3-6 SHV Transmission Experiments

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NHK has been studying “4K/8K Super Hi-Vision (ultra high definition) TV” as next generation TV system and aimed to achieve the 4K/8K broadcasting services for satellite. In this paper, we report experimental results of the demonstrations and performance evaluations for 8K multi-channels and functional verifications for transmission systems.

1 Introduction

NHK has been working to realize the transmission of 4K/8K Super High Vision [1] high capacity signals to individual households via satellite and establish a broadcast service. 8K video signals have a pixel count of 7,680 × 4,320, making them 16 times more detailed than the current 2K service. 8K information bit rate extends to a non-compressed maximum of 144 Gbps, and when using the latest high-efficiency video coding (HEVC) [2], the transmission bit rate is assumed to be approximately 80–100 Mbps.

Satellite broadcast frequencies are set to the internationally decided bandwidths of 12 GHz (11.7–12.75 GHz) and 21 GHz (21.4–22.0 GHz). Currently, with the ISDB-S, 12 GHz satellite broadcasting uses right-hand circular polarization (RHCP) to secure 52 Mbps transmission capacity for the occupied bandwidth of each channel (34.5 MHz). Additionally, the use of left-hand circular polarization (LHCP) has also become possible, and approximately 100 Mbps transmission capacity can be secured for each channel with the ISDB-S3 [3]–[5], allowing for 4K/8K transmissions. Further, with 21 GHz bandwidth satellite transmissions, it is expected that we will see a 600 MHz [6] bandwidth split into two 300 MHz-class wideband transmissions, and work is progressing on the use of this as a high-capacity transmission channel of multiple 8K broadcastings, etc [7]–[9].

NHK is carrying out various types of transmission experiments directed toward R&D for 4K/8K transmissions on 12 GHz and 21 GHz bands, and has been utilizing the WINDS satellite as a transmission channel for a simulated broadcasting satellite.

In this paper, we report the results of using the WINDS satellite for: (1) functional verification of the ISDB-S3 premised on 12 GHz band satellite broadcasting [10], and (2) performance verification of a broadband modem premised on 21 GHz band satellite broadcasting.

2 Transmission experiments premised on 12 GHz satellite broadcasting

2.1 ISDB-S3

The main transmission parameters of the (ISDB-S3) for 12 GHz band satellite broadcast are shown in Table 1. The transmission capacity of 8K broadcasting is assumed at approximately 80–100 Mbps by HEVC compression technology. ISDB-S3 adopts a roll-off factor of 0.03 and a symbol rate of 33.7561 Mbaud. Compared with the current

Table 1 Main transmission parameters for ISDB-S3

Modulation scheme	π/2 shift BPSK, QPSK, 8-PSK, 16-APSK, 32-APSK
Symbol rate	33.7561 Mbaud
Roll-off factor	0.03
Information bit rate	16 APSK (7/9): 99.95 Mbps
Error-correcting code	LDPC (internal code) + BCH (external code)
LDPC (inner code) code rate	1/3, 2/5, 1/2, 3/5, 2/3, 3/4, 7/9, 4/5, 5/6, 7/8, 9/10
Transmission control signal	TMCC

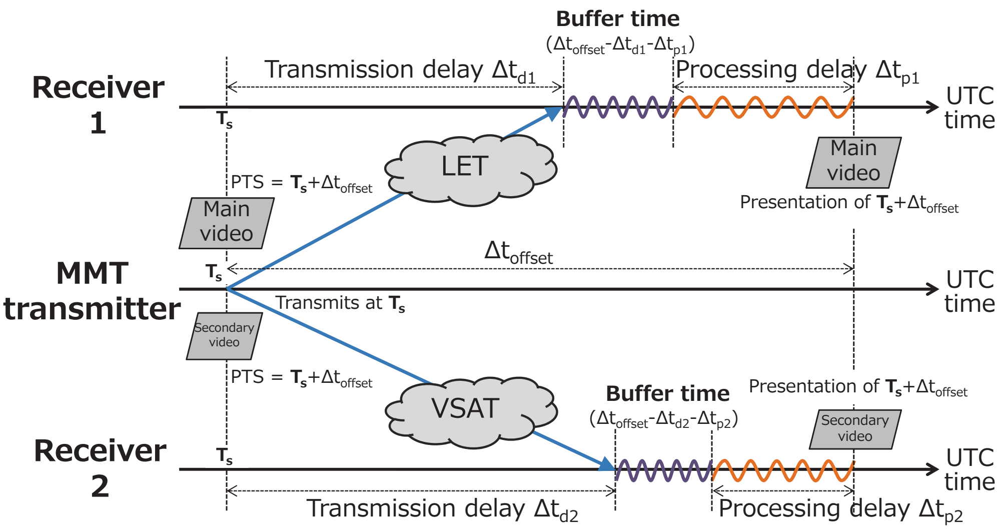

Fig. 1 Mechanism for syncing

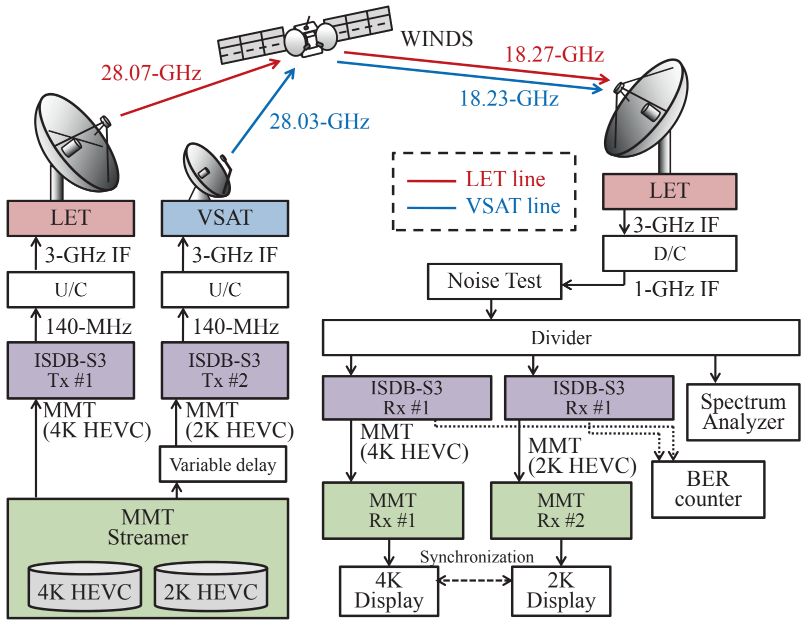

Fig. 2 Composition of WINDS satellite transmission testing (ISDB-S3)

BS digital broadcasting (ISDB-S), there is a 17% improvement in frequency usage efficiency. Further, ISDB-S3 adopts APSK modulation schemes. It is possible to secure transmission capacity of approximately 100 Mbps when 16-APSK (code rate: 7/9) is used. This allows for an 8K transmission on one channel for 12 GHz band satellite (occupied bandwidth of 34.5 MHz).

Concerning the standards for the transport layer, MPEG-H MMT was introduced to realize broadcasting-communication services. We give the results of the transmission performance on the physical layer and of the syncing functionality on the transport layer as below.

2.2 MMT signal and testing composition

The syncing mechanism by MMT is shown in Fig. 1. On the transmitter side, transmission is made with a presentation timestamp (PTS) attached that takes into account transmission and processing delays. On the receiver side, synced transmission is achieved by comparing the coordinated universal time (UTC) obtained from the NTP server with the PTS time before displaying the video.

The composition of the WINDS satellite transmission testing is shown in Fig. 2. The verification objective of the testing is to time syncretize two programs received from different lines, so we used two types of uplink device: large earth terminal (LET) and very small aperture terminal (VSAT). On the LET side, a 4K signal is transmitted simul-

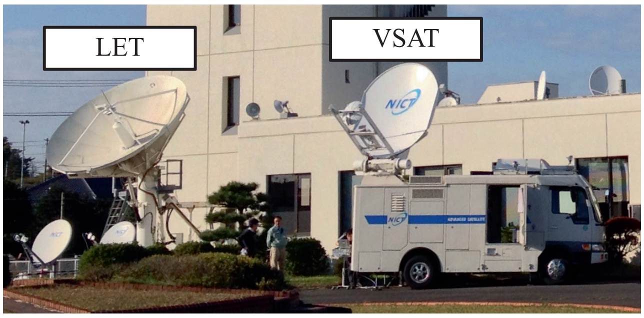

Fig. 3 Exterior of LET and VSAT antenna

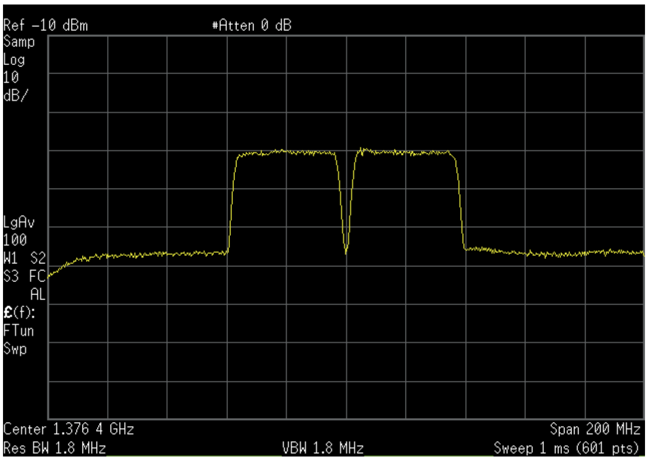

Fig. 4 Reception spectrum (1 GHz band BS-IF signal)

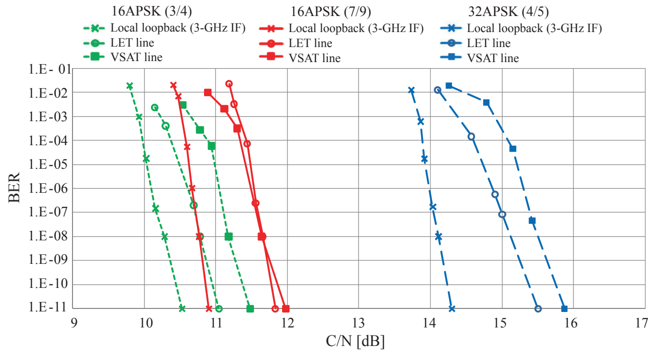

Fig. 5 C/N vs. BER characteristics at WINDS satellite loopback (ISDB-S3)

Fig. 6 4K and 2K video synchronization by MMT

taneously with a 2K signal on the VSAT side and goes through the WINDS satellite. A LET antenna receives these two waves. The center frequency of the wave modulation signal from the LET for uplink is set to 28.07 GHz and that from the VSAT is set to 28.03 GHz. The frequency spacing for each channel is 40 MHz. The center frequencies corresponding to these two waves for downlink were 18.27 GHz and 18.23 GHz, respectively. An exterior view of the LET and the VSAT is shown in Figs. 3 and 4 shows the reception spectrum for the 1 GHz band BS-IF signal.

2.3 Transmission performance results (physical layer)

C/N vs. BER characteristics at the WINDS satellite loopback [LET—WINDS—LET and VSAT—WINDS—LET] are shown in Fig. 5. Modulation schemes for evaluation were 16-APSK (3/4), 16-APSK (7/9), and 32-APSK (3/4). First, when comparing the required C/Ns (@1 E-11) on the LET and VSAT channel, those on the VSAT were worsened by around 0.2–0.5 dB. Next, when comparing the required C/Ns at the IF loopback and WINDS loopback [VSAT—WINDS—LET] for 16-APSK (3/4), 16-APSK (7/9), and 32-APSK (3/4), those at the WINDS loopback were worsened by 1.0 dB, 1.1 dB, and 1.6 dB, respectively; and, accompanying multi-leveling, there tended to be a large impact over satellite accompanying multi-modulations. Further, it became possible to transmit with a C/N margin for all modulated signals because the required C/N for 32-APSK (4/5) at the WINDS loopback was about 15.9 dB; it is estimated that received C/N was more 20 dB from the reception spectrum in Fig. 4.

2.4 Syncing functional verification results (transport layer)

Next, we verify the syncing functionality by MMT when using the modulated signals for which reception performance has been confirmed. The main video signal as 4K on the LET channel was received by MMT receiver #1 in Fig. 2, decoded, and displayed. The secondary video signal as 2K on the VSAT channel was received by MMT receiver #2, decoded, and displayed. Synced timing of 4K video and 2K video by MMT function is shown in Fig. 6. Further, for performance verification of the function, variable delay was set at the MMT streamer output on the VSAT channel to verify the syncing functionality. The result of syncing performance for time delay on the VSAT channel is shown in Table 2. From the result, we confirmed that two video signals could be synchronized even with a

Table 2 Syncing performance for time delay

LTE (4K) Modulation scheme	VSAT (2K) Modulation scheme	VSAT (2K) Time delay				
		0 sec	1.0 sec	2.0 sec	3.0 sec	4.0 sec
16APSK (3/4)	16APSK (3/4)	OK	OK	OK	NG	NG
	16APSK (7/9)	OK	OK	OK	NG	NG
	32APSK (4/5)	OK	OK	OK	NG	NG
16APSK (7/9)	16APSK (3/4)	OK	OK	OK	NG	NG
	16APSK (7/9)	OK	OK	OK	NG	NG
	32APSK (4/5)	OK	OK	OK	NG	NG
32APSK (4/5)	16APSK (3/4)	OK	OK	OK	NG	NG
	16APSK (7/9)	OK	OK	OK	NG	NG
	32APSK (4/5)	OK	OK	OK	NG	NG

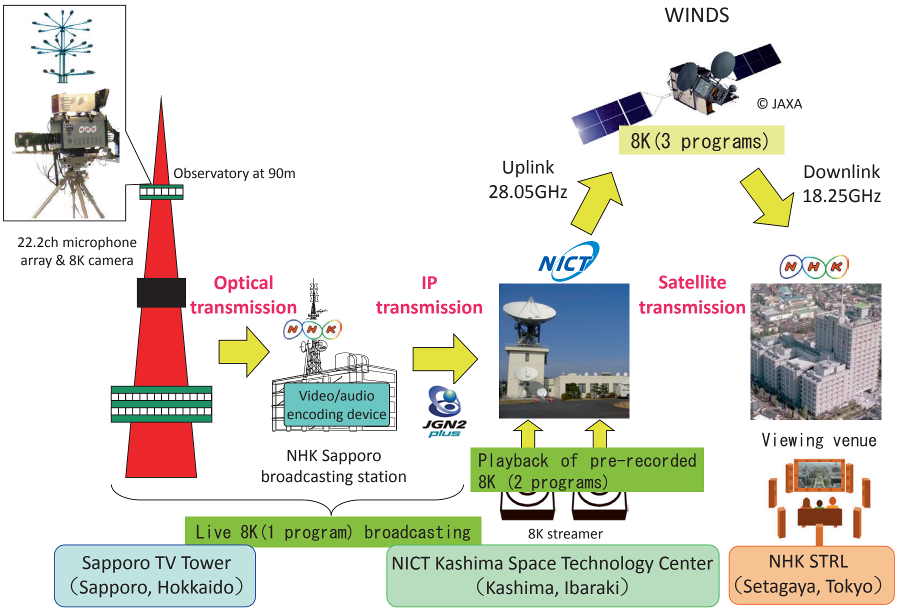

Fig. 7 Composition of transmission experiments for 8K multi programs (wideband transmission)

2-second delay. We also confirmed from Table 2 that syncing performance did not rely on the parameters of physical layers such as modulation schemes, etc.

3 Transmission Experiments Premised on 21 GHz Satellite Broadcasting

3.1 8K multichannel transmissions

The composition of the transmission experiments for 8K is shown in Fig. 7. On the transmitter side, we used the uplink earth station (transmitting antenna with a diameter of 4.8 m) at the NICT Kashima Space Technology Center, and on the receiving side, we set up a receiving antenna with a diameter of 2.4 m at the NHK Science & Technology Research Laboratories (NHK STRL) and received an 8K signal. For the transmission program, we sent the video signal, as an IP via the JGN2 plus test bed network, from an 8K camera mounted on the Sapporo TV Tower in Sapporo City to the NICT Kashima Space Technology Center, and achieved 8K live broadcasting. Furthermore, we prepared the other two 8K signals by streamers and broadcasted three multiplied 8K signals in total. Modulated signal after multiplexing resulted in a 300 MHz-class broadband signal at a symbol rate of 250 Mbaud.

The main transmission parameters of the wideband modem are shown in Table 3.

From the transmission experiments for the WINDS satellite, we could verify 8K live broadcasting and multiple 8K programs per channel.

3.2 Strengthening synchronization performance by phase reference burst signal

With the current satellite broadcasting transmission system (ISDB-S), phase reference burst signal is employed

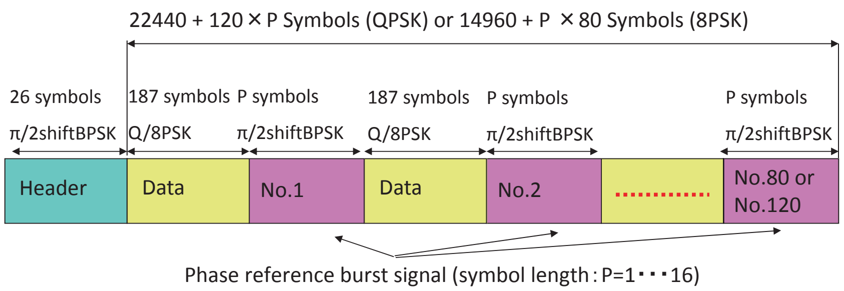

Fig. 8 Phase reference burst signal frame composition

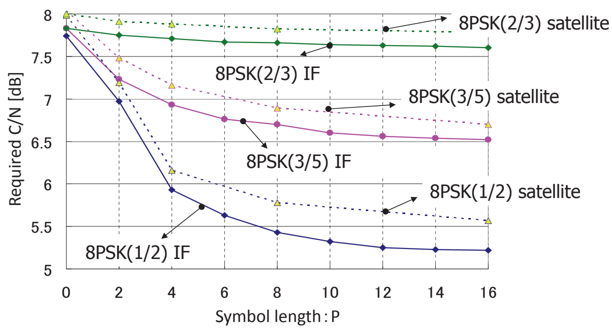

Fig. 9 Characteristics of symbol length vs. necessary C/N

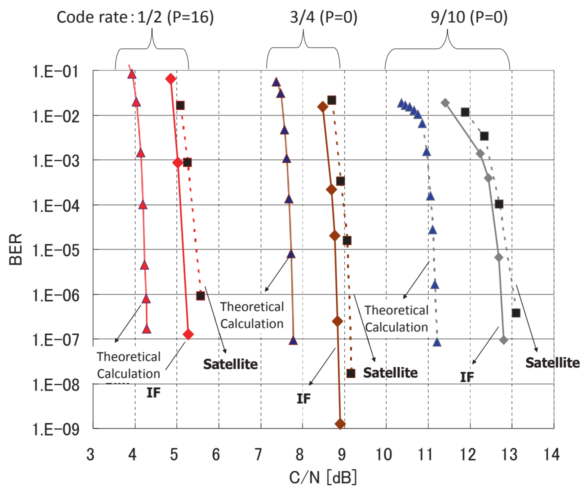

Fig. 10 C/N vs. BER characteristics in WINDS satellite loopback

Table 3 Transmission parameters for wideband modem

Modulation scheme	QPSK, 8-PSK
Symbol rate	250 Mbaud
Roll-off factor	0.1, 0.2, 0.35, 0.5
Information bit rate	QPSK (3/4): 370 Mbps, 8-PSK (2/3): 500 Mbps
Forward error correction	LDPC (internal code) + BCH (external code)
LDPC inner code rate	1/2, 3/5, 2/3, 4/5, 5/6, 7/8, 9/10

to strengthen robustness against noise. In the case of wideband modems, the modulation scheme for the phase reference burst signal was π/2 shift BPSK. The frame composition of the phase reference burst signal is shown in Fig. 8.

We assigned the phase reference burst signal to each 187-symbol data length, and made it so that symbol length “P” could be assigned through the range of 1–16.

3.3 Results of transmission performance by strengthening synchronization

The results of the characteristics of “P” symbol length of the phase reference burst signal versus the required C/N (@1 E-6) at the IF and WINDS satellite loopback are shown in Fig. 9. The modulation scheme was set to 8-PSK and LDPC inner code rates were set to 1/2, 3/5, and 2/3. The other transmission parameters were as listed in Table 3, and the roll-off factor was fixed at 0.1. Transmission experiments were conducted by using the same uplink earth station (transmitting antenna with a diameter of 4.8 m) listed in Fig. 7. The noise was added to the downlink signal so that C/N value was set. As a result, the required C/N for a code rate of either 1/2 or 3/5 was improved along with an increase in “P” symbol length, but that for a code rate of 2/3 was barely improved.

C/N versus BER characteristics for 8-PSK with code rates of 1/2, 3/4, and 9/10 at the IF and WINDS loopback are shown in Fig. 10. From the results of Fig. 9, P=16 was only set during 8-PSK (1/2), and all others were fixed at P=0. As a result, the degradation of the required C/N was around 0.3–0.4 dB by going through the WINDS satellite.

4 Conclusion

We hypothesized the 12 and 21 GHz band satellite broadcastings and carried out verification for each of their functions and performances with an actual satellite transmission channel of WINDS. The experimental results premised on the 12 GHz band satellite broadcasting contributed to the realization of a 4K/8K test satellite broadcasting (beginning August 2016) and of practical satellite broadcasting (scheduled for 2018). Further, one part of the results premised on the 21 GHz band satellite broadcasting contributed to the ITU-R report (BO.2007-2 Annex 2).

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