345 SCARBOROUGH ROAD
BRIARCLIFF MANOR, N. Y. 10510
PHONE: (914) 945-6000

NORTH AMERICAN PHILIPS CORPORATION

June 22, 1987

PHILIPS LABORATORIES

To: NCTA Technical Committee Members

From: Arpad G. Toth
PHILIPS LABORATORIES
North American Philips Corporation

Subject: ADVANCED TELEVISION SYSTEMS STUDIES AT NORTH AMERICAN PHILIPS CORPORATION

Advanced Television Systems present challenging opportunities for the North American television industry. Improved, enhanced and high definition television are rapidly evolving and will impact all segments of the television business. We are especially enthusiastic about our effort in advanced television and would like to share with you our progress.

In Philips Laboratories, we have defined a television systems hierarchical evolution plan with the following four layers:

* **MAC-60** master feeder signal for satellite delivery of the HDTV signal between the program origination and the signal redistribution points (e.g. CATV headend). MAC-60 is also the signal for Direct Broadcast Satellite (DBS). MAC-60 is NTSC-friendly and easily convertable to the lower hierarchical level signals including NTSC.

* **ENTSC** (Extended-NTSC) signal is fully compatible with NTSC and delivers HDTV quality signal to the homes via two NTSC compatible 6 MHz channels. ENTSC is the proposed transmission format for CATV delivery. It may also be the desired option for terrestrial broadcast.

* **EDTV** signal is fully compatible with NTSC and its 6 MHz channel. NTSC-compatible solutions may improve luminance, chrominance resolutions and noise performance, could implement progressive scanning at the camera and receiver, and may extend the 4:3 aspect ratio to 16:9. An industry consensus is required to select the desired alternative(s).

* Current **NTSC** system and evolving improved-NTSC (**INTSC**). Continuous improvements are expected within the television receiver to improve signal detection and image plus sound reproductions without any change in the signal emission standard or in the studio.

Our research effort is concentrating on a total systems approach, considering all aspects of video applications including terrestrial broadcast, CATV, direct broadcast satellite, fiber optic distribution and stand-alone applications based on Video Cassette Recorder (VCR) or laser video disc player. We believe advanced television will bring to the world an ENHANCED VIEWING EXPERIENCE, but its implementation must be cost-effective and evolutionary. Our goal is to define the path for a compatible hierarchical evolution of advanced television, where each evolution stage could coexist in harmony with NTSC the lowest and HDTV (MAC-60) the highest hierarchical level.

We are pleased to share our preliminary results with you and the attachment includes our latest publications on the subject.

A. Toth

Arpad G. Toth
Principal Research Scientist

HIERARCHICAL EVOLUTION OF ADVANCED TELEVISION SYSTEMS

In this decade, television technology has been going through a major evolutionary phase. First, television has improved significantly within the limits of the NTSC standard. The use of digital, very large scale integrated circuit (VLSI) technology combined with advanced signal processing within the consumer television receivers and the introduction of stereo audio transmission permit potentially improved image and sound reproduction capabilities. Alternate display techniques have also evolved (e.g., projection TV) along with the conventional direct-view cathode-ray-tube (CRT)-based receivers. Television in the USA has reached full penetration with more than one receiver per home. Video Cassette Recorders (VCRs) have become a critical driving force in the entertainment program production and delivery business. The penetration has grown so fast in North America during the past three years that it has considerably influenced the entire business structure of television.

Second, intensive efforts have been made to arrive at technically and commercially viable solutions for High Definition Television (HDTV). This technology is now gaining acceptance in specialized applications (e.g., electronic publishing). The next challenge is to apply this technology in consumer television and broadcasting. One of the outstanding tasks is to arrive at a set of HDTV standards for program production, video transmission and distribution environments, and for recording and display applications.

We have developed an attractive plan for the hierarchical evolution of HDTV in the NTSC world. Ours has been a total system approach considering the use of today's program delivery systems: terrestrial broadcast and cable television (CATV); new broadcast systems: direct broadcast satellite (DBS) and fiber optics; and existing plus new information carriers: VCR, compact disc with integrated audio, data and video storage capability (CDI, CDV) and video disc. Our results indicate that a high degree of compatibility with the current NTSC television technology-base can be maintained with the proper selection of the system parameter values, time division multiplexing, and studio and receiver signal processing techniques. This guarantees a smooth transition to HDTV without major frontend investment by the broadcasters, signal carriers and consumers.

We propose a compatible hierarchical system that includes HDTV, ENTSC and NTSC. The HDTV signal, which we refer to as MAC-60, uses time division multiplexing that easily transcodes to a standard NTSC signal. MAC-60 offers an attractive opportunity as the main feeder for terrestrial broadcast stations, CATV headends and as the carrier for DBS. The ENTSC system can also be derived from MAC-60 with a low-cost transcoder. ENTSC is optimized for the conventional CATV distribution environment, making an economic use of the available channel spectrum, the installed CATV headend and coaxial tree structured cable-plant. It may also present an attractive solution for the terrestrial broadcast of wide aspect ratio advanced television services.

ENTSC Two-Channel Compatible HDTV System

Mikhail Tsinberg
Philips Laboratories
North American Philips Corporation

ABSTRACT

This paper describes the architecture and signal processing methods involved in the realization of a two-channel NTSC-compatible television system capable of delivering a wide aspect ratio and high definition (HDTV) television signal to the consumer via existing networks of broadcast television.

1. Introduction

In recent years HDTV has been evolving towards a level of maturity that warrants serious consideration upon actual introduction. The most notable proposal hitherto has come from NHK in Japan. Though it is a very impressive achievement, this proposal as well as its derivative for transmission, MUSE, lacks compatibility with the current TV standards.

Philips is one of the parties that considers compatibility of future HDTV systems with these standards to be of vital importance. In the US, for example, there is an installed base of about two hundred million NTSC receivers, while large investments have also been made in the approximately ten thousand CATV headends and in about 1200 VHF and UHF terrestrial broadcast stations all designed to operate with NTSC standard only.

Our approach for the environment in North America is based on two main elements: a MAC type feeder signal that carries HDTV information via satellite to cable headends, local terrestrial broadcast stations and future DBS receivers with HDTV capability and a NTSC compatible CATV delivery system that uses two normal (CA)TV channels. The former is called MAC-60, the latter was given the name ENTSC. MAC-60 as well as ENTSC are capable of carrying the information that is needed to create a picture, with specifications to be given below, that truly can be regarded as HDTV. MAC-60 has been designed to be easily transcodable into ENTSC and one of the two channels used by ENTSC is identical with NTSC, thus providing compatibility.

We stress that other current developments such as Japanese EDTV and INTSC are not discussed in this paper, although these techniques can contribute in principle to our proposed system in various ways.

In the remainder of this paper and in the two following papers, [2],[3], we will discuss ENTSC only. This system has been built in our laboratories and was recently demonstrated to the industry. In the present stage it does not yet contain the full horizontal resolution of which the system is capable but in the near future this addition will be made. Also our design of MAC-60 will be realized in hardware. As we mentioned in the above MAC-60 will carry all the information that is needed for the ENTSC signal.

2. Overview of ENTSC

ENTSC was designed to be a two channel delivery system with full compatibility with NTSC. This was achieved by making one of the two channels identical to NTSC. We refer to this channel as the main channel or channel 1. The other channel which was called the augmentation channel or channel 2 carries the additional information that is required for the construction of the HDTV picture as well as for sound rendition on the quality level of compact disc.

We stress that the compatibility is upward as well as downward: normal NTSC receivers can simply receive channel 1 and new ENTSC receivers will receive channel 1 only if they do not receive an indication that in the current broadcast it is accompanied by an augmentation channel.

It follows from the above that channel 1 carries an aspect ratio of 3:4, and that the "panels" needed for an aspect ratio of 9:16

extent.

Originally the bandwidth of the source signal in the present implementation (our technique to increase the horizontal resolution to approximately the level of MUSE will be described in the near future) is equal to 4.2 MHz times 4/3 to provide wide aspect ratio, times 2 because of sequential scan. This amounts to 11.2 MHz. Therefore the line differential signal at the present stage of the description has this bandwidth also and thus has to be low pass filtered by a factor of 8/3 down to 4.2 MHz in order to pass it through the second channel. The factor of 8/3 actually is the expansion factor that was applied in the center and panel processing described above, and for that reason no low pass filtering has to be applied in that processing.

Note that it has never been assumed that the two panels are of equal width. This is reflected in our implementation as well and consequently provisions could be built in that provided for a pan and scan feature.

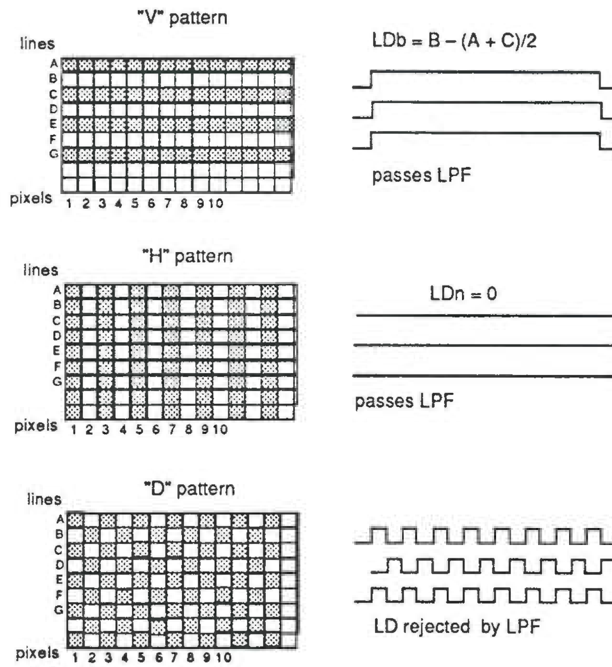
4. Consequences of Line Differential Encoding

The line differential signal as described above carries the information that is needed to restore a sequentially scanned picture at the receiver side. Assuming that in a certain frame the (n-1) th and the (n+1) th lines, L(n-1) and L(n+1) respectively, have been sent through channel 1 and the panel part of channel 2 and that the n th line has been sent as a line differential signal LD(n), this n th line can be reconstructed in the receiver by the operation

$$L(n) = LD(n) + [\, L(n-1) + L(n+1) \,]/2$$

If LD(n) had not been low pass filtered this reconstruction procedure would produce a complete sequentially scanned picture without flicker in the details. Because of the low pass filtering of the line differential signal we are left however with flicker in diagonal detail. Figure 2 will serve to clarify this in a pictorial way.

The "V" pattern shown has high vertical detail only and consequently the line differential signal has the shape of a line-long pulse. Therefore the low pass filter only changes the edges of this pulse and the rest of the sequential scan is fully restored. The "H" pattern has high horizontal detail only. Therefore the line differential signal is zero and thus is not affected by the low pass filtering at all. In this case the sequential scan is again fully restored. The "D" pattern produces a line differential signal of containing high frequencies only. This signal is rejected by the low pass filter and therefore does not contribute to the ultimate picture. As a result diagonal detail is transmitted in interlaced fashion leading to flickering of such a detail.



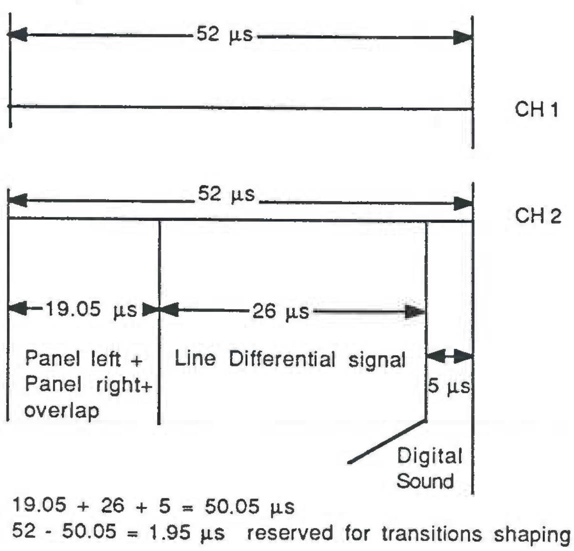
TV worse patterns

Figure 2

Obviously a differential signal can have two polarities instead of one as in the case of a normal video luminance signal. This restricts the available dynamic range and therefore imposes a noise penalty. We have found that with our low pass filtering procedure this penalty is limited to 4dB. In the future we will drop the NTSC sync pulses in channel 2, which will increase the attainable dynamic range in this channel. Therefore the noise penalty will be reduced to 1 dB only. Amplitude companding techniques could be used to eliminate this penalty altogether. Our experiments with the system show that there is undetectable amount of flicker with 4.2 MHz LPF for LD signal and exelent motion portrayal on the output of the decoder.

attenuation is in the area of 3.579545 MHz and 131.5 cph [5] which is the region where modulated NTSC chroma contains the most energy. I and Q are not affected by this filter because they already were prefiltered two-dimensionally by the sequence of two one- dimensional filters: first the analog front-end LPF before A/D conversion and second the digital vertical LPF (" vertical chroma prefilter").

The "NTSC modulator" is a standard digital NTSC modulator with data clock rate of 4*fsc [3] which multiplies each I and Q by 1 or -1 and inserts them in the correct sequence I,Q,-I,-Q.... After digital chroma is formed it is added to the luminance to become a digital representation of composite NTSC for both center and panels. The 52 usec center is transmitted as channel 1 active line, and the 19.05 usec of panels together with the other signals form the channel 2 active line (see Active Line Time Figure 4) .



Active LIne Time Figure 4

"Subcarrier phase" identifies the correct subcarrier phase of fsc to form the VITS (vertical interval training signal) which has 50 cycles of burst in phase with I [3].

In the beginning of the encoder discussion the Y component was processed by "2:1 decimator phase = 0" which discarded every other sequential line to form a properly interlaced sequence.

The Y component is also processed by a separate path called the LD encoder (line differential encoder) . The LD encoder consists of three elements . The first is the "line differential generator" which is a simple 3-tap vertical HPF with coefficients -1/2 ; 1 ;-1/2 (note that LDn = Ln-(Ln+1 + Ln-1)/2 is the LD equation). The output of this filter is 525 LD lines . The second element is "2:1 decimate phase=180" which is a circuit to interlace the 525 LD lines in opposite phase to the main Y phase where if lines 1,3,5... are transmitted as centers and panels, lines 2,4,6... are transmitted as LD encoded. The third is a "4.2 MHz LPF" which is a horizontal low pass filter to reduce the LD bandwidth from 11.2 MHz to 4.2 MHz.

LDn lines are 26 usec long because they were not time altered and carry the same timebase as the original sequential lines. They are inserted during the active line time on the augmentation channel next to the previously inserted panels (see Fig.4).

A Dolby digital encoder is currently used to encode 16-bit high quality stereo sound into a 408 kb/sec digital bit stream . This signal is organized by "digital sound encoder" in 5 usec bursts of digital data to be inserted during the active line time on the augmentation channel.

After the processing described above the main and augmentation channels are ready to be converted to analog signals. The VITS (which is described in [3]) is inserted on both channels for matching purposes at the decoder.

6. Decoder Block Diagram Description

The function of the Decoder is to receive and process the two channels, prepare digital data for the Dolby digital decoder, and output to a 525 line, 59.94 frames per second, progressive scan, 9:16 aspect ratio RGB display. The display as it was mentioned earlier could have a different line-number format, but this is not discussed in this paper.

Referring to Fig.6 (Decoder Block Diagram) notice that much of the circuitry is duplicated for channel 1 and channel 2. The PLL locks to the channel 1 color burst input only. The PLL outputs 2 clock frequencies: $4f_{sc}$ and $\frac{32}{3}f_{sc}$.

Both signals are digitized with the same $4f_{sc}$ clock by two 9-bit A/D converters and are passed to the "synchronizer". It is not only possible but highly probable that due to differences in the gain of the signal to be adjusted such that 120 IRE (-20 to +100) quantizes 256 levels.

Chroma-Luma separation for the channel 1 signal and the panel portions of the channel 2 signal (which are NTSC encoded) is accomplished by the use of 2-dimensional "adaptive comb filters". The resultant chroma signals are applied to the "chroma demodulators".

The input to each of the "chroma demodulators" are the channel 1 and channel 2 chroma signals and two 8-bit coefficients from the microprocessor circuitry. The coefficients are derived from the analysis of the VITS and represent the arbitrary phase relationship between the sampling clock and the color burst as well as the attenuation of the channel at the subcarrier frequency. By use of these coefficients, the chroma signal can be demodulated and gain corrected to give the I and Q components at a 2fsc data rate.

The "8/3:1 compressors" accept the Y data at a $4f_{sc}$ rate and the I and Q data at a $2f_{sc}$ rate with a 63.55 usec. line time and time compress these data streams by a factor of 8/3. This is accomplished by taking the 52 usec of active video samples, writing them into a memory set up as a double buffer and then reading out a line of samples with the $\frac{32}{3}f_{sc}$ clock. The resulting output is one line of video lasting 31.75 usec followed by a blank 31.75 usec segment of time. Note that the channel 2 compressor does not operate on the LD portion of the signal, only on the panel portions, which are NTSC encoded.

Compressed Y, I, Q data for both channels are applied to the "center and panel combiner" circuitry where the channel 1 and channel 2 data are combined. The "line interpolator" then accepts the compressed data, creates the average of two adjacent lines and inserts this line into the data stream in place of the blank line in the format.

Summarizing, the format of the signal at the output of the "line interpolator" is a parallel Y, I, Q data stream, representing 9:16 aspect ratio, 31.75 usec line time, sequentially scanned 59.94 frames/sec video. The line differential signal has not been added to the signal yet and, as such, the Y signal can be enhanced and "cored" in an FIR filter. This process takes place in the "horizontal enhancement" circuitry just prior to D/A conversion.

The function of the "LD processor" is to window out the LD signal from the entire channel 2 line.

After D/A conversion the analog LD signal is applied to the "vertical enhancer" which is a manually controlled variable gain amplifier. Its output is then combined with the Y signal and in turn matrixed with I and Q to create the output RGB signals.

The "audio processor" prepares a continuous data stream from 5 usec bursts of data located on the active line time on channel 2. The data stream is then decoded by a Dolby digital decoder into an analog stereo pair.

7. Channel Matching Techniques

The need for channel matching arises from the fact that different portions of the wide aspect ratio display have been delivered through different imperfect channels and possibly through different circuits. All media distort the video signal to some extent and it is the difference in the distortions which would create an objectionable picture if not corrected.

The Decoder is capable of correcting the following parameters:

1)Static Time Delay

2)Black Level (DC Restoration)

3)Brightness (low frequency gain)

4)Chrominance Saturation

5)Hue

All corrections are made in conjunction with the microprocessor subsystem except for static time delay. In addition to functions to correct for video parameters, the microprocessor subsystem must also provide information to aid in the recovery of audio data. A more elaborate description of the channel matching procedure is given in [3].

8. Conclusion

Presented above is a progress report on work directed towards creating the Philips MAC-60/ENTSC systems-concept as a totally

An Extended Definition Television System Using Quadrature Modulation of the Video Carrier with Inverse Nyquist Filter

YOSHIO YASUMOTO, member, IEEE, SADASHI KAGEYAMA, SYUHJI INOUYE, HIDEYO UWABATA, and YOSHIO ABE

Wireless Research Laboratory, Matsushita Electric Industrial Co., Ltd.
1006 Kadoma Kadoma-shi, Osaka 571, JAPAN

Abstract --- A QUadrature Modulating Extended definition television system -QUME- , which enhances NTSC to higher definition , is proposed. The QUME system uses quadrature modulation of video carrier with inverse nyquist filter and creates an independent transmission channel (Bandwidth : 1MHz) without using additional channel resources. One of the features of QUME is that the multiplexed signal hardly interferes with the conventional TV receivers, and another is that there is no crosstalk between the multiplexed signal and the main NTSC signal. These features enable a wide aspect ratio image to be transmitted as well as high frequency components of luminance and/or chrominance signals, while keeping compatibility with the NTSC system.

I. INTRODUCTION

Recently, improvement on television receiver has been remarkably progressed such as large screen CRT, utilizing digital processing and IDTV. Still now, strong demand for higher quality picture exists. Since the 1970's, much efforts for developing a high definition television system have been made by engineers led by Fujio [1] in NHK (Japan Broadcasting Corporation). This HDTV system primarily aims at DBS (Direct Broadcasting Satellite) in Japan, and has no compatibility with the present NTSC system.

On the other hand, some proposals of NTSC compatible high definition television system have been made such as SLSC [2] and FUCE [3] system. The SLSC system uses 2 channels to transmit higher bandwidth of luminance and chrominance signals and LoCicero [4][5] extended this system to transmit wide aspect ratio image. Fukinuki [3] uses only 1 channel to transmit over 6MHz luminance signal, keeping receiver and transmission compatibility with NTSC. His system uses vacant frequency bands in the first and third quadrants which conjugate with the carrier chrominance signal, and transmits high frequency components of luminance or chrominance signal of a still picture. The FUCE system cannot transmit high frequency components of motion parts of images, and therefore cannot be used to transmit wide aspect ratio image.

The authors have developed a new extended definition television system using quadrature modulation of video carrier with inverse nyquist filter -QUME- [6]. The QUME system uses a single channel (Bandwidth : 6MHz) and keeps full compatibility with NTSC. These are very important matters especially in Japan, because there are no more channel resources available and 70 million NTSC receivers in use. [7] The first feature of QUME is that the multiplexed signal hardly interferes with the main NTSC signal, especially if detected using a PLL synchronous detector. The second feature is there are no crosstalk between the multiplexed signal and the main signal, and therefore edge portions of wide aspect ratio image as well as high frequency components of luminance and/or chrominance signal in the motion part of the image can be transmitted.

Considering that the nyquist filter and PLL synchronous video detector are universally used in most of the conventional TV receivers, an inverse nyquist filter is adopted for filtering the multiplex signal before added to the main NTSC signal. By using this filter, the multiplexed signal never interferes with the main NTSC signal in principle if detected by the PLL synchronous detector, because the multiplexed signal is shaped into double side band signal at the receiver.

Detailed principles of the QUME system is described in the next section. Experimental results of transmitting high frequency component of luminance signal and simulation results of transmitting wide aspect ratio image are discussed in section III and IV, respectively.

II. QUADRATURE MODULATION

A. Modulation of Multiplex Signal

The conventional NTSC signal has the frequency spectrum as shown in Fig.1 (a), which is called VSB-AM (Vestigial Side Band Amplitude Modulation). In this figure, P_1, C and S indicate video carrier, chrominance subcarrier, and sound subcarrier, respectively, and the lower part of bandwidth than P_1 is 1.25MHz. Considering a multiplex signal which bandwidth is 1.25MHz, a second video carrier P_2 is used, which phase is 90 degree different from P_1 as shown in Fig.1 (b). Next step is band limiting of this modulated signal as shown in Fig.1 (c). This band limiting is -6dB at video carrier P_2, 0dB at P_2 -1.25MHz, and - infinite at P_2+1.25MHz. This characteristic is symmetrical to the nyquist filter at the video IF stage in the conventional TV receiver. This band limiting characteristic is called an *Inverse Nyquist Filter*. As the last step, combining the main signal of Fig. 1 (a) and the multiplex signal of Fig. 1 (c), the QUME signal is obtained as shown in Fig.1 (d). Quadrature modulation of video carrier with the inverse nyquist filter is a feature of the QUME system. Using the multiplex signal, edge portions of wide aspect ratio image as well as frequency-shifted high frequency components of luminance and/or chrominance signal can be transmitted.

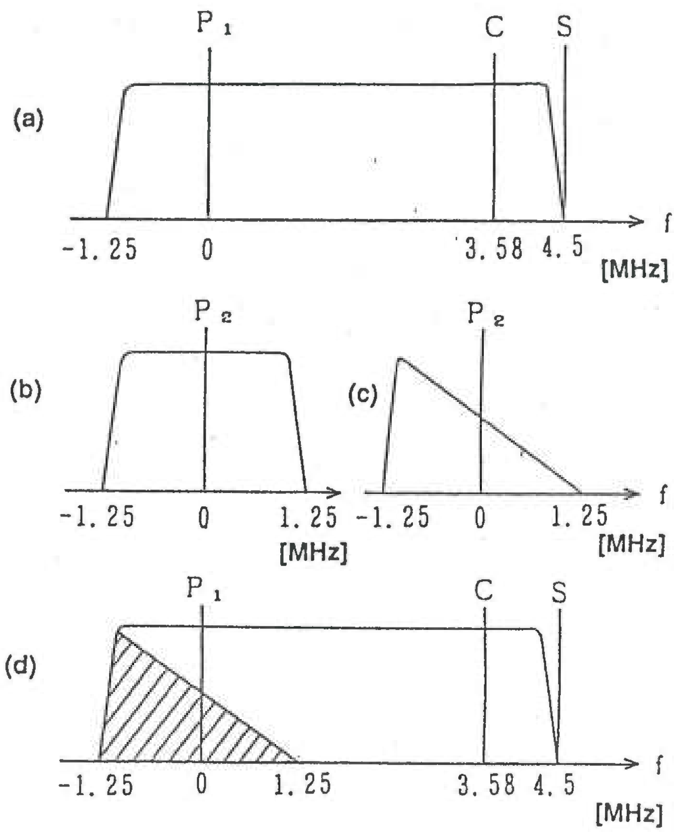


Fig. 1. Frequency Spectrum of QUME
(a) NTSC (b) Multiplex Signal (c) Multiplex Signal after Inverse Nyquist Filter (d) QUME

B. Demodulation in a conventional NTSC receiver

Now let us consider receiving of the QUME signal as described before by the conventional receiver. This signal contains the multiplexed signal which is filtered by the inverse nyquist filter at the transmitter. In the conventional receiver, incoming signal is band limited by a nyquist filter at the video IF stage and shaped into the spectrum shown in Fig.2 (a). The vector chart of this processing is shown in Fig.2 (b). In this figure, $\mathbf{I_1}$ is the video carrier of the main signal and $\mathbf{I_2}$ indicates the carrier of the multiplexed signal, which is 90 degree different from $\mathbf{I_1}$ and suppressed at the transmitter. In Fig.2 (b), $\mathbf{a_u}$ is the upper side band signal and $\mathbf{a_L}$ is the lower side band signal; the length of both vectors are different from each other because the main NTSC signal is vestigial side band. The $\mathbf{a_u}$ and $\mathbf{a_L}$ signals are decomposed to orthogonal components $\mathbf{a_1}$ and $\mathbf{a_2}$. As the multiplexed signal is double side band, the upper and lower side band signals, $\mathbf{b_u}$ and $\mathbf{b_L}$, have the same length and the composed vector of them, $\mathbf{b_2}$, is in the direction of $\mathbf{I_2}$. If

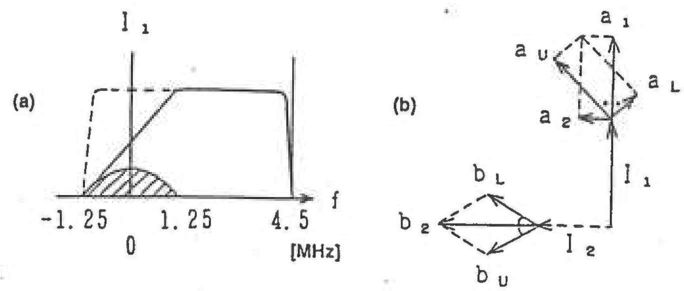


Fig. 2. Demodulation in a conventional receiver
(a) Spectrum (b) Vector Chart

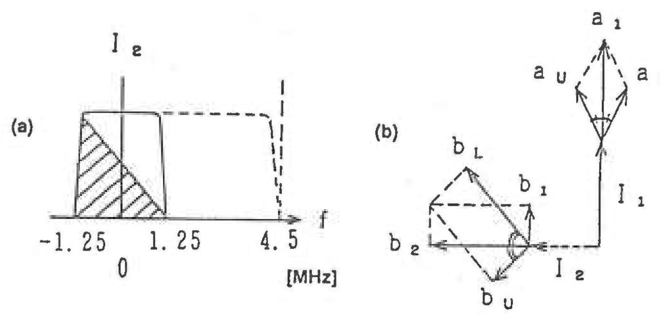


Fig. 3. Demodulation in a QUME receiver
(a) Spectrum (b) Vector Chart

the multiplexed signal is detected along $\mathbf{I_1}$ by the synchronous detector, there arises no quadrature distortion caused by vector $\mathbf{a_2}$ and $\mathbf{b_2}$. Thus the multiplexed signal $\mathbf{b_2}$ never interferes with the NTSC signal in the receiver with the synchronous video detector.

On the other hand, the multiplexed signal $\mathbf{b_2}$ is detected also by the envelope video detector, but power of crosstalk by the multiplexed signal is 10dB less than the case without the inverse nyquist filter.

C. Demodulation in a QUME receiver

In a QUME receiver , the multiplexed signal is detected by the synchronous detector after passing through a band-pass filter from the tuner. This band-pass filter eliminates signals greater than 1.25MHz of the main NTSC signal and shapes it to double side band as shown in Fig.3 (a). The vector chart of this signal is shown in Fig.3 (b). In this figure, $\mathbf{b_u}$ and $\mathbf{b_L}$ are upper and lower side band components of the multiplexed signal, and are decomposed to orthogonal vectors $\mathbf{b_1}$ and $\mathbf{b_2}$, which length are different because the multiplexed signal is vestigial side band. On the other hand, $\mathbf{a_u}$ and $\mathbf{a_L}$ are upper and lower side band components of the band limited main signal, and composed to vector $\mathbf{a_1}$, which is in the direction of $\mathbf{I_1}$ because this signal is double side band. Thus the multiplexed signal is detected along $\mathbf{I_2}$ by the synchronous detector without quadrature distortions of vectors $\mathbf{a_1}$ and $\mathbf{b_1}$.

D. QUME Transmitter and Receiver

Fig.4 shows the complete QUME system of transmitter and receiver. In addition to the conventional broadcasting system, quadrature modulator and demodulator, and inverse nyquist filter are newly added. Considering the cost performance of the total system, cost increase of the receiver should be minimum. Since the QUME receiver needs no field or frame memories, and the PLL synchronous detector is already equipped in most of the conventional receivers, a QUME receiver can be realized by slightly modifying a conventional receiver with little cost increase.

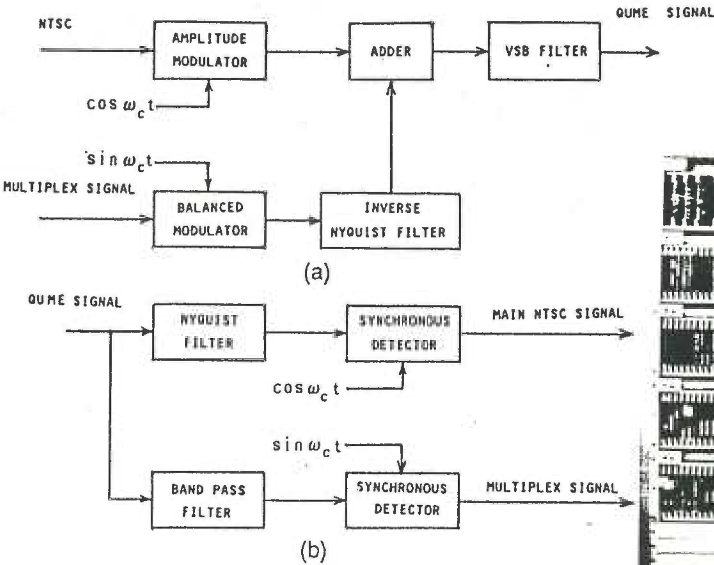


Fig. 4. Block Diagram of the QUME system
(a) Transmitter (b) Receiver

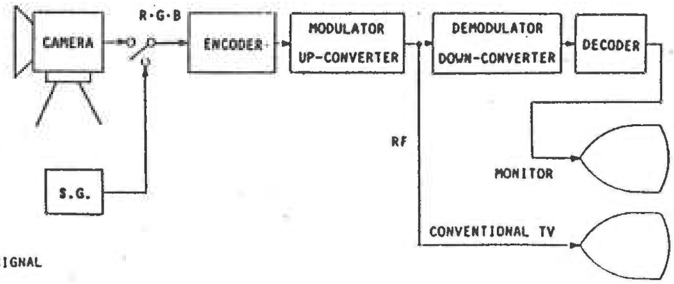


Fig. 5. Experimental QUME system

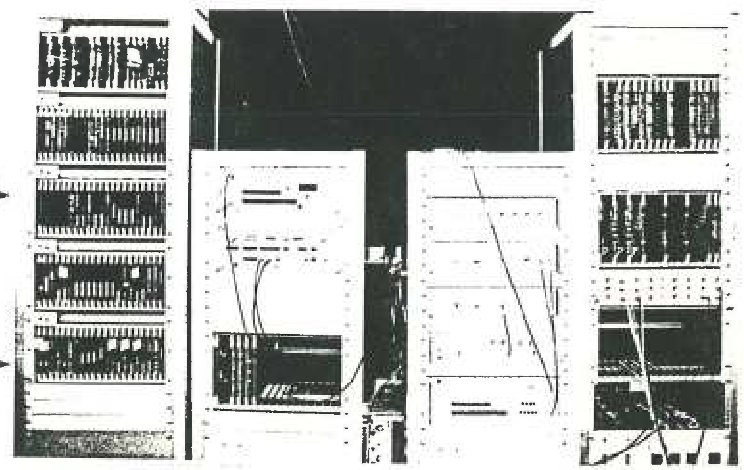


Fig. 6. Photograph of the Experimental System

III. Experimental System for Transmitting High Frequency Component of Luminance Signal

Using an additional channel of quadrature modulation, it is possible to transmit various multiplex signals, such as high frequency component of luminance and/or chrominance signals, edge portions of wide aspect ratio image, and sub images and sounds. As the first experimental system of QUME, high frequency component (4.2 - 5.2MHz) of luminance signal is chosen to be transmitted for system simplicity.

A. System Configuration

The block diagram of the experimental QUME system for transmitting high frequency component of the luminance signal is shown in fig.5. In this figure, the encoder receives RGB signals from a progressive scanning camera or signal generator, and encodes them to NTSC signal and composes a multiplex signal from the high frequency component (4.2 - 5.2MHz) of the luminance signal. A modulator includes a quadrature modulator and an inverse nyquist filter, and generates a QUME signal. A conventional TV receiver receives this QUME signal and displays a picture for the compatibility evaluation. On the other hand, the QUME signal is fed to down-converter that converts RF signal to IF band. The demodulator includes a PLL synchronous circuit and can demodulate both the NTSC main signal and the multiplexed high frequency component of luminance signal. The decoder includes an adder of the NTSC and multiplex signals, a motion adaptive luminance and chrominance separator, and a motion adaptive scanning converter. A progressive scanning monitor exhibits improvements of the QUME system.

Fig.6 shows a photograph of the experimental QUME system.

B. Encoder and Modulator

A detail of the encoder is shown in Fig.7. All circuits of the encoder use digital processing for system flexibility; filter characteristics and subcarrier frequency are easily changed by ROM contents.

Fundamentally, large part of the encoder is identical to the NTSC encoder, but the frequency shifter for the high frequency components of the luminance signal is new. In order to transmit high frequency component of luminance signal, Y_H, by quadrature modulation of video carrier, Y_H must be extracted from broad band luminance signal by a BPF, and converted to Y_H', the frequency shifted high frequency component. Using subcarrier f_s (=4.0MHz) in the frequency shifter, Y_H (4.2 - 5.2 MHz) is shifted to Y_H' (0.2 - 1.2MHz), that can be used as a multiplex signal of QUME. Each spectrum of this processing is shown in Fig.8. Blanking signal for modulator, in addition to NTSC and multiplex signals, is generated at this encoder.

Fig.9 shows a block diagram of the modulator and up-converter. The main NTSC signal from the encoder is amplitude-modulated by a commercially available standard modulator into IF band, and the multiplex signal is amplitude-modulated by a video carrier which phase is 90 degree shifted from that of the main carrier. The modulated multiplex signal is band-limited by the inverse nyquist filter, and added to the modulated NTSC signal after passing a switching circuit operated by the blanking signal. The multiplex signal is amplitude modulated with carrier suppression; no signal is multiplexed during horizontal and vertical blanking periods. A RF band QUME signal is obtained through the up-converter.

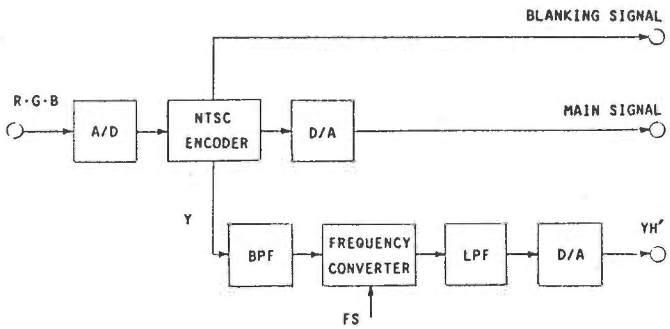


Fig. 7. Block Diagram of the Encoder

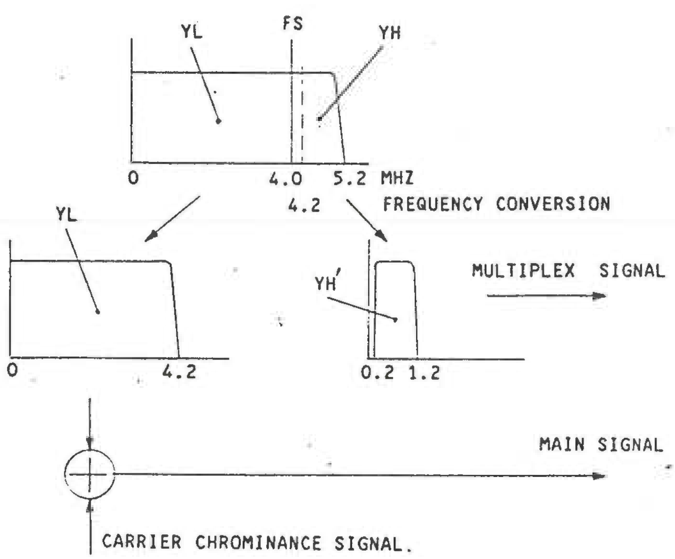


Fig. 8. Frequency Spectrum of the Multiplex Signal

C. Inverse Nyquist Filter

The performance of a conventional NTSC receiver was evaluated by the RF band QUME signal, and heavily influenced by inverse nyquist filter. It is important to balance the frequency characteristic of the inverse nyquist filter and that of the nyquist filter in the receiver. The frequency characteristics of a current nyquist filter and a sample of inverse nyquist filter are shown in

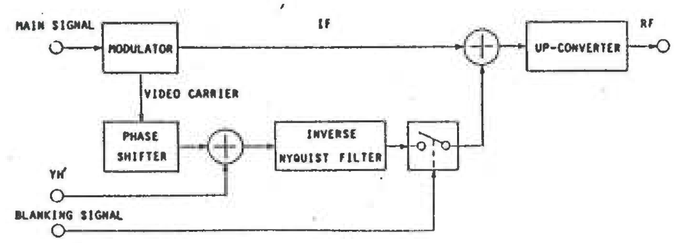


Fig. 9. Block Diagram of the Modulator

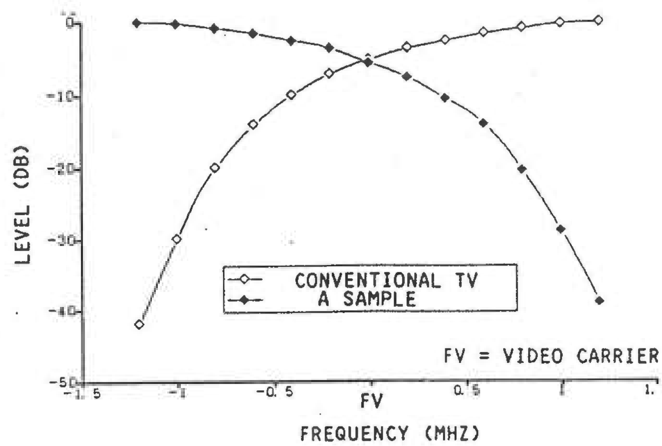


Fig. 10. Frequency Response of the Nyquist Filter and the Inverse Nyquist Filter

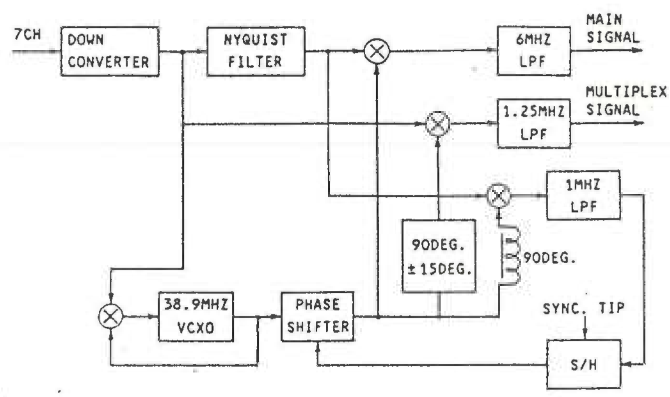


Fig. 11. Block Diagram of the Demodulator

Fig. 10. This sample shows almost symmetrical characteristics and there is little problem with interference from the multiplexed signal to the conventional receiver.

D. Demodulator and Decoder

Fig.11 shows a block diagram of the demodulator. The incoming RF signal is converted to IF by the down-converter. The main NTSC signal is detected by a PLL synchronous detector after passing through a nyquist filter, and the multiplexed Y_H' is detected by a 90 degree shifted video carrier and passes a 1.25MHz LPF.

A block diagram of the decoder is shown in Fig.12. Both of the main NTSC signal and the multiplex signal are converted to digital form and the latter is fed to a converter. Y_H' is frequency shifted to Y_H, added to the main signal, and generates a wide band NTSC composite signal. A motion adaptive Y/C separator, a scanning converter, and a chrominance detector are employed to improve picture quality. Analog Y, I and Q signals are fed to the display after D/A conversion.

E .Frequency of subcarrier

To prevent buzz and maintain phase of regenerated video carrier in a conventional receiver, subcarrier frequency f_s for shifting the high frequency component of luminance signal must be chosen so that the shifted signal Y_H' does not include DC component. In this experiment, f_s uses 4.0MHz and such interference was not present.

Furthermore, to eliminate crosstalk from the main NTSC signal to the multiplex signal at the demodulator, the subcarrier f_s is line and field offset. The multiplex signal was successfully detected by the offset subcarrier, and the crosstalk from the multiplex signal to the main NTSC signal is too small to degrade the main picture.

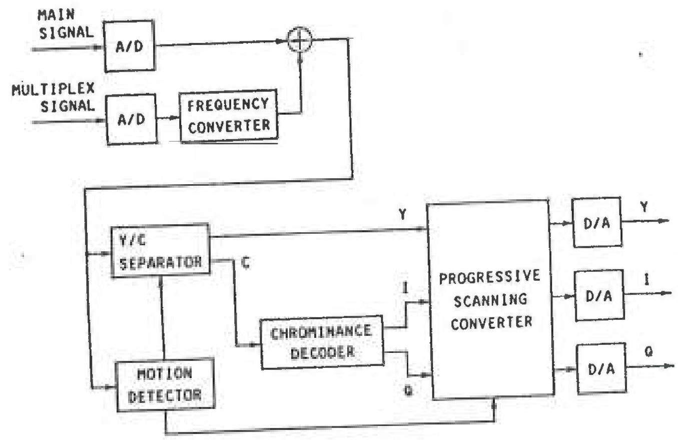
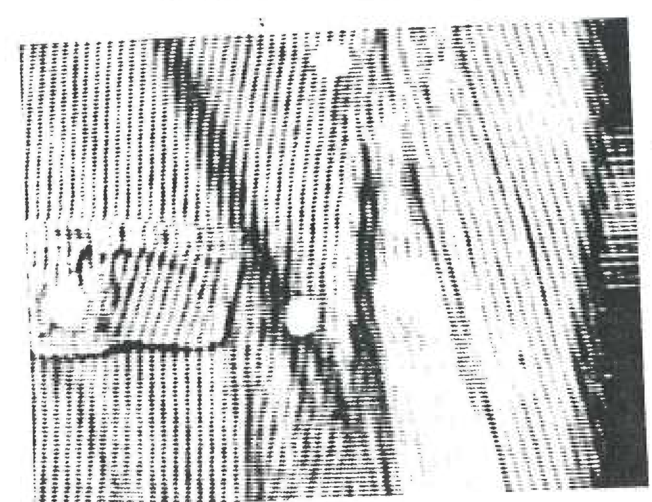


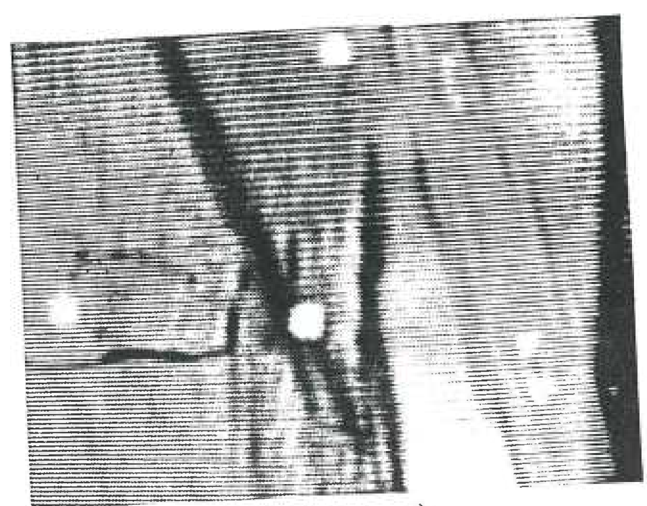
Fig. 12. Block Diagram of the Decoder

(a) QUME (Luminance : 5.2MHz)

(b) NTSC



(c) QUME (enlargement)



(d) NTSC (enlargement)

Fig. 13. Photographs of QUME and NTSC pictures

F. Results

Fig.13 (a) shows an example of picture obtained by the experimental QUME system, and (b) shows a picture by a NTSC receiver. Y_H (4.2 - 5.2MHz) was successfully transmitted and regenerated by a QUME receiver. This experimental system shows that the high frequency component of luminance signal of motion picture as well as still picture can be transmitted.

A small degradation of the main NTSC signal by multiplexing was detected but far less than an allowable level on the receiver with the quasi synchronous or envelope video detector. No degradations were found on the receiver with the PLL synchronous detector.

Fig.14 shows crosstalk from the multiplex signal to the main NTSC signal. In this figure, it reveals that the crosstalks on the receivers with the envelope detector and with the PLL synchronous detector were about - 20 dB and - 35 to - 45 dB, respectively. The former level can be accepted if the multiplex signal is high frequency component as seen in the experiment, and the latter level leads to the possibility of transmitting various other multiplex signals.

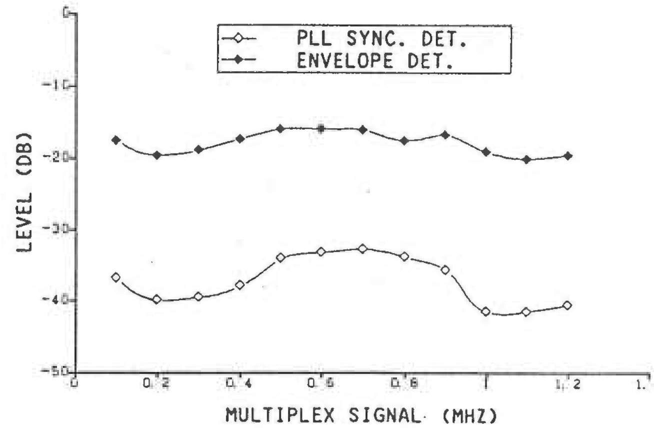


Fig. 14. Crosstalk from the Multiplexed Signal to the Main NTSC Signal

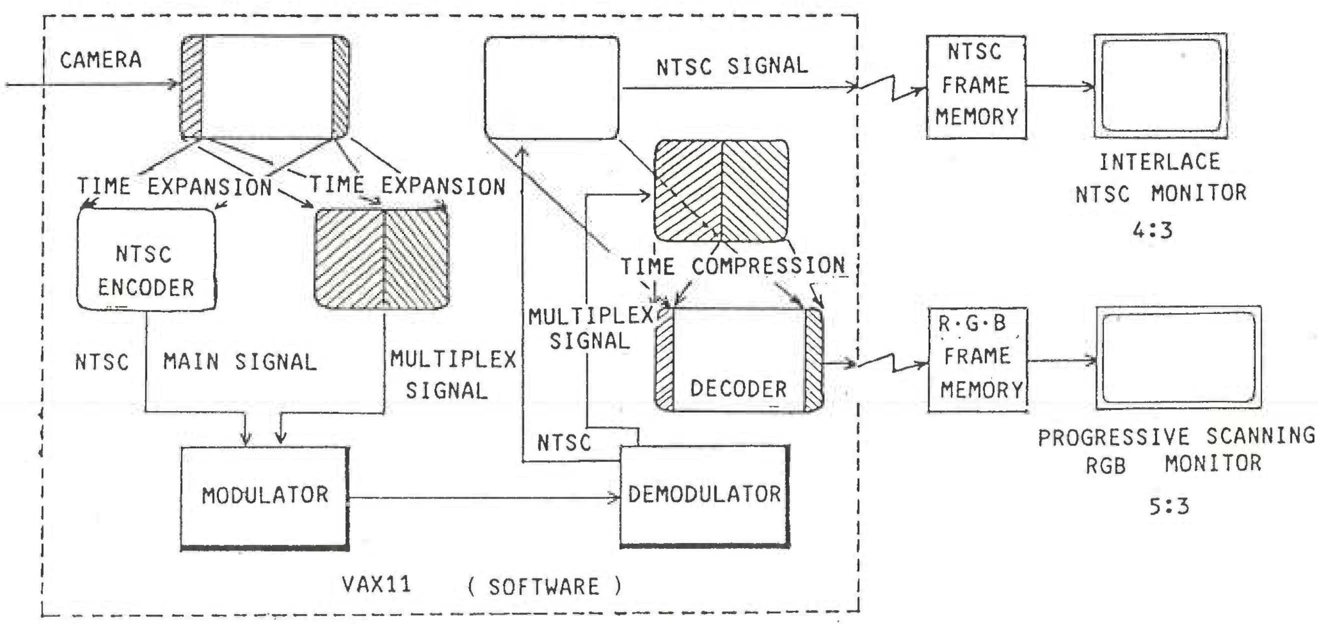


Fig. 15. Simulation of QUME Wide Television

IV. TRANSMISSION OF WIDE ASPECT RATIO IMAGE

Using an additional channel of quadrature modulation, it is possible to increase the aspect ratio from the current 4:3 to at least 5:3. To check the feasibility of wide television, computer simulation to transmit edge portions of wide aspect ratio image was made.

A. Simulation of Wide Television

Fig.15 shows hardware and program flow of the computer simulation. The original wide aspect ratio RGB images are previously taken by a progressive scanning camera, and 2 frame memories and monitors are connected to a host computer, VAX11/785. The first step is to separate center image and edge images of the 5:3 image, and time-expand them. The center portion is expanded by 1.25 to the conventional 4:3 image and encoded into NTSC format, and transmitted as the main signal. The edge portions are expanded by 5 to 1 MHz bandwidth signal, that is transmitted as the multiplex signal.

There are some methods of encoding luminance and chrominace signals of the edge portions, such as time compression integration and TAT [8]. In this simulation, a subcarrier $f_{SC}/5$ (f_{SC} = 3.58 MHz) is used to multiplex chrominance signal just as the same fashion in NTSC system. Fig.16 (a) shows the frequency spectrum of the NTSC signal and (b) and (c) show the multiplex signal with modulated chrominance signal of the edge portions before and after passing an inverse nyquist filter, respectively, and (d) shows the generated QUME signal obtained by combining (a) and (c).

QUME modulation and demodulation is implemented in software. The center portion is demodulated and decoded in the fashion of the normal NTSC, and displayed on a NTSC monitor. The edge portions are demodulated by a PLL synchronous video detector and time-compressed by 5, and combined with the time-compressed center portion. The combined image is displayed on a 5:3 aspect ratio progressive scanning monitor.

B. Results

Fig.17 shows images on the 2 monitors in this simulation: (a) is a composed wide aspect ratio image of an RGB monitor, that is a QUME wide television. In this picture stiches of two image portions are almost invisible, although no special processing [5] is introduced. Fig. 17 (b) is an image of a NTSC monitor that is equivalent to the conventional receiver with the PLL synchronous detector. There is no degradation in this picture caused by multiplexing edge images. But some interference is detected in the case of the quasi synchronous and envelope detector, especially on the white portion of images.

By displaying a 5:3 aspect ratio image, reality and impression are increased[9] and its preference has been pointed by almost all people who have watched the images generated by this simulation.

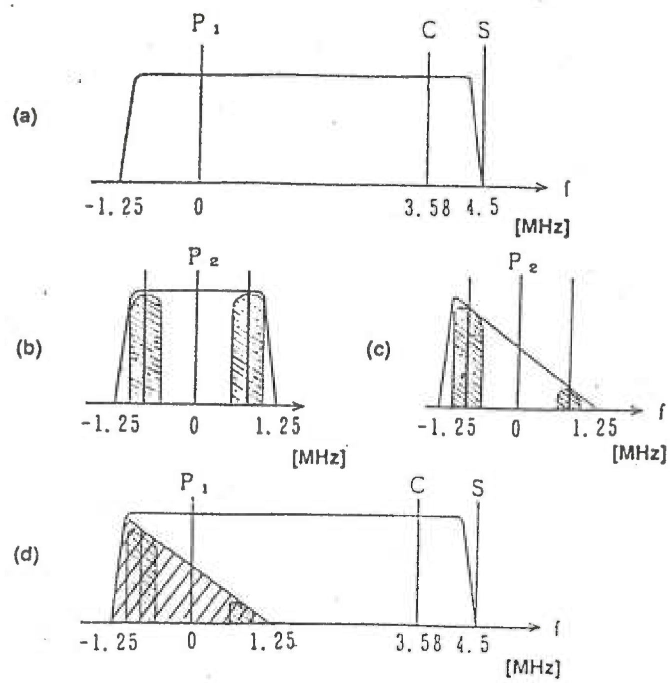


Fig. 16. Spectrum of Wide Television
(a) NTSC (b) Multiplex Signal before Inverse Nyquist Filter
(c) Multiplex Signal after Inverse Nyquist Filter
(d) QUME Wide Signal

(a) (b)

Fig. 17. Photographes of 5:3 and 4:3 pictures
(a) 5:3 RGB Monitor (b) 4:3 NTSC Monitor

V. CONCLUSION

In this paper, QUadrature Modulating Extended definition television -QUME- system is introduced and the first experimental system which transmits the high frequency component of luminance signal has been developed. The experiments reveals the feasibility of the QUME system, that the multiplexed signal hardly interferes with the NTSC main signal and thus the compatibility is maintained, and the transmitted multiplexed signal is successfully demodulated and wide band luminance signal is regenerated on the display in the moving part as well as in still images.

The computer simulation reveals that a wide aspect ratio image can be transmitted by using the QUME system. NTSC terrestrial broadcasting can move to wide television system -improving aspect ratio from 4:3 to at least 5:3 -, keeping full compatibility with the conventional receivers. The QUME system is so flexible as to transmit various multiplex signals, and applicable to PAL and SECAM as well.

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*

Yoshio Yasumoto (M'82) was born in Osaka, Japan, on October 20, 1951. He received the B.S. and M.S. degrees in electronics engineering from Kyoto University, Kyoto, Japan, in 1974 and 1976, respectively.

He joined Matsushita Electric Industrial Co., Ltd. in 1976, and from 1977 untill 1983 he had been engaged in the design of TV receiver and IC, digital signal processing, and image processing at Television Division. From 1983 to 1985, he was a Visiting Scholar at the Department of Electrical Engineering, University of Southern California, Los Angeles. He is currently a Research Engineer at Wireless Research Laboratory, Matsushita Electric. His current research interests include computer vision, image processing, and their applications.

Mr. Yasumoto is a member of the Association for Computing Machinery, the Institute of Electronics, Information and Communication Engineers of Japan, the Information Processing Society of Japan, and the Institute of Television Engineers of Japan.

Sadashi Kageyama was born in Izumo, Japan, in 1957. He received the B.S. and M.S. degrees in electronics engineering from Kyoto University, Kyoto, Japan, in 1981 and 1983, respectively.

He joined Matsushita Electric Industrial Co., Ltd. in 1983, and since then he has been engaged in the research and development of display control systems and television systems at Wireless Research Laboratory of Matsushita.

Mr. Kageyama is a member of the Institute of Television Engineers of Japan.

*

Syuhji Inouye was born in Muroran, Japan, in 1960. He received B.S. and M.S. degrees in electronics engineering from University of Electric Communications, Tokyo, Japan, in 1983 and 1985, respectively.

He joined Matsushita Electric Industrial Co., Ltd. in 1985, and since then he has been engaged in the research and development of digital image processing at Wireless Research Laboratory of Matsushita.

Mr. Inouye is a member of the Institute of Television Engineers of Japan.

Hideyo Uwabata was born in Ishikawa, Japan, in 1963. He received B.S. degree in computer science from Kanazawa Institute of Technology, Ishikawa, Japan, in 1986.

He joined Matsushita Electric Industrial Co., Ltd. in 1986, and since then he has been working on Extended Definition TV system and image processing at Wireless Research Laboratory.

Yoshio Abe was born in Kyoto, Japan, in 1946. He received the B.S. degree in electric engineering from Kyoto University, Kyoto, Japan, in 1970.

He joined Matsushita Electric Industrial Co., Ltd. in 1970, and since then he has been engaged in the research and development of graphic display systems, advanced CRT processor, and new television systems. He is currently a Senior Research Engineer at Wireless Research Laboratory, Matsushita Electric.

Mr. Abe is a member of the Society of Motion Picture and Television Engineers and the Institute of Television Engineers of Japan.