RECOMMENDATION ITU-R BR.1375*

HIGH-DEFINITION TELEVISION (HDTV) RECORDING

(Question ITU-R 108/11)

(1998)

The ITU Radiocommunication Assembly,

considering

a) that the Common Image Format, having 1 080 x 1 920 square pixels, is now recommended as the image capture format for HDTV to be used in the future;

b) that a HDTV broadcasting service via satellite, based on Recommendation ITU-R BT.709 is now in operation in Japan;

c) that it is expected that a digital terrestrial broadcasting service for HDTV programmes, which includes some other scanning options, will be in operation in the United States toward the end of 1998;

d) that various analogue and digital formats for HDTV tape recording have been developed;

e) that many countries hold large archives of valuable, irreplaceable HDTV programmes, based on the signal formats defined in Recommendation ITU-R BT.709;

f) that analogue HDTV open-reel recording formats are considered to be obsolete for use in programme production today, but the programmes recorded on those formats in the past are often valuable;

g) that digital recording of HDTV programmes is now widely used in HDTV production and post-production;

h) that there are several types of equipment available for digital HDTV recording today, that differ in the recording medium, in the recording format, or in the recorder model, e.g.: recorders that use or do not use bit-rate compression, recorders that use open-reel tape or cassettes, deck or portable/camcorder, etc.;

j) that bit-rate compression technique based on DCT and VLC coding can provide highly efficient methods of recording HDTV programmes, whose source data rate exceeds 1 Gbit/s;

k) that the operational and handling characteristics of digital HDTV VTRs have improved to the point that the VTRs can be used not only in the studios but also in the field, with a level of convenience similar to that of conventional VTRs;

l) that HDTV cameras using two-million pixel CCD imaging devices and digital signal processing with advanced VLSI chip(s) can provide high quality HDTV pictures while offering the operating features and small size of conventional cameras,

recommends

1 that digital HDTV tape recording should be preferred in the future for HDTV programme origination and production, and for storage for programme exchange;

2 that analogue HDTV tape recordings should preferably be transferred to a digital recording format for postprocessing and archives;

3 that the 1 080 x 1 920 Common Image Format specified in Recommendation ITU-R BT.709 shall be preferred for image capture in the future, while the other image formats specified in Recommendation ITU-R BT.709 will retain their value especially in view of the need to ensure the possibility to re-use archived HDTV programme assets;

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* This Recommendation should be brought to the attention of the International Electrotechnical Commission (IEC).

4 that HDTV programmes intended for extensive and complex postprocessing should preferably be recorded on a digital tape format that does not use lossy compression, while HDTV programmes intended for limited or no postprocessing may preferably be recorded on a digital format that uses a modest amount of compression.

Note: Appendix 1 of this Recommendation provides information on the present state of HDTV recording technology. Further reading on this subject can be found in the bibliography included in Appendix 2 to this Recommendation.

APPENDIX 1

CONTENTS

List of Attachments

1 Introduction

HDTV technologies have been studied in many countries and have been discussed for a long period of time by authorities in order to achieve a world-unified standard. It has recently become again one of the most important technologies for the television industries and the idea of the "Common Image Format" is now defined in Recommendation ITU-R BT.709.

With the advent of the "Digital Era", digital signal processing technologies, especially the technology of bit-rate reduction (commonly known as MPEG-2), have been highly developed for application to television. Semiconductor technologies have also matured sufficient enough to make high-speed devices available for HDTV applications.

Using such technological infrastructures, the Hi-Vision Broadcasting is already on the air via broadcasting satellite in Japan. In North America around 1998, digital terrestrial broadcasting for HDTV programmes including some other optional variations, such as multichannel SDTV programmes and 525 progressive programmes, will be on the air. The "DTV Standard" in the United States has several signal variations but most likely "1 920 x 1 080" HDTV will be used for programme origination and presumably for a fairly large percentage of broadcasting time. Digital HDTV services are also planned to be broadcast via satellite around the year 2000 in Japan.

In view of the recent trend toward a wide recognition of the applicability of HDTV technologies, it seems likely that we may need a thorough investigation of HDTV recording as a key device for programme production.

2 HDTV recording overview

HDTV has a higher picture resolution compared with conventional SDTV. It is roughly five times higher than that of SDTV. Although several kinds of VTRs are in daily use for SDTV without any operational difficulties, recording of HDTV signals by using current advanced technologies requires special consideration in order to accommodate higher signal speeds. Ideally, even for HDTV operations, user requirements, such as recording time, operational features and capabilities similar to the ones applicable for SDTV, must be satisfied.

Studies have shown (see Appendix 2) that while the most advanced technology for tape and disk recording are close to achieving the packing density needed for HDTV, further advances or new technologies will be needed to completely satisfy the requirement. Innovative technology like perpendicular recording, more efficient use of PRML playback technology and new devices like GMR (giant magneto resistive) head are potential candidates. Some of those new technologies are still in the experimental stage and they are not available yet, but some of them have already been used to a degree in some current models.

2.1 Analogue HDTV VTR

Since the expected packing density is almost the same for both SDTV and HDTV recording, a track roughly five times longer is required for HDTV recording than for SDTV recording. Instead of a long single track implementation, a combination of multiple shorter tracks is usually used in practical VTR design. One television picture field is divided into several segments and each segment is recorded as a single track. Recording of multiple tracks per field is thus necessary and it is realized by using multiple heads per scan and/or by higher drum rotation speed, in other words a multiple head scan within a field time period. In any event, a certain degree of signal processing, such as expansion and/or compression, delay, and so on is necessary and it is performed digitally.

The cassette type HDTV recorder, commonly known as UNIHI in Japan, uses six tracks to record a field of the picture. Two recording channels are used in TCI recording mode. The drum is rotating at 90 rps and the tape wrap angle on the drum is 216 degrees. Since the wrap angle is over 180 but far less than 360 degrees, two pairs of cluster heads (a total of four heads with the pairs located 180 degrees apart on the drum surface) are used for recording.

The TCI signals are derived from the original HDTV signal as a result of signal processing in the digital domain. The luminance signal, which has wider bandwidth than the chrominance signal, is expanded in the time domain to create a lower bandwidth signal. The chrominance signal is processed in the opposite way. Then, the luminance and the chrominance parts are combined into one single signal, which is a new form of signal with a lower bandwidth but still retains the same picture details. Two channels of TCI signals are generated and recorded on the tape in parallel. To obtain a better picture quality in the fast search mode of the tape transport, each picture field is line-sequentially shuffled into three segments. Each field of the HDTV signal is thus segmented into six tracks of recorded patterns.

2.2 Full bit-rate digital HDTV VTR

Table 3 shows the specifications for both the 1-inch open-reel type recorder and the D-6 cassette type recorder. A bit stream of more than 1 Gbit/s must be handled in full bit-rate recorders. The D-6 VTR tape transport was designed based on that of the D-2 VTR, which is a composite digital VTR for conventional SDTV. To record 9.5 (D-6/D-2=1 212 Mbit/s/127 Mbit/s≈9.5) times higher speed of signal, the D-6 digital VTR has 16 heads for recording, another 16 heads for playback and two erase heads on the drum. The drum is rotating at 150 rps. In this configuration one field of HDTV signal is distributed and recorded on 40 tracks. The number of tracks for D-6 is about 6.7 (40/6) times that of the D-2 format. The linear packing density of D-6 is roughly calculated to be 1.4 (9.5/6.7) times higher than D-2. Since the minimum wavelength is similar for the two formats, extra packing capacity may come from the 8-12 channel coding and slightly longer track length of the D - 6 format. Based on the track pitch and the number of tracks per field, it can be calculated that the amount of tape consumption of D-6 is 3.75 times more than that of D-2. Considering the data rate of HDTV signals, which is 9.5 times higher than that of SDTV, this can be regarded as a noteworthy improvement in recording technology. Several factors of improvement in the relevant technological areas, such as tape, head, and scanning mechanism have contributed to this advancement. The L type cassette, which is 366x206x35 mm, can store 64 minutes of HDTV programme compared to 208 minutes of composite television programme on D-2.

2.3 Digital compression HDTV VTR

There are two different types of digital compression HDTV VTRs available for 1125/60. Type A in Tables 1 and 3 has been designed based on “Digital Betacam” and the other type, which is Type B in Tables 1 and 3, is using the 4:2:2 digital component D-5 Format. Both types are using or are at least based on the already-available VTR formats and mechanisms. Type A can manage to record a data stream of about 140 Mbit/s. Type B, on the other hand, can store a stream of 235 Mbit/s. To record the higher data rate of HDTV, which is about 1 Gbit/s, it is mandatory to reduce the rate so that it can be accommodated within each recording capacity of the aforementioned conventional or modified conventional DVTRs.

Type A needs about 1/7 compression ratio. It is reported that a careful investigation of picture quality suggests that a direct DCT bit-rate reduction to that extent is difficult and is not an appropriate way to go. Instead of direct DCT reduction, Type A has adopted two consecutive stages of processing. The first processing used is a pre-filtering of a 5/8 horizontal band limitation. This process makes 1 440 samples out of 1 920 samples and the net data rate is compressed to 622 Mbit/s. The second stage processing is a reduction of 622 Mbit/s to 140 Mbit/s. This amount of reduction can be obtained by adaptive intra field/frame DCT without any obvious picture degradation. Although it employs intra field/frame DCT, field edit precision is guaranteed.

Type B needs roughly 1/4 to 1/5 bit-rate reduction ratio. This amount of reduction ratio can be obtained by intra field DCT coding. For luminance, a DCT matrix size of 8 x 4 (8 pixels in the horizontal and 4 lines in the vertical direction) is used for in compression encoding; for the two chrominance signals, the rather common 8 x 8 DCT matrix is applied. A unique special overlapping technique is adopted in each DCT encoding. It is a technique by which the DCT blocks are positioned overlapping with each other. This special arrangement makes the format robust enough for large size burst errors.

2.4 HDTV disk recording

There are two different kinds of analogue disk drives available in the market. They are the playback only (ROM-Type) and the Write-Once type of disk drives. No recordable analogue disk drive has been announced yet except the Write-Once type. In Table 2, the specifications of those two types of disk drives are given. Like in the UNIHI HD VTR, the wideband HDTV signal is split into two narrow-band signals. Then the two signal channels are stored on disk by frequency modulation. The same signal processing and RF schemes are used for both the ROM and the Write-Once type. The difference between the two types is in the way adopted to generate dual laser beams. For the ROM-type drive, dual beams are generated or rather separated by an optical grating from a single beam. For the Write-Once type drive, because of the temperature required to melt the alloy on the surface of disk, a new monolithic dual laser beam diode has been developed.

As far as recordable digital disk drives are concerned, a bit-rate compression type of drive with removable media was announced in July 1997. It is a 300 mm diameter magneto-optical disk drive system. Originally the drive has been designed for conventional composite television recorders with a recording bit rate of 94 Mbit/s. The specifications of the drive are listed in Table 2. The source bit-rate at the input is 594 Mbit/s. The luminance signal is sampled at 44.55 MHz and the two chrominance signals are sampled at 14.85 MHz. Intra frame DCT coding is used to compress the data stream into 94 Mbit/s.

Another type of digital recorder can be implemented with the usage of hard disk drives. Hard disk drives are now widely used not only in computer but also in video/audio applications. The price of hard disk drives is becoming lower and the storage capacity is becoming higher. One of the nice aspects of these devices is that they can be easily used in very large parallel ways because of the compactness and price of the devices. If the disks are to be organized as a system, this can be constructed as a RAID. The capacity and transfer rate of a RAID system can be flexible enough to accommodate from SDTV to HDTV depending on the number of disks used in the RAID. Following is a brief explanation of RAID:

RAID is a technology introduced by D. Patterson, R. Katz, and G. Gibson, in their paper “A Case For Redundant Arrays Of Inexpensive Disks (RAID)”. The design goal for the technology was highly reliable, high-performance disk subsystem built out of inexpensive, albeit slower and less reliable, components.

RAID 0 is non-redundant and simply shows a model of disk striping. RAID 1 is disk-mirroring and thus has redundancy of 100%. Above level 1, that is 2, 3, 4 and 5 or even higher, some kind of error correction schemes are involved. Level 2 (RAID 2) uses Hamming code. Level 3 is the first of the RAID level with practical significance. In this configuration, bit- or byte-interleaved data-recording is used to stripe data across multiple disks, and then parity data is recorded on a separate disk drive. In RAID 4 sectors are interleaved, instead of bits or bytes, and parity is also written sector by sector. Level 5 rotates parity sectors across all the disks in the array, so that each disk contains both data and parity. By distributing parity sectors across the array, two simultaneous write accesses to the array become possible. This simultaneous write access is not possible for the RAID 4 configuration since the parity disk cannot simultaneously accept double-accesses for parity refresh.

Today, the price of hard-disks is becoming lower and lower. A cost-effective storage system of large and flexible capacity is thus available for storing high resolution images.

3 HDTV technology and environment around it

3.1 ITU Recommendations for HDTV

3.1.1 The common image format

The Common Image Format, which contains a total of 1 920 pixels in the horizontal and 1 080 pixels in the vertical direction, is confirmed in Recommendation ITU-R BT.709. The idea of the Common Image has been included as part of Recommendation ITU-R BT.709, whose title is “Parameter Values for the HDTV Standards for Production and International Programme Exchange”. What is common is the number of pixels within a picture frame, independent of the scanning system used in the television standards. The HDTV picture frame has an aspect ratio of 16:9. The 16:9 picture aspect ratio is agreed worldwide for the future image standard. By adopting the pixel numbers of the Common Image Format and the 16:9 picture aspect ratio, each picture element has an ideal square aspect ratio. The Common Image Format is particularly important for future devices, such as CCDs and flat panel displays.

The pixel aspect ratio of current HDTV equipment is slightly off square, since it has been designed based on current HDTV standards. This small amount of departure from a square pixel can easily be adjusted by an appropriate signal processing. This problem can be solved in newly designed CCD imaging devices in the foreseeable future once a worldwide agreement on the image size has been achieved.

3.1.2 International programme exchange in electronic form

Recommendation ITU-R BR.714 “International Exchange Of Programmes Electronically Produced By Means Of High-Definition Television” recommends that “when programmes produced in high-definition television are exchanged between broadcasters, in order to preserve the best quality, they should be exchanged in video form, e.g. live or videotape”.

The conclusions of Annex 1 to the Recommendation state as follows:

“For international exchange of HDTV-produced programmes between broadcasters, technical considerations suggest that clear preference should be given to an all-electronic process, i.e. to the exchange of video copies of the HDTV edited master videotape, with or without standards conversion, as the circumstances may dictate.”

According to this Recommendation ITU-R BR.714, tape or disk recording of HDTV programmes seems to be quite important for programme exchange.

3.2 HDTV related technology innovations

HDTV has been used as an image capture and manipulation tool for electronic cinemas, and for industrial and educational purposes for many years. Recent advancement in many technological areas, such as signal processing algorithms and semiconductor design and process innovation, makes HDTV a more generalized and practical way for programme production and opens a new horizon for many more applications. Secondary transmission of HDTV signals is a good example of the new applications. HDTV programme broadcasting to the home surely opens a brilliant future for the HDTV arena. This Section 3.2 covers several technology areas in which recent HDTV related innovations originated. This will give a clear view of current and future HDTV applications.

3.2.1 MPEG-2 MP@HL

MPEG-2 is a well-known and common technology for video compression. This compression scheme has been widely accepted in many application areas because of its ways to define its applications, called “Profiles and Levels”. MPEG-2 is especially efficient and thus important for those applications in which a high compression ratio is required. It is popular and rather common technology for secondary distribution in order to fit high speed data streams in a bandwidth limited TV spectrum resources.

In this regard, transmission of HDTV signals through the air, which is actually planned to be launched in North America around late 1998, is a good example of this type of application. The Digital Television Standard in the United States uses MPEG-2 MP@HL. The original HDTV signal rate is around 1 Gbit/s. To fit it within a standard 6 MHz television channel, in other words to compress it to about 20 Mbit/s, implies a need for roughly a 1:50 or greater compression ratio. The following explanations on the adoption of the Profile and Level for the Digital Television Standard are extracted from “Guide to use of the ATSC digital television standard”.

“The Digital Television Standard is based on the MPEG-2 Main Profile. The Main Profile includes three types of frames for prediction (I-frames, P-frames, B-frames), and an organization of luminance and chrominance samples (designed 4:2:0) within the frame. The Main Profile does not include a scaleable algorithm, where scalability implies that a subset of compressed data can be decoded without decoding the entire data stream. The High Level includes formats with up to 1 152 active lines and up to 1 920 samples per active line, and for the Main Level is limited to a compressed data rate of no more than 80 Mbit/s. The parameters specified by the Digital Television Standard represent specific choices within these constraints.”

3.2.2 Current VLSI technologies

As it has been observed in § 2 “HDTV recording overview”, the role of semiconductor devices is increasingly important in implementation of HDTV recorders.

This is especially true where digital VTRs are concerned. Conversion of HDTV signals from analogue to digital needs a set of high bandwidth A/D converters for each component signal, namely luminance, and two colour difference signals.

In the HDTV camcorder HDW-700 from Sony, three high performance A/D converters are used to digitize three wideband RGB signals directly out of their CCD imaging subsystems. The A/D converter has 10 bit precision and it is sampled at a 74.25 MHz clock rates. It has implemented using high-speed CMOS circuits with 0.3 μm semiconductor technology and it can operate at 3.3 volts. The whole camera processing after A/D conversion is performed in one VLSI microchip. It is designed to use 0.35 μm semiconductor technology and it operates at 2.5 volts.

The compression algorithm for the HDTV recorder has been implemented by contemporary 0.35 µm ASIC technology. The goals of size, weight, power consumption, and modest costs have been realized in these ASIC designs. As signal processing becomes complex, the usage of digital technology and the way in which it is implemented gain importance.

3.3 Technology trend toward HDTV broadcasting

3.3.1 CCD imaging devices and camcorder

The role played by the camera in HDTV programme productions is considered to be very important. The sensitivity and the resolution of the imaging devices are the target of continuing improvement efforts. The S/N ratio of HDTV cameras had improved with CCD devices. 54 dB S/N under 2 000 lx and F8.0 has been achieved with 2/3 inch two million pixels CCD. This level of performance, which was first achieved by using 1 inch CCD with 2 million elements in 1992, can be considered as practical as the level of conventional television cameras.

To improve the portability of cameras and to gain a better handling performance and lower cost, a small CCD device was badly required. A smaller CCD means generally lower sensitivity. This inherent size and sensitivity problem was solved by several technological design efforts. Now, 2/3 inch CCDs are available in the market. As the table below shows almost the same or in some case even better specification values have already been achieved, e.g. for smear.

Table of comparison between 1 inch vs. 2/3 inch CCD specifications.

	2/3 inch	1 inch
Optically sensitive area	9.7(H)x5.4 mm(V)	14.0(H)x7.9 mm(V)
Unit cell size	5.0(H)x5.2 µm(V)	7.3(H)x7.6 µm(V)
Sensitivity	75 mV/lx	80 mV/lx
Saturation	500 mV	500 mV
Dynamic range	70 dB	72 dB
Smear (V/10)	–120 dB	–100 dB

3.3.2 Serial digital interface

The Serial Digital Interface (SDI) for HDTV has been standardized based on the SDI interface for SDTV. There is a substantial difference of bit rate between the two SDIs. The bit rate of the HDTV-SDI is 1 485 Gbit/s if 10 bits/sample are adopted. The devices currently available for this interface have been designed with much faster semiconductor chips than conventional Silicon devices. Optical fibres are usually preferred for the connection between equipment. Conversion between optical light and electronic signal is also required in that instance.

3.3.3 Optical serial interface

For broadcasting stations of the near future, and even for current broadcasting stations in a sense, a flexible adaptation to multiple signal formats such as SDTV, EDTV, and HDTV is required depending on the production process and the broadcasting mode. Since distribution and transmission systems in a broadcasting station are an important infrastructure, which cannot easily be replaced, they have to be flexible to accommodate those television signals.

The new broadcast centre of Fuji Television Network Inc. in Japan has employed a newly developed "wavelength-division and time-division hybrid multiplexed (WD/TD) optical network" for video/audio signal distribution/transmission in new facilities.

To accomplish their design goal, the first essential requirements set for the network are:

– Broadcasting formats: HDTV, EDTV, SDTV.

– Transmission formats: digital serial (composite/component).

– Number of distribution/transmission signals: more than 150 (future—more than 200).

– Number of studios and related rooms: more than 20 (future—more than 50).

The answer for these requirements is the use of WD/TD optical networks. Brief specifications of these networks are:

– Wavelength: 1 545 - 1 560 nm.

– Wavelength spacing: 1 nm.

– Number of channels: 16.

– Bit rate/channel: 2.48 Gbit/s.

3.3.4 HDTV displays for the home

The number of HDTV display monitors for high-grade home usage in Japan has begun to increase. The price of such monitors is becoming significantly low compared to the past. In the domestic market of electronic home appliances, HDTV monitors are regarded as a high-grade model among 16:9 TV display monitors, which are now widely accepted by the general consumer in Japan.

Plasma display panels (PDP) have been studied for a long period of time and after a significantly long survey period, 40 inch full colour plasma panels of HDTV (1 920 x 1 035) resolution have been finally realized. Several manufacturers of display devices are now announcing their recent models in the market. The price of PDPs is still quite high but it will gradually decrease coincided with their penetration into the home.

4 HDTV recorders in production and post-production

There are several HDTV VTR formats available ranging from analogue to digital, and open-reel to cassette types. Analogue open-reel VTRs, whose parameter values are shown in Table 1, Table 4 and Table 7, are considered to be a little bit obsolete now. The analogue UNIHI format is still frequently used and it is considered to be valuable especially when production in the field is envisaged. In field usage, portability and the capability to accept a DC power supply is important. Concerning digital VTR for HDTV, there are several formats available and the parameter values for those VTRs are listed in Table 1, Table 3, Table 4 and Table 6. Detailed parameter values are shown in Table 3 and Table 6 for each 1125/60 and 1250/50 scanning system. Here, we should recognize that there are two distinctly different types of VTRs. One type is a straight recording non-compression type and the other is a bit-rate compression type. Non-compression VTRs are preferred in high-end applications in terms of picture quality. On the other hand, compression types are preferably used in wider production applications in view of their portability and easy handling. At the current level of technology, it seems that HDTV productions comparable to those currently found in the conventional SDTV environment, will not be considered possible without the use of compression-type VTRs within the foreseeable future.

4.1 Studio production VTR

Some of the essential features for studio production VTR can be listed as 1) a multi-dubbing capability, 2) editability with TV field precision and 3) a playback capability in various tape speed modes, such as slow-motion, variable and shuttle.

Non-compression type VTRs for full bit recording are excellent in performance in terms of picture quality and editability, but they tend to be large in size and power, and in tape consumption. Seeking for the better operational performance, a compression type VTR has been developed. HD D5 is one of the examples in this category of products and it is designed based on D5 component. It fits applications in studio production and in signal feeding purposes for transmission. The recording format of the HD D5 is exactly the same as that of the D5 digital VTR. The HDTV picture is compressed to 1/4 and results in a data stream of 235 Mbit/s data. Two hours of programme can be stored on one L-type cassette, whose size is 296x167x25 mm. The compression algorithm is based on the well-known DCT scheme. In the HD D5 case, each DCT block is formed within a TV field. This so-called intra-field DCT coding makes it possible to edit with field precision. It can also playback signals in a wide range of tape speeds. The speed range can cover from -1 to +2 times normal speed in variable mode and up to ±50 times in shuttle mode. This level of performance can be regarded as comparable as that of conventional digital VTRs for SDTV.

Input/output specifications conform to Recommendation ITU-R BT.709. When the picture quality is subjectively assessed to Recommendation ITU-R BT.500, a picture degradation of less than 4% can be anticipated after 10 multi-generation dubbing operations under the conditions of no-picture shift in successive dubbings. Even if the DCT blocks are shifted every time from the preceding encoding process, the 5th generation of the original picture can still keep the quality within of less than 12% degradation. This level of performance can be considered sufficient for most studio productions.

4.2 Field production by camcorder and portable VTRs

Field production is important or it is mandatory for TV programme production. Currently there are two ways of doing this. One way is to use a portable type of UNIHI VTR. Based on the studio deck type of UNIHI VTRs, a portable type UNIHI VTR has been designed by removing some lower-priority features, such as four channels of PCM audio capability rather than two, or the playback capability. This portable UNIHI VTR system with a separate CCD camera unit was actually first used in the 1992 Olympic Games. The system has been used to not only cover sports events but also some other big events such as the wedding ceremony of the Royal Family of Japan. It is also used at important national ceremonies, documentary programmes, and big news coverage such as large-scale catastrophes in Japan.

As it has already been mentioned in § 2.3 “Digital compression HDTV VTR”, a camcorder, which is a common term to indicate a combination of CCD camera and VTR in one unified form, is now available on the market. Like Betacam for SDTV, this HDTV camcorder will surely increase the possibility for producing programmes. A studio deck model of this camcorder is also available. Although the recorded tape patterns of those two models are the same, the way of implementing the format on the two models is different. The design of a compact VTR necessitates special design tactics to lower power consumption, acoustic noise etc. The size of the drum diameters is almost the same. But the number of recording heads is different and it has been set to eight for the camcorder. It is twice as many heads as those of studio deck model. A doubling increase of the head counts helps to reduce the drum rotation speed to half of that of studio deck. The relevant parameters are listed in Table 3 and Table 6. By this approach the camcorder also suffers less acoustic noise and gyro-effects. The number of available audio channels is halved. Two audio channels may not be sufficient in certain applications but they represent a practical compromise for camcorder implementation.

5 Studio implementation with current HDTV equipment

As discussed above, several kinds of HDTV equipment, such as cameras, VTRs, and serial digital interfaces, are already usable to create a HDTV production studio. It might be valuable to confirm the results of this survey by referring to some examples of actual HDTV studio implementation.

In Japan, the “MUSE” HDTV broadcasting service is now on the air more than 17 hours a day. A joint body of several Japanese broadcasters conducts this service. NHK and seven commercial broadcasters of Japan are forming the body. NHK has prepared five HDTV-ready studios by now. Four of them are mixed or rather ambivalent studios for HDTV and SDTV. Each studio has its own target usage. With the other CT-510 studio, which is a pure HDTV studio, a wide range of HDTV programmes, ranging from news, dramas, and entertainment and educational programmes can be produced.

In these studios HDTV is the basic and fundamental signal format. A HDTV digital video switcher plays a fundamental role in the studio signal flow. Up-converters are also used frequently so that conventional TV programmes from the other studios can be used in HDTV broadcasting programmes.

A dedicated local switcher is used for the selection of VTRs for the sake of efficient operation. An analogue UNIHI VTR and/or digital HDTV VTRs are connected to the switcher. Conventional VTRs, such as a Betacam and a D-3 composite VTR, are also connected after up-conversion to be integrated as part of a broadcasting HDTV programme.

In current operations in these studios, 16:9 and 4:3 picture aspect ratios are used in mixed form. NTSC signals are put out as the output of a down-converter at the final stage of the studio signal flow for broadcasting of SDTV. For interconnections among the studio equipment, current analogue component connections will be replaced with serial digital interfaces in future.

The CT-510 studio of NHK is primarily designed for news and live coverage. The main video switcher has 27 inputs and four mix-keyers. It also has two channel 3D digital video effect generators inside it. Current analogue inputs are to be up-graded to serial digital interfaces in future. The studio is equipped with various machines, such as four 2/3 inch

2 million pixel CCD cameras, three HD D-5s (D-5-based compression digital VTRs) and one analogue UNIHI VTR, a HDTV still picture file system, and a weather forecast support system. The optical transmission system and input frame synchronizer can provide capability to interface to the outside of studio.

Transmission of HDTV programmes via communication satellite has been developed. MPEG-2 MP@HL and 8-PSK Trellis modulation techniques are used to compress the signal to 45 or 60 Mbit/s and transmit it through 27 or 36 MHz transponders. The possibility of the wireless transmission provides a great deal of flexibility for programme production. The HDTV camcorders in sports events can also provide a new step in the approach to HDTV production and its broadcasting.

6 Summary

After a long period of experiments and standardization discussions, HDTV has finally begun to form a clear shape. Various technological requirements for realizing practical HDTV equipment have been almost met today. This study has shown that the various key technologies have already been realized to step into a new HDTV world.

Beside these crucial technology requirements, requirements for HDTV broadcasting are also gaining importance. HDTV digital broadcasting through the various transmission media will soon be on the air in several regions of the world.

Many viewers are already becoming accustomed to 16:9 SDTV or EDTV display monitors. CRT monitors with HDTV resolution are in the consumer market these days at a reasonable price. Studies of flat panel displays in many laboratories have shown that commercial HDTV flat panel displays are not a dream but will be a reality in the home within several years.

This study tries to show that the world is now about to step into the HDTV age. With the steady improvement of technology it is expected that HDTV production will achieve the same operational convenience as SDTV production within a reasonable period of time.

APPENDIX 2

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Table 1 Tape 1125/60 (59.94) *Overview*

Digital/Analogue		Digital				Analogue	
Comp./Non-Comp.		Compression		Non-Compression		Cassette	*<OBSOLETE>* Open Reel
Package Type		Cassette		Cassette	Open Reel		
Format or Type		Type-A	Type-B	D6	1'Type-C(mod)	UNIHI	1' Type-C(mod)
Conventional Name*		HDCAM*	HD D5	GBR, DCR	HDD/HDDP	HDV, AU-HD	HDV
Rec./Pb. Time (max.)		124 min	123 min	64 min	96 min	63 min	63 min
Video Spec.	Luminance	23 MHz	1 920 s/line	1 920 s/line	1 920 s/line	20 MHz	20 MHz, 41 dB
	Chrominance	7 MHz	960 s/line	960 s/line	960 s/line	7 MHz	10 MHz, 45 dB
	No. of lines	1 035(1 080)*	1 080			1 036 lines	1 045 lines
Audio Spec.	Dig. or Anlg.	PCM	PCM	PCM	PCM	PCM	Analogue
	No. of Ch's	4 ch	4 ch	5 stereo pairs	8(Dig)+1(Ana)	4 ch	2 ch
		48 kHz, 20 bit	48 kHz, 20 bit	48 kHz, 20/24 bit	48 kHz, 16 bit	48 kHz, 16 bit	S/N 54 dB
Meta Data					5 VBI lines		
Media	Size	254x145	296x167	366x206	14 inch Reel	205x121.5	inch (HD-1-63)
	Substance	Metal Particles	Metal Particles	Metal Particles	Metal Particles	Metal Particles	CofÁ- Oxide
Application Example		Camcorder	Portable	Studio deck	Studio deck	Studio deck Portable	Studio deck
Notes		1/2 inch Intra Fi/Fr Field Editable DTC (1/7)	1/2 inch (D5) Intra Field DCT (1/4)	3/4 inch tape		1/2 inch tape	

* Each Format or Type is commonly known as listed here.

* HDCAM is a handy camera-recorder type VTR. Deck-type HD Digital VTR is also available.

* A current CCD camera used for the HDCAM has a resolution of 1 920 x 1 035.

Table 2 Disk 1125/60 (59.94) *Overview*

Digital/Analogue		Digital				Analogue			
Comp./Non-Comp.		Compression		Non-Compression		Removable			
Handling		Removable	(Non-Rem.)	(Removable)	Non-Rem.				
Rec. and/or Pb.		Rec. and Pb.			Rec. and Pb.	Pb. Only	Write-Once	Rec. and Pb.
Format or Type		MO*			HDD(RAID)*	Optical	Wobbling	MO
Conventional Name*						HDL-2000	HDL-5800	
Rec./PB. Time		32 min				15min(CLV)	20min(CLV)	
Video Spec.	Luminance	44.55 MHz, 8 bit				20 MHz	20 MHz	
	Chrominance	14.85 MHz, 8 bit				6 MHz	6 MHz	
	No. of lines	1 088						
Audio Spec.	Dig. or Anlg	PCM				PCM	PCM	
	No. of Ch's	4 ch				2 ch	2 ch	
		48 kHz, 20 bit				48 kHz, 16 bit	48 kHz, 16 bit	
Meta Data		256 Kbytes/ Frame						
Media	Size	300 mm				300 mm	300 mm	
	Substance	Magnetic Coat				Aluminium Coated	Alloy Coat	
Notes		Intra Frame 94 Mbit/s Drive Double Sided				Single Sided	Single Sided	

MO: Magneto Optical

HDD(RAID): Hard Disk Drive (Redundant Array of Inexpensive Disks)

* Each Format or Type is commonly known as listed here.

Table 3 HDTV Digital VTR (1125/60) *Details**

Format or Type			1 inch	D-6	Type-A	Type-B	DVC-HD
Conventional Name**			HDD/HDDP	GBR, DCR	HDCAM	HD D5	
Sampling Freq.	Video	MHz	74.25	74.25	74.25	74.25	40.5
	Audio	kHz	48	48	48	48	48/44.1/32
Quanti-zation	Video	bit/ Sam	8	8	8	10/8	8
	Audio		20	20/24	20	20	16/12
Audio Ch's		Num.	8(Dig)+1(Ana)	10	4	4	4/6/8
Compression (Video)			–––	–––	Intra Fi/Fr DCT 1/7***	Intra Field DCT1/4 1/5	Intra Fi/Fr DCT 1/6
Ch. Coding			8-8 map	8-12 map	S-NRZI	8-14 map	24-25 S-INRZI
Total Rate		Mb/s	1,188	1,212	185	301	83.7
Video Rate		Mb/s	958.5	958.5	140	235	49.896
Rec. RF Ch's		Num.	8	8	2	4	2
ECC	Inner		110, 104	227, 211	231, 219	95, 87	85, 77
	Outer		64, 60	254, 240	250, 226	128, 120	149, 138
Drum Diameter		mm	134.6	96.5	81.4	76.0	21.7
Drum Rotation		rsp	120	150	45	90	150
No. of Tracks		/Field	16	40	6	12	20/Frame
Tape Speed		mm/s	805.2	497	96.8	167.228	37.625
Track Pitch		µm	37	22	21.7	20.0	10
Min. Wavelength		µm	0.69	0.81	0.49	0.63	0.49
Width of Tape			25.4	19.01	12.65	12.65	6.35
Media Substance			Metal Particles	Metal Particles	Metal Particles	Metal Particles	Metal evaporated
Hc		Oe	1450	1600	1700	1800	1500
Cassette size		mm	11.75/14 inch reel	S 172x109 M 254x150 L 366x206	156x96 254x145	S 161x98 M 212x124 L 296x167	66x48 125x78
Rec. time		min	63/94	8/28/64	40/124	32/63/124	30/135
SMPTE Standard				277M,278M			
IEC Standard							

* See Appendix 2 "Recording Systems; 7-1 Standards of VTR" by K. Kamijo NHK, The Institute of Television Engineers of Japan, Vol. 50, No. 11 PP1738~1741 (1996).

** Each Format or Type is commonly known as listed here.

*** 5/8 Horizontal Prefiltering and 1/4.4 DCT.

Table 4 Tape 1250/50 *Overview*

Digital/Analogue		Digital						Analogue	
Comp./Non-Comp.		Compression		Non-Compression				Cassette	<*OBSOLETE*> Open Reel
Package Type		Cassette		Cassette			Open Reel		
Format or Type		Type-A	Type-B	D6	Multi-D1		1’ Type-C(mod)		1’ Type-C(mod)
					Biga	Quadriga			
Conventional Name*									
Rec./Pb. Time				64 min					
Video Spec.	Luminance								
	Chrominance								
	No. of lines								
Audio Spec.	Dig. or Anlg.			PCM					
	No. of Ch’s			U stereo pairs					
Meta Data									
Media	Size								
	Substance			Metal Particle					
Application Example				Studio deck					
Notes				3/4 inch tape					

* Each Format or Type is commonly known as listed here.

Table 5 Disk 1250/50 *Overview*

Digital/Analogue		Digital				Analogue		
Comp./Non-Comp.		Compression		Non-Compression		Removable		
Handling		Removable	(Non-Rem.)	(Removable)	Non-Rem.			
Rec. and/or Pb.		Rec. and Pb.			Rec. and Pb.	Pb. Only	Write-Once	Rec. and Pb.
Format or Type		MO*			HDD(RAID)*	Optical	Wobbling	MO
Conventional Name*								
Rec./PB. Time								
Video Spec.	Luminance							
	Chrominance							
	No. of lines							
Audio Spec.	Dig. or Anlg							
	No. of Ch's							
Meta Data								
Media	Size							
	Substance							
Notes								

MO: Magneto Optical

HDD(RAID): Hard Disk Drive (Redundant Array of Inexpensive Disks)

* Each Format or Type is commonly known as listed here.

Table 6 HDTV Digital VTR (1250/50) *Details*								
Format or Type			1 inch	D-6	Type-A	Type-B	DVC-HD
Conventional Name*							
Sampling Freq.	Video	MHz		74.25			40.5
	Audio	kHz		48			48/44.1/32
Quanti-zation	Video	bit/ Sam		8			8
	Audio			20/24			16/12
Audio Ch's		Num.		12			4/6/8
Compression (Video)							Intra Fi/Fr DCT 1/6
Ch. Coding				8-12 map			24-25 S-INRZI
Total Rate		Mb/s		1,212			83.7
Video Rate		Mb/s		958.5			49.896
Rec. RF Ch's		Num.		8			2
ECC	Outer			227, 211			85, 77
	Inner			254, 240			149, 138
Drum Diameter		mm		96.5			21.7
Drum Rotation		rsp		150			150
No. of Tracks		/Field		48			20/Frame
Tape Speed		mm/s		497			37.625
Track Pitch		µm		22			10
Min. Wavelength		µm		0.81			0.49
Width of Tape				19.01			6.35
Media Substance				Metal Particles			Metal Particles
Hc		Oe		1600			1500
Cassette size		mm		172x109 254x150 366x206			66x48 125x78
Rec. time		min		8/28/64			30/135
SMPTE Standard				277M,278M			
IEC Standard							

* Each Format or Type is commonly known as listed here.

Table 7 HDTV ANALOGUE VTR (1125/60),(1250/50) *Details*

Format or Type			1125/60	1125/60	1250/50		
			1 inch	UNIHI	1 inch		
Conventional Name*							
Video	Luma.	MHz	20	20			
	Chro.		10	7			
Audio Sampling		kHz	—	48			
Audio Ch's		Num.	2 Analogue ch's	4			
Rec. RF Ch's		Num.	4	2			
Drum Diameter		mm	134.6	76			
Drum Rotation		rsp	60	90			
No. of Tracks		/Field	4	6			
Tape Speed		mm/s	483	119.709			
Track Pitch		µm	89	24.8			
Width of Tape		mm	25.4	12.650			
Media Substance				Metal Particles			
Tape Hc		Oe					
Cassette size		mm	___	205x121.5			
Rec. time		min	63	63			
SMPTE Standard							
IEC Standard							

* Each Format or Type is commonly known as listed here.