OPTICAL DISC SYSTEM FOR WIDEBAND HIGH DEFINITION VIDEO SIGNAL

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Abstract *An optical video disc system for reproducing high-definition pictures with digital audio was developed, based on two-channel recording and playback technology. A 20-MHz bandwidth luminance (Y) signal and 6-MHz bandwidth line-sequential chrominance (C) signals for the 1125/60 HDTV standard were recorded without bandwidth compression. The maximum playback time is 8.4 minutes per side in a constant angular velocity (CAV) disc rotational mode, and can be prolonged to 15 minutes per side in a constant linear velocity (CLV) mode.*

1. Introduction

A complete system of production-use high-definition television (HDTV) equipment is now available and is being used to produce movies, TV commercials, music videos and other such programs for which a high-quality picture is required. These programs are converted into 35 mm film or TV signals of existing standards, and delivered. Furthermore, the bandwidth compression technology which enables the HDTV signals to be broadcast without conversion have been developed, and they have now reached the stage where they can be practically applied.

When it comes to package media, there have been a number of reports concerning the development of video disc players and half-inch VCRs which employ the bandwidth compression technology for broadcasting. [1], [2], [3] Bandwidth compression is an effective method for recording wide-band video signals onto a recording medium with a limited packing density. The compression, however, inevitably brings about a deterioration of the picture quality which is inherent to the compression method. For instance, it results in reduced resolution in moving pictures. This is the reason we have developed an HDTV optical video disc system which records wideband video signals without bandwidth compression.

The most salient feature of this system is its two-channel recording and playback method. There are two ways to record a wideband HDTV signal on an optical disc. One is to increase the disc rotational speed, and the other is to increase the number of recording channels. In view of the following considerations, we decided to adopt a method using two recording channels instead of a method doubling the rotational speed.

In order to rotate a disc at a speed of 3,600 rpm, a powerful motor is required, and wide-bandwidth servo actuators for focusing and tracking are also required. As to such physical parameters of the discs as tilt and eccentricity, a high precision is required to increase the rotational speed.

On the other hand, when the number of recording channels is two, there is the possibility that the structure of the optical pickup will become complicated and that the scale of the signal processing circuitry will increase. In actual fact, however, a two-channel optical pickup can be made through simple modification of a conventional pickup,

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and since parallel processing is required even with single-channel recording for wideband video signals, no great difference results.

This paper will describe the technical details of our HDTV video disc system and will present the results.

2. Format

This video disc system uses 1125-line, 60-field and 2:1 interlace, which conforms to the SMPTE 240M standard. [4] Luminance and chrominance bandwidths are limited to 20 MHz

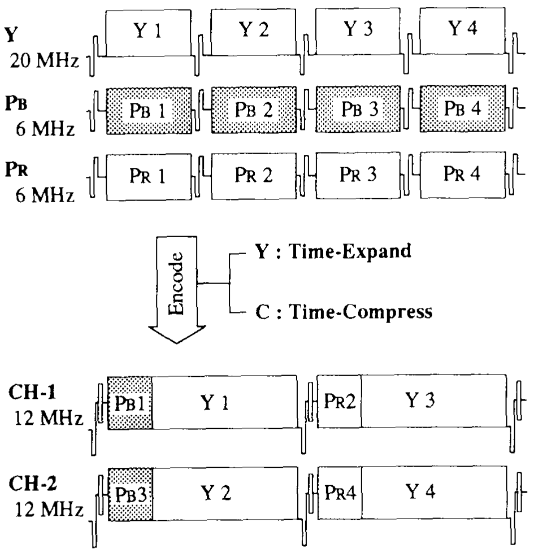


Fig. 1 Encode of video signals

and 6 MHz respectively, and two chrominance signals are line-sequential. The audio signals of two channels are sampled at 48 kHz and quantized into 16 bits.

To maintain a high picture quality with conventional video discs, the problems which troubled us were disc dropouts,the asymmetry of the signals pits on the discs, and the crosstalk from the adjacent tracks. Giving thorough consideration to these problems, we decided on a two-channel signal format.

2.1 Video

As is shown in Fig. 1, the video signals which are recorded on the disc are the two 12-MHz time-division-multiplexed signals of the Y component and the line-sequential C components, that is, the two color differences P_B and P_R. Y component is time-expanded and C components are time-compressed.

The two-channel video signals are arranged on the disc as shown in Fig. 2. Y is next to Y, P_B is next to P_B, and P_R is next to P_R in the two-channel tracks on the disc. This arrangement is designed to reduce the influence of crosstalk, by emphasizing the correlation between two-channel signals.

Furthermore, as shown in Fig. 3, the adjacent signals on the disc are distanced by 5 scanning lines on the monitor for the Y components and 6 scanning lines for the C components. Most of the dropouts are a size of several microns and extend at least two tracks on the disc, as the track interval is 1.5 µm. By arranging the video signals on the disc in this way, the dropouts do not appear in

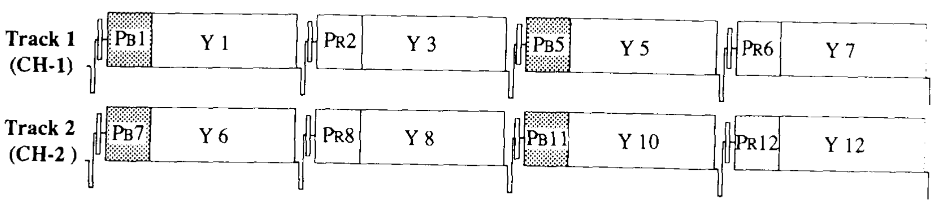


Fig. 2 Video signals on disc

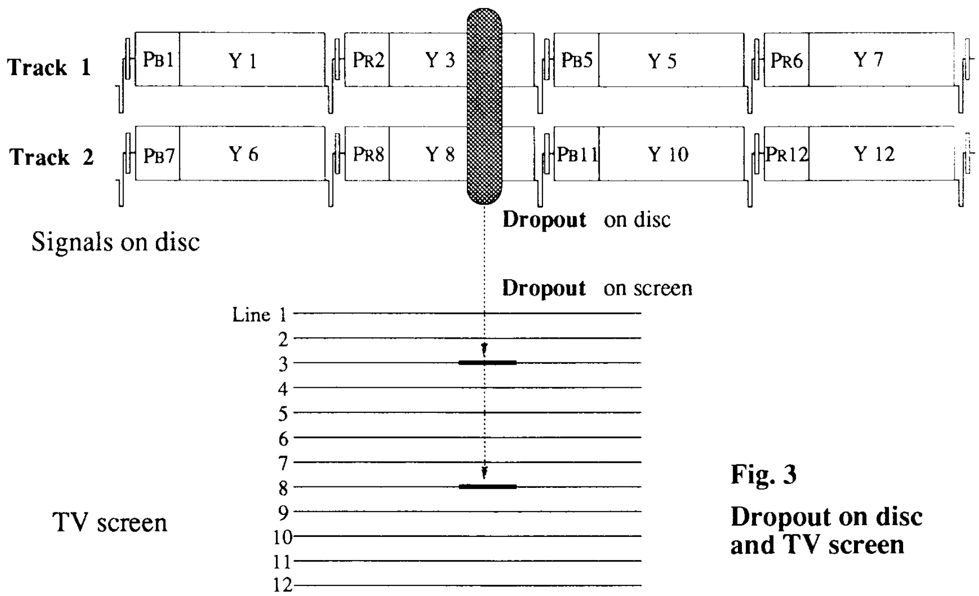


Fig. 3
Dropout on disc and TV screen

adjacent scanning lines on the TV screen but are dispersed as shown in Fig. 3. This makes it possible to ensure the reproduction of a high picture quality after dropout compensation.

The digital audio data is time-division-multiplexed during the vertical blanking interval of the baseband video signals as shown in Fig. 4 (a). These signals are then FM-modulated and recorded onto the disc. Therefore, the recorded signal of each track is a single FM signal, which prevents intermodulation between audio and video signals caused by asymmetry of the signal pits. The FM carrier frequency is 16.3 MHz for a 50% gray level and the frequency deviation is 1.74 MHz for 100% amplitude of video signals. (See Fig. 4 (b).)

2.2 Audio

The audio signals of the two channels are sampled at 48 kHz and linearly quantized into 16 bits. The amount of data per video frame is, therefore, (2 x 48k x 16 x 1/30) bits = 6,400 bytes. In this system the capacity of the data which is recorded in the vertical blanking interval of the two-channel video signals is 9,856 bytes per frame. Approximately two-thirds of this are used in recording the audio data; the remaining one-third is not used.

The format of the error control code is described below. The data is divided into four

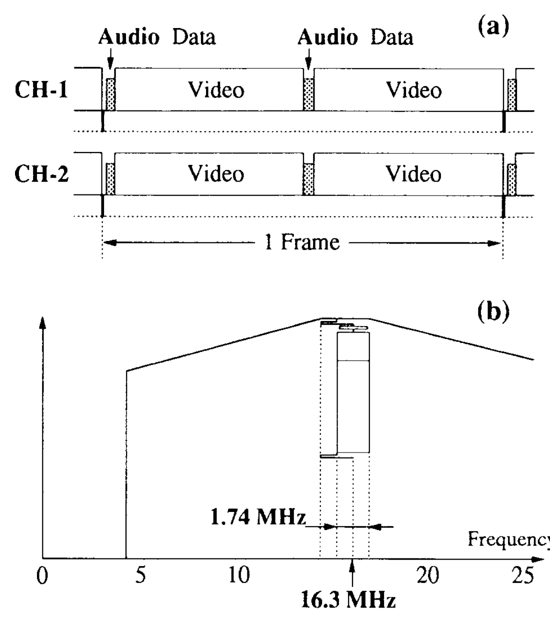


Fig. 4 Modulation of video and audio. (a) multiplexed signals of video and audio data; (b) FM carrier frequency

blocks, as shown in Fig. 5 (a). Reed-Solomon codes are added to the 2,464-byte data in each block as shown in Fig. 5 (b). More specifically, an 8-byte inner parity applies to 77-byte data and a 4-byte outer parity applies to 32-byte data. The inner parity is used to correct random errors, but it cannot be used to correct burst errors over 4 bytes. The correction of those errors is done by using the outer parity.

As shown in Fig. 5 (b), the block is again divided from top to bottom into 18 sub-blocks. The 170-byte data of each sub-block are multiplexed with the video in the form of a one-line video signal, as in Fig. 6(a). This data is multiplexed in the video signals at a rate of 12.15-Mbaud in the form of four levels. Consequently, the bit rate is 24.3 Mbps. Before the 12.15-Mbaud audio data is multiplexed with the video signals, its bandwidth is limited as shown in Fig. 6 (b). This is done in order to minimize the waveform distortion by guarding against overmodulation during FM modulation, and to enable the playback waveforms to be equalized by a simple low-pass filter.

The audio data does not contain any sync bits, so the sync and clock pulses for the video time base corrector are used for the audio data.

2.3 Disc

As shown in Fig. 7, the track pitch is between 1.5 and 1.7 μm. Since the two-channel video signals are designed to be resistive to inter-channel crosstalk, the pair of two-channel tracks have been separated by a narrow track pitch. The recording pit length is a minimum of approximately 0.47 μm. This is about the same as that of the conventional video disc. The playback time of the CAV disc is 8.4 minutes. The rotational speed of the CAV disc is 1,800 rpm, and the recording area is a radius from 98.1 to 146 mm. The playback time of the CLV disc is extended to 15 minutes by expanding the recording area up to 67.2 mm toward the inner radius. The linear velocity is 18.5 m/s, and the rotational speed at the innermost radius increases to 2,630 rpm. This

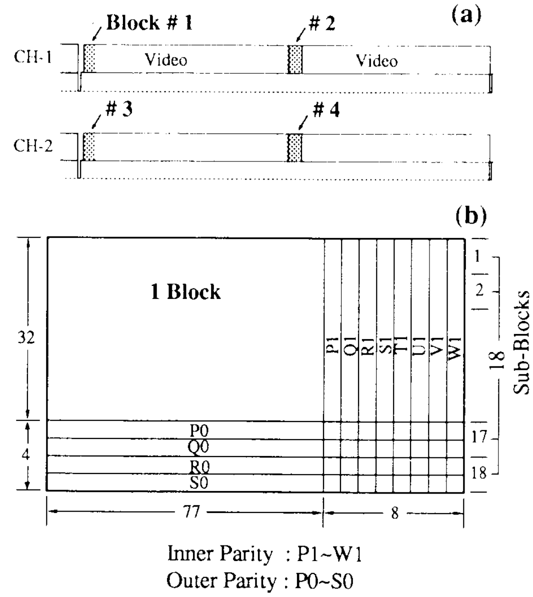


Fig. 5 Error control code of audio data. (a) blocks; (b) Reed-Solomon code structure

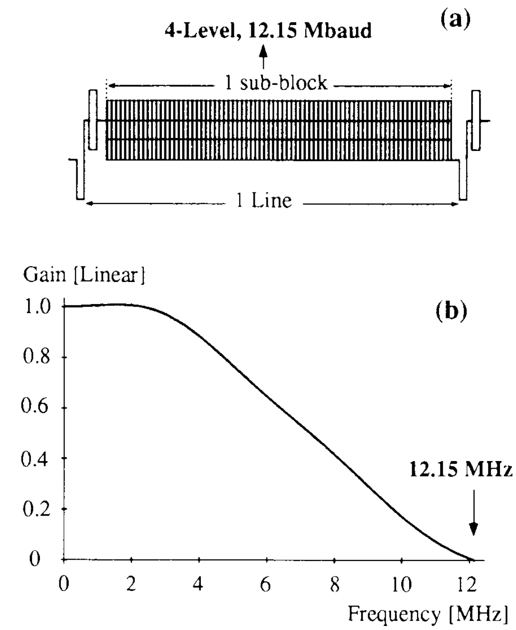


Fig. 6 Audio data sub-block. (a) waveform; (b)spectrum

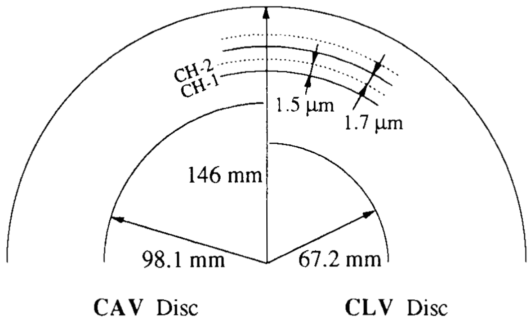


Fig. 7 Disc format

rotational speed is approximately the same as that for a disc of CD-Video standard.

3. Master cutting

Master disc cutting is the only step in the disc manufacturing process which differs from the conventional process. Two-beam master disc cutting has been achieved by the two technologies: a precise adjustment of two-beam spacing by monitoring the beams using CCD camera, and introduction of a Kr ion laser.

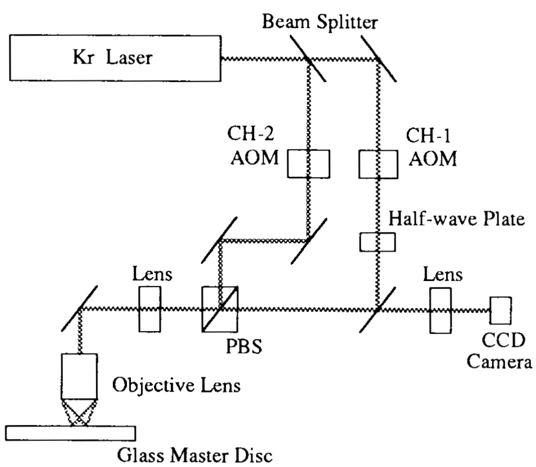


Fig. 8 Optics of the cutting machine

Figure 8 is a schematic diagram showing the optical set-up of the recording system. The beam splitter divides the laser beam into two beams, one for channel-1 and the other for channel-2. The acousto-optic modulators modulate the intensity of the respective beams by the respective recording signals. The polarization plane of the channel-1 beam is rotated through a half-wave plate and mixed again through the polarized beam splitter (PBS). The mixed beam is focused on a glass substrate coated with photo-resist.

The spacing between the two focused beams can be controled by adjusting the reflection angle of the PBS. The focused beam positions and intensity profiles can be monitored by the CCD camera. The beams reflected by the glass substrate are focused on the CCD through the lens. The reflected image of the focused beams is magnified by one thousand-fold on the CCD, hence the beam spacing of 1.5 μm becomes 1.5 mm on the CCD which corresponds to 150 raster lines on the CRT monitor. The beam spacing is adjusted to an accuracy of 0.01 μm in this system.

Extra laser power is required in order to record the two-channel signals simultaneously at the high linear velocity of 27.3 m/s (outermost circumference of CAV). Ar ion and He-Cd lasers are candidates as the source, but both a 458 nm Ar ion laser and a 442 nm He-Cd laser are insensitive to photo-resist. If the former were used, the required recording power would be enough to damage the acousto-optic modulator.

On the other hand, the 442 nm He-Cd would not have sufficient output power. A 413 nm Kr ion laser is most sensitive to photo-resist but the operating lifetime of the conventional Kr ion laser tubes is insufficient. In this system, therefore, an improved Kr ion laser was integrated and an output power of 200 mW was made available after 600 hours of operation. The 413 nm Kr ion laser is 6 times more sensitive to photo-resist than the 458 nm Ar ion laser.

4. Optical pickup

A new tracking error detection method has made it possible to ensure stable servo operation and the reproduction of two-channel signals using a relatively simple structure for the optical pickup. Figure 9 shows the construction of the optical pickup. The basic configuration is the same as that of a conventional video disc although the laser diode, grating and photo-detector are different. Wavelength of the laser diode is the same 780 nm as the conventional pickup but its power is 5 mW instead of 3 mW for getting enough output for two-channel signals.

Figure 10 shows the locations of the spots on the disc and detector. As the conventional pickup the grating diffracts the single laser beam into three beams, which, however, have been changed in order to increase the intensity of the two side beams. The power ratios among the three beams are 3:2:3, whereas that of the conventional pickup is 2:11:2. The two side beams are used to reproduce the two-channel signals. The detector pattern has been changed, as seen in Fig. 10, because of the new tracking error detection system.

In the case of a conventional video disc, the center spot is for signal reproduction, and

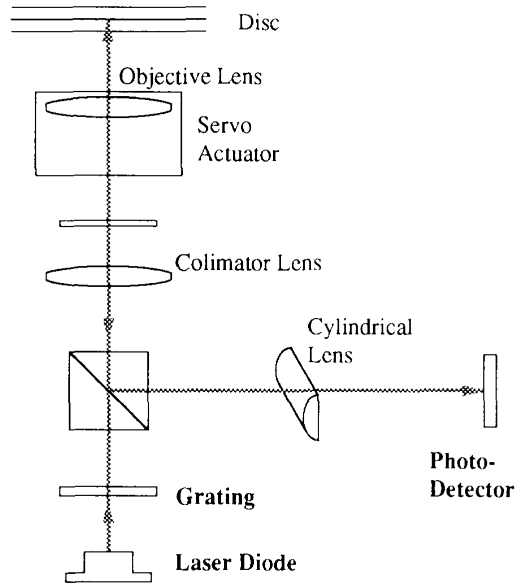


Fig. 9 Construction of optical pickup

the two side spots are used to detect tracking error by half tracing playback tracks. This tracking error detection method is called the twin-spot method. In this new pickup, however, the side spots are used for signal reproduction, so the twin-spot method cannot

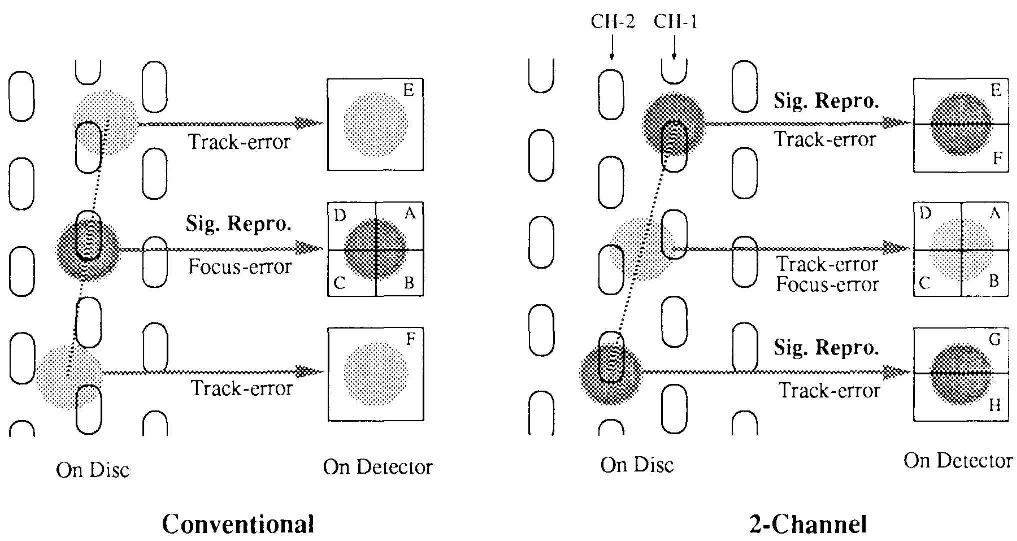


Fig. 10 Spot locations of optical pickup

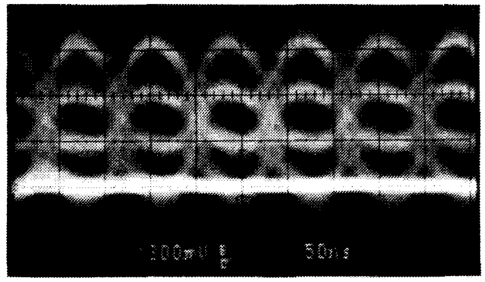
be used. Push-pull method is a candidate, but the conventional push-pull method has a problem: the push-pull tracking error signal is biased by tilt or eccentricity of the discs, which makes tracking srevo unstable. For this reason, we used a new tracking error detection method called differential push-pull, [5] which overcomes the problem of the conventional push-pull method and enables stable tracking.

The photo-detector is a specially developed low-crosstalk detector. Since the photo-detector handles two high-frequency signals on a single chip, it is necessary to pay attention to the crosstalk between the two signals. The crosstalk on the detector is different from that resulting from the reading spots. Between the two-channel signals on the detector there is a 1.6-to-2.4 μs time difference which corresponds to the 45-μm interval between the two spots on the disc. So the correlation of the two-channel signals is lost on the detector, and inter-channel crosstalk on the detector seriously affects the picture quality. The actual detector has crosstalk of between -48 and -50 dB without sacrificing either bandwidth or sensitivity.

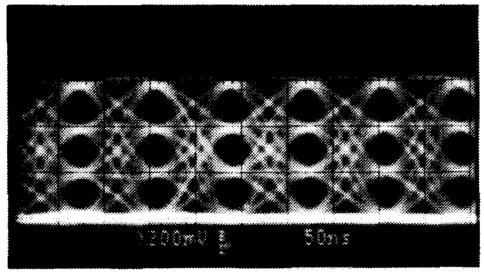
5. Results

The carrier-to-noise ratio is approximately 60 dB with a 30-kHz bandwidth, which is virtually identical to that for a conventional videodisc. An unweighted signal-to-noise ratio of more than 42 dB is yielded for the luminance signal. The signal-to-noise ratio for the chrominance signal is the same as that for the luminance signal but it appears to the visual sense to be much noisier than the luminance signal, because the chrominance bandwidth is less than one-third that of the luminance signal and its noise is in the low-frequency band.

Figure 11 (a) shows the eye pattern before the audio data is equalized. In accordance with the policy of equalizing outlined above, this audio signal is equalized by a simple low-pass filter to form the well opened eye pattern shown in Fig. 11 (b). As a result, the error rate of the audio data is about 8×10^{-5}, which means that errors are corrected almost perfectly.



(a) before equalization



(b) after equalization

Fig. 11 Eye pattern of audio data

The new tracking servo is stable and even discs having an eccentricity of approximately 80 μm can be played back without any problems in the various playback modes including the random access.

6. Conclusion

In conclusion, we developed an HDTV video disc system having the capability of reproducing 20-MHz Y and 6-MHz C signals without bandwidth compression. The significance of this development is that we introduced a two-channel recording method with optical disc and made a simple and reliable player. Although there is a problem that the playback time is short, as the technology for higher recording density is refined, such as the development of a short-wavelength laser diode, its application will expand.

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References

[1] T. Toyama et al., "Optical Video Disc for High-Definition Television by the MUSE", *SMPTE Journal*, vol. 95, no. 1. pp. 25-29, 1986.

[2] H. Takaki et al., "Optical Video Disc for HDTV", *ITE Japan Technical Report*, VR87-15, pp. 61-68, 1987. (in Japanese)

[3] T. Furuhata et al., "A High-Definition MUSE VCR with Analog Segment Recording Method", *IEEE Trans. on Consumer Electronics*, vol. CE-32, No. 2, pp. 107-115 May 1986.

[4] Proposed American National Standard, 1125/60 high-definition production system, SMPTE 240 M, *SMPTE Journal* Vol. 96, No. 11, pp. 1150-1152 (Nov. 1987)

[5] K. Osato, "A New Tracking Servo Method", *Proc. of Symposium on Optical Memory '86*, pp. 127-132, 1986. (in Japanese)

Biography

Kaoru TACHIBANA, Assistant Manager of the Opto-Electronics Research Department, received his B.S. degree in electrical communications in 1979 from Tohoku University. He joined Sony Corporation the same year and has participated in the development of video recording technology with optical disc. Since 1984, he has been engaged in the development of HDTV video disc system.

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Hiroaki MOMIYAMA is Manager of HD Business Department of Communication Products Group. He joined Sony Corporation in 1966 and has participated in the design of video tape recorders. Now he is a project manager engaged in the development of HDTV video disc player.

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