HEVC/H.265 CODEC SYSTEM AND TRANSMISSION EXPERIMENTS AIMED AT 8K BROADCASTING

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ABSTRACT

This paper introduces the world's first video and audio codec system that complies with 8K broadcasting standards and describes transmission experiments via a broadcasting satellite using this system.
8K Super Hi-Vision (8K) is a broadcasting system capable of highly realistic 8K Ultra High Definition Television (UHDTV) video and 22.2 multichannel audio. In Japan, domestic standards for 8K broadcasting were formulated in 2014 and 8K test broadcasting will begin in 2016. We have developed an 8K High Efficiency Video Coding (HEVC)/H.265 codec system that complies with the domestic standards.
In this paper, we first explain the features and a roadmap for 8K broadcasting. We then introduce the features of the 8K HEVC/H.265 codec system developed. Finally, we describe transmission experiments using a satellite system that is equivalent to the one that will be used in test broadcasting. The results allowed us to confirm that the developed system provides high-quality transmission at the expected bit rate during test broadcasting.

INTRODUCTION

An 8K Super Hi-Vision (8K) broadcasting system capable of highly realistic 8K Ultra High Definition Television (UHDTV) video and 22.2 multichannel (22.2 ch) audio is currently under development. In Japan, domestic standards for 8K broadcasting were formulated in 2014 and 8K test broadcasting using a broadcasting satellite will begin in 2016. The standards prescribe video coding, audio coding, multiplexing and transmission schemes, and other such procedures. Compression of video data to a transmittable bit rate while maintaining high quality is a key issue that must be addressed in order to realize 8K broadcasting.
A new video coding scheme, referred to as High Efficiency Video Coding (HEVC)/H.265 (1), was standardized in 2013. HEVC supports 8K video formats and achieves approximately twice the compression level of the existing Advanced Video Coding (AVC)/H.264 scheme. Its coding performance shows a particularly significant improvement relative to the previous schemes for high-resolution video such as 8K. On the other hand, the computational cost for HEVC encoding and decoding is quite high and is reported to be more than twice that of AVC. This makes realization of real-time HEVC processing challenging.
We have developed the world's first 8K HEVC/H.265 real-time codec (encoder and decoder) system that complies with the domestic standards. The system allows 22.2 ch audio coding and video/audio multiplexing, with these functions integrated into the video

encoder and decoder. The system was tested by transmission experiments using a broadcasting satellite in 2015.
In this paper, we first explain the features and a roadmap for 8K broadcasting. We then introduce the features of the 8K HEVC/H.265 codec system. Finally, we describe transmission experiments using a satellite system that is equivalent to the system that will be used for the test broadcasts.

8K BROADCASTING

In this section, we explain the features and a roadmap for 8K broadcasting.

8K Super Hi-Vision

8K is a TV broadcasting system designed to deliver highly realistic 8K video and 22.2 ch audio. Table 1 shows the parameters for 8K and a current 2K digital broadcasting system using a broadcasting satellite (BS) in Japan. The 8K provides much higher fidelity than the existing broadcasting system.

		8K Super Hi-Vision	2K BS digital broadcasting
Video	spatial resolution (pixels in H x V)	7,680 × 4,320	1,920 × 1,080
	aspect ratio	16:9	16:9
	scan mode	Progressive	Interlaced
	frame rate (Hz)	120, 120/1.001, 60, 60/1.001	60/1.001
	bit depth (bit)	10, 12	8
	color gamut	Rec. 2020	Rec. 709
Audio	number of channels	22.2	maximum 5.1
	sampling rate (kHz)	48, 96 (optional)	32, 44.1, 48
	quantization bit (bit)	16, 20, 24	16 or more

Table 1 - Parameters for 8K Super Hi-Vision
and current BS digital broadcasting in Japan

The 8K video format is internationally standardized in Recommendation (Rec.) International Telecommunication Union Radiocommunications Sector (ITU-R) BT. 2020 (2). Since the number of pixels in the horizontal direction is 7,680 pixels, it is called “8K.” Its characteristics are higher spatial resolution, higher frame rate, higher bit depth, and wider color gamut than those of the existing broadcasting video formats. The uncompressed bit rate for the 8K/12 bit/60 Hz format is approximately 72 Gbps.
The 22.2 ch audio format is standardized in Society of Motion Picture & Television Engineers (SMPTE) 2036-2-2008 (3). It is characterized by a larger number of channels, increased sampling rate, and larger quantization bit. The uncompressed bit rate for the 22.2 ch/48 kHz/24 bit format is approximately 25 Mbps.
Because of the enormous uncompressed bit rate of 8K video, compression of the video to a transmittable bit rate while maintaining high quality is a key issue for 8K broadcasting.

8K Broadcasting Roadmap

In Japan, a committee of the Ministry of Internal Affairs and Communications (MIC) presented a roadmap for 8K broadcasting in 2014. According to the roadmap, 8K test broadcasting will begin in 2016 and 8K broadcasting is planned to begin by 2018.

Broadcasting satellite system will be used for transmission in both broadcasting types. Moreover, 8K broadcasting is expected to become common in 2020, the year of the Olympic and Paralympic Games in Tokyo, Japan.

8K HEVC/H.265 CODEC SYSTEM

We have developed the world's first 8K HEVC/H.265 codec (encoder and decoder) system that complies with the 8K broadcasting standards.
Figure 1 shows a photograph of the system. The system is composed of an encoder to compress video and audio data, a decoder to decompress encoded video and audio data (upper silver devices in the racks), and interface converters for encoder input and decoder output. The 8K HEVC encoder was developed in 2013 as reported by Sugito et al. (4), and the 8K HEVC decoder has been newly developed in 2015. Table 2 shows the system specifications. In this section, we introduce the features of the new system.

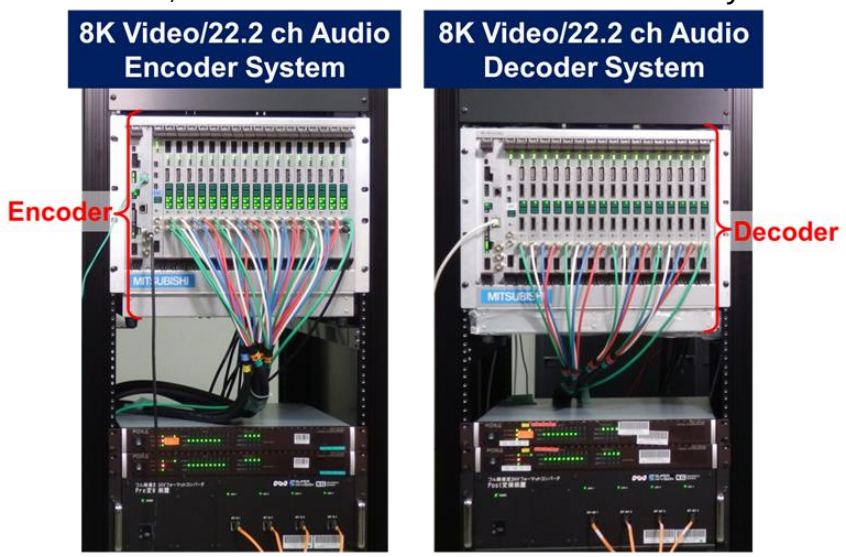

Figure 1 - 8K HEVC/H.265 codec system

Video	coding scheme	MPEG-H HEVC/H.265 Main 10 profile@ Level 6.1
	spatial resolution and frame rate	7,680 × 4,320/59.94 P
	chroma format and bit depth	4:2:0/10 bit
	input/output interface	3G-SDI × 17
Audio	coding scheme	MPEG-4 AAC Low Complexity (LC)
	number of input/output channels	22.2 ch
	sampling rate and quantization bit	48 kHz/24 bit
	input/output interface	MADI (AES10)
Multiplexing	multiplexing scheme	MPEG-H MMT
	input/output interface	RJ-45 × 1

Table 2 - 8K HEVC/H.265 codec system specifications

Real-time 8K HEVC Video Encoding and Decoding

The codec is capable of real-time 8K HEVC video encoding and decoding, which require an extremely large number of calculations. Figure 2 is a diagram of the 8K HEVC encoder.

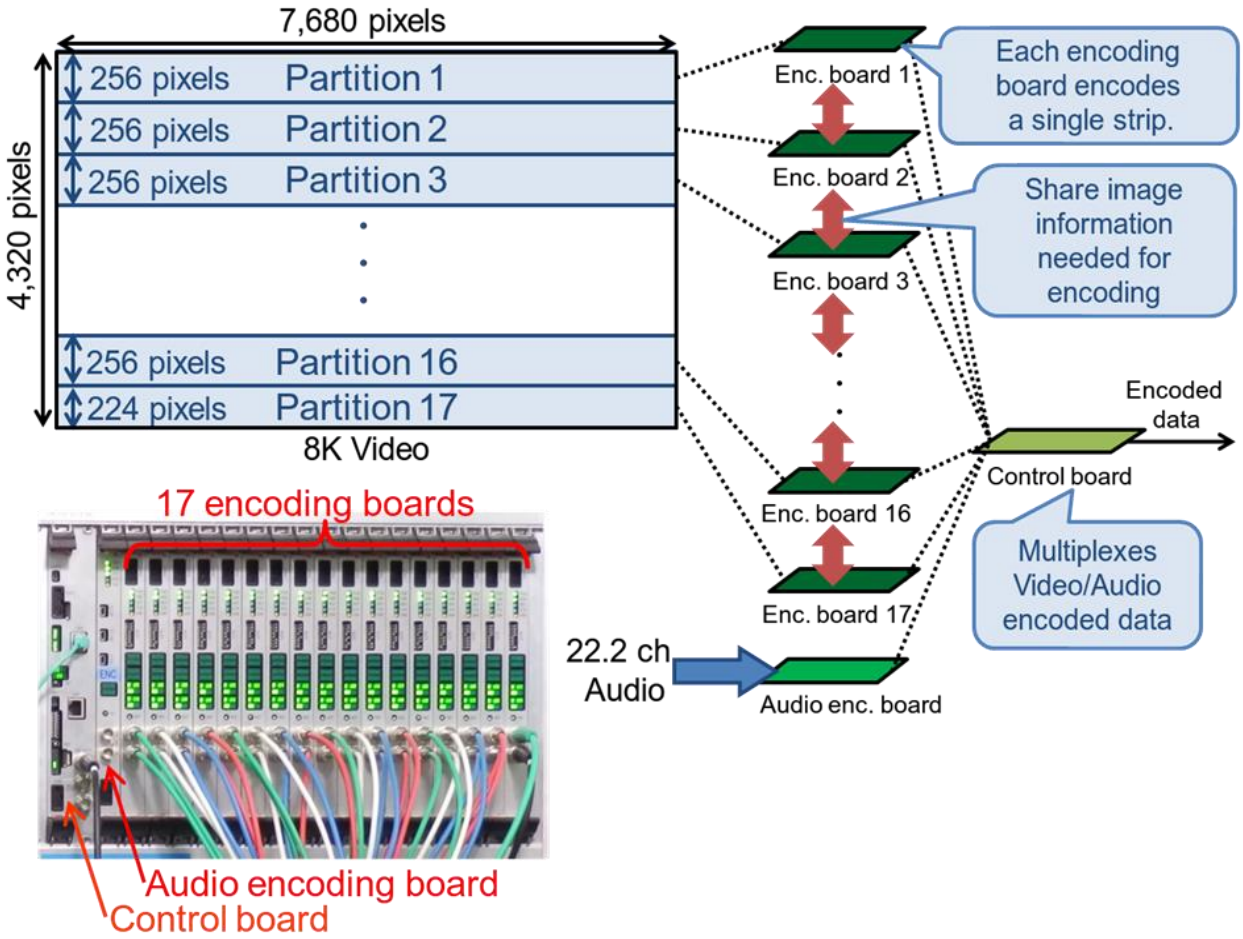

Figure 2 - A diagram of the 8K HEVC encoder

To enable real-time processing, each video frame is spatially divided into 17 horizontal strips, and these strips are encoded in parallel. The encoder consists of 17 encoding boards. Each encoding board processes a single strip, and adjacent boards share the motion information needed for encoding. This method of partitioning was chosen based on a number of factors, including the transmission capacity of shared motion information between encoding boards, the pixel count for the 3G-SDI standard, and the convenience of a wider horizontal motion search range.

The codec system adopts HEVC/H.265 (1) as the video coding scheme. HEVC is the latest video coding scheme standardized in 2013; its coding performance is significantly improved compared to previous schemes, especially for high-resolution videos such as 8K. This is because HEVC has many more coding modes compared to the previous video coding schemes. On the other hand, the availability of many coding modes can lead to difficulties in selecting the most appropriate mode, and this is one of the current problems for real-time processing using HEVC. To address this, the encoder automatically determines the coding parameters depending on the complexity of the original image, coding result, and parameter setting.

The newly developed decoder is implemented following a similar design. The decoder is

composed of 17 decoding boards, and each decoding board processes a spatial partition of the video frame in parallel.

Audio Codec and Multiplexing Capability

The codec system includes a 22.2 ch audio encoder/decoder using Moving Picture Experts Group (MPEG)-4 Advanced Audio Coding (AAC) (5) and a multiplexing/demultiplexing capability using MPEG-H MPEG Media Transport (MMT) (6) to combine and transmit compressed video and audio data**.**
As shown in Figure 2, the audio encoder is implemented by one board and integrated into the 8K HEVC encoder. The audio decoder is made in the same manner. The multiplexing capability is implemented as a function of the control board in the encoder. The board combines elementary stream (ES) from video and audio encoding boards and outputs encoded data in the MMT format. Demultiplexing capability is contained in the decoder control board that interprets the data in the MMT format and distributes ES for video and audio decoding boards.

Compliant with domestic standards for 8K broadcasting

This is the video and audio codec system that complies with the 8K broadcasting standards. In Japan, the domestic standards for 8K broadcasting were formulated by the Association of Radio Industries and Businesses (ARIB) in 2014. The standards prescribe video coding, audio coding, multiplexing and transmission schemes, and other such procedures. The video coding, audio coding, and multiplexing schemes of the system comply with the domestic standard ARIB STD-B32 ver.3.1 revised in December 2014.
The standard governs the 8K video encoding method, and we therefore modified the 8K HEVC encoder to conform to the standard. Figure 3 shows the encoder modification based on the standard.

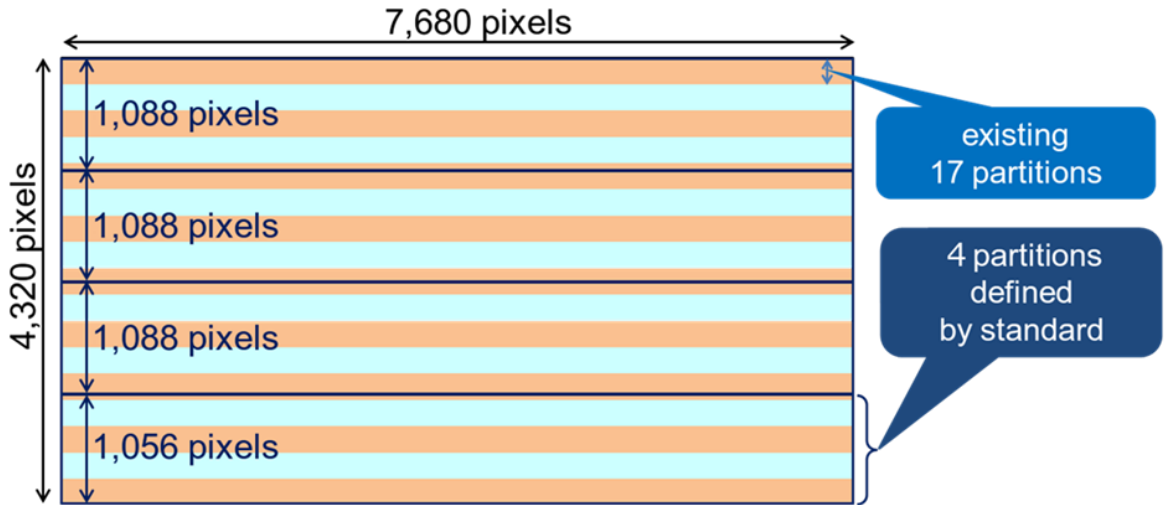

Figure 3 - Encoder modification based on domestic standard

For 8K video encoding, the standard mandates four horizontal spatial divisions; three of these consists of 1,088 pixels in the vertical direction and the fourth one consists of 1,056 pixels in the vertical direction. Since the standard allows subdivision of the required four partitions, we modified the encoder to subdivide the four partitions by the existing 17 partitions.

TRANSMISSION EXPERIMENTS

We conducted the world's first transmission experiments via a broadcasting satellite using the developed 8K HEVC/H.265 codec system. The experiments were exhibited in OPEN HOUSE at NHK Science & Technology Research Laboratory (STRL) in May 2015 (7). In this section, we describe the 8K experimental broadcasting system and the transmission experiments.

8K Experimental Broadcasting System

Figure 4 shows a diagram of the 8K experimental broadcasting system.

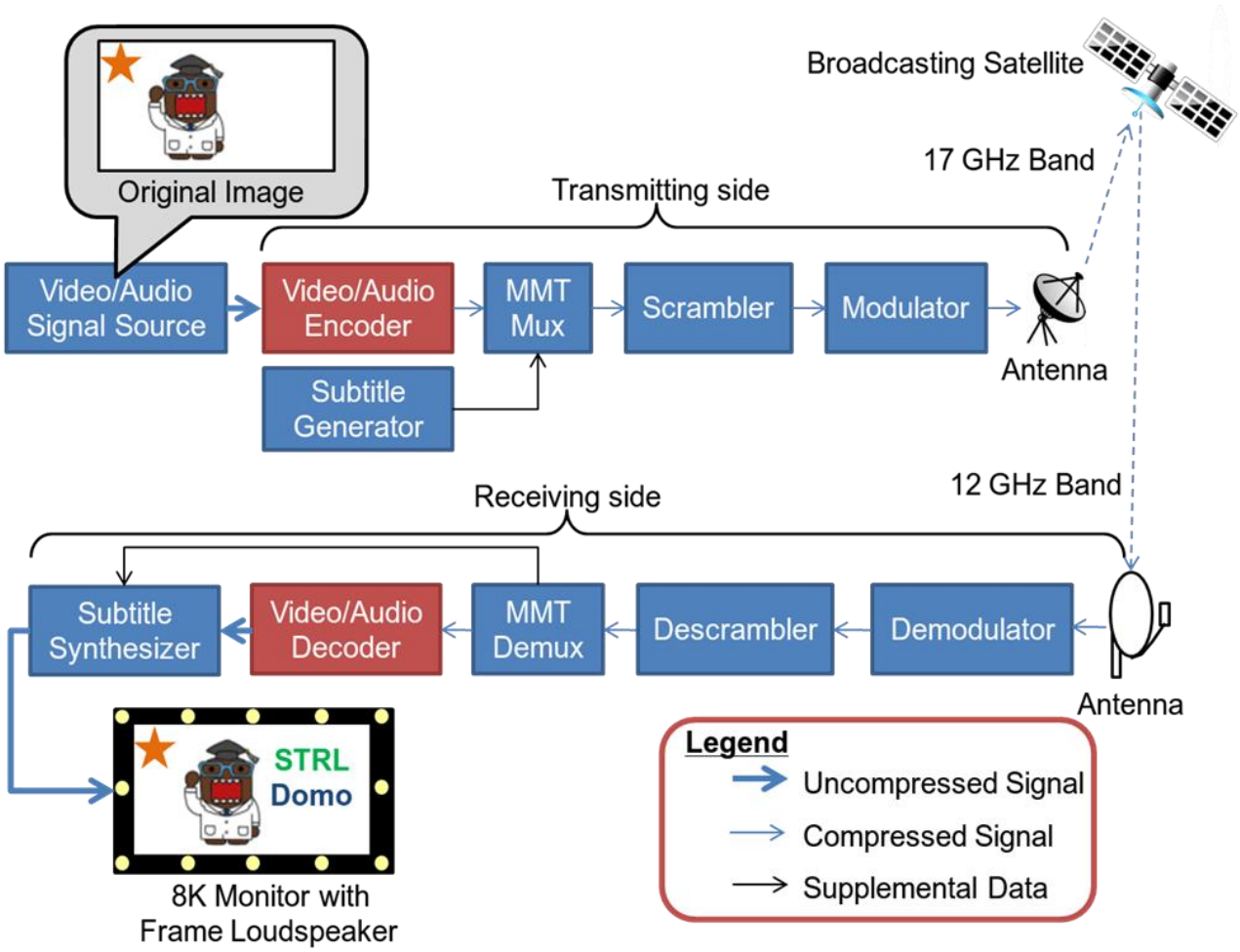

Figure 4 - A diagram of the 8K experimental broadcasting system

In the system, uncompressed video and audio is provided from a signal source. More specifically, the signal is generated from recorders or cameras and microphones. An encoder then compresses the video and audio to a transmittable bit rate and outputs the compressed data in the MMT format. Table 3 shows the video and audio compressed bit rate settings in ES and the compression ratio. Although the video and audio bit rate for 8K broadcasting is still under consideration, we chose the bit rate by taking the bit rate for data broadcasting, transmission header, and the transmission capacity of the satellite into consideration. Uncompressed video and audio formats in the system are 8K/59.94 Hz/12 bit and 22.2 ch/48 kHz/24 bit, respectively. The compression ratio for the video is very large because of the HEVC scheme.

	compressed bit rate (ES)	approx. uncompressed bit rate	approx. compression ratio
Video	85 Mbps	72 Gbps	840
Audio	1.4 Mbps	25 Mbps	20

Table 3 - Compressed bit rate settings in the experiments

Next, the compressed and the subtitle data are combined by an MMT Multiplexer (Mux) and are encrypted by a scrambler. To adapt to the transmission path, the amount of the encrypted data is restricted to not more than 100 Mbps. Finally, the data is transmitted via a broadcasting satellite through a modulator and an antenna. The above devices are on the transmitting side and generally exist in a broadcasting station.

In TV transmission, the data for video dominates the transmission. As shown in Table 1, the uncompressed bit rate for 8K video is 32 times larger (16 times larger in spatial resolution and twice larger in temporal resolution) than that of the current BS broadcasting. In the system, 8K transmission is realized by adapting the HEVC scheme and transmission scheme. The compression performance of HEVC is approximately 4 times larger than that of the MPEG-2 video coding scheme used in the current 2K BS broadcasting. In the experiments, the broadcasting satellite is the same as the one currently used in the 2K BS broadcasting; however, because of the improvement in the transmission scheme, it can transmit twice as much data (up to approximately 100 Mbps) as the existing system studied by Suzuki et al. (8). The transmitting scheme is defined by the domestic standard, ARIB STD-B44 ver.2.0, in 2014. The satellite used in the experiments is planned to be used in 8K test broadcasting in 2016.

As shown in Figure 4, the transmitted data from the satellite is received by a demodulator through an antenna and decrypted by a descrambler. An MMT demux (demultiplexer) separates the subtitle data and the compressed data for video and audio. Video and audio are then expanded into the uncompressed data formats by a decoder, and a subtitle is synthesized on the video. These are on the receiving side and will be installed in consumers' homes by 2020.

Experimental Results

We conducted transmission experiments for the 8K broadcasting system.

The results showed that 8K video and 22.2 ch audio are properly encoded, transmitted, and decoded. We confirmed that the developed system provides high-quality transmission at the expected bit rate during test broadcasting. We measured the delay time between the original video input and the decoded video display and found that it was approximately 3.5 s.

CONCLUSIONS

We have developed the 8K HEVC/H.265 codec system that complies with 8K broadcasting standards. We conducted transmission experiments with the system by using a broadcasting satellite. The results showed that the system is capable of 8K broadcasting.

REFERENCE

1. ISO/IEC 23008-2, 2013. High efficiency coding and media delivery in heterogeneous environments - Part 2: High Efficiency Video Coding | Recommendation ITU-T H.265, 2013. High Efficiency Video Coding
2. Recommendation ITU-R BT.2020-1, 2014. Parameter values for ultra-high

definition television systems for production and international programme exchange
3. SMPTE 2036-2-2008, 2008. Ultra High Definition Television —Audio Characteristics and Audio Channel Mapping for Program Production
4. Y. Sugito, K. Iguchi, A. Ichigaya, K. Chida, S. Sakaida, Y.Shishikui, H. Sakate, T. Itsui, N. Motoyama and S. Sekiguchi, 2013. Development of the Super Hi-Vision HEVC/H.265 Realtime Encoder, SMPTE Conf. Proc., vol. 2013, no. 10, pp. 1-16.
5. ISO/IEC 14496-3:2009/Amd 4, 2013. Coding of audio-visual objects - Part3: Audio
6. ISO/IEC 23008-1, 2014. High efficiency coding and media delivery in heterogeneous environments - Part 1: MPEG media transport (MMT)
7. http://www.nhk.or.jp/strl/open2015/en/tenji_1.html, 2015. 8K Satellite Broadcasting Experiment
8. Y. Suzuki, K.Tsuchida, Y.Matsusaki, A.Hashimoto, S.Tanaka, T.Ikeda and N.Okumura, 2014. Transmission System For 8K Super Hi-Vision Satellite Broadcasting, IBC2014 Conference, p.8.4