DOC-CR-BT-88-001

"THE IMPACT OF DIGITAL TELEVISION ON THE CABLE TV, BROADCASTING AND CONSUMER ELECTRONICS INDUSTRIES"

Cablesystems Engineering

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REPORT TO THE
DEPARTMENT OF COMMUNICATIONS

DSS CONTRACT # 37ST. 36100-6-4272

This report was prepared under contract by Cablesystems Engineering on behalf of the Canadian Department of Communications. The views expressed and the conclusions reached are those of the authors and do not necessarily represent the official view of the company or the department.

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EXECUTIVE SUMMARY

This project was undertaken under a joint contract to the Department of Communications, the Canadian Cable Television Association and Rogers Cablesystems Inc. The purpose of the study was to identify the current developments in digital television technology and to assess their impact on Cable TV, broadcasting and consumer electronics industries.

The implied effects of digital television technology can be broken into near term issues which stem from current implementations of conventional television using presently available digital processing circuitry, and longer term issues which stem from future implementations of extended definition, and high definition television systems which will generally be based on next generation digital processing circuitry.

Near Term Implications

The near term implications of using digital televisions fall into three categories:

1) potential compromise of scrambling security
2) added complexity to consumer equipment interconnections
3) improved CATV technical performance requirements.

1. <u>Potential Compromise of Scrambling Security</u>

   Pay TV security for the majority of Canadian cable operators, who rely primarily on sync suppression scrambling techniques, is somewhat compromised by the use of digital television receivers which results in an increased threat of lost revenue through piracy to both cable companies and to Canadian Pay TV broadcasters.

   <u>Recommended Actions</u>

   A) The position of the cable industry and the Canadian Pay TV broadcasters should be made clear to consumer electronics firms importing products into Canada that these products should be designed and built to minimize the potential for tampering to defeat sync suppression techniques.

   B) Products which can be retrofitted into existing sync suppression encoders at pay TV uplink and cable headend facilities should be made available on short notice should action 1 above fail. (Experimental work undertaken as part of this contract indicates that this is a feasible approach to improve the security of sync suppression techniques).

C) For a longer term planning horizon, the cable industry and Pay TV broadcasters should consider alternative security methods not relying solely on sync suppression techniques for premium program security.

2. Added Complexity to Consumer Equipment Interconnections

Digital TV technology offers 'picture-in-picture' features which require either multiple TV tuners or a single agile tuner at the input of the television . These tuners must have access to all television channels supplied by the cable system, not just a single channel output from a cable converter or descrambler. As a result, the degree of "consumer friendliness", or the ease with which a subscriber can interconnect his television set and VCR to the cable system, is once again potentially compromised and affects both the cable and consumer electronics industries.

Recommended Actions

A) The cable and consumer electronics industries in Canada, should actively promote the proliferation of Multiport decoders and televisions. The use of multiport decoders with suitably equipped cable compatible multiport televisions enables premium programming decoding without requiring a channel constricting converter/descrambler to be placed ahead of the television receiver input connector.

B) Once again for the longer term planning horizon, the cable industry should consider alternative security methods such as off-premise denial/interdiction techniques or a universal encrypted scrambling system which would not require converter/descramblers ahead of the subscribers television or VCR and thus would not interfere with the functionality of this equipment.

3. Technical Performance Requirements

Digital implementations of comb filters in television receivers enable wider luminance bandwidths which provide higher resolution displays. Higher resolution displays are often marketed with larger screen sets both of which tend to show up technical faults such as noise and ghosts caused by underdesigned or misadjusted cable television plant or transmission impairments in over the air broadcasting. With competing delivery technologies with less noticeable faults, such as Direct Broadcast Satellite and super-VHS or extended definition beta VCR technologies, the cable industry and the broadcast industries may risk further market erosion as a result of inferior technical quality.

Recommended Actions

A) The cable industry should continue its efforts to maintain high technical performance standards.

B) The cable industry in Canada should take an active position in conducting basic technical testing to establish the effects of classically ignored technical impairments on television pictures, such as phase noise and close-in multiple reflections, as these impairments may be more noticeable on higher resolution displays.

C) The cable industry in Canada should liaise closely with their counterparts in the U.S. to share the cost of research on solutions to common problems.

Longer Term Implications

The longer term implications of digital processing fall into four categories:

1) threat of alternative delivery of EDTV & HDTV
2) the cost barriers to offering EDTV & HDTV via cable resulting from spectrum considerations
3) the cost barriers to offering EDTV and HDTV via cable resulting from technical quality considerations
4) implications on premium program security methods for EDTV and HDTV

1. Threat of Alternative Delivery of EDTV and HDTV

Several proposed EDTV and HDTV standards may provide a competitive edge for direct broadcast satellite service providers and for consumer electronics manufacturers in the VCR or laser disc market, which could adversely affect the broadcast and cable television industries ability to compete in the delivery of EDTV and HDTV.

Recommended Action

The Canadian Cable TV and Broadcast industries should actively participate in the standards setting process through the Canadian Advanced Broadcast Systems Committee (CABSC) to ensure that EDTV and HDTV standards which are conducive to CATV and terrestrial broadcast delivery are quickly established and implemented.

2. The Cost Barriers to Offering EDTV & HDTV resulting from Spectrum Considerations

Terrestrial broadcast spectrum is a finite resource which must be used wisely. Cable TV spectrum space is available at a premium since spectrum expansion requires very costly capital expenditures. For the Cable TV industry to competitively offer multiple channels of EDTV and HDTV programs it is imperative that EDTV and HDTV standards be adopted which conserve spectrum. In general, standards which are backwards compatible to NTSC conserve spectrum best since dual programming in NTSC and EDTV or HDTV is not required. EDTV systems such as Philips ENTSC require only two standard television channels to deliver both conventional NTSC as well as EDTV version of a program to viewers. Non compatible systems such as MUSE or Extended Definition B-MAC require two standard channels for the EDTV signal plus an additional NTSC channel for existing receivers, a total of 3 channels, an increase of 50% over that for a compatible system.

Recommended Action

The cable and broadcast industries should actively promote the adoption of EDTV and HDTV emission standards which are spectrum efficient and backwards compatible with the installed base of NTSC television receivers.

3. The Cost Barriers to Offering EDTV & HDTV via Cable Resulting from technical Quality Considerations.

At this point in the development of EDTV and HDTV standards it is difficult to estimate the potential cost implications to delivering good technical quality EDTV and HDTV programs via cable. Much is dependant on determining the subjective effects of noise, distortion and echoes on various proponent EDTV and HDTV standards.

Recommended Action

A) The cable industry in Canada, in close liaison with their U.S. counterparts, should arrange to perform technical tests to determine the subjective perceptibility of cable transmission effects on proponent EDTV and HDTV standards and to influence the adoption of those emission standards which are less sensitive to transmission defects.

B) The CATV industry should invest in improving cable television plant as may be required based on the results of the above tests and assuming that a cable friendly HDTV standard is adopted.

4. Implications on Premium Program Security Methods

Conventional premium program security methods may well be unacceptable in an environment of EDTV and HDTV.

Recommended Action

The Cable TV industry should consider alternative security methods such as off-premise denial/interdiction techniques or a universal encrypted scrambling system which would not only alleviate consumer interconnect problems but would be more compatible with EDTV and HDTV formats. The more attractive universal scrambling solutions will require the cooperation of television manufacturers, pay television security system vendors and government regulation. Determining the feasibility of a DES type encryption standard for pay television should be a part of the mandate of the Canadian Advanced Broadcast Systems Committee (CABSC).

A sense of urgency is appropriate in determining how to deal effectively with HDTV. Current transmission systems for television do not distribute HDTV quality pictures. In the meantime, the pre-recorded media threat is real.

The upgrading of transmission systems to carry HDTV programming has been studied by a number of television research institutions. Their work has culminated in a number of new television system proposals.

North American Philips have proposed satellite and CATV systems termed MAC-60 and ENTSC respectively which is a NTSC backwards compatible two-channel transmission scheme.

The principle researcher at the New York Institute of Technology, William Glen, has a two-channel system proposal that combines conventional NTSC with a slow scan, high resolution enhancement signal. The augmentation channel requires only 3 MHz which may be more easily accommodated in the UHF band than a full bandwidth NTSC signal.

The Japanese National Broadcaster NHK has developed a bandwidth compression system to accommodate HDTV quality images within 8.1 MHz. This bandwidth is somewhat larger than that required for NTSC and is not divisible into two channels. There is no provision for backwards compatibility with NTSC receivers.

The Digital Video subsidiary of Scientific Atlanta has developed two television systems based on Multiplexed Analog Components or MAC. Their B-MAC system is used for closed circuit television in North America. A high definition version, termed HDB-MAC is being prototyped and will deliver HDTV quality images using a bandwidth of 10.7 MHz. Again, there is no compatibility with NTSC, although the conversion process to generate NTSC compatible signals is simple compared to MUSE.

The Del Ray Group of California have proposed a system they call Tri-Scan to enhance resolution within conventional NTSC transmission. Integration over several frames allows the display of high resolution in receivers equipped with specialized circuitry. Conventional television receivers would display a normal image.

A system announced since this report was prepared also enhances television images within a single conventional NTSC channel. The David Sarnoff Research Center, with support by GE, NBC and RCA, have developed a means of augmenting NTSC television transmission with increased resolution and wider aspect ratio which appears very interesting. It may actually be possible to satisfy the picture quality expectations of consumers without abandoning the current NTSC transmission format.

All those involved in the Canadian television industry should participate in a comprehensive evaluation of the various ATV systems. Physical testing of each system on terrestrial broadcast, CATV and satellite facilities should be undertaken. At the same time, means of adapting these familiar media to the new television formats should be investigated. Consumer interest and psychovisual constraints related to image enhancement should be obtained to ensure the new technology meets the needs of the viewing public.

CATV operators in particular need to consider the pay television security implications of new television transmission formats. A desirable goal is an integration of scrambling within the transmission standard such that external converter/descrambler equipment does not interfere with television user features.

The Canadian government, through its various agencies and departments, should serve as catalyst to this study. The provision of technical experts, facilities and funding would ensure that an advanced television distribution system for Canada would be equitable to all sectors of the industry. In addition, the involvement by government could facilitate exploration of Canadian industrial opportunities brought about through HDTV. New test and measurement equipment, standards converters and other specialized video equipment are potential candidates for development and manufacture in Canada.

Timely effort by all entities involved in Canadian television can ensure that the viewing public in this country will benefit from advanced television. The Canadian television industry can benefit as well through the new opportunities generated by ATV.

REPORT OUTLINE

1. Introduction To Digital Television

A television primer is offered in Chapter 1 for those readers who wish to learn or review how television receivers operate. Each of the functional blocks in a receiver is briefly described. An explanation of how television images are generated using raster scanning is also explained. Many of the signal processors and their attributes that are discussed in the body of this report are introduced in Chapter 1. The introduction of digital electronics to television receivers is outlined. The basics of digital signal processing is explained to enable the reader to follow the discussion of digital television in this report. A more complete introduction to a digital television set is given in Appendix A. Those knowledgeable in the field of television technology may skip chapter 1 without losing any new material. A glossary is given in Chapter 8 to assist the reader with unfamiliar terms or acronyms.

2. Industrial Implementation of Digital television Technology

The degree to which digital technology has been implemented in products available to the consumer is discussed in this chapter. Much of the publicity of digital television is a result of such features as picture-in-picture, freeze frame, and on-screen display of remote control commands. There are also product introductions such as comb filters and progressive scan converters that attempt to use digital signal processing to improve picture quality . The subjective effects of these attempts to improve picture quality are reviewed. A summary of various products, listing features, manufacturer and price is given near the end of the chapter.

3. CATV Implications

The immediate implications of the new digital television receivers on CATV are presented in this chapter. New picture-in-picture features create new consumer electronics interconnect problems. The potential solution to inter-connect problems embodied in a new interface called Multiport is discussed. The risk posed by the new television technology to current pay television scrambling methods is assessed. The combination of consumer electronics interconnect problems and reduced scrambling effectiveness initiates a search for alternatives for delivering pay television in a better way. A number of potential methods of delivering pay television are reviewed. The trends accompanying digital television such as larger screen sizes and increased resolution made possible by sophisticated comb filtering allows consumers to view picture quality that is only limited by the delivery system.

Therefore CATV performance must not degrade picture quality. To this end two common impairments are identified as potential candidates for improvement, noise and microreflection. The recent implementation of BTSC stereo audio in television signals highlights audio quality issues confronting cable operators. All digital television receivers have stereo decoders for the BTSC system. The possibility of using digital signal processing to enhance signal quality at the CATV headend is discussed at the end of the chapter.

4. Enhanced Quality Television

Digital processing of television signals makes possible a new level of picture detail in the home if departure from the conventional NTSC transmission format is allowed. Efforts by research groups have resulted in several new television systems being designed. These systems are described. Performance parameters and bandwidth requirements are compared. The implication of the new formats on CATV distribution are discussed. Particular issues of concern to CATV are transmission bandwidth requirements and backwards compatibility with television receivers presently in subscriber's homes. Pay television security implications of the new television formats are reviewed. The threat of bypassing CATV via prerecorded tapes or laser discs in the delivery of enhanced quality television is examined. The direct broadcast satellite delivery mechanism is also available and poses a potential threat to CATV which could be bypassed.

5. Status of Digital Video Processing Development

This chapter is a review of television signal processing and transmission systems based on digital techniques. Current state of the art technology as it exists in laboratories around the world is summarized and results from information gathered from published papers and interviews with experts in the field of television research.

Digital signal processing techniques often included in digital television receivers are briefly reviewed with numerous references given for those readers interested in further research. Subjects include improved separation of colour and luminance in NTSC systems, noise, ghost and echo cancellation, intermodulation distortion masking, and electrical noise suppression. The efforts of improving picture quality by progressively scanning to reduce interlace flicker and improve vertical resolution are also reviewed, particularly when those efforts are confined to processing in the television receiver.

Various extended definition television systems are described as are the efforts of the Advanced Television System Committee in the United States to coordinate an orderly evolution to new television systems.

A description of how digitally assisted television, in conjunction with the use of motion vectors, can allow bandwidth compression of high definition television transmission to the home concludes this chapter.

6. Industrial Opportunities

A number of opportunities for Canadian business development have arisen as a result of the introduction of digital technology into television equipment. Products of low volume and high volume/high technology suited to Canada's manufacturing infrastructure are suggested.

7. Future Study

There are important issues falling outside the scope of this study that require follow-up work. These areas for future investigation and coordination are discussed in this chapter.

8. Glossary

A comprehensive list of terms specific to the television industry are explained in this glossary. The reader should be able to find most of the unfamiliar terms used in this report defined in this glossary.

9. Appendices

A number of laboratory reports and a condensed description of the ITT chip-set for digital television receivers are given in appendices to the report.

1

CHAPTER 1

INTRODUCTION TO DIGITAL TELEVISION

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BASICS OF TELEVISION

Picture Scanning

A television picture is composed of a rapid succession of still images (fields), nominally 60 fields per second. The human eye begins to interpret a picture sequence shown at a rate of 15 pictures per second as continuous motion. Picture to picture flicker is evident until the rate is greater than about 40 images per second, depending on picture brightness. A rate of 60 fields or 30 frames per second is used in North America. Each frame is generated from a number of lines of video information, 525 lines per frame. The lines in a frame are scanned on a television screen in an interlaced pattern as shown in exhibit (1.1).

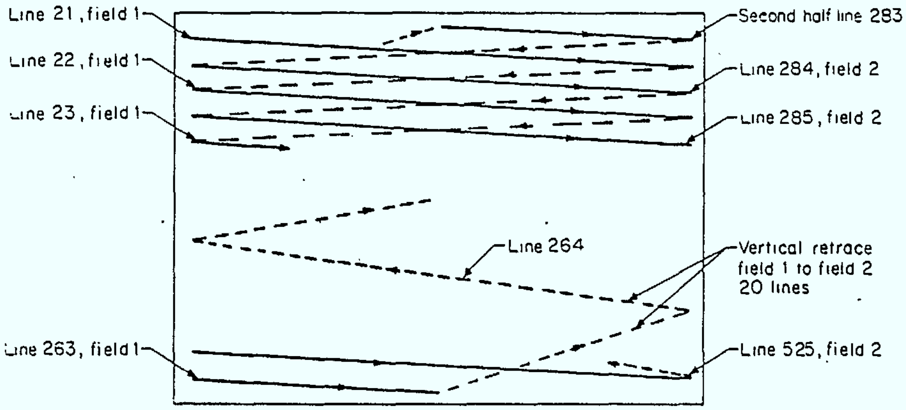


EXHIBIT 1.1 INTERLACED NTSC RASTER SCAN

A raster scan pattern is necessary for the transmission of a two dimensional picture. Exhibit (1.1) demonstrates the method used to increase the rate at which still pictures are updated on the CRT screen, the screen is scanned twice using an interlaced pattern for each frame of 525 lines. During each field or scanning sequence only alternate lines are displayed. For the first field of a frame only odd numbered raster line positions are scanned and during the second field only even raster line positions are scanned.

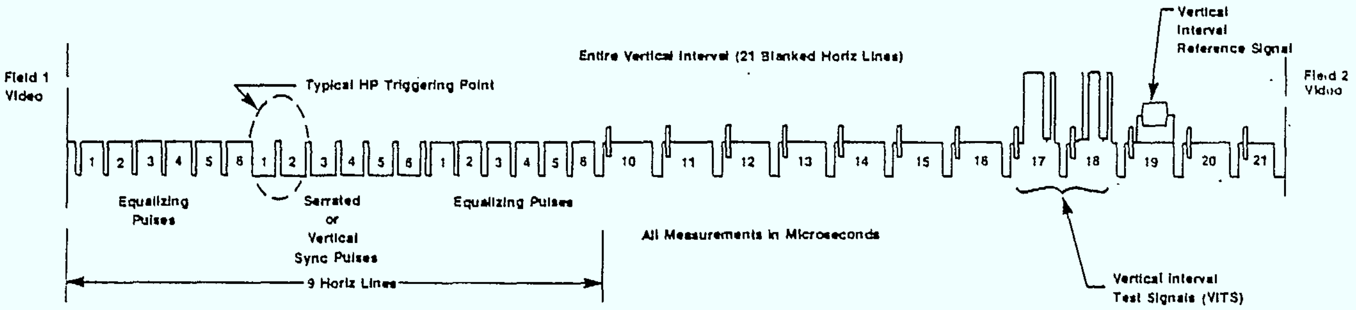
The sequence of illuminating odd line positions followed by even line positions causes a line to line flicker because adjacent line positions are never active during the same field. The flicker effect is more visible on larger CRT and rear projection screens and on edges or lines in the display that are nearly horizontal.

The dimensions of the raster depends on the screen size but the ratio of width to height is 4:3 and the number of lines per frame is a constant 525 for the NTSC television system used in North America. Only 480 lines of active video are displayed on the television screen.

Picture Scan Synchronizing

Synchronizing pulses imbedded in the video signal are used to synchronize the television receiver to the signal source so that an accurate representation of the picture can be presented. Correct raster scan synchronizing is necessary so that the displayed picture is not distorted. Erroneous horizontal scan line synchronization will cause the displayed picture to tilt or tear. Pay television scrambling makes use of this phenomenon with the suppression of synchronizing information in the television signal.

At the end of the last scanning line of a field the electron beam illuminating the display is shut off while it is retraced to the top of the screen. Timing pulses in the video signal during this retrace time, shown in exhibit (1.2), also called the vertical blanking interval (VBI), are used by the television receiver to maintain synchronization of the raster scan control circuitry with the incoming video signal. Problems with poor field or frame synchronization can cause the displayed picture to roll or jump vertically on the CRT screen.



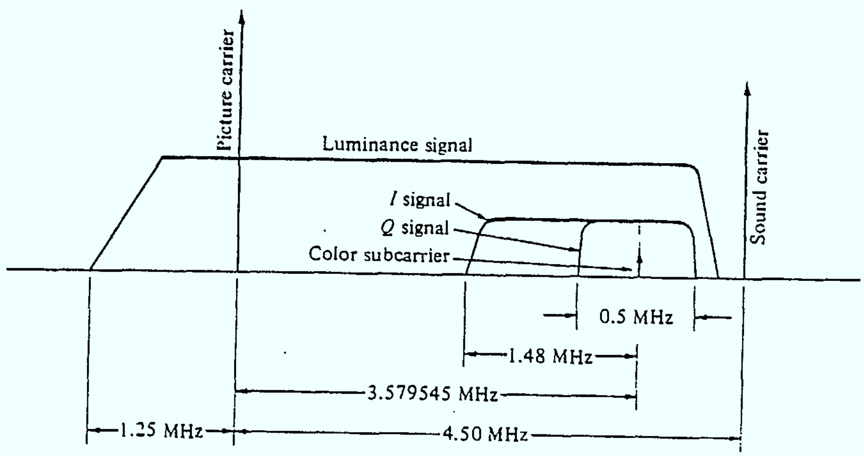
Entire Vertical Interval (21 Blanked Horiz. Lines)

EXHIBIT 1.2
TELEVISION SIGNAL SYNCHRONIZING PULSES

Colour Subcarrier and Luminance Separation

An important function of a colour television receiver is the separation of the colour information in the video signal from the luminance information. The luminance information forms the monochrome or black and white picture. The colour signal is modulated on a subcarrier as shown in exhibit (1.3), which allows the colour and luminance information to share a common spectrum. The frequency of the colour subcarrier is chosen so that the colour (chrominance) and luminance energy are interleaved as in exhibit (1.4), so that the chrominance and luminance energy interference is minimized while maximizing the bandwidth available to each.

Until recently chrominance and luminance separation has been accomplished by bandpass and low pass filtering. The bandpass filter passes the chrominance signal and rejects luminance while the low pass filter with cutoff at 2.5 MHz passes mainly the luminance and not the chrominance information. This method of separation limits the usable luminance frequencies and therefore limits the amount of detail in the picture.



Color television spectrum showing I and Q spectra.

EXHIBIT 1.3

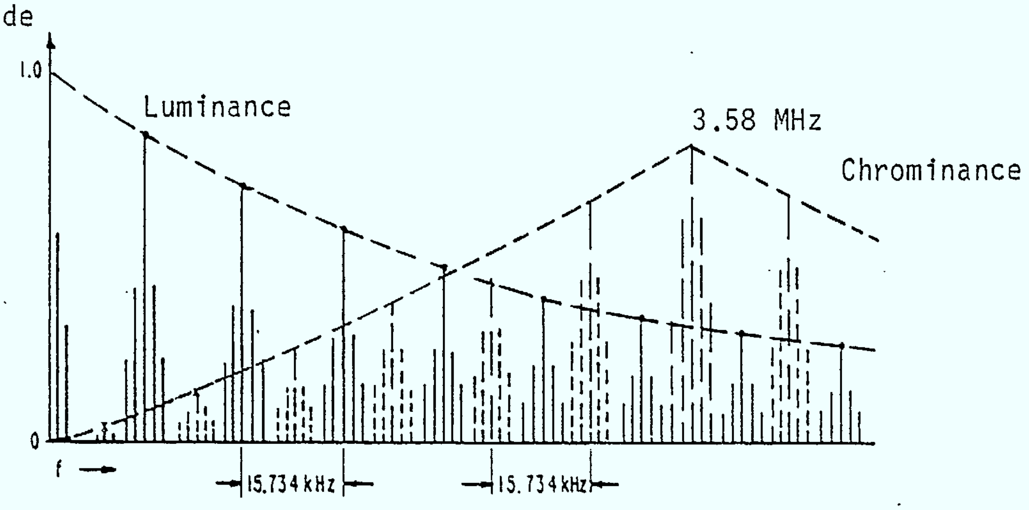


EXHIBIT 1.4 INTERLACED LUMINANCE AND CHROMINANCE SIDEBAND SPECTRUM

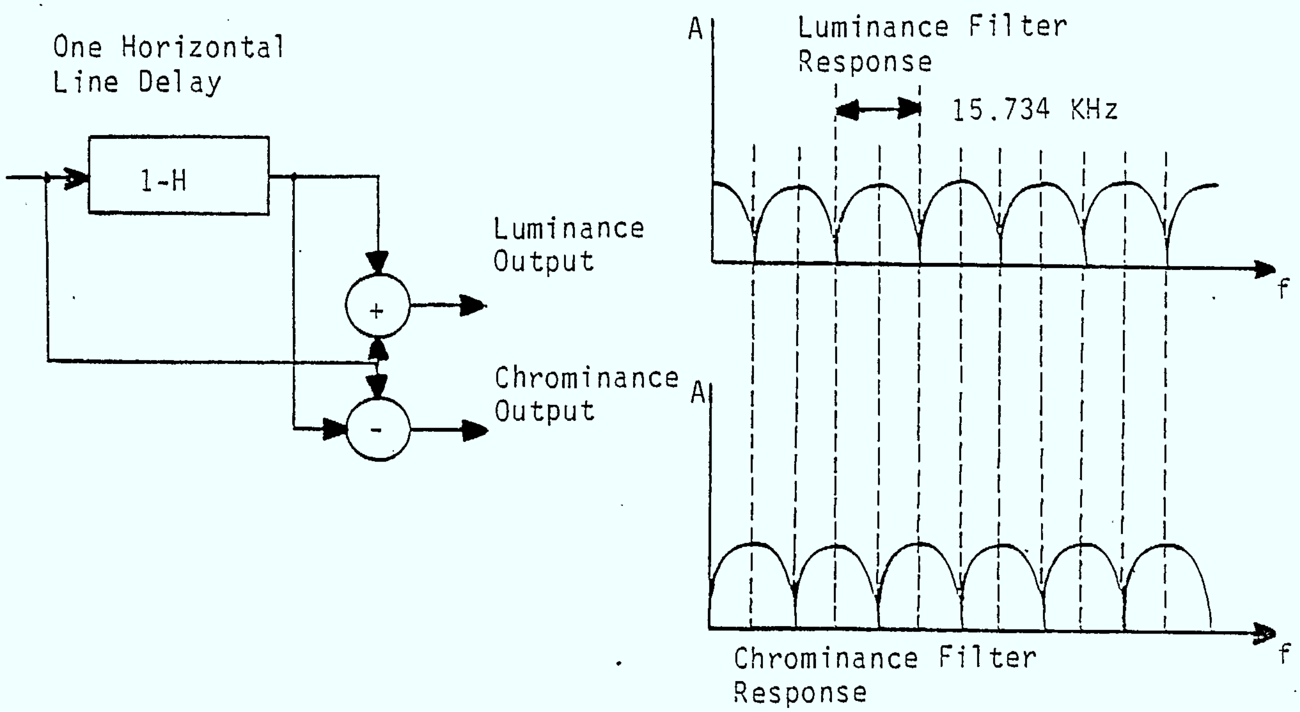


EXHIBIT 1.5 COMB FILTER BLOCK DIAGRAM AND FILTER RESPONSE

If signal separation is not perfect the chrominance and luminance signals will interfere with each other and cause picture errors such as rainbow patterns on fine line or herringbone patterns. Optimal separation is achieved by comb filtering the video signal, exhibit (1.5), thereby eliminating colour errors and isolating the chrominance and luminance information. A comb filter eliminates the need for a luminance low pass filter so that high frequency luminance components can be separated and passed to produce more picture detail in the horizontal scanning line. See Appendix D.

The method used to multiplex colour information on the colour subcarrier requires that the television receiver remain locked to the phase and frequency of the video colour signal source. A colour reference signal, the colour burst, which is present in the video signal is detected and used to demodulate the colour subcarrier and derive the two chrominance signals I and Q. The I and Q signals are filtered to reject unwanted signals and sent to a combining or matrix circuit to produce the red, blue and green signals used to drive the CRT electron guns.

Colour reproduced by a colour television receiver is defined by two colour characteristics:

a) hue which defines the actual colour such as red or blue

b) saturation which indicates the brightness of the colour, for example bright blue or pale blue.

A particular colour is reproduced on the television screen by illuminating three primary colours; red, green and blue in varying proportions on the CRT screen.

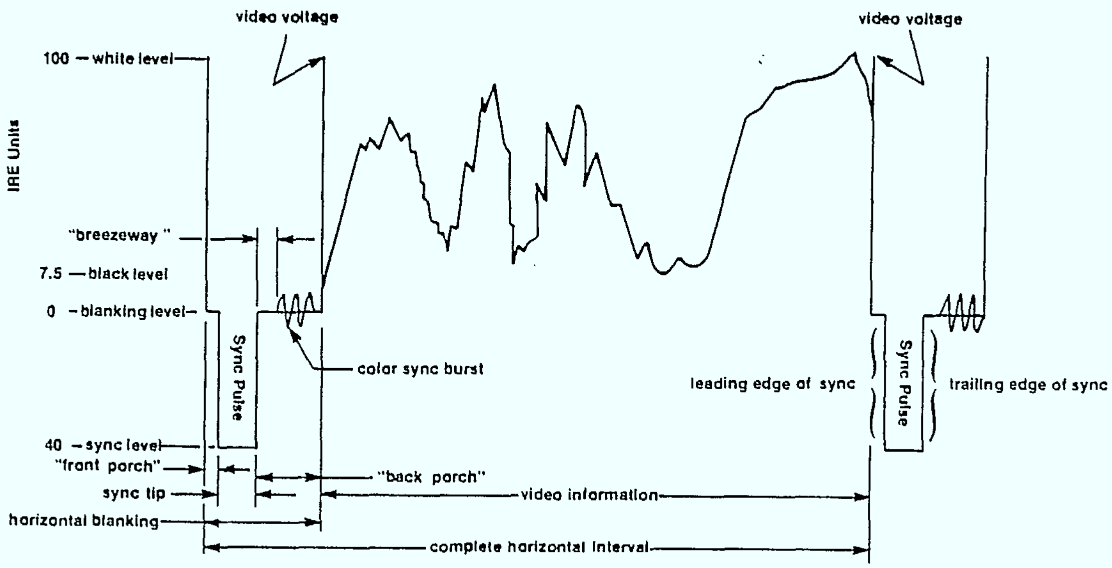


EXHIBIT 1.6 NTSC VIDEO WAVEFORM

Video Signal

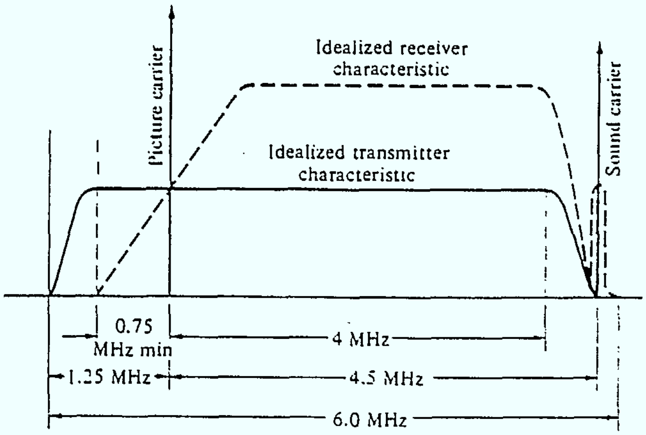
The NTSC video signal is a complex waveform consisting of several parts as shown in exhibit (1.6), which depicts one of the 525 lines in each television frame.

A single line of the video signal can be divided into three components which can be related to the various functions of a colour television receiver.

i) The horizontal synchronization pulse, or Sync Pulse, is used as described in the 'Synchronizing' section to synchronize the start of all the video lines at the same place on the CRT screen. A horizontal sync pulse precedes every line of video.

ii) The colour sync burst is the reference signal used to demodulate the colour information on the colour subcarrier. Each colour burst consists of eight cycles of a frequency equal to the colour subcarrier frequency of approximately 3.58 MHz. The colour reference signal must be free from excessive noise and jitter so that the television receiver can produce a true colour representation of the transmitted picture.

iii) The largest portion contains the active video information of the signal, the chrominance and luminance information which forms the picture on the CRT screen.



Simplified spectrum of a television channel.

EXHIBIT 1.7

Television Channel

A complete television channel is contained in 6 MHz of spectrum, a simplified channel spectrum appears in exhibit (1.7). The video information and sound carrier at 4.5 MHz is amplitude modulated on a radio frequency (RF) signal to form a television channel. A normal AM signal has two sidebands surrounding the carrier, but in a television signal the lower sideband is attenuated as in exhibit (1.7) to allow close channel spacing. This is called vestigial sideband amplitude modulation.

PICTURE PARAMETERS

Brightness

The term brightness is used to classify the picture in terms of white, black and intermediate shades of grey. Brightness can be measured using the highest intensity of white observable on the CRT screen. The primary limit on display brightness is the ability of the CRT to keep the picture focused at high brightness levels.

Contrast

Contrast is the difference between the darkest black and the brightest white displayed on the TV screen, commonly a ratio of 40:1.

Sharpness or Horizontal Resolution

The bandwidth of the luminance after processing by the television receiver is a direct measure of the achievable picture sharpness or horizontal resolution. The higher luminance frequencies in a video signal add detail or sharpness to the edge of objects displayed by the television. These transitions from a dark area to an adjacent light area must be clear and sharp to provide a good picture.

Colour Uniformity (Purity)

A receiver must have the ability to reproduce a constant colour (hue) over a large area without any colour fluctuation. The accuracy of the colour demodulation and processing directly affect the colour purity on the television screen.

Noise

Noise on the input signal can adversely affect the colour synchronizing circuits resulting in colour streaks in the picture. Noise can enter the picture through the chrominance demodulator channel and produce disturbances such as colour specks in the picture. Luminance noise can be either impulse or a constant thermal noise which produces sparkles or specks in the picture.

A GENERALIZED COLOUR TELEVISION RECEIVER

A generalized colour television receiver is presented as a block diagram in exhibit (1.8). Each functional component in the television receiver block diagram will be briefly described to provide a background on its operation.

Tuner

The television tuner has two basic functions, to reject out of band RF signals that would interfere with the television receiver's operation and to amplify the channel of interest. The amount of amplification provided depends on the AGC level which is an indication of the incoming signal strength. The tuner converts the desired channel to a lower intermediate frequency (IF).

IF Amplifier

The IF stage provides the bulk of the television's selectivity by rejecting unwanted signals and disturbances outside the desired channel. The majority of the amplification required by the following detector stage is performed by the IF stage, under the control of the AGC circuit.

AGC

The automatic gain control (AGC) circuitry monitors the level of the detected video signal and adjusts the tuner and IF amplifier gain so that the amplitude of the detected video signal is kept stable.

Video and Audio Signal Demodulation and Separation

The demodulation or detection stage recovers the picture information and the sound (audio) carrier signal. The video signal, 0 - 4.2 MHz is sent to the video amplifier. The sound subcarrier signal travels through the sound amplifier to the FM detector for detection of television sound. The video level at the output of the video detector is used to generate an AGC voltage which controls the tuner and IF amplification.

Video Amplifier

The video amplifier boosts the video signal level so that it can drive the colour processing circuit.

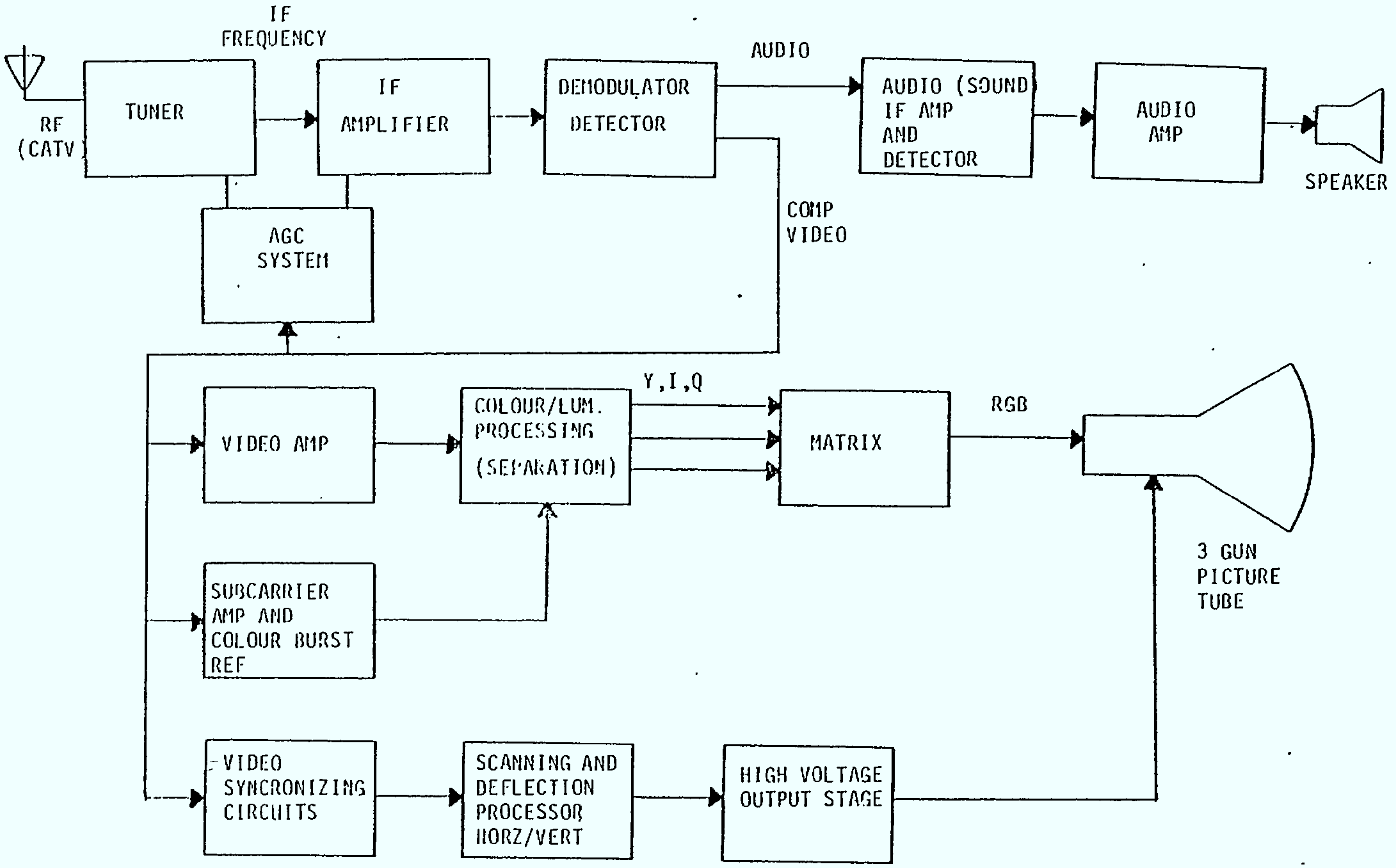


EXHIBIT 1.8 GENERALIZED ANALOG TV BLOCK DIAGRAM

Colour and Luminance Processing

At this stage the colour (chrominance) information is separated from the brightness (luminance) information. In older conventional television receivers a bandpass filter is used to isolate the colour information from the luminance information. In more recent receivers a comb filter (see chapter 3, section 7) is used to separate the luminance and chrominance signals while introducing minimal picture distortion. The colour subcarrier signal is demodulated to obtain the two colour signals I and Q. The I and Q signals are sent along with the luminance signal to a matrix combiner to produce the red, green and blue drive signals for the cathode ray tube (CRT) display.

Colour Subcarrier Amplification and Colour Burst Reference

This section of the receiver locates and amplifies the colour burst reference signal used to define the colours that will be displayed on the CRT in response to the chrominance signal. The colour reference signal must be accurately reproduced with minimal signal error. The colour subcarrier signal is boosted before being sent to the colour and luminance processing circuitry.

Video Synchronizing Circuits

Here the timing signals required to display the picture are separated from the detected video signal. The synchronizing signals lock the picture display to the video signal source for faithful picture reproduction. These synchronizing signals are also sent to the scanning and deflection processor to align the picture on the CRT screen.

Scanning and Deflection Processor

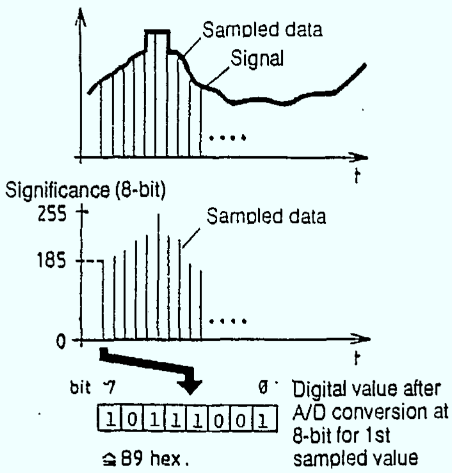
A video picture display is composed of a sequence of still images shown quickly enough to give the illusion of motion. The vertical deflection unit determines when a new still image is to be displayed on the CRT screen. Each still picture is divided into a number of horizontal lines of information. The horizontal deflection unit determines when a new line of video information should be shown. Video picture information is transferred to the display screen by varying the intensity of an electron beam appearing as a dot on the screen. The dot is deflected across the screen by the horizontal deflection circuitry. When the dot reaches the bottom of the screen the vertical deflection circuit returns it to the top.

High Voltage Output

The deflection and electron beam control signals must be converted from the low voltage signal derived from the video signal to high voltage drive signals required to control the electron beam.

INTRODUCTION TO DIGITAL PROCESSING

A video signal as processed by the television receiver is a continuous voltage function which in the television receiver undergoes processes such as: amplification, addition, filtering, demodulation and comparison. The first step in digitally processing a video signal after it has been demodulated is the conversion of the continuously varying signal shown in exhibit (1.9) to a discrete digital signal composed of a series of zeros and ones. The digitization process is accomplished in an analog to digital converter (A/D) which samples the continuously varying analog signal at regular intervals determined by the sampling clock.



A/D converter: Conversion of an analog signal into individual digital values

EXHIBIT 1.9

Depending on the number of bits used to represent the digitized signal, the A/D generates a number of voltage or quantization levels for comparison to the sample level. For instance if 8 bits are used to represent each sample, then the A/D generates 256 voltage levels. The A/D compares the analog signal sample to the generated quantization levels and chooses the combination of bits that represents the level closest to the level of the sample as shown in exhibit (1.9). Thus at any point in time the voltage of the analog signal can be represented by a digital word of 8 bits.

The sampling frequency which determines how often a sample is taken, must be very stable so that the interval between samples is equal for all samples. When digitizing a video signal the sampling frequency should be referenced (locked) to the incoming signal so that any changes in the source signal is followed by the sampling rate.

The sampling frequency must be fast enough, or the sampling interval small enough, so that any level changes, especially fast changes in the signal level, are sampled by the A/D and converted to digital information. For accurate representation of the source signal the sampling frequency must be equal to or greater than twice the highest frequency contained in the signal being digitized. Common sampling frequencies used in digital television sets are 3 or 4 times the colour subcarrier frequency.

Digital Processing

The digitally represented video samples generated by the A/D are sent to the processing circuitry at the same rate as the sampling clock so that none of the timing information is lost. The video processor processes the digitized video signal sample by sample and provides the required television receiver functions such as:

1) separating synchronizing signals from input video

2) regenerating the colour reference for subcarrier demodulation

3) chrominance and luminance separation

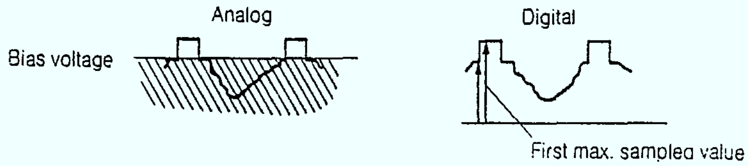
4) demodulation of the chrominance information on the subcarrier

5) amplification, correction and compensation of the video for display.

One can imagine that the digital video processing circuitry is simply a small computer that processes the video in numerical form. The arithmetic operations and sequences of operations are not completely controlled by software, rather overall control is dictated by the layout of the digital circuitry and how it reacts to the control data stored in memory. Analog technology process signals using amplifiers, voltage dividers, RLC filters, rectifiers and voltage comparators. In the digital domain analog receiver functions are accomplished by corresponding digital components such as: adders, shift registers and digital memory. After all digital processing is complete a digital to analog (D/A) converter transforms the digital video data to analog drive signals for the CRT.

Synchronization and Signal Separation

In the analog domain separation of synchronizing signals is achieved by comparing the input signal to a reference voltage shown in exhibit (1.10 a) and identifying any parts of the signal that exceed the reference value. Exhibit (1.10 b) demonstrates that digitized video data can be used to identify and separate the required synchronization pulses.



Pulse separation: A digital value determines the switching threshold

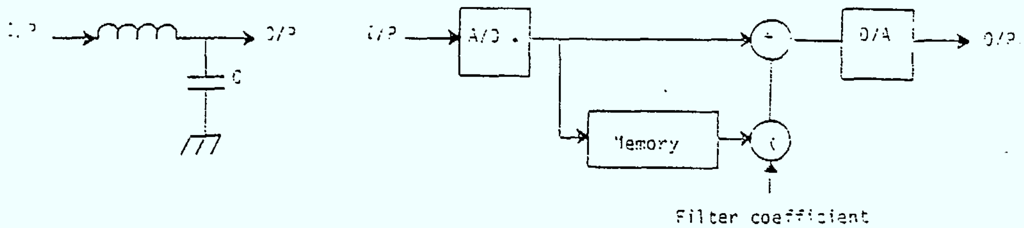
EXHIBIT 1.10

Colour Reference Regeneration

Separation of the chrominance and luminance signals is much simpler and more precise when completed digitally. The digital comb filter simply requires a shift register to delay the data and an addition function to combine the incoming and delayed video data. The analog alternatives are comb filtering using less precise analog delay lines or a more primitive form of separation employing bandpass and notch filtering.

Digital Filters

A simplified representation of a digital filter is given in exhibit 1.11.



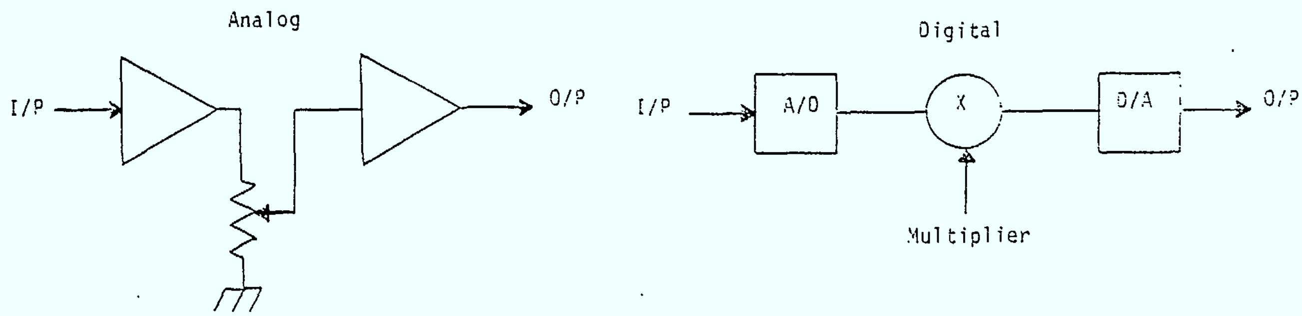
Filter: Every sampled value must be seen in relation to the preceding value; this is essential for establishing the slope of the signal.

EXHIBIT 1.11

Since the characteristics of a signal cannot be determined from only one sample a memory function in the filter is needed to retain weighted information about past samples. Signals can be separated or modified by RLC analog filters or by a digital filter, which is formed by a series of multiplications and additions. If a digital filter is used the filter type and performance can be changed dynamically by altering the co-efficients used in the filter multiplication process.

Signal Amplification or Compensation

In order to adjust the volume, picture contrast or colour saturation an analog television receiver uses an amplifier and potentiometer combination as shown in exhibit (1.12). To generate the same function the digital processor multiplies the digital sample by an integer number smaller than one to attenuate the original signal or larger than one for amplification of the signal.



Comparison of analog and digital control elements: In digital technology, the potentiometers used in analog system are replaced by a multiplier.

EXHIBIT 1.12

GENERALIZED DIGITAL TELEVISION RECEIVER

A generalized digital television block diagram is presented in exhibit (1.13). In contrast to the video processing in the generalized digital television, exhibit (1.14) shows an analog television with a digital subsection which was added to provide 'digital' features.

Although not yet practical the display stage could be digitized when digital displays built of liquid crystal display (LCD) devices become available.

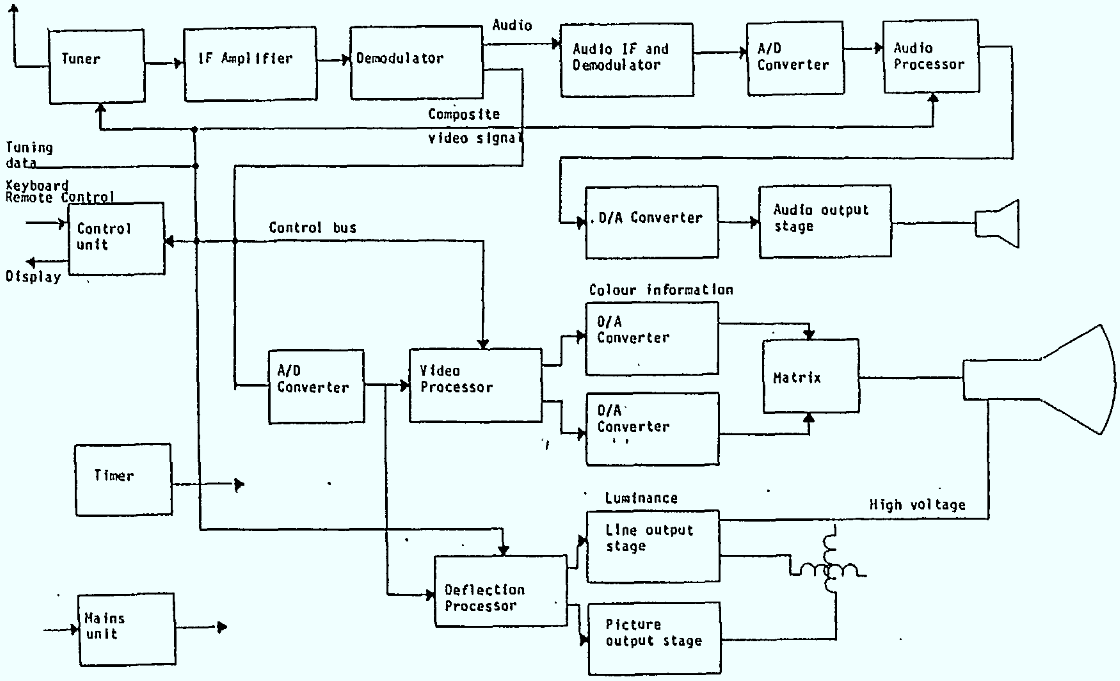


EXHIBIT 1.13

BLOCK DIAGRAM OF A DIGITAL COLOUR TELEVISION

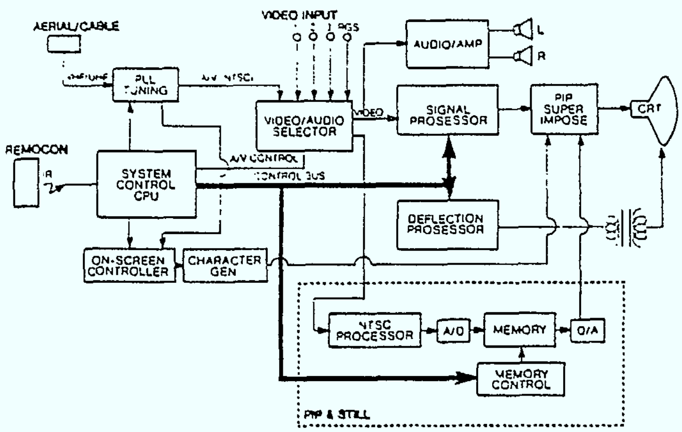


EXHIBIT 1.14 TELEVISION RECEIVER WITH DIGITAL PIP

Tuner, IF and Video Detector

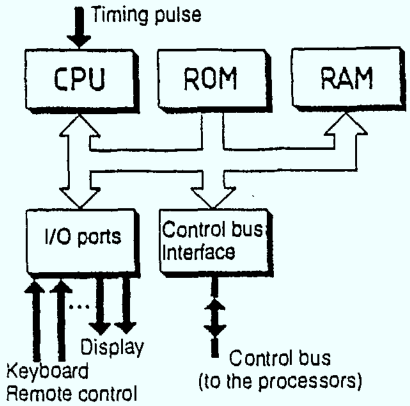
Referring to exhibit (1.13) the tuner, IF and video detector use conventional analog circuits and provide the same functionality as do the tuner, IF and video detector in a conventional analog television.

Analog to Digital Converter

The output of the video demodulator is digitized by the A/D converter and from this point all further video processing is accomplished in the digital domain. The sampling rate of the A/D is controlled by the system timer which obtains its reference signals from the digitized colour burst and horizontal synchronization pulses.

Control Unit

The control unit for the digital processing is shown in exhibit (1.15). It is responsible for transmitting operational settings such as: user selected volume level, brightness, contrast, hue and saturation to the video processing unit.



Control unit: It receives its data from the user controls or from the internal program

EXHIBIT 1.15

The control unit controls information stored in fixed memory (ROM) such as: digital filter coefficients, factory picture parameter settings, factory alignment information, A/D sampling rate and video processing rate. Other information under the control units supervision which is stored in RAM includes current operational settings such as: condition of the CRT, CRT aging, aging and drift of the discrete television circuitry. In response to changes in the measured operational parameters the control unit recalculates present control parameters and coefficients for the various signal processing blocks. Communication between the various blocks of digital circuitry is supervised by the control unit.

Video Processor

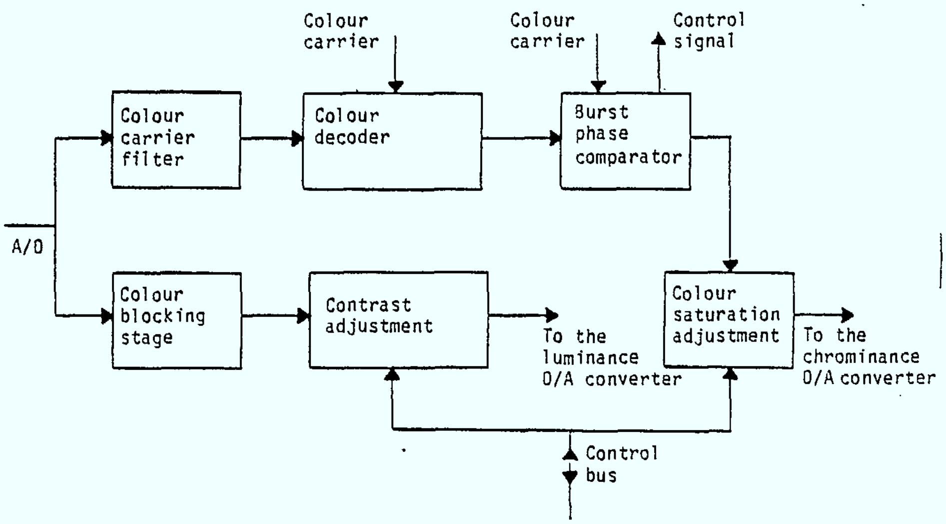
The digital video processing section shown in exhibit (1.16) provides many of the television receivers basic functions:

a) regeneration of the colour burst reference signal

b) separation of the chrominance and luminance information by digital comb filtering

c) luminance signal processing to provide signal peaking for edge enhancement and maximizing contrast.

d) demodulation of the chrominance I and Q signals on the colour subcarrier



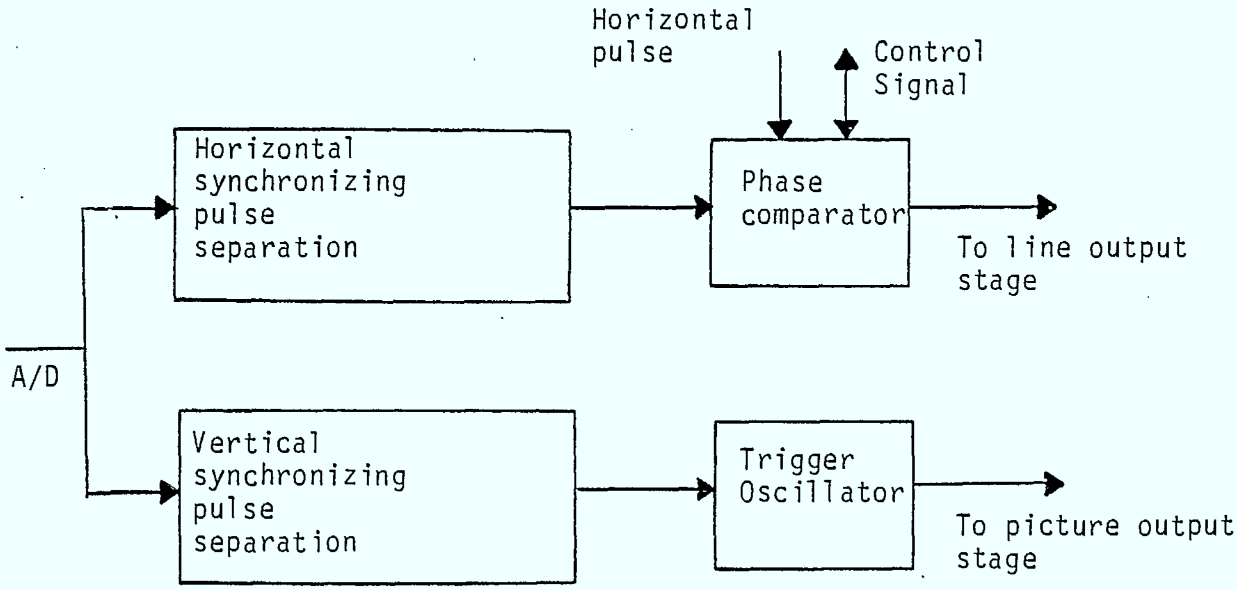
Video Processor: This processes the video and the colour signal.

EXHIBIT 1.16

The colour reference signal is maintained at constant amplitude and phase so that colour errors are not generated in the picture during the colour subcarrier demodulation process. The saturation of the displayed colours is adjusted and the hue is constantly corrected to correspond with the references provided by the source signal. The video processing can also digitally delay the luminance or chrominance signals to minimize signal imperfections or picture distortions due to unequal transmission delays.

Deflection Processor

The deflection processor shown in exhibit (1.17) clamps the incoming video to a stable level and separates the required timing signals to provide horizontal and vertical timing of the raster scanning process. If the horizonal synchronizing pulses are distorted the deflection processor can derive synchronizing information by dividing the colour burst reference frequency down to the synchronizing pulse rate. It is this capability that causes digital television receivers to be potential descramblers of sync suppressed pay TV signals. This alternative method of generating synchronizing signals is only feasible if the colour burst frequency and horizonal synchronizing pulse rate have a constant relationship. Attempting to generate horizontal sync from colour burst if this relationship is not fixed will result in an unstable picture. The deflection processor is able to dynamically correct for non-linearity in the CRT display process.



Deflection Processor: Free-running or colour locked operation is possible.

EXHIBIT 1.17

Digital to Analog Converter

Digital to analog converters are used to generate analog luminance and colour signals from a sequence of digitized video data. Once in the analog domain the chrominance I and Q signals are combined (matrixed) with the luminance signal to form the red, green and blue (RGB) CRT drive signals.

WHY DIGITAL TV IS BETTER

The advantages of the new technology are reduced parts count, elimination of manufacturing tolerances, elimination of performance degradation as a result of component parameter drift, and automatic computer controlled alignment.

In addition, digital processing of video facilitates the implementation of picture quality improvements such as reduced false colour rainbows through the use of digital comb filtering, and sequential scan with line interpolation to reduce interline flicker and line structure.

As well, additional features such as freeze frame with noise reduction and zoom can be implemented more easily once the video signal is digitized. These features lend themselves more towards VCR applications. A digital television chip set produced by ITT provides a teletext option which can be implemented at minimal incremental cost in TV receivers.

In conversation with representatives of several TV sets manufacturers, no one attribute of the new technology alone is sufficient to drive the wholesale change from analog to digital processing. It will take the combined factors of features, improved performance and lower manufacturing costs to convince consumer electronics companies to embrace digital signal processing.

A summary of the advances facilitated by digital video processing is given in Table 1.1.

There are some natural applications for digital video. In special effects VCRs where high quality freeze frame reproduction is desired, the use of a digital frame store can compete economically with multiple head analog mechanisms and can produce a superior quality picture. Also in top-of-the-line TV receivers, digital comb filters offer superior performance to their analog counterparts.

As TV screen sizes become larger, some of the limitations of NTSC become more noticeable. In particular horizontal resolution, line structure and interline flicker become more dominant. It is these factors which will likely drive the development and use of improved digital processing techniques.

TABLE 1.1 OBJECTIVES OF DIGITIZATION OF COLOUR TV

1. Improvement of basic functions of colour TV	1) Motion adaptive separation of Y/C 2) Edge enhancement 3) Impulse noise suppression 4) Flicker reduction 5) Reduced noise 6) Ghost cancellation
2. Providing additional functions	Special reproduction of image by employing field memory 1) Still picture 2) Monitor in TV 3) Multipicture 4) Strobomultipicture 5) Zoom 6) Hard copy
3. Rationalization in production	1) Parts saving, lower cost 2) No adjustments 3) Rationalization in system . Multisystem for NTSC/PAL/SECAM . Reasonable interface to teletext; video text, computer 4) Reliability of circuit

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2

CHAPTER 2

INDUSTRIAL IMPLEMENTATION OF DIGITAL TELEVISION TECHNOLOGY

TABLE OF CONTENTS

DIGITAL TECHNOLOGY IN CONSUMER TELEVISION RECEIVERS

Judging by new television products, several television manufacturers seem to be leading the industry in the application of digital technology to television receivers. Television receivers marketed by various manufacturers have differing degrees of video signal digitization and digital processing. The level of digital processing in a marketed product cannot be used to imply the degree of a company's activity or lack of activity in digital television research and development.

Product introductions made by television receiver manufacturers are driven by perceived consumer preferences in television products, not by the latest developments in television technology.

Consumers generally purchase a television receiver on a cost to benefit criterion. The cost of the television receiver is balanced against benefits and features such as: clarity of picture, better colour representation, improved picture resolution, receiver screen size, anticipated performance in the home - elimination of picture artifacts, sound quality, ease of use - simple controls and minimal required adjustment, remote control of picture parameters, multiple source switching, compatibility with VCR or cable, ability to view two programs simultaneously, and actual physical appearance of the receiver. If a consumer cannot justify a higher cost by features that have benefits readily apparent to him, he will choose a lower cost unit without those features.

Television manufacturers that have marketed DTV's with limited digital functions have done so because of cost versus performance and marketability considerations. At the present time full digital processing is more costly than analog processing for the basic television functions because of the extra digital/analog conversion and multiplier functions that are required for digital processing. The addition of other desirable features is made much easier and less costly when working with a digital television chassis. Such things as picture-in-picture, teletext decoder, on screen display of controls are all cheaper to add to a DTV compared with analog chassis. To date, therefore, it has been economically advantageous to implement digital technology in the top-of-line sets which have these features. Differences in technology between digital and conventional television mean that major changes in receiver manufacturing are required for DTV, and subsequently the transition is being made gradually. In the end, consumers dictate the salability of a product, so manufacturers want to gauge groups of digital features before going ahead with the marketing of advanced digital technology. Another reason for the gradual introduction of DTV is that manufactures do not want to overwhelm the average consumer by manufacturing a product for which the market is not ready.

In a number of television receivers, all the video processing and control functions except for RGB conversion and display are done in the digital domain. In contrast, other television receivers claimed by manufacturers to be 'digital' do all the video processing in the analog domain and only digitize the video signal to provide special digital features.

Digitization of the video signal can be the first step towards digital processing to reduce picture imperfections and to mask signal problems.

Signal improvement has not been a driving force for the introduction of digital processing because either many picture imperfections are not readily identifiable by the average consumer or, if observed, are accepted as a minor annoyance not worth the extra expense of television receivers with digital processing.

Application of Digital Technology to Television Receivers

Digital television receivers on the market in Canada have several features made possible by video signal digitization and processing, these features are:

1) Picture in a Picture (PIP)
2) Still PIP (SPIP)
3) Multiple PIPs (MPIP)
4) Digital comb filtering
5) On-screen display of picture parameters
6) Ability to choose factory settings of picture parameters
7) Ability to control receiver performance to compensate for picture tube aging
8) Picture improvement by processing
9) Non-interlaced picture scanning.

PICTURE IN A PICTURE FEATURE

Of all the television receiver digital features presently being marketed, the Picture in a Picture or PIP feature is the most obvious result of video digitization. The PIP feature is a small inset picture which is usually about 1/9 the area of the television screen. A PIP is used to display a second picture source on a portion of the screen while the main picture is viewed on the remainder of the screen. Television receivers from some manufacturers allow the PIP to be enlarged to one quarter of the screen or to be reduced to 1/16 of the screen. Generally, the position of the PIP can be changed to any one of the four corners of the television screen.

At present, two different methods are used to generate the PIP feature. In both methods the video signal destined for the PIP circuitry is first decoded in order to separate colour (chrominance) and brightness (luminance) information. This may occur either before the signal is digitized by an analog to digital (A/D) converter, or after digitization. The digitized video is subsampled and filtered to reduce the video information and the picture size to a ninth of the original size. In a fully digital television the reduced picture information is combined (overlaid) with the digitized main picture before it is sent to the digital to analog (D/A) converter. At the D/A converter, the combined video signal is converted from a digital signal to the analog signal required for display proposes. In an analog television receiver with a digital PIP subsystem, the digitized PIP video is first converted to an analog signal before it is combined with the analog main picture information for display.

SPIP

The Still PIP feature gives the television receiver the capability to 'freeze' the action in the inset PIP. The Still PIP feature is best created in the digital domain and is the primary reason for generating a digital PIP rather than an analog PIP. In order to provide the Still PIP feature, the compressed digital video data is stored in memory and used to repeatedly generate a Still PIP picture. To minimize the amount of memory required to implement the Still PIP, the compressed video data is reduced further before storage in memory. The Still PIP picture quality as compared with that of the main picture is directly related to the amount of video data reduction that occurs before the data is stored in memory. Generally, the digitization and storage of video for the Still PIP function is limited to six bits, which means the PIP picture will be about three times as noisy (fuzzy) as the main picture. The video data reduction results in picture errors which are visible as a mosaic or block like appearance of the picture and cause unstable colour definition.

MPIP

The Multiple PIP feature, an extension of the Still PIP, allows the display of four to six PIPs on the television screen from either single or multiple sources. A Still PIP (SPIP) capability is required to produce the Multiple PIP (MPIP) feature because only one PIP can contain an active picture at any given time. The MPIP can be used to offer a 'strobe' effect that freezes three or more sequential video 'snapshots' (frames) from a video source and displays them in the MPIP locations.

The PIP feature is useful when simultaneous viewing of two different video sources is required. If the television is equipped with two tuners, two different television channels can be viewed, otherwise a separate tuner unit such as a VCR is required. The MPIP and SPIP are handy when comparing different video sources or different video frames from a single source during video tape editing.

DIGITAL COMB FILTER

A comb filter serves to reduce certain types of television artifacts or distortions and also provides a sharper and crisper picture by increasing the horizontal resolution. In fully digital televisions, where the video processing is digital, only a minimal amount of additional memory is required to implement a digital comb filter. The basic requirement to implement a comb filter is the ability to delay the incoming video by one scanning line time.

If the video has been previously digitized to provide other features, the comb filter function can be easily and inexpensively implemented.

In order to comb filter analog video signals, typically less reliable and more expensive components are needed.

ON-SCREEN DISPLAY OF PICTURE PARAMETERS

Digital technology simplifies on screen/display and control of picture parameters such as tint, colour, brightness, and contrast. The digitized video signal passes through various processing units which can adjust picture parameters in predefined increments. Since control of video parameters is digitized, preset factory levels of these parameters can be stored in memory and used for instant alignment. Performance parameters integral to the television's operation are automatically updated to compensate for component temperature drifts and set aging. Digital control of a television's operational parameters is a benefit because consumers can instantly and remotely adjust picture parameters within factory preset limits and need not be concerned about loss of picture quality with set aging.

NOISE REDUCTION

The amount of noise observable in a picture can be minimized by a form of picture averaging, using digital video processing. In presently available television receivers, only a small amount of the potential for noise reduction by digital processing is utilized. Existing digital television receivers eliminate noise by two methods, either small amplitude signals characteristic of a random noise level are reduced or large amplitude noise spikes characteristic of impulse noise are clipped. In addition to reducing noise, the reduction of small amplitude video signals tends to mask fine detail in a picture. An example of this masking effect is the loss of detail on images showing individual people in a picture of a crowd.

NON-INTERLACED PICTURE SCANNING

A method for possible picture improvement presently marketed using digital processing, is the reduction of scanning line flicker. Scanning line flicker is most noticeable in larger screen televisions and projection sets. The spaces between the scanning lines change position with successive pictures (fields) and create scanning line flicker.

The reduction of scanning line flicker is made possible by double scan processing in which the digital television displays each scanning line twice, effectively doubling the number of scanning lines in a picture.

As the number of scanning lines in a picture is doubled, the spaces on the screen between successive scan lines in a field are filled in. In order to produce a double scan picture, the television receiver must digitize each line of the video signal and store it in memory. The digitized video is retrieved from memory and sent at double the conventional scanning rate, twice in succession, to the D/A where it is converted to an analog display signal. While both scanning lines of information are retrieved from a first memory register and displayed, the next incoming line of information is stored in a second memory register, then the process is repeated using data in the second memory for display.

In contrast to digital processing that provides viewing features which can not improve the picture, double scanning makes it possible to theoretically improve on the shortcomings of the conventional display process and is a step towards progressive scan television.

PROBLEMS ASSOCIATED WITH THE INTRODUCTION OF DTV

When connecting a digital television to a CATV delivery system, the most apparent interface problem involves the descrambler or decoder.

Digital televisions with dual tuners used to supply separate signals to the PIP and main screen cannot tune to any CATV channels except for the descrambler's single output channel. The descramblers output is generally fixed at channel 3 so the television tuner remote control and any dual tuner systems become inoperative. This is not a problem exclusive to digital televisions as it occurs to all televisions with special feature tuners or dual tuners.

Most digital television manufacturers have tried to address this problem, and their solution is to provide two remotely switchable RF inputs on the television. The two RF inputs allow the consumer to connect his descrambler to one input and the CATV feed to the other input. While viewing signals from the CATV input the consumer can utilize the television receiver's features including dual tuners and PIP functions. By remotely switching to the descrambler RF input the consumer can view premium scrambled channels.

Signal impairments caused by the CATV delivery system become more evident in pictures displayed by the larger screens characteristic of DTV's, but again large screen analog televisions suffer form the same problems.

The potential for improving impaired signals received by a DTV is much greater than for conventional analog televisions. Digital processing using full picture (field) memory and adaptive motion detection and filtering algorithms has been demonstrated to be capable of reducing the perceptibility of picture impairments. Unfortunately little of this potential is embodied in the DTV's presently being marketed because of the cost of memory and processing circuitry.

As the cost of implementing digital storage and processing drops and consumers grow to expect better quality pictures the additional cost of expanded digital processing in the DTV will become acceptable.

Some digital processing such as comb filtering is most beneficial when it is complemented by television signal processing at the point of origin.

Is DTV Required for New 'Digital' Features

Not all of the television features marketed as 'Digital TV' features require digital processing to obtain. Only the features which require storage of video information such as SPIP and double scan cannot be implemented using conventional analog television circuitry. The PIP feature can be and has been implemented entirely in the analog domain, but in fact many so called DTV's are using digital processing to provide a better PIP feature while the main picture is still processed in the analog domain. While a comb filter function can be accomplished using analog circuitry, it requires minimal additional circuitry and is more precise when implemented with digital circuitry. For a television receiver to provide a double scan picture the video signal must be digitized, stored in memory and processed to double the display scan rate. These hardware requirements for the various features are summarized in Table (2.1).

TABLE 2.1

DIGITAL TECHNOLOGY REQUIREMENTS

Feature	Digital Hardware	Analog Equivalent
Comb Filter	line memory	glass delay line
Enhanced Comb Filter	2 line memory	none
Still PIP	256 KBit memory	none
Multiple PIP (4)	1 MBit memory	none
Noise Reduction	1.5 MBit field memory	none
Progressive Scan Display	1.5 MBit field memory	none
Freeze Frame	2.5 MBit frame memory	none

MANUFACTURERS' DIGITAL TELEVISION PRODUCTS

At present, four digital television manufacturers are marketing a total of five different DTV receivers in Canada. Of these four manufactures, three; NEC, Sony and Toshiba are off-shore and one, Zenith is a North American manufacture. Toshiba was the first television manufacture to successfully market a fully digital television receiver in Canada. The Toshiba DTV was offered in 1985 almost 18 months before competitors DTV's became available in Canada. When the Toshiba DTV was marketed other manufactures had DTV prototypes but no product on the North American market. Before the Toshiba DTV was marketed ITT had introduced in Europe a DTV based on their newly developed DTV chip set which was also a primary building block in the Toshiba DTV.

To ascertain the number and type of digital television products being marketed in Canada fifteen television manufacturers, six in the US, one in Canada and nine off-shore companies were polled. The expected marketing plans of these companies as related to DTV's are shown in Table (2.2). Two of the fifteen manufacturers not presently marketing DTV's in Canada plan to do so in late 1987 or early 1988.

It appears that a much greater percentage of the Japanese manufacturers are interested in testing consumers reactions to DTV and hastening the evolution of conventional televisions to DTV.

TABLE 2.2

CROSS-SECTION OF DIGITAL TELEVISION INTRODUCTION
BY MANUFACTURING COMPANY

Company	Presently Marketing a DTV in Canada	Planned Future Intro of DTV	North American Companies
NEC	Yes	Yes	No
Sony	Yes	--	No
Toshiba	Yes	Yes	No
Mitsubishi	No	Yes	No
Zenith	Yes	Yes	Yes
Hitachi	No	Yes	No
RCA	No	No	Yes
Sharp	No	No	No
Panasonic	No	No	No
ITT	No	--	No
Telefunken	No	No	No
Proton	No	Yes	Yes
Electrohome	No	No	Yes

Table (2.3) presents a break down of the features for the five DTV units presently marketed in Canada and the additional DTV units that are expected to be introduced to the Canadian market in 1987.

Generally the prices for the DTVs are around $2,000 CDN which supports the claim that DTV units are targeted toward the high end television receiver market.

The unit price places the DTV's in a cost/benefit position where the consumer must perceive a substantial improvement in receiver performance and usefulness of features over conventional televisions before they are able to justify the cost.

All of the DTV's recently introduced have large 'square flat' screens with diagonal dimensions of 26 to 29 inches to help increase the perceived value of the unit. Everyone of the DTV units has the PIP feature with most units also providing the SPIP feature.

The PIP and SPIP features are the major digital features used to market a DTV unit and differentiate it from conventional televisions.

A majority of the DTV units presently available are full digital televisions with all video signals being digitized and digitally processed. The remaining DTV's have analog video processing in the main signal path and reserve digital processing for only the PIP function. The advantages of DTV such as: a lower parts count, less required circuit adjustment, less critical tolerances of discrete parts and performance parameter programmability are not available to this latter category.

TABLE 2.3
CROSS-SECTION OF DIGITAL TELEVISION PRODUCTS

FEATURES	EXISTING MODELS NEC DT-2680	Sony KV-2786	Zenith SC2791	Toshiba CX2897	FUTURE MODELS Toshiba CX3087	Hitachi TT7500	Hitachi CT4275	Multi-Vision 3.1
Price CDN$	2110.00	2499.00	1725.00	1800.00	2100.00	4400.00	2800.00	670.00
Screen Diagonal	26"	27"	27"	28"	30"	33"	42"	----
Square Flat Screen	Yes	Yes	Yes	Yes	Yes	Yes	Rear Proj.	----
PIP	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
MPIP	Yes	Yes	Yes	Yes	Yes	No	No	Yes
SPIP	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Strobe	Yes	Yes	----	No	Yes	No	No	No
Total # of PIP	4	4	4	1	4	1	1	4
RGB Input	Yes	Yes	Yes	Yes	----	----	----	No
Video Ports In/Out	3/2	3/1	2/1	2/1	2/1	2/1	2/1	2/1
Switchable RF Port	2	2	----	2	2	2	2	2
Super VHS Ports	No	No	No	No	No	Yes	Yes	No
Full DTV	Yes	No	Yes	Yes	Yes	Yes	Yes	No
DTV COMB Filter	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Horizontal Resolution	500	480	400	----	600	600	----	----
Noise Reduce Circuit	Minimal	Minimal	Minimal	Minimal	Minimal	Minimal	Minimal	----
Digital Picture Control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Double Scan	No	No	No	Yes	No	No	No	No
Teletext	No	No	Yes	No	No	No	No	----
# of Tuners	1	2	1	1	1	2	2	2
Audio Ports In/Out	3/3	2/3	2/2	2/2	2/2	2/2	2/2	2/1
Stereo	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Surround Sound	No	No	No	No	No	Yes	Yes	No
Unified Remote	No	No	----	Yes	Yes	----	----	No

Over half of the DTV's presently available in Canada depend on components of the ITT digital chip set.

Both Toshiba and Zenith have used ITT DTV chips in their DTV receivers in order to quickly get their product to market . Once they had a DTV in their product line Toshiba developed their own DTV chip set which has been built into their latest DTV product. Other manufactures such as Sony and NEC decided not to market a DTV product until they had developed their own DTV integrated circuits and did not have to rely on ITT.

All of the DTV sets have full on-screen display and control of the picture parameters which is an improvement over the simple channel number or signal source display that has been marketed for several years.

Noise reduction and video processing in the DTV's are limited to signal enhancements similar to those that have been available in conventional analog television receivers.

The DTV's being marketed are high end sets that have non-digital features added to increase the DTV's value as perceived by the customer. These additional features include CATV compatible synthesized tuners, larger screens and stereo sound. The capability to switch video and RF signals is a common feature since the potential purchaser of a high end DTV will likely have one or more other video components.

One markedly different DTV, which is being marketed by Toshiba, is the CS2897 double scan DTV. The Toshiba CS2897 attempts to eliminate horizontal line flicker and to improve the displayed picture. A comparison between the Toshiba CS2897 DTV 28" and the Sony KV27HFR 28" analog television allowed the qualitative evaluation of the CX2897's performance characteristics. Using a laser disk video source the double scan DTV quite noticeably had less detail than the conventional receiver.

The most annoying characteristic of the double scan set was the way it distorted moving objects in the displayed picture.

The object in motion, or background when panning, appeared to break up or have a mosaic pattern effect. Double scanning causes picture distortion in the diagonal direction which shows up as the described picture artifacts. When a detailed line pattern was shown on the double scan DTV the resulting moire patterns were more noticeable on the Toshiba double scan DTV. The Toshiba CX2897 displayed 6% less picture on the screen, in other words the over scan on the CX2897 provided less viewable picture information. There was no improvement observed in the Toshiba set in terms of horizontal line flicker reduction.

The diagonal distortion of moving objects in the double scan picture was a major complaint with a Sony developed double scan DTV which was not a successful market introduction. It will be interesting to see how the Toshiba DTV fares and whether the introduction of further DTV's by Toshiba will be affected by its CX2897's market acceptance.

Trends in Marketing Digital Video Technology

Several companies involved in manufacturing and marketing digital television and video products have agreed that the introduction of digital technology follows a general trend. The progression of digital video processing and digital editing/display features is from commercial editing and broadcast equipment, to consumer VCRs and lastly to consumer televisions. As a general rule the market introduction of digital features in DTV has usually been preceded by their appearance in top of the line consumer VCR's.

FUTURE DIGITAL TELEVISION PRODUCTS

North American Philips (NAP), Hitachi and Toshiba are planning to introduce new DTV products to Canada in late 1987 or early 1988. NEC is in the process of marketing the DT2680 DTV and has no plans for further DTV product introductions in 1987. NEC has developed a non-interlaced scan television that they believe will lead the way for the marketing of enhanced definition television (EDTV) features in their products. The NEC non-interlaced scan television has not been marketed as yet, possibly they are monitoring the success of Toshiba's double scan DTV. Further developments in LCD technology lead NEC to expect flat screen DTVs in the future.

Toshiba is planning to introduce an upgraded version of the CX2094 using their proprietary DTV chip set in 1987.

Hitachi expects consumers will have no problem differentiating its new TT7500 DTV from the half dozen existing DTV's on the market. The TT7500 boasts a 33" 'square flat' screen with full digital processing of the composite video signal. This new DTV has the PIP feature without SPIP or MPIP because of the reasoning that when interfacing the DTV with a digital VCR, such as Hitachi's VT2350, the special features will be provided by the VCR.

Hitachi plans to concentrate on providing a large screen DTV with superior picture performance and to build the SPIP, MPIP, freeze frame and other display features into their top of the line digital VCR's.

The TT7500 achieves a horizontal resolution of 600 lines by using a fine pitch CRT, wide bandwidth video amplification, and digital comb filtering.

The TT7500 is an excellent monitor for the newly developed Super-VHS or ED-Beta VCR as a signal source.

It is expected that the next generation of DTV's will be fully digital with memory capabilities, to allow the implementation of noise reduction circuitry and signal enhancement processes using inter-field and intra-field interpolation.

If the introduction of digital processing functions in VCRs indeed precedes similar introduction in DTVs then noise reduction processing in NEC's new DX-1000U should soon appear in their DTVs. The DX-1000U noise reduction circuitry uses 256 Kbyte RAM memory chips to store a field of digitized video luminance information which is combined with the next luminance field and used to update memory and form the analog video output. The end result of field storage and digital processing is a reduction in playback video noise by up to 9 dB.

Larger display screens will benefit from digital video processing to eliminate picture artifacts such as poor colour separation, low resolution, interlace flicker and poor signal to noise.

FORECAST OF DIGITAL TELEVISION PENETRATION

Digital Television is a new product, because of this it is difficult for the DTV manufactures or market research agencies to generate figures for market penetration of DTV. However there have been surveys done to determine consumer response to DTV. These can provide some general indications of DTV penetration.

A market research firm, MacKintosh International estimates that by 1992 up to 40% of colour television sets sold will use digital circuitry.[1]

This figure includes televisions with minimal digital circuitry so the actual penetration estimate figure for true DTV receiver is a fraction of the 40%.

One method of estimating the penetration of DTV is to assume that future demand of DTV's is related to the present sales figures of stereo sound or top of the line television receivers. The argument supporting this relationship is that consumers who are interested in upgrading their television sound quality will also be interested in upgrading their picture quality or adding additional useful DTV features. Potentially, people who are willing to pay for top of the line television sets will also be willing to pay for new DTV features and improved performance. In the United States in 1985 the sale of stereo television was 10% of total colour television sales, a penetration of approximately 1%. If DTV sales follow the penetration figures for stereo television the sale of DTV needs to more than double each year from 1% in 1987 to reach 40% penetration in 1992. Figures available for 1984 and 1985 indicate that sales of stereo television has doubled in this time period.

Information available on consumer interest in DTV and figures for sale of new television features indicate that consumers are interested in purchasing DTV's but penetration figures will not reach 10% until 1990.

CONCLUSIONS

There are several problems DTV manufacturers must address in order to spur DTV sales.

Consumer frustration with complex DTV (or analog TV) and VCR to descrambler interfaces must be alleviated.

The use of dual RF input ports on DTVs is a good first step toward reducing consumer annoyance. DTVs will need to incorporate more digital processing to provide a noticeably improved picture on large screen DTVs while generally working with poor quality source signals.

There are many new features being offered on DTVs such as increased resolution, improved colour definition, reduction of chrominance/luminance artifacts, constant set performance with aging and set reliability.

These features are not readily apparent to the consumer and must be augmented by special effect features to make the difference between conventional analog TVs and DTV 'jump out' at the consumer.

The DTVs on the Canadian market represent the first step in introducing DTVs to the consumer, gauging the marketability of various 'digital' features, gaining DTV manufacturing experience in DTVs and providing a base on which to market further digital developments that will improve the consumers viewing pleasure and help expand the market of television products.

For the present, DTV penetration is very limited, although it is not unreasonable to expect it to follow the penetration of stereo sound and begin to double annually.

DTV developments and performance improvements such as digital PIP features, programmable set alignment and noise reduction are being constantly introduced, and DTV will eventually evolve to the point where it achieves the market position conventional colour TV has held for years.

References

[1] Electronic Market Data Book 1986

Electronic Industries Association
June 1986, pages 5-16

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CHAPTER 3

CATV IMPLICATIONS

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CATV IMPLICATIONS

The introduction of digital television signal processing and television sets with digital features such as picture-in-picture (PIP) has spawned a number of issues to be considered by the CATV industry. Among these issues, the implications on Consumer electronic interconnect, scrambling security, alternative scrambling techniques and CATV system performance are discussed below.

CONSUMER ELECTRONIC INTERCONNECT

With the advent of pay television and the descrambling equipment associated with it, the CATV industry has become a participant in the distribution of consumer electronic equipment.

The CATV operator is required to connect descrambling equipment to the subscriber's television set(s) and/or VCR(s) in such a way that the subscriber can view and/or record the programs when and as he desires.

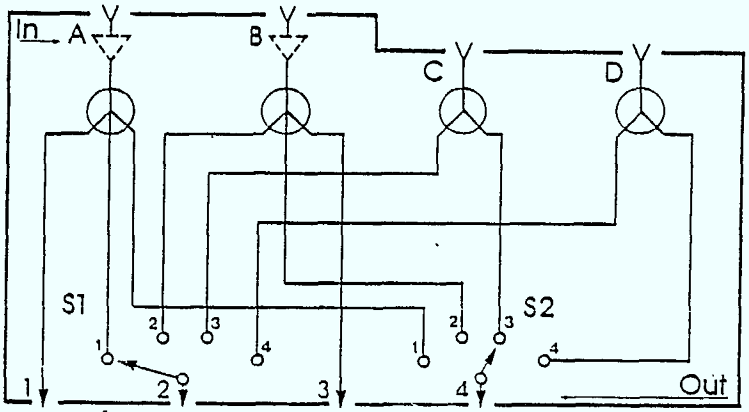
The connection of a combination converter/descrambler in the home where only a conventional, single tuner analog TV set is found, is a straight forward exercise. The subscriber uses his converter to select channels and potentially control volume, with the television set fixed tuned to the converter output channel, typically channel 2, 3 or 4. It is preferable that the television set automatically tune to the converter output channel on power-up so that the on/off switch on the converter/ descrambler can be used to turn the TV set on and off without requiring any interaction with the television set.

The addition of a VCR presents a problem. A converter/ descrambler can only decode one television channel at a time as it only has one tuner feeding one output channel and does not pass all CATV channels through for access by other equipment. On the other hand, VCRs can often tune to any channel distributed by the CATV drop cable and pass on all channels to a converter/descrambler feeding the television receiver. The problem occurs when VCRs are required to use the decoder/ descrambler to gain access to a pay-TV program. In this case the converter/descrambler must be placed between the CATV drop cable and the VCR which means that the only channel passed through to the television receiver is the channel being recorded, which is often not what is required.

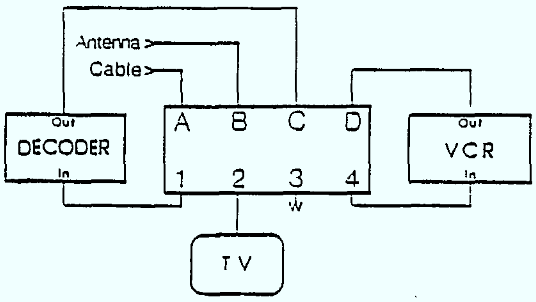
The converter/descrambler must be shared between the TV and the VCR as both equipments are equally likely to need the descrambling capabilities to view or record pay-TV programs.

This is most commonly achieved by means of a switch that can route the required television signal to the appropriate device as desired by the subscriber. In most cases, it is still possible to satisfy the subscribers' viewing choices by sharing one descrambler between the television set and the VCR, albeit accompanied by a loss of many of the remote control features and programming flexibility offered by the TV and VCR. In extreme cases, a second converter/descrambler may be added so both the VCR and TV set have a dedicated converter/descrambler connected to their input. Exhibit (3.1) illustrates a typical VCR-Decoder-Television hook-up. A full appreciation of the consumer interconnect problem may be obtained from Reference [7] which is a culmination of many man-hours effort by several members of the National Cable Television Association Engineering Committee. A large number of VCR - Decoder - Television connection configurations are presented. Finally, a programmable timer may be used in conjunction with the converter/descrambler connected to the VCR to restore full programmability for timed recording of all signals available on the CATV cable.

Functional Schematic



Connection Diagram



A	CABLE INPUT	SWITCH 1		VIEW
B	ANTENNA (OR EXT)		POS 1	CABLE
C	FROM DECODER OUTPUT		POS 2	ANTENNA
D	FROM VCR OUTPUT		POS 3	PREMIUM
1	CABLE TO DECODER		POS 4	TAPE
2	TO TV SET	SWITCH 2		RECORD
3	(not used)		POS 1	CABLE
4	TO VCR INPUT		POS 2	ANTENNA
			POS 3	PREMIUM
			POS 4	(not used)

EXHIBIT 3.1 UNIVERSAL VCR SWITCHER AND CONNECTION DIAGRAM

MULTIPORT INTERFACE

Technical people from both the traditional consumer electronics and CATV industries have analyzed the problems of consumer electronics interconnect.

They realized that the ideal way to solve the problem is to make pay TV descramblers part of the television set and VCR.

A joint EIA/NCTA engineering committee appointed a working group, known as R-4, to draft an interface standard that would allow any descrambler to be connected to any television set via a universal baseband connector. The converter portion of the converter/descrambler would be eliminated under this interface standard, as would any demodulator and modulator required for baseband descrambling.

The resulting descrambler would have no user controls and be inexpensive enough to warrant separate descramblers for each television and VCR used to receive pay television programming.

This interface has since been created and is known in the consumer electronics industry as Multiport and is defined in EIA IS-15 [1].

The Multiport interface allows for the transfer of scrambled and descrambled composite baseband video signals as well as special AGC and synchronization control signals between the host television or VCR and the descrambler. It also provides for flexible routing of audio signals to allow stereo decoding of BTSC signals by either the television or an external decoder. The interface also supports the optional carriage of RGB signals and allows for future functions using two as yet undefined data lines. Exhibit (3.2) illustrates a Multiport interface.

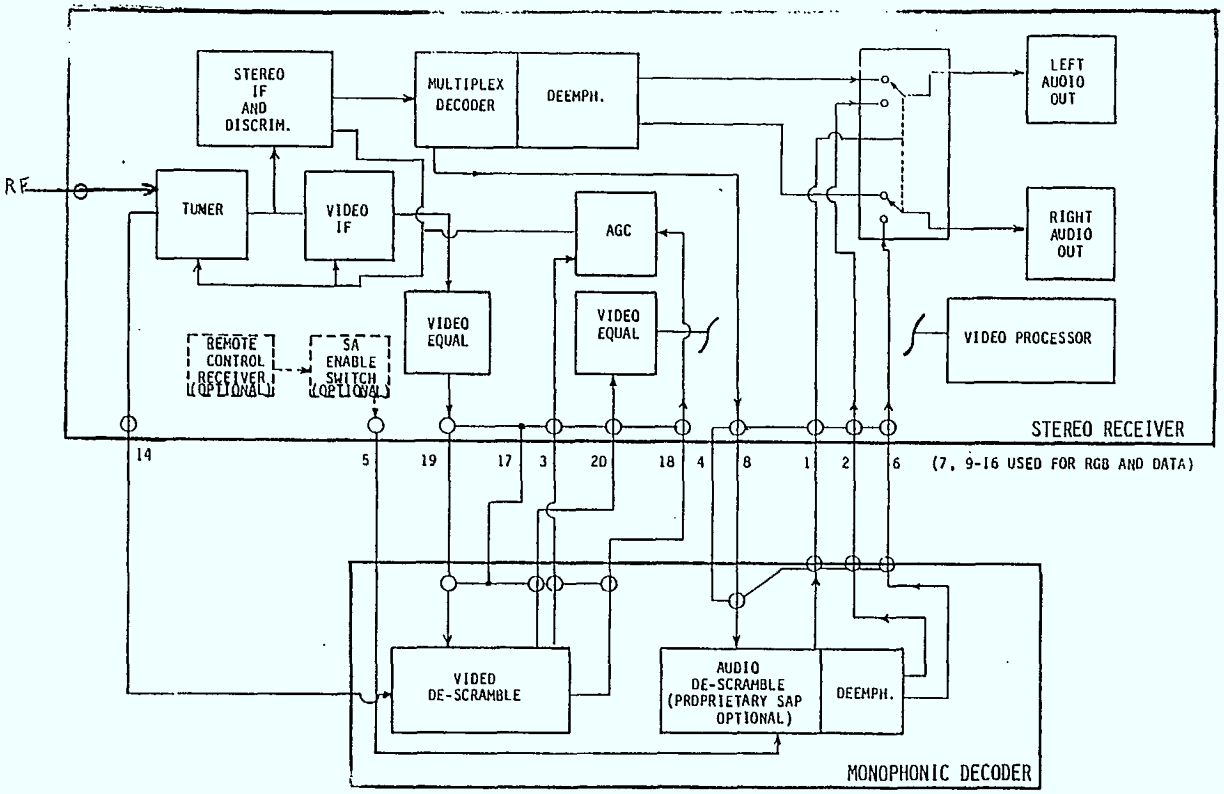
The recent introduction of digital video processing and PIP had not been anticipated during the development of the Multiport interface.

Initial products do not have the Multiport interface. Two potential problems of extending multiport to digital TV that can be readily identified are the dual channel tuning capability and the limited analog signal processing performed in some digital television sets.

It is common in televisions offering the PIP feature to have a second tuner to supply the inset picture.

It is essential, therefore, that such sets have a full complement of television signals available at the input connector rather than a single converter/descrambler output channel.

ANTENNA INPUT TO TUNER BLOCK



INTERFACE WITH STEREO RECEIVER AND MONOPHONIC DECODER

PIN NO.	FUNCTION	PIN NO.	FUNCTION
1	Audio	11	Green
	Select Function	12	Reserved
2	Audio Input (left)	13	RGB Ground
3	AGC Time Constant	14	Channel Change
4	Audio Ground		and Power
5	Second Audio		Indicator
	Program Select	15	Red
	Line	16	Fast Blanking
6	Audio Input (right)	17	Video Ground
7	Blue	18	Decoder
8	Audio Output		DRS
9	RGB Ground	19	Receiver Video
10	Reserved	20	Peripheral
			Video

EXHIBIT 3.2 MULTIPORT CONNECTOR INTERFACE

In a few cases, the second tuner may scan several channels, updating up to nine inset still pictures on each scan. In this application, the signal must stabilize quickly following each channel change to reduce the time required to complete each scan and hence maximize the refresh rate for the inset stills. The normal acquisition time for scrambled signals, sync suppression in particular, is 3 to 5 seconds which precludes rapid scanning, even if a Multiport interface was available for the PIP tuner. Currently, these sets do not have the Multiport interface and it is likely that only the main channel tuner would be equipped with a Multiport interface on future products.

In spite of the Multiport limitations, it offers the best short term solution to the problem of supplying descramblers to owners of sets equipped with the PIP feature.

Certainly without Multiport, new television products with PIP present a new challenge to the cable operator.

One potential solution is some form of drop and insert device that selectively tunes and descrambles a particular pay channel and then inserts it on to a vacant channel or the cable along with all the other signals.

This would allow one pay program to be viewed among the channels monitored on a PIP set. Devices to perform this function are not currently available, but their development should not be hampered by any technical obstacles.

A second solution available with a baseband descrambler is to connect a baseband output from the converter/descrambler to a baseband input on the PIP equipped television set. In this way, the subscriber views pay-TV by switching his set to the video input and simultaneously viewing any non-scrambled signal via the television tuner.

A second potential hurdle presented by digital television in connection with Multiport is the radically different architecture and signal processing. Multiport was designed and field tested based on a quasi-universal television chassis architecture. Familiar "rules of thumb" could be used to circumvent the subtle differences in the various manufacturers' products to arrive at a universal interface. The full impact of digital processing is unknown, but it may require modification of the interface specifications, particularly those related to AGC. The treatment of AGC was the most sensitive aspect of the Multiport design, so changes in how AGC is performed in digital television sets may have serious implications for the Multiport interface.

The Multiport interface specifies analog composite baseband video which exists at the demodulator output in digital television sets, so it is conceivable that the Multiport interface can be accommodated before the video is digitized in the set. Similarly, audio and RGB interfaces can be accommodated at the equivalent analog stages in the digital set. What is less clear is how the decoder restored sync and AGC time constant control signals will be accommodated. It would appear that special provisions will need to be made for Multiport signals at the design stage of digital sets, whereas in analog sets, the necessary hooks for Multiport were generally present as a matter of course.

The author is unaware of any digital television set with a Multiport interface in existence at the time of writing this report.

Digital processing aside, the implementation of Multiport in the market place will likely be cautious.

Only two set manufacturers (Matsushita and RCA) have publicly announced Multiport products for 1987.

However, an anonymous survey by the EIA indicated that up to 5 television receiver manufacturers and one VCR manufacturer had intended to offer Multiport in 1987. Several other television receiver manufacturers intend to introduce multiport products in 1988. In discussions with engineers in the various television manufacturing companies, it has been determined that designs to implement Multiport have been completed, so production can commence soon after the decision is made to introduce a Multiport product.

The slow implementation of Multiport is due in part to the traditional chicken and egg problem.

Without a generous population of Multiport pay television decoders in existence, the television manufacturers see little market incentive to introduce a product that is more expensive to produce and difficult to demonstrate as clearly superior. Cable operators on the other hand, are reluctant to make significant investments in Multiport decoders without an indication that appropriately equipped receivers will find their way into subscribers' homes. As indicated earlier, the advent of dual tuner televisions with PIP further reduces the effectiveness of Multiport as a universal cure. Cable operators can potentially affect this situation by purchasing larger quantities of Multiport descramblers. Slow growth in pay television subscriptions over the past year has resulted in minimal requirements for new descramblers. It is unlikely that many operators will be inclined to overextend themselves unduly by purchasing hardware they don't need in the hope that doing so will lead to Multiport compatible television sets being sold.

The Multiport connector may succeed provided that pay-TV penetration improves, cable operators support it and subscribers don't require descrambling of both main and PIP channels. In the meantime, it appears that the penetration of Multiport products will be very slow at the outset. The connector is likely to be restricted to top line sets where the cost penalty is less significant and the consumer more receptive to the idea of plugging a descrambler into his TV set, even if he can only watch pay-TV on the main picture of his PIP set. An optimistic forecast for the penetration of Multiport is given in Exhibit (3.3). It would seem that the impact of Multiport on the consumer electronic interconnect problem will not be apparent for several years, if ever.

Efforts by many CATV operators and equipment manufacturers are being focused on alternatives to traditional scrambling systems to secure pay television programs.

These ideas will be examined in the "Alternative Security Methods" section of this chapter. An analysis of the impact of digital television on current scrambling systems, particularly sync suppression is given next.

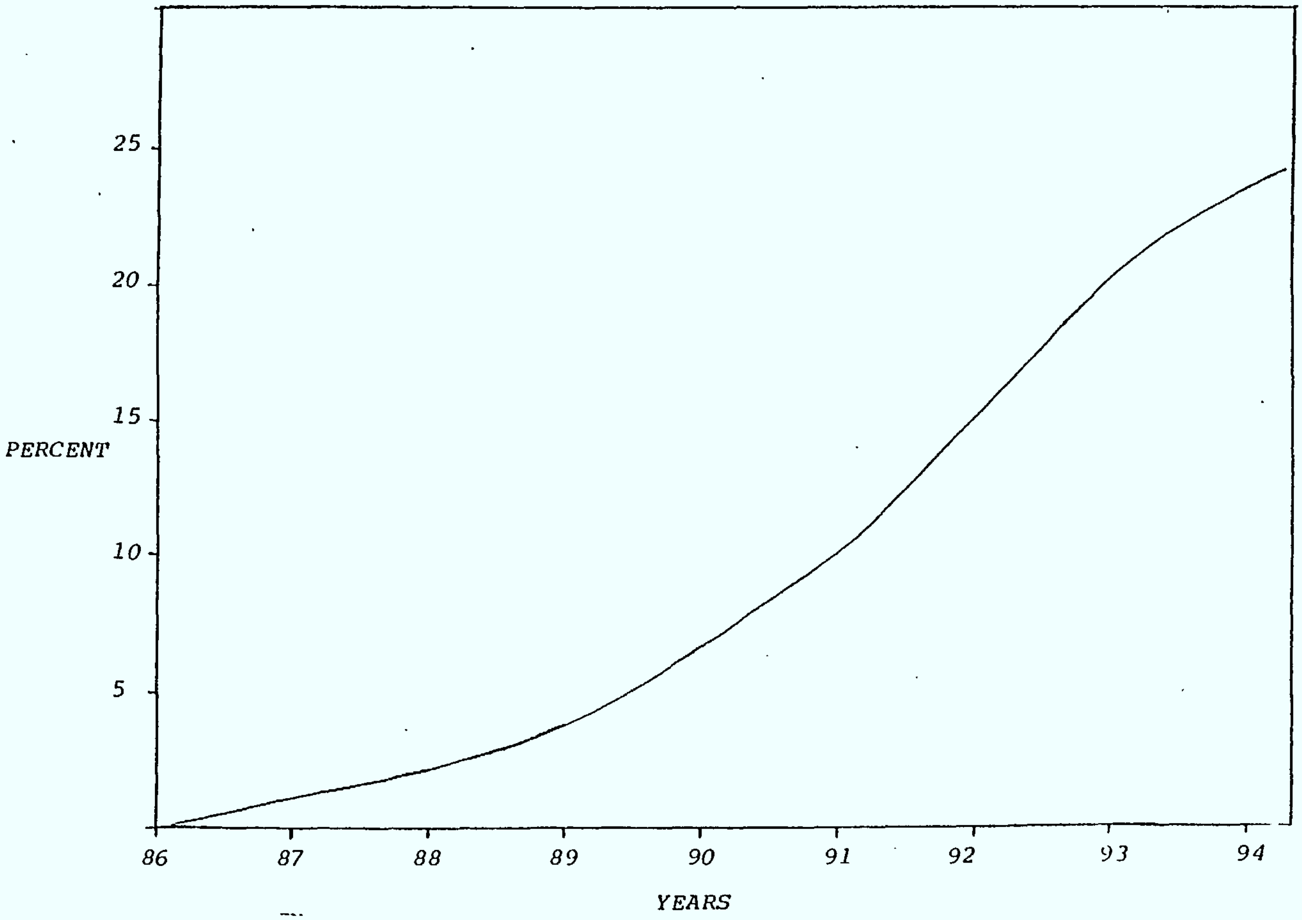


EXHIBIT 3.3 MULTIPORT PENETRATION OF CABLE TV HOUSEHOLDS

SCRAMBLING SECURITY IMPACT

The threat of defeating sync suppression scrambling techniques by signal processing in DTV sets depends on several factors, the most important being the make of the digital chip set used in the DTV. Sync suppression scrambling can be defeated if the DTV has a colour-lock mode and the ability to be forced into this mode. Also, one must be able to easily adjust the DTV viewing parameters to produce a viewable picture. The threat is increased if the DTV control bus is easily accessible. Another important factor is whether the DTV design is open or closed, in other words, the amount of descriptive information that is available for the DTV control circuitry. The design for the ITT chip set which all DTV's in North America are presently using, is very open because of the way ITT is marketing the chip set. In the future, it is expected that the Japanese manufacturers will use a closed design, making it more difficult to understand how the DTV generates its horizontal sync.

It has been demonstrated that a DTV can be used to decode video signals with sync suppression.

The resulting picture quality while viewable, is perceptibly degraded from a signal produced by authorized decoding. The ability to derive a viewable picture from a sync suppressed video source using TV circuitry is not exclusive to digital processing, it can be done using analog processing also.

The increasing improvement in television synchronizing systems in both analog and digital designs will make sync suppression unusable as a scrambling system within a few years.

The threat to sync suppression scrambling depends on the ease of modification of a DTV to force it to lock-up to a sync suppressed signal and produce a viewable picture.

The ease of modification depends on the existence of a colour burst lock-up mode in the DTV circuitry, the ease of access to the DTV control bus without hardware modifications, whether the DTV is an open or closed design and whether the manufacturer has provided the relevant commands in the DTV control program.

A letter outlining the concerns of the cable industry relative to signal security was sent to all TV set manufacturers.

It is hoped they will respond positively with set designs not easily amendable to descrambling sync suppression. A copy of this letter is contained in Appendix B, along with a full report in Appendix C describing the laboratory work on decoding sync suppression with a digital television set.

It was found that all investigated DTV's available in North America used the ITT digital chip set. The Toshiba DTV tested in the laboratory lended itself most readily to lock-up on sync suppressed video, the remaining DTV sets investigated required more extensive hardware and software modifications. Video inversion techniques require external correction of the video signal in combination with video input and output connections on the DTV host.

It also has been shown that it is possible to modify the video input signal to counteract the capability of unscrambling sync suppressed signals by defeating the colour-lock mode of the DTV.

This is most easily demonstrated by using a VCR to destroy the fixed relationship between the colour subcarrier frequency and the horizontal sync frequency. A black box to accomplish this process may be required to enhance sync suppression scrambling.

ALTERNATIVE SECURITY METHODS

In the foregoing discussions of consumer electronic interconnect implications, the special problems of digital televisions supporting PIP with dual tuners were described as well as the Multiport interface.

The problem of signal security for pay programming is at the root of the interconnect difficulties, as far as the cable operator is concerned.

It is a logical development, then, for those involved in the CATV industry to explore alternative means to restrict viewing of pay programming to only those who pay the associated premium.

An introduction to the concept of pay-per-view is appropriate at this point. The option of selecting and paying for individual pay program events such as movies, boxing matches or sports events has been offered in many American cable systems and is known as pay-per-view. There are basically two methods for controlling access to this type of programming which are known as addressable and store-and-forward. In addressable systems, the programming is normally scrambled or denied and when a subscriber makes a request for an event, an addressing signal is sent to a switch or descrambler near the subscriber premises to allow unimpeded viewing of the program. At the end of the program, another addressing signal is sent to turn the switch or descrambler off again.

In store-and-forward systems, the programming is normally unscrambled and available, but a recorder monitors access to the pay channel. When the monitor is polled by the cable operator, it forwards the information on whether the pay channel has been watched to the operator so that appropriate billing can be produced.

The ability to support pay-per-view is a critical parameter for many operators as they evaluate the alternative pay security options being explored.

Although pay-per-view is currently not available in Canada, the economics of CATV hardware development suggests that the same solutions to pay security and consumer electronics interconnect problems be used in both Canada and the United States. It is also believed by many Canadian operators that it would be short sighted to implement technology in Canada that precludes pay-per-view because they anticipate its eventual introduction, now that it appears to be gaining strength in the United States.

In the effort to improve the cable service, a concept of off-premise signal security has been gaining support.

The basic idea is to provide all signals into the subscriber's home unscrambled if subscribed to and scrambled or removed if not.

Any television or VCR in the home then has unrestricted access to all authorized services. There are no descramblers in the home to provide tempting targets for tampering or which serve to complicate selection of the cable services. The new digital TV or VCR with PIP can function as intended by the manufacturer, complete with full operation of all remote control and programmable timer capabilities. Three forms of off-premises security are discussed.

In its simplest form, off-premise security is implemented by means of passive frequency selective filters or traps which prevent the unauthorized reception of channels not subscribed to. These devices are usually located at the cable tap which connects the subscriber drop cable to the main feeder cable of the CATV system. The tap is normally located in a backyard pedestal enclosure or spliced into the aerial feeder cable which is strung between hydro-electric or telephone poles near the subscriber's home. The filters are passive which means no powering is required but they need to be physically removed or changed if the subscriber decides to subscribe to a different set of pay channels. The cost of changing traps or filters makes this approach to signal security unattractive in many cases, particularly where the choice of pay services is extensive. Finally, this technology does not lend itself to pay-per-view without the installation of additional equipment in the subscriber's home. In spite of these limitations, tap mounted traps and filters are used extensively as basic tier delineators and have been used in some cases to improve subscriber "friendliness" by removing the converter/descrambler requirement.

A second approach to off premises security that is beginning to gain favour is the exterior wall mount service entry enclosure at which the subscriber drop terminates. The enclosure may contain passive traps or filters and may have active electronics to perform switching and addressing functions.

The passive type is similar to the tap mounted filter approach described above but makes the traps and filters more accessible. It also reduces spigot breakage at the tap which is a common occurrence when the traps or filters are removed from the tap. The addition of a lock or seal reduces the likelihood of unauthorized removal of the trap or filter.

More complex service entry enclosures contain addressable switches and require a source of power. The power is normally supplied by a power inserter located inside the subscriber's home and delivered via the coaxial cable entering the house from the enclosure. Inside the enclosure, an array of traps and filters are connected with bypass switches which can be remotely controlled by the cable operator. This arrangement allows a choice of pay programming alternatives to be offered without requiring an addressable descrambler inside the home.

All authorized services are available to all television sets and VCRs inside the home via one broadband coaxial cable.

The digital television with PIP and two tuners can display any channel(s) including the pay signals subscribed to. Similarly, the VCR timer can be programmed unhindered by other equipment limitations. It is common to have an amplifier in the enclosure to ensure that adequate signal levels are available to all outlets and to compensate for attenuation in signal level caused by the filters, traps, and bypass switches connected in series.

The addressing capability facilitates the offering of pay-per-view services by allowing a subscriber to phone in a request and view a program within a few seconds. At the conclusion of the pay-per-view event, the program channel can be switched off again. Alternatively, the pay-per-view request can be transmitted along two way cable by a transmitter in the enclosure.

A third approach to the off-premise security option is interdiction at the tap, or alternatively at the service entry enclosure, to jam signals not authorized. The opportunity to share common electronics among more than one subscriber would favour the tap location.

In the process of interdiction, an interfering signal is generated to jam the unauthorized channels while leaving the authorized channels unimpaired.

In practice, a single synthesized oscillator is rapidly stepped through all the channels to be secured. A high isolation switch in each tap spigot path controls which channels are jammed for each individual subscriber by turning on or off the jamming signal as it steps through the channels.

The selection of which channels are to be jammed is addressable for each subscriber, so that service changes can be made easily and again, pay-per-view can be supported.

Technology that implements interdiction at the tap locations is currently in the development stage and as such may eventually be offered to the CATV industry. The cost impact of installing this type of interdiction system can be substantial as every tap needs to be replaced (one for every two to three subscribers typically) and more power supplies are required to operate the new electronics (approximately twice as many as originally installed). These cost implications can be reduced if the interdiction hardware is mounted in a service entry enclosure or even inside the home, but the unit cost will increase as the economies of shared electronics is lost.

One aspect of interdiction may make it more attractive as new television transmission standards to support HDTV evolve.

The interdiction technology is potentially effective for any transmission system and is not limited by the bandwidth of the channels currently in use because of its programmability.

Other benefits of interdiction include excellent picture and sound destruction for unauthorized signals while giving impairment free authorized service without requiring a descrambler of any kind.

The primary compromise of any off-premises denial or interdiction scheme for signal access control is in system security against tampering. The removal or deactivation of the off-premise hardware will allow full service to be received. Detection of tampering that affects full service may be very difficult, and since the equipment is located off the subscribers' premises, prosecution of offenders will be unsuccessful in most cases. It may be feasible to monitor the status of the interdiction hardware using two-way cable where available. Many CATV operators are prepared to accept some theft by a minority in exchange for enhanced services to the majority of subscribers.

Still another security method may be available in the future. The evolution of digital television may make it possible to have the functionality of a pay television descrambler incorporated into every television and VCR.

Digital algorithms could be used at the cable headend to scramble the premium services. The digitized video at the receiver would be processed by an appropriate descrambling algorithm with an encrypted key to restore the original viewable signal. The descrambler in this case would be an inexpensive addition to the television or VCR circuitry so it would no longer be as scarce a resource as it is currently. The security of this approach is excellent while the cost of implementation is low, but depends on everyone using a single universal method of control for which standards will be required.

The introduction of new transmission standards and HDTV television formats could make the implementation of digital descrambling a viable means of controlling access to television programming.

CATV SYSTEM PERFORMANCE REQUIREMENTS

The impact of the introduction of digital television on the CATV operation has yet to be fully appreciated. The associated PIP feature has created some interface/interconnect problems as described at the beginning of this section. The effect on picture quality has been less obvious and to date, the performance of the cable system has not detracted from the viewing enjoyment of those owning digital television sets.

An evaluation of a digital TV set in the laboratory has revealed no significant improvement relative to state of the art analog sets with respect to picture quality. This will soon change, however, as manufacturers gain familiarity with digital video processing and implement improvements achievable in the laboratory, as described in Chapter 5, "Status of Digital Video Processing Developments".

In particular, a better separation of luminance and chrominance in NTSC signals using multi-line comb filters will allow full utilization of the 4.2 MHz spectrum available for luminance. The simultaneous trend to larger picture display size and smaller relative viewing distance with respect to picture height will make currently imperceptible impairments quite visible. It is highly probable therefore, that noise will become a more objectionable distraction. The current requirement of 40 dB carrier-to-noise ratio for cable delivered signals gives barely perceptible snow in a 20 inch picture which has an effective luminance bandwidth of 3.0 MHz. The effect of increasing picture size to 35 inches and luminance bandwidth to 4.2 MHz will be to make the impairment caused by noise more objectionable as it will detract from image clarity.

It can be argued that the input carrier-to-noise ratio must increase by 4 dB to give the same apparent picture quality on the new larger sets as historically delivered to analog 20 inch sets.

The 4 dB figure is based on Reference [2], using a constant viewing distance of seven feet and the luminance bandwidth increase factor of 4.2/3.0. A new carrier-to-noise ratio for cable delivered television signals may have to be increased to 44 dB. This number is based on theoretical work so empirical testing with a variety of viewers and new large screen television sets should be performed before any new delivery parameter values are specified.

Digital processing of the video in future digital television sets may reduce the visible effects of the theoretical increased sensitivity to noise in newer large screen displays.

Various recursive filter algorithms are being developed in conjunction with frame stores (see Chapter 5) and may improve the picture quality of large screen sets so that they exceed what is available on smaller sets today. At the same time, work is also proceeding on edge enhancement processing using digital techniques which would restore picture clarity in the presence of noise.

In the interim, there will be a number of cases confronting cable operators where the subscriber has a new large screen television set with super comb filtering and marginal cable service. In these cases, where there is no facility for noise improvement, special provisions will need to be made to increase signal levels or otherwise fine tune the distribution system to optimize service.

In the long run, the worst case will be that the noise reduction and edge enhancement techniques will not be practical and delivery standards for cable will need to improve as indicated above.

A similar problem to the increased sensitivity to noise may arise because of the multiple reflections in cable distribution systems which are currently masked by a relatively low bandwidth display (3 MHz).

The extension of luminance bandwidth to 4.2 MHz as required to give good resolution on large screen sets will make close-in reflections more visible.

The source of the majority of undesired reflections is the multitaps which split off the cable signals for each subscriber drop cable. These devices are located approximately every 100 feet, so each reflection is delayed by the transmission time required to cover double this distance or 200 feet. The resolution of a conventional television set (3 MHz) masks reflections from multitaps located less than 150 feet apart but new high resolution sets (4.2 MHz) will display the reflections of multitaps spaced 100 feet apart as distinguishable echoes or ghosts. Therefore, many more reflections will become visible than previously, detracting from the subscriber's enjoyment of his cable service.

There are two potential solutions to this problem. The first is to reduce the reflection that occurs at each multitap. This requires that every multitap be replaced with units that do not reflect as much signal. This would be a very expensive solution as there are many multitaps in a cable distribution system (one for every 2-3 subscribers).

A better solution is to develop edge enhancement processing in the digital television to suppress ghosts and echoes.

This has proven difficult to achieve in the analog sets but powerful real time digital processing should be able to foster a successful ghost and echo canceller in digital television sets [3].

It is believed that the impact of digital television will be minimal on other cable delivery parameters.

The tolerable level of distortion products, both composite and discrete intermodulation, as well as cross modulation, will remain the same.

In fact, it may be possible that recursive digital filtering will suppress distortion products, particularly discrete intermodulation beats, allowing the distortion specifications for CATV to be relaxed (see Chapter 5).

AUDIO CONSIDERATIONS

The effort to improve picture quality has been accompanied by increasing attention to audio quality. Within the past two years, stereo decoders in new television sets have increased from zero to 44% (1987 EIA estimate). These decoders supply stereophonic sound when receiving BTSC encoded television signals.

Sound quality has been improved significantly with programmers and receiver manufacturers both starting to focus their attention on the audio.

The BTSC stereo standard for television is completely backwards compatible with existing television receivers and with most pay television scrambling systems [4]. It was therefore a natural expectation that the cable industry would provide a transparent conduit for the new format. The achievement of the required transparency requires that all equipment which processes stereo television signals be tested and modified where necessary to ensure sufficient bandwidth is provided for the new stereo audio signal.

The two major equipment categories that are affected by BTSC signal requirements are headend electronics and pay television descramblers [5]. There are a limited number of headend signal processors, modulators and demodulators so upgrading them for stereo is a manageable undertaking. The large number of pay television descramblers presents a more serious problem, particularly those that process the video at baseband. A complete replacement of baseband descramblers has been unnecessary to date due to the relatively small number of subscribers with stereo television receivers. Those subscribers purchasing stereo receivers, either in the form of television sets, VCRs or standalone decoders, must receive a replacement descrambler which has been upgraded to be transparent to the BTSC stereo signal.

Stereo audio quality achievable with the BTSC signal is determined by the ability of all electronics between the signal source and the subscriber's speakers to maintain separation and signal fidelity.

The BTSC standard in particular is extremely delicate and achieving more than 14 KHz response and 20 dB separation is extremely difficult. While these numbers represent a significant improvement over conventional television audio, they are noticeably inferior to today's standard for high fidelity as embodied in compact audio disk technology.

The digital processing of BTSC stereo audio signals is being introduced at the BTSC encoder and subscriber decoder equipment [6]. Digital filters will provide a better and more consistent implementation of the BTSC specifications resulting in a more faithful reproduction of the original stereo program in the home. As overall performance of encoders and decoders improves, the baseband descramblers will need to keep pace or be removed entirely.

The progressive improvement of audio quality again underscores the undesirability of additional processing electronics, particularly pay television descramblers, in the cable subscriber's home.

Invariably, overall enjoyment of the signal supplied by the CATV operator is compromised by the extra equipment.

The off-premise approach to signal security outlined earlier provides an attractive alternative.

Audio quality can tend towards compact disc fidelity as a result of the evolution of television towards EDTV as described in

Chapter 4. The audio signal will be transmitted in digital form as part of a time multiplexed data signal and, as such, will share the same spectrum as the video. Special filters required for current 4.5 MHz subcarrier audio will no longer be required so both video and audio signal quality will improve as a result of the higher bandwidth available to both.

HEADEND PROCESSING

In the CATV industry, the main reception point for terrestrial broadcast and satellite signals is referred to as the headend. Signals collected at the headend are often processed to make them compatible with the cable distribution system. Typically terrestrial broadcast signals are converted to a different channel number to minimize interference at the subscriber's television set caused by strong local broadcast signals. Satellite signals typically undergo more extensive processing to convert from a wide bandwidth FM modulated signal format optimized for satellite transmission to the narrower bandwidth VSB-AM standard that broadcasters use and which all North American television receivers are designed to receive.

Unless care is taken, signal quality can be seriously degraded by the processing required at the headend.

The channel converter must have sufficient bandwidth to pass all elements of the broadcast signal including stereo sound. At the same time, the output signal from the headend can be no better than the broadcast studio input. Any deficiency in the basic transmission signal at the television studio cannot be corrected by the CATV headend.

The more complex processing of satellite signals makes them more vulnerable to impairment at the headend. The satellite receiver must be of the highest calibre to optimize received signal quality. Modulators are used to insert the satellite signal on the television channel for distribution on the CATV cable.

The bandwidth for the video and audio signals must be sufficient to prevent impairment.

Traditionally these bandwidths have been 3.75 MHz for video and 50 KHz for audio. The advent of digital comb filters and stereo audio has made it necessary to increase these bandwidths to 4.2 MHz and 200 KHz respectively to give acceptable quality. The video bandwidth cannot increase further due to the presence of the audio signal at 4.5 MHz in the NTSC system. However, with its possible removal in EDTV signals the full 4.7 MHz bandwidth could be available.

In all cases, the video signal received at the headend is already encoded with colour information and no processing is performed on separate colour and luminance components. The use of alternative satellite transmission systems which distribute separate components, such as B-MAC, would require transcoding to NTSC at the headend.

Currently colour encoding is receiving considerable attention since limitations of conventional techniques are becoming apparent when compared with the performance attainable with digital comb filters. Cross-colour and cross-luminance artifacts, described more fully in Chapter 5, can be significantly reduced by better colour encoding. An evaluation of the subjective improvements realized by pre-combing of the colour and luminance components prior to encoding is described in Appendix D.

It has been observed that all television receivers have reduced artifact visibility, when displaying comb encoded signals, with the greatest improvement occurring in receivers with digital comb filters.

Television studios are converting to video switching and editing using separate colour and luminance components followed by encoding just prior to transmission with better quality comb filter encoders. One manufacturer of comb filter encoders, Faroudja Labs, has installed 150 comb filter encoders in North America as of April 1987.

The processing of television signals at CATV headends will need to be more transparent than it has been in the past as digital television sets capable of displaying large screen high resolution images reach subscriber's homes. It is likely that headend processing equipment will need to be replaced as more performance is squeezed from the NTSC format. It may even be necessary to add comb filter colour encoders for component type satellite signals. This would follow the stereo audio model where two discrete sound channels are received and then BTSC encoded in the headend. A significant number of BTSC encoders have been installed in CATV headends to encode the stereo audio that accompanies many of the pay television channels.

Most cable operators recognize their responsibility to deliver optimal signal quality. They also realize that the quality of the signal delivered to subscribers cannot exceed the quality of the headend signal source. As digital processing continues to make subscribers' receivers better, headend electronics must keep pace.

CONCLUSIONS

Introduction of the Picture-in-Picture (PIP) capabilities in television receivers has increased the problems encountered interconnecting consumer electronics to cable.

Pay television descramblers, in particular, are becoming less tolerable in their current configuration. The combination converter/descrambler only processes a single channel and passes it on to the television set, rendering multi-channel PIP capability in the latter useless.

Signal routing switchers can alleviate some of the interconnection problems with converter/descramblers at the expense of making the hook-up in subscriber's homes much more complex and difficult to operate. The addition of a VCR complicates matters still further, to the point where many subscribers ask that cable services be discontinued.

A joint consumer electronics and cable initiative to improve the interface to pay television descramblers has led to Multiport, a new interface connector which allows back-of-set connection to a descrambler.

The descrambler would no longer hamper the functionality of the television receiver and could be potentially inexpensive enough to be attached to every receiver and VCR in a subscriber's home. The advent of digital processing and PIP in TV sets raises new questions as to the long term prospects for Multiport. As a result, the cautious attitude by both receiver manufacturers and cable operators to Multiport implementation may continue, reducing the benefit that could have been realized.

Alternative pay television security methods are receiving serious consideration by many cable operators and CATV equipment suppliers.

Off premises equipment is an attractive means of avoiding the current descrambler interconnect problems.

Primary obstacles to implementation are cost and uncertainty of reliability and security effectiveness. Suppliers are striving to reduce the implementation and operating costs of their systems while supporting pay-per-view. Field testing will give the answers needed to address reliability concerns.

Increasing picture quality and screen size are placing greater demands on CATV delivery. In particular, impairment due to noise or close-in reflections will potentially require more stringent performance specification for cable carrier-to-noise ratio and impedance match at multitap connections. Television receiver capability through digital processing to enhance signal-to-noise ratio and reduce echoes will potentially mitigate these new cable performance requirements in time. Further monitoring of this situation is required, as the cost impact to CATV operators of improving either parameter is substantial.

Headend upgrades to provide greater transparency to video and multichannel audio are occurring. The limited quantities and critical rate of headend equipment turnover makes it easier to justify expenditures to improve quality.

Unauthorized descrambling of pay television signals by digital television hardware was a distinct possibility when ITT introduced their Digit 2000 chip set.

Initial product offerings could be configured to circumvent sync suppression scrambling through the service interface. Appeals by CATV operators to the set manufacturer persuaded them to reduce the threat of unauthorized descrambling through reduction in externally accessible configuration parameters. Today, the threat of digital television sets being converted into pay descramblers is very small.

Not withstanding the susceptibility to modification, television sets with sophisticated sync recovery techniques, which are characteristics of digital sets but also becoming more common in analog sets, can synchronize on their own to a television signal scrambled through sync suppression. Appropriate video content (bright scenes) leave the sync pulses exposed and, once synchronized, these sets remain locked, albeit with poor vertical hold and reduced contrast, but much the same as for the case of forced lock-up to colour burst reference.

This vulnerability of sync suppression scrambling can be alleviated by destroying the fixed relationship between colour reference and horizontal scan frequencies at the scrambling encoder.

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[6] Borth, D.E.; Raz, Zo.: "Digital MTS System", IEEE Trans CE - 32, No. 3, August 1986.

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4

CHAPTER 4

EXTENDED DEFINITION TELEVISION

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EXTENDED DEFINITION TELEVISION

The evolution of digital video processing will lead to materially enhanced picture quality and improved fidelity of the associated aural signal on future television systems. The ultimate goal is the introduction of high definition television (HDTV) which displays approximately twice the resolution of current NTSC with a wider aspect ratio of 16:9. A significant step towards HDTV will be extended definition television (EDTV) which is an intermediate stage that may begin as soon as 1990. In EDTV, the number of scan lines remains the same as in NTSC, that is 525 lines for a complete frame. The aspect ratio may change as well as the transmission bandwidth in order to deliver better pictures. This chapter examines various aspects related to the evolution in digital television and the impact on the cable television industry.

NEW PERFORMANCE OBJECTIVES

The overall goal of those engaged in the development of television has been and continues to be to duplicate the movie theatre experience in the home. This goal is far from being static; current television surpasses the theatrical experience of the 1940's. As theatrical presentation quality continues to improve, television is similarly improving so that today, large screen (60 inch) displays and stereo sound are capable of delivering a pleasing rendition of movies, sporting events and entertainment. There is still room for improvement, however, as experimental systems will confirm. The scanning structure of NTSC becomes annoying as viewing distance, expressed in terms of picture height multiples, decreases because of the growth in picture size. Similarly, the resolution limitation of the current NTSC standard becomes apparent with larger display sizes. The advent of the compact disc has given a new standard in audio reproduction that is far ahead of current television sound quality. The response of the human visual system to a wide field of view leads to the desire to have a wider aspect ratio display, similar to that in movie theatres. This goal has been embodied in the definition of high definition television or HDTV.

Both the horizontal and vertical resolution of HDTV should be twice that of conventional NTSC, which would make the quality of HDTV similar to that of 35mm film. **The aspect ratio should be increased from the current** 4:3 **to** 16:9 **or** 5 1/3:3. **The audio fidelity should match stereo compact disc quality.** These improvements are illustrated in Exhibit (4.1).

The equipment to generate HDTV signals exists and is being used, as discussed in the next chapter. There are several possible methods of distributing the HDTV signal to the consumer, none of which exist in terms of available hardware. A number of transmission schemes have been proposed to convey reduced bandwidth

HDTV, some of which also provide some degree of backwards compatibility with existing television receivers.

All the transmission schemes make extensive use of digital processing in the television receivers to generate an EDTV picture.

It is therefore appropriate to associate digital television with improved picture quality, albeit to various degrees.

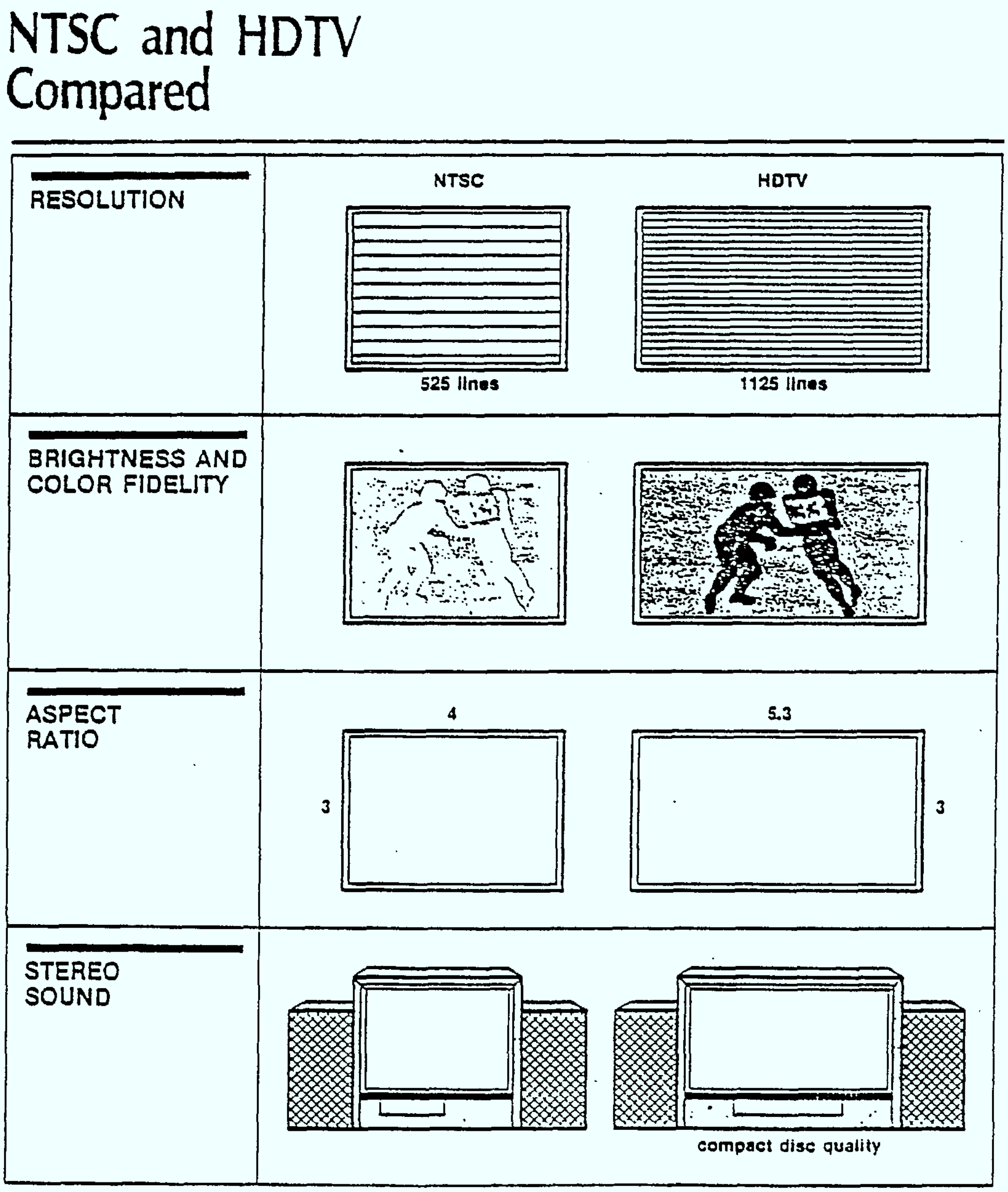


EXHIBIT 4.1

TRANSMISSION BANDWIDTH REQUIREMENTS

The schemes put forward to date for distributing HDTV to the consumer include Philips' ENTSC, NHK's MUSE, the New York Institute of Technology two-channel system, Del Ray's TriScan, and Scientific Atlanta's wide MAC. Working prototypes of these systems have been built by their respective developers and all but one, have been shown to the television engineering community, namely Triscan. The NYIT scheme will potentially be tested over-the-air by NAB in Washington in the fall of 1987.

The transmission characteristics of these systems are given in Table (4.1). A brief description of each system is presented so that the compromises of each may be appreciated. The parameters for unprocessed 1125 line HDTV, which represents the source signal, are also given. Parameters for the NTSC system are provided for comparison.

TABLE 4.1

EDTV SYSTEMS DESCRIPTION

PARAMETER	HDTV SOURCE	ENTSC	NYIT	TRISCAN	HDB-MAC	MUSE	NTSC Reference
Number of Scan Lines	1125	525	1125	525	525	1125	525
Interlace	2:1	1:1	2:1	2:1	1:1	2:1	2:1
Field Rate Resolution * HXV	60.0 Hz	59.94 Hz	59.94 Hz	59.94 Hz	59.94 Hz	60.0 Hz	59.94 Hz
Still Picture	519x471	490x338	519x471	425x376	430x338	519x471	338x220
With Motion	519x362	490x338	338x154	283x145	430x338	315x362	338x169
Aspect Ratio	16:9	16:9	5:3 vertical)	14:9 (cropped vertical)	16:9 (cropped	16:9	4:3
Baseband Bandwidth	20 MHz	4.2 MHz +4.2 MHz	4.2 MHz +3.0 MHz	4.2 MHz	10.7 MHz	8.1 MHz	4.2 MHz
NTSC Compatible	No	Yes	Yes	Yes	No	No	Yes
Colour Multiplexing	Time	Frequency	Frequency	Frequency	Time	Time	Frequency
Audio	Digital (CD)	Digital (CD)	FM-BTSC	Digital 600k ADM	Digital 254k ADM	Digital 305k DPCM	FM-BTSC

* Resolution is expressed in lines per picture height and uses the following factors:

Kell factor = 0.7, static interlace factor = 0.65, dynamic interlace factor = 0.5

A) ENTSC

The Philips enhanced NTSC (ENTSC) transmission system requires two conventional 6 MHz television channels, a main channel which is completely NTSC compatible and carries a conventional 4:3 aspect ratio picture and an augmentation channel to transport the extra side panel information to generate a 16:9 aspect ratio display as well as time compressed line differential information required to generate a 525 line sequential scan [1]. The two channels need not be contiguous as the main channel has information in the VBI to define the location of the augmentation channel for the ENTSC compatible receiver. See Exhibit (4.2).

The main channel is conventional NTSC; it is a 525 line, 2:1 interlaced system with colour information modulated on a 3.58 MHz subcarrier. A conventional mono or BTSC stereo audio signal is frequency modulated onto a 4.5 MHz subcarrier. In order to reduce cross-colour and cross-luminance artifacts, the chrominance and luminance channels are precombed to remove potential interference before encoding. The exact characteristics of this two dimensional filtering are adaptive to scene content, particularly dependent on vertical and horizontal transitions in luminance and/or chrominance levels. Therefore, conventional television sets with comb filters to separate chrominance and luminance will deliver a better picture when tuned to the main channel of an ENTSC transmission.

The main channel is derived from a High Definition TV (HDTV) signal which has 16:9 aspect ratio and a 525-line progressive scan. A "pan and scan" of the original scene is performed to selectively crop information from each side to generate a 4:3 aspect ratio scene. This can be done dynamically by an operator to give the most pleasing NTSC compatible picture. The interlaced signal is generated by selecting only even, then odd number lines on an alternate field basis. The lines that don't get transmitted in the main channel are processed, along with the immediately preceding and succeeding lines to generate a "line difference" signal which is time compressed 2:1 and transmitted in the augmentation channel.

The process is illustrated below:

________________________ line a

------------------------------------- line b $LD = \frac{a + c}{2} - b$

________________________ line c (luminance only)

line a and c are transmitted
LD is computed and transmitted in augmentation channel

MAC-60/ENTSC/NTSC HIERARCHICAL TELEVISION SYSTEM

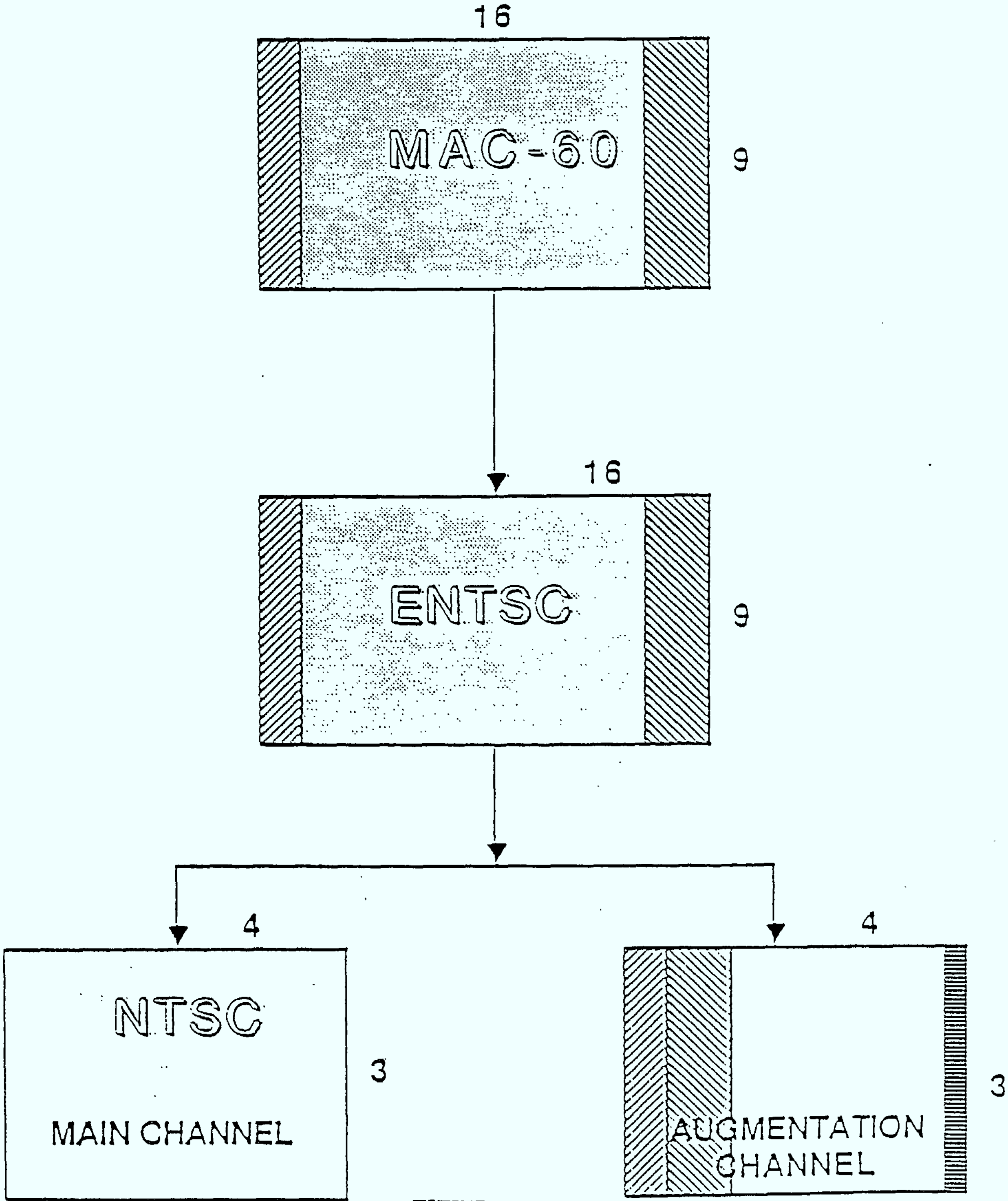


EXHIBIT 4.2

In addition to the time compressed line difference information, alternate sets of lines from the cropped side panels are transmitted, in time multiplexed fashion, in the augmentation channel. The structure of the video in the augmentation channel

is the same as conventional NTSC and is viewable on a standard NTSC receiver. Synchronization and timing signals on both the main and augmentation channels follow RS 170A. There is also a digital data channel in the augmentation channel to carry digital audio (stereo) at CD quality. Exhibit (4.3) illustrates the ENTSC transmission system.

An ENTSC compatible receiver requires two tuners to receive the two channels required to generate the ENTSC display. The receiver is able to tolerate up to 64 uS delay between channels, as it has a one-line time base corrector as part of the stitching hardware to combine the main channel and side panels. Separate conventional RF and IF AGC systems for each channel allow significant level differences to exist between channels without presenting any problem in recombining. A microcomputer controlled video AGC system, using reference levels in the VBI of both channels at 0 and 70 IRE, matches the two video signals to within 0.2 IRE (9 bit A/D resolution). Similarly, colour phase is matched to within several nanoseconds (1.3 degree per nanosecond). This high degree of matching is required in order for the seam line not to be visible. A randomization of the seam time over 3 uS will further reduce the visibility of the seam.

The ENTSC receiver displays a 525 line sequential scan display by scanning all lines transmitted in each field and filling in the alternate lines, which are not transmitted, by using the line difference signal from the augmentation channel. Only a few line stores are required to perform this real time operation.

B) MUSE

The MUSE system for transmission of HDTV signals was developed by the Japanese broadcasting company NHK. The name MUSE is an acronym for Multiple Sub-Nyquist Sampling Encoding. MUSE was developed in an attempt to compress the bandwidth required for a HDTV signal so it can be transmitted through a Ku-band satellite transponder. A compressed baseband signal bandwidth of 8.1 MHz is achieved, as indicated in Table (4.2), which summarizes the characteristics of the MUSE signal.

The input HDTV signal at the transmitter has a luminance bandwidth of 22 MHz and is sampled by means of an analog to digital converter with a sampling frequency of 64.8 MHz. The bandwidth of the sampled signal is limited depending on motion in the picture.

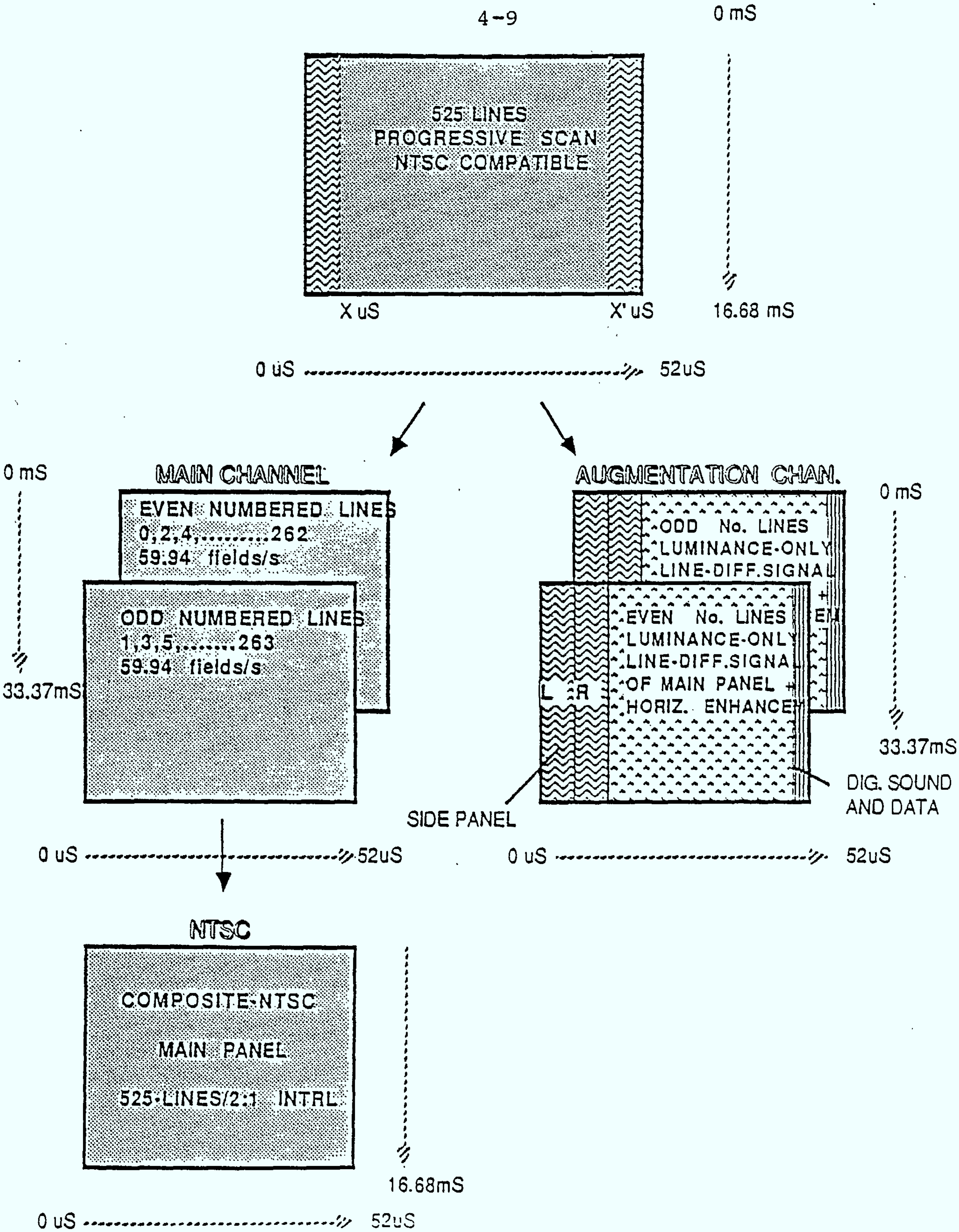


EXHIBIT 4.3 PHILIPS ENTSC TRANSMISSION SYSTEM

1) Moving Picture: The bandwidth is limited diagonally in the spatial domain so that only a quarter of the samples will give a satisfactory picture when transmitted.

2) Still Picture: The bandwidth is limited in the temporal spatial domain so that the HDTV picture can be recreated at the receiver by combining samples over four fields without blurring.

TABLE 4.2
MUSE TRANSMISSION SYSTEM SPECIFICATIONS

Specifications of the HDTV signal for the satellite broadcasting

Items	Specifications
Scanning method	1125 lines/60 fields 2:1 interlace
Luminance (Y) bandwidth	20~22 MHz with still picture 12.5 MHz with moving picture
Chrominance (C) bandwidth	7.0 MHz with still picture 3.1 MHz with moving picture
Multiplexing system of Y and C	Time division multiplexing (TCI*1 with line sequential chrominance)
Transmission base-band width	8.1 MHz (-6 dB)
Horizontal sync-signal	Signal of positive polarity with alternation by line
Vertical sync-signal	Frame pulse signal multiplexed in the vertical blanking period
Sound signal	Radio frequency time-division multiplexed PCM signal with Q-DPSK*2

*1 TCI: Time Compressed Integration
*2 Q-DPSK: Quadrature Differential Phase Shift Keying

After sampling at the 64.8 MHz frequency, the number of samples for each transmitted field is reduced to one quarter by selecting every fourth sample as shown in Exhibit (4.4). These samples now at a frequency of 16.2 MHz are subsequently averaged to result in a final bandwidth of 8.1 MHz.

The brightness (luminance) and colour (chrominance) information are transmitted at different time intervals so no cross-talk or mutual interference can impair the received picture. There is also digital sound data to provide compact disc quality stereo to accompany the picture. The format of the total multiplexed signal is illustrated in Exhibit (4.5). A more elaborate description of MUSE can be found in references [2,3].

It is noteworthy that the total MUSE signal occupies a contiguous bandwidth of 8.1 MHz at baseband which is more than the 6 MHz available in a single NTSC channel. This has some serious implications for the CATV operator which will be examined in the Channel allocation implication section. In addition, there is no backwards compatibility with existing TV sets.

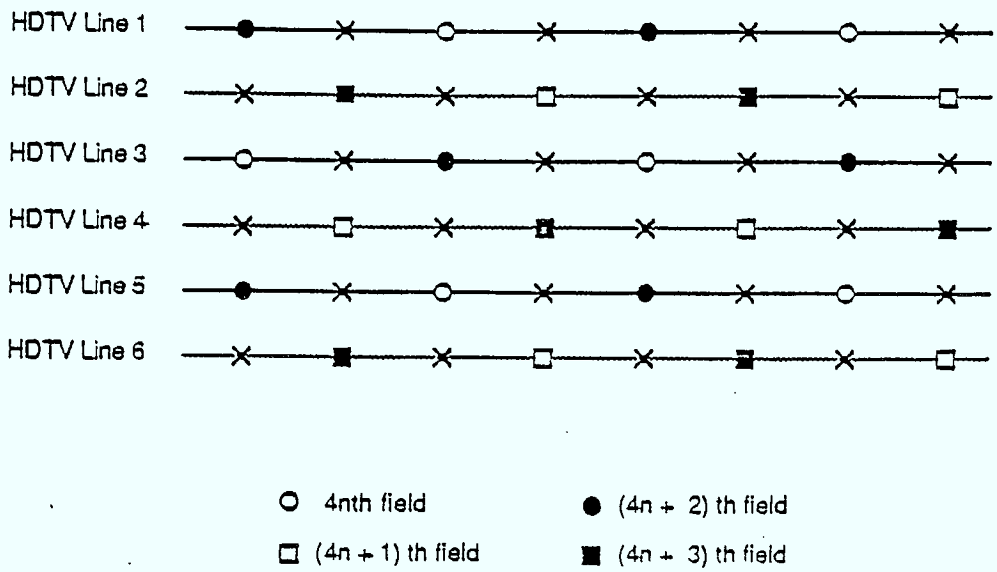
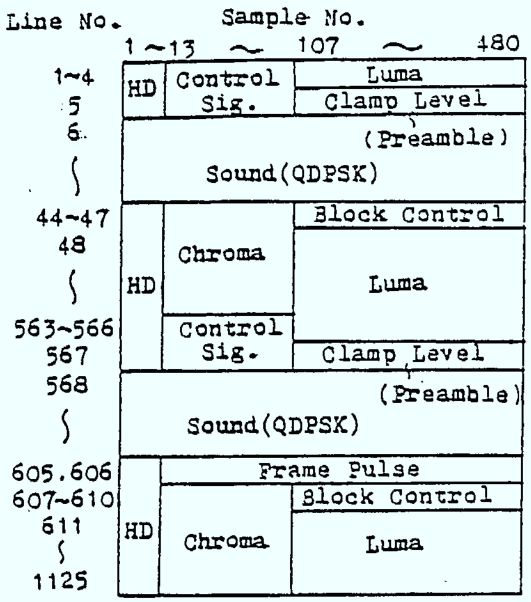


EXHIBIT 4.4 MUSE SUBSAMPLING



Format of the MUSE signal

EXHIBIT 4.5
MUSE SIGNAL FORMAT

The MUSE transmission system was demonstrated in the United States where several deficiencies were observed. The 2:1 interlace of the display caused annoying interlace flicker in areas of high vertical detail. The motion adaptive nature of the presentation led to perceptible changes in picture clarity, with backgrounds appearing in and out of focus depending on motion in the scene. The system also appears sensitive to ghosting and multipath, with significant multiple edges in the horizontal direction on abrupt transitions. The time division multiplexing of colour and luminance successfully prevented any cross-colour or cross-luminance artifacts from appearing in the picture.

C) TRISCAN

An alternative multiple subNyquist sampling scheme for the bandwidth compression of HDTV signals has been put forth by the Del Ray Group in California and is called TriScan. TriScan differs from MUSE in the following ways:

1) Backwards compatible with existing television receivers

2) Somewhat lower resolution (still picture)

3) Conventional frequency multiplexed colour rather than time division multiplexed

4) Occupies less transmission bandwidth of 4.2 MHz rather than 8.1 MHz.

5) 14:9 aspect ratio instead of 16:9

The comparisons listed above are based on a paper concept for TriScan since a working system is not available for demonstration. In essence, the TriScan concept uses conventional NTSC transmission parameters in conjunction with a smart television receiver and suitable preprocessing to prevent undesirable artifacts. Increased picture resolution is obtained for still pictures by scanning three sub-elements of each NTSC "pixel" over a three frame (or six field) period. In order to obtain higher resolution, a special receiver display is required to separate the three subpixels and illuminate them individually at the appropriate time. This concept is illustrated in Exhibit (4.6) and explained more fully in reference [4].

When there is motion, the TriScan system returns to conventional NTSC mode where all three subpixels show the same information in each frame to eliminate smearing that would otherwise occur. The horizontal resolution consequently reduces to that for conventional NTSC in the presence of motion.

The conveyance of colour information uses the same frequency division multiplexing and subcarrier frequency as for Philips ENTSC and conventional NTSC. Digital filters preprocess the colour and luminance information before combining to prevent cross-talk between the frequency multiplexed channels. Similar high quality digital comb filters in the smart receiver keep the colour and luminance channels separate to allow clean high resolution pictures to be displayed without undesirable rainbows.

A wider aspect ratio of 14:9 is displayed on a TriScan receiver by cropping the top and bottom of a conventional 4:3 display. In addition, a conventional NTSC receiver would not display the complete width of a TriScan transmission since there is normally a 10% overscan. The TriScan receiver would display the entire width, in combination with masking a few lines at the top and bottom of the picture to result in a wider aspect ratio display than conventional without requiring any additional bandwidth. It is proposed that the cropped lines, totalling 69, could be used to transmit high quality stereo audio with better performance than BTSC (see Table 4.3).

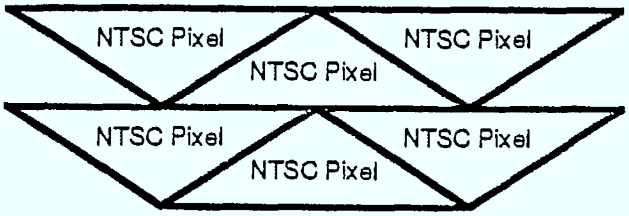
TABLE 4.3 MULTICHANNEL AUDIO PERFORMANCE

Parameter	HD-NTSC (delta modulation)	MTS Stereo
Frequency Response:	20 Hz ~ 16 KHz	50 Hz - 15 KHz (13KHz typical)
Dynamic Range:	85+ db	45 db typical
Distortion:	less than 0.2%	less than 2.5%
Channel Separation:	60+ db	25 db typical at receiver

An examination of the TriScan concept shows that the undesirable softening of the picture in the presence of motion that occurs in MUSE will be more pronounced in TriScan. MUSE requires four fields to reproduce a maximum resolution display, TriScan requires six, making it less tolerant of even slow motion. When falling back to motion-tolerant, low resolution mode, the 4.2 MHz bandwidth available will result in a much more drastic reduction in resolution relative to MUSE which has 8.1 MHz available in the low resolution motion-tolerant mode. In addition, the 14:9 aspect ratio achievable with TriScan will be less impressive than the 16:9 aspect ratio available with MUSE or ENTSC.

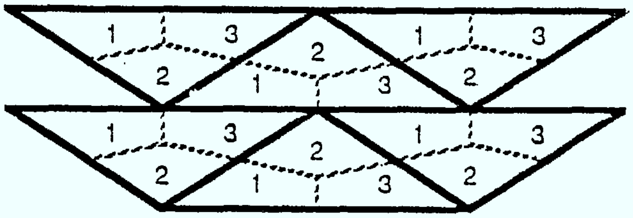
The TriScan system would appear to compromise the final quality of the HDTV source material beyond that which is acceptable in the attempt to retain compatibility with current NTSC receiver and channel bandwidth.

(a)



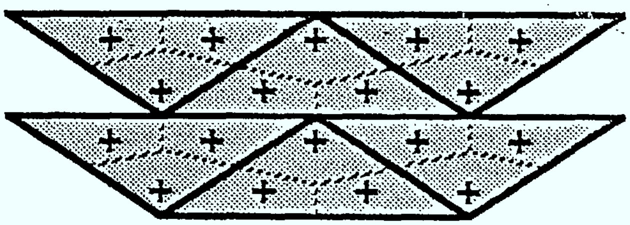
Here we have chosen the triangular pixel representation. There are 483 pixels within the vertical dimension of the TV screen, and for an assumed bandwidth of 4.2 Mhz there are about 440 pixels within the width of the screen. In total, about 213,000 pixels comprise the total NTSC picture.

(b)



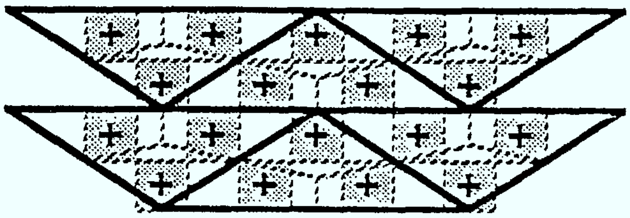
The TriScan process divides the NTSC pixels further into smaller "Subpixels", labelled "1", "2", and "3" at left. On the first scan, only the "1" portions are displayed, with the "2" and "3" portions processed on the succeeding scans. Dividing the pixel into smaller areas by means of diagonal lines allows for increased resolution in both the horizontal and vertical directions.

(c)



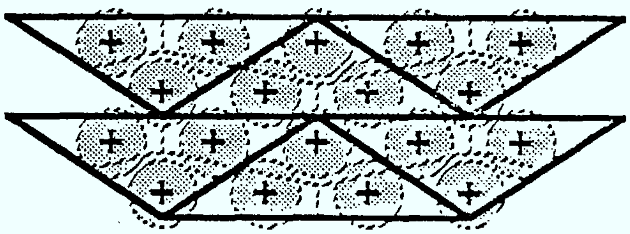
The crosses at left represent the approximate centers of the subpixel areas for the purpose of creating a subpixel grid of equal spacing.
The physical representation of the two pixel areas does not necessarily have to be as an assembly of oddly-shaped quadrilaterals, as shown here. For example, the subpixels could be displayed as:

(d)



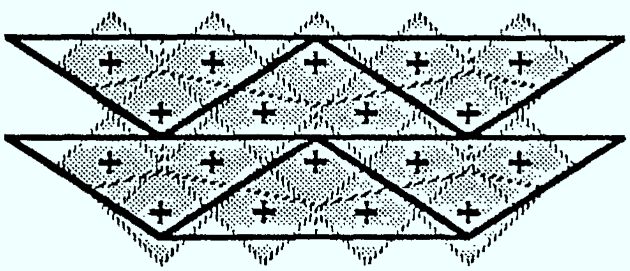
small rectangles or squares,

(e)



circles or ellipses,

(f)



or diamond-shaped areas.

EXHIBIT 4.6 THE TRI-SCAN SUBPIXEL CONCEPT

D) NYIT

A system for transmitting HDTV signals that uses a primary NTSC compatible channel and a reduced-bandwidth auxiliary channel has been developed by W. Glenn of the New York Institute of Technology [5]. Demonstration of this system was featured at the 1986 NAB Convention. Effort is currently being made to conduct over-the-air tests of the system using the UHF facilities of WUSA-TV in Washington, tentatively set for the Fall of 1987.

Extensive use has been made of the psychovisual response of people in the design of this system. It has been determined that the ability to resolve fine detail requires an integration time of at least 200 ms. This observation forms the basis for the proposal of a reduced frame rate for transmission of luminance detail and colour detail information. This is achieved through the use of a second enhancement channel in addition to the main NTSC channel which is adequate for good motion rendition of low resolution information. This affords the system backwards compatibility with existing NTSC receivers as well. The NYIT system is illustrated in Exhibit (4.7).

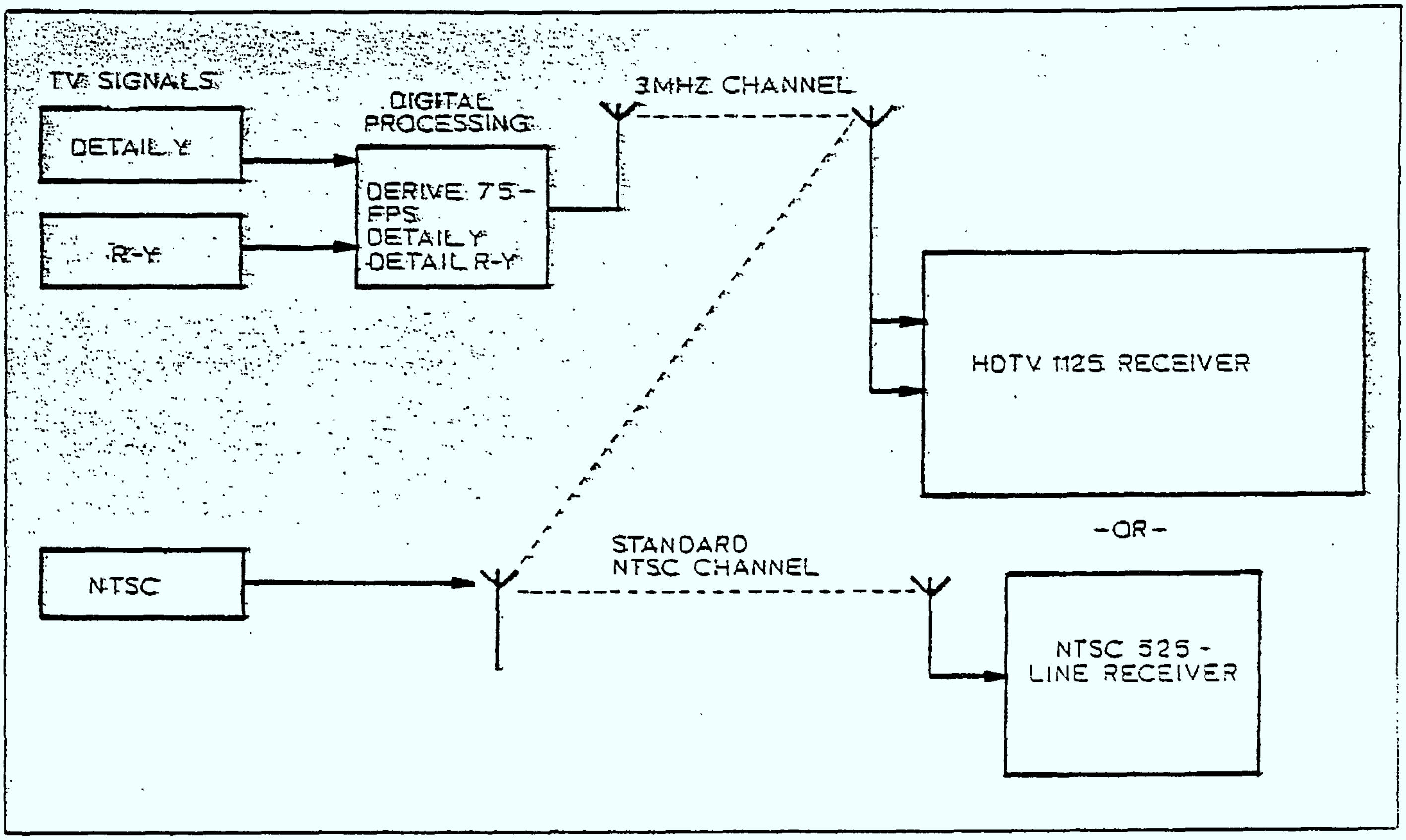
Like the MUSE system, the NYIT system achieves some of its bandwidth reduction by the use of diagonal sampling. Offsetting samples by a half-clock interval on adjacent lines yields a diagonal sampling pattern. This pattern reorients the axes of sharpest resolution in the image from diagonal to horizontal and vertical, corresponding to the orientation of sharpest acuity of the visual system. Therefore, for a given resolution, fewer pixels are required than for orthogonal sampling without the half-clock offset between samples on adjacent lines.

A conventional 525 line colour camera scanning at 60 fields interlaced provides the main channel video which, together with a 4.5 MHz audio subcarrier, occupies a conventional 6 MHz channel. The detail signal is derived from a high resolution black and white camera progressive scanning at 15 frames per second with 5:3 aspect ratio. This 'detail' signal is digitally filtered and translated to 7.5 frame per second 2:1 interlaced for transmission in a 3 MHz half-channel. Colour information is transmitted on a conventional 3.58 MHz subcarrier in the main channel, similar to TriScan and ENTSC. Prefiltering the colour and luminance channels prevents cross-talk.

The HDTV receiver processing a NYIT two channel signal will crop 10% off the height of the main channel and use 10% more of its width to generate a 5:3 aspect ratio display similar to the TriScan approach. It is proposed that the video be allowed to invade the horizontal blanking interval of the NTSC signal by 4 uS to facilitate the wider aspect ratio display.

The 'detail' signal transmission has its own synchronizing signals. The 'detail' information is stored in a frame store in the receiver and clocked out in synchrony with the scan-converted NTSC signal. Consequently, transmission path differences between the detail and NTSC signals do not result in misregistration in the image.

There is no new format suggested for digital audio transmission, although it is possible to use the cropped scan lines for this as proposed in the TriScan concept.



NYIT's proposed compatible HDTV system for terrestrial broadcast.

EXHIBIT 4.7

E) MAC

The extended 525 line sub-committee of the ATSC were considering presenting the B-MAC transmission system as a standard. In a 525 line format, B-MAC is adaptable to standard television receivers by the addition of a set-top decoder. The B-MAC system is currently being used to deliver a television service to 20,000 DBS receivers in Australia for the Australian National Broadcasting Service, chiefly to service sparsely populated rural areas of that country [8, 9]. B-MAC is one member in a family of MAC (multiplexed analog component) formats that differ from each other principally in the manner in which digital data is multiplexed with the video.

In MAC systems, the luminance component is time compressed in the ratio 3:2 so that one line of NTSC video is transmitted in 35 uS. Each of the two colour difference components are time compressed 3:1 resulting in a colour transmission time of 17.5 uS for each line as shown in exhibit (4.8).

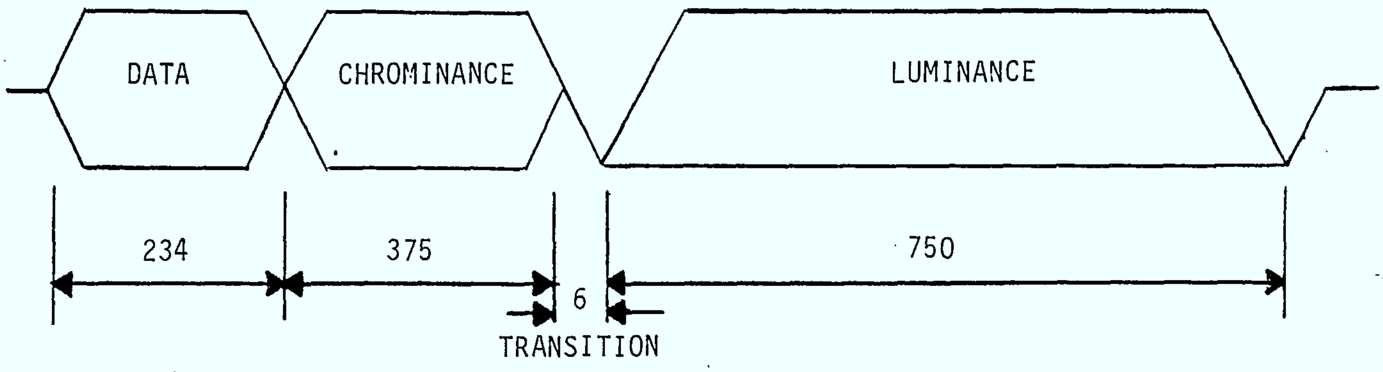


EXHIBIT 4.8
B-MAC SIGNAL SAMPLE PERIODS OF 1365fH (21.477 MHz)

The two colour components are sent on alternate lines, time multiplexed with the compressed luminance signal. There is no separate colour subcarrier, and there is no separate audio subcarrier because the audio is digitized and time compressed to fit into the horizontal blanking interval, which can support a data rate of 1.8 MBit/sec. in B-MAC. The MAC format is particularly well suited to FM satellite transmission [10]. MAC was developed for the satellite transmission of video signals using an FM modulated channel.

Composite NTSC coding was developed for AM terrestrial transmission with its flat noise distribution across the luminance and chrominance portions of the video signal. FM modulation has a triangular noise distribution which results in a much poorer signal to noise for the chrominance information carried on the higher frequency colour subcarrier than for the lower frequency luminance.

The MAC signal dispenses with the chrominance and audio subcarriers and equalizes the signal to noise for the audio, colour and luminance portions of the video signal. Transmission of the luminance and chrominance components in separate time intervals eliminates separation problems characteristic of NTSC.

The perfect separation of colour and luminance combined with non-existent differential gain and phase distortion and improved chroma bandwidth of the MAC transmission system facilitates the delivery of RGB quality video to the receiver.

There are several different versions of MAC, the letters A through D preceding MAC indicate the transmission process used for audio and data information. Each of the formats has its own advantages and disadvantages summarized in table (4-4) tailored to the group supporting each format. A description of the various MAC systems is given by Lowry in reference [10].

TABLE 4.4 MAC FORMAT OPTIONS

	A-MAC	B-MAC	C-MAC	D-MAC
Data Capacity (Approx.)	2 Mb	1.8 Mb	2.5 Mb	3 Mb
Cable Compatible	No	Yes	No	No
STV/MDS Compatible	No	Yes	No	No
Conventional Satellite Receiver Compatible	Yes	Yes	No	No
VCR Compatible	No	Yes	No	No
Compatible with HDTV in Bandwidth	No	Yes	Yes	Yes
Cost	Medium	Low	Medium	Low

A-MAC offers a rugged data channel but has a constrained bandwidth that is difficult to extend for HDTV. C-MAC can be directly demodulated into digital form, but it uses a channel bandwidth greater than 10 MHz to transmit video. D-MAC is suitable only for satellite distribution and requires dual video and data receivers. B-MAC can be held to 6 MHz for cable distribution or extended in bandwidth for HDTV signals.

A paper presented by C. Rhodes at the 1985 ICCE [11] describes how the B-MAC format lends itself to extended definition television. The luminance bandwidth available is 4.2 MHz when a sampling clock of 14.3 MHz is used. This frequency is 4 times NTSC colour subcarrier and 910 times the horizontal scanning frequency. These important relationships are maintained in B-MAC in order to simplify conversion to a NTSC compatible display. The 4.2 MHz luminance bandwidth requires 6.3 MHz of transmission bandwidth due to the 3:2 time compression. The extension, using

B-MAC, from 4:3 aspect ratio to a more desirable 16:9 wide aspect ratio is conceptually simple - a matter of clock speed in the decoder three-line memory. A 16:9 aspect ratio transmission would be received on a compatible 16:9 receiver using the same clock relationship as 4:3 transmission to a 4:3 receiver, i.e. 12x:8x:4x where 12x = receiver sample (memory write) frequency, 8x = luminance read clock, 4x = chroma read clock where x is 455/4 times the horizontal scanning frequency. A 16:9 aspect ratio transmission to a 4:3 display is processed with clock relationship 12x:6x:3x and side portions of the wide screen picture are cut off. Extra information could be sent to a compatible receiver to indicate what parts of the picture to crop. Notice as well, that the receiver needs to be adaptive with respect to read clock frequency in order to be compatible with both 4:3 and 16:9 transmissions.

The evolution to wide screen is only trivial if it is anticipated and MAC decoders are equipped with the necessary adaptability at the outset. It appears from a paper presented to IBC 86 by M. Windram et al [12] that decoder manufacturing economics will play havoc with forward compatibility as they cite short cuts the French and Germans are condoning in their respective DBS system specifications for D2-MAC.

M. Annegarn and company discuss the adaptation of MAC to the transmission of HDTV in an IBC 86 paper [13]. High definition pictures would originate at a source with a high number of scanning lines to avoid any compromise at the source. Similarly, the display device has a sufficient number of lines to eliminate visible line structure, even in displays up to 1 m^2 in area.

The additional picture information to transform a 4:3 aspect ratio, 525-line interlaced picture to a 16:9 aspect ratio 1050-line interlaced or 525-line sequential scan picture can be transmitted by one of two different methods depending on transmission requirements. The enhancement information can be sent as a separate SCPC signal on the satellite transponder, exhibit (4-9a), or on a subcarrier as shown in (4-9b) for cable distribution.

The enhancement information contains the difference (A-B) between the lines of the standard 525 line interlaced signal (A) and the additional lines required for HDTV (B). Since the enhancement signal contains the line difference information it has a wide bandwidth only when the original picture has high frequency diagonal information.

Since the HDB-MAC requires less than 12 MHz, the signal can be sent on two adjacent 6 MHz CATV channels. Therefore, only 2 CATV channels are required to provide a HDTV signal to HDTV receivers and a decoded NTSC signal to corresponding television receivers.

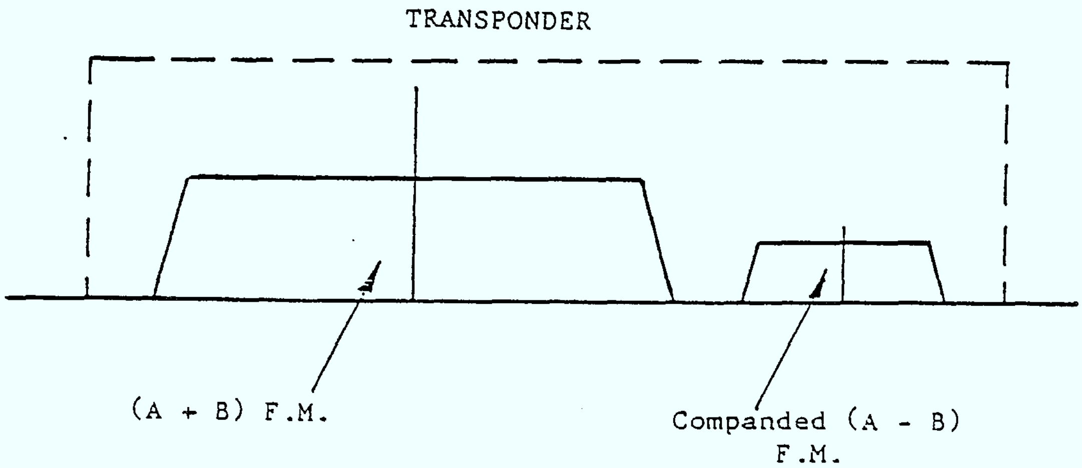


EXHIBIT 4-9a SCPC APPROACH FOR TRANSMISSION OF B-MAC

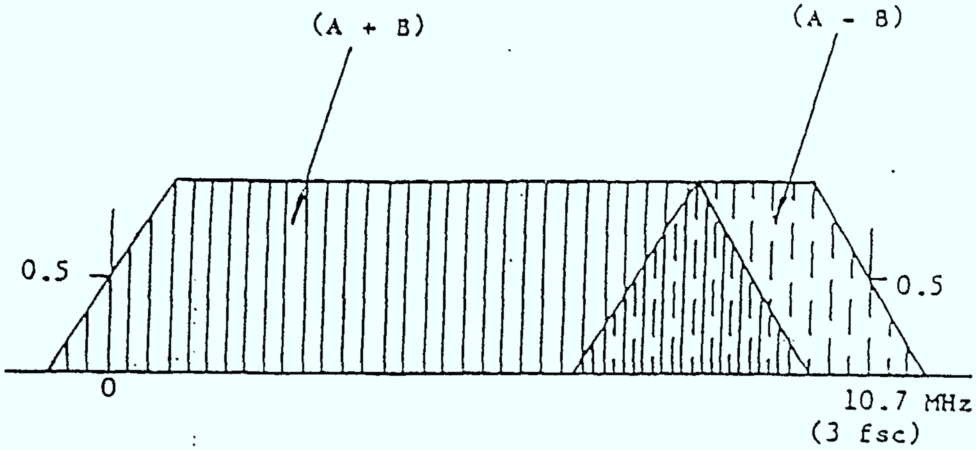


EXHIBIT 4-9b SUBCARRIER APPROACH FOR TRANSMISSION OF B-MAC

CHANNEL ALLOCATION IMPLICATIONS

Enhanced television transmissions are a very likely step in the evolution of HDTV's becoming available to consumers. The format used for EDTV may be one of a number of potential candidates as described in the previous section. Table (4.5) summarizes the transmission bandwidth requirements and the number of channels required, expressed in terms of standard NTSC channels, for several proposed EDTV systems.

Carriage of EDTV signals on CATV facilities is a desirable means of distributing the new programming to consumers. The degree of compatibility with current CATV performance and channel utilization is therefore of prime importance.

At this time, none of the proposed EDTV schemes have been tested on a CATV system so there are considerable performance questions to be answered. A few of the obvious parameters to be investigated for each system are carrier-to-noise, carrier-to-interference, carrier-to-hum ratios tolerance, compatibility with comb referenced phase-locked carriers, tolerance to multiple close-in echoes caused by signal reflection at cable connectors, and the equivalent w-curve for interference susceptibility as a function of frequency in the vicinity of the EDTV channel. Equally important is the determination of the extent to which the new signal format will cause interference, either directly, or indirectly to existing signals anywhere in the CATV system.

TABLE 4.5

CHANNEL REQUIREMENTS FOR EDTV

EDTV System	Baseband Bandwidth	NTSC Channels Required	Contiguous Channels
MUSE	8.1 MHz	2	Yes
ENTSC	4.5 + 4.5 MHz	2	No
NYIT	4.5 + 3.0 MHz	1.5	No
TriScan	4.5 MHz	1	N/A
HDB-MAC	10.7 Mhz	2	Yes

Based on the channel requirements as given in Table (4.5), it would appear that some alternatives are friendlier than others when considering CATV distribution. The TriScan scheme in particular would appear to fit cleanly into the normal channel plans. The MUSE and HDB-MAC systems on the other hand requires two contiguous channels, a requirement not commonly encountered in the cable media. Two non-contiguous channels are required for the remaining schemes which will be potentially straightforward to deal with.

It must be assumed that when EDTV is introduced to the consumer, only a fraction of cable subscribers will wish to avail themselves of the new service. A majority of subscribers will not have the special receiving hardware required to display an extended definition picture. It would be an undesirable situation if this majority tuned through unwatchable signals in the course of channel scanning. For this reason, it is expected that nonstandard signals will be located near the highest frequencies available on the CATV distribution facility. Unfortunately, this is usually where signals suffer the worst carrier-to-noise ratio due to the attenuation characteristics of coaxial cable used in CATV systems. The augmentation or detail channels; which would logically be placed at the top of the channel lineup, should therefore be somewhat tolerant of noise.

Compatibility with NTSC receivers is also desirable since it is assumed that the programming software being distributed in enhanced form is of interest to more subscribers than only those equipped with EDTV receivers.

Duplication of the program in NTSC form requires an additional channel which, in the case of MUSE in particular, means three channels are required to distribute the program to all subscribers. There will be very few CATV operators prepared to sacrifice 18 MHz of cable spectrum for one program.

Currently, a degree of intermodulation distortion is tolerable in CATV systems since the distortion products occur at frequencies where conventional television signals have low sensitivity. Hence, the allowable level of third order distortion in cable systems is -51 dB relative to carrier level. A tolerable level of second order distortion products is -53 dB relative to carrier level. The tolerable amount of interfering signal level for all frequencies within a television channel has been documented and is referred to as the "W" curve. This data is reproduced in Exhibit (4.10). Data similar to the "W" curve is required for each EDTV system before a definitive statement can be made regarding new distortion performance criteria for transmission on CATV facilities. **The cost implication of reducing the distortion generated in CATV facilities to facilitate EDTV distribution may be stated as approximately $6 per dB improvement per subscriber.** Preliminary theoretical analysis of the Philips ENTSC system indicates no improvement is required in distortion performance of cable systems.

In summary, the EDTV schemes that have the least impact on CATV channel alignments will be looked upon most favorably by the CATV industry. Similarly, systems that require special technical performance considerations will be unlikely candidates for cable distribution. The reason for this is economic. It is believed by most operators that there is minimal additional revenue available from the provision of extended definition television to offset any expenditure incurred to deliver it.

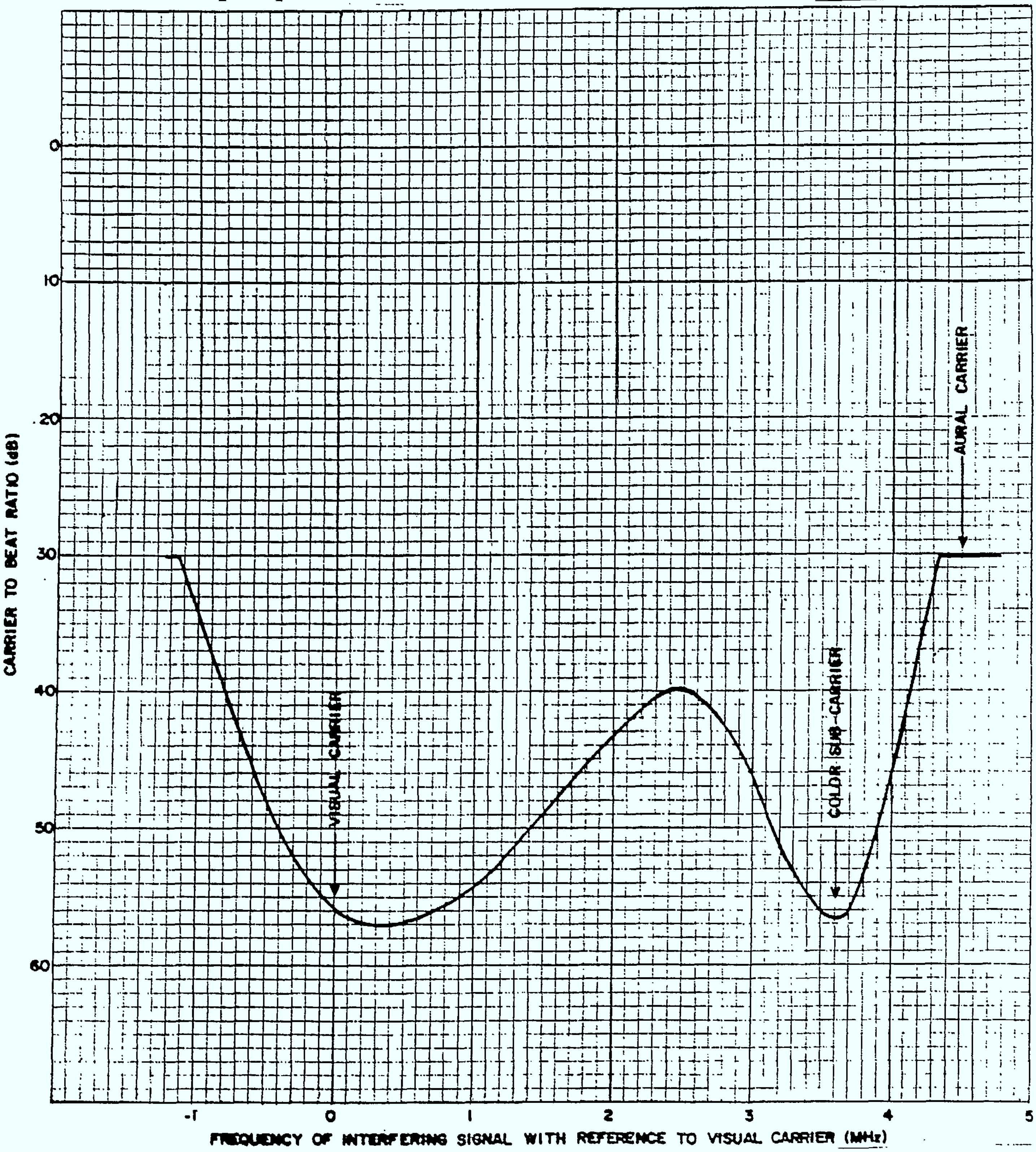


FIGURE 4.10
PERMISSIBLE LIMITS FOR MINIMUM CARRIER TO BEAT RATIO (SINGLE FREQUENCY)

BACKWARDS COMPATIBILITY WITH NTSC

One factor that will be of primary significance in the achievement of extended definition television is the degree to which the transmission scheme selected supports program delivery to the consumer without special receiving equipment. This is due to several factors, including the desire of the software provider to maximize his audience and hence his revenue; the limitations on spectrum available to the terrestrial television broadcaster which precludes duplication of programs in two different transmission systems coupled with the desire to maximize viewing audience and hence advertising revenue; and the similar reluctance by CATV operators to allocate large segments of cable spectrum to a single program.

Television transmission systems such as MUSE or MAC derivatives such as Scientific Atlanta's HDB-MAC are incompatible with NTSC receivers. Currently, a $250 decoder is required to transcode a B-MAC signal to the NTSC format while a home transcoder for MUSE is totally impractical for many more years. There is very little appetite in the cable industry for decoder boxes, so undesirable program duplication is required with these noncompatible transmission systems.

At the same time, the visual impact of the extended definition service must be sufficiently great, relative to that of good quality NTSC, to motivate the consumer to purchasing a new receiver. It is therefore reasonable to expect significant departure from the standard NTSC format will be required to achieve a spectacular improvement, including the requirement for additional bandwidth.

The two channel EDTV schemes appear an attractive compromise in the quality versus bandwidth tradeoff as well as offering backwards compatibility of the main program channel.

In both the two-channel EDTV systems, the main NTSC compatible channel is prefiltered to give optimum clarity and colour fidelity to the final display. This prefiltering is also beneficial for conventional television receivers, particularly those with comb filters. Therefore, even those without compatible EDTV receivers will enjoy better quality pictures on the enhanced service, which will help foster the association of extended definition with the EDTV services.

The desire to maximize viewing audience is a key element in obtaining payback on the investment in producing a movie or other piece of television programming. Extra costs will be incurred in distributing an extended definition signal due to the extra bandwidth and additional processing required. Recovering these additional costs from a small base of consumers with compatible receivers will require each consumer to pay a significant premium. The combination of receiver and programming cost in such a case will prove to be too great a price for the resulting benefit realized by most consumers and the EDTV service will never reach a profitable state. Recovering the cost of delivery from license fees or advertising revenue obtained from airing the program to the large number of viewers with conventional receivers as well as to those with EDTV receivers will allow the extended definition service to be introduced and reach profitability. Therefore, having one distribution system that can deliver an NTSC compatible signal to the majority and an extended definition signal to the videophile's special receiver is highly desirable.

Trying to squeeze more information into the NTSC format will not likely give adequate improvement. The use of vertical cropping and horizontal overscan to generate a slightly wider picture is not good enough. Transmitting additional side panel information to create a wide aspect ratio display using a second channel is much better. Filling the unused portion of the second channel with resolution enhancement information in real time overcomes problems with motion that impair most schemes for enhancing picture quality by using frame stores and locally interpolating at the receiver.

The two-channel ENTSC scheme looks to be the most promising EDTV technique proposed to date.

SIGNAL SECURITY IMPLICATIONS

There is equal probability of public broadcast and discretionary programming services being available in enhanced form if a broadcast friendly distribution technique is adopted. The discretionary services will need to be restricted to those paying the appropriate premium. This can be accomplished by a variety of means as discussed in the signal security sections of "CATV Implications" in Chapter 3. In general, the choices available are scrambling, interdiction, and denial via filters.

The most appropriate treatment of discretionary enhanced definition services in a particular CATV operation will depend largely on how conventional pay television signals are secured. The addition of an augmentation channel to enhance a pay service is assumed in this discussion. Where traps or filters are used to secure the pay channel, it may not be necessary to make any changes to existing hardware. The filters used may also prevent the new augmentation channel from reaching those not paying if the filter attenuates more than one channel. The augmentation channel may not give a viewable picture even if it were receivable by unauthorized subscribers. Even where the augmentation channel is receivable, it may be deemed to carry insufficient program information to be of concern. Where traps are used it may therefore be unnecessary to take any steps to secure the augmentation channel.

Where interdiction methods are used to secure the original pay signal, similar implications apply for two-channel EDTV as for the case of traps discussed above. Interdiction systems for more than one pay channel are most likely to require that those channels are close together in frequency. This may make it impractical to secure the augmentation channel by using interdiction if it occupies a slot at the top of the band. Scrambling techniques for securing pay channels most commonly include removal or suppression of horizontal synchronizing signals to prevent normal television receivers from displaying a stable picture. The addition of an augmentation channel, which must be synchronized with the main channel to allow the assembly of an enhanced picture, potentially compromises the scrambling effectiveness by supplying a conventional source of synchronizing signal. New digital television sets with Picture-in-Picture (PIP) features may be able to synchronize on the augmentation channel and display the main channel unscrambled. A similar capability may exist in add-on digital feature units which have two tuners and PIP capability. PIP is the key to "descrambling" since the two input channels must be internally synchronized in order to be displayed together.

The obvious response to the potential compromise in signal security is to remove synchronizing signals from the augmentation channel. This may not be desirable, however, since subscribers wishing to avail themselves of enhanced quality pay television would require two descramblers, one for each of the two channels used to deliver EDTV. This increases the access cost significantly in addition to adding to the complexity of the consumer electronics interconnect jungle. Orchestrating all the components required to generate the EDTV picture will be beyond the capability of most cable subscribers so external descramblers for the augmentation channel are undesirable.

A means should be found to secure the total EDTV service as well as the main NTSC compatible channel so that current scrambling systems remain in operation. The considerable investment in descrambling equipment by Canadian cable operators makes them reluctant to opt for any security alternative that renders this equipment obsolete prematurely. It should remain possible to secure the main channel with current equipment without compromising security when attempting to provide enhanced quality through an augmentation channel.

Effective signal scrambling should therefore be an inherent part of the EDTV system.

In particular, the augmentation channel should support some form of line translation scrambling that is recoverable at the EDTV receiver in conjunction with an in-band encrypted data channel.

In this way, no additional descrambling equipment is required for the EDTV compatible subscriber and the scrambling is generic enough to work with any sync suppression scrambling currently in use without compromising its security.

In the event a non-backwards compatible EDTV system is adopted, a means of securing the signal for pay television is desired. Since there would be no constraints imposed on EDTV scrambling forcing the system to work with existing NTSC receivers, the system can make effective use of line translation or variable line start scrambling. Considering the amount of digital processing involved in EDTV systems, it seems viable to use digital encryption to scramble the picture. Universal descrambling using the DES encryption algorithm would eliminate the need for any stand-alone descrambling equipment. New EDTV receivers would have the required descrambling function as part of the digital processing system.

The implementation envisaged is an encryption of the video in digital form at the transmitter. Subsequent to encryption, using the DES algorythm, the digital signal is converted to an analog signal for transmission. The reverse process takes place at the receiver, where the television signal is digitized, decrypted and processed to generate the appropriate signal for display. The analog to digital conversion and its complement at the receiver will generate some level of uncertainty in the least significant bit of the received digital signal so it should probably not be used in the encryption algorithm.

The opportunity to include a scrambling system into the EDTV system exists. Those engaged in the development of EDTV systems must be encouraged to think of signal security as they transform their ideas to hardware design.

One fundamental requirement for any EDTV signal distribution on CATV facilities is scrambling compatibility. A means has been identified above, that will address the CATV operator requirements.

It should be a prerequisite to the distribution of EDTV in Canada that such scrambling means be included in the signal unless some other technique that is equally compatible is accepted by the CATV industry.

The only other alternative would be a costly transfer to alternative signal security equipment which is undesirable, potentially leaving cable out of the EDTV distribution business.

BYPASS THREAT OF PRE-RECORDED MEDIA

There are a significant number of broadcast television executives concerned that they will be left behind in the progression to HDTV. The American Centre for Advanced Television Studies (CATS) has as members all of the major television networks ABC, NBC, CBS and PBS as well as organizations with television related business interests. This group is currently wrestling with the question of how to deal with the apparent development of HDTV tape and laser disc formats for the consumer market.
The large Japanese electronics firms are spending large amounts of money (approximately $200 million U.S.) on research and development for HDTV equipment. This level of investment in new television technology cannot be justified by the limited professional/industrial market.

The reasoning within CATS is that the primary goal of the Japanese is to develop a video equivalent of the audio compact disc which would completely bypass the normal broadcast chain in delivering high quality video software to the consumer.

This scenario is reinforced by the introduction of two new consumer video cassette recorder (VCR) signal formats, super VHS and extended definition Beta. Both of these new schemes extend the recording bandwidth on new metal particle magnetic tape to 7 MHz. The larger bandwidth makes it possible to increase picture resolution to 500 lines (ED Beta), greater than the maximum theoretical NTSC capability of 340 lines, and double the performance of typical VCR equipment available to date. Table (4.5) compares the resolution and signal-to-noise performance of the common television media. It is obvious that the resolution, or ability to distinguish fine detail in a picture, of the new tape formats is much greater than any other available video media apart from 35 mm film.

The combination of higher resolution plus wider aspect ratio (16:9 versus 4:3) will make the new consumer video equipment stand out in the retail store when compared with conventional receivers. The salesman can assure the consumer that nothing, especially cable, will get in the way to impair picture quality. What he sees in the store is the same high quality he will see at home. All the latest movies will be in the new format, just as all the latest hits are on compact discs. Even VCR tape rental outlets will appreciate the new market for EDTV rentals.

TABLE 4.5
TYPICAL PICTURE QUALITY

Medium	Signal To Noise	Resolution
35 mm film	50 dB	2000 lines
HDTV camera	50 dB	1030 lines
ENTSC	45 dB	500 lines
ED Beta VCR	45 dB	500 lines
Super VHS VCR	45 dB	430 lines
Laser Video Disc	45 dB	400 lines
Broadcast TV	45 dB	330 lines
Cable TV	43 dB	330 lines
Conventional VCR	40 dB	240 lines

The above scenario may happen relatively quickly. Projection TV set manufacturers in particular are well poised to take advantage of the new format. Building a wider display area will not be difficult and it's the larger displays that will benefit most from the improved resolution. The new Super VHS and ED Beta VCRs will support wide aspect ratio formats without modification; the signal parameters will appear the same as for normal aspect ratios.

The introduction of EDTV via prerecorded media can proceed without requiring that any broadcast or cable transmission system be upgraded first.

The threat of bypass around terrestrial broadcast and cable will be amplified if these traditional distributors sit back and do nothing.

A way must be found to improve broadcast quality so it is equivalent to the new VCR formats,

including wide aspect ratio. Most consumers will continue to prefer receiving EDTV software via cable or antenna rather than suffering the inconvenience of visiting a kiosk or store to pick it up.

One viable solution is the adoption of the Philips two-channel ENTSC format.

This scheme is capable of delivering high quality, wide aspect ratio video and accompanying compact disc quality music as well as being compatible with conventional NTSC. There is sufficient spectrum in the UHF band in most parts of Canada for terrestrial broadcasters to use for the required augmentation channel while the upgrades necessary on the main VHF channel are modest. Similarly, there is space on most cable companies' facilities to accommodate several EDTV augmentation channels.

The reason two-channel EDTV is a viable means of preventing bypass by pre-recorded media is due to the advanced digital processing of the video that is now possible in television receivers. The equipment described above for playback of EDTV cassettes requires no special digital processing at all - it simply takes advantage of extended bandwidth available on the new metal particle tape. Broadcasting of EDTV and ultimately HDTV must uniquely conserve bandwidth and hence complex digital processing at the signal transmitter and receiver must be exploited to achieve enhanced television in the home. As techniques in motion adaptive processing improve, increasingly higher definition video will be squeezed through the limited bandwidth allocated for television broadcast. Some potential developments are discussed in the next chapter.

The work being performed by television engineers will be of little use however if no action is taken to put their results into practice.

Now is the time to decide on how broadcasters and CATV operators will proceed from the comfortable world of NTSC to HDTV.

DBS OPPORTUNITY

One of the most significant bypass mechanisms around terrestrial broadcast and cable television is direct broadcast via satellite. Satellite receivers currently deliver a wide variety of television programming to thousands of homes in Canada, much of it American pay television and network feeds. The cost of the equipment required to receive satellite transmissions has dropped to less than $2,000, with the dominant element now being the large dish antenna required for mainly C-band programming.

The use of higher frequency Ku-band channels and more powerful satellites would reduce the size of the antenna from the current 2m to less than a meter while delivering a better quality signal. The bandwidth available on some Ku-band satellite channels is 54 MHz which makes them extremely well suited for EDTV and even HDTV distribution.

It is technically feasible to offer an HDTV service via satellite tomorrow.

The most significant hurdle is a lack of receiving hardware.

Home satellite receivers became popular <u>after</u> a large number of commercial users had established satellite transmission of pay television and network signals. People in outlying areas not served by cable or terrestrial broadcast and hobbyists intrigued with the new readily available signals began installing satellite receive dishes in their backyards to enjoy a large variety of free programs.

A possible DBS development scenario for HDTV can be described in a similar way. Commercial users currently use a non-NTSC standard television system called B-MAC. This analog component system lends itself to picture quality considerably better than that available with NTSC and is effectively secure using variable line delay scrambling. As enhanced definition forms of this transmission system evolve, it may become attractive to firms engaged in closed-circuit promotions as well as theatre operators as a means to eliminate film handling and transportation.

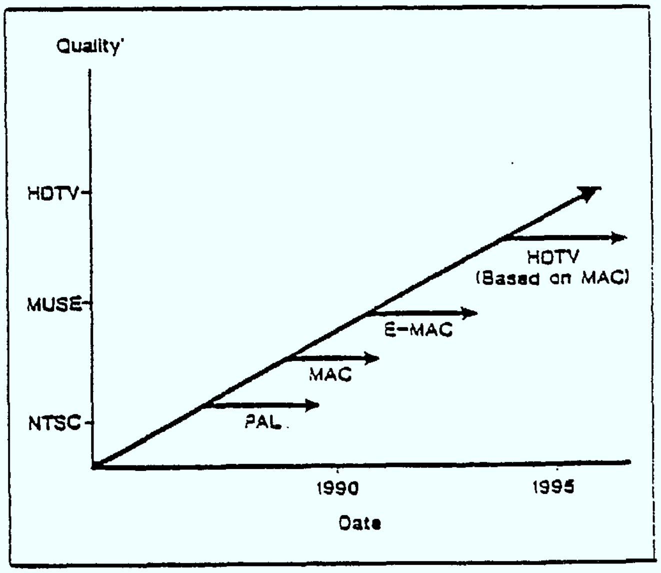
As commercial development of EDTV and ultimately HDTV via satellite increases, equipment cost will decrease. In particular, wide aspect ratio displays will become more numerous and eventually affordable to the consumer. A DBS service then becomes financially viable, either on a stand alone basis or using existing program transmissions for theatres. In either case, the consumer requires a new satellite receiver which will contain the MAC decoder and can adapt to a hierarchy of MAC standards. The output signal can range from standard NTSC to wide aspect ratio enhanced resolution formats for display on a suitable monitor. A progression of MAC standards has been envisaged by European DBS planners and their implementation timetable is given in Exhibit (4.11).

Again, extensive use of digital video processing is required to generate a display from the MAC components. Exhibit (4.12) illustrates the time multiplex of the various components required to reassemble a picture for an E-MAC signal. The complexity of these processes is not beyond the capabilities of technology available today. Extension to HDTV is envisaged through an increase in baseband bandwidth from 6.3 MHz for MAC to 11.6 MHz [6,7].

Part of the Philips ENTSC system is a MAC based satellite distribution system they call MAC-60. Little detailed information is available regarding MAC-60 but it is conceptually organized in such a way that HDTV quality is supported while being easily transcoded to two channel ENTSC.

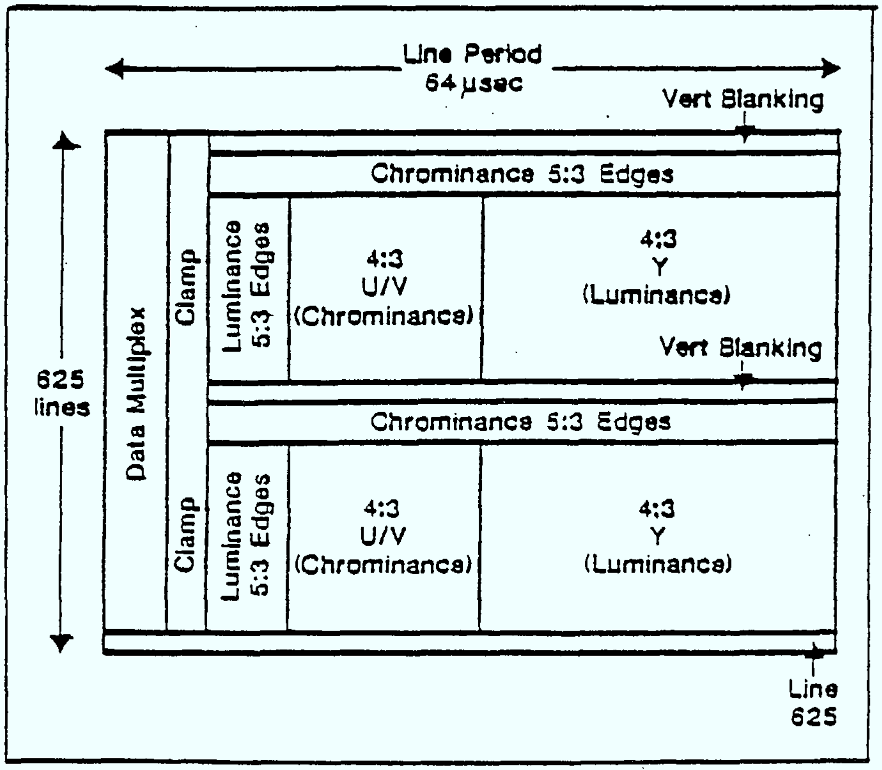
There can be no doubt that HDTV signals will eventually be transported via satellite. Less certain is whether home receivers will be able to tune in directly. To some degree, that will depend on how difficult it will be to distribute EDTV and HDTV via cable.

If CATV has difficulty adapting to the new signal formats, it may be detrimental to their future existence.



Evolution of television systems

EXHIBIT 4.11



One frame of E-MAC TDM

EXHIBIT 4.12

CONCLUSIONS

Television transmission systems capable of delivering to the home an image quality approaching that of 35 mm film have been proposed and demonstrated by a number of research teams active in television signal processing. Full compatibility with current television receivers is possible and desired to conserve transmission capacity while allowing improved quality to be realized.

One of the most promising systems has been proposed by Philips and is called ENTSC. This two-channel system is fully compatible with existing receivers, it produces wide aspect ratio pictures of 16:9 and improved resolution which is not degraded with motion in the displayed scene. As in all EDTV schemes, extensive use is made of digital signal processing in the transmitter and receiver to create an enhanced definition image in the home. Processing at the transmitter will improve picture quality for conventional receivers on the backwards compatible EDTV systems.

A paper concept called TriScan on the other hand, attempts to squeeze an EDTV picture into one conventional NTSC video channel. The constraints this imposes on EDTV transmission limits both aspect ratio and resolution achievable to the extent that it will be difficult to notice the improvement over conventional NTSC.

A large amount of publicity has surrounded the Japanese MUSE system for transmitting HDTV signals. This system is entirely incompatible with existing television receivers and places significant new channel allocation constraints on CATV systems. Program duplication for NTSC receivers seems unavoidable, requiring that a total of three conventional television channels be used for each MUSE program.

The MAC type transmission systems suffer the same drawbacks to CATV carriage as does MUSE in so far as being incompatible with conventional receivers and requiring two contiguous channels. The cost of converting the MAC transmission to NTSC for display is low enough, however, to allow home decoders to be a viable means of avoiding the necessity of duplicating programming on a third channel used to serve those with conventional receivers. Very good picture quality and a wide screen 16:9 aspect ratio are possible with MAC as embodied in HDB-MAC (for High Definition B-type Multiplexed Analog Component) being developed by Digital Video Systems division of Scientific Atlanta. This format is definitely well suited for satellite distribution of HDTV to CATV headends.

Pay television scrambling security may be compromised by two-channel EDTV systems unless scrambling provisions are made. A very undesirable outcome of any two-channel EDTV system is a requirement for two descramblers. Therefore, some inherent line translation or variable line start scrambling system for the augmentation channel of the two-channel systems seems desirable.

Similarly, in order for cable systems to carry new non-backwards compatible EDTV formats, some similar scrambling mechanism should be inherent in the design so that a universal addressing system is adopted in all receivers for the new EDTV signals.

The introduction of high quality VCR formats such as Super VHS and extended definition Beta to the consumer presents a new standard of picture quality to the CATV subscriber. New demands for better performance from cable will result from the new VCR formats. In a few years, HDTV levels of quality are potentially going to be available. Cable systems need to offer programming of similar quality in order to remain competitive. It is imperative, therefore, that CATV systems distribute HDTV programs in the near future. The CATV industry must be actively involved in the international arena of HDTV transmission standards development. If CATV is unable or unwilling to embrace HDTV distribution, it will most certainly see its subscriber base eroded by the bypass mechanism of VCRs and other prerecorded media and by direct reception of satellite signals using backyard dishes.

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CHAPTER 5

DEVELOPMENT IN DIGITAL VIDEO PROCESSING

TABLE OF CONTENTS

DEVELOPMENTS IN DIGITAL PROCESSING

The introduction of digital video processing into consumer television sets and video cassette recorders occurred several years ago. A single supplier of processing ICs, ITT Intermetal of Germany, has been able to motivate television and VCR manufacturers to change dramatically the way these products are designed and built. The advantages touted by the vender [1] of this new technology included:

- significantly reduced parts count
- elimination of manufacturing tolerances
- elimination of performance degradation over time as a result of parameter drift
- fully programmable
- features determined by software rather than hardware
- automatic computer controlled alignment
- facilitated multi-standard TV design, i.e. PAL, NTSC or SECAM

In addition, the digital processing of video would facilitate such functions as:

- adaptive noise reduction by correlation or non-linear response
- improved display quality through intermediate storage and increased horizontal and vertical frequencies
- reception of digitally transmitted TV signals
- ghost compensation and suppression of reflections
- improved picture quality by means of a digital comb filter
- test processing
- picture improvement through automatic brightness, contrast, colour and fleshtone control
- picture-in-picture

A number of digital television sets and VCRs are currently available in North America. Chapter 2 has a synopsis of the implementation of digital video processing.

A review of the various functions and features alluded to in the foregoing will now be presented. The degree to which each is implemented in current products will be given. Where possible, an implementation scenario will be described for features not yet in product form.

IMPROVED COLOUR AND LUMINANCE SEPARATION

The standard ITT digital chip set used in all TV sets and VCRs with digital video processing includes a comb filter for the separation of chrominance and luminance information in the NTSC signal. This comb filter is constructed around a single horizontal line of delay (63.5 uS) comprised of RAM. The luminance bandwidth is 4 MHz for video signals demodulated from the tuner or 7 MHz for baseband video input.

The common artifacts that result from cross-colour and cross-luminance interference are not removed with a single-line comb filter. The progression in receiver hardware to two-line comb filters can significantly reduce, but not totally eliminate, these artifacts. Engineers at Mitsubishi have presented [2] adaptive two-line comb filter technology suitable for consumers' receivers. The choice of video samples used in the chrominance/luminance separation algorithm is a function of the presence of luminance transitions in either the vertical or horizontal direction. An adaptive system is capable of significantly reducing the incorrect interpretation of high frequency luminance information as chrominance or the similarly false portrayal of chrominance as luminance. It is likely that two-line comb filters will be available in television sets by 1989.

A developer of enhanced comb filter encoders and decoders, Yves Faroudja, states that cross-colour reduction achieved by using a two-line comb filter encoder and one-line comb filter decoder (Sony Profeel or similar) is a factor of 2.7 relative to simple filter technology. Upgrading the television decoder to a two line comb filter increases the cross-colour reduction factor to 6 [14].

In a study conducted by Dubois and Faubert [3], various combinations of encoder and decoder types are compared subjectively. Their finding is that beyond implementing a two-line comb filter at the receiver, the most significant improvement is achieved by prefiltering luminance and chrominance at the encoder to eliminate cross-contamination of the luminance and chrominance "channels". Furthermore, it was found that suitable intrafield filtering was adequate to give a perceived subjective quality improvement almost as good as the theoretical limit of NTSC. It seems, therefore, a moot point to entertain three dimensional filtering, involving field stores, in order to further improve luminance and chrominance separation in NTSC video.

Improved chrominance/luminance separation is one enhancement that is lost on most consumers. There is very little perceived value in the consumer's eye for such improvement and hence little likelihood of it appearing in products until its cost of inclusion becomes practically nil.

NOISE REDUCTION

Recursive temporal filtering of the video signal using a frame delay as the delay element yields about 10 dB of noise reduction [4]. NEC has implemented this capability in their digital VCR, model DX-2000. It works very well on freeze frame, as expected, but on moving scenes, the temporal filter which performs a weighted average of successive frames causes smearing on moving edges. The noise reduction circuitry must therefore be motion adaptive to give acceptable improvement.

Full recursive filtering can be applied to areas of the picture where there is no motion while areas with motion would have reduced or no noise reduction.

The requirement of a frame store to achieve noise reduction results in a relatively high implementation cost. In high end VCRs, frame store memory has been added to achieve perfect freeze frame operation and hence the incremental cost of implementing filters for noise reduction is minimal. Currently, memory technology used for frame store implementation is based on 256 Kbit DRAM chips so that 16 chips are required for a full frame store with 8 bit quantization of the composite video. Very few control chips are required for the frame store if scan-line memory chips such as those available from NEC are used. Currently, 1 MBit DRAM chips are available for $30.00 each, while 4 MBit DRAM prototypes have been built by IBM and a 16 MBit DRAM chip has been prototyped by Nippon Telephone and Telegraph.

The anticipated mass production of 4 MBit DRAM chips will significantly reduce the physical size as well as the cost of a frame memory. The achievement of this technology by 1990 will facilitate the introduction of frame stores into television receivers.

Efforts conducted by Rossi [5] on signal averaging using less than a full frame store gave disappointing results. High frequency coring techniques were found to be more effective than horizontal averaging over a single scan line. Vertical averaging gave measurable improvement in signal-to-noise ratio, but there was minimal subjective improvement.

The development of motion detection algorithms suitable for adaptive noise reduction is ongoing. It appears likely that work in motion detection and the use of motion vectors in extended definition television (EDTV) and bandwidth compression schemes for HDTV will result in a successful adaptive recursive filter for improved signal-to-noise ratio of the displayed video signal.

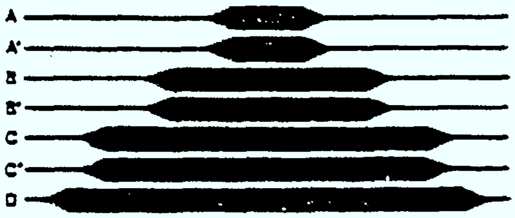
PROGRESSIVE SCAN

The interlaced scanning that is part of the current NTSC transmission system (see Chapter 1 for description) was developed in order to optimize the trade off between bandwidth and vertical resolution [6]. Transmitting 525 lines 60 times per second requires twice the bandwidth than the current 262.5-line field transmission. Transmitting 525 lines 30 times per second would require a comparable bandwidth but would result in objectionable flicker. This flicker can be eliminated by storing the image lines as they arrive and refresh the television screen at 60 Hz. Motion portrayal would suffer however as the image update rate would be only 30 Hz compared to the present 60 Hz. Using interlace in conjunction with a high field rate of 60 Hz provides good motion portrayal, better vertical resolution and less flicker. The vertical resolution achieved with NTSC is derated from the 525 line theoretical by an empirical fraction, known as the Kell Factor, of 0.7. Furthermore, not all 525 lines are normally displayed but rather 480 lines actually illuminate the television screen. Hence, the vertical resolution for NTSC is approximately 336 lines which is significantly more than that possible using a progressive scan of 240 active lines in the same bandwidth. An undesirable consequence of interlace scanning is 30 Hz line flicker on horizontal luminance transitions. Larger screen sizes, in particular, accentuate the scanning line structure and line flicker which gives a noticeable lack of vertical resolution compared to the horizontal resolution made possible by comb filters.

Progressive scanning of the image at the receiver can reduce the line flicker as well as increase the vertical resolution by taking advantage of the repetitive nature of television transmissions [7].

Several variations to a sequential scan converter with line interpolation have been proposed. Sony in particular, for a brief time had a digital scan processor and compatible double scan rate monitor available in North America. This device tried to achieve intrafield line interpolation in order to keep memory requirements down to 3 lines [8]. The output of the scan processor was a 525 line progressive scan video signal that required a 31.5 KHz line rate capable monitor for display (See Exhibit (5.1). The limitations of intrafield processing were apparent through the perception of reduced vertical resolution in the case of line averaging processing or residual vertical jitter with line repetition. The increased scanning frequency did result in a brighter image. The Sony equipment is no longer available outside Japan. Toshiba have since introduced a double scan television, Model CS-2897, but it too suffers from motion artifacts.

A better picture can be generated by using information from the previous field to generate the missing lines for progressive scan. In those parts of the picture where there is no motion, the lines from the previous field can be inserted between the lines of the current field with no processing required. In areas with motion, either an intrafield average or line repeat may be selected [7] (See Exhibit 5.2). Alternatively, motion vectors may be computed before transmission and appropriate linear transformations on the pixels of the previous field can be performed at the receiver to generate the missing line. The complex calculation of motion vectors at the transmitter reduces the complexity and cost of the receive, which can simply apply the vectors supplied along with the video signal to the field store contents. This concept is referred to as digitally assisted television. Computer simulations of this technique were reported at the 128th SMPTE Technical Conference by Thomas of the BBC [9]. It will obviously take several more years before a good sequential scan converter for television receivers is available.



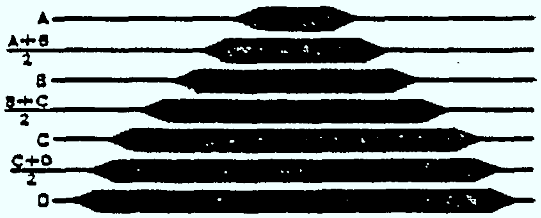
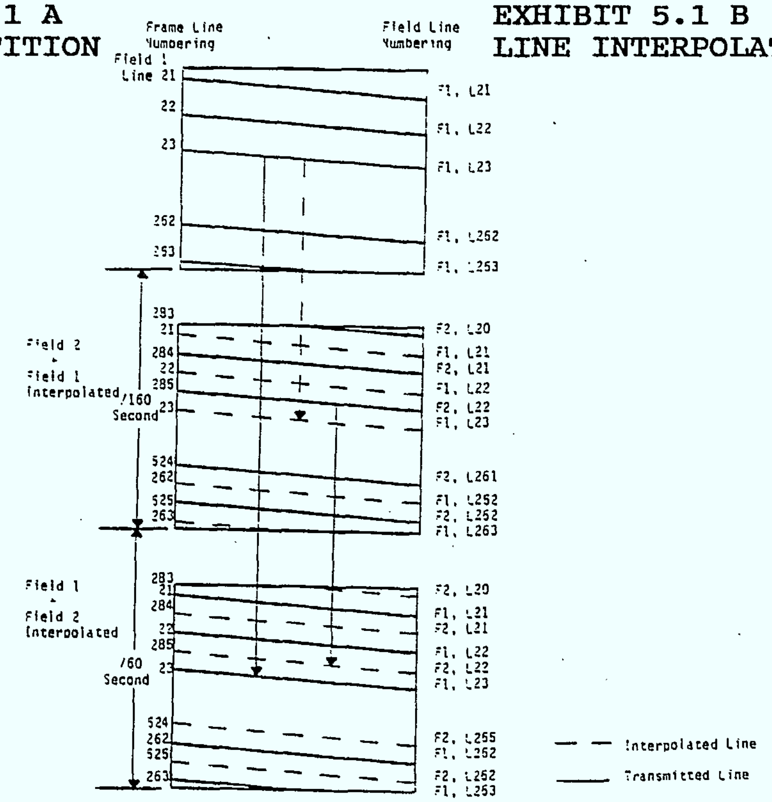


EXHIBIT 5.1 A
LINE REPETITION

EXHIBIT 5.1 B
LINE INTERPOLATION



LINE INSERTION TO IMPROVE DISPLAY RESOLUTION
EXHIBIT 5.2

GHOST AND ECHO CANCELLATIONS

The digital receiver may make ghost elimination available in consumer television. The digitized video signal can be passed through a delay chain and by extracting inverted video at various delay taps and proportionately adding to the incoming video, ghost images can be eliminated [13]. Phantom sync signals in the vertical blanking interval provide the information required to calculate the required delay and amplitude parameters. It is uncertain whether this technique can be applied to the multiple close-in reflections that occur in cable television systems due to the very large number of ghosts. Current NTSC transmission is not seriously degraded by these reflections. Any transmission scheme for High Definition Television (HDTV) will need to be immune to close-in reflections as well if it is to be used over cable. The demonstration of the MUSE system (described in Chapter 4) in Washington, DC, highlighted the need for immunity to reflections. The high definition pictures were very good excepting the visible and annoying ghosts that were present. It would appear that the MUSE system is more susceptible to ghosts than is NTSC. No testing of MUSE on a cable system was permitted while the equipment was in Washington, to the disappointment of the National Cable Television Association (NCTA).

INTERMODULATION DISTORTION MASKING

A process similar to echo cancellation is intermodulation distortion masking. Amplitude modulated video signals are especially susceptible to intermodulation distortion that can easily occur in a CATV system. Most annoying are discrete frequency beats that appear as diagonal lines in the received television picture. It seems plausible that a relatively simple digital correlator could be developed to detect the beat and generate a cancelling signal to be added to the video.

The implementation of such a scheme is considerably simplified if the receiver already has digitized video and memory.

A demonstration of B-MAC [10] revealed a different way of reducing the visibility of intermodulation distortion. Inherent in B-MAC is a variable delay line shift that effectively scrambles the transmitted video. Reconstruction of a stable picture in the decoder de-correlates the undesired beats making them much less visible.

Similarly, digital encryption before transmission and complementary decryption at the receive will de-correlate the intermodulation distortion, potentially reducing susceptibility.

ELECTRICAL NOISE SUPPRESSION

One feature available in the ITT digital chip set is a noise invertor which is intended to suppress electrical impulse noise. The noise invertor is located directly after the video analog-to-digital converter (ADC) in the Video Codec Unit. Maximum peak white output of the ADC is equal to value 126 of the 7 bit output. Any sample that generates the value 127 is converted to a medium grey level of 70 (approximately 40 IRE) before any further video processing is done in the television.

PICTURE-IN-PICTURE, FREEZE FRAME

There recently have been a number of consumer televisions and VCR products introduced to the market that have picture-in-picture and/or digital freeze frame capability. In most cases, these features are not a result of adding digital video processing but rather are made possible by adding memory to the analog receiver chassis. In most cases, standard 64 KBit DRAM chips are used to store one field of composite video with 6 bit quantization. Only the picture-in-picture (PIP) can display 'freeze frame' and it is at most a quarter of the size of a normal picture. The PIP input can be the tuner output of the host receiver or an external video input. There is no second tuner to serve the PIP separate from the main display unit.

There has been no effort made to utilize the PIP field memory for video processing to improve picture quality in television receivers. Integration of the memory into the digital video processing chain will occur by 1990 when the first application of field memory, to improve picture quality in television receivers, will occur. The situation for VCRs is more advanced. NEC in particular have a digital VCR with a frame store that is used to reduce noise by up to 9 dB. Frame stores of somewhat higher resolution will need to be added to VCRs to keep pace with the higher quality formats being introduced. The latest, called super VHS, is touted to be capable of playback resolution exceeding 400 lines of horizontal resolution which rivals laser disc performance. A frame store with 8 bit quantization (totalling 2.5 million bits) is required to match this level of picture quality.

An add-on consumer unit that connects to any conventional television, the Multivision 3.1 Digital Video Adapter, is also available to deliver PIP. The Multivision 3.1 contains two tuners and a conventional 6 bit quantization PIP memory. The Digital Video adaptor is capable of varying PIP position and size, freezing the PIP picture and choosing broadcast or cable tuning for each tuner. The main picture and PIP signal sources can be independently selected from either a tuner or a separate baseband video input. There are separate RF and composite video outputs. It shouldn't be long before a video enhancement unit that uses digital video processing in conjunction with a frame store will be available to the videophile.

MANUFACTURING CONSIDERATIONS

The change from analog to digital video processing has proceeded very slowly, with only a limited number of high end modules currently using digital processing. One potentially serious problem with digital processing is the interference of the high level 14 MHz fundamental and associated harmonics of the sampling clock, required for digitizing the video, with low level IF and RF signals in the television set. Traditional approaches of sealing the digital electronics in a metal box and using EMI proof interconnect have been used initially. These techniques introduce a significant cost penalty for digital sets relative to analog sets which don't required similar measures. Considerable effort is being expended to reduce the shielding requirements by judicious use of ground planes, localized shielding of signal routing and pulse shaping to minimize harmonic content.

There is also a considerable amount of development required to learn how to equal the performance of time-perfected analog circuits with digital circuits. Rather than achieving better performance with digital, engineers are hard pressed to equal the picture quality currently achieved with analog techniques. Some nonlinear processing is more difficult in the digital domain while near perfect digital filters surpass analog filters. An examination of the ITT Digit 2000 chip (see Appendix A) set reveals that there are a large number of programmable variables and hence many design choices to be optimised. The fact that this task is mainly software optimization greatly accelerates the progress and shortens the production lead time considerably. Consistency within digital processing is also much higher, relieving the engineer of the requirement of maintaining tight tolerance windows. Every television set manufactured to a particular design will be identical, and this is indeed the experience of those currently using the ITT chip set. The parts count of digital TV sets is not that different from analog sets because of the high level of circuit integration already achieved in an analog chassis. The number of chassis required to support a large number of television models can be reduced by using one programmable digital chassis and modifying the control processor for each model.

Some peripheral television features are certainly easier to accommodate in a digital TV set. On screen display of status, user controls, and signal routing becomes trivial. Inclusion of a teletext decoder is accomplished with only minor additions. Picture-in-picture is also easier to accommodate relative to analog sets. The availability of digitized video, a colour-locked clock, digitized horizontal timing signals, a microcomputer controller and an interchip communication bus in a digital TV greatly simplifies the implementation of the features discussed above.

EDTV DEVELOPMENT

Television research teams in North America, Europe and Japan have worked diligently to find ways of dramatically improving the quality of television pictures in consumers' homes. The most dramatic outcome is the Japanese NHK high definition television production system; a system which has 1125 lines, a 16:9 aspect ratio, a 2:1 interlace, and a 60 field per second video signal that requires 30 MHz of bandwidth. The transmission of the high definition television (HDTV) signal to consumers' homes is hampered by the excessive bandwidth requirement and a lack of suitable display hardware. The effort to circumvent these obstacles has fostered a number of evolutionary proposals describing how to get from current NTSC to HDTV via various stages of extended definition television (EDTV).

In an effort to steer development effort in North America, an Advanced Television System Committee (ATSC) has been established. This committee has been in turn divided into three working groups to address improved NTSC, extended 525 line systems and full high definition transmission systems.

The improved NTSC Committee have been studying the removal of the 7.5 IRE set up which would increase the dynamic range of the video signal from 92.5 IRE to 100 IRE (approximately 1 dB). A small increase in signal-to-noise ratio is thereby achieved. Generally, the committee supports this idea and an implementation plan will be prepared. The other goal of this committee is to prepare a comprehensive document describing baseband NTSC since this does not currently exist.

The enhanced 525 line sub-committee is monitoring the trial of systems that pre-comb the luminance and chrominance signals before combining them into composite NTSC video. The equipment being tested by several broadcasters is supplied by Faroudja Labs and is basically a two-line comb filter. It is fully compatible with current broadcast standards and television receivers and does provide a significant reduction in cross luminance and cross chrominance artifacts, particularly with the increasing number of televisions also containing comb filters. The improvement is brought about by significantly reducing the cross-talk between the frequency multiplexed chrominance and luminance channels at the video signal source. Currently, a degree of cross-talk exists that cannot be eliminated by the receiver, even if it separates chrominance and luminance frequencies perfectly. The broadcaster could make received signal quality approximately equal to RGB if more complex 15 x 11 (horizontal and vertical) order prefilters were used in conjunction with two-line comb filters in the receiver [3]. In addition to eliminating false "rainbow" effects in areas of high frequency luminance, e.g. herringbone suits, close spaced lines, and hanging dots on vertical colour transitions, the image will have enhanced horizontal resolution due to full utilization of the 4.2 MHz bandwidth available. There would also be less chroma noise.

The large number of analog to digital encode/decode processes currently performed in television stations prior to broadcast has hampered efforts to improve the encoder. Multiline recursive filtering leads to the formation of ever growing transition zones at the beginning and end of each field because of increasing numbers of cascaded multiline encoders and decoders. The evolution of the increasing use of component signals by broadcasters will solve this problem because only one NTSC encoding need be performed just prior to on-air transmission.

A range of high definition receivers is envisaged to regenerate differing levels of quality. A simple HDTV receiver contains motion adaptivity and can switch from interframe to intrafield interpolation of the line quincunx samples in the presence of motion. More sophisticated receivers could make use of a motion compensation vector calculated at the transmitter and sent in the MAC data packet to process the frame store contents before performing interframe interpolation.

Philips Labs are developing two transmission schemes for EDTV. A MAC based system called MAC-60 is intended for satellite distribution of HDTV quality video and is formatted in such a way that a compatible NTSC type signal can be derived by either broadcasters or cable television TVRO sites using low cost transcoders. The second scheme is a two channel system for distributing wide aspect ratio (16:9) pictures to consumers via either terrestrial or cable broadcast channels. Chapter 4 has a more complete description of the two channel EDTV distribution system Philips calls ENTSC.

One of the two channels is a conventional 4:3 aspect ratio NTSC signal compatible with any current television receiver. The second channel or augmentation channel also occupies a 6 MHz NTSC slot and transmits the side panel information to generate a 16:9 aspect ratio picture as well as line differential information required to generate a 525 line sequential scan display based on intrafield interpolation. The augmentation channel also contains a time multiplexed data channel of approximately 3 MBit/sec for digital audio and picture format information (pan and scan) used to indicate what picture information belongs to which side panel. The panel stitching is randomized in time to hide the stitch line. Colour information is sent in conventional NTSC subcarrier fashion but a reduction in cross-colour and cross-luminance artifacts is achieved through prefiltering the luminance and chrominance channels before encoding.

DIGITALLY ASSISTED TELEVISION

The use of motion vectors to compensate for motion in reduced bandwidth transmission schemes is presented by G. Thomas [9]. **The use of motion vectors might also enhance the quality of receiver based progressive scan convertors and recursive filter noise reduction systems discussed previously.** Motion vectors transmitted with each field indicate what scaler displacement to apply to each pixel of the previous frame in order to bring it into the correct position for interframe interpolation. This type of motion controlled interframe interpolation can be used for progressive scan or bandwidth reduced HDTV or interframe addition in the case of recursive filter noise reduction.

An example of a system that did not use motion vectors is first generation MUSE, which is motion adaptive. A noticeable reduction of resolution occurs with MUSE in areas of well correlated motion as intrafield interpolation is used in the presence of motion. This loss of resolution seriously compromises the overall image quality assessment as witnessed during MUSE broadcasts in Washington, DC in January 1987. The second generation of MUSE decoders have substantially improved images for moving scenes.

Motion vectors are calculated from the high definition, full bandwidth source signals before transmission. As few as three or four vectors would be sufficient to describe the motion of the principle objects in most cases. These motion vectors are assigned to appropriate parts of the scene and used to distort the prefilter operations and move the sampling structure in such a way that the moving areas appear to be stationary. The decoder is told the values of the motion vectors during vertical blanking, and is continuously told the spatial location of the vectors via a separate digital assist channel. The processor then applies appropriate displacements to the stored samples from the preceding fields and interpolates a highly detailed image. The requirement of updating vector information every other field means the digital assist data rate needs to be approximately 1 to 2 MBits per second.

The use of DATV greatly simplifies the HDTV receiver. The control data instructs the receiver on how to adapt the memory contents to provide the best picture, rather than having local intelligence to perform the required correlation calculations in real time.

HDTV EVOLUTION SCENARIOS

The Philips two-channel wide-screen television system plays directly to the limitations of current display systems as well as the spectrum segmentation of cable. The two 6 MHz channels are recombined in a relatively inexpensive process involving only a three-line memory to generate a wide screen display. Direct view tubes up to approximately 30" diagonal will give a high quality picture, providing an enhanced viewing experience relative to conventional NTSC. Cable will be able to distribute the signals with no changes required to any equipment other than the addition of an extra receiver/modulator at the headend. The wide screen signal would be distributed to cable companies on two conventional satellite transponders.

Philips are having discussions among program providers interested in distributing wide screen video. The same programming that is available now could be enhanced simply by sending the augmentation information on extra satellite transponders. Philips have a lot to gain from the distribution of wide screen video; they stand to sell a lot of new wide screen television sets if enough software is available to the consumer. And by being compatible with cable, the cable operator will have little objection to distributing that software.

The scenario outlined above is one feasible evolutionary path to wide screen television.

Most industry experts believe wider aspect ratio will be the first development towards HDTV in the home as it is this attribute that the consumer will readily recognize first.

Within the next five years, the display quality of large screen receivers will more nearly match that of smaller direct view tubes as a result of development work. At that point, videophiles will be looking for software to match the new display capability, and they will most likely find it in prerecorded material first. Super VHS or better video-tape players will be one suitable source; HDTV laser discs will be another. Conventional broadcast signals will give good results if the receiver is within the grade A contour and not subject to multipath or electrical interference of the off-air reception. The broadcast pictures can be significantly improved by digital signal processing.

Given the assumption that high quality large screen displays will become available and also that HDTV quality software will be produced, several HDTV delivery scenarios are possible.
One scenario, involving cable television and satellite was outlined during the description of the Philips two-channel concept. This delivery vehicle could continue to serve as the conduit from studio to consumer, with appropriate upgrades in terminal equipment and cable distribution electronics, if required, as HDTV evolution progresses.

A second scenario foresees the distribution of HDTV programming to consumers via prerecorded video tape or laser disc. Dedicated playback equipment in the consumer's home allows faithful reproduction of the high quality HDTV images. This scenario appears to be unfolding with the advent of Toshiba's HDTV laser disc player as well as with the new high performance video cassette equipment.

The third alternative is distribution of software to television broadcasters via closed circuit satellite links. Broadcasters must then find ways of reducing the signal bandwidth and transmitting the signal in the UHF band using two channels. Cable might remain a part of the distribution network or in fact might even be the sole distribution vehicle, with no HDTV broadcast signals at all. Cable television facilities now exist in virtually all urban areas in Canada and typically serve any region with at least 40 homes per mile along any roadway. In total, there are 5.2 million out of a possible 7 million cable homes in Canada, so that most people are served by a CATV system. In addition, all local broadcast signals are available on the cable. It is clear then that the broadcaster does not need to rely on over-the-air broadcasts to deliver programming.

It is wholly feasible that broadcaster sponsored programming, particularly in enhanced formats could be distributed solely via cable.

Many satellite delivered, cable distributed, advertiser supported services are operating today, particularly in the United States. There is no inherent reason why traditional broadcasters can't join those successful programming suppliers who don't have conventional VHF/UHF transmission facilities.

The fourth alternative is transmission by direct broadcast satellite (DBS) to the home by the software provider. Satellite receivers with or without descramblers deliver a considerably enhanced RGB picture to a high quality monitor. The recent announcement of a move by HBO to the Ku-band might indicate that interest in DBS is still alive.

A fifth distribution vehicle being discussed is broadband ISDN via fiber optic cable. The most common scenario foresees the telephone company connecting to every home an optical fiber which would transport in a high speed digital, time multiplex manner, all the voice, data, and television signals required. The fibers would closely parallel the twisted copper pair topology currently used, with switching centres controlling the routing of data packets to the appropriate destinations. In particular, the fiber would transport only those television channels actually requested by the subscriber since the data capacity required to deliver the full complement of channels available on a cable system would far exceed the capability of the fiber.

The ISDN will very likely be implemented. One telephone system operator in the southern United States has stated they will start installing fiber optic cable to homes in favour of twisted copper pairs by 1989. It will take a very long time, however, to replace all the existing copper plant with optical fiber; probably 25 years at least. Until a large number of homes are served via optical fiber drops, ISDN is not a viable option for distribution of video programming to the home. Some small sections and new subdivisions may be ready sooner.

CONCLUSIONS

The various technical developments highlighted in the foregoing section point to dramatic improvements in picture quality, size and aspect ratio for the consumer. It is going to take some time to get there however, and just how the evolution will happen is not clear. Ultimately, it will be the entrepreneurial and business acumen of the key players that will decide the successful course. Several facts can be identified today that will certainly guide the course of events.

Various groups are currently producing electronic video using the NHK HDTV production equipment. Examples include: the CBC production "Chasing Rainbows", the Italian RAI full length feature "Julia & Julia", Rebo Associates' music videos, commercials, a complete rock concert, and Hollywood based 1125 Productions Ltd. who plan to complete three feature length productions in 1987.

The electronic equivalent to 35mm film is now available and 60 complete HDTV production systems have been ordered world wide.

The introduction of Super VHS in the consumer electronics market provides an alternative medium to terrestrial broadcast or cable for distribution of high quality video. Historically, video tape has had inferior quality relative to VHF distribution but super VHS rivals conventional laser disc in video quality and resolution. Super VHS lends itself to enhanced definition and wide aspect ratio television with no changes required in the playback equipment.

Terrestrial broadcasters have limited bandwidth available in the UHF band in which to transmit additional information, either for wider aspect ratios or extended definition which both require more than the 6 MHz alloted to NTSC channels.

Petitions have been prepared by broadcasters and submitted to the FCC in the United States requesting that either UHF or KU-band spectrum be reserved for broadcast use.

In the event that no terrestrial capacity is available for over-the-air broadcasting of HDTV programs, a viable alternative is distribution depending solely on CATV facilities. Limitations on the numbers of channels available for off-air broadcasting is most likely to occur in urban areas where CATV networks are most readily available.

Receivers for extended definition service would need to have complex two-channel tuners or be connected to TVRO equipment. In the case of UHF, a number of historical taboos must be accommodated or removed in order to make the required channels available. It would appear broadcasters will not have an easy time adapting to EDTV or HDTV if they can do so at all. The introduction of digital video processing in consumer television sets is a prerequisite to EDTV and HDTV reception which relies extensively on digital processing to generate the improved picture. Any of the EDTV/HDTV transmission systems being proposed utilize time compression, motion adaptivity, line interpolation and spatio-temporal processing, these are much easier to perform in the digital domain. The ultimate implementation of bandwidth reduced HDTV transmission systems uses motion vectors to allow interframe processing. Only digitized video can be processed with motion vectors in real time.

Cable television systems are not a completely transparent signal transportation link to the consumer. The minimum carrier-to-noise ratio that can be expected is 40 dB in Canada which is the minimum DOC requirement [12]. In the U.S., where there is no regulated minimum, carrier-to-noise ratios can easily fall below 40 dB. The amplifiers used are very linear but still generate intermodulation distortion products that occur at regular 6 MHz intervals. Current practice optimises performance for 6 MHz spaced vestigial sideband AM NTSC video channels. Reducing intermodulation distortion and increasing the carrier-to-noise ratio at the same time is a costly undertaking.

Any new transmission scheme may be expensive to transport on cable if it straddles two or more 6 MHz channels.

The converse is also important; the new signal must not cause interference to conventional NTSC signals.

Standalone HDTV playback and display systems will be introduced in the market place shortly. Toshiba have introduced a laser disc player capable of 45 minutes of HDTV quality video. Limited production HDTV monitors have been sold as part of the HDTV production system and are available. The first uses of this standalone playback equipment will be commercial presentations at trade shows and special exhibitions, auto shows, boat shows, home shows, etcetera. The general public, thronging to these events, will be exposed to the new format and quality and will be introduced to the next generation of television technology. The most obvious enhancement will be the wider picture. Large screen display hardware capable of emphasizing the enhanced quality of 1000 line television has yet to be commercially developed so the public won't readily appreciate that aspect of HDTV for several more years.

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6

CHAPTER 6

CANADIAN INDUSTRIAL OPPORTUNITIES

The application of digital technology to the television receiver is just one of many advances the microchip has fostered. There is a sizable pool of experts in Canada who know how to put the microchip to work, and this number increases with every graduating class of electronic engineers. The calibre of these individuals is equal to those of any other country. The skill required to apply digital technology to television exists in Canada, and a concrete example are the developments of Digital Video in Scarborough, Ontario. This division of Scientific Atlanta, the American parent company, developed and builds the B-MAC decoders used in Australia and by closed-circuit television clients in the United States. This group is well poised to capitalize on any development of MAC based EDTV or HDTV transmission systems.

Relatively low volume satellite receiver hardware for Australian DBS and video conferencing in the United States generates a comfortable business for Digital Video. The potential use of a MAC based transmission system for HDTV could provide a good opportunity for Digital Video to supply suitable transcoding equipment to adapt the signal for terrestrial broadcast or carriage on cable. The adoption of a MAC type distribution system for EDTV and HDTV requires program duplication to be backwards compatible with the majority of the 5.2 million cable subscribers making it an undesirable option from the point of view of both broadcasters and CATV operators. A market for B-MAC decoders at the consumer level is therefore unlikely to develop in Canada.

Television receiver manufacturing, including those with digital video processing, is unlikely to occur in Canada. The necessary support infra structure to supply components and subassemblies such as tuner and display devices is absent. Specialists familiar with television manufacturing are not available, either, so it is reasonable to expect the television receiver purchased in Canada will be imported.

An ancillary business of add-on image enhancement devices is a strong candidate in Canada. After market picture-in-picture features can be made available to anyone with a television, the unit could even have a channel 3 loop for an external pay television decoder as well as a Multiport connector. This type of product is similar to channel converters, with which several Canadian manufacturers are familiar. The position of the Canadian dollar relative to the American dollar would make this type of consumer electronics device attractively priced in the large American market. In addition to PIP capability, a number of image quality improvements could be included as they are developed including noise reduction and edge enhancement as well as signal routing and status display. One product on the market similar to this is the Multivision 3.1 Digital Video Adapter described in Chapter 5.

Low volume, high technology equipment to perform standard conversion from HDTV to EDTV or NTSC will be required as HDTV comes to fruition. Similarly, high quality colour encoding and decoding equipment are required as a result of more television production occurring in component form. This type of niche supply presents a number of opportunities well suited to the capabilities of Canadian electronics firms.

A CATV premium channel protection system which has potential for low to medium volume production is the interdiction type systems. These security systems involve digital and RF hardware of limited complexity and therefore a much lower level of development cost can be expected when compared to encoder/decoder systems. The marketing requirements are significantly less than large volume consumer oriented electronics.

The market for image enhancers and video stabilizers is quickly increasing as the number of VCRs and VCR users doing multiple generation taping increase. This market offers an opportunity to develop several versions of video correctors and stabilizers with various levels of performance extending to image enhancers at the high end of the product line. These video products can initially be low volume limited technology and expand to higher volume and high tech products. A generic diagram of a universal corrector/enhancer is given in exhibit (6-1). The video processing done by the video corrector/enhancer could be extended as new technology is introduced and existing technology becomes less expensive.

A niche in the video/television market that should be investigated is that of video test and measurement equipment. These products are high performance medium volume items using high technology and providing a margin higher than that offered by consumer electronics. The demand for low cost equipment is expanding as a result of the proliferation of video taping and transfer houses and the number of companies with in-house video capability.

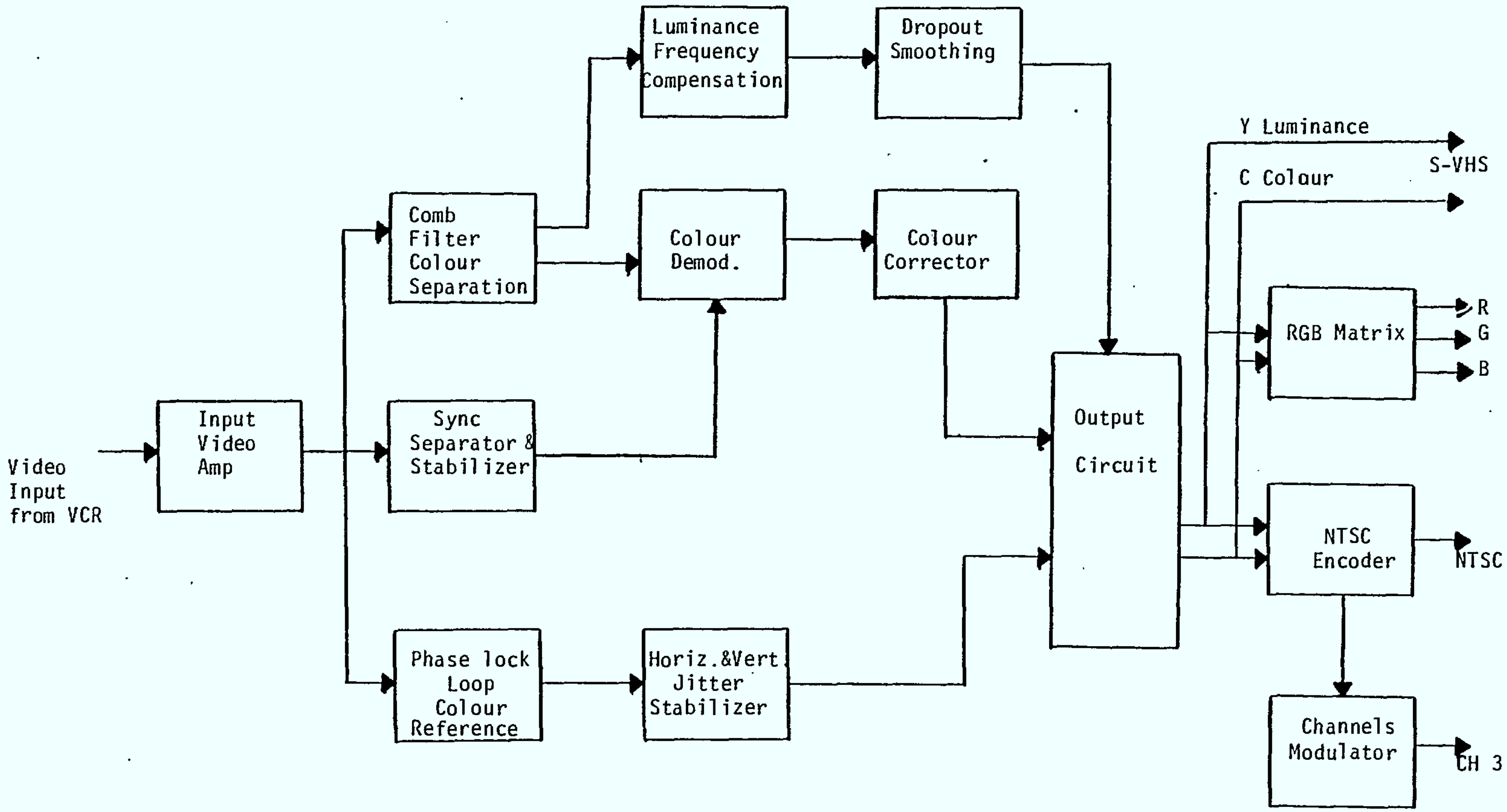

EXHIBIT 6-1 GENERIC VIDEO CORRECTOR/ENHANCER

7

CHAPTER 7

AREAS FOR FUTURE STUDY

The pace of digital video processing research and recent EDTV proposals point to an imminent introduction of new television formats and transmission systems. Parallel advancements in the technical quality of programs on prerecorded media will soon cause traditional broadcast and cable television to appear inferior.

1) In light of the trends, Canadian cable and broadcast interests must focus on the new EDTV transmission schemes. Evaluation and testing of the proposals must be conducted, or at a minimum, witnessed as they are performed by others, eg NCTA, ATSC, with broadcast and cable compatibility a primary concern. Testing of EDTV proposals on operating CATV facilities is essential before implementation can occur.

2) At the same time, broadcast and cable entities must cooperatively investigate the current technology being used to deliver television signals in an effort to identify how it may be adapted to facilitate EDTV. An inflexible adherence to a position requiring any new TV system to be completely compatible with current transmission technology will ensure that prerecorded media is given a most favourable playing field. Delays of traditional broadcast media in delivering EDTV will give the prerecorded media vendors a corresponding head start; ample reason to address the issue of distributing EDTV and HDTV formats now.

3) Continuous monitoring of consumer electronics capability must be conducted by broadcast and cable operators. In particular, new signal transmission parameter specifications may be required such as better carrier-to-noise and carrier-to-interference ratios, reduced levels of short delay echoes and reduced tolerable levels of distortion. Subjective tests with a cross section of viewers using state of the art receivers and transmission equipment should be performed to update the efforts of past researchers such as the TASSO Committee, the CRC and P.A. Lapp Ltd.

4) An improved economically viable method must be developed for securing pay television signals. The presence of a descrambler in the subscriber's consumer electronics package becomes more undesirable with time as this equipment becomes more sophisticated and complex. Several interesting research efforts are underway but a financial model is required to facilitate the investigation into which approach has the best chance of success. Analysis of revenue expectations will be a major element and this will be shaped

by what types of services cable will be licenced to carry.

5) The ability of the Multiport interface to adapt to new digital television features and capabilities needs to be investigated.

6) Equipment suppliers need to be polled regarding their plans for digital television sets with Multiport, similar to the EIA poll taken for Multiport recently.

7) A method for pay television security is required when EDTV and HDTV are introduced . An auto-scrambling capability in the distribution system would be most attractive with the EDTV or HDTV compatible receivers containing an addressable descrambler. Obviously, cooperative development work is required with equipment vendors for this to be possible. At issue is a scrambling standard, which should at least be investigated as to feasibility and desirability. Alternatively, off-premises security systems may need to be installed by cable operators to protect pay television revenue.

8) An interim stage of EDTV introduction, with EDTV descrambling equipment alongside conventional descrambling equipment must also be addressed. The pay television channels are the most likely beneficiaries of EDTV and it is desirable that scrambling security currently in place not be jeopardized. It is important, therefore, that those developing EDTV hardware and those involved in CATV work together towards a mutually satisfactory implementation of new TV technology.

9) The introduction of new VCR to television interconnection formats which are not constrained to the transmission of NTSC format video signals with the resulting picture limitations must be investigated to establish the amount of picture improvement obtained. Issues which need to be addressed are: the amount of subjective picture improvement offered by the S-VHS and J connector formats; can comparable picture quality be obtained by existing CATV plant using conventional NTSC signals; how highly does the consumer rate the picture improvement and will the S-VHS and J connector formats experience wide spread implementation.

8

GLOSSARY

A/B Switch: A selector for routing one of two inputs to a common output; commonly used to switch between cable and VCR inputs to a television set.

Active Lines: Lines of the television signal that appear on the display; the NTSC television signal has 525 lines per frame, of which 480 are displayed; the remaining lines are used for vertical synchronization and reference purposes.

AGC: Automatic gain control; a functional block in a television receiver that adjusts the gain of the input stage so as to keep the detected video signal at a fixed reference amplitude.

Analog: The representation of signals by a continuously variable physical quantity, such as voltage. (Contrasted with digital)

Artifacts: Visible effects, generated in a picture due to its transmission, that were not present in the original scene.

Aspect Ratio: Television picture width divided by picture height; standard television has a 1.33 (or 4:3) aspect ratio; extended and high definition television will have a wider aspect ratio, perhaps 1.78 (or 16:9) more like that of motion picture film.

Audio: That portion of the television signal that represents what is heard by the viewer, otherwise referred to as sound.

Bandwidth: The range of frequencies required to enable a given amount of information to be transmitted without distortion or loss; directly related to the quantity of information to be transmitted.

Baseband: Denotes that the signal has not been modulated onto any medium for transmission; the basic form of a signal as it exists at a camera output, microphone output, television receiver output (video and audio).

B-MAC: Multiplexed Analog Component video system with 1.8 MBit/sec data channel occupying a baseband bandwidth of just over 6 MHz. MAC systems are based on compatibility with the scanning structure of conventional NTSC, i.e. 525 lines, 30 frames per second interlaced. Two essential features of MAC are:

(a) it is a component system transmitting the luminance and chrominance information separately (rather than merging them into the same waveform as in NTSC);

(b) it uses time division multiplexing (TDM) techniques to separate the luminance, chrominance and data by transmitting them at different times.

BTSC: Broadcast Television System Committee: commonly used to refer to a multi-channel sound (MTS) standard for television which supports stereo plus second audio program sound signals and is compatible with the original monophonic audio signal that was part of North American television signals. The main components of the BTSC composite are a left-plus-right main channel, a left-minus-right difference channel which is companded, a companded second audio program (SAP) channel and a narrow-band subsidiary channel. The composite bandwidth of the BTSC signal may be as high as 120 KHz.

CATV: Community Antenna Television: commonly referred to as cable TV; a business entity to provide a variety of television services to subscribers' homes, most commonly via coaxial cable, in a frequency multiplexed manner that can extend from 50 MHz to 550 MHz (sufficient for 80 television channels).

CCTA: Canadian Cable Television Association: a trade association of members who operate CATV facilities in Canada.

Chrominance: Part of the television signal that characterizes the colour (hue and saturation) without reference to its luminance intensity (brightness).

Colour Subcarrier: In the NTSC television signal, a frequency of 3.58 MHz which is amplitude modulated with the chrominance signal with principle sidebands occurring at frequencies between harmonics of the horizontal scanning frequency, where most of the luminance information is located.

Comb Filter: A filter for separating chrominance from luminance in the composite video signal by "combing" between the horizontal line frequency harmonics. This is usually achieved by means of a signal delay element with delay equal to the time required to scan one horizontal line (63.5 uS) otherwise referred to as a one-line delay. More complete comb filters use 2 or 3 line delay elements. Use of comb filtering allows extension of luminance bandwidth beyond the 3.0 MHZ limit imposed by band pass filtering of the 3.58 MHz colour subcarrier.

Compact Disc: A relatively new medium for very high fidelity stereo audio with frequency response of 10 Hz to 20 KHz, dynamic range of 90 dB and signal-to-noise ratio greater than 90 dB. The audio is recorded onto the plastic disc in digital form and does not degrade with repeated playback.

Components: Separate signals to convey colour or chrominance and luminance information; not multiplexed as in composite video. The components may be in the form of: (a) red, green and blue (RGB) or (b) colour difference ie. Y-R, Y-B, Y where Y denotes luminance, R denotes red and B denotes blue or (c) Y and C as in the new super VHS-S connector where Y is luminance and C is the modulated colour subcarrier.

Composite Video: The total frequency multiplexed television signal before modulation containing luminance, chrominance and audio signals and occupying a bandwidth of approximately 4.6 MHz.

Coring: A non-linear filtering process which may be applied to the high frequency components of the video signal to reduce the visibility of high frequency noise. After high pass filtering, the video signal undergoes a clipping process that removes the noise energy located near the average value of the signal. Input signal-to-noise ratio should be above 32 dB in order for coring to be effective.

Cross-Colour: Undesirable false colour produced in areas of a television picture containing narrowly spaced lines; striped shirts, windows on a building, and herringbone suits because of the high frequency luminance components in these areas incorrectly decoded as chrominance.

Cross-Luminance: Small dots produced in large areas of saturated colour and near sharp vertical colour transitions (hanging dots) produced in the television receiver by falsely treating chrominance as luminance. This artifact is more likely to occur in sets with comb filters which extend the luminance bandwidth into the colour subcarrier region.

Definition: Refers to the sharpness or resolution of an image: greater detail is visible in a picture with higher definition.

Diagonal Sampling: Samples taken at discrete points in the television picture arranged in such a way that successive rows are offset by half the distance between samples (contrast with orthogonal sampling).

Digital: The representation of signals (audio or video) in the form of discrete integral numbers by dividing the total dynamic range of the analog signal into a large number of units, sampling the signal at a rate, known as the clock rate, sufficiently fast to retain all the information in the signal, and assigning the appropriate unit value to each sample. The number of units possible is given by the number of base 2 digits, or bits, that are used. For example, 6 bits can support 64 units; 8 bits can support 256 units.

Display Factor: A constant, for a given scanning system, that converts the number of active lines transmitted into the number of vertical lines perceived on a television display. For NTSC interlaced scanning, this is also known as the Kell Factor and has a value of 0.7.

Double Scanning: Scanning of the television signal across the face of a picture tube at twice the normal rate to allow time to display intermediate lines which may be a duplication of or interpolation between the normal incoming lines.

DRAM: Dynamic random access memory: memory implemented in micro-electronic chips which allows random access to any of the memory calls within the chip via the external connections. Dynamic RAM loses all stored data unless a refresh signal is applied on a regular basis. Up to one million bits can be stored in one commercially available DRAM chip. Prototype chips have been built that store 4 million bits.

Drop:	The CATV or telephone cable that feeds signals to the house from the distribution system tap.
DTV:	Digital Television: television receivers which process video signals in digital form.
EDTV:	Extended Definition Television: a non-NTSC television system which maintains the 525 line frame of NTSC, but which may have a wider aspect ratio, greater resolution, and require more transmission bandwidth than NTSC.
ENTSC:	Enhanced NTSC: an EDTV system devised by Philips (a television receiver manufacturer) that requires two NTSC compatible channels to transmit a 16:9 aspect ratio image with greater resolution than NTSC.
Field:	A portion of the lines in a television picture (or frame): a field in NTSC TV consists of 262 1/2 lines transmitted in 1/60 seconds; i.e., all the odd or even numbered lines in the picture.
Frame:	Smallest number of fields comprising one complete television picture; in NTSC television, two fields having a total of 525 lines transmitted in 1/30 seconds (i.e., all the lines in a picture).
Frame Memory:	A digital device using DRAMs to store a complete television picture. The size of the memory is determined by the sampling rate and the number of units each sample can represent. For 7 bit quantization at a 10.7 MHz rate, the memory required for one NTSC frame is 2.5 million bits.
Frequency Division Multiplex:	The combining of different signals for transmission by assigning each signal a unique range of frequencies: frequency selective filters are used to separate the signals after transmission; signal leakage across frequency boundaries causes signal interference.
HDTV:	High Definition Television: television system capable of displaying twice the horizontal and vertical resolution of conventional NTSC with a wider aspect ratio to more closely match motion picture film.
Headend:	The main television signal reception and processing location associated with a CATV system: all distribution of CATV signals begins here.

Horizontal Line Rate:	The rate at which new lines of a television picture are transmitted; for NTSC equal to 445/2 times the colour subcarrier or 15.734 KHz.
Inter-diction:	A scrambling technique which uses a high level interfering signal to "jam" the television signal to be scrambled. There is no complementary descrambler; if the service is authorized, the jamming signal is turned off. It is therefore necessary to have a means of directing the jamming signal to individual subscribers.
Interlaced Scan:	A means of displaying a picture whereby the lines of the second field of a frame are placed halfway in the vertical direction between the horizontal lines of the first field of a frame.
Line:	One horizontal pass across the width of a television picture.
Line Flicker:	The visual effect of near horizontal edges appearing to move slightly up and down as a result of interlaced scanning.
Line Memory:	The memory required to store the signal information to display one line of a television picture; approximately 5000 bits of digital memory.
Line Translation Scrambling:	Application of a variable delay in the horizontal blanking period between lines to achieve a redistribution of the picture information in time, yielding a scrambled picture that is totally obscure, yet can be reconstructed in the descrambler to a high-quality picture with no visible degradation or artifacts relating to the scrambling techniques.
Luminance:	Part of the television signal that characterizes the light intensity (brightness) without reference to its colour (chrominance). A black and white television picture contains only luminance, or grey levels.
Motion Vector:	Information describing the direction and speed of the predominant moving objects in a scene; transmitted with the television signal to assist the receiver in improving the quality of resolution enhancement in the display.
Multiport:	An interface connecter standardized by the Electronic Industries Association as IS-15 designed to exchange baseband video and audio signals between

a television receiver and a peripheral device, such as a pay television descrambler.

MUSE: Multiple Sub-Nyquist Sampling Encoding: a signal compression technique devised by the Japanese Broadcasting Corporation (NHK) to allow their HDTV production signal to be carried by conventional satellite transmission channels; basically formed by sending each HDTV field in four parts and recombining at the receiver.

NAB: National Association of Broadcasters: a trade association of members who operate terrestrial broadcast facilities for television and radio in the United States.

NCTA: National Cable Television Association: a trade association of members who operate CATV facilities in the United States.

NHK: Japanese Broadcasting Corporation: active proponents of HDTV and developers of an HDTV production system of 1125 lines, 2:1 interlace scanning, 60 fields per second, 16:9 aspect ratio, component colour.

NTSC: National Television Standards Committee: established the ground rules for colour television production and transmission in North America in 1953, also used in Japan; all television broadcasts in these countries comply with the 525 line, 2:1 interlace, colour and sound subcarrier, 59.94 Hz field ratio, 4:3 aspect ratio.

NYIT: New York Institute of Technology: sponsors, via William Glenn, of two channel EDTV system.

Orthogonal Sampling: Samples taken at discrete points in the television picture arranged in such a way that successive rows are aligned above each other into well defined columns (contrast with diagonal sampling).

Overscan: The part of the transmitted picture not displayed on the face of the television to allow for picture tube registration tolerance; typically less than 5% in the horizontal and vertical dimensions.

PIP: Picture-In-Picture: one or more inset pictures displayed on a television screen which may be a freeze-frame stored from the same signal displayed on the main picture or a separate channel or video input; a feature commonly associated with digital televisions.

Progressive Scan:	A means of displaying a picture whereby all the lines of a frame are presented one after another in sequence and so eliminate the line flicker; typical display factor approaching unity, also referred to as sequential scan.
Quincux:	An arrangement of five video samples on three adjacent raster lines that form a pattern with one sample on each corner of a rectangle and one sample from the centre line in the middle of the rectangle.
Recursive Filter:	Frequency selective filter achieved by using signal summing and delay elements. Comb filter is an example; also known as digital filter.
Resolution:	The number of lines that may be represented in a distance equal to the height of a display; for NTSC both the vertical and horizontal resolution possible are 340 TVL/Ph (TV lines per picture height); resolvable black lines are separated by white lines to give two lines per resolvable black line.
RGB:	Red-Green-Blue: colour component means of defining a television picture; most high resolution computer colour monitors interface using RGB; each component is transmitted on a separate conductor, and together are able to reproduce all possible colour.
SCPC:	Single carrier per channel.
Subcarrier:	A means for translating a baseband signal to a different frequency band to allow frequency multi-plexing; e.g. chrominance information is modulated on a 3.58 MHz subcarrier and sound on a 4.5 MHz subcarrier for combining with baseband luminance to form the composite video television signal.
Subscriber:	Person paying a monthly fee for connection to a CATV facility to receive a variety of television programming.
Sub Sample:	Sampling of a signal at a rate below the minimum required to render a full rendition of the original when reconstructed from the samples. By sub sampling a television picture a number of times, the full image may be recreated while reducing the transmission bandwidth required.
Sync Suppression:	A form of television scrambling where the synchronizing signals required to generate a stable picture in a television set are reduced in size or changed in format so that standard television sets cannot display a picture.

Tap, Multitap:	The device which taps off a portion of the signals on the CATV distribution system and passes it on to the drop feeding signals to the individual home; typically one multitap is required for every four homes passed by the distribution cables.
Time Division Multiplex:	A means of sharing a communications channel among a number of signals by allocating the entire channel for a fraction of the time to each signal; various signals are transmitted sequentially in time.
Transcoding:	Or transform coding is the process in which a video field is divided into smaller blocks and each individual block undergoes a linear transform before being coded.
Trap:	A frequency selective device which prevents one or more television channels from passing through; normally located in a subscriber drop to prevent unauthorized viewing of pay television service.
TriScan:	An EDTV television concept developed by the Del Ray group which approximately triples resolution for still pictures by dividing each field into three interlaced parts; compatible with NTSC receivers and transmission facilities.
VCR:	Video Cassette Recorder: consumer electronic device for recording and playback of magnetic tape cassettes with video and audio signals.
Video Inversion:	A form of scrambling where the polarity of the video signal (luminance plus chrominance) is reversed; inverted video appears as a negative since black becomes white and white become black.

APPENDICES

A

APPENDIX A: DIGITAL TELEVISION PRIMER

INTRODUCTION

The ITT Digit 2000 system for digital television signal processing is the first commercially available chip-set to digitize composite video signals in a television set and perform most of the video processing in a digital format. The chip set was introduced several years ago and several television receiver manufacturers have since incorporated the chip set into their top-of-line TV sets and VCR's.

The advantages of the new technology are reduced parts count, elimination of manufacturing tolerances, elimination of performance degradation as a result of component parameter drift, and automatic computer controlled alignment, among others.

In addition, digital processing video signals facilitates improvement in picture quality such as better chroma/luminance separation, through the use of digital comb filtering, and reduced interline flicker and line structure, through sequential scan with line interpolation.

As well, additional features such as freeze frame with noise reduction and zoom can be implemented more easily once the video signal is digitized. These features lend themselves more towards VCR applications. The ITT chip set also provides a teletext option which can be implemented at minimal incremental cost in TV receivers.

DIGITAL TV BLOCK DIAGRAM

A block diagram of a television receiver built around the ITT 2000 chip set is shown in Figure 1. Conventional analog blocks include the tuner and demodulator, the audio amplifier and speakers, the picture tube and associated signal amplifiers and deflection drive circuits and the power supply.

The composite video and sound AF signals available at the output of the tuner/demodulator are digitized in the Video A/D (MAA 2100) and Audio Processor (MAA 2300) respectively. The digitized video is passed to the video processor (MAA 2200) in gray-coded 7 bit parallel form. The 7 bit composite video signal is digitally processed in the video processor chip (MAA 2200). The functions performed in this chip are:

- comb filter to separate chroma from luminance
- chroma bandpass filter
- luminance filter with peaking facility
- contrast multiplier with limiter
- automatic colour control, colour killer, hue correction, and
- monitoring CRT drive currents

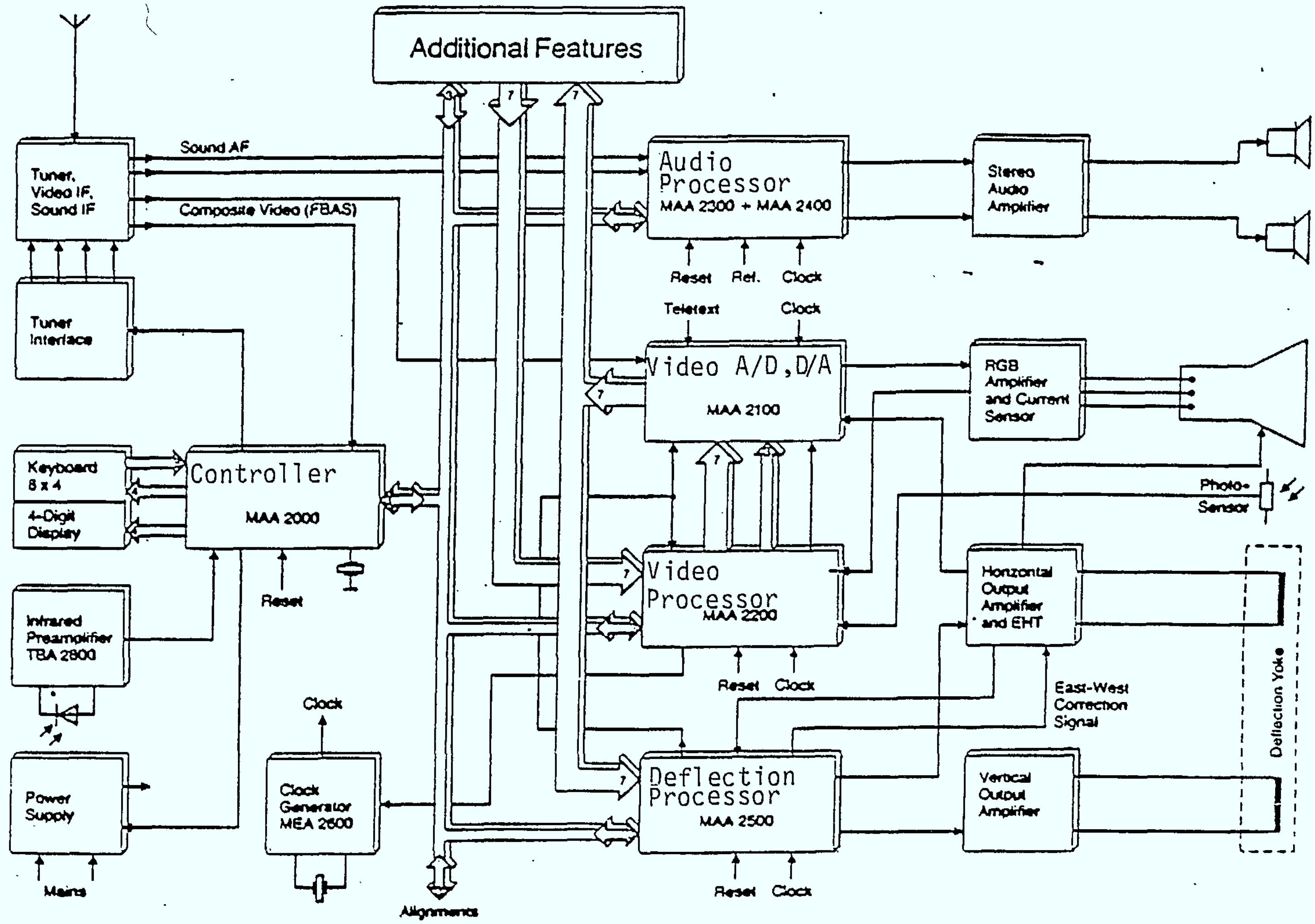

FIGURE 1: BLOCK DIAGRAM OF A CTV RECEIVER BUILT AROUND THE DIGIT 2000 CONCEPT

ANALOG TV WITH DIGITAL FEATURES

In contrast to a true digital television as described above, several analog TV sets have been augmented with digital memory for digital features such as picture-in-picture and freeze frame. A block diagram for this type of television set is given in Figure 2. Conventional analog processing of the video signal is performed by the blocks at the top of the diagram. If the user wishes to invoke picture-in-picture or freeze frame, the microcomputer controller will switch the appropriate composite video signal into the "Digital" section (bottom portion of diagram). Two colour difference and the luminance channels are separated using conventional analog processing and then digitized separately with 5 bit resolution for each. The digital samples are buffered in memory and clocked into separate digital to analog converters for each signal so that they can be sychronised with the main channel horizontal and vertical sychronizing pulses. Matrixing of the analog signals to form red, green and blue components allows reinsertion of the Picture-in-Picture or freeze frame video into the main signal path for display.

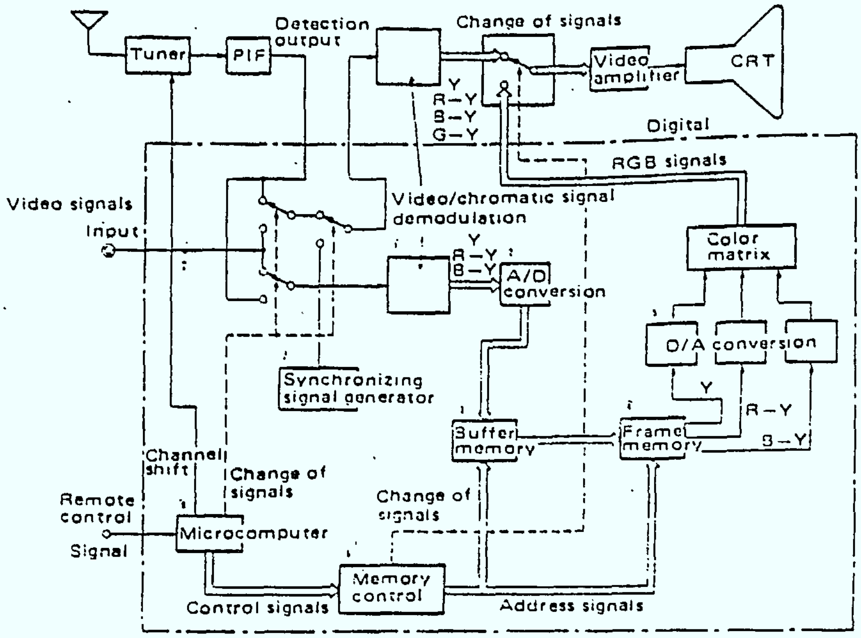

Figure 2: Analog TV with Digital Features

The video signal enhancement achievable with true digital processing is not possible in this configuration. The duplication of functions, particularly colour demodulation actually increases parts count rather than reducing it. The manufacturing benefits of digital television such as product consistency, elimination of tolerances and performance degradation due to aging, automatic alignment and adaptive control of signal processing parameters are not realizable in the analog set with memory. A complete description of a true digital television follows in the next section.

VIDEO PROCESSING

A block diagram of the video processing performed by the two ITT 2000 digital chips, MAA 2100 and MAA 2200 is given in Figure 3 which shows the signal flow and the several functional blocks in their logical sequence regardless of whether these blocks are in the MAA 2100 or MAA 2200.

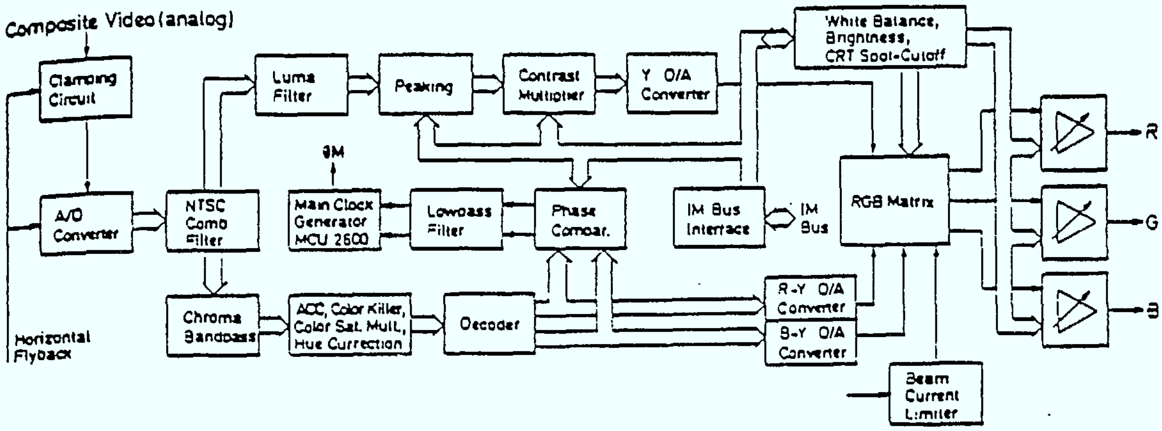

Figure 3: Block diagram of digital signal processing in MAA 2100 and MAA 2200

VIDEO A/D CONVERTER

The composite video is digitized in the MAA 2100, with a sampling clock rate of 14.3 MHz (4 x colour subcarrier) and 7 bit quantization. Pseudo eight bit resolution is achieved by changing the A/D converter reference voltage on alternate lines by an amount corresponding to one half of the lease significant bit. In this way, a grey value located between tow 7 bit steps is converted to the next lower value during one line and to the next higher value during the next line. The two grey values on the screen are averaged by the viewer's eye, thus producing the impression of grey values with 8 bit resolution.

COMB FILTER

Once the composite video has been digitized by the A/D converter it is separated into luminance and chrominance channels by the comb filter. This recursive filter effectively separates the chrominance subcarrier and related sidebands from the composite signal with RAM being used to generate a one horizontal line period (63.5 US) delay. This broad band comb filter lends itself to much better separation of the luminance and chrominance information.

LUMINANCE CHANNEL

A low pass filter in the luminance channel limits the noise bandwidth to 4 MHz in the case of RF input signals or 7 MHz in the case of direct video input from a camera, VCR or laser disc player. The digital filter passband width is switched via the 3 line IM control bus under control of the MAA 2000 controller in response to user commands of signal source selection.

The peaking filter can modify the amplitude versus frequency response of the luminance channel at 3 MHz from -3 dB to +10 dB relative to the response below 1 MHz (0 dB reference). This peaking may be used to increase picture clarity, with the amount of peaking controlled by the MAA 2000 controller via the IM Bus. The luminance signal is now 8 bits wide to allow for the overshoot caused by the peaking filter.

Following the peaking circuit is a contrast multiplier and limiter to prevent the signal amplitude from becoming excessive. The contrast setting is controlled by the controller via the IM bus and can be automatically varied over 64 steps (6 bits) in response to the ambient room lighting in conjunction with a photo sensor connected directly to the MAA 2210. The output of the contrast multiplier is effectively 10 bits wide, achieved by pulse width modulating the least significant bit line to produce 2 extra bits. The output of the multiplier is fed to the luminance digital to analog converter to generate an analog signal for the RGB Matrix.

CHROMINANCE CHANNEL

The chrominance output of the comb filter is band pass filtered with an adaptive chroma filter which can be controlled via the IM bus to compensate for asymmetrical amplitude response in the IF stage of the television set. Following the filter is the automatic colour control (ACC) circuit, which sets the burst amplitude to a constant value, and invokes the colour killer in the case of loss of phaselock to the colour subcarrier (eg., weak signal).

A multiplier in the ACC is used to adjust colour saturation and hue. The two colour difference signals R-Y and B-Y are processed in time multiplexed fashion since they are only 1 MHz bandwidth. Each component is multiplied by a 5 bit value plus sign bit (plus or minus) whose value is determined by the MAA 2000 controller. Hue correction via phase rotation is achievable in steps of 3° via the relationships:

$$(R-Y)^1 = (R-Y) \cdot f_s \cdot \cos x - (B-Y) \cdot f_s \cdot \sin x$$

$$(B-Y)^1 = (B-Y) \cdot f_s \cdot \cos x + (R-Y) \cdot f_s \cdot \sin x$$

by calculating the appropriate multipliers cosx and sinx for the desired phase angle x. This calculation is performed in the MAA 2000 controller. The fs multiplier is the colour saturation which is automatically compensated whenever the luminance contrast is changed. Both the contrast and hue multiplier values are supplied by the controller via the IM bus. Finally, the digital colour difference signals are fed to separate digital to analog converters and input to the RGB matrix. The output red, green and blue signals are subsequently amplified and sent to the picture tube. Several picture tube parameters are monitored by the controller chip via interface electronics in the MAA 2100. By means of these feedback signals, correct white balance may be maintained, black level can be adjusted correctly, appropriate brightness is achieved and compensation for picture tube aging is possible. The IM bus and digital processing of the video signals makes it possible to have a microcomputer controller maintain optimum picture quality.

SYSTEM CLOCK

The system clock which controls all timing in the digital television receiver is generated in the MEA 2600 clock generator chip (Figure 1). The correction voltage for the clock VCO is generated in the digital video processing chip (Figure 3) which compares the clock signal with the colour subcarrier frequency measured during burst. The system clock is always locked to the burst frequency so that the digital comb filter operates properly.

DEFLECTION CONTROL

The MAA 2500 Deflection Processor Unit performs all tasks associated with raster generation in digital TV sets including:

- sync separation
- generation and synchronization of the horizontal and vertical deflection frequencies
- vertical deflection sawtooth waveform generation

Composite digitized video is input and low pass filtered to 1 MHz to improve noise immunity in the sync separator. The sync separator digitally separates signal levels above and below a reference level corresponding to 50% of the sync pulse level relative to blanking. The derived sync pulses may be used in one of two ways, depending on input signal condition. If there is no fixed relationship between the colour burst frequency and the horizontal sync pulse frequency, the separated sync pulses are used to control the deflection circuits in the television display directly. This is the case for black and white programs and VCR supplied signals. In the case of a fixed 455:2 ratio between colour burst frequency and horizontal scanning frequency (the normal case for colour television transmissions) the deflection is controlled from a frequency divider which counts down from the colour burst. This mode of operation may be referred to as colour locked. The deflection processor uses the separated sync pulses only to confirm that locked operation is appropriate. If inconsistencies develop between separated sync and count-down sync, the deflection processor reverts to non-locked operation. The decision to invoke colour lock operation is normally made in the deflection processor chip by confirming that the observed ratio of colour burst to separated sync is within 1 part in 10^7. The controller (MAA 2000) is able to force colour locked operation via the IM bus, however, this capability may facilitate undesirable attempts to descramble sync-suppressed pay television signals illegally if readily available.

CONCLUSION

Many parameters in a digital television sets are made programmable and controlled by a microcomputer. It is possible to configure the signal processing blocks for optimal picture quality and in the digital domain, achieve superior picture quality and consistency relative to analog techniques. A more complete description of the ITT 2000 digital chip set is contained in the ITT publication "Digit 2000 VLSI Digital TV System".

B

APPENDIX B: FORM LETTER FROM NCTA TO MAJOR TELEVISION SET MANUFACTURERS

B-2

Dear

The National Cable Television Association looks forward to the many customer benefits which new television sets employing ITT Digit 2000 chip technology will offer. However, one aspect of the technology troubles us deeply. Our extensive tests indicate that a television set employing the ITT Digit 2000 chip set can, if externally manipulated, defeat sync suppression scrambling. Sync suppression scrambling is the most widespread encoding technique which cable operators use to prevent unauthorized reception of cable services. It will be many years before more advance encoding schemes are cost effective for use on a widespread basis.

Our specific concern is as follows: If the IM control bus is made easily accessible via a rear panel connector, and if the chip set's software is written to permit the external forcing of the MAA2500 Deflection Processor Unit to the burst sync acquisition mode, third party vendors may sell the necessary equipment to permit theft of CATV signals. We seek your assistance in making the development of such "blue boxes" impractical. If you plan to make the IM bus available via a readily accessible connector, we ask that you take the necessary steps to make it impossible to externally force the MAA2500 DPU chip to the burst sync acquisition mode. We also ask that you make it impossible for the MAA2500 chip to be forced to the burst sync acquisition mode via an infra-red remote unit which service facilities might utilize. Failure to take these steps may in fact, encourage the connections of third party hardware from all manner of sources, to attempt to defeat premium signal encoding. Such attempts may result in improper operation or damage to the sets, which may result in added warranty costs and customer dissatisfaction. Further, pirating attempts in the manner described may result in the cable industry's moving in an undesired direction - away from cable technology which would permit the development of true cable ready television receivers.

We have focused our attention on the ITT Digit 2000 chip set, only because it is the first digital system to permit the recovery of synchronization information from sync suppressed signals. Our concern extends, however, to any chip set which exhibits the same characteristics.

We have every confidence that you will share our concerns. We note that certain manufacturers such as Zenith Electronics Corporation have already taken positive steps to prevent the potential problems which we describe. We applaud their efforts.

We also reiterate our commitment to cooperate with the Electronic Industries Association for the benefit of all television viewers. Please send us your response. We look forward to hearing from you.

Very truly yours,

NATIONAL CABLE TELEVISION ASSOCIATION

C

APPENDIX C: REPORT ON THE THREAT OF DIGITAL TELEVISION PROCESSING TO SYNC SUPPRESSION SCRAMBLING TECHNIQUES

Introduction

This report is intended to investigate the threat Digital Television (DTV) processing poses to sync suppression scrambling. This will be accomplished by reviewing the results of laboratory testing on a DTV, extending the results of this testing to other DTV's on the market, comparing the threat of digital TV processing to analog TV processing, presenting a way of securing the sync suppressed video signal and concluding with an assessment of the DTV threat.

Laboratory Testing of Digital Television Processing on Sync Suppressed Video

In order to facilitate the testing of DTV processing on sync suppressed video signals, it was imperative that a "test" television set which would allow control of internal processing with a minimum of hardware modification be chosen. One of the first "Digital TV" sets on the Canadian market, the Toshiba CX2094C, lends itself to external control of its digital processing. This particular DTV has a dedicated port on the digital board to interface with a test and repair jig which allows easy access to the DTV control bus. This test jig allows the user to control numerous internal processes of the DTV by functionally replacing the set's microcontroller.

Normal Operation of Toshiba DTV Horizontal Sync System

The particular area of interest is the horizontal synchronization circuitry. The CX2094C DTV has two modes in its horizontal synchronization sequence. In mode one, the non-colour lock mode, a clamped input video signal is sliced at the 50% amplitude point of the sync level to regenerate a composite sync signal. This signal's phase is compared to the output of a horizontal scanning frequency oscillator to generate a correction signal. Once the horizontal oscillator is phased locked in wide then narrow bandwidth comparison, the horizontal synchronization circuitry switches to mode two. In this mode, colour locked operation, the horizontal sync is generated by dividing down from the colour reference burst. As long as the 455:2 colour burst to horizontal sync relationship is maintained, the DTV will remain in mode two. The separated horizontal sync is continuously compared to the horizontal sync generated from colour burst and if the comparison fails, the DTV reverts to mode one.

Modification of DTV Operating Parameters

Once the test jig is connected to the digital board, DTV control can be transferred from the DTV's internal microcontroller to the test jig. Through a sequence of control commands from the test jig, a viewable picture can be generated from a video source scrambled with suppressed sync. The sequence of DTV parameter modifications are:

1. forcing the DTV into colour-lock mode
2. setting the DTV vertical synchronizing oscillator circuitry into the free running mode with a pre-set vertical sync divider ratio
3. setting DTV brightness to maximum
4. setting DTV contrast to maximum

5. redefining contrast correction data

6. increasing DTV saturation control.

Forcing the DTV into colour-lock mode allows the horizontal sync to be derived from the colour burst and not from the sync separator output. Allowing the vertical scanning oscillator to free run means that vertical synchronization is not affected by the loss of output from the sync separator. The input video is sync tip clamped so that the sync tip defines the bottom of the quantization window within which the analog to digital converter digitizes video. As a result of sync suppression, the sync tip clamping level is shifted up into the active video region above low amplitude luminance signals. As a result, the digitization window does not include low amplitude luminance signals so they are lost in digitization. In order to produce a watchable picture, the brightness level needs to be maximized to increase the DC level of the picture and the contrast must be maximized to emphasize the video information that remains after digitizing the suppressed sync video. Increasing the saturation of the picture attempts to compensate for the loss of chrominance information on low amplitude luminance. Once these parameters are defined for a suppressed sync video source, a watchable picture can be produced using the DTV. One of the most important advantages of DTV becomes evident when one wishes to view a video source with normal sync levels, a single command will reset the DTV parameters to their original values.

The suppressed sync video signal as viewed on a "modified" DTV has been described as viewable which means a large part of the luminance and chrominance information in the original signal is still present with reduced picture brightness, contrast and loss of detail in the darker portions of the picture.

The DTV has no provision for correcting input signals that have undergone video inversion. The most straight forward method to descramble video inversion is to include a custom circuit to detect and invert the video before it arrives at the DTV digitization circuitry. This circuitry can be co-located with the DTV external control jig and the video feed to the DTV looped through this jig. The DTV has a video output from the RF tuner/demodulator which can be looped through the control jig and back to one of the DTV video input ports. A shortcoming of the video inversion correction circuit is that it requires an active video gate to be transmitted from the DTV or derived directly from the loop through video in the control jig. At this point, a slight boosting of the video loop through signal can improve the perceived contrast in the DTV picture.

Extension of External DTV Control to Other DTV Sets

Presently, the Toshiba CX2094 is the only DTV readily available in North America with a readily accessible control connector and a control sequence that can force the DTV to produce a predefined picture from a source with suppressed sync. The command sequence that can be used to externally control the DTV is defined by the DTV manufacturer during production. The possibility of establishing external control of DTV as demonstrated using the CX2094 can only be extended to those sets using the ITT Digit 2000 chip set. Several Japanese manufacturers are developing their own DTV chip sets which will probably be closed designs and therefore access to the control bus and operational information required to force the DTV to decode suppressed sync signal will be severely limited. All DTV manufacturers indicate that they are intending to interface postmanufacturing test and repair to their DTV's via the operation of the handheld IR controller. The IR interface eliminates direct access to the DTV internal control bus and will restrict ability to force the DTV into operating modes not programmed in the internal microcontroller.

The Advantage of Digital Processing Over Analog Processing in Television Sets when Attempting to Decode Sync Suppressed Video Signals

The colour-lock circuitry in the DTV which locks on to suppressed sync signals can also be developed in a TV with analog processing. The advantage of digital processing is the ease with which the DTV operating parameters can be changed to decode suppressed sync signals and then as easily reset to normal operating conditions. Also, the colour-lock process is already available in the ITT DTV chip set.

A reason for doing the decoding in the analog domain is the familiarity with existing analog TV signals and the fact that an analog video loop through is required at any rate to decode video inverted signals. Video signal functionality is more difficult to identify when the signals have been digitized.

Protection of Suppressed Sync Video Signals Against Decoding by Colour Burst Lock Techniques

Several ways to modify suppressed sync video, to defeat signal decoding by generating horizontal synchronization from the colour burst reference, were investigated. It was proposed that by phase modulating the suppressed horizontal sync signal, the horizontal sync regenerated from colour burst would not agree with the separated horizontal sync and the DTV would jump back to mode one. Although this would hold true for a colour locked DTV in normal operation, a DTV forced into mode two cannot exit to mode one. The amount of horizontal jitter introduced would have to be minimized so that an authorized decoder would not be affected. A protection method that was found to work well involved inserting an equal amount of jitter on to the colour burst and colour subcarrier. The DTV forced into colour lock mode will generate a jittering horizontal sync which the television sets tested were unable to lock-up to. The reproduced picture was unintelligible and appeared similar to a standard television response to sync suppression. One thing to be kept in mind is that the inserted jitter must be of a high enough rate to make the modified DTV unable to lock-up to the regenerated sync. A random or pseudo random jitter of the subcarrier proved to be the best at defeating the DTV in colour-lock mode. The easiest way of generating equal amounts of jitter on the colour burst and chroma subcarrier is to use a VCR to produce an "off tape" signal without time base correction. This method of jitter generation is straight forward to implement but does not allow control of the amount of jitter placed on the colour burst and chroma subcarrier. To control the amount of 3.58 MHz jitter generated on the composite video signal, the chroma information must be detected and then remodulated with a 3.58 MHz colour subcarrier not related to the line frequency. Scientific Atlanta have in fact patented such a system to enhance sync suppression scrambling.

A television with a standard sync separator can lock onto a video signal from an authorized baseband decoder with the colour subcarrier jitter as mentioned above. The Zenith baseband decoder used to descrambler the video does not reconstruct the horizontal sync from the colour burst. Therefore, the descrambled video sent to the television will have a stable horizontal sync with the colour burst and chroma subcarrier jitter as generated by the VCR. The sync separator of a normally operating television ignores the jitter since the same jitter is present on both the colour burst and colour subcarrier, so the detected chrominance information is jitter free.

Threat Decoding Video with Sync Suppression Using a Modified DTV

The overall threat of DTV to sync suppression scrambling techniques depends on several factors, the most important being the operation of the digital chip set that the DTV uses. The DTV must have a color-lock mode and the ability to be forced into this mode. Also one must be able to easily adjust the DTV viewing parameters to produce a viewable picture. It would be a great benefit if the DTV control bus was easily accessible. Another important factor is whether the DTV design is open or closed, on other words, the amount of information that is available on the DTV control circuitry. The design for the ITT chip set which all DTV's in North America are presently using, is very open because ITT is marketing the chip set. In the future, it is expected that the Japanese manufacturers will use a closed design making it more difficult to understand how the DTV generates its horizontal sync.

It is not expected that DTV's in the future will have the capability to deal with video inversion so a baseband video loop through on the DTV would be an important feature.

Conclusion:

It has been demonstrated that a DTV can be used to decode video signals with sync suppression. The resulting picture quality while viewable, is perceptibly degraded from a signal produced by authorized decoding. The ability to derive a viewable picture from a sync suppressed video source using TV circuitry is not exclusive to digital processing, it can be done using analogue processing also.

The threat to sync suppression scrambling depends on the ease of modification of a DTV to force it to lock-up to a sync suppressed signal and produce a viewable picture. The ease of modification depends on the existence of a color burst lock-up mode in the DTV circuitry, the ease of access ot the DTV control bus without hardware modifications, whether the DTV is an open or closed design and whether the manufacturer has provided the relevant commands in the DTV control program. A letter outlining the concerns of the cable industry relative to signal security was sent to all TV set manufacturers. It is hoped they will respond positively with set designs not easily amendable to descrambling sync suppression. A copy of this letter is attached.

It was found that all investigated DTV's available in North America used the ITT digital chip set. The Toshiba DTV tested in the laboratory lended itself most readily to lock-up on sync suppressed video, the remaining DTV sets investigated required more extensive hardware and software modifications. Video inversion techniques require external correction of the video signal using a video loop through from the DTV.

It also has been shown that it is possible to modify the video and defeat the color-lock mode of the DTV.

D

APPENDIX D: SUBJECTIVE IMPROVEMENT OF RECEIVED NTSC SIGNALS ATTAINED BY COMB FILTERING DURING SIGNAL ENCODING & DECODING

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Approved by:
Date: June 30, 1987
Report No.:

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INTRODUCTION

The intended purpose of this report is to investigate the subjective improvement of a received NTSC picture gained by using comb filtering during the NTSC encoding and decoding process. Picture improvement will be evaluated in eight different test situations for comparison:

1) conventional encoding and decoding of a baseband signal;
2) conventional encoding and comb filter decoding of a baseband signal;
3) comb filter encoding and conventional decoding of a baseband signal;
4) comb filter encoding and decoding of a baseband signal;
5) comb filter encoding and decoding of a baseband signal which has been modulated for broadband transmission;
6) comb filter encoding and conventional decoding with modulation;
7) conventional encoding and comb filter decoding with modulation; and
8) conventional encoding and conventional decoding with modulation.

A summary of the test findings are presented with the report conclusion in table (1).

BACKGROUND

Traditionally, comb filters have been implemented using glass delay lines or more recently, charge coupled devices (CCD). If a digital video signal is available in a digital TV or processing equipment then a digital comb filter can be implemented more inexpensively and easily than with a glass delay line or CCD and may become cost effective where it may have not been before.

Two terms are used to describe picture artifacts caused by incomplete separation of the colour (chrominance) and picture (luminance) information in a composite video signal namely, cross-colour and cross-luminance. Luminance information is carried on the harmonics of the 15.734 KHz (f_h) visual carrier sideband where as chrominance information is carried on the harmonics of the 15.734 KHz (f_h) colour subcarrier sidebands offset by 1/2 f_h so that the colour subcarrier sidebands fall between the visual carrier sidebands. The repetitive nature of the luminance sideband information along with the interlaced chrominance sideband information is illustrated in Figure 1.

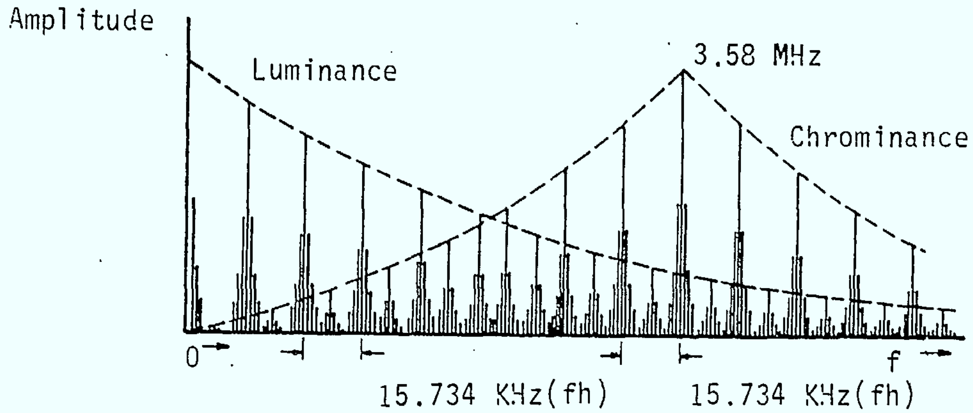


Figure (1) Interlaced Luminance and Chrominance Sideband Spectrum

Cross-colour refers to luminance information carried on the harmonics of the visual carrier sidebands that is separated and decoded as colour information. The effects on the picture include rainbow patterns where high frequency luminance information is present. This high frequency luminance information exists near the 3.58 MHz subcarrier and is typified by fine detailed lines which are very close together. Very sharp edged graphic characters can also produce colour fringing.

Cross luminance refers to high frequency chrominance information produced by sharp transitions in colour that is incorrectly identified as luminance information. The cross-luminance artifacts show up as a line of dots hanging below a vertical colour transition or as 'dot crawl' seen at a sharp vertical juncture between dissimilar colours.

Picture artifacts due to cross-colour and cross-luminance are a direct result of incomplete chrominance luminance separation as found in conventional television receivers. Conventionally, the luminance signal is separated by low pass filtering the video signal and chrominance information is isolated by using a bandpass filter centered about the 3.58 MHz colour subcarrier. The response of these conventional overlapping NTSC separation filters along with the regions of the baseband television signal susceptible to cross-colour and cross-luminance are shown in figure (2).

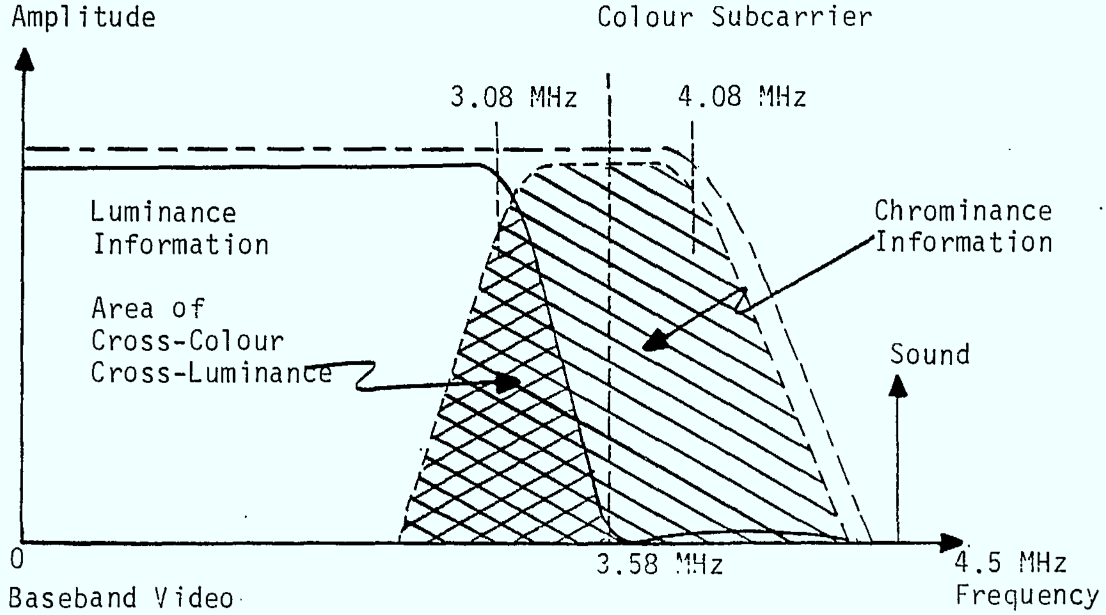


Figure (2) Response of Chrominance and Luminance Separation Filters

Conventional signal separation allows luminance information in the chrominance channel to be mistaken for colour information and chrominance information in the luminance channel to be mistaken for picture information. In addition to incomplete chrominance luminance separation, conventional luminance low pass filtering also limits horizontal resolution to about 260 lines.

Comb filters operate on the theory that successive horizontal lines of picture information have 180 degree phase shifts in the colour subcarrier, thus by delaying picture information by one horizontal line (1H) and adding it to the next line the colour information can be cancelled out leaving luminance information. By subtracting a delayed line of picture information from the present line, one can isolate the chrominance information.

A 1H comb filter's effective chrominance and luminance passband response is shown in figure (3).

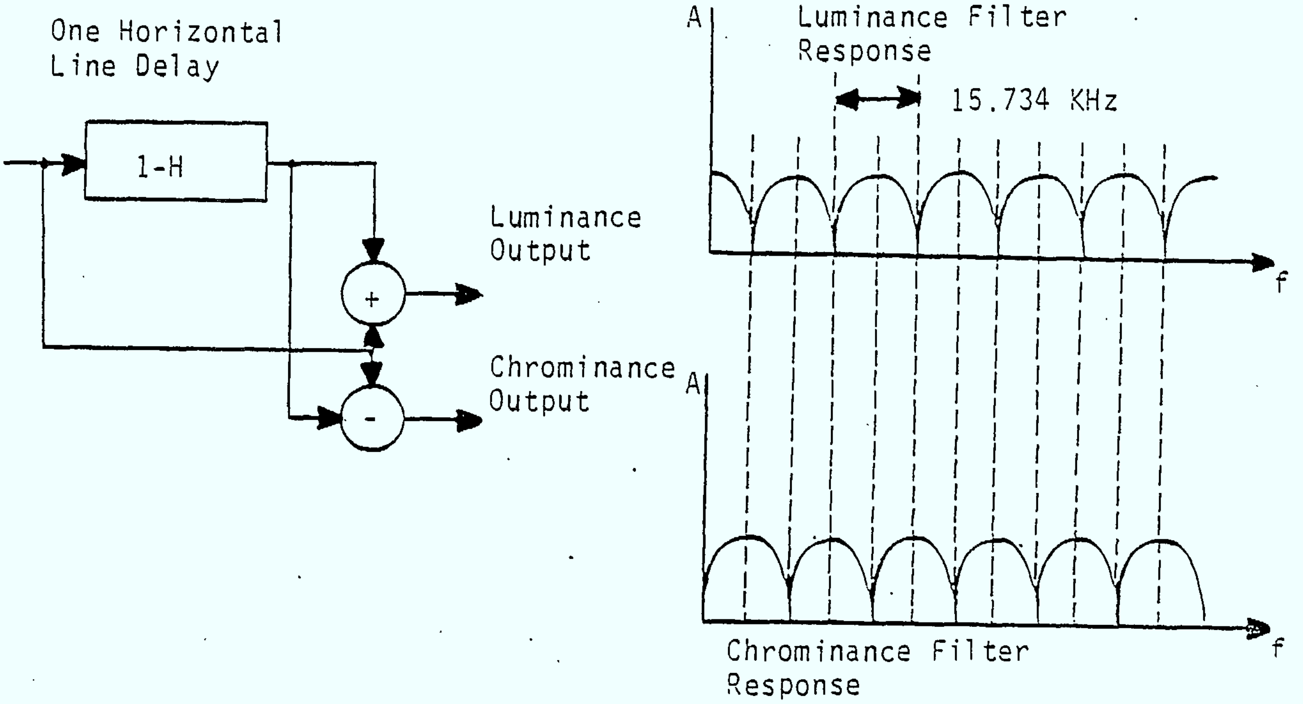


Figure (3) 1-H Comb Filter Block Diagaram and Filter Response

The narrow region of rejection at unwanted frequency values produced by a 1H comb filter can be widened to include more of the undesired signal by adding another stage to the 1H filter to form a 2H comb filter. The use of a comb filter for chrominance luminance separation rather than using conventional bandwidth limiting results in an increased luminance bandwidth and therefore, more horizontal picture resolution, potentially 27% more.

To achieve the optimal chrominance luminance separation the portion of the composite signal comb filtered should be limited to 1 MHz centered on the 3.58 MHz colour subcarrier. Limiting the combing function protects the low frequency vertical detail components in the luminance signal.

DESCRIPTION OF TEST SET-UP

A TTV 2705 Colour Slide Scanner was used to provide a clean source of RGB test signals and to emulate motion. The colour slide scanner can reduce the area on the slide that is being scanned effectively magnifying the picture as it is converted to RGB. Moving the scanning window around the slide simulates motion of the stationary test pattern.

A Faroudja CTE-N encoder was used because it could be switched between comb filter mode and conventional NTSC encoding mode. In other words, a chrominance or luminance comb filter could be switched in or out of the encoding process. Synchronizing signals required by the CTE-N encoder were provided by a Leitch CTG-210N Video Test Signal generator genlocked to the TTV 2705.

To provide an off-the-shelf COMB filter RF/video receiver, a Toshiba CX 2094 TV was used. A conventional NTSC decoding process was accomplished by a SONY Trinitron and a Zenith system 3 SZ1963W7. A Scientific Atlanta SA 6350 was used to modulate the baseband video signal up to RF.

A block diagram of the test set-up is shown in figure (4).

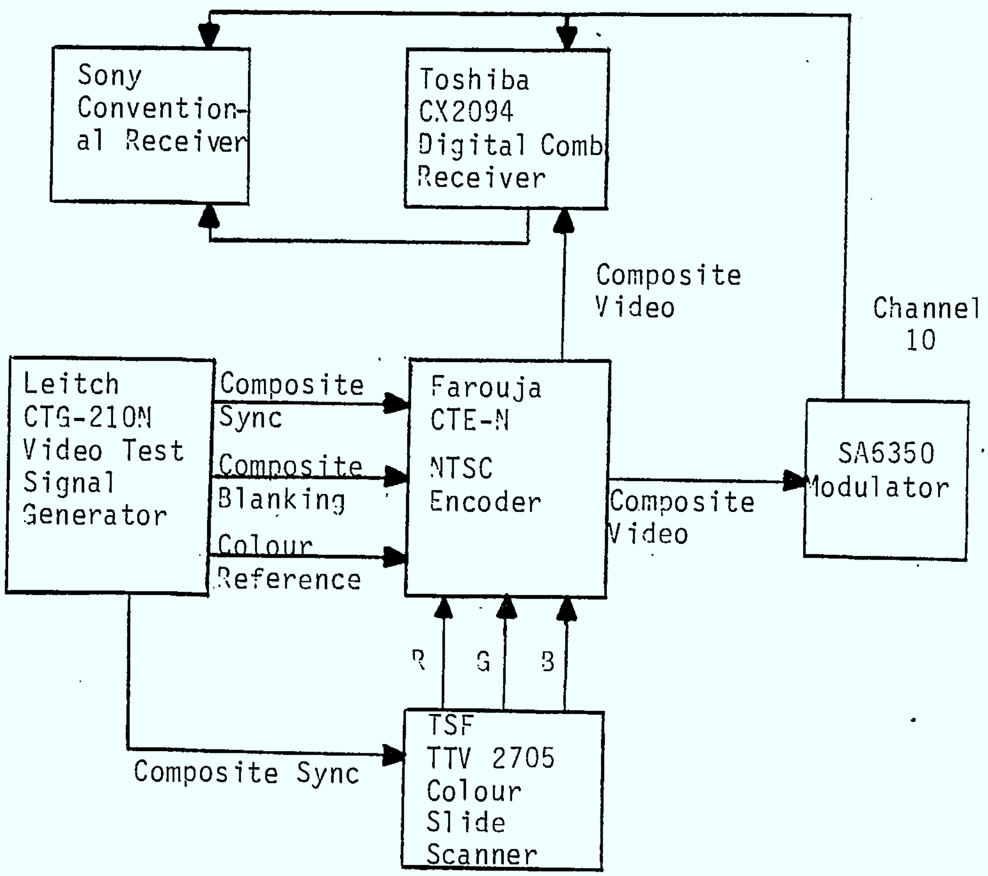


Figure (4) Comb Filter Encoder/Decoder Test Set-up

The Farouja NTSC encoder separately prefilters the luminance and chrominance channel with a full bandwidth two-line comb filter. Prefiltering at the encoder using a two-line comb filter should result in better chrominance luminance separation and a less objectionable hanging dot pattern than a one-line comb filter.

DESCRIPTION OF TEST SIGNALS

A battery of five test slides were used to provide a possible source of NTSC encoding and decoding artifacts. These test slides are illustrated in appendix A and are labeled as follows:

1) Tektronix radial converging line pattern.

2) SMPTE resolution slide with vertical and horizontal converging lines.

3) Picture containing a striped shirt and a fine patterned sports jacket.

4) Picture that contains objects to produce sharply defined changes in colour.

5) EBU Test Chart #1.

PRESENTATION OF TEST RESULTS

The results of testing are evaluated under three different scenarios; the first involves the comparison of a conventional NTSC receiver with a comb filter receiver using a conventional encoded baseband signal, the second uses a baseband signal encoded with a comb filter NTSC encoder, and lastly, the first two test situations are repeated using a modulated broadband signal.

1.1 Comparison of a Conventional NTSC Receiver and a COMB Filter Receiver using a Conventionally Encoded NTSC Baseband Signal

A conventional encoder has minimal circuitry to prevent chrominance luminance spectral overlap during NTSC encoding. Therefore, cross-colour and cross-luminance contamination are generated with conventional NTSC encoding.

When comparing the two different receivers, it becomes evident that the horizontal resolution of the comb filter receiver is better at the expense of the diagonal resolution. The luminance and chrominance signal components are more effectively separated by the comb filter and are not band limited by conventional luminance low pass filtering and chrominance bandpass filtering. As a result of this more efficient separation, high frequency luminance components which produce the fine detail and sharpness in television pictures are not severely attenuated. These high frequency luminance components generate the increased horizontal resolution. The vertical resolution of both receivers remained the same.

Subjectively the amount of cross-colour distortion in stationary test patterns with fine diagonal lines appears to be the same for both receivers. Thus, 1H comb filtering at the receiver does not seem to reduce the amount of cross-colour in the diagonal direction. The conventional set exhibited cross-colour in fine vertical converging lines where the comb filter set did not. Overall the comb filter set does reduce cross-colour although it does not eliminate it in all pictures or all patterns with fine detail in the diagonal direction.

Cross-luminance shows up on the conventional set as a vertical dot-crawl pattern on horizontal colour transitions. The pattern is most prevalent on colour transitions where the two hues differ by more than 90°. The 1H comb filter eliminates the vertical dot crawl between horizontal transitions but causes a hanging dot pattern at vertical colour transitions. To a certain extent, the comb filter has no subjective effect on dot crawl or cross-luminance artifacts.

1.3 Subjective Effect of Modulating the Baseband NTSC Signal
The amount of observable cross-colour in each test pattern was reduced by 20% when the modulated signals were passed through the set's RF tuner. This reduction in observable cross-colour is due to the lower bandwidth of the television IF signal and video detection path which also causes a loss of horizontal resolution observable in fine line patterns. Cross-colour is not initially visible in comb filter encoded and decoded NTSC signals so it is not subjectively effected by the modulation/demodulation process. The slight improvement in cross colour found while viewing the signal on a non-comb filter receiver is accompanied by a decrease in horizontal resolution or picture sharpness.

If the modulated test patterns undergo motion, the amount of cross colour doubles on the non-comb receiver as it did in baseband signal transmission whether or not the signal is encoded with comb prefiltering. The cross colour on the comb filter encode/decode test set-up becomes just perceptible with motion.

The hanging dot patterns are not effected by broadband transmission. The vertical dot crawl or cross-luminance becomes more apparent because the further processing of the video signal during modulation and detection creates opportunities for chroma-luma crosstalk.

CONCLUSION

The results of this study are summarized in Table C-1.

With conventional filtering during NTSC encoding, the addition of a 1H comb filter to the NTSC receiver/decoder eliminates most of the cross-luminance artifacts although a hanging dot pattern on vertical colour transitions becomes apparent. The 1H comb filter in the receiver only results in a marginal subjective improvement in cross-colour rainbow effects on fine line patterns.

If comb filter processing is added to both the NTSC encoding and decoding process cross-colour in stationary pictures is eliminated and barely perceptible in moving fine line patterns, also cross-luminance is minimized. If comb filtering is done in NTSC encoding only and a conventional receiver is used then cross-colour is markedly reduced except in the diagonal direction although cross-luminance experiences no subjective improvement. Any motion of the fine line patterns increases the amount of apparent cross-colour rainbow effects.

Modulation of the baseband signal has little effect on the picture improvement made by NTSC encoder or decoder comb filtering other than slightly improving cross-colour for a given pattern because of reduced signal bandwidth due to modulation and detection circuitry bandwidth limitations. Since there is more potential for crosstalk in broadband transmission because of increased processing of the video signal, cross-luminance effects are marginally more apparent in a modulated signal.

In summary, the comb filter encoder minimizes chrominance luminance cross-talk in the encoded NTSC signal so that it can be very accurately decoded. If a non-comb filter receiver is used to decode the baseband signal, then visable cross-colour is significantly reduced when compared to a conventionally encoded signal and the picture's horizontal resolution is increased at the expense of the diagonal resolution. Decoding by a comb filter decoder results in a displayed picture approaching RGB quality with no visable cross colour. The test slides used were chosen to demonstrate cross colour and cross luminance, in normal program material these effects occur infrequently and usually are not objectionable.

Table C-1:

Summary of Evaluation of Comb Filtering during NTSC Encoding and Decoding.

NTSC Signal Processing			Observed Picture Characteristics (See notes below for explanation of rating system)					
Modulation of Base-band onto RF carrier	Encoder Comb Pre-filtering	Decoder Comb Filtering	Horizontal Resolution Rating	Vertical Resolution	Diagonal Resolution Rating	Cross Colour Rating	Cross Luminance Rating	Motion Effects on Cross Colour Rating
1) No	No	No	4	No Change	1	5 (F)	5 (E)	5 (G)
2) No	No	Yes	3	"	3	4 (F)	1 (A)	4 (F)
3) No	Yes	No	3	"	3	2 (C)	4 (C)	3 (E)
4) No	Yes	Yes	1	"	5	1 (A)	1 (A)	2 (C)
5) Yes	No	No	5	"	1	4 (F)	5 (E)	5 (G)
6) Yes	No	Yes	4	"	3	4 (E)	2 (B)	4 (F)
7) Yes	Yes	No	4	"	3	2 (B)	4 (D)	3 (E)
8) Yes	Yes	Yes	2	"	5	1 (A)	2 (B)	2 (B)

<u>Relative Column Rating</u>

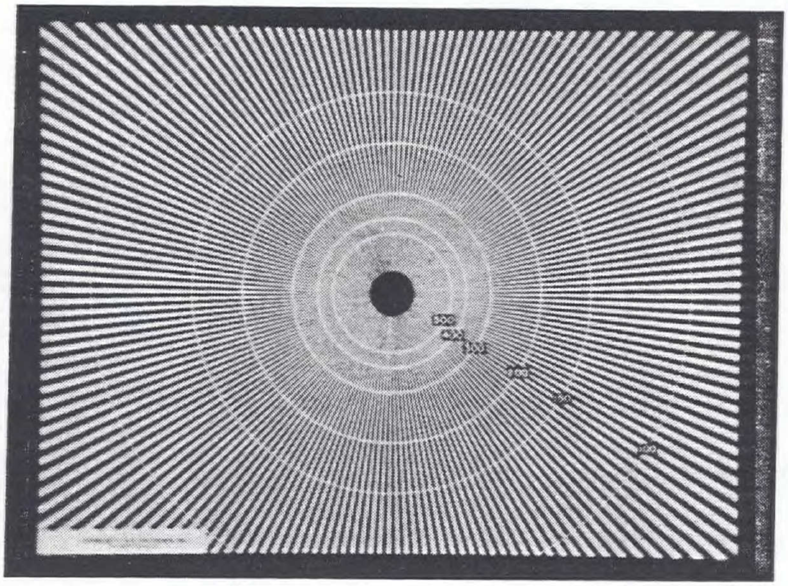
(1) Best
(2) Good
(3) Acceptable
(4) Poor
(5) Worst

<u>Descriptive Rating</u>

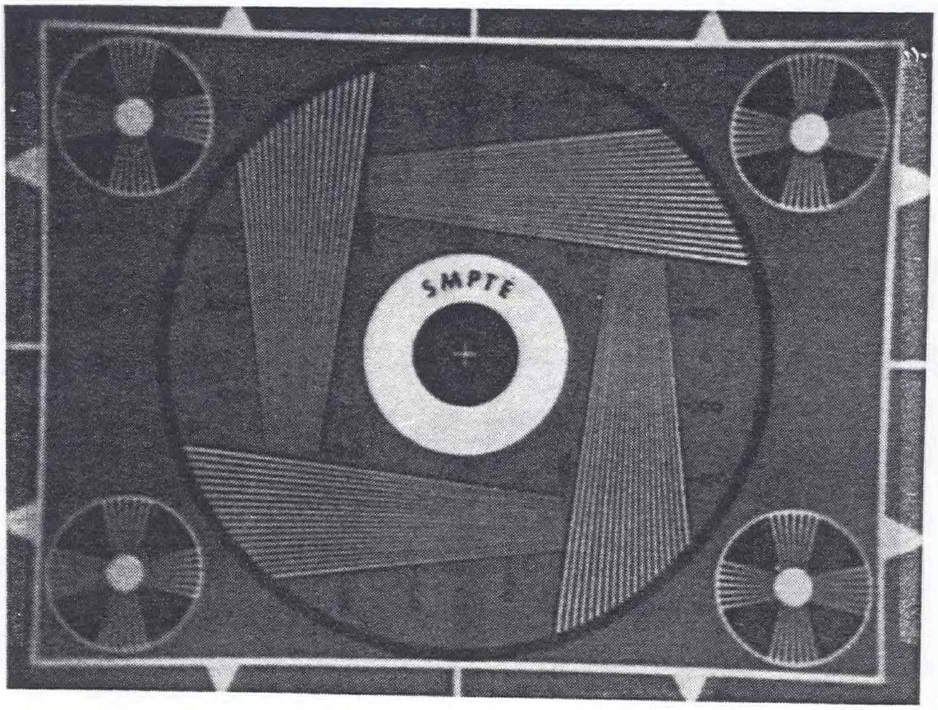
(A) Not Perceptible
(B) Just Perceptible
(C) Perceptible
(D) Not Annoying
(E) Slightly Annoying
(F) Annoying
(G) Very Annoying

APPENDIX

ILLUSTRATION OF TEST PICTURES

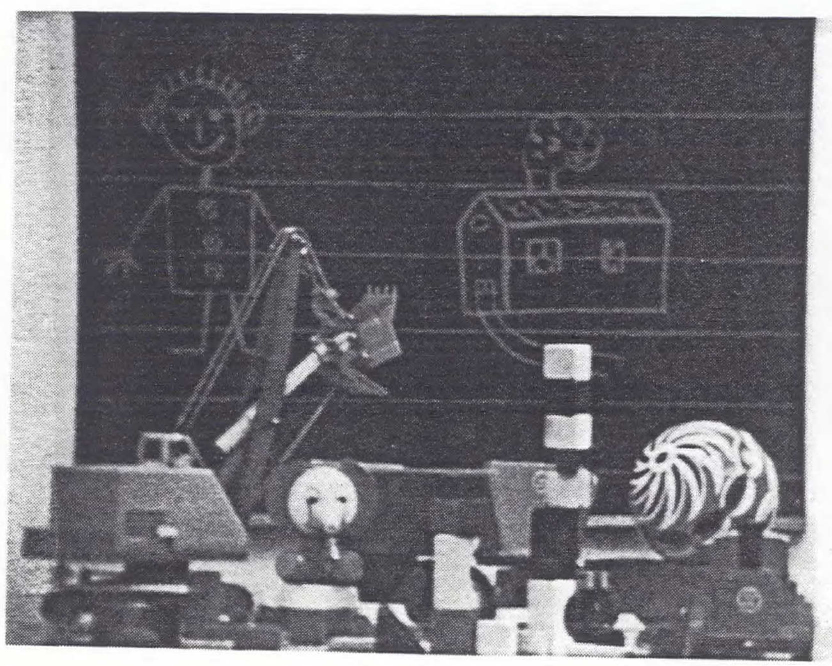


TEST SLIDE (1): TEKTRONIX RADIAL CONVERGING LINE PATTERN

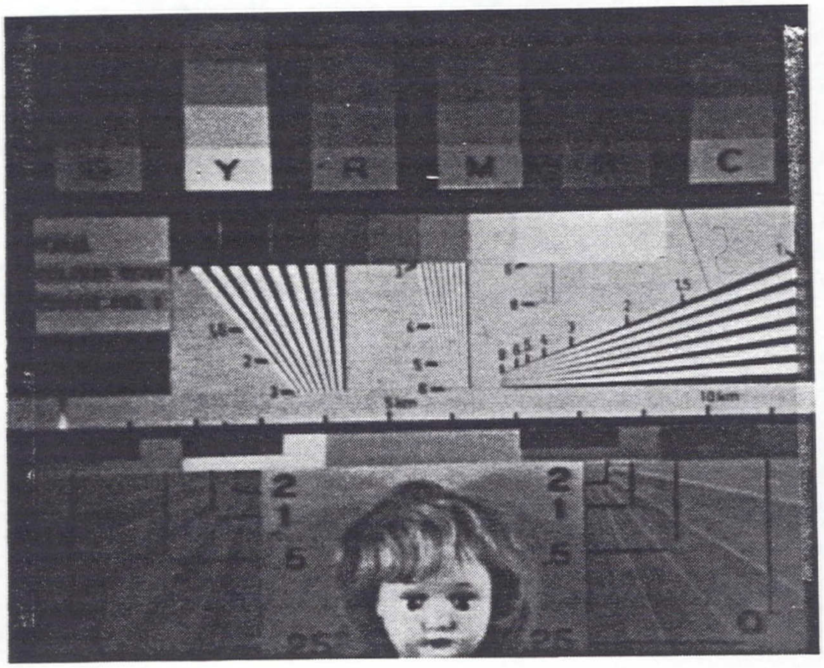


TEST SLIDE (2): SMPTE RESOLUTION SLIDE WITH VERTICAL AND HORIZONTAL CONVERGING LINES

TEST SLIDE (3): PICTURE CONTAINING A STRIPED SHIRT AND A FINE PATTERNED SPORTS JACKET



TEST SLIDE (4): PICTURE THAT CONTAINS ORBJECTS TO PRODUCE SHARPLY DEFINED CHANGES IN CLOLOUR



TEST SLIDE (5): EBU TEST CHART #1

DUE DATE

SEP 19	1988		
NOV 2 -	1988		
JUN JUIN - 6	1990		
JUN JUIN 27	1990		
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