International Telecommunication Union

ITU-R

Radiocommunication Sector of ITU

Report ITU-R BO.2397-0
(10/2016)

Satellite transmissions for UHDTV satellite broadcasting

BO Series

Satellite delivery

International Telecommunication Union

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BO	**Satellite delivery**
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Note*: This ITU-R Report was approved in English by the Study Group under the procedure detailed in Resolution ITU-R 1.*

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Satellite transmissions for UHDTV satellite broadcasting

(Question ITU-R 292/4)

(2016)

TABLE OF CONTENTS

Page

1 Introduction 3

2 Status of ITU-R standardization of UHDTV broadcasting 3

3 Satellite transmissions for UHDTV satellite broadcasting 3

Annex 1 – Satellite transmissions in Japan 4

1 Introduction 4

2 Technical characteristics (ISDB-S3) for transmission system and main parameters used in satellite transmissions 4

3 Satellite transmission experiments in the 12 GHz BSS band in Japan 6

3.1 Measurement system 6

3.2 Results from measurements 7

4 UHDTV satellite test broadcasting in the 12 GHz BSS band in Japan 13

4.1 Roadmap for UHDTV satellite broadcasting 13

4.2 Summary of UHDTV satellite test broadcasting 14

5 Summary 17

References 18

Abbreviations/Glossary

AAC	Advanced Audio Coding
ARIB	Association of Radio Industries and Businesses
APSK	Amplitude and phase shift keying
AWGN	Additive White Gaussian Noise
BPSK	Binary phase shift keying
BCH code	Bose-Chaudhuri-Hocquenghem code
BER	Bit error rate
BSS	Broadcasting-satellite service
C/N	Carrier to noise ratio
D/C	Down converter
EPG	Electronic Program Guide
FIR	Finite Impulse Response
HEVC	High efficiency video coding
HPA	High power amplifier
HDR	High dynamic range
HTML	Hyper text markup language
IF	Inter frequency
ISDB-S3	Integrated Services Digital Broadcasting for Satellite, 3rd generation
LCD	Liquid crystal display
LDPC code	Low density parity check code
MPEG	Moving Picture Experts Group
MMT	MPEG Media Transport
OBO	Output back off
OBW	Occupied bandwidth
PN	Pseudo noise
PSK	Phase shift keying
QPSK	Quadrature phase shift keying
RMP	Rights management and protection
TDM	Time division multiplexing
TLV	Type length value
TMCC	Transmission & multiplexing configuration control
TS	Transport stream
TOC	Technical operation center
TTML	Timed text markup language
UHDTV	Ultra-high definition television
U/C	Up converter

1 Introduction

Ultra-high definition television (UHDTV) is one of the major applications of next-generation satellite broadcasting. New technologies such as amplitude and phase shift keying (APSK), low density parity check code (LDPC), and spectrum shaping by lowering the roll-off factor are required to implement UHDTV services via satellite within the same bandwidth as conventional high definition television.

This Report provides useful information such as experimental results obtained from UHDTV broadcasting via satellite and satellite test broadcasting. Administrations are encouraged to contribute further information on the implementation of the UHDTV services via satellites.

2 Status of ITU-R standardization of UHDTV broadcasting

The ITU-R Recommendations relevant to UHDTV broadcasting are listed below as informative references.

Informative references

– Recommendation ITU-R BT.2020 – Parameter values for ultra-high definition television systems for production and international programme exchange

– Recommendation ITU-R BT.2100 – Image parameter values for high dynamic range television for use in production and international programme exchange

– Recommendation ITU-R BT.1887 – Carriage of IP packets in MPEG-2 transport stream in multimedia broadcasting

– Recommendation ITU-R BS.2051 – Advanced sound system for programme production

– Recommendation ITU-R BT.2073 – Use of the high efficiency video coding (HEVC) standard for UHDTV and HDTV broadcasting

– Recommendation ITU-R BT.2077 – Real-time serial digital interfaces for UHDTV signals

– Recommendation ITU-R BT.2075 – Integrated broadcast-broadband system

– Recommendation ITU-R BT.2074 – Service configuration, media transport protocol, and signalling information for MMT-based broadcasting systems

– Recommendation ITU-R BT.1870 – Video coding for digital television broadcasting emission

– Recommendation ITU-R BT.1869 – Multiplexing scheme for variable-length packets in digital multimedia broadcasting systems

– Recommendation ITU-R BT.1852 – Conditional-access systems for digital broadcasting

– Recommendation ITU-R BS.1873 – Serial multichannel audio digital interface for broadcasting studios

– Recommendation ITU-R BS.1196 – Audio coding for digital broadcasting

– Recommendation ITU-R BO.2098 – Transmission system for UHDTV satellite broadcasting

3 Satellite transmissions for UHDTV satellite broadcasting

Annex 1 provides the details on the satellite transmission experiments of the ISDB-S3 system conducted in Japan in September 2015. The geostationary satellite BSAT-3b located at 110 degrees east longitude was used for transmission in the 12 GHz BSS band. The results indicate that all of the combinations of modulation and inner coding rate defined in Annex 1 are feasible and 16-APSK (7/9) transmission provides an approximately 100 Mbit/s transmission capacity in a 34.5 MHz-bandwidth single satellite transponder. Annex 1 also introduces the UHDTV satellite test broadcasting in the 12 GHz BSS band which was launched in August 2016 in Japan.

Annex 1

Satellite transmissions in Japan

1 Introduction

A 4K/8K UHDTV satellite broadcasting system named as ISDB-S3 was standardized as ARIB STD-B44 in Japan in 2014.

The key technologies in ISDB-S3 include highly efficient video coding with the HEVC/H.265 standard [1], a flexible multiplexing scheme with the MMT protocol [2], and a larger channel capacity by the new transmission system. The target channel capacity for a single satellite transponder in the BSS band is set to 80-100 Mbit/s [3], which is shown as one of the basic parameters for UHDTV broadcasting using the HEVC standard in ITU-R BT.2073. 16-APSK and LDPC code with a coding rate of 7/9 and a symbol rate of 33.7561 Mbaud by lowering the roll-off factor of 0.03 can provide a capacity of approximately 100 Mbit/s in a satellite transponder with a 34.5 MHz bandwidth.

Japan conducted satellite transmission experiments using a 12 GHz band broadcasting satellite in 2015 [4] to demonstrate the feasibility of this system. The geostationary satellite BSAT-3b located at 110 degrees east longitude was used for transmission on the 12 GHz BSS band. The results indicated that all of the combinations of modulation and inner coding rate are feasible and 16-APSK (7/9) provides a 100 Mbit/s transmission capacity in a 34.5 MHz-bandwidth single satellite transponder.

Japan also launched UHDTV satellite test broadcasting on 1st August 2016 via BSAT-3b satellite, whose transmission system is IDSB-S3 with a 100 Mbit/s transmission capacity. Japan plans to start the practical broadcasting in 2018.

Section 2 gives the technical specifications for the new transmission system. Subsection 3.1 presents the measurement system used in the satellite transmission tests. The experimental results are summarized with the results obtained from *C/N* vs. BER measurements in § 3.2. Subsection 4.1 introduces a roadmap for UHDTV satellite broadcasting in Japan. Subsection 4.2 shows the summary of UHDTV satellite test broadcasting launched in August 2016 in Japan.

2 Technical characteristics (ISDB-S3) for transmission system and main parameters used in satellite transmissions

The technical specifications are summarized in Table 1. This system has adopted 0.03 as the roll-off factor for the raised-cosine square-root Nyquist filters implemented in the transmitter and receiver. Lowering the roll-off factor to 0.03 enables the symbol rate to be increased to 33.7561 Mbaud, and this combination also meets the occupied bandwidth (OBW) of 34.5 MHz [5].

ISDB-S3 does not specify the specific symbol rate. Japan chose 33.7561 Mbaud according to domestic regulation in the experiments. The symbol rate of ISDB-S3 can be set according to the various kinds of satellite transponder bandwidth flexibly.

A transmitter and receiver that satisfied the technical specifications listed in Table 1 were developed. There are photographs of these two units in Figs 1 and 2. The Finite Impulse Response (FIR) raised-cosine square-root Nyquist filter that achieved a roll-off factor of 0.03 was implemented in the transmitter and receiver, and the numbers of tap coefficients were 678 for the former and 512 for the latter. The centre frequency of the transmitter was 140 MHz, which is the inter frequency (IF) of the 17 GHz feeder link. The spectrum of transmitter output is shown in Fig. 3.

TABLE 1

Technical specifications for the ISDB-S3 system

Item		**Description**
Input signal format		MPEG-2 TS, TLV
Modulation scheme		π/2-shift BPSK, QPSK, 8-PSK, 16-APSK, and 32-APSK
Transmission control		TMCC
Forward error correction	Inner code	LDPC code (code length: 44880)
	Coding rate	1/3 (41/120), 2/5 (49/120), 1/2 (61/120), 3/5 (73/120), 2/3 (81/120), 3/4 (89/120), 7/9 (93/120), 4/5 (97/120), 5/6 (101/120), 7/8 (105/120), 9/10 (109/120) (nominal value (true value))
	Outer code	BCH (65535, 65343, T = 12) shortened code
TMCC	Modulation scheme	π/2-shift BPSK
	Inner code	LDPC (31680,9614), LDPC (44880,22184) shortened code
	Outer code	BCH (9614,9422, T = 12), BCH (65535,65343, T = 12) shortened code
	Control unit	Transmission control in units of slots
TDM frame structure		120 slots per frame
Symbol rate		Not specified The symbol rate of ISDB-S3 can be set according to the various kinds of satellite transponder bandwidth flexibly.
Roll-off factor		0.03
Nonlinear compensation signal		Pilot signal, which can transmit unique word sequence by using same modulation scheme as that for input signal. Averaged pilot signal was used on receiver side for reference point of LDPC decoding.

FIGURE 1

Transmitter

Report BO.2397-01

FIGURE 2

Receiver

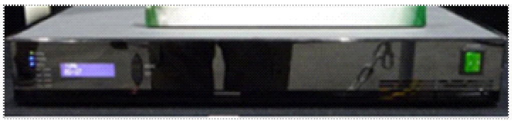

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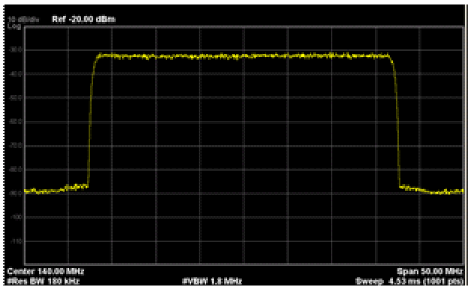
FIGURE 3

Spectrum of Transmitter Output



Report BO.2397-03

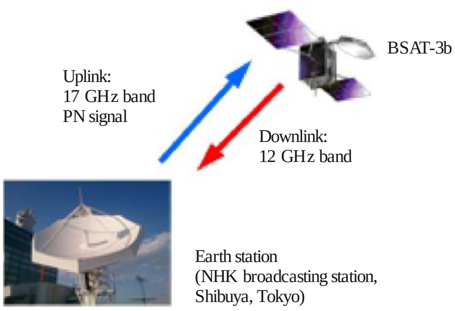
3 Satellite transmission experiments in the 12 GHz BSS band in Japan

3.1 Measurement system

Figure 4 shows schematic and photographs of the measurement system used in the satellite transmission experiments with the BSAT-3b satellite. The earth station with a 5.5-m transmitting and receiving antenna was located at NHK, Nippon Hoso Kyokai (JAPAN BROADCASTING CORPORATION) Broadcasting Station, Shibuya, Tokyo, Japan. The uplink frequency was in the 17 GHz band and that of the downlink was in the 12 GHz band. Figure 5 shows schematic of the measurement system. The satellite transmission experiments were conducted from 31 August to 14 September, 2015.

FIGURE 4

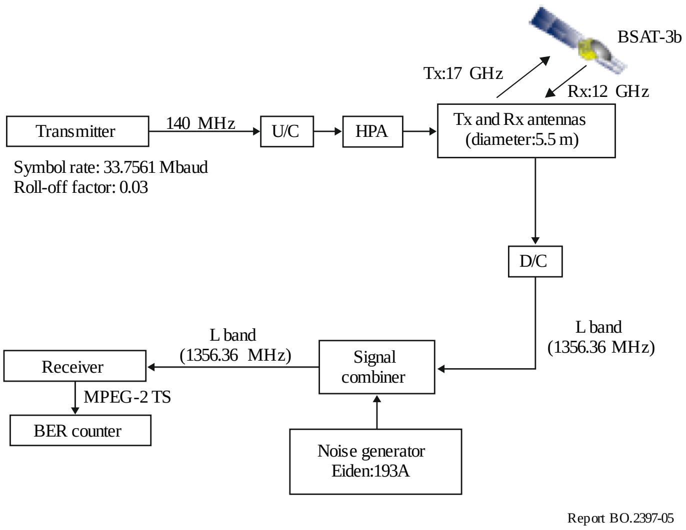
Measurement system



Report BO.2397-04

FIGURE 5

Schematic of measurement system



3.2 Results from measurements

The results obtained from *C/N* vs. BER measurements are plotted in Figs 6-1 to 6-5. Tables 2-1 to 2-5 summarize the required *C/N*[1] obtained from Figs 6-1 to 6-5. These tables list the information bit rate for type length value (TLV) input, the calculated required *C/N* for ideal performance[2], and the measured required *C/N* for satellite-transmission-loopback using BSAT-3b. The output back off of the satellite transponder is set to 2.2 dB. Figure 7 shows the relationship between the information bit rate for TLV input and required *C/N* obtained from Tables 2-1 to 2-5. This indicates that 99.9552 Mbit/s transmission was achieved using 16-APSK (7/9). It also can meet a worst-month service availability of 99.7% using a 45 cm receive antenna in Tokyo [6].

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1 The required *C/N* is defined as the smallest *C/N* at which the bit error rate (BER) is 1×10^{-11}. The noise bandwidth of *C/N* is set to 33.7561 MHz equivalent to the symbol rate in units of baud for the experiments.

2 The ideal performance is defined as the computer simulation results for the AWGN channel where the maximum number of iterations for LDPC decoding is set to 50.

FIGURE 6-1

Results from *C/N* vs. BER measurements of π/2-shift BPSK

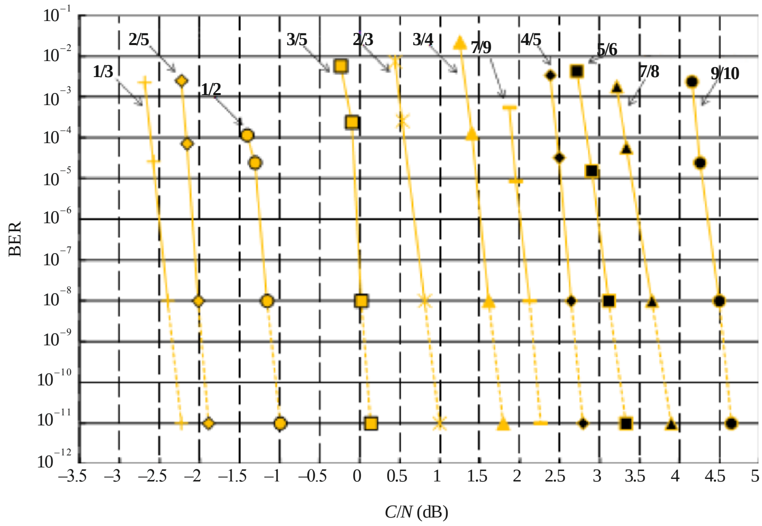

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FIGURE 6-2

Results from *C/N* vs. BER measurements of QPSK

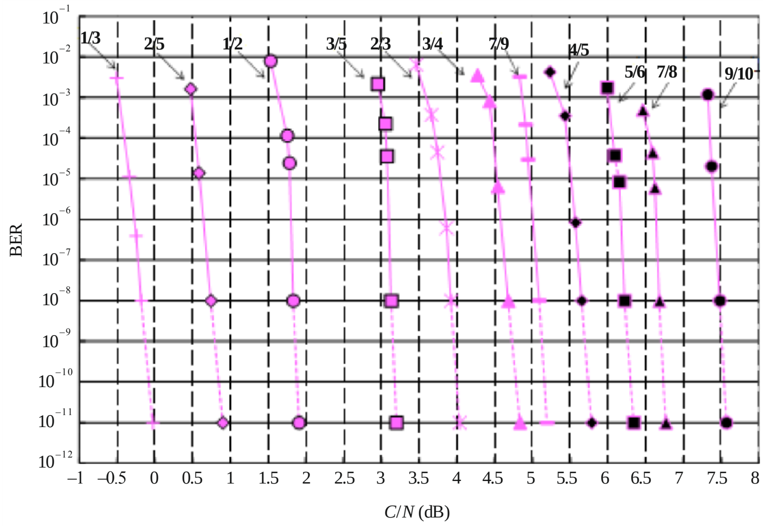

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FIGURE 6-3

Results from *C/N* vs. BER measurements of 8-PSK

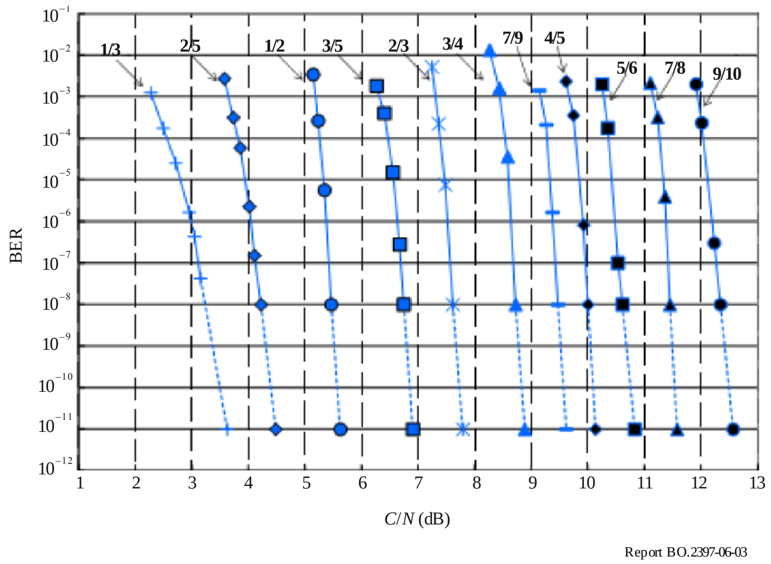


FIGURE 6-4

Results from *C/N* vs. BER measurements of 16-APSK

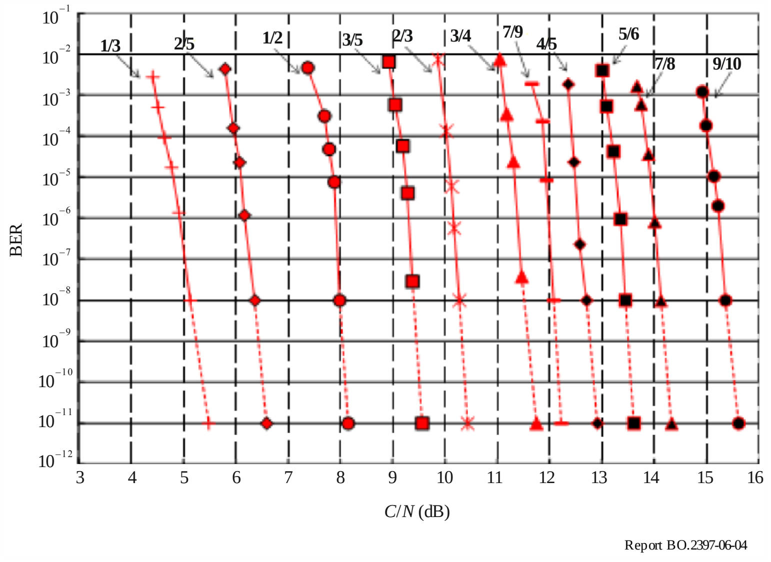
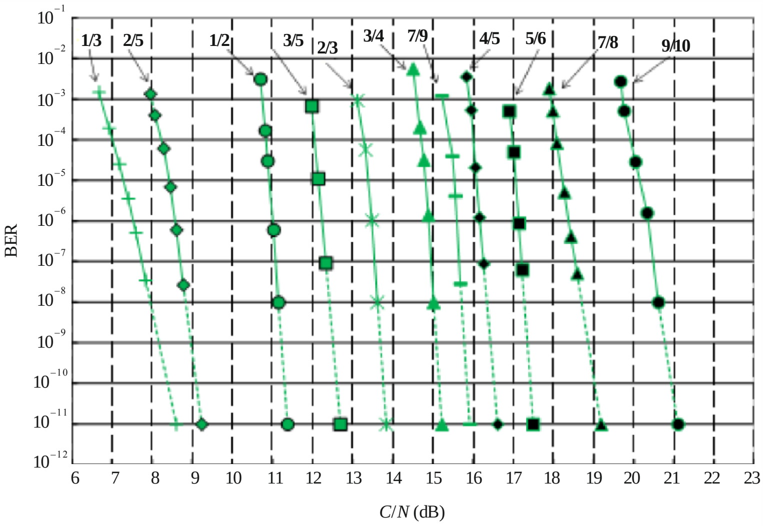


FIGURE 6-5

Results from *C/N* vs. BER measurements of 32-APSK



Report BO.2397-06-05

TABLE 2-1

Required *C/N* for satellite transmission experiment of π/2-shift BPSK

Inner coding rate	Information bit rate (Mbit/s)	Calculated required *C/N* (dB)	Measured required *C/N* (dB)
1/3	10.8647	−4.0	−2.2
2/5	13.0376	−3.0	−1.9
1/2	16.2971	−1.8	−1.0
3/5	19.5565	−0.5	0.1
2/3	21.7294	0.3	1.0
3/4	23.9023	1.0	1.8
7/9	24.9888	1.5	2.3
4/5	26.0753	2.0	2.8
5/6	27.1618	2.5	3.3
7/8	28.2482	2.9	3.9
9/10	29.3347	3.8	4.6

TABLE 2-2

Required *C/N* for satellite transmission experiment of QPSK

Inner coding rate	Information bit rate (Mbit/s)	Calculated required *C/N* (dB)	Measured required *C/N* (dB)
1/3	21.7294	−1.0	0.0
2/5	26.0753	0.0	0.9
1/2	32.5941	1.2	1.9
3/5	39.1129	2.5	3.2
2/3	43.4588	3.3	4.0
3/4	47.8047	4.0	4.8
7/9	49.9776	4.5	5.2
4/5	52.1506	5.0	5.8
5/6	54.3235	5.5	6.3
7/8	56.4964	5.9	6.8
9/10	58.6694	6.8	7.6

TABLE 2-3

Required *C/N* for satellite transmission experiment of 8-PSK

Inner coding rate	Information bit rate (Mbit/s)	Calculated required *C/N* (dB)	Measured required *C/N* (dB)
1/3	32.5941	2.2	3.6
2/5	39.1129	3.1	4.5
1/2	48.8912	4.4	5.6
3/5	58.6694	5.7	6.9
2/3	65.1882	6.7	7.8
3/4	71.7070	7.9	8.9
7/9	74.9664	8.6	9.6
4/5	78.2258	9.1	10.1
5/6	81.4853	9.7	10.8
7/8	84.7447	10.4	11.6
9/10	88.0041	11.4	12.6

TABLE 2-4

Required *C/N* for satellite transmission experiment of 16-APSK

Inner coding rate	Information bit rate (Mbit/s)	Calculated required *C/N* (dB)	Measured required *C/N* (dB)
1/3	43.4588	4.1	5.5
2/5	52.1506	5.1	6.6
1/2	65.1882	6.6	8.1
3/5	78.2258	8.0	9.6
2/3	86.9176	9.1	10.4
3/4	95.6094	10.2	11.7
7/9	99.9552	10.8	12.2
4/5	104.3011	11.3	12.9
5/6	108.6470	11.9	13.6
7/8	112.9929	12.5	14.3
9/10	117.3388	13.5	15.6

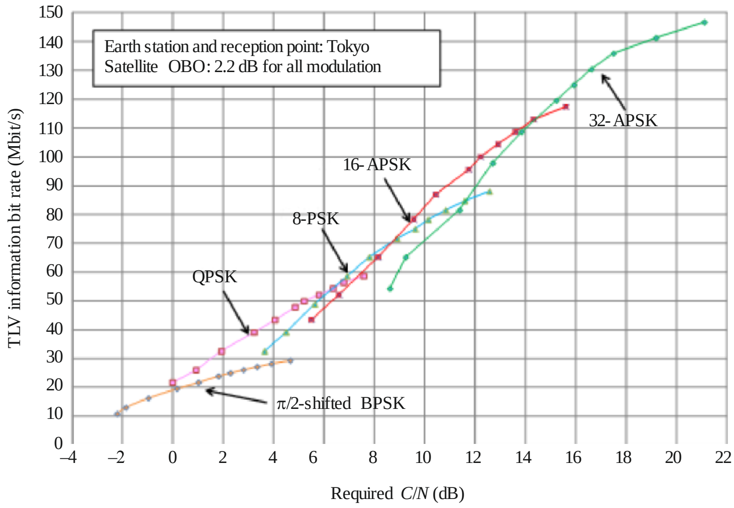
TABLE 2-5

Required *C/N* for satellite transmission experiment of 32-APSK

Inner coding rate	Information bit rate (Mbit/s)	Calculated required *C/N* (dB)	Measured required *C/N* (dB)
1/3	54.3235	6.4	8.6
2/5	65.1882	7.2	9.2
1/2	81.4853	9.2	11.4
3/5	97.7823	10.6	12.7
2/3	108.6470	11.7	13.8
3/4	119.5117	12.8	15.2
7/9	124.9441	13.4	15.9
4/5	130.3764	14.0	16.6
5/6	135.8088	14.5	17.5
7/8	141.2411	15.3	19.2
9/10	146.6735	16.3	21.1

FIGURE 7

Relationship between measured required *C/N* and TLV information bit rate



Report BO.2397-07

4 UHDTV satellite test broadcasting in the 12 GHz BSS band in Japan

4.1 Roadmap for UHDTV satellite broadcasting

The Ministry of Internal affairs and Communications (MIC) in Japan issued a roadmap for initiatives for UHDTV satellite broadcasting in Japan in 2015. Figure 8 shows the overview of the roadmap, which indicates that UHDTV satellite test broadcasting will be launched in 2016 and UHDTV satellite broadcasting will be launched in 2018. NHK successfully launched UHDTV satellite test broadcasting on August 1st 2016. A-PAB [7] has a plan to launch 4K UHDTV satellite test broadcasting in December 2016. Figure 9 shows the opening ceremony of UHDTV satellite test broadcasting. Both organizations share the common transmission facility at NHK Broadcasting Station in Tokyo. NHK will mainly broadcast in 8K, and A-PAB will broadcast in 4K by sharing the time slot. Details of this endeavour are given in the following section.

FIGURE 8

Roadmap for UHDTV satellite broadcasting in Japan

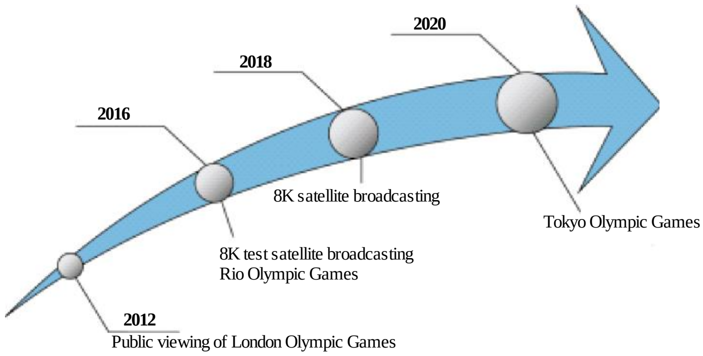


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FIGURE 9

Opening Ceremony of UHDTV satellite test broadcasting

Report BO.2397-09

4.2 Summary of UHDTV satellite test broadcasting

Table 3 shows the technical specifications of UHDTV satellite test broadcasting in the 12 GHz BSS band in Japan. 16-APSK and an LDPC coding rate of 7/9 were chosen as the transmission parameters. Figure 10 shows the overall system of UHDTV satellite test broadcasting. Figure 11 shows the console and the wall-type display at the Technical Operation Center (TOC). Figures 12 and 13 show the ISDB-S3 modulator and the uplink antenna installed in the earth station respectively. Figure 14 shows the ISDB-S3 receiver with the basic function to decode 8K video and 22.2-multichannel sound. This receiver also has the ability to receive 4K programmes, which will mainly be broadcasted by A-PAB. In addition, HTML 5, and ARIB-TTML [8] are supported so that subtitles and data broadcasts can be presented on the screen. Figure 15 shows a "public viewing system", which consists of 85-inch HDR supporting 8K LCD monitor and 22.2-multichannel sound system. The same public viewing system has already been installed at all local stations of NHK.

TABLE 3

Technical specifications of UHDTV satellite test broadcasting in Japan

Item	Description
Frequency	Uplink: 17.63436 GHz Downlink: 12.03436 GHz
Bandwidth	34.5 MHz
Symbol rate	33.7561 Mbaud
Roll-off factor	0.03
Modulation	16-APSK
Inner coding rate	7/9
TLV information bit rate	99.9952 Mbit/s
Multiplexing	MMT

TABLE 3 (*end*)

Item	Description
Video format	7680×4320/59.94p, 3840×2160/59.94p
Colorimetry	ITU-R BT.2020
Video coding	H.265|MPEG-H HEVC Main10
Audio format	22.2 ch, 5.1 ch, 2 ch
Audio coding	MPEG-4 AAC
Multimedia coding	HTML5, ARIB-TTML

FIGURE 10

Overall system of UHDTV satellite test broadcasting

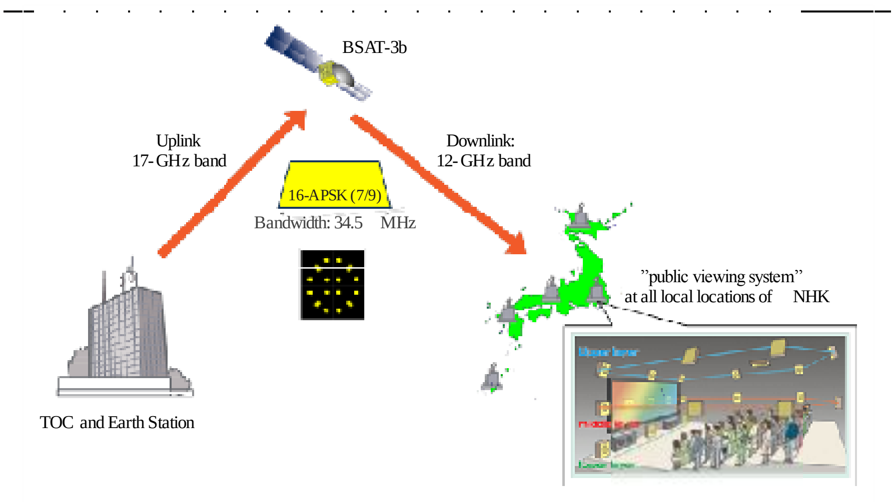

FIGURE 11

Technical operation center

Report BO.2397-11

FIGURE 12

ISDB-S3 Modulator

Report BO.2397-12

FIGURE 13

Earth station transmitting antenna

Report BO.2397-13

FIGURE 14

ISDB-S3 receiver

Report BO.2397-14

FIGURE 15

UHDTV public viewing system

Report BO.2397-15

5 Summary

Japan is planning to start 4K/8K UHDTV broadcasting via a broadcasting satellite in the 12 GHz BSS band. The project is now under way with test broadcasting having been started in 2016 and practical broadcasting scheduled to begin in 2018.

Japan standardized a new satellite UHDTV transmission system called ISDB-S3 in 2014 and conducted experiments in the 12 GHz band in 2015.

The experiments obtained the required *C/N* of all of the combinations of modulation and inner coding rate defined in ISDB-S3 and showed the feasibility of a 100 Mbit/s transmission capacity in consideration of HEVC performance with 16-APSK (7/9) transmission on a 12 GHz band broadcasting satellite.

UHDTV satellite test broadcasting with HDR in the 12 GHz BSS band was launched in August 2016 in Japan. NHK has installed UHDTV public viewing systems at all of its local stations so that the viewers can experience the test broadcasts.

References

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[8] ARIB STD-B62 Version 1.2 (Fascicle 1) (http://arib.or.jp/english/html/overview/doc/6-STD-B62v1_2-1p2-E1.pdf).