stripe pattern of some spatial frequency, inputted the luminance signal of the camera into a digital oscilloscope, and observed the spectrums by FFT (fast Fourier transform) processing. Next, we measured the intensity of the frequency spectrum of the measurement chart and that of the alias spectrum. We used the ratio of these two spectrums as a yardstick for evaluation. We call it the signal to alias ratio (S/A). The greater the effects of aberration, the smaller the effects of spatial offset imaging. As a result, the alias signal portion increases, and S/A is reduced. In this measurement, in order to eliminate the effects of the harmonics, we made and used the chart which had a stripe pattern of white and black density that changed like a sine wave. As the CCD with 1.3 million pixels has a band width of about 700 TV lines (24.3 MHz), we set the vertical stripe spatial frequency of the measurement chart at 800 TV lines (27.5 MHz) and measured alias signal portions that occur within about 600 TV lines (21.1 MHz).

The results of this measurement are shown in Fig. 8. It is clear that S/A is smaller in the peripheral area of the lens than at its center with both the RGB method and the four-CCD system, apparently as a result of lateral chromatic aberration. It can also be seen from the results that the degree of the drop in S/A is much greater with the RGB camera than with the four-CCD one, indicating that the former is much more susceptible to lateral chromatic aberration than the latter. This finding agrees with the calculation results.

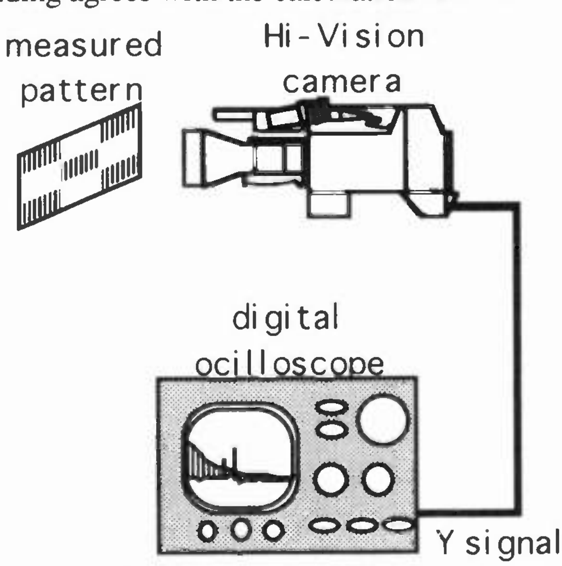


Fig. 7 Block diagram for measuring alias

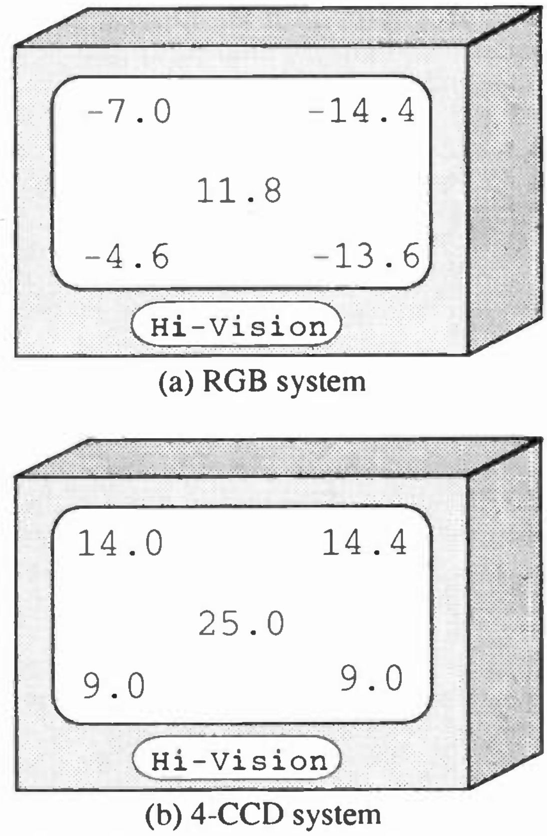


Fig. 8 Relation between signal to alias ratio (dB) and position in picture

ALIAS SIGNAL IN CHROMATIC SIGNALS

The four-CCD system facilitates the effects of spatial-offset imaging over a wide range of chromatic signals, reproducing pictures with fewer pseudo color signals. In order to prove this, we studied by calculations and actual measurement, how the four-CCD system and the RGB method benefit differently from spatial-offset imaging for the color signal.

With the RGB method, the luminance signal equation has the same formula as the one before.

$$Y = 0.50G + 0.25B + 0.25R$$

For an uncolored object, the effects of spatial-offset imaging are most prominent when the green term equals the sum of the blue and red one, as shown below, because the offset imaging takes place between green and blue and between green and red.

$$0.50G = 0.25B + 0.25R$$

Therefore,

$$2G = B + R$$

On the other hand, with the four-CCD system, the luminance signal equation also has the same formula as the one before.

$$Y = 0.35G1 + 0.35G2 + 0.15B + 0.15R$$

This time, the pixel arrangement is shown in Fig.2. The alias signal portions can be canceled out when the following condition is met.

$$0.35G1 + 0.15R = 0.35G2 + 0.15B$$

Here, G1 and G2 are identical as they are exactly half of the same green light divided by the half mirror. Therefore, we get the following.

$$G1 = G2$$

Therefore,

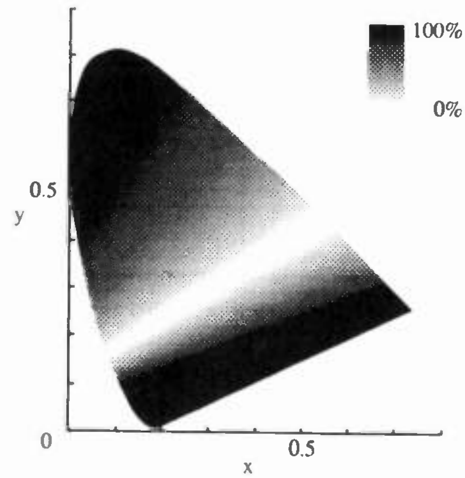
$$R = B$$

This condition is much easier to attain than that for the RGB method. In other words, spatial-offset imaging can be expected to work over a wider range of color signals for the four-CCD system than for the RGB method.

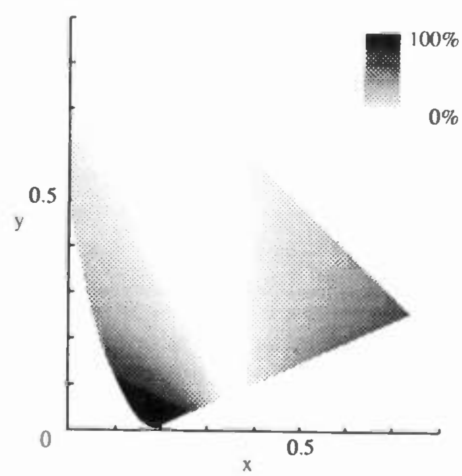
To illustrate this point quantitatively, we calculated the alias portions and displayed the results on the CIE chromaticity diagram (Fig.9). In these figures, 0% means there is no alias, which occurs when the alias signal is completely held down by spatial-offset imaging, 100% means that the signal portion and the alias portion are exactly the same. In the RGB method, as is clear from the diagram, the effects of offset imaging are seen only in the area where the condition of 2G = B + R is satisfied, whereas the effects are evident everywhere except in places near monochromatic blue and red.

To demonstrate the advantages with color signals of the four-CCD system over the RGB method, we used the prototype camera and measured the S/A by varying color signals. We placed a color filter in front of the camera lens and measured and evaluated S/A (Fig.6). The measurement was carried out using the center of the lens where the effects of chromatic aberration are smaller.

Table 2 shows the results of the measurement. With the RGB method, spatial-offset imaging is most effective with white light (no color filter), and to some degree with cyan (Cy) by green and blue and yellow (Ye) by green and red, but S/A drops sharply near monochromatic colors and magenta (Mg) not related to green. With the four-CCD system, S/A drops sharply only near monochromatic blue (B) and red (R) in comparison with the white light S/A, but the effects of the spatial-offset imaging are evident with all the other colors. These findings confirm that the four-CCD system enjoys the effects of spatial-offset imaging over a wide range of color signals.



(a) RGB system



(b) 4-CCD system

Fig. 9 Calculated alias component

Table 2
Relation between signal to alias ratio and object color

filter	RGB	4CCD
(without)	11.8	25.0
G	-6.0	20.6
B	-4.2	6.6
R	-5.0	-1.6
Cy	6.0	19.0
Ye	6.8	16.2
Mg	-3.2	13.8
	(dB)	(dB)

SUMMARY

To realize an HDTV camera that is compact and easy to carry, we proposed a four-CCD imaging system, produced a prototype camera and demonstrated its effectiveness.

Even with a reduction in image size, this system secures enough pixel area by reducing the number of pixels each CCD possesses. In this way, it prevents deterioration in image pickup qualities, and, with an additional CCD, compensates for the lack of spatial sampling points. The system has two CCDs allocated for the green and one CCD each for the blue and red to cancel out the effects of chromatic aberration by means of spatial-offset imaging and holds down alias disturbances over a wide range of color signals. Moreover, the use of two CCDs for green provides higher resolution and a wider dynamic range. The sampling points are allocated for green, blue and red according to the ratios of G:B:R = 2:1:1, which closely matches the sampling number ratios of the luminance signal and color-difference signal of VCR's and other equipment.

Manufacturers started the production and marketing of Hi-Vision four-CCD cameras in the fall of 1994 (shown in Photo 3). The size of the camera head is only 96W x 250H x 293D mm including the 1.5-inch viewfinder and weighs 5.7 Kg; this compactness and lightweight are one of our major development targets. Despite this small size, in the reproduction of high-quality pictures it almost equals a 1-inch RGB camera with 2-million-pixel CCDs. Its portability is highly appreciated not only for studio shooting and electric field production (EFP), but also in news gathering which is a new Hi-Vision application area. This world-first four-CCD camera has begun a new era in Hi-Vision news gathering. 3 cameras are in actual use, primarily for news gathering in the field at NHK. NHK has recently started news programs for Hi-Vision beginning from November last year. These news programs have been well received so far, and the performance of the four-CCD camera is also greatly appreciated. The great Hanshin earthquake provided such an occasion (Photo 4, 5).

Photo 3
4-CCD HD camera "HDL-70A"

Photo 4
4-CCD HD camera being used for news gathering after the great Hanshin earthquake

Photo 5
Reproduced image that is used by "Weekly Hi-Vision News"

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525 COMPONENT PROGRESSIVE SCAN OB VAN SYSTEM

Akihiro Hori
Nippon Television Network Corporation
Tokyo, Japan

1. Abstract:

NTV is now preparing a 525 component progressive scan OB Van, which will be used mainly for EDTV-II, a wide-screen NTSC compatible broadcast scheduled to start summer 1995 in Japan. This is the world's first progressive scan OB VAN. The features of the OB Van are as follows:

(1) 16:9 progressive scan/4:3 interlace scan switchable system.
(2) The system is entirely digital from cameras to switcher.
(3) The progressive signal output can be easily converted to any other scanning format such as MUSE HD (1125/1035 interlace) and ATV (1125/1080 interlace, 750/720 progressive).
(4) D5 is employed as a VCR. A compressor is used for progressive scan recording.
(5) Two interlace signal processors are used synchronously for progressive signal switching.

This OB Van will be produced by May 1995, and will be used for NTV's wide-screen program.

2. Why NTV will use a progressive scan system:

(1) Image quality:
EDTV-II is NTSC compatible letterbox transmission scheme. Three kinds of signal source can be used as input to the encoder:

(1) 525 progressive scan signal
(2) 525 interlace scan signal
(3) 1125 interlace scan signal

A 525 interlace signal and 1125 interlace are cross-converted into a 525 progressive scan signal and processed into EDTV-II signal at the encoder. Meanwhile, two kinds of display can be used in EDTV-II, interlace and progressive. This is called a hierarchical structure in EDTV-II as shown in Figure 1.

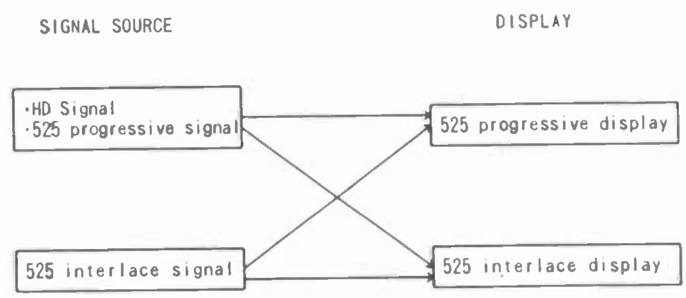

Figure 1 Signal Hierarchy in EDTV-II

Generally, a 525 progressive signal or a 1125 interlace can provide better image quality than an 525 interlaced signal for both progressive and interlaced displays in EDTV-II.

(2) Cost:
Generally, the cost of 525 progressive signal equipment is about 30 percent more than that of the 525 interlace 4:2:2 equipment.

The data rate of 525 progressive is 360 Mbps or 540 Mbps, which is 1.3-2 times that of the 4:2:2, 270 Mbps digital interlace. I will describe this digital interface in detail below. Meanwhile, the data rate of HD equipment is about 1.5 Gbps, which is 5.5 times that of the 4:2:2, 270 Mbps interlace.

Therefore 525 progressive scan will provide a good cost to performance ratio for the system.

(3) Media conversion:
One advantage of the progressive scan signal is the ease of conversion to the other scanning formats such as the 1125 interlace.

In regard to scanning format conversion from interlace to other scanning formats, such as 525 interlace to 1125 interlace scan, the original picture is processed differently depending on the content of the image. Processing differs for images in motion as opposed to still images. Normally, more than one field of information is used in the conversion process. The previous field information is used as well for a still picture. In the case of a moving picture, however, only the single field information is used. This conversion scheme is shown in the Figure 2.

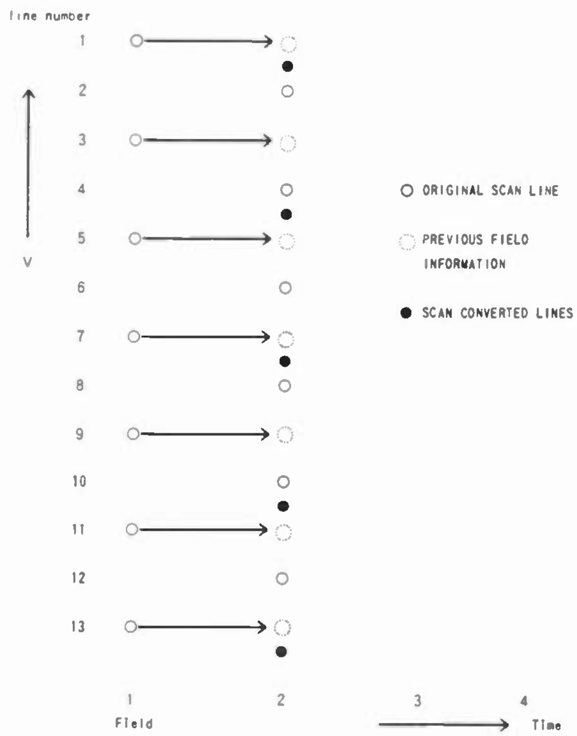

Figure 2 Scan Conversion from the Interlace

Therefore motion detection is necessary for such a conversion process. This often causes picture quality degradation due to the imperfection of motion detection. Similarly, a sudden change from a still picture with high resolution to a picture with motion and lower resolution is problematic.

In the case of scan format conversion from the progressive signal, only the intrafield conversion is necessary. Although the conversion hardware is simpler, the converted picture still has higher quality and a natural look.

We have experimented with scan conversion from 525 line progressive to 1125 interlace and MUSE HD conversion. Subjective assessment by a 5-grade Double-Stimulus Continuous Quality-Scale Method was used in these tests. Figure 3 and 4 show the results.

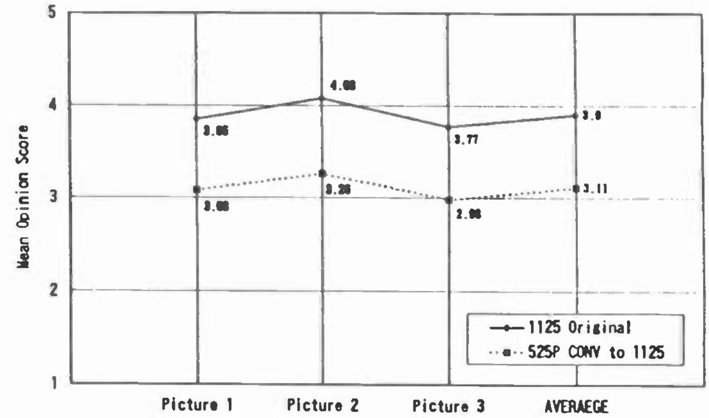

Figure 3 Subjective Assessment Results for HD

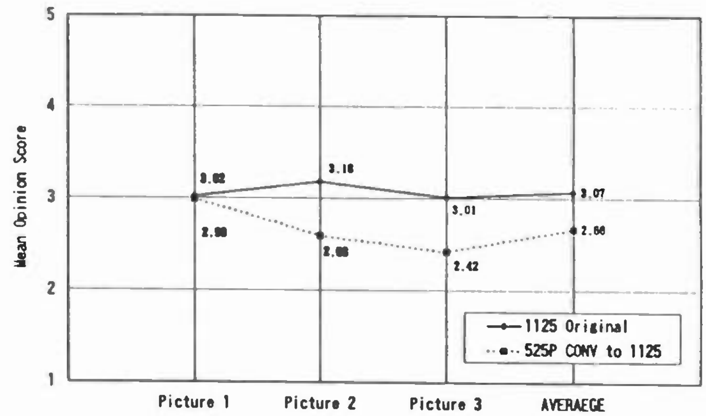

Figure 4 Subjective Assessment Results for MUSE HD

Grade 0.79 degradation was obtained by the baseband picture and 0.41 in the MUSE HD picture. All of the pictures selected for these tests contained a high vertical frequency component. Usually a much smaller difference can be expected in ordinary pictures.

(4)Compatibility with the future TV system:
Digital TV broadcasting will be available in the future, and harmonization with the computer system will therefore be an important factor. The progressive scan has good compatibility with computer systems because a progressive scan monitor is used with computers. In addition, component transmission will definitely be employed in the future digital broadcasting system. Therefore, this OB VAN will conform to future trends in broadcasting.

(5) High quality interlace source:
The area that 525 progressive and 525 interlace signal can display is shown in Figure 5.

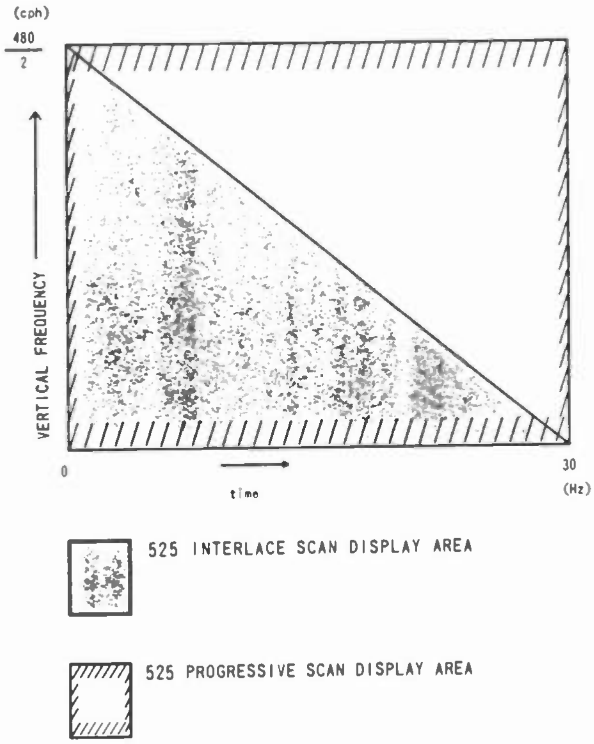

Figure 5 Area Displayed by 525 Progressive and Interlace

Two neighboring line photo diodes output signals are added to obtain a 525 interlace signal inside a conventional CCD device. This is equivalent to the application of a 2-tap vertical filter. The reason for this process is to compromise vertical aliasing and vertical resolution. A higher quality interlace signal can be obtained by applying ideal vertical-temporal filtering for a progressive signal and subsampling to interlace. Because the 525 progressive signal has vertically and temporally twice the sampling points as the 525 interlace signal, it would provide higher vertical resolution and less vertical aliasing than a conventional interlace CCD camera.

3. System block diagram for this progressive scan OB VAN:

This OB VAN is 16:9 progressive/4:3 interlace switchable. The switching operation is done by a single master switch operation, and this mode-changing signal is sent to equipment such as the monitors, cameras and switcher. The OB VAN has 8 studio-type cameras and 5 hand-held cameras. The system block diagram for the progressive scan OB VAN is shown in Figure 6. Two parallel digital signal outputs of the progressive scan cameras, each of which is compatible with SMPTE 259M 270Mbps, are connected to the switcher. The switcher consists of two 4:2:2 interlace processing units.

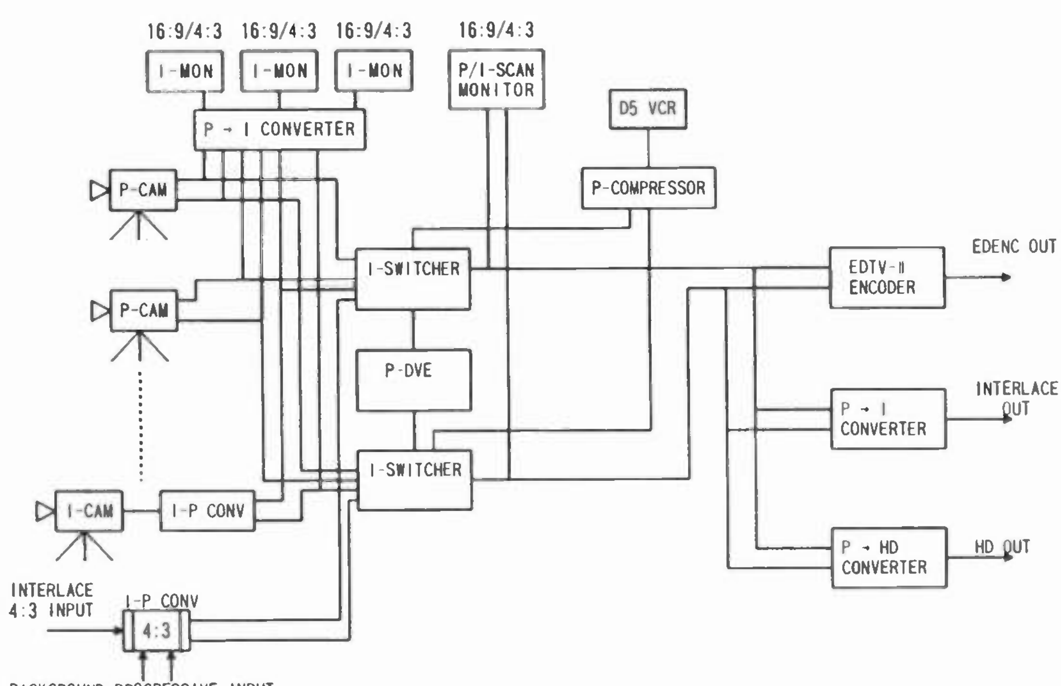

Figure 6 PROGRESSIVE SCAN OB VAN BLOCK DIAGRAM

To use a interlace scan signal source or external interlace input, a cross converter from the interlace to the progressive scan is necessary and is installed in the OB VAN.

All of the small monitors displaying each switcher input signal are 10 inch interlace. Because the interlace monitor is inexpensive and a wide variety of selection and for image- only content checking, the interlace monitor is sufficient. These small monitors have the function of a switching aspect ratio of 16:9/4:3 by remote control.

The master monitor for tracking switcher output is a 20 inch display. This monitor has the function of displaying 16:9/4:3 and progressive/interlace scan switchable.

The switcher output progressive signal is input to the EDTV-II encoder and encoded as an EDTV-II signal, NTSC-compatible letterbox signal. This switcher output signal is also input to "the progressive to the interlace converter (P->I CONVERTER)" which is used in cases such as when interlace editing is necessary or when only interlace transmission is available.

In cases when an HD signal source is necessary such as for MUSE HD broadcasting, the progressive signal is converted into a 1125 HD signal. This is done by "the progressive to the HD converter (P->HD CONVERTER)".

In the case of 4:3 interlace conventional broadcasting, the progressive cameras are switched into the 4:3 interlace mode, one interlace switcher is active and the D5 progressive compressor is switched to "bypass (non-compression) mode". The EDTV-II encoder works as a pure NTSC encoder in the 4:3 operation.

In cases when an interlace 4:3 signal is input to the 16:9 progressive signal operation system, image aspect conversion and interlace to the progressive scan conversion are done by the I->P converter. The output image of this interlace to the progressive converter is shown in Figure 7.

As for transmission of the progressive signal from the OB VAN to the NTV main station, a fiber-optic transmission system will be utilized when an optical fiber link is available. If an optical fiber link is not available, however, digital compression transmission using a satellite will be used.

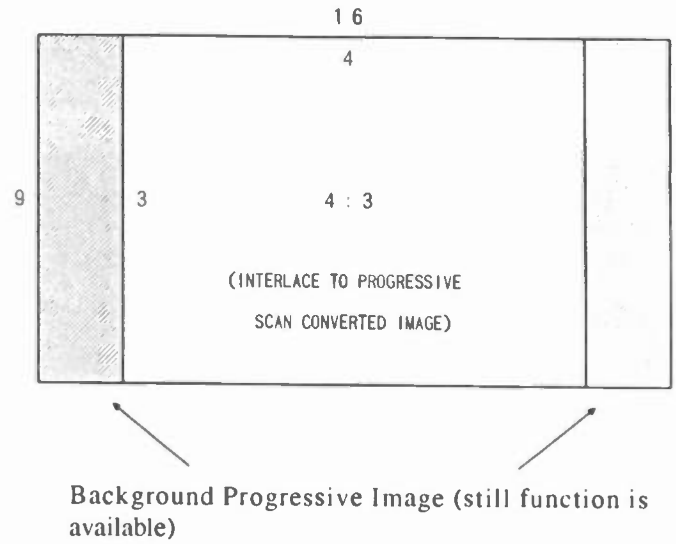

Figure 7 I->P Converter Output Image

4. Components of this OB VAN:
Major components of the OB VAN are described as follows:

4.1 Progressive Scan Camera:
The progressive scan camera has the following features 1):

(1) 16:9 progressive/16:9 interlace/4:3 interlace, 3 mode switchable operation
(2) High sensitivity (F8 at 2000 lux), low smear and high dynamic range (600%) (equivalent or higher than the conventional interlace camera)
(3) Low cost (about 1.3 times that of the conventional interlace camera)
(4) All digital camera and digital fiber-optic transmission between the camera head and the base station
(5) CCD:2/3 inch 520 thousands pixel M-Fit CCD X 3
As for the lens, a 0.8 times converter is inserted into the lens in the 4:3 mode operation to maintain the same viewing angle between 16:9 and 4:3.

4.2 Digital switcher:
The parallel operation of two interlace switchers has 24 input ports, 3 mixers and keyers, 3 superimpose inputs, and 2 DVEs.
The switcher system is flexible:

(1) One processing unit can process one interlace signal (4:2:2).
(2) Two processing units can process one progressive

signal.

DVE (Digital Video Effecter) is specially designed for progressive scan to utilize high-quality performance progressive scan image.

4.3 VCR:
Four D5 VCRs are installed in the OB VAN. Each VCR has a progressive compressor. The D5 VCR is used to record the progressive scan signal. To record a progressive signal, a progressive signal compressor is used. This compressor is based on DCT, and the compression ratio is 1/1.4.

4.4 SCAN CONVERTER:
1) P->I CONVERTER:
There are two kinds of progressive-to-interlace converters. One is located in the switcher input for interlace monitoring. The most important factors here are compactness and low cost. Therefore the simplest processing is used in the conversion process:

(a) The progressive luminance signal is added vertically by the two neighboring lines.
(b) The chroma signal is subsampled as interlace structure.

The other P->I converter is located in the final output. This provides the higher-quality interlace signal. The conversion process is as follows:

(a) The vertical low-pass filter including enhancement is applied to the progressive luminance signal and subsampled to the interlace.

(b) The chroma signal is merely subsampled because it is already filtered vertically at the camera head.

2) I->P CONVERTER:
Three-field interlace information is used and filtered to produce interpolated lines in the interlace to the progressive scan converter (I->P Converter). Although it is impossible to provide the identical picture quality as the originally progressive scan image by the progressive signal converted from the interlace signal, the converter provides a natural image because of no motion detection. Another advantage of this converter is its compactness and low cost because of the simple conversion algorithm.

3) P->HD CONVERTER:
The conversion algorithm is quite simple, featuring the advantage of the progressive signal. It can be achieved by merely interpolation and filtering vertically. But in addition to colorimetry conversion based on the SMPTE 170M to HD colorimetry, field frequency conversion from 59.95 to 60 Hz is also necessary. This converter is located on the outside of the OB VAN and used if an HD signal is needed.

5. Digital interface:
The digital progressive signal standard has been proposed for SMPTE in the U.S. and BTA in Japan. Two types of digital interfaces have been proposed for the progressive interface 2):

1) 4:2:2P
2) 4:2:0P

These standards are not yet finalized in either organization. But the contents of the proposed interface are described as follows:

1) 4:2:2P:
The progressive signal can be divided into two interlace signals as shown in Figure 8.

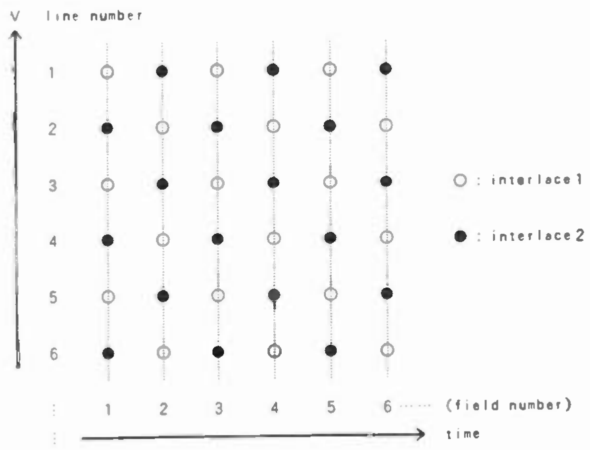

Figure 8 4:2:2P Sampling Structure

Therefore two links of interlace 4:2:2 can interface with the progressive signal (270 Mbps X 2). Although it is rather troublesome to connect two cables between equipment, this interface has the advantage in that existing conventional 4:2:2 interlace equipment can be used to process the progressive signal. This is a great advantage in terms of system construction, especially in the early stage of the development when all sorts of the progressive equipment is yet to be developed and currently unavailable in the market.

Another advantage of this dual-link system is the switchable function. The interlace and the progressive mode switchability is easily performed with this interface. The single use of the 4:2:2 interface can process the interlace signal, and dual use of the 4:2:2 can process the progressive.

Dual-link operation of 4:2:2(4:2:2P) is employed in the OB VAN for the above-mentioned reason.

2) 4:2:0P:
As described in the previous item, 4:2:2P has the disadvantage of two cables being required to connect the equipment. Therefore a single-link connection 4:2:0P is also proposed. The signal generation of 4:2:0P is described as follows:

The chroma signal of the dual-link 4:2:2P is vertically filtered and sub-sampled into half as the interlace structure. Therefore the luminance signal is a 27 MHz sampling and the chroma signal is a 6.75 MHz sampling. The sampling structure of the 4:2:0P is shown in Figure 9.

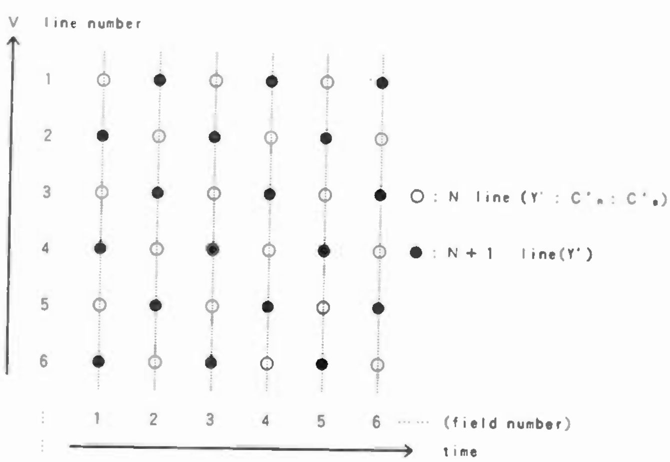

Figure 9 4:2:0P Sampling Structure

This sampled data is multiplexed into the 360 Mbps data rate which is used for the 18 MHz sampling version of 4:2:2 interlace interface. this data structure difference between the conventional 18 Mbps sampling serial digital interface and 4:2:0P digital interface is shown in Figure 10. The HANC (Horizontal ANCillary data) area is compressed as shown in Figure 10.

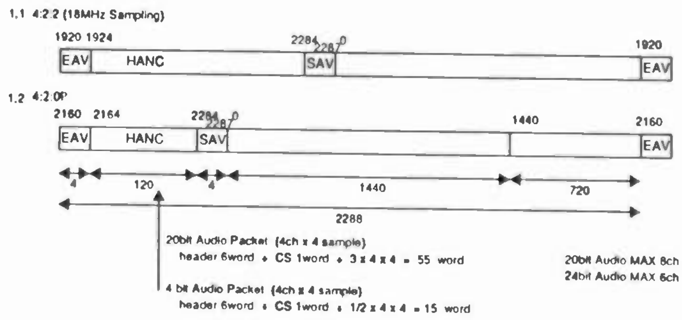

Figure 10 The Data Structure Difference between 18MHz Sampling 4:2:2 and 4:2:0P

This is an abnormal process but it has the advantage that the conventional ICs and equipment developed for 360 Mbps can be used. Even in the case of 4:2:0P, 8 channel 20 bit audio data can be installed in the HANC.

6. Conclusion:

It is predicted that 4:3 conventional NTSC broadcast will continue to be a major means of TV broadcasting in the near future. Meanwhile in Japan, sales of 525 interlace wide-screen TV sets have already reached more than two million so far, with expected sales of more than 3.5 million this year. In the year 2000, more than 80% of TV sets sold in Japan will be of the wide-screen model 3). There is the potential that wide-screen programs will boom in the near future. Therefore we have to prepare equipment for both 4:3 conventional NTSC programming and the next generation of wide-screen programs within a limited budget, equipment and studio space. One good, economical solution to adapting to this uncertain future is to use the progressive system because of the low data rate, good image quality and compatibility with the conventional 525 interlace signal.

The OB VAN will be available in May 1995. The OB VAN will be used not only for NTV's 16:9 widescreen programs but also for conventional 4:3 programs. This system will provide flexibility from now into the future multimedia era.

References:

1) A. Hori et al., "525-line progressive scanning TV camera with 16:9 aspect", NAB 1994 Broadcast Engineering Conference Proceeding pp423-431.

2) "Proposed SMPTE Standard for Television-4:2:2P and 4:2:0P bit-serial digital interface for progressive 483 active line scanning systems, second draft, s17.394.

3) "EIAJ report for TV set estimation in Japan" November 2, 1994 Denpa Newspaper.

THE GREAT HANSHIN EARTHQUAKE COVERED IN HDTV AND SKIP BACK RECORDER

Yosuke Sato, Yoshifumi Hokamura and Hiroshi Fujimoto
NHK
Tokyo, Japan

ABSTRACT

In this paper, two points are described related to the news coverage of the Great Hanshin Earthquake. First of all is the HDTV coverage of the quake. With its highly detailed and dynamic pictures, HDTV has managed to convey the true situation of the disaster very powerfully. Secondly, is the Skip Back Recorder(SBR) developed by NHK. The NTSC recording system by using SBR made it possible to record on camera the situation just the quake itself.

NHK'S HDTV NEWS PRODUCTION

INTRODUCTION

HDTV, or Hi-Vision as it is called in Japan, has started covering real-time news events in earnest. First of all, let me give you a brief description of HDTV coverage of The Great Hanshin Earthquake. On this occasion, HDTV delivered a very powerful impact with its wide screen and dynamic pictures. It made a deep impression on many people.

The earthquake hit Kobe and the surrounding area on the morning of January 17, 1995. More than 5400 died and much of the area was reduced to rubble. NHK's HDTV crew in Tokyo went into action immediately. Ground crews and helicopter crews were sent to Western Japan and they started gathering news on the same day that the earthquake struck. The videos they made were sent to Tokyo were aired in the afternoon of the next day. Two or three years ago, this would have seemed impossible. Many people--including those involved in HDTV are delighted with this new speed and flexibility and they are looking forward to seeing HDTV put to more extensive use.

HDTV NEWS PRODUCTION IN THE PAST

HDTV broadcasts in Japan started on June 3, 1989. NHK aired one hour of HDTV broadcasts every day on Satellite Channel 2 as an experiment. From November 25, 1991, HDTV broadcasts were expanded to eight hours of test broadcasts. These broadcasts were supervised by the HDTV Promotion Association, a consortium of broadcasters, manufacturers and many other organizations. This service focused on sport, music, travel and art. These categories showcase the full advantages of HDTV's high quality picture, sound and screen.

Technology, meanwhile, was moving fast. We soon had portable HI-Vision cameras and VCRs. This equipment was used experimentally in news gathering. News programs are essential to any broadcast medium and they represented an important challenge for HDTV. The experiments were very successful. In 1993, the Wedding of the Crown Prince and the Tokyo Summit were both covered for broadcast in HDTV. Since then, HDTV has been used to cover various natural disasters all over the world. This gave HDTV an opportunity to display its power in communicating about the real world.

On July 12, 1993, a wave with a maximum height of 30 meters hit Okushiri, an island in Northern Japan. This wave came after an earthquake. 231 people were killed or went missing and 90 billion yen's worth of damage was done. HDTV gave an impressive account of the destruction. Using aerial views and composite pictures, HDTV was an excellent means to generate pictures that formed the basis for analysis and discussion. In September of the same year, HDTV covered the floods that spread through the US Midwest. Before this, in 1991, Kyushu in western Japan was the scene of another natural disaster. The Fugen peak of Mount Unzen erupted and caused a series of destructive pyroclastic flows. The volcano is still erupting. Fixed point HDTV monitoring has been extremely helpful in clarifying the nature of pyroclastic flows.

Based on HDTV's effectiveness on these occasions, we introduced a new current affairs show last November. November 25 marked the beginning of full-scale pilot broadcasting in HDTV. Since that day, NHK and seven commercial broadcasters have been providing their own HDTV broadcasts and sharing one HDTV channel. The new program is part of NHK's independent service. It's called "NHK Weekly HDTV News", and it's a 45-minute round-up of news broadcast once a week. As this suggests, the program reviews what's been going on in the last week, but because it's all in HDTV, it offers the information a new quality, and the viewer a new experience.

COVERAGE OF THE GREAT HANSHIN EARTHQUAKE

It was soon after this news show had started that the quake hit western Japan on January 17. As I said earlier, more than 5400 people were killed. Many died in collapsing buildings, or in the fires that broke out after the quake. We have covered many aspects of this disaster. The wide screen and the dynamic sound of HDTV make a major difference. We have been broadcasting new HDTV pictures from the disaster area each week on the Weekly HDTV News. Our ultimate objective is to compile a perfect record that will also serve as a valuable source of information for future scientific studies. Therefore, we have put heavy emphasis on why and how so many lives were lost, and what actually separated survivors from victims. Of course, media coverage of the Great Hanshin Earthquake has been exhaustive. But we now know that no other medium has the power to convey the true situation as strongly as HDTV. The fact that the Weekly HDTV News was already being regularly broadcast provided extra advantages. First the equipment could be arranged immediately, and secondly, the crew already had a clear idea about how to gather news in HDTV.

CONCLUSION

In Japan, more than 50,000 HDTV sets are presently in use. HDTV is putting down roots in Japanese society. From now on, NHK will be working with manufacturers to develop more lightweight equipment and also to integrate cameras and VCRs.

Our present aim is to deploy this new HDTV equipment all over the country by the time of the Winter Olympic Games in Nagano in 1998. We will then increase the hours of HDTV news programs. Daily HDTV news broadcasts are just around the corner.

SKIP BACK RECORDER

INTRODUCTION

In the Great Hanshin Earthquake, a scene from the moment just before the earthquake to the climax was broadcast all over the world. Such a scene, which has never been caught before, has made a great impression on the general public viewing the image at home. The scene was captured by an earthquake recording system, which consists of the SKIP BACK RECORDER (SBR) developed by NHK, a camera, a Video Cassette Recorder (VCR) and a seismograph. This system can capture, with certainty, the climax of sudden unpredictable incidents.

We intend to provide technological information about the SBR, showing how it was able to record the quake scene, even including the seconds before it happened.

VIDEO RECORDING UNPREDICTABLE INCIDENTS

It is very important and worthwhile to record unpredictable incidents. NHK has recorded such critical moments by various methods. But catching the scene of an earthquake from the moment it hit was almost impossible. If you want to record an earthquake which may or may not happen you would have to keep a camera operating 24 hours a day. In fact, we used to do that because we had no other way. If you did that, however, you would be troubled with the wear of both the machine and the tape or blinding of the video cassette recorder (VCR) heads, due to long uninterrupted operation. Therefore, in the long run it was not suitable as a means for recording unpredictable events.

As a result of thinking, we hit on the idea that we might be able to record the incidents if we go back to the moments before they happen. Going back in time is impossible, but it is not so difficult in the processing of video and audio signals.

EARTHQUAKE RECORDING SYSTEM USING SKIP BACK RECORDER (SBR)

If video or audio signals caught by a camera or a microphone can be input into the VCR with their input time continually delayed, the input signals the VCR receives may always be "retroactive" by the length of the delayed time. The SKIP BACK RECORDER (SBR) is a device which delays input signals by use of a small-capacity semiconductor memory.

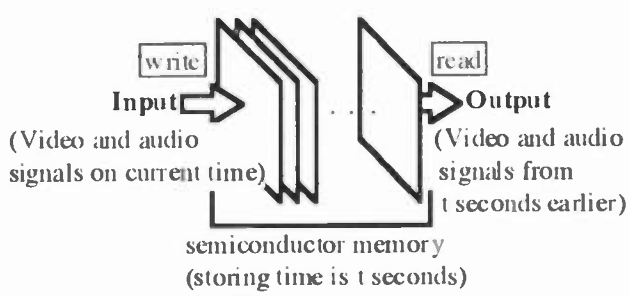

Figure 1 The theory of SBR

Figure 1 shows the SBR's operational principles. The SBR changes video and audio signals [from the camera and microphone] into digital signals and writes them sequentially in the semiconductor memory. When the signals fill up the memory, they are output (read) on a first-in first-out basis while the memory continues to input (write) new signals. This means that the video and audio signals are delayed by the length of the memory's recording time. In other words, assuming the memory's recording time is 10 seconds, the SBR always outputs video and audio signals that have been delayed by 10 seconds.

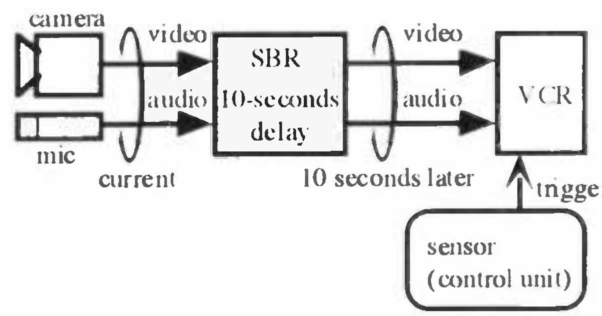

figure 2 Block giagram of recording system

A basic recording system using SBR is shown in Figure 2. The SBR provides 10 seconds of delay for video and audio signals going to the VCR. It turns on the moment that a sensor (control unit) detects the occurrence of an event and outputs a trigger signal. Because the VCR's input signals are delayed by 10 seconds, we are able to catch the climax of sudden unpredictable incidents even if the VCR starts just after the event happens. Assuming, for example, that the SBR's delay time is 10 seconds, that the time needed by the seismometer to output the trigger is about one second and that the time necessary for the VCR to start is about 3 seconds, then the system can record a scene 6 seconds in advance of the event occurring.

Using the SBR in the video recording system, we have thus succeeded in achieving that unprecedented effect. It is a result of the following two technological ideas:

The first is the idea of using conventional semiconductor memory for signal delay. This enables the scene caught by a camera and microphone to be input into a VCR as "retroactive" signals. As a result, an incident can be clearly recorded from its very beginning.

The second is the idea of combining a semi-conductor memory with a VCR into the same system. Semiconductor memories have the advantage of working stably as they have no mechanical parts, but they are expensive and bulky for recording video signals. VCRs, meanwhile, are compact and available at a low cost, but they require a long time to start up and have limited durability of their mechanical parts due to continuous operation. This recording system is an innovative system in which a VCR and a semiconductor memory complement each other to eliminate their shortcoming.

APPLICATION EXAMPLES

This system, by changing detecting sensors, can record various unpredictable events on VCR, to say nothing of an earthquake.

First of all is sports. In the live broadcast or news gathering of sports, it is possible to prepare beforehand the start of recording on VCR for decisive scenes, such as a home-run (baseball) or a goal (soccer). But if things do not go as anticipated, with no home-run or goal, the recorded tape is wasted.

Using the SBR in the recording system, we can record necessary scenes with no loss of tape because it is not too late to start recording after a home-run or a goal has been confirmed.

Another application is Documentaries. You have to record on VCR for a long period of time before a decisive incident occurs. This requires lots of tape, puts you under great stress for long periods of time and forces you to worry about how much tape remains in your machine.

Using the SBR in a video recording system, you would eliminate almost all these problems. If, for example, you would like to catch a jumping whale, you would aim the camera at the water surface, wait for a whale to jump, and then start the VCR. You could be certain of catching the moment in the VCR.

CONCLUSION

NHK has set up the system in each of our stations. Also, NHK has applied for a patent (Application No. 0 5-113170) on the video recording system by use of the SBR in 1993.

Last but not least, we would like to express our heart-felt condolences to all the bereaved families and relatives of the victims of the Great Hanshin Earthquake. We would also like to express our deep sympathy to the many people still leading uncomfortable lives at shelters.

AUTHOR INDEX

COMPANY INDEX

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