An MP@HL Codec and its Performance

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Abstract: In Japan, digital HDTV services via broadcasting satellite are planned to start in 2000. NHK has developed an HDTV codec conforming to the MPEG-2 MP@HL and estimated the coded picture quality with diverse image sequences. This paper shows the codec specifications and presents the result of the picture quality assessment.

1. Introduction

In Japan, digital broadcasting via broadcasting satellite (BS) is in preparation for starting in 2000. NHK has been developing the Integrated Services Digital Broadcasting (ISDB) system, which is intended for a digital HDTV broadcasting system exhibiting "high quality audio and video" and "high performance multimedia services."

The video compression (encoding) technique is the key technology to realize digital broadcasting. The MPEG-2 video standard (ISO/IEC 13818-2)[1] is now employed worldwide, and is expected to serve as a generic encoding system capable of handling a wide range of operations. We have developed a new MPEG-2 HDTV codec, which serves a wide range of applications from program material transmission to emission[2].

The quality of digitally encoded picture at lower bit rates depends greatly on image content; therefore, a variety of video materials should be tested to verify the digital encoding system applied to practical broadcasting. Subjective assessment tests have been carried out to evaluate the picture quality using various broadcast program materials.

This paper describes the specifications of the HDTV codec and shows the relation between bit rates and the picture quality for digital HDTV broadcasting .

2. Specifications of HDTV Codec

When considering the digital HDTV broadcasting system, it is necessary to confirm decoded picture quality under such varied conditions as bit rates and encoding parameters, and to monitor the coding status quantitatively. The MPEG-2 standard is employed for our HDTV codec as video coding, audio coding

and multiplexing, considering that the MPEG-2 standard is internationally adopted for broadcasting. In addition, an extension of the specifications is installed to study the coding scheme for digital HDTV broadcasting use, ranging from program material transmission to emission. Table 1 shows the basic specifications of HDTV codec experimentally developed.

2.1. Video Coding

The video coding scheme used in the codec complies with MPEG-2 MP@HL (Main Profile at High Level), which is also the standard for DTV (Digital Television) in the U.S.A. The codec also works in conditions such as Simple Profile including Intra-Slice for low delay and at H1440 level. Adaptive temporal-spatial noise reduction and band limitation filters are introduced for preprocessing to reduce the apparent degradation of picture quality. Moreover, while MP@HL conforms only to the 4:2:0 chrominance format, with the maximum bit rate limited to 80Mbps, the codec is designed to conform to the 4:2:2 chrominance format, and its maximum bit rate is extended to 120Mbps, in consideration of the high picture quality applicable for contribution purpose.

The MPEG-2 standard contains 4:2:2 profile for 4:2:2 encoding, where only specifications equivalent to those of the SDTV are defined now. When determining the codec specifications, those for 4:2:2@ML were extended to the HDTV level. Table 2 compares the specifications of our codec, MP@HL and 4:2:2@ML.

Table 1 Specifications of HDTV codec.

Item		Specification
Video	Input/Output signal	ITU-R Rec. BT.709 1125/60/2:1 HDTV
	Coding algorithm	MPEG2 MP@HL (M=1,3,N=1-60)
	Coding format	1920/1440-pel, 1035/1080-line, 4:2:2/4:2:0
	Motion estimation	1/2-pel accuracy, full search P-picture: ±31.5(H), ±31.5(V) and ±127.5(H), ±15.5(V),cross-shaped B-picture: 1-frame interval ±31.5(H), ±31.5(V) 2-frame interval ±63.5(H), ±31.5(V)
	Bit-rate	15-120Mbps
Audio	Input/Output signal	AES3(AES/EBU), 48kHz, 16bit linear
	Number of channels	2-5 ch
	Coding algorithm	MPEG-2 / PCM
	Bit-rate	128k/192k/768k bps/ch
Auxiliary data		9.6kbps , 64kbps
Multiplex		MPEG-2 Transport Stream
Transmission interface		TS / TS+RS(204,188) / ISDB
Transmission bit-rate		15-120Mbps

2.2. Audio Coding, Multiplexing, and Interface

The audio coding scheme of the codec conforms to MPEG-2 (ISO/IEC 13818-3), while MPEG-2 AAC (ISO/IEC 13818-7) is to be adopted for the BS digital broadcasting in Japan. In addition, uncompressed PCM is available for contribution purposes. Up to five-channel audio can be transmitted.

The multiplexing system conforms to MPEG-2 TS (Transport Stream). User data transmission is also available.

Three types of interface are provided: MPEG-2 TS, TS with channel coding similar to DVB, and the type for ISDB. The ISDB interface conforms also to the variable bit rate encoding to be used for flexible multiplexing, which can assign an arbitrary bit rate according to picture contents.

2.3. Monitoring

To monitor the encoding status, the codec is designed to have the capability of collecting a variety of information concerning the operation status. On a real-time basis, picture type, quantization characteristics, generated number of bits, buffer occupation and PSNR can be measured per frame. DCT type, prediction mode, quantizer scale and average luminance level can be measured per macro block on an off-line basis.

3. Picture Quality for Digital HDTV Broadcasting

3.1. Criticality of HDTV Programs[4]

In digital coding, picture quality obtained depends on picture contents. Criticality is a objective measure of difficulty for digital coding, where entropy-type criticality is defined as "amount of output bits per pixel of a hybrid DCT encoder with a fixed quantizer."[3] Criticality values are useful when selecting test images to be used to subjectively evaluate the quality of coded pictures.

Our HDTV codec has a monitoring functionality for encoding status, as mentioned previously, allowing measurement of criticality. The codec measures the number of bits generated for every frame and convert it into criticality. In general, the number of bits per frame generated is influenced greatly by the

Table 2 Comparison of video encoding specifications.

Item	Our HDTV Codec	MP@HL	4:2:2@ML
Coding format	1920x1035 / 1080 1440x1035 / 1080	1920x1035 / 1080 etc.	720x483 etc.
Chrominance signal format	4:2:2 / 4:2:0	4:2:0	4:2:2 / 4:2:0
GOP structure	IPPPPPP... IBBPBBP... PPPPPPP... etc.	IPPPPPP... IBBPBBP... etc.	IPPPPPP... IBBPBBP... IIIIIII etc.
Quantization matrix	Y/C Independent	Y/C Common	Y/C Independent
Intra DC precision	8,9,10,11 bit	8,9,10 bit	8,9,10,11 bit
Maximum bit-rate	120Mbps	80Mbps	50Mbps
vbv buffer size	14,680,064 bit	9,781,248 bit	9,437,184 bit

type of picture: I, P, and B. For this reason, when measuring criticality, all frames are coded as P-picture(Intra-Slice) to eliminate variations in the number of bits generated due to differences among picture types.

Figure 1 shows the measured criticality of several test sequences and the cumulative frequency of occurrence of criticality in real HDTV programs. The criticality of HDTV programs was measured for one week, from February 5 to 11, 1997, for a total of 55 hours and 45 minutes.

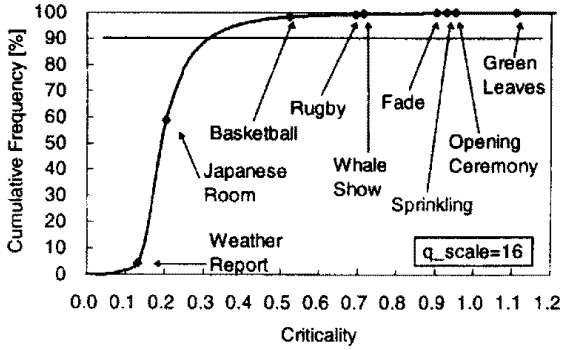

Figure 1 Cumulative frequency of occurrence of HDTV broadcast programs and criticality of test sequences.

3.2. Subjective Assessment by the Codec

To study an appropriate bit rate for digital HDTV broadcasting, an assessment test for picture quality was carried out.

Tables 3 and 4 show the conditions of the subjective assessment test and the test sequences, respectively. The test sequences subjected to the assessment test are chosen referring to their criticality. As it is stated that

Table 3 Conditions of subjective assessment test.

Assessment Method	DSCQS(double stimulus continuous quality scale) ITU-R Rec. BT.500-7[5]
Test Sequence	1125/60/2:1 HDTV, 11 sequences
Display	41-inch CRT for studio use (HDM4130)
Viewing Distance	3H(H: Picture Height)
Observer	18 non-experts (valid 17)
Test Item	MP@HL (M=3,N=15) Bit-rate: 16, 18, 22Mbps

Table 4 HDTV test sequences for subjective assessment.

Sequence	Contents
Weather Report	Woman standing in front of a synthesized weather map (ITU-R)
Japanese Room	Woman walking through a Japanese room, slow pan (ITU-R)
Basketball	Basketball players in rapid motion, zoom/pan (MPEG/NHK)
Rugby	Rugby players in a field in front of spectators, random fast motion (NHK)
Whale Show	Spectators watching at a whale jumping show, fast pan (ITU-R)
Fade	"Rustling Leaves"(ITU-R) with fade in/out
Sprinkling	Woman under synthesized sprinkling water, random motion (ITU-R)
Opening Ceremony	Stadium overview, green lawn field, red carpeted stage (ITU-R)
Green Leaves	Path in a wood, zoom/random motion (ITU-R)

ITU-R : ITU-R HDTV test sequences (ITU-R Rec. BT.710-2[6])

MPEG : MPEG test sequences

NHK : NHK HDTV programs

test sequences should be chosen to be "critical but not unduly so" in ITU-R Rec. BT.500-7[5], most of the sequences used are those whose criticality is relatively high. The majority of the sequences are located in the upper 10% of the distribution of criticality for HDTV programs. The bit rates for the test were chosen taking into account the condition that two HDTV programs be provided within one BS transponder using Trellis-coded 8PSK modulation. The transmission bandwidths under consideration are 27, 33, and 36MHz.

3.3. Results of Assessment Test

The results of the assessment test are given in Figure 2. The difference in picture quality is shown as a percentage between the reference and a coded picture. ITU-R Recommendation[7] describes that user requirements demand a picture quality difference of DSCQS 12% or less when reception condition is good.

With a bit rate of 18Mbps, some high criticality images have a picture quality difference exceeding 20%. At the lower bit rate of 16Mbps, degradation of picture quality increases. At 22Mbps, most sequences show excellent picture quality, although some still show degradation. Even 22Mbps is not sufficient for a high criticality scene, as is found in "Green Leaves."

The high criticality sequences often contain vigorous motion, such high-frequency components as sprinkled water or a large audience in a stadium, or a temporal level fluctuation, such as fade in/out and scene

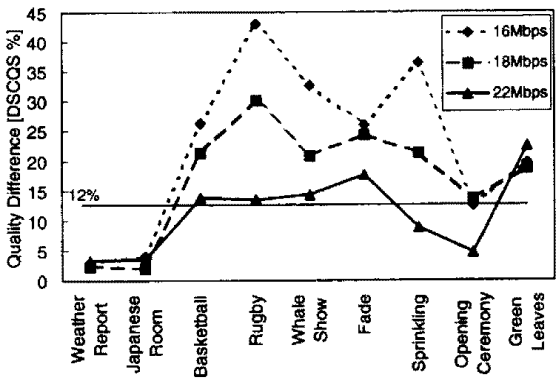

Figure 2 Result of subjective assessment test .

changes. Other degradations of picture quality occur partially in areas with highly saturated colors.

The evaluation test proves the necessity of improving picture quality especially for high criticality sequences. Improvement of picture quality for MPEG-2 can be achieved by modifying the encoding method, maintaining compatibility with the existing decoder. For further improvement of picture quality, an investigation into the factors of quality degradation is under way, along with studies to improve the encoding method, including improvement of motion estimation, reduction of amount of overhead information, optimization of quantizer, optimization of selection criteria for various modes, as well as improvement of picture quality by post-processing at the decoder.

4. Conclusion

An HDTV codec conforming to MPEG-2 MP@HL was developed for the purpose of emission as well as program material

transmission. This codec has been effectively used in developing the standard of BS digital broadcasting in Japan.

Subjective evaluation tests show that with 22Mbps, sufficient picture quality is obtained, while with 18Mbps, some quality degradation is observed in images containing vigorous motion. Improvement of the picture quality for images having higher criticality is under development by studying an efficient encoding method, including improvement of motion estimation method.

When considering the total system at a broadcast station, compression techniques are being introduced in various program production equipment. In the broadcasting chain, evaluation of performance with encoding and decoding in tandem are important, and thus should be studied in the future.

References

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