CELEBRATING THE LAUNCH OF 8K/4K UHDTV SATELLITE BROADCASTING AND PROGRESS ON FULL-FEATURED 8K UHDTV IN JAPAN

Satoshi Hara, Akira Hanada,
Ichie Masuhara, Takayuki Yamashita, and Kohji Mitani

NHK, Japan

ABSTRACT

NHK started the world's first test satellite broadcasting of 8K/4K ultra-high-definition television (UHDTV), called Super Hi-Vision (SHV), on August 1, 2016. Coverage of the Rio Olympic Games and many fascinating 8K and 4K programs were broadcasted to 8K prototype receivers installed at all of NHK's local stations in Japan.

This paper describes the SHV test broadcast system, especially the program play-out and transmission system and the 8K/4K receivers. In addition, it describes the progress made so far in developing a full-featured 8K system with a 120-Hz frame frequency.

INTRODUCTION

NHK has been engaged in the development and standardisation of the 8K "Super Hi-Vision" (SHV) system since 1995. Super Hi-Vision is a state-of-the-art television (TV) broadcasting system that provides ultra-realistic viewing experiences to viewers, creating the sensation that they are in the actual scene. It consists of ultra-high definition (UHD) video that contains 16 times the number of pixels of high-definition television (HDTV) and 22.2-channel three-dimensional sound.

In September 2014, the Ministry of Internal Affairs and Communications of Japan released a road map for ensuring the spread of 8K/4K through its "Study Group for Advancement of Broadcast Services."[1] The road map[2] called for test satellite broadcasting to begin in 2016, with practical broadcast services to follow in 2018. In parallel with these developments, NexTV-F (the Next Generation Television & Broadcasting Promotion Forum)[3] was established in 2013 to prepare a framework for promoting and deploying 8K/4K broadcasting throughout Japan. NexTV-F has studied the technical specifications necessary for achieving the goals of the road map.

NHK has been following the road map as it has made preparations for 8K/4K broadcasting. Approximately two years were required to develop the play-out and transmission system so that one channel of 8K or two channels of 4K test broadcasting via satellite could start on August 1, 2016.

In this paper, we present an overview of the 8K/4K satellite broadcasting system, with an emphasis on the play-out and transmission system and the 8K/4K receiver. In addition,

because we have started to study a higher-frame-rate system, i.e., full-featured 8K, we present an 8K /120p camera and a 17.3-inch compact 8K monitor working at 120 fps.

8K/4K UHDTV BROADCASTING SYSTEM

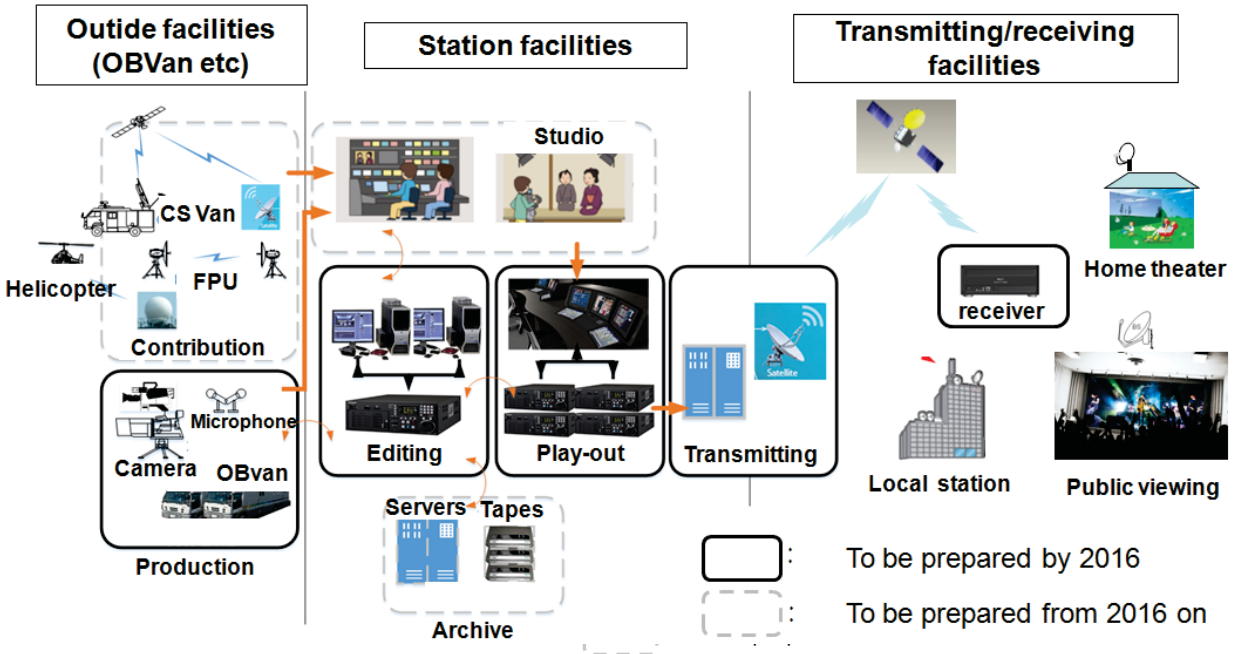

Figure 1 – UHDTV broadcasting equipment

Figure 1 illustrates the overall scheme of the 8K/4K UHDTV satellite broadcasting system.

To produce ultra-realistic 8K content, NHK has been steadily developing and maintaining production equipment for use inside and outside its studios, including cameras, audio equipment, mobile units, and production facilities for post-production and other editing tasks.

The development and maintenance of play-out and transmission systems and monitoring sets for the test broadcasting conducted in 2016 were completed in May 2016.

NHK has also built and maintained 8K/4K broadcast receiving facilities at all 54 of its regional broadcasting stations.

In addition to the existing facilities, an 8K studio and archiving system will be developed for the practical broadcasting to come after the test broadcasting has been completed.

We reported on the 8K production and editing system at IBC 2015. The play-out and transmission system and the receiving facilities are described in detail below.

Play-out and distribution system

Figure 2 is an overview of the transmission system development conducted and planned through 2020. To develop a transmission system in time for the test broadcasting in 2016, NHK has pursued the establishment of standards related to high-speed broadband satellite digital broadcasting at ARIB (the Association of Radio Industries and Businesses) since October 2013. In parallel with this activity, NHK has assisted in preparing operational guidelines at NexTV-F, with version 1.1 being released in March 2016. The play-out and

transmission system and the 8K/4K receiver were developed on the basis of these guidelines.

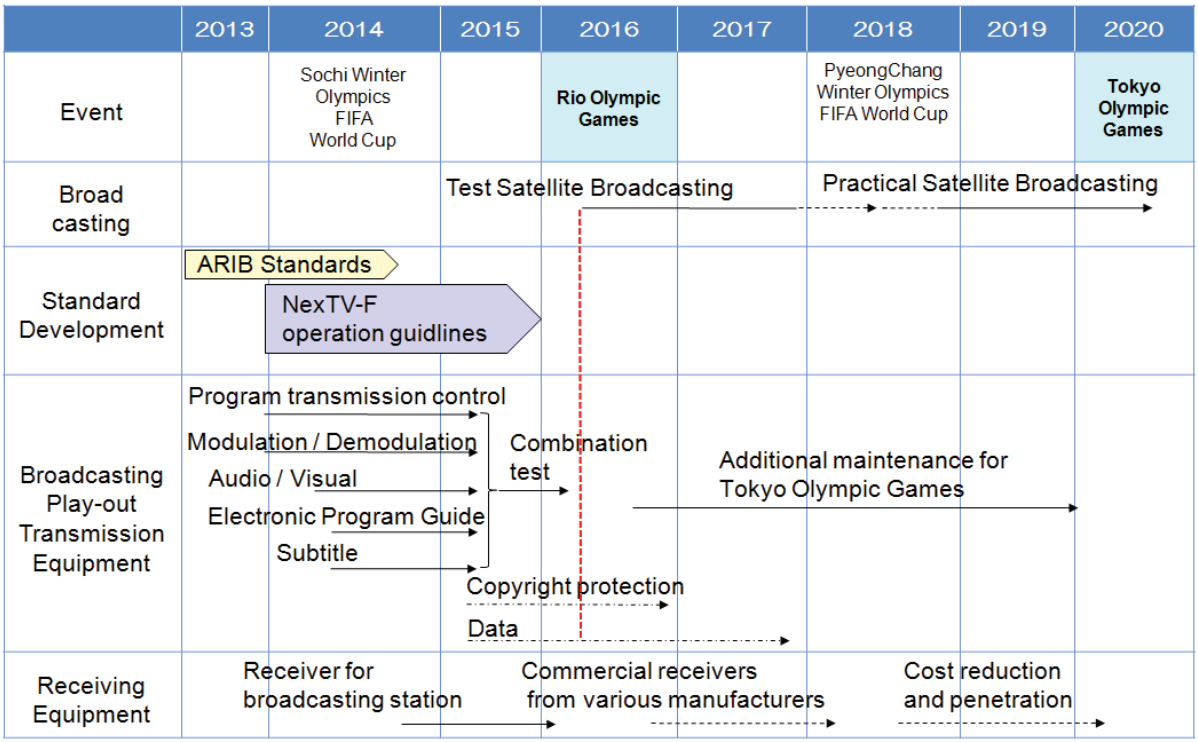

Figure 2 – Roadmap for preparing the play-out and distribution system

Figure 3 presents an overview of the play-out and transmission system, and **Table 1** presents its key specifications. Using a broadcasting satellite (BS), these facilities can distribute a single 8K program or two 4K programs (via a main channel and sub-channel), together with 22.2-ch, 5.1-ch, and 2-ch audio channels (with a maximum of 32 audio channels).

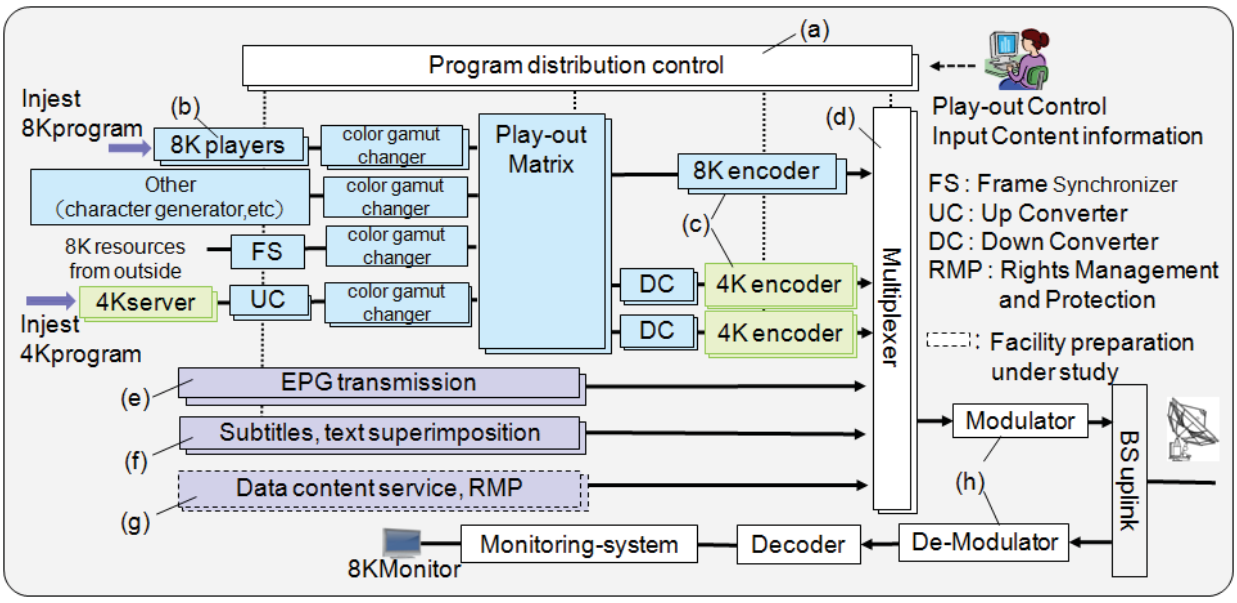

Figure 3 – Play-out / transmitting equipment for test broadcasting

Table 1 – Specifications of play-out and distribution facility

Item	Specifications
Frequency band	11.7～12.2GHz (BS17ch 12.03436GHz)
Bandwidth	34.5MHz
Modulation	π/2 shift BPSK, QPSK, 8PSK, 16APSK
Symbol rate	33.7561 Mbaud
Payload bit rate	Approximately 100Mbps
Broadcasting service	1 8K signal or 2 4K signals
Error correction	LDPC , BCH
Multiplexing	MMT
Video format	4320/60/P , 2160/60/P SDR / HDR(Hybrid Log Gamma)
System Colorimetry	Recommendation ITU-R BT.2020
Video coding	HEVC / Main10
Audio format	22.2ch , 5.1ch , 2ch
Audio coding	MPEG-4 AAC
Multimedia coding	HTML 5 , ARIB-TTML

We have constructed core facilities for 8K equipment that up-convert (UC) and down-convert (DC) input/output 4K signals so that all video signals can be routed in the same manner as 8K signals. The play-out and transmission system has 3G-SDI based interfaces. An 8K video signal and a sound signal with a maximum of 32 channels are embedded in eight 3G-SDIs. A 4K video signal and sound signal embedded in four 3G-SDIs can also be transmitted. The signal can be switched for each program with a 3G-SDI-based routing matrix.

The transmission colorimetry is supposed to compliant with ITU-R BT 2020[4], but there is still a considerable amount of 8K/4K content with the colorimetry of ITU-R BT.709[5]. To accommodate this content, a colour gamut changer is placed downstream of the 8K player and 4K transmission server.

To efficiently broadcast high-capacity and high-quality video/audio information in UHDTV, we are planning to use new source coding schemes, such as high-efficiency video coding (HEVC) and MPEG4 advanced audio coding (AAC). We are also seeking to introduce advanced technologies, such as the new MPEG media transport (MMT) multiplexing system, the latest browser standard (HTML5), and the timed text makeup language standardised by the Association of Radio Industries and Business (ARIB TTML).

The primary functions and services are listed below:

1. The ability to automatically play-out programs by registering program line-up information beforehand.
2. The ability to broadcast by lining up one 8K program or two 4K programs and seamlessly switching between them.
3. The ability to broadcast simultaneously in 22.2-multichannel sound, 5.1-channel sound, and stereo (with a maximum 32 channels).
4. The ability to broadcast subtitles and text superimpositions with 4K resolution.
5. The ability to broadcast electronic program guides (EPG) up to eight days in advance.
6. The ability to broadcast existing 2K content, such as news, subtitles for breaking news, and earthquake bulletins, by up-converting to 8K.

Most blocks of the system have redundancies to ensure stable broadcasting. The primary blocks or functions are described in detail below.

(a) Program distribution control facility

This system automatically transmits programs in accordance with the registered broadcast schedule. It can dynamically manage program line-ups by registering alternative broadcast plans from a control console in advance and switching to an alternate plan when, for example, the ending time of a live sports program changes or a sudden news bulletin appears.

(b) 8K playout devices

8K programs are played out using players equipped with memory cards (Express P2 cards). 4K programs are input into 4K playout servers equipped with XAVC-format HDDs. **Figure 4** illustrates a rack of 8K players**.**

Figure 4 – 8K players

(c) Encoding facility

NHK has developed an 8K/4K HEVC real-time encoder (see **Figure 5**). For video encoding, highly efficient signal compression is needed to transmit a high-capacity 8K. High-efficiency video coding (HEVC) is used for 8K/4K encoding. HEVC is more efficient than MPEG-2 or H.264 (MPEG-4 AVC), which are currently used in Japan for terrestrial and satellite broadcasting, and it allows for more data computations.

The 8K HEVC encoder uses four 4K HEVC LSIs, defined by Rec. ITU-R BT-2073[6], to encode four slices in real time. This system reduces data processing latency and achieves high-resolution encoding that supports broadcasting at 85 Mbps. The audio codec embodies the MPEG-4 AAC standard for broadcasting programs in 22.2-channel sound.

In addition, NHK has developed an 8K software decoder for monitoring that decodes broadcast signals in real time.

The specifications of the video and audio encoding are summarised in **Table 2**.

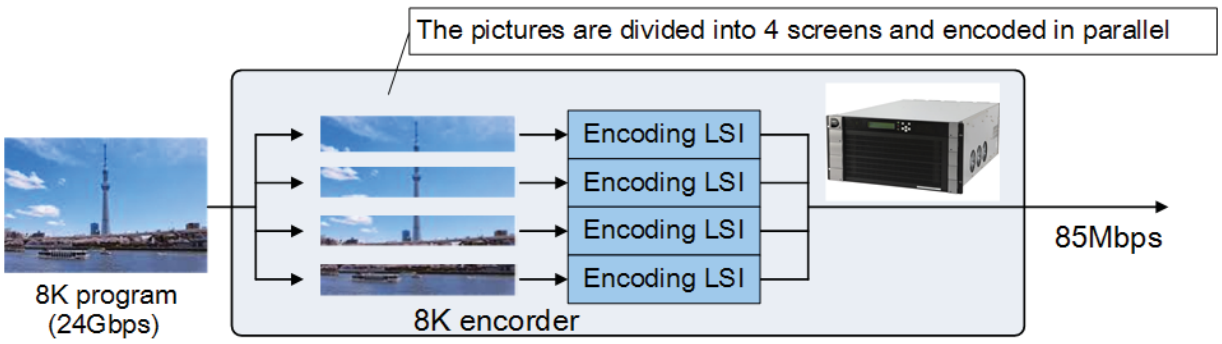

Figure 5 – HEVC real-time encoder

Table 2 – Elements of 8K/4K codec

Video		
Item	Specifications	
Resolution	7,680×4,320	3,840×2,160
Aspect	16:9	
Chroma subsampling	4:2:0	
Bit depth	10	
Scanning method	Progressive	
Frame frequency(Hz)	60 / 1.001	
Color model	Wide colour gamut (ITU-R BT.2020)	
Dynamic Range	SDR / HDR(Hybrid Log Gamma)	
Compression	HEVC / Main10	

Audio	
Item	Specifications
Mode	22.2ch / 5.1ch / 2ch
Sample rate	48kHz
Quantization bit	24 bit
Compression	MPEG-4 AAC

(d) Data multiplexing facility

MPEG media transport (MMT), defined by Rec. ITU-R BT.2074[7], is used for data multiplexing. To broadcast over IP, the output stream format is type length value (TLV), defined by Rec. ITU-R BT.1869[8]. These standards take into account the proliferation in networks that we are experiencing today and are highly compatible with broadcast transmission routes and communication paths.

The multiplexer supports the MMT/TLV standards for multiplexing encoded video, audio, EPG, subtitles, etc. MMT has a video component descriptor that describes the characteristics of the carried video, such as resolution, aspect, and so on. One of the tags of the MMT video component descriptor is 'video_transfer_characteristics', which identifies the dynamic range of the video, i.e., the high dynamic range (HDR) or the standard dynamic range (SDR). By controlling these tags using the data input to the program transmission control facility, SDR/HDR can be identified in the receiving equipment and displayed properly by changing the electro-optical transfer function (EOTF) of the receiving equipment for each program.

(e) Electronic Program Guide (EPG) transmission facility

The EPG transmission facility provides a schedule of the broadcasting programs up to eight days in advance. The equipment repeatedly sends detailed program information, such as title, description, and audio mode, in the form of signalling information (SI) in MMT, to receivers. Each receiver can show the EPG on its 8K monitor. The 8K receiver also shows HTML 5 data that provides information about the current and following programs.

(f) Subtitles, text superimposition facility

The test broadcasting featured subtitled broadcasts for viewers with auditory disabilities. The subtitles are transmitted with 4K resolution based on the ARIB-TTML encoding, an extension of TTML 1.0 (timed-text markup language) recommended by the W3C[9]. Subtitles in smaller fonts than those previously used can be beautifully displayed at 4K resolution in scalable vector graphics (SVG) images.

(g) Data content service

The test broadcasting also included a service that uses the 8K receiver to display data received through the Internet in HTML 5 format. The receiver shows content such as video thumbnails and programs with inserted 4K photographs that display detailed information. An example of these images is shown in **Figure 6**.

Figure 6 – Data content

(h) Modulation/demodulation facility

To maintain a transmission rate of approximately 100 Mbps, i.e., the rate needed to send 8K/4K signals and information such as the EPG and subtitles over satellite broadcasting transmission paths, NHK has developed modulation and demodulation systems that support 16 APSK (16-ary amplitude and phase shift keying), as shown in **Figure 7**.

Figure 7 – 8K/4K Modulator

Operations and monitoring facility

Figure 8 shows the control and monitoring environment of the transmission facility. The control console can change programs in various ways and carry out integrated operations.

Two 85-inch monitors are placed in front of the control console. An environment in which production staff can monitor broadcasts and comprehend the overall conditions of the transmission is facilitated by the installation of a monitoring shelf that keeps track of the conditions of all the equipment and displays their online/offline status and by creating a 22.2-channel sound environment around the control console.

Receiver and Monitor

NHK developed receiver facilities for public viewings at which many people have enjoyed the test broadcasting. We built receiving environments in the public spaces at NHK broadcasting stations. One such receiving facility is shown in **Figure 9**.

Figure 8 – Control room

Figure 9– receiving facility

Each receiving facility is composed of a receiver, an 8K 85-inch monitor, and a 22.2-channel sound system. The receiver is equipped with a newly developed LSI that enables real-time 8K video decoding. 8K/4K video, EPG, subtitles, and text superimposition, as well as services such as HTML5 content received via the Internet, can be displayed on an 8K monitor equipped with four HDMI 2.0 cables.

The receiver also detects the dynamic range of the broadcast content, i.e., whether it is SDR or HDR, and switches the EOTF of the monitor to display the transmitted content correctly. NHK also built a 22.2-channel sound environment with an 85-inch liquid crystal display (LCD) monitor that displays SDR/HDR from the broadcast signals and three 8-channel AV amplifiers.

FUTURE IMPROVEMENTS AND ISSUES

The test broadcasting has been an impressive start to the 8K era. NHK is now making progress on the 8K/4K systems that will broadcast the 2020 Tokyo Olympics and Paralympics. However, there are still many challenges involved in bringing UHDTV broadcasts to viewers, such as developing new equipment and improving existing equipment.

With respect to production facilities, we will provide even higher-resolution video with 'full-featured 8K Super Hi-Vision', which has a 7,680 × 4,320 pixel count, 120-Hz frame frequency, and higher dynamic range with hybrid log-gamma (HLG). We will push forward the development of this full-featured equipment.

Figure 13– 8K/120Hz camera

We have developed an 8K/120-Hz camera to support the HLG system (**Figure 13**)[10]. This camera uses three CMOS image sensors that have 2.8-μm-square pixels. A colour separation prism in the camera head is designed specifically to cover the BT.2020 colour gamut. As a result, an average colour error of less than 1, represented in terms of delta E, is achieved when calculated from 24 colours patched on the Macbeth chart. The dynamic range of the camera output is greater than 2,000%, so it is suitable for shooting 8K/HDR content. 8K displays with a 120-Hz frame frequency have also been developed[11][12]. One is an 85-inch LCD for mastering and home use; the other is a 17.3-inch LCD (**Figure 14**) to be installed in OB vans for 8K production. The smaller one uses IPS (in-plane switching) technologies to provide a wide viewing angle.


Figure 14 – 17.3-inch display

Because the bandwidth of the signal of the full-featured system is greater than 143 Gb/s, the signal interface used to connect devices is a significant issue. In the case of the use of 12G-SDI, which has expanded in the field of 4K production devices recently, we need at least 12


Figure 15– U-SDI (left) and coaxial (right) cables

connections for just one signal. To address this issue, we proposed and standardised a ultra-high-definition signal/data interface (UHD-SI) for ITU-R[13], SMPTE[14], and ARIB. The physical layer of this interface is based on multi-link optical technology. A cable consists of 24 optical fibres, and each fibre can carry a 10.3125-Gb/s-payload signal using a VCSEL transmitter and receiver. As a result, the interface as a whole can carry a 256-Gb/s-payload signal, which is sufficient to carry a full-featured signal. All of the full-featured Super Hi-Vision devices are installed with connectors for this type of interface.

Other challenges include the development of satellite mobile units (SNG), which are essential for live transmissions of sporting and other outside events and for news gathering, wireless transmission equipment (FPUs) for aerial 8K video transmissions from helicopters, and 8K studios that play programs that switch between content from different locales. It is especially important to study methods for transmitting high-capacity data using as little of the frequency band as possible.

With respect to transmission facilities, NHK is working to improve compression processing to make stable, higher-quality encoding possible. It is also necessary to improve the quality of video and value-added services by ensuring high frame rates (120 Hz) using communication paths and hybrid communications and broadcasting.

It is also important to diversify systems and equipment and lower their costs to popularise 8K/4K broadcasting. The test broadcasting has laid the groundwork for reducing prices by increasing the distribution of related equipment and improving power consumption. Furthermore, it is an effective way to share the technology with other domains, such as digital cinema, Internet, and information technology. It also holds promise for expanding the use of 8K-related equipment. NHK will continue to study how to develop systems and prepare environments while keeping costs down.

CONCLUSION

The world's first test satellite broadcasting of 8K/4K UHDTV started on August 1, 2016. Many fascinating 8K and 4K programs are now being broadcasted 7 hours a day to 8K prototype receivers installed at all of NHK's local stations in Japan.

This paper described NHK's facilities for UHDTV test broadcasting, especially its transmission and receiving facilities. The facilities can broadcast one 8K program or two 4K programs and seamlessly switch between them. A maximum of 32 channels' worth of sound signals can be broadcasted simultaneously, including 22.2-multichannel sound and 5.1-channel sound and stereo. These broadcasting facilities can provide many other services, such as an EPG, subtitles, and text superimposition.

Going forward, NHK will popularise 8K/4K broadcasting. Practical broadcasting on a number of channels and services will start in 2018, and we hope that it will make a strong impression on and instil enthusiasm in the audience of the 2020 Tokyo Olympics. We at NHK wish to provide broadcast services of the highest level of quality to viewers.

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