PROPOSED HDTV SYSTEMS AND SOME IMPLICATIONS FOR CABLE

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ABSTRACT

High Definition Television (HDTV) is subject to much debate in the industry. The economic opportunity has prompted a high level of competitive activity. The cable community must appraise the business and technical impact of HDTV amid a blizzard of conflicting information. The brief summary of several systems and discussion of the various techniques presented is intended as some small aid to this effort. Two of the many technical issues raised by HDTV, noise and reflections, are assessed with particular attention to the effects of time compression.

INTRODUCTION

Technological progress has reached a point where significant improvement in television performance is possible. This includes developments in source equipment, digital signal processing and VLSI. Historically, the economic opportunity created by new technology has resulted in the creation of new and, hopefully, more useful and enjoyable products. Television has reached that point. HDTV is coming. Technology is the vehicle but economics is the engine. There are many technical questions to be answered but the factors which are key to determining direction are of strategic business and economic nature.

HDTV can be delivered by a variety of media. The constraints of each are different making a single "best" system design unlikely. Encoding for recorded media is likely to be different just as it is today. For example, available recording bandwidth is increasing while spectral space for terrestrial broadcast is, at present, fixed. In this paper we will consider HDTV from the cable transmission perspective.

STRATEGY FOR INTRODUCING HDTV ON CABLE

The decisions would be simple indeed if picture and sound quality were the only criteria. A standard of performance could be set and each system evaluated against this standard. There are many tradeoffs to be considered between resolution, bandwidth, decoder cost, and transmission system constraints. Since many of these constraints will change with time, the timing of introduction and potential for future development must be considered. Each of the proposed systems have made implicit assumptions about strategy. The cable community should consider the implications of basic choices.

Should every HDTV transmission on cable be available to customers having only NTSC equipment? This is one of the primary strategic questions. Is totally differentiating the HDTV service to command a higher price advantageous or, would the broader initial market represented by adding NTSC customers offer a better economic model? Will NTSC based formats continue well into the future? The answer to these questions will determine some of the technical decisions on compatibility. Compatibility also has potential impact on the quality of the signal which can be delivered. The requirement for quality is considered below.

Should increased transmission bandwidth be considered to achieve higher performance and/or lower decoder cost? This is indeed a complex issue. Future development in optical fiber and reduction in decoder cost will change the model with time. It is quite probable that the level of performance achieved in recorded media will be relatively high. This will serve as a yardstick for the consumer in evaluating alternatives for program sources. It is tempting to say that the quality of the transmitted picture must be equal to that of recorded pictures. The degree to which this is possible within realistic constraints is not clear. Other factors will also be important. Certainly, the introduction of the compact disc has not caused the demise of FM radio, even though compact disc quality is substantially higher. Few cars have TV's, however, and the markets are very different. Quality is important but other factors must accompany quality. Recording time had a large impact on the VTR market. The convenience and durability of compact discs is a part of their market advantage in addition to sound quality.

COMPATIBILITY

We have discussed above the need to define the requirements for compatibility. In comparing the NTSC compatibility of various systems, we will give a value for "Compatible Bandwidth" which is the total transmitted bandwidth required to allow reception directly by NTSC equipment. The quality of the received signal is presumed to have negligible degradation against a purely NTSC signal. This is no small point. The interest in HDTV will very likely increase sensitivity to the quality of all signals. The alternative to increasing bandwidth to transmit a compatible signal would be to require that NTSC customers desiring to receive the HDTV broadcast pay for a transcoder. One aspect of compatibility is independent of the requirement for complete compatibility. This is the issue of field rate and number of scan lines. If there are advantages to be gained by having field rate different from 59.94Hz and a number of scan lines not an integer multiple of 525, then they should be considered along with other tradeoffs. The writer has heard no proposed advantages and none come to mind. Neither are there any apparent disadvantages to invoking these constraints. Transcoding advantages gained by using 59.94Hz and 2X525 interlace or 525 progressive are obvious. Not having to drop frames, for example, eliminates one potential artifact and simplifies transcoding. The fact that transcoding complications occur in going to film or other video formats seems little cause for gratuitous incompatibility with NTSC.

THE SYSTEMS AND THEIR PARAMETERS

There are several proposed systems. We will first present a general description of the various techniques used in encoding, since several are common to more than one system. We will then present a brief overview of several individual systems and a summary of their parameters. The systems included are limited because of time and space.

All of the systems begin with input from standard cameras (or recordings of such) with the exception of those of Dr.'s Glenn & Glen (NYIT) [1,2] and Mr. Iredale (The Del Rey Group) [3,4]. The RGB signals are matrixed into a constant luminance set of luminance and two chrominance signals. The bandwidth of the chrominance channels is reduced to take advantage of the lower resolution of human color vision. In this form, the signals are subsampled to reduce transmission bandwith requirements. The subsampling generally capitalizes on the fact that human visual perception on the diagonal requires less resolution. The systems vary considerably as to the degree of bandwidth reduction (relative to final display resolution) they introduce at this step. The NHK MUSE [5,6], and Del REY systems are the most extreme in this regard. The bandwidth is recovered in the receive decoder by use of line difference information, intra-frame or interframe information processing. The complexity of the decoder increases as the amount of storage increases. The complexity progresses through requirement for line store to frame store to multiple frame store. Quite simply, information required to produce the display resolution is transmitted time sequentially over several frames with an obvious reduction in bandwidth requirement. This works well for static pictures, but moving pictures must either use motion compensation or simply revert to the resolution dictated by the transmitted real time bandwidth. Temporal artifacts can be generated where interframe information is used. (Temporal aliasing artifacts are well known to moviegoers in the form of the backward turning wheels of the stagecoach in westerns). Systems which use intrafield information do not require the complication of motion compensation.

Many of the systems use time compression or expansion of signals before transmission. Where time division multiplexing of the luminance and chrominance is employed, the signals are time compressed so that chrominance and luminance are transmitted time sequentially within one line time. This is the format of the MUSE Time Compression Integration (TCI)signal. Others refer to this as Multiplexed Analog Components (MAC). In any case, the chrominance and luminance are encoded as analog voltage levels time compressed. Time compression raises the transmitted bandwidth required to support a given signal (luminance or chrominance) bandwidth. Since the chrominance bandwidth is lower, it is compressed to a greater extent.

The MUSE signal is shown in Fig. 1. Note that there is no synchronizing pulse extending beyond signal modulation. This offers improvement in signal to noise. Note that two lines are required to send the chroma since there are two such signals.

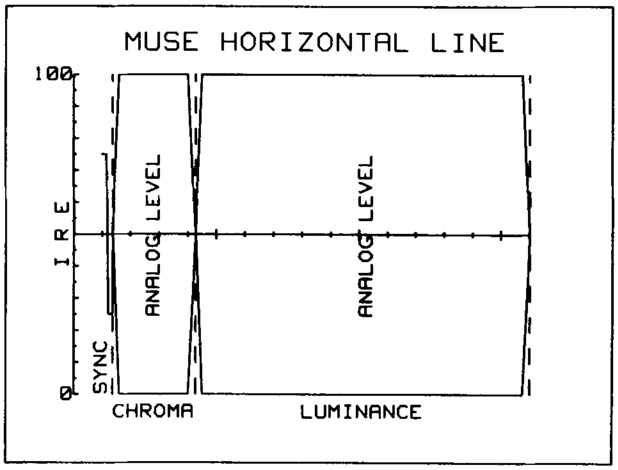

FIGURE 1

Another approach is to take the principles of NTSC encoding to greater lengths. The ACTV [7] system uses an additional quadrature modulated subcarrier and quadrature modulation of the visual carrier to transmit additional information. This allows transmission within one standard channel and provides a signal with NTSC compatibility, albeit with potential artifacts. The use of subcarriers has impact on signal to noise and quadrature modulation of the picture carrier has some implications for phase noise in set top converters.

A remaining difference between systems is the number of separate channels used. The NA Philips [10,11] and Glenn systems propose two separate channels for both terrestrial and cable transmission. Others propose single channels. Some achieve compatibility within the single channel and some do not.

Many systems provide "CD" quality sound. This may well be a key issue in the competition. Often, what may at first seem a side issue will prove vital. Some would hold that wide screen with good sound are really what is needed. Opinions abound, solid market evaluation is imperative.

Table of Parameters

Table 1 presents a summary of some key parameters. Much of the information is derived from Mr. William Schreiber's response to the FCC NOI [12] and Robert Hopkins paper [13]. The resolution numbers are based on scanning standard and bandwidth only. The numbers for resolution are in lines-per-height which, for horizontal, is total horizontal lines divided by aspect ratio. Values for stationary and moving areas are given. Bandwidth is the total transmission bandwidth required, regardless of the number of channels into which it is divided. The "Compatible Bandwidth" is the total transmission bandwidth required to allow an unaided NTSC receiver to display a picture. The number of channels is the number of separate channels transmitted, regardless of bandwidth. Storage is intended to reflect decoder complexity since processing requirements also increase as information is drawn from a wider temporal range.

	MUSE	NAPC	ACTV	NYIT	HDBMAC
	DISPLAY FORMAT				
LINES	1125	525	525	1050	525
FIELD RATE	60	59.94	59.94	59.94	59.94
FRAME RATE	30	59.94	59.94	59.94	59.94
ASPECT RATIO	16:9	16:9	5:3	5:3	16:9
	STATIONARY RESOLUTION				
LUMA-VERT	728	480	480	800	480
LUMA-HORIZ	1007	874	650	1300	420
	MOVING AREA RESOLUTION				
LUMA-VERT	520	480	480	480	480
LUMA-HORIZ	629	494	316	441	420
	BANDWIDTH REQUIREMENTS				
TRANS. BW	10	12	6	9	SEE
COMPATIBLE BW	16	12	6	9	TEXT
CHANNELS	1	2	1	2	
STORAGE	3X FRAME	LINE	FRAME	FRAME	LINE

TABLE 1

The Del Rey system is not shown in the table. The sampling pattern used and methods for recovering data do not permit ready conversion into appropriate scan parameters and resolution. These parameters are addressed in the text on this system.

The MUSE System

The MUSE (Multiple Sub-Nyquist Sampling Encoding) was developed for the single channel direct satellite broadcast of HDTV [5,6]. The signal bandwidth is 8.1MHz. The system is based on 1125 lines 2:1 interlaced at a 60Hz field rate with 16:9 aspect ratio (See Table 1). The input signal would be 1125/60 "Studio Standard" RGB. It provides either 4 channel (15KHz BW) or 2 channel (20KHz BW) digital audio in the vertical interval. The signal format is multiplexed analog components with 1:1.25 time compression of luminance and 1:5 time compression of chrominance (Fig.1).

Chrominance is boosted 3dB to help balance signal to noise compared to luminance. Active line time is 29.25 microseconds. Significant amounts of digital processing is done requiring motion area and vector detection in the encoder. This information is transmitted to the decoder. The synchronizing signal does not extend beyond signal modulation. Clamping level is provided in the vertical interval. For FM transmission, AFC is keyed to this level. Averaging AFC is not considered appropriate for FM modulation of MUSE.

The MUSE format is not well suited to VSB AM modulation. Tests of broadcast in this format were carried out in Washington D.C. in Jan. 1987. Limited tests on cable were performed in Oct,1987 at Alexandria, Va. More data in this regard are needed. A number of public demonstrations of MUSE transmitted via FM have been made. Laser disc MUSE recordings have also been demonstrated. Hardware development on this system is the most advanced of any proposed. It is also the most complex. Development of the required VLSI decoder chips is underway at present. These are very complex, large chips in many cases.

MUSE is not compatible with NTSC. A transccoder is required. Further, it has a different field rate and line count so that transcoding is more complex. Nonetheless, such tsancoders have been demonstrated.

HDB-MAC

This Scientific-Atlanta system has been proposed as an extension of the existing B-MAC [8] system which is in use in several countries for satellite broadcast and private network. HDB-MAC [9] is a 525 progressive system with 10.7 MHz bandwidth, 59.94Hz field rate, and 16:9 aspect ratio (see Table 1). The system has high quality digital stereo sound (as does the existing B-MAC)

The system, as the name implies, is Multiplexed Analog Component and is based on an evolution of B-MAC. Data, chroma, and luminance are time multiplexed within each line. Active line time is 52.5 microseconds with chroma compressed 3:1 and luminance 1.5:1. Sound is carried in the digital data. Clamping level is in the vertical interval and a clamped exciter is recommended for FM transmission. The 525 sequential signal is transmitted as a combination of 525 interlace and line difference. This has the advantage of limiting the transmitted bandwidth without introducing storage cost in the decoder, and without requiring motion compensation. The signal is derived from either a 1050 line interlaced or 525 sequential RGB. The input is sampled and diagonally filtered to make room for line difference signal. Alternate samples are discarded to give the "quincunx" sampling pattern. The next step is to interleave odd and even lines by taking samples alternately from each. This has the effect of transmitting the sum of the odd and even lines at low frequency with the line difference transmitted interleaved at higher frequency.

The HDB-MAC format is a part of a compatible evolution from B-MAC. B-MAC uses 6.3MHz bandwidth and is 525 interlaced. The increase in bandwith to 10.7MHz permits several options, one of which is that described above. A second option is the transmission of 16:9 aspect ratio with horizontal resolution increased to 420 lines-per-height. This system is compatible with present B-MAC decoders which have dual aspect ratio capability with pan and scan. The third option is to transmit a 4:3 aspect ratio signal with horizontal resolution of 560 lines-per-height. A Y/C output from the decoder would make this system compatible with S-VHS recorders and Y/C equiped television sets. Such signals could be carried on cable in two channels, one carrying luminance with increased bandwidth and compatible with current scrambling etc., the other carrying chroma and sound. This would provide an enhanced 4:3 picture free of NTSC artifacts and digital stereo sound.

HDB-MAC has been demonstrated with all features save the line difference to extend vertical resolution, which has been simulated. It is not compatible with NTSC. Decoder complexity is relatively low, having minimal storage requirements.

North American Philips

Philips proposes a system which uses two different formats, one optimized for satellite and another for terrestrial broadcast and cable [10,11]. The satellite format is a Multiplexed Analog Ccomponent format called HD-MAC60. This format, like MUSE, is well suited to satellite transmission. A less complex data reduction method is elected so that motion correction and frame stores are not required. The cable/terrestrial format is two channel, one of which is standard NTSC.

The system is based on 525 line progressive scan with 59.94Hz field rate 16:9 aspect ratio (See Table 1). The input signal would be 525 progressive scan RGB. Active line time is 26 microseconds. As with other systems, chrominance bandwidth is limited. The information is then "repackaged" in the form of several different signals. One is a line differential signal which is a low pass filtered version of the difference between the present line luminance and the average of the adjacent lines (a prediction error). Luminance for every other line (n, n+2, n+4 etc.) is sent alternately uncompressed and 16:9 time expanded. Time expansion lowers the transmission bandwidth required to support a given signal bandwidth,thus increasing resolution. Similarly, chrominance is transmitted for every four source lines alternating between 1:2 and 1:4 time compression. The signal bandwidths and compression are such that each has a common 9.5MHz of transmission bandwidth. In order to have a uniform distribution of temporal and spatial information and to facilitate transcoding, subsequent frames have different content. The total cycle is 4 frames. The information transmitted in the four frame sequence maintains full temporal resolution with a reduction in diagonal detail . This diagonal detail is available at lower temporal rate and can be recovered by added storage provision. Alternately, the higher diagonal detail may be filtered out at the source.

The satellite signal is transcoded to a two channel format for terrestrial use. This format is called HD-NTSC and consists of one standard NTSC channel (Main Signal Package) and an augmentation channel (Augmentation Signal Package). Transcoding is relatively simple and does not introduce artifacts. The NTSC channel contains only standard NTSC information. Adaptive comb filtering would be used to reduce NTSC artifacts. The second channel contains sidepanels to increase aspect ratio from 4:3 to 16:9, information for increased resolution, and digital audio. Several formats for the ASP are being considered. An analog method has been outlined in some detail [10]. The augmentation information includes time expanded line difference VSB modulated onto a subcarrier. High horizontal luminance is time expanded and SSB modulated since it has no DC component. Chroma is handled in similar fashion. Detailed description is beyond the scope of this paper. The modulation format and exact packaging is still being evaluated. The scheme described and those being evaluated fit within a 6MHz channel. Cable would carry this augmentation channel and a standard NTSC channel. A provision is made for selecting the portion of the 16:9 picture to be transmitted in the NTSC channel (commonly called "pan and scan"). The pan and scan control would be established by production requirements and transmitted within HD-MAC60. The transcoder to HD-NTSC will use this information to select the portion of the picture to be placed in the NTSC channel.

The system has been demonstrated with most features. Development is not so advanced as MUSE but the processing is not so complex which may allow more rapid advancement.

ACTV

This system is based on multiple subcarriers with quadrature modulation [7]. The signal is NTSC with one additional subcarrier (quadrature modulated) and quadrature modulation of the picture carrier. It is based on 525 progressive 59.94Hz field rate system with 5:3 aspect ratio (See Table 1). While the 5:3 aspect ratio is preferred and analyzed, it could be 16:9 by modification. A spectrum is shown in Fig. 2.

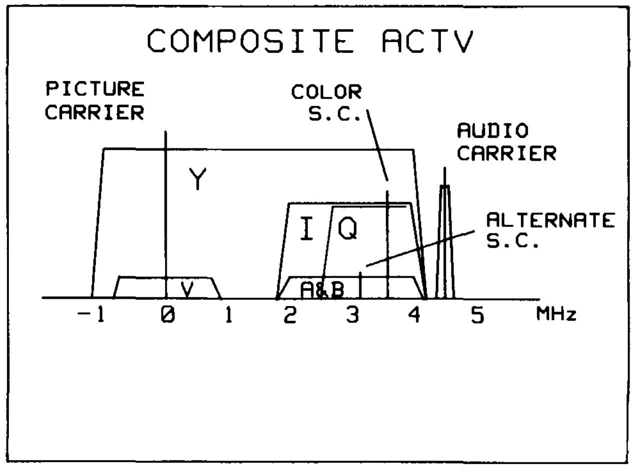

FIGURE 2

The source would be 525 progressive RGB. This is matrixed to YIQ and prefiltered. Active line time is 52 microseconds. The luminance is converted to 4:3 interlace scan by first expanding the center panel of the input signal to 50 microseconds. The remaining sidepanels are separated into low and high frequencies. The low frequency portion is time compressed 6:1 into 1 microsecond at each end of the center panel. The filtering and compression is such that the transmitted bandwidth of this signal is standard NTSC (4.2MHz luminance and .5MHz chrominance). The luminance and chrominance are 3-D filtered to produce little crosstalk between luminance and chrominance. The sidepanel highs are NTSC encoded and time expanded to reduce bandwidth to 1MHz,then quadrature modulated onto a 3.108MHz subcarrier. Horizontal luminance detail related to the main signal (with same expansion/compression) is likewise quadrature modulated onto this alternate subcarrier. A Vertical Temporal helper signal, a temporal prediction error , is quadrature modulated onto the picture carrier. This signal is zero for stationary pictures. The resulting signal package can be transmitted in a standard 6MHz channel.

When received by an NTSC receiver, the compressed sidepanels are decoded in compressed form but are hidden by overscan. The sidepanel highs rely on an interlaced subcarrier and the fact that they should appear as 30Hz complementary color flicker. Such flicker is not normally perceived. It is also important that the level of these added signals be relatively low. This system uses time compression and expansion but transmits components through time parallel modulation techniques instead of time sequential as with MAC signals. Added information is placed "in the cracks" between existing spectral information. Sound would be carried by the NTSC sound carrier.

This system has been simulated by computer but has not been demonstrated in hardware. Computer simulated television pictures have been demonstrated.

NYIT

Dr's. Glenn and Glenn propose a system which begins with a different source. It is based on 1050 line progressive scan 59.94Hz field rate with 16:9 aspect ratio (See Table 1). There are, in effect, two cameras within one. One scans the image 525 line 2:1 interlace 59.94 Hz with RGB output. The other is a single tube scanned 1050 line progressive 59.94/4Hz and provides high resolution luminance information. Low resolution information is provided by the RGB camera at 59.94 Hz. The high resolution information is provided by the second camera at 1/4 this rate. The high resolution information is digitally processed and the rate further reduced by a factor of two. When received, the high resolution signal is frame stored. The low resolution signal is scan converted to 1050 progressive by line interpolation and added to the frame store information to produce the display. No motion correction is performed. The low frame rate high resolution information will cause elongation of pixels in moving areas. Arguments based on visual perception predict that these effects will not be perceived as degradation.

Transmission is via two channels. One is standard NTSC except for the aspect ratio. A 3MHz augmentation channel contains the low frame rate information. Aspect ratio is dealt with by using a 56 microsecond active line for the NTSC signal, extending from immediately after burst to immediately before sync. The number of active vertical lines is reduced. This eliminates vertical overscan on an NTSC set. Extra width is cropped by horizontal overscan. Sound would be carried on the standard NTSC sound carrier.

Some hardware has been demonstrated.The system uses a totally new camera concept. The decoder is moderately complex.

The Del Rey Group

This system is based on a unique scanning concept which is called tri-scan [3,4]. The camera scans with spot wobble which is different frame to frame to create a three frame sequence (Fig. 3).

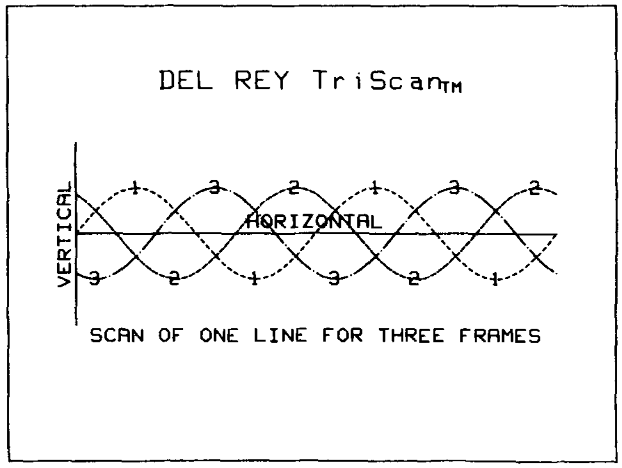

FIGURE 3

The numbered points (scan number) on the scan line correspond to the triplets of pixels making up one NTSC pixel. The resulting scan could be considered as 1050 interlace, 59.94Hz field rate. The spot wobble reduces the horizontal sampling rate and converts vertical frequency into the horizontal. Each frame consists of 440X414 pixels (the system uses 414 active vertical lines). This is based on using the full 4.2MHz bandwidth. There are three frames in a complete sequence, giving 547,000 pixels to be shared between horizontal and vertical. Assuming that the wobble could be viewed as generating 2X414 vertical lines, we have a horizontal resolution of 659 lines. This gives a somewhat simplified view which indicates the system capabilities.

As noted, the spot wobble translates vertical information into horizontal frequency. Consider the case where a vertical black/white transition is spanned by the beam wobble. In the figure, the transition would be at the horizontal line. This generates a large component at the wobble rate. The effect is not unlike the use of a subcarrier and the same care must be used in regard to interference with other components.

Encoding is NTSC. An NTSC receiver would treat all frames the same, displaying lines as transmitted. The "smart" receiver would display with the same wobble as in th original scan. The NTSC receiver would see each of the three scans as information from the same space, even though each scan is slightly offset. Edges would show low temporal rate flicker (10 Hz).

This process basically sends the complete data sequentially over three frames. Rather than use a frame store, a longer phosphor time constant is proposed. The desired result is achieved when static pictures are displayed. Motion causes blurs due to phosphor lag and the blur is in three bands because of the slow refresh rate. Frame storage is proposed as an alternative. A "Dual Resolution Processor" is referred to. Resolution switching would be used rather than motion compensation. A 14:9 aspect ratio is proposed which would be attained by reducing active lines vertically to eliminate vertical overscan and encroach into the display of NTSC sets. The image on the NTSC set would approach the 14:9 ratio while new sets would take full advantage. The possibility of expanding active line time to achieve 16:9 aspect ratio as does Glenn is mentioned. Sound data would be carried in the now unused lines of the vertical scan.

This system is remarkably similar to the MUSE approach in the use of multi-frame sampling. It is quite different in that encoding is NTSC, and a narrower transmitted bandwidth is used.

The elements of this system have not been denonstrated. Some simulation has been performed. The complexity is high. Use of phosphor time constant rather than frame stores has been proposed to reduce complexity. The approach places priority on using one 6 MHz channel for compatible transmission.

The transmission characteristics for this system are the same as NTSC since it is purely NTSC encoded. Noise and reflections would behave in the usual way. All of the enhacement is via frame sequential data.

IMPLICATIONS FOR CABLE

Clearly all systems present some new concerns for cable transmission. The fundamental question of "compatible bandwidth" is key. The ACTV and Del Rey systems place the highest priority on this concern, keeping to one 6MHz channel. Other systems require 9 to 12 MHz in two channels. MUSE places lowest priority on compatibility, requiring two channels totaling 16MHz. MUSE places highest priority on resolution.

Decoder complexity/cost is not easily compared between systems except that MUSE is likely the most expensive and systems requiring only line stores should be near the lower end.

Signal to Noise

It is reasonable to assume that the closer viewing distance permitted by HDTV will require an increased signal to noise ratio in the displayed picture. We can make some effort to relate the carrier to noise to final signal to noise. The perceptibility of noise varies with frequency. This is accounted for by weighting filters which simulate the way we perceive noise. While these functions are specified in Hz, they relate to the perceptual function which is in cycles per height (cph). This is based on the fact that observation is specified at standard ratio of picture height. This relates well to practical viewing conditions. For sake of comparison with well known parameters, I will begin with the well known CCIR weighting function (not the unified).

$$A = \frac{1 + \left[\frac{f}{f3}\right]^2}{\left[1 + \left[\frac{f}{f1}\right]^2\right]\left[1 + \left[\frac{f}{f2}\right]^2\right]} \qquad \text{EQ 1}$$

here A= power ratio
f1= 0.270 MHz
f2= 1.370 MHz
f3= 0.390 MHz

The frequency in Hz is related to the horizontal spatial frequency in cph by:

$$F = \frac{Ta}{AR} \cdot f \cdot \frac{1}{K} \qquad \text{EQ 2}$$

where F= horizontal patial frequency (cph)
Ta= active line time of signal component(sec)
AR= aspect ratio (W/H)
K= compression ratio = Ta/Ts
Ts= occupied time of signal
f= frequency (Hz)

Ta is usually total active line time. However, when the component is a partial line as such as ACTV sidepanels, it is the active line time associated with the partial line.

From the values above and the NTSC parameters one can calculate F1,F2, and F3 to be:

F1= 10.63 cph
F2= 53.95 cph
F3= 15.36 cph

We can now convert to another aspect ratio, line rate or compression ratio. For example, for MUSE luminance:

Ta= 29.63 microseconds
AR= 16/9
K= 1.25

which yields (for MUSE)

f1= 0.795 MHz
f2= 4.050 MHz
f3= 1.152 MHz

These are new values for a weighting filter which would be used for MUSE luminance. This function would be used to integrate baseband noise to determine signal to noise ratio. It should be understood that some modification of the CCIR function for the broader bandwidth may be desirable but the function as is should give reasonable results. This function, with the new frequency values, accounts for the fact that time compression shifts signal frequencies up. In the receiver, time expansion returns these frequencies to their proper value. This expansion also lowers the frequency of noise components, making them more noticeable. We can now determine signal to noise for VSB modulation on cable. If we integrate the CCIR function for NTSC from .01 to 4.2 MHz we get a weighting factor of 6.2 dB for flat noise. Similarly, if we integrate the weighting for MUSE (derived above) from .01 to 8.1 MHz we get a weighting factor of 4.8 dB. Then, for NTSC;

S/N = C/N - 6.9db + WEIGHTING
= C/N - 6.9dB + 6.2dB
= C/N - 0.7dB

The 6.9 dB derives from the definition of signal to noise and the modulation parameters [14]. For MUSE the signal level will be 3dB higher because there is no negative sync. However, the C/N for a given noise level will be 3dB lower because of doubling bandwidth (from 4.2 to 8.1MHz). Thus, the MUSE signal to noise relative to NTSC for the same noise power density would be:

S/N (MUSE) = C/N (NTSC) - 3dB - 3.9dB + WEIGHTING (MUSE)
S/N (MUSE) = S/N (NTSC) - 6.2 dB + 4.8 dB

S/N (MUSE) = S/N (NTSC) - 1.4 dB

In order to recover the signal to noise, we could increase carrier power. This would seem practical since the broader bandwidth will reduce the number of carriers present on a system. Also, the interference caused by the MUSE modulated carrier may be less due to the greater spreading of energy. By this means, signal to noise might actually be improved several dB. An analysis of the susceptibility of MUSE to interference is also needed. Chroma noise will also need attention.

When interframe information is used, noise effects are reduced because the noise contribution in each sample is uncorrelated and averages over the samples to reduce the net effect. This will occur with certain signals in several systems.

The side panel lows in ACTV are compressed 6:1. This causes almost the entire bandwidth of baseband noise to be lowered into the perceptible range when displayed. An analysis such as above yields a weighting factor of 1.7 dB. This indicates that signal to noise in the sidepanel area would be 4.5dB lower than in the center panel. Information on subcarriers and how they may fare with noise is incomplete. The relatively low levels implied raises some concern.

In the case of the NYIT system, one channel is simply NTSC and will behave as we are accustomed. The second channel is high frequency information time expanded to reduce bandwidth. The 1125 line progressive scan is transmitted at 7.5 FPS. This doubles the line time compared to NTSC. It is time compressed when received, reducing noise visibility. Noise does not appear to be a major concern for this signal.

The Philips case is somewhat different. The sidepanels are transmitted in a separate channel. Matching of noise characteristics is important here. Their transmission characteristics would be the same as the main signal. The high frequency augmentation and line difference signals are time expanded for transmission so that they have a reduction of perceptible noise when compressed after reception. The complex nature of the overall modulation scheme makes complete analysis impractical within this paper. The choices for the second channel encoding are still being evaluated and could involve digital modulation (according to Philips response to the FCC NOI).

Reflections

The subjective effects of reflections have been reported by Pierre Mertz [15]. As is the case with many efforts, his complex analysis is usually reduced to presenting a simplified guideline referred to as the Mertz curve. This curve relates the echo level barely discernible to echo delay. A portion of this curve from 10 to 1000 nanoseconds is shown in Fig. 4. Echoes with coordinates which fall above and to the right of the curve would be visible, while those below would not. Above about 5 microseconds, the level is a constant 40dB.

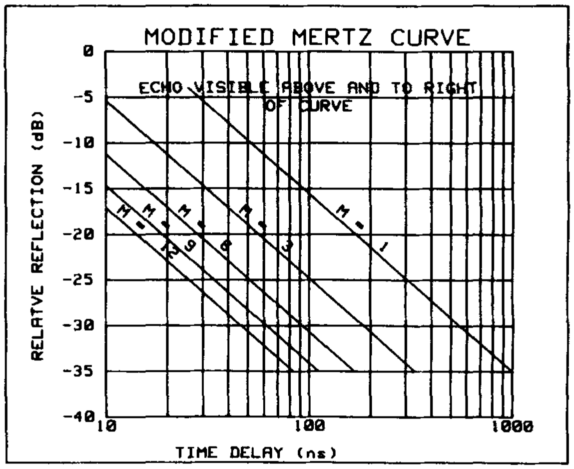

FIGURE 4

The original curve was developed for NTSC with 4:3 aspect ratio. A conversion of this curve is necessary to use the information for other systems.

The echo delay axis really relates to horizontal displacement on the screen. A system using a shorter active line time will cause a given horizontal displacement to relate to a commensurately shorter delay. A wider aspect ratio has a similar effect. Many systems being considered also transmit information in time compressed form. Echo delay is increased when the received signal is expanded to the proper display time. All of these effects can be accounted for by multiplying the actual delay by a constant and using the standard Mertz curve. Alternatively, the curve can be shifted to the left by this same ratio (as in Fig. 4) and actual delay used. This ratio, M, can be determined by:

$$M = \frac{3}{4} \cdot AR \cdot K \cdot \frac{52.56 \cdot 10^{6}}{Ta} \qquad \text{EQ 3}$$

The parameters of M were defined above.

For example, if we were to halve the halve the active line time and change aspect ratio to 16:9:

$$M = 2.7$$

Curves for several values of M are given in the figure. Using MUSE luminance parameters:

$$Ta = 29.63 \text{ microseconds}$$
$$K = 1.125$$
$$AR = 16/9$$

which gives $M = 2.7$

A similar calculation for MUSE chroma gives a value of 11.8. The appearance of echoes in the color signal for a constant luminance signal may not be so clear as echoes in luminance. Another point to be noted is that echoes can cause color signal echoes to appear as luminance information due to the time multiplexing of the components with luminance following color. Both are analog voltages distinguished only by timing.

Cable systems generally have discontinuities located at 50 to 150 ft intervals. For a single pair of reflections, this equates to echo delay of 113 to 339 ns. As MERZ noted, multiple reflections appear as ripples in the amplitude and phase in the frequency domain. The effects of multiple reflections at short delay spacing as encountered in cable are best comprehended in this way. A good way of testing would be response with 2T pulse or bar rising edge. For the broader band signals of HDTV a narrower pulse (along with a broadband modulator and demodulator) would be necessary. For the 8MHz of MUSE, a transmitted pulse with a half amplitude width of 125 ns would be required.

The ACTV system compresses the sidepanels by 6 which gives value of 5.9 for M. However, only very low frequency information is transmitted in this region. As a result, short delay echo will still have little effect.

It is apparent that the reflections in a cable plant can be expected to be of more concern in HDTV. Primarily because short delay reflections which do not have to be suppressed so much presently will become significant. These effects need to be analyzed for each potential system.

CONCLUSIONS

HDTV may be viewed as a threat to cable, an oportunity or simply another format to be dealt with. The threat would be potential bypass by other broadcast or recorded media. The opportunity would be a service of value to the consumer which would command a higher price. The third case assumes that almost everyone will have HDTV sets eventually and cable simply must provide the signal to stay even. Which of these views is proven out will depend at least in part on the degree to which the cable community is active in the decision making process. Regardless of which opinion is held, an informed and prepared position will maximize opportunity or reduce risk.

There will, no doubt, be unforseen technical challenges in carrying HDTV on cable. The systems are different in the priority placed on various tradeoffs. Each presents some different challenge to cable. We have tried to provide some insight into the effects of noise and reflections in some candidate systems. Continuing effort is required to gain a sufficient understanding. A more complete evaluation will become practical as systems are better defined and understood.

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