High-Quality Picture Transmission in a Digital Audio System

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A high-quality digital video signal is transmitted with low bit rate in a digital audio system. Several digital audio systems have been developed for professional and consumer use. The transmission rate of most two-channel digital recorders is approximately 2 Mbit/s. For digital television, systems have been worked out by CCIR, SMPTE, and EBU. Digital video tape recorders are also under development; their transmission rate is about 300 Mbit/s using a component television signal. Since the ratio of video to audio rates is more than 100, it is difficult for digital audio recording media to capably record a television video signal. A new signal format for still-frame picture transmission is presented. The advantages and disadvantages of composite-signal and component-signal methods have been studied. The format can be extended to partial moving pictures, computer-generated moving graphics, and still pictures for high-definition television (1125 lines).

Also discussed are mastering equipment and decoding techniques. Program materials are converted to a video signal and then digitized by an analog-to-digital converter. The digital signals are rearranged to fit the digital audio signal format and are recorded on a master tape. The master tape is replicated on the disk. For reproduction, the digital picture signals from the audio decoder are fed to a video decoder which consists of digital memory, memory driver, line-number converter, video signal generator, and TV signal encoder. The new signal format uses a small memory and a simple high-performance decoder.

0 INTRODUCTION

JVC researched and developed the audio high-density (AHD) digital audio disk system, which is compatible with the video high-density (VHD) video disk player. The AHD system has four digital audio channels.

Several digital audio systems have been developed in which most of the signal processing can be done in digital form. Such equalizing, editing, recording, and reproducing systems allow us to reproduce sound of higher quality.

In digital video, digital signal processors, effects generators, and digital video tape recorders have been developed and also allow high-quality video mastering. The major advantage of digital video is in recording and reproduction. Digital video tape recorders eliminate signal degradation caused by the recording media. This fidelity is especially important and useful in program editing. Digital video tape recorders are in development for professional use, but it seems difficult to apply them in the consumer market at present because the digital video signal requires such a wide frequency band.

The transmission rate of the usual two-channel audio recorder is around 2 Mbit/s, but a digital video tape recorder requires about 300 Mbit/s using a component television signal.

The ratio of these two rates is greater than 100. It is difficult to have a digital television signal in a digital audio system. However, a low-bit-rate video signal, such as that required for still-frame pictures, can be transmitted with the assistance of a frame memory.

Fig. 1 shows the block diagram of the system which has two frame memories, R and P. Digitized still-picture signals are stored in memory R and transmitted to memory P at a low bit rate using the digital audio disk system. In reproduction, the digital still picture in

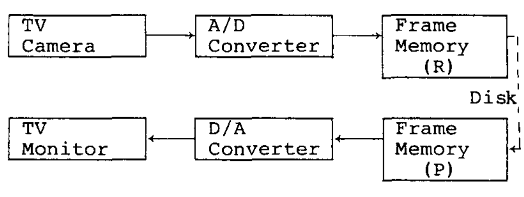


Fig. 1. Basic block diagram of still-frame transmission.

memory P is read at normal speed with a high bit rate, converted to an analog signal, and fed to a television monitor. The video information is a still picture, but the signal maintains high quality, and no picture degradation is caused by transmission media.

1 BASIC EXPLANATION OF THE AHD SYSTEM

Table 1 shows the specifications. AHD has four digital transmission lines and four applications, AHD-Q, AHD-W, AHD-T, and AHD-S.

Fig. 2 shows AHD-Q, using all transmission lines for audio signals of the same program. This system reproduces four-channel stereo or quadraphonic sound.

AHD-W uses all four transmission lines for audio, but the program material is different for each channel. Two stereo programs are recorded simultaneously so that the capacity of the disk is doubled, for a total of up to 240 min playback per disk (Fig. 3).

AHD-T uses three of the transmission lines for audio and the fourth for digital still pictures. The third audio channel drives the center loudspeaker, giving better sound-image localization and a wider listening area (Fig. 4).

AHD-S uses two transmission lines for stereo music, while the other two lines are used for still pictures. In this case the transmission rate of the picture is twice that in AHD-T, and two types of pictures are possible (Fig. 5).

Quantization is 16-bit linear, which is the same as most professional pulse-code-modulated (PCM) master recorders.

The sampling frequency of the audio signal was 47.25 kHz (a 15:14 ratio with 44.1 kHz). We now propose 44.1 kHz as the AHD sampling rate. An AES digital meeting in 1981 November in New York recommended 48 kHz for professional equipment and 44.1 kHz for professional equipment having a direct relation to consumer equipment. We have built a PCM recorder which uses a U-type video cassette recorder, and its sampling rate is 44.1 kHz.

At the same time we shall change the digital modulation format from MFM to scrambled nonreturn to zero (NRZ). By so doing, the error rate of the disk is improved, and we are able to use simple decoder circuitry.

For picture transmission our development first used the NTSC composite method, but we feel the component

Table 1. Specifications of AHD system.

Number of channels	4
Quantization	16 bits
Sampling rate	44.1 kHz
Transmission rate	5.733 Mbit/s
Modulation	Scrambled NRZ–FM
Picture transmission	Component

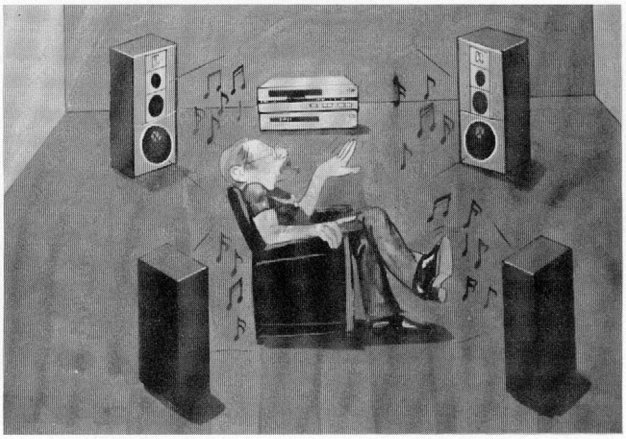


Fig. 2. AHD-Q quadraphonic reproduction.

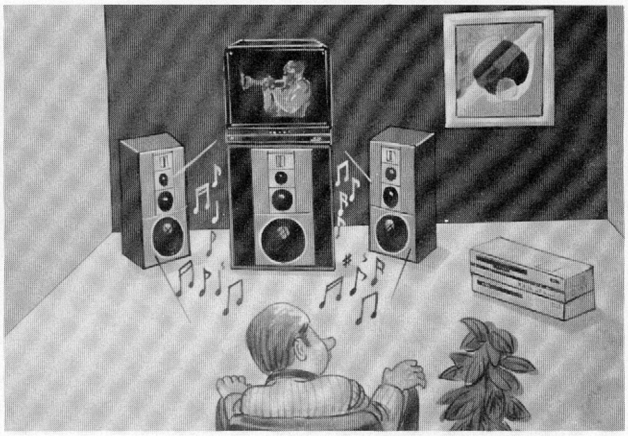


Fig. 4. AHD-T three-channel audio and still-picture reproduction.

Fig. 3. AHD-W double program reproduction.

Fig. 5. AHD-S two-channel audio and still picture.

method is a better final format.

Fig. 6 shows the signal format in the AHD system. One block consists of 130 bits and is recorded continuously at 44.1 kHz. The first 10 bits are the synchronization word. Channels 1–4 are data information. In AHD-S, channels 1 and 2 are used for audio and channels 3 and 4 for still pictures. *P* and *Q* are parity codes for error correction, and CRC is the error-detection word generated by the cyclic redundancy check code. The last bit is the address code for program search.

Fig. 7 shows the address code consisting of four parts, the time code, chapter A, chapter B, and chapter C. The time code is related to the playback time of the disk. The chapter A code is related to each musical number. The aim of chapters B and C is to search still pictures. AHD-S has two still-picture channels, and the picture information in channels 3 and 4 can be searched separately.

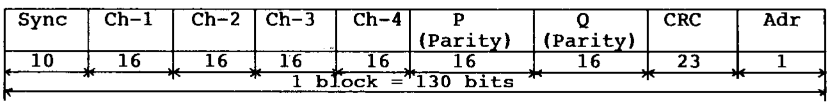
Fig. 8 diagrams the AHD recording system. The digital signals of the audio and video master tapes are fed to the signal processor. The audio signal, still-picture signal, and address code are converted to serial data according to the AHD signal format, with error-detection and -correction words (Fig. 6).

After scrambled NRZ encoding and FM modulation, the signal is fed to the VHD cutting machine. The AHD disk is manufactured by the VHD disk manufacturing facility, and played back with the VHD player. Fig. 9 shows the interconnection of the AHD decoder and VHD player.

In the VHD system the rotation speed depends upon whether the disk format is 525 lines or 625 lines. The AHD disk format uses one worldwide standard, and the rotation speed is always 900 r/min. The VHD player is fed with a 15.75-kHz reference signal, which allows the turntable to rotate at 900 r/min for both PAL and NTSC. The RF signal is fed to the AHD decoder.

Fig. 10 is the block diagram of the AHD reproduction system. The FM signal is demodulated and fed to the synchronous word detector. The scrambled NRZ signal is decoded. Errors are detected, and the error corrector corrects the data using parity words *P* and *Q*. Digital audio signals are fed to the digital-to-analog (D/A) converter, while still-picture digital data are fed to the picture decoder and generate video signals. Table 2 gives the specifications of the AHD disk. The pickup method is the grooveless capacitance system. Fig. 11 shows a cross section of the stylus and disk. The electrode detects capacitance variations in the signal pits. AHD has both information pits and tracking pits. The playback position of the stylus is controlled by a tracking servo.

Fig. 12 illustrates VHD/AHD production. The glass master surface is made photosensitive and is then cut



Number of channels	4
Data word	16-bit linear 2's Complement
Error-detecting word	CRC 23 bits ($X^{23} + X^5 + X^4 + X + 1$)
Modulation	Scrambled NRZ–FM
Carrier frequency	6.5 MHz
Sampling frequency	44.1 kHz
Transmission rate	5.733 Mbit/s

Fig. 6. Signal format of AHD system.

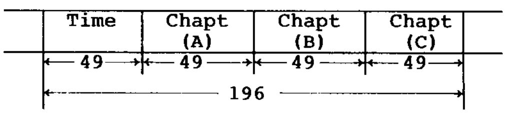


Fig. 7. Address code of AHD.

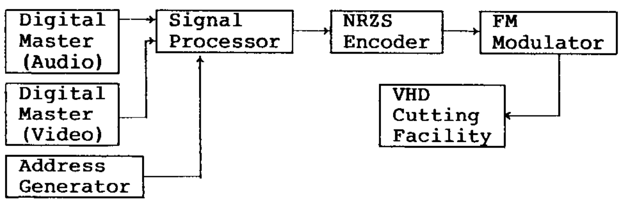


Fig. 8. AHD recording system.

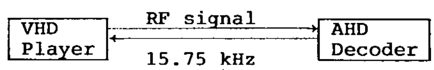


Fig. 9. Basic connection of AHD decoder.

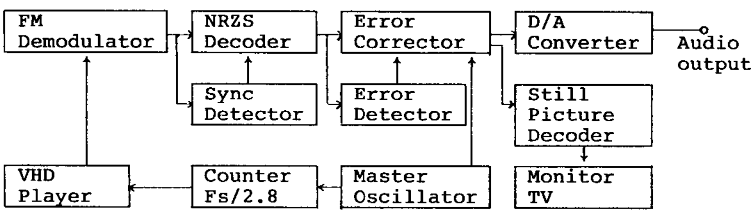


Fig. 10. Block diagram of AHD reproduction system.

by an argon laser beam. After development, the metal master is made by plating. The metal mother and metal stamper are made by the same technique used for the two-channel audio disks.

In the interests of economy, a standard analog record press, only slightly modified, is used for AHD manufacture. This has proven to be quite satisfactory, although at times slight imperfections, such as bumps, can appear on the disk (Fig. 13). However, this 20-μm bump was removed simply by playing the disk once (Fig. 14). There was no equipment damage in this process. Errors caused by the bump are corrected completely by the error-correction circuit.

2 AHD PICTURE SYSTEM

Table 3 gives the specifications of the still-picture system. The coding method is component video. Coding signals are the luminance signal Y and chrominance signals red-Y and blue-Y. The number of lines is 625. The sampling rate of the luminance signal is 9 MHz, and that of the chrominance signal is 2.25 MHz. Quantizations of the luminance and chrominance signals are 8-bit linear.

If the three basic color signals red, green, and blue were transmitted, the picture quality would be best, but this procedure requires three frame memories for R, G, and B. Instead, the RGB signals are converted to Y, R-Y, and B-Y. In this case the bandwidth of the chrominance signals can be reduced by one-half or one-quarter. Another method is composite coding, in which the RGB signals are converted to YIQ signals, and the chrominance signal is superimposed on the luminance signal by modulation. In composite coding the size of the frame memory can be reduced but in problems, such as line-number conversion, the data processing is more difficult. For these reasons, AHD

Table 2. Specifications of AHD disk.

Pickup method	Grooveless capacitance
Disk size	260 mm (10.2 in)
Track pitch	1.35 μm
Rotation speed	900 r/min
Playing time	2 h (both sides)

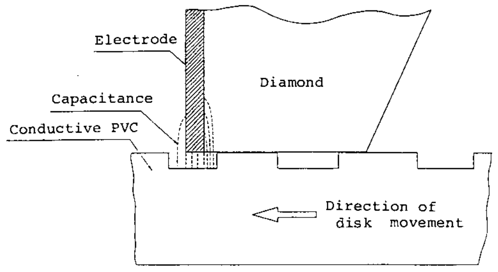


Fig. 11. Cross section of stylus and disk.

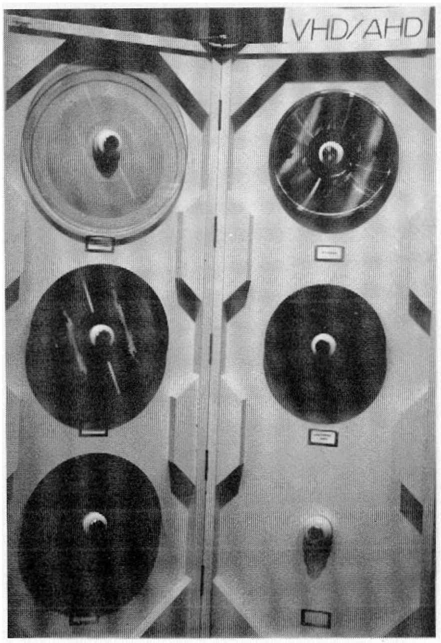


Fig. 12. Glass master, metal master, metal mother, stamper, and disk in VHD/AHD system.

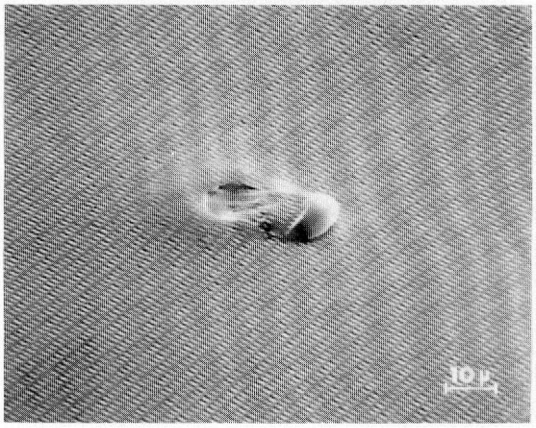


Fig. 13. Defect on disk.

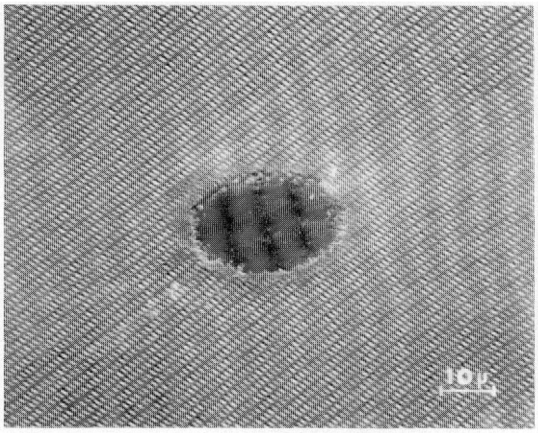


Fig. 14. Defect removed during playback.

Table 3. Specifications of still picture.

Coding method	Component
Coding signals	Y, R-Y, B-Y
Number of lines	625
Sampling rate	
Luminance	9 MHz
Chrominance	2.25 MHz
Quantization	
Luminance	8-bit linear
Chrominance	8-bit linear

uses the component coding method.

There are 525- and 625-line television systems. To avoid picture degradation in the 625-line system, video information is recorded for 625 lines, and line-number conversion is required for the NTSC system. Fig. 15 shows the sequence used to generate five lines from six. S shows the original picture signal and T the new line signal. The 6–5 sequence is repeated for every six input lines, increasing n by 1. Line T_0 uses line S_0. Line T_1 is three quarters of S_1 plus a quarter of S_2. Line T_2 is half of S_2 plus half of S_3.

Half of S_2 is generated by shifting the data 1 bit toward the least significant bit. A quarter of the data can be obtained by another shift.

Figs. 16–18 show reproduced pictures using medium-definition television. Fig. 16(a) is a PAL-encoded signal, and the line-number converter is not used. Fig. 16(b) is the same signal from the disk, but the number of lines is converted to 525. Fig. 17(a) is PAL picture synchronized with the vocal recording and words of the song, and Fig. 17(b) is a converted picture. Fig. 18(a) is a PAL picture. The capital A has oblique lines, and the capital D has semicircles. Fig. 18(b) is the converted picture. The conversion process is applied at low bit rate before storing data in the frame memory.

These pictures indicate that even with the simple line-number conversion method, the converted picture has adequate quality.

The number of samples per horizontal line is 576, but the conventional line signal includes horizontal blanking, color burst, front porch, and back porch. To save on memory size, this system does not transmit such a signal. The active samples per line are chosen to be 456. The active lines per frame are 572.

These figures guide effective memory-circuit design. Active samples per frame are 260 832 (456 × 572), and the capacity of a 256-K RAM is 262 144 (2^{18}). Therefore one 256-K memory chip can store 1-bit information for one frame. If the still-picture decoder is designed to use 8 bits, eight 256-K chips are used for luminance-frame storage, and eight 64-K chips for each chrominance signal. Memory mapping is so simple that

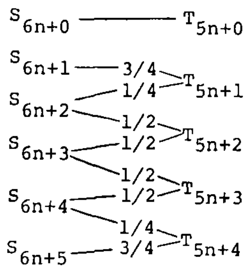
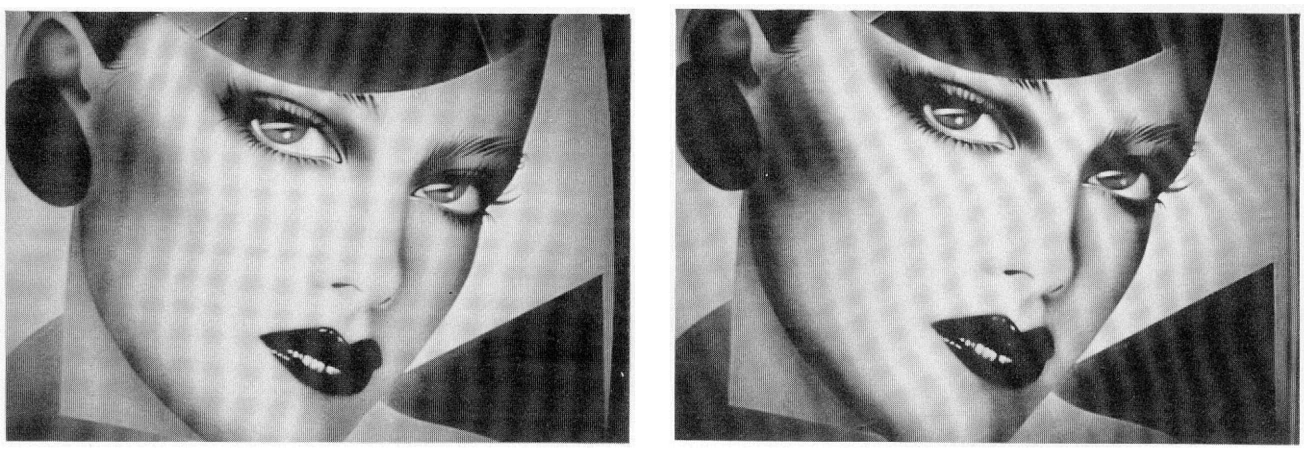


Fig. 15. 6–5 line-number conversion method.



(a) (b)

Fig. 16. (a) Reproduced picture on PAL television from AHD. (b) Converted to 525 lines.

(a) (b)

Fig. 17. (a) Reproduced picture on PAL television from AHD. (b) Converted to 525 lines.

the address signals to control the memory chips are fed as a common signal.

Fig. 19 shows a block diagram of the video data-mastering system. Most object materials are slides, overlays, and pictures. These are converted to RGB video signals by a PAL television camera or flying-spot scanner. The video switcher console has such functions as wipe, effect, and chromakey. The RGB output is converted to Y, R-Y, and B-Y signals by a matrix circuit and is digitized by a video analog-to-digital converter. The digital video signal is stored in frame memory, read according to the sampling rate of the audio PCM processor, and recorded with a U-type video cassette recorder. In this format the digital video tape can be edited by a PCM audio editing machine, synchronizing it with the audio master tape.

3 FORMATTING AND EXPANDABILITY

Fig. 20 shows the signal format of the still picture. These signals are transmitted by channel 3 or channel 4 of the AHD system.

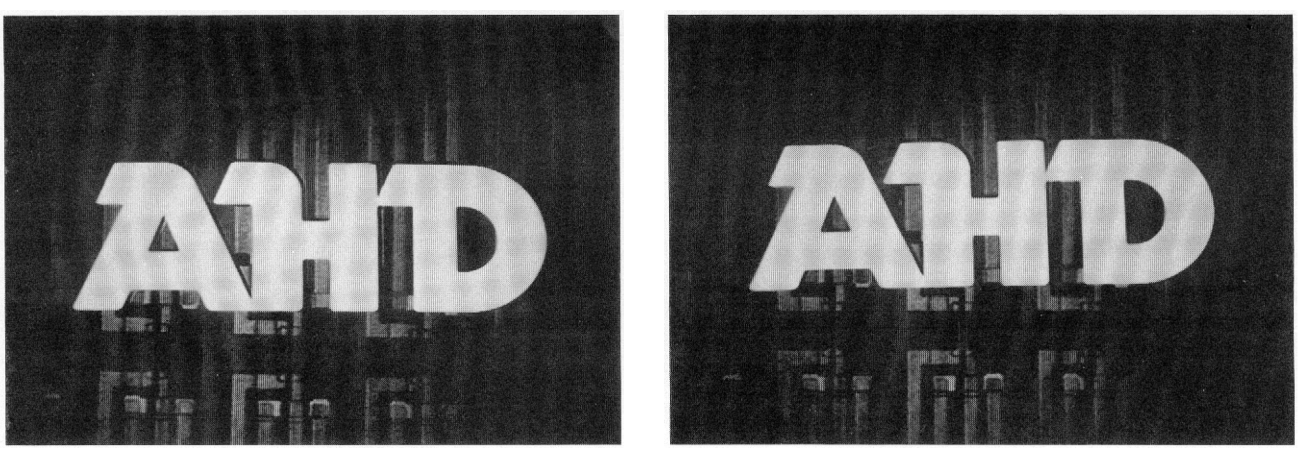
The first 16 bits are the synchronization word. The sync code is FFFF, all bits being high. The next 16 bits are the identification code, which specifies the video data in this block. The identification code consists of six codes, as follows. First is the mode code, which shows whether the video data are the standard type or another type, such as high definition (1125 lines), computer-generated moving graphics, three-dimensional pictures, and so on. The second code is the effect command for changing the picture: to cut in, cut out, fade in, fade out, or change from the left side to the right side of the picture. The third code is the program category which identifies the picture as a scene of the recording, a portrait of the artist, scenery, or a score. The fourth code shows whether the picture is a frame or a field. In a field picture there are half the number of lines, and vertical filtering is applied to prevent a jagged effect. The fifth code shows whether it is a still picture or a partially moving picture. The sixth code concerns the use of transmission channels: whether channels 3 and 4 are transmitting different kinds of pictures or the same kind of picture at double the transmission rate.

The next 64 bits show the address number of the frame memory. Address numbers of the 525-line memory and the 625-line memory are different. For this reason this number contains both figures. For partially moving picture transmission this number indicates the proper memory address. Picture data are 8 bits, and two picture words are transmitted in one audio word slot. At the end of picture data, the EOD 0000 code is transmitted. The picture decoder detects this word and displays the newly stored picture.

4 CONCLUSION

Digital still-picture recording and reproduction has been introduced, and by a rather simple system, high-quality picture transmission is achieved.

The main purpose of a digital audio system is reproduction of high-quality audio, but high-quality audio with a high-quality picture is a useful concept. One application is high-definition television with 1125 lines. The production of memory chips is increasing rapidly, and their price is decreasing more rapidly. Line-number conversion is made easily between 1125, 525, and 625



(a) (b)

Fig. 18. (a) Reproduced picture on PAL television from AHD. (b) Converted to 525 lines.

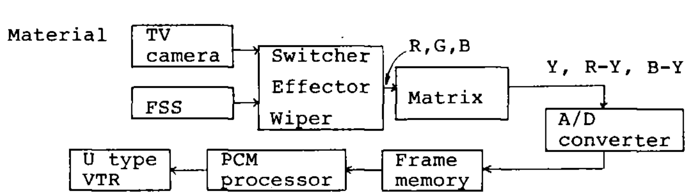


Fig. 19. Block diagram of the video data-mastering system.

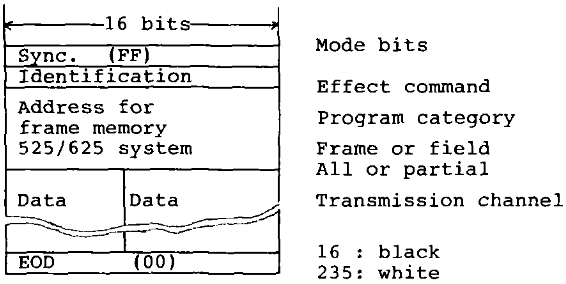
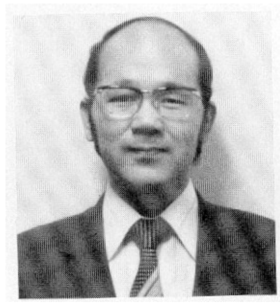


Fig. 20. Signal format of still picture.

lines, which affords compatibility of these television systems.

RGB monitor TVs are being marketed for use with personal computers. Large-screen display units, such as projection television, will require high-definition video signals. Proposals have been made for three-dimensional television systems. AHD-S has two-channel picture transmission capability for left and right viewing, and so it is not a dream to realize high-quality music reproduction with high-quality three-dimensional pictures.

THE AUTHOR



Nobuaki Takahashi was born in Hokkaido, Japan, and was graduated from the Muroran Institute of Technology in 1963.

After joining Victor Company of Japan, he was involved in the development and design of electronic circuits, such as graphic equalizers, reverberation equipment, and automatic tuners. In 1970, when the company's Audio Engineering Research Center was founded, he worked as a project leader in the development of the CD-4 quadraphonic disk system. He is also a project leader in the development of the Biphonic system and the digital audio disk system.