Doc T-22/7

ABU Technical Department

REPORT OF TOPIC CHAIRMAN

TRANSMISSION TOPIC AREA

Topic Chairman : **Kenichi MURAYAMA**

Period of Report: **December 2021 to November 2022**

Date of Report : **27 November 2022**

Introduction

Transmission topic area comprises five projects. The matters concerning digital terrestrial television broadcasting, digital satellite broadcasting, digital sound broadcasting and these frequency planning are studied or investigated by these projects. This topic area also covers research on IBB and OTT, including platforms and standards, etc.
This document has been submitted for this Technical Committee Annual meeting.

1. Frequency Planning for Digital Broadcasting(T/FPDB)

Project Manager: **Ms. Momoko Suyama** (NHK, Japan)
Co-project Manager: **Mr. Yuen Man** (TVB, Hong Kong, China)
Mr. Rajeev Kumar (DDI, India)

Reports from the project managers and the contributor are as follows.

1.1 ITU-R text related to DTTB coverage and frequency planning
1.2 Latest ASO situations in the region
1.3 Latest topics over frequency policies in the world

The reports for T/FPDB are attached as Annex 1.

2. Next Generation Terrestrial Broadcasting (T/NGTB)

Project Manager: **Mr. Akihiko Sato** (NHK, Japan)
Co-project Manager: **Dr. Jeon Sungho** (KBS, Korea),
Mr. Chen Delin (ABS, China),
Mr. Halil Us (TRT, Turkey),
Mr. M S Duhan (DDI, India)
Mr. Rajesh Meena (India)

Mr. A K Mangalgi(DDI, India)
Mr. Zhang Yu (ABS/China)
Mrs. Xiao Jingting (ABS, China),

Reports from the project managers and the contributor are as follows.

2.1 Investigate efforts toward the realization of next-generation terrestrial broadcasting in Japan
2.2 Development of ATSC 3.0 & 5G-Broadcbast Transmission Technique in the Republic of Korea

The reports for T/NGTB are attached as Annex 2.

3. Integrated Broadcast-Broadband and OTT (T/IBBOTT)

Project Manager: **Dr. Go Ohtake** (NHK, Japan)
Co-project Manager: **Ms. Momoko Suyama** (NHK, Japan)
Dr. Yuto Komatsu (NHK, Japan)
Dr. Shinya Abe (NHK, Japan)
Mrs. Zhang Dingjing(ABS, China)
Zhang Yu(ABS, China)
Xhang Wei(ABS, China)
He Jing(ABS, China)
Wang Lei(ABS, China)
Mr. A. K. Mangalgi (DDI, India)
Mr. A K Srivastava (India)

Reports from the project managers and the contributor are as follows.

3.1 Standardization of Integrated Broadcast-Broadband System in Japan
3.2 Studies in ITU-R
3.3 Studies in ITU-T
3.4 Cyber Security in USA

The reports for T/IBBOTT are attached as Annex 3.

4. Satellite Broadcasting (T/SB)

Project Manager: **Dr. Masashi Kamei** (NHK, Japan)
Co-project Manager: **Mr. KK Rao** (India)
TBD (TRT, Turkey)
TBD (IRIB, Iran)

Reports from the project managers and the contributor are as follows.

4.1 ITU-R documents related to satellite broadcasting systems
4.2 Latest topics on satellite broadcasting

The reports for T/SB are attached as Annex 4.

5. Digital Sound Broadcasting System (T/DSBS)

Project Manager:	**Mr. Shabib Hyder** (AIR, India)
Co-project Manager:	**TBD** (IRIB, Iran)
	TBD (RRI, Indonesia)
	TBD (TRT, Turkey)

Annex 1

Project: Frequency Planning for Digital Broadcasting(T/FPDB)

Project Manager: **Ms. Momoko Suyama** (NHK, Japan)
Co-project Manager: **Mr. YUEN Man** (TVB, Hong Kong, China)
Mr. Rajeev Kumar (DDI, India)

1.1 ITU-R text related to DTTB coverage and frequency planning

1.1.1 Recommendations (http://www.itu.int/rec/R-REC-BT/en)

BT.1306 "Error correction, data framing, modulation and emission methods for digital terrestrial television broadcasting"

BT.1368 "Planning criteria, including protection ratios, for digital terrestrial television services in the VHF/UHF bands"

BT.1877 "Error-correction, data framing, modulation and emission methods for second generation of digital terrestrial television broadcasting systems"

BT.1895 "Protection criteria for terrestrial broadcasting systems"

BT.2033 "Planning criteria, including protection ratios, for second generation of digital terrestrial television broadcasting systems in the VHF/UHF bands"

BT.2036 "Characteristics of a reference receiving system for frequency planning of digital terrestrial television systems"

BT.2052-1 Planning criteria for terrestrial multimedia broadcasting for mobile reception using handheld receivers in VHF/UHF bands

BT.2136 Assessing interference into digital terrestrial television broadcasting from other services by means of Monte Carlo simulation

BT.2144 "Guidance for the introduction of new DTTB systems, technologies and applications in the broadcasting service"

1.1.2 Reports (http://www.itu.int/pub/R-REP-BT/en)

BT.2035 "Guidelines and techniques for the evaluation of digital terrestrial television broadcasting systems, including assessment of their coverage areas"

BT.2140 "Transition from analogue to digital terrestrial broadcasting"

BT.2209 "Calculation model for SFN reception and reference receiver characteristics of ISDB-T system"

BT.2265 "Guidelines for the assessment of interference into the broadcasting service"

BT.2294 "Construction technique of DTTB relay station network for ISDB-T"

BT.2295 "Digital terrestrial broadcasting systems"

BT.2302 "Spectrum requirements for terrestrial television broadcasting in the UHF frequency band in Region 1 and the Islamic Republic of Iran"

BT.2343 "Collection of field trials of UHDTV over DTT networks"

BT.2386-3 Digital terrestrial broadcasting: Design and implementation of single frequency networks (SFN)

BT.2468-1 Guidance for selection of system parameters and implementation of second generation DTTB systems

BT.2470 "Use of Monte Carlo simulation to model interference to DTTB"

BT.2485 "Advanced network planning and transmission methods for enhancements of digital terrestrial television broadcasting"

1.1.3 Handbook (https://www.itu.int/pub/R-HDB-63)

"Handbook on Digital Terrestrial Television Broadcasting networks and systems implementation"

1.2. Latest ASO situations in the region

1.2.1 Fiji

The wider Western region in Fiji implemented a smooth transition to Digital transmission from analogue television services in July 3, 2022. The switch from analogue to digital television in Fiji's Northern Division also started in September 2022 and is expected to take up to two months to complete.

Fiji introduced its DVB-T2 digital terrestrial service by Walesi, a Fijian Government initiative delivering free-to-air television, in testing phase 2016 and rolled out to public in December 2017. After that, the country began the phased nationwide transition to digital TV in December 2021. Through a mix of terrestrial and satellite technologies, Walesi is expanding broadcast coverage across the nation for Fijians who otherwise could not access free-to-air television before.

Walesi will continue to provide free Set-Top Boxes to every household that has a combined annual income of up to $30,000 and UHF Antennas at a subsidised cost. To date, Walesi has distributed 217,358 set-top boxes

Source:

https://www.fbcnews.com.fj/news/end-of-analog-tv-broadcasts-for-west/

https://www.fbcnews.com.fj/news/west-welcomes-successful-transition-to-digital-tv/

https://www.abu.org.my/2022/09/21/fijis-northern-division-set-to-switch-to-digital-tv/

1.3 Latest topics over frequency policies in the world

1.3.1 5G spectrum auction results in Bangladesh

The regulator awarded 190 MHz of mid-band spectrum for a total of BDT 106 billion (€1,13 billion) in March, 2022. All four of the country's national mobile operators acquired licences. Both Grameenphone and Robi purchased 60 MHz in the 2.6 GHz band. Bengalink bought 40 MHz in the 2.3 GHz band while Teletalk bought 30 MHz in the same band. 30 MHz of spectrum

went unsold.
All licences are valid for 15 years and operators are expected to pay in instalments.
The BTRC says it hopes these new licences will play a "crucial role" in expanding existing networks as well as the implementation of new 5G networks.

Source: https://5gobservatory.eu/bangladesh-completes-5g-auction/

1.3.2 5G spectrum auction results in South Africa

South Africa's mobile network operators Vodacom, MTN, Rain, Telkom, Cell C and Liquid Telecom all obtained spectrum licenses in March, 2022.
Licences were sold in the 700 MHz, 800 MHz, 2.3 GHz, 2.6 GHz and 3.5 GHz bands.
The highest bidder, Vodacom, paid R5.38 billion (€333m) for its licences. The company said it was pleased with the outcome of the auction despite the high prices paid.
Communications minister Khumbudzo Ntshavheni said the government's priority for the spectrum was to get more schools, health facilities and police stations connected.

Source: https://5gobservatory.eu/south-africa-completes-5g-auction/

1.3.3 5G spectrum auction results in Belgium

The Belgian regulator BIPT has announced the winners of its 5G auction in June, 2022. Spectrum licences were available in the 700 MHz, 1800 MHz, 2.1 GHz and 3.6 GHz bands. The auction raised a total of €1.2 billion.
The three established mobile operators – Orange Belgium, Proximus and Telenet – all acquired 100 MHz of mid-band spectrum. The new market entrant Citymesh won 50 MHz in the 3.6 GHz band and 2 x 5 MHz in the 700 MHz band. This new swath of spectrum is expected to be used for 5G services.
Citymesh is currently focused on private networks. With its newly acquired spectrum, the company plans to develop a country-wide network. The company has also announced a partnership with Romanian telecommunications group Digi.
"Citymesh already delivers mobile services to the business market," said chief executive Mitch De Geest. "Thanks to the additional spectrum, Citymesh can start offering a hybrid mobile strategy, roaming from private to a public network and back."

Source: https://5gobservatory.eu/belgium-completes-5g-spectrum-auction/

1.3.4 5G spectrum auction results in India

India's biggest ever spectrum auction ended in August, 2022, with bids upwards of Rs 1.5 lakh crore coming in after seven days of bidding spread over 40 rounds. Reliance Jio emerged as the largest spender in the 5G spectrum auction, acquiring almost half of all the airwaves sold for more than Rs 88,000 crore, and was also the only one (among four applicants) to have acquired spectrum in the premium 700 MHz band.
A total of 51.2 GHz of spectrum was sold, of the total 72 GHz that was up for grabs – close to 71%.

Reliance Jio spent Rs 88,078 crore and acquired a total of 24.7 GHz of spectrum in the 700 MHz, 800 MHz, 1800 MHz, 3300 MHz and 26 GHz bands. The country's second largest telco, Bharti Airtel, shelled out Rs 43,084 crore to acquire a total of 19.8 GHz of spectrum in the 900 MHz, 1800 MHz, 2100 MHz, 3300 MHz and 26 GHz bands. Vodafone Idea spent Rs 18,799 crore and bid for the 1800 MHz, 2100 MHz, 2500 MHz, 3300 MHz and 26 GHz bands, acquiring a total of 6,228 MHz of airwaves. The fourth applicant, Adani Data Networks Limited, a subsidiary of the Adani Group, acquired spectrum only in the 26 GHz band and spent Rs 212 crore.

Source: https://indianexpress.com/article/business/india-concludes-19-bln-5g-spectrum-auction-8064216/

Annex 2

Project: Next Generation Terrestrial Broadcasting (T/NGTB)

Project Manager: **Mr. Akihiko Sato** (NHK, Japan)

Co-project Manager: **Dr. Jeon Sungho** (KBS, Korea)
Mr. Chen Delin (SARFT, China)
Mr. Halil US (TRT, Turkey)
Mr. M S Duhan (DDI, India)
Mr. Zhang Yu (ABS, China)
Mrs. Xiao Jingting (ABS, China)
Mr. Rajesh Meena (India)
Mr. A K Mangalgi (India)

2.1 Investigate efforts toward the realization of next-generation terrestrial broadcasting in Japan

2.1.1. Introduction

Next-generation digital terrestrial television broadcasting will be dominated by UHDTV applications. UHDTV broadcasts consist of a huge amount of data and therefore require large-capacity transmission paths.

Japan is conducting research on large-capacity transmission technology for next-generation digital terrestrial broadcasting systems that will provide large-volume content services such as 8K. In order to transmit the 8K signal, which has a resolution 16 times greater than HDTV, it will be essential to utilize new technologies that expand transmission capacity, such as higher order modulation (4096-QAM), orthogonal frequency-division multiplexing (OFDM), and dual-polarized multiple-input multiple-output (MIMO).

This experiment establishes parameters for maximizing transmission capacity. However, in actual implementation, these parameters will have to be decided taking link budget, the transmission network, the receiving environment, and other factors into account.

2.1.2. 4K/8K-UHDTV field experiments with advanced system in urban area; Tokyo and Nagoya

2.1.2.1 Overview of advanced DTTB system

The objective of the advancement is to provide improved transmission performance compared to ISDB-T in terms of the increased transmission capacity and the reduced C/N required. The advanced system has been designed to inherit the feature of ISDB-T, i.e. it aims to provide a 4K or 8K UHDTV service for fixed reception and an HDTV service for mobile reception simultaneously by frequency division multiplexing (FDM) within a single channel. It also uses a frequency-segmented structure that allows partial reception. The bandwidth per segment is reduced to increase the number of segments from 13 (for ISDB-T) to 35, allowing for flexible bitrate distribution between layers such as the mobile reception layer and fixed reception layer. The advanced system allows a higher spectral efficiency and/or a transmission robustness with multiple-input multiple-output (MIMO).
A prototype modulator and demodulator for the advanced system were developed and their performances were confirmed through laboratory experiments. The feasibility of the system is being verified through large-scale field trials in urban areas.

2.1.2.2 Transmission parameters

Field experiments were conducted with the parameters listed in Table 2.1.1. The occupied bandwidth was expanded by about 5% compared to that of ISDB-T to increase transmission capacity. The 31 and 4 segments out of 35 segments were assigned for UHDTV and HDTV services, respectively. As for error-correcting code and carrier modulation, low density parity check (LDPC) code and NUCs were used for both UHDTV and HDTV services to enhance transmission robustness.

Table 2.1.1 Parameters for field experiments of hierarchical transmission in urban area (Tokyo and Nagoya)

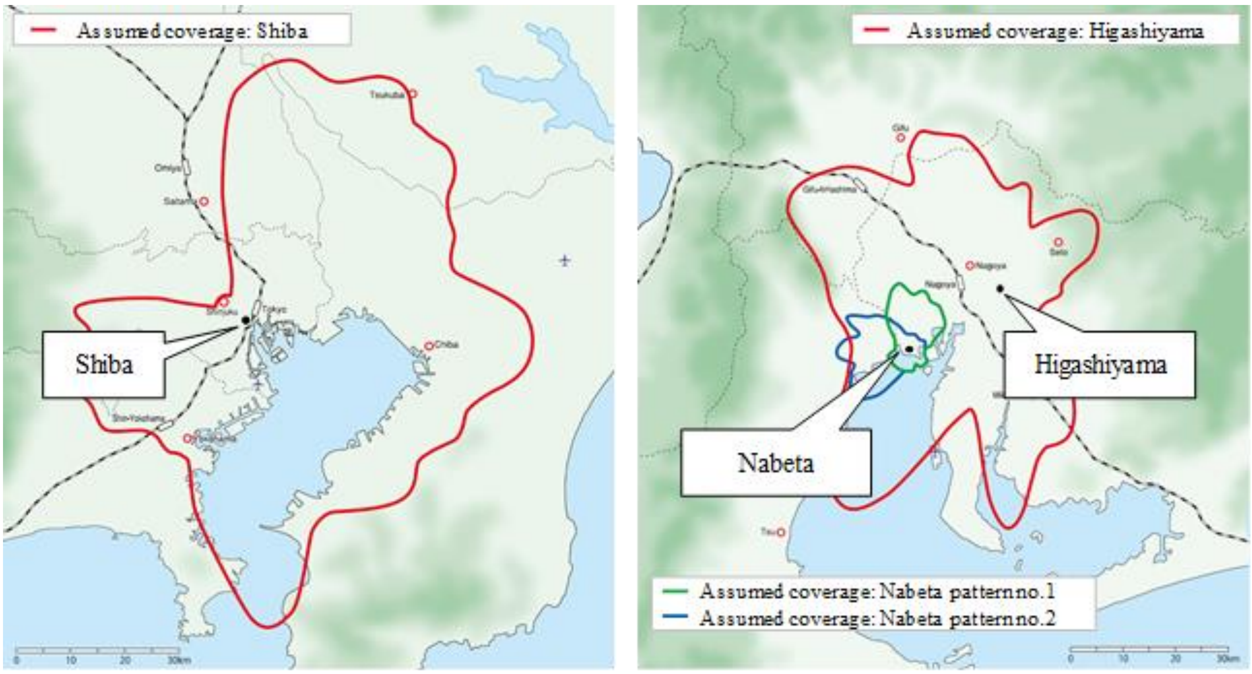
Modulation	OFDM	
Occupied bandwidth	5.83 MHz	
Reception scenario	Fixed (Rooftop)	Mobile (Car-mounted)
Number of segments	31	4
Carrier modulation	1024 NUC QAM	64 NUC QAM
FFT size (number of radiated carriers)	16k (15,121)	
Guard interval ratio (guard interval duration)	800/16384(126μs)	
Error-correcting code	Inner: LDPC, code rate = 11/16 Outer: BCH	Inner: LDPC, code rate = 7/16 Outer: BCH
Transmission capacity	31.4 Mb/s (SISO) 62.8 Mb/s (MIMO)	1.5 Mb/s (SISO) 3.0 Mb/s (MIMO)
Video coding	HEVC	
Video format	3840 ×2160/60/P (4K) 7680 ×4320/60/P (8K)	1920×1080/60/P (2K)
Video bit rate	SISO: 25 Mb/s (4K)	SISO: 1.0 Mb/s (2K)

	SISO: 28 Mb/s (8K)* MIMO: 56 Mb/s (8K)*	MIMO: 1.0 Mb/s (2K)
Audio coding	MPEG-H 3D Audio LC level 4	
Audio bit rate	768 kb/s (22.2ch + 3 objects)	192 kb/s (2ch)

* Pre-processed before encoding by MPEG-H HEVC with a state-of-the-art software encoder offline taking plenty of time.

2.1.2.3 Field measurements

To evaluate the performance of the advanced system in different propagation environments, large-scale experimental environments were constructed. Two locations (in the Tokyo and Nagoya areas) were selected to have the same scale as the main stations currently used for terrestrial broadcasting. Figure 2.1.1 shows the transmitter sites and assumed coverage areas for the experimental parameters in Table 2.1.1. Table 2.1.2 lists the specifications of the transmission stations. Each transmission station is equipped with two transmitters and two antennas for horizontally and vertically polarized waves. The directional patterns of transmitting antennas at Nabeta relay station are designed to be selectable.



a) Tokyo area b) Nagoya area

Figure 2.1.1 Experimental environments

Table 2.1.2 Specifications of transmission stations

	Tokyo area	Nagoya area	
Transmitter site	Shiba (main station) (Minato Ward, Tokyo)	Higashiyama (main station) (Showa Ward, Nagoya, Aichi)	Nabeta (relay station) (Yatomi, Aichi)
Transmission frequency	563.143 MHz	605.143 MHz	
Polarization	Horizontal, Vertical		
Transmission power	Horizontal: 1 kW Vertical: 1 kW	Horizontal: 1 kW Vertical: 1 kW	Horizontal: 10 W Vertical: 10 W
Transmitting antenna height	280 m above sea level	203 m above sea level	42.5 m above sea level

Transmission experiments were conducted in the two experimental urban areas.
Experiments were launched in November and December 2018 in the Nagoya and Tokyo areas, respectively.
The experiments involved field trials of hierarchical transmission of UHDTV/HDTV using a single channel based on the advanced DTTB system. The UHDTV (4K or 8K) content for fixed reception and HDTV (2K) content for mobile reception shown in Table 2.1.1 were recorded in advance in a player, and the video and audio streams were played back at the experimental stations. The block diagram of transmitting and receiving system is shown in Figure 2.1.2. UHDTV and HDTV streams from the player are multiplexed by the remultiplexer (remux) into a single IP stream and input to the advanced DTTB modulator. The frequency of two output signals from the modulator are converted and power-amplified by the transmitter. The audio of UHDTV was an object-based audio that transmitted a 22.2 channel audio encoded by MPEG-H 3D Audio and three narration objects in Japanese, English, and French. For the HDTV content, the video was encoded by HEVC and the stereo audio signals were encoded by MPEG-4 AAC.
Figure 2.1.3 shows the locations of the transmitting and receiving points in the Tokyo area. The NHK Science and Technology Research Laboratories (NHK-STRL), which is approximately 12 km away from the Shiba station, was selected as the receiving point. On the receiving side, the received spectrum was observed by a spectrum analyser, and the delay profile was confirmed by a signal analyser. The UHDTV signal output from the demodulator was decoded in real time by the HEVC decoder and displayed on a 4K/8K LCD monitor. The 22.2 channel audio was decoded in real-time by MPEG-H 3D Audio decoder, converted to 7.1 channel audio, and reproduced using a commercially available sound bar. The HDTV signal was converted from multicast to unicast, then transmitted via WiFi router, and decoded by an MMT player installed on a tablet or smartphone. Figure 2.1.4 shows the spectrum of the received signals.
Figures 2.1.5 and 2.1.6 show the delay profile and constellation of the received signal of SISO transmission using horizontal polarized wave. As for the delay profile, almost no reflected waves were confirmed as shown in Fig. 2.1.5 In this experiment, it was

demonstrated that UHDTV and HDTV contents can be successfully received with the advanced DTTB system.

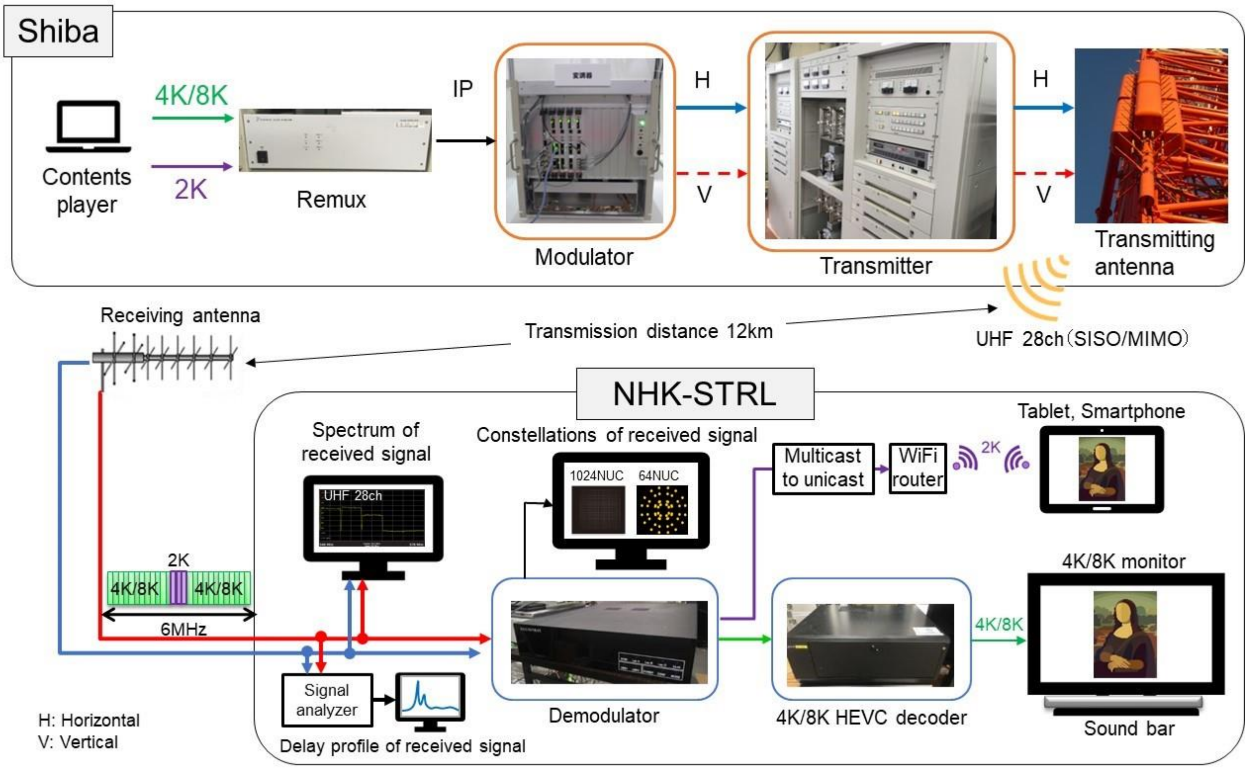


Figure 2.1.2 Block diagram of transmitting and receiving system in Tokyo

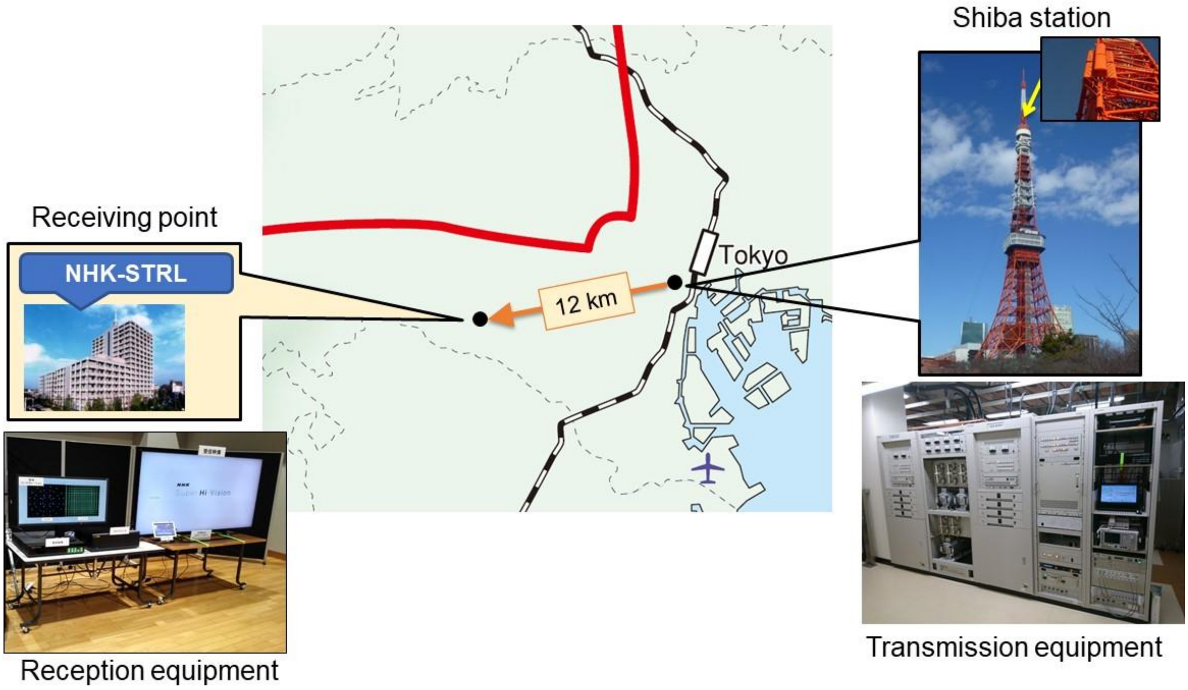


Figure 2.1.3 Locations of transmitting and receiving points in Tokyo

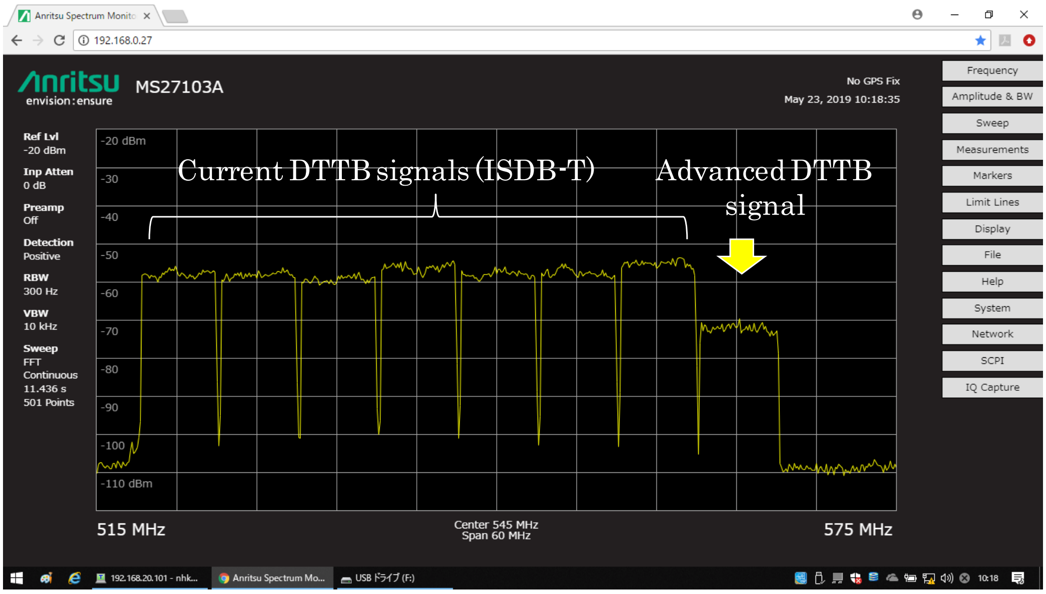


Figure 2.1.4 Spectrum of received signal at NHK-STRL (SISO)

Note: The advanced DTTB signal was allocated upper-adjacent to the current DTTB signals. The difference in the received power between the advanced DTTB signal and the current DTTB signals is due to the different transmitting power and the transmitting points.

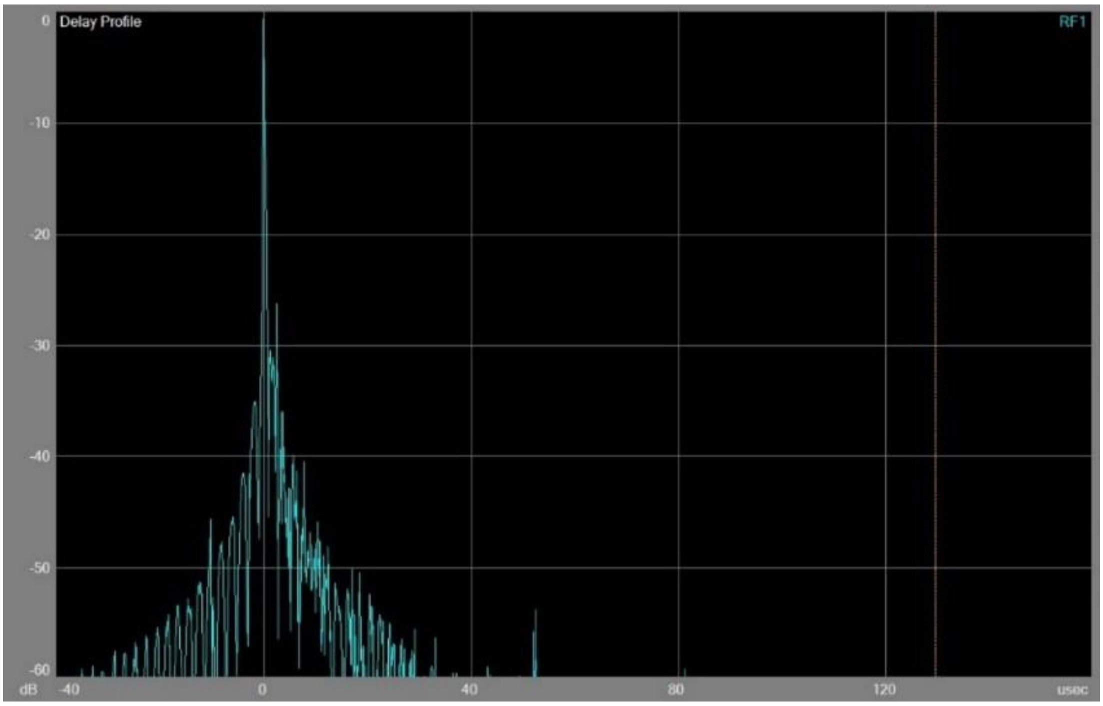


Figure2.1.5 Delay profile of received signal at NHK-STRL (SISO)

(a) 1024 NUC QAM for UHDTV (b) 64 NUC QAM for HDTV

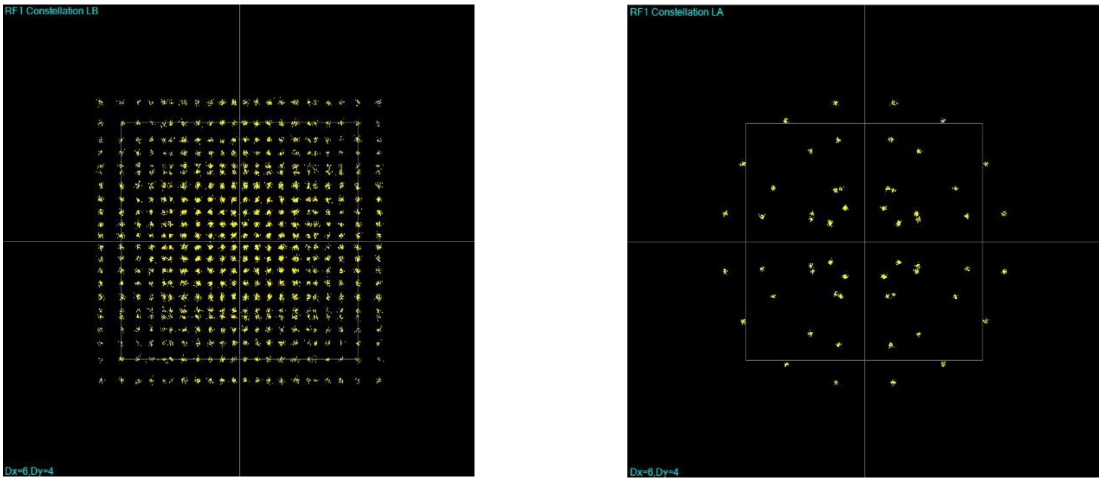


Figure2.1.6 Constellations of received signal at NHK-STRL (SISO)

The block diagram of transmitting and receiving system in Nagoya is shown in Fig. 2.1.7. Figure 2.1.8 shows the locations of the transmitting and receiving points in the Nagoya area. As a receiving point, the Nagoya port building, which is approximately halfway between the Higashiyama and Nabeta experimental stations, was selected. The remultiplexer was installed at the Higashiyama station and the IP packet was sent to the two modulators installed at the Higashiyama and the Nabeta stations. A 200 Mbit/s bandwidth secured line was used as the IP line between the Higashiyama and Nabeta stations. The radio waves were emitted from the two stations to carry out the transmission experiments in a SFN environment. The modulated signals were generated at each transmission timing.

At the receiving point (the Nagoya port building), the receiving antenna was installed facing the Nabeta station. Additionally, the transmission power of the Higashiyama station was adjusted to demonstrate severe SFN reception conditions. As an example, the desired-to-undesired signal ratio (DUR) of 3.2 dB and 1.9 dB for horizontal polarization and vertical polarization between the Nabeta station (D) and the Higashiyama station (U) was demonstrated with the reduction in the transmission power of the Higashiyama station by 5 dB for both polarizations. Regarding the delay setting of the remultiplexer, the transmitting timings of the Higashiyama and the Nabeta stations were aligned at the same time. As the Higashiyama station is geographically 500 m closer to the reception point than the Nabeta station, it was expected that the transmitted signals from the Higashiyama station would arrive 1.6 μs earlier than the signals from the Nabeta station. However, it was confirmed that the signals from the Higashiyama station arrived about 2 μs later than the signals from the Nabeta station. The delay was caused by a feedback compensation circuit installed in the transmitters at the Higashiyama station.

Figures 2.1.9, 2.1.10 and 2.1.11 show examples of the spectrum, delay profiles, and reception constellations of the received signals for MIMO transmission using horizontal and vertical polarizations. For the reception spectrum, ripples caused by the undesired signals from the Higashiyama station were confirmed. For delay profiles, horizontal to horizontal, horizontal to vertical, vertical to horizontal and vertical to vertical components are shown in blue, green, yellow and pink, respectively. The Higashiyama station is located in the direction opposite to the main lobe of the receiving antenna; therefore, many reflected signals transmitted by the Higashiyama station were observed. The demonstration of UHDTV/HDTV reception with the advanced DTTB system in the SFN environment was presented to the press. It was confirmed that even under severe SFN reception conditions, the UHDTV/HDTV video and audio could be received without any transmission errors.

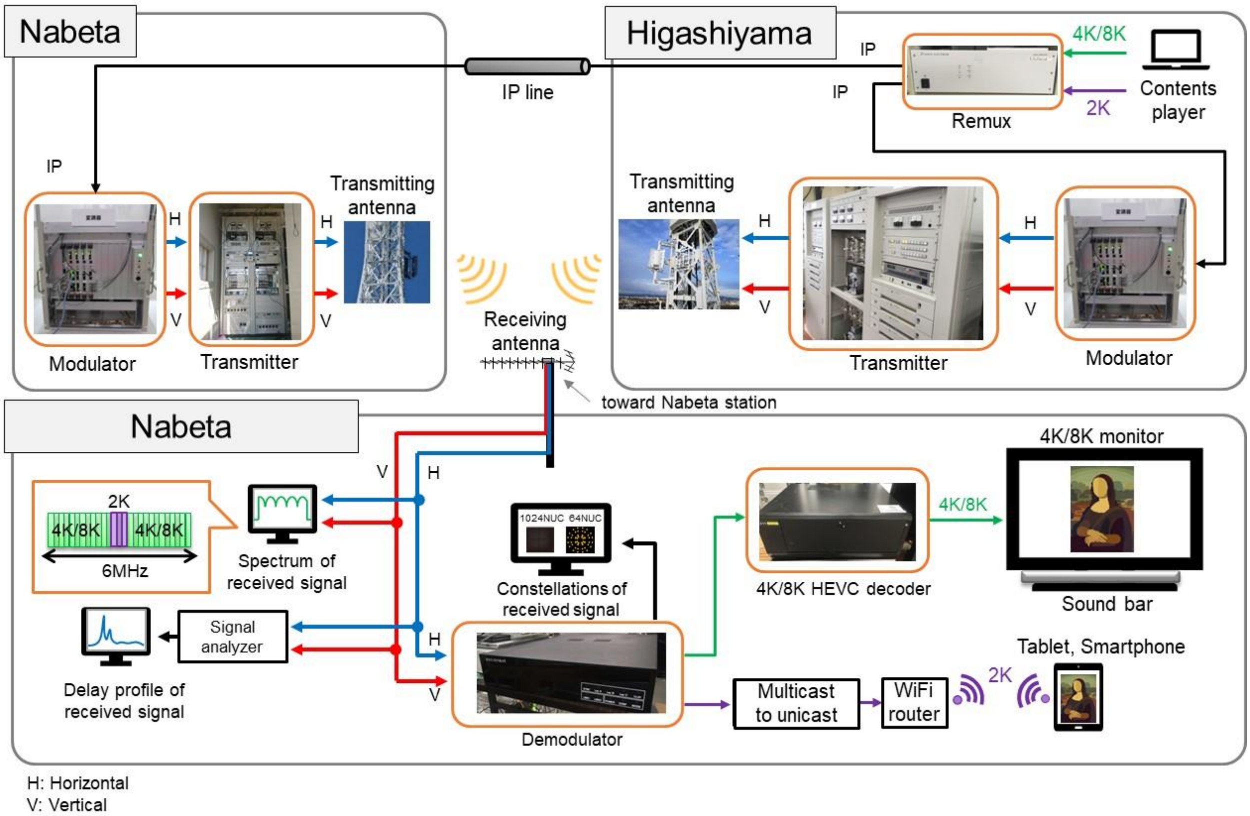


Figure 2.1.7 Block diagram of transmitting and receiving system in Nagoya

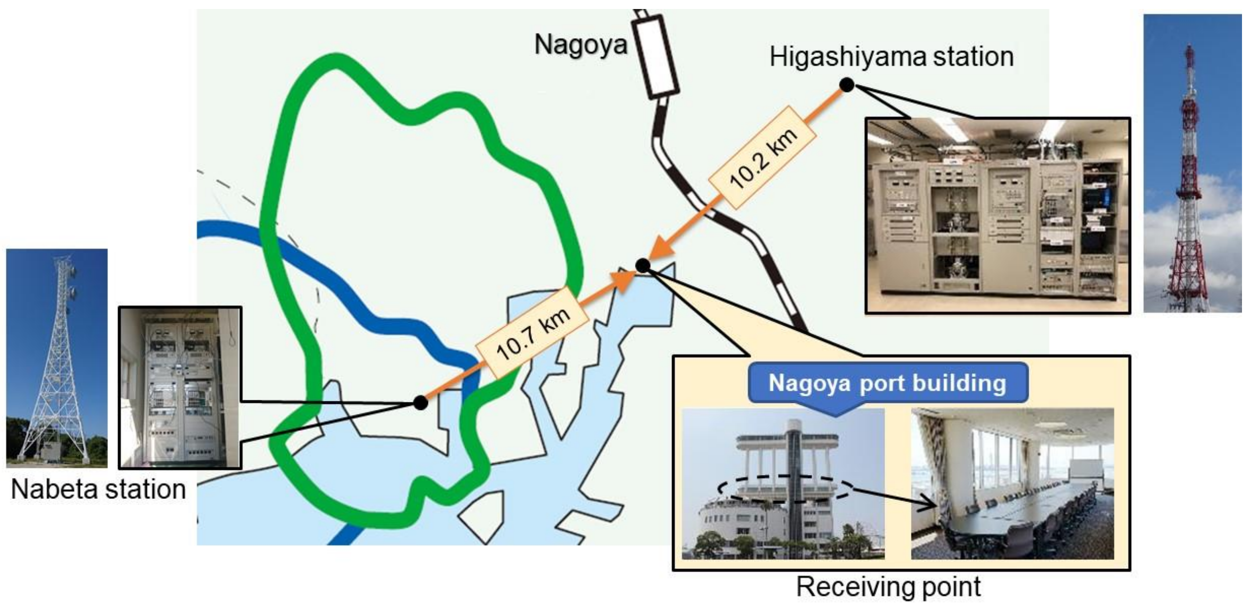


Figure 2.1.8 Locations of transmitting and receiving points in Nagoya

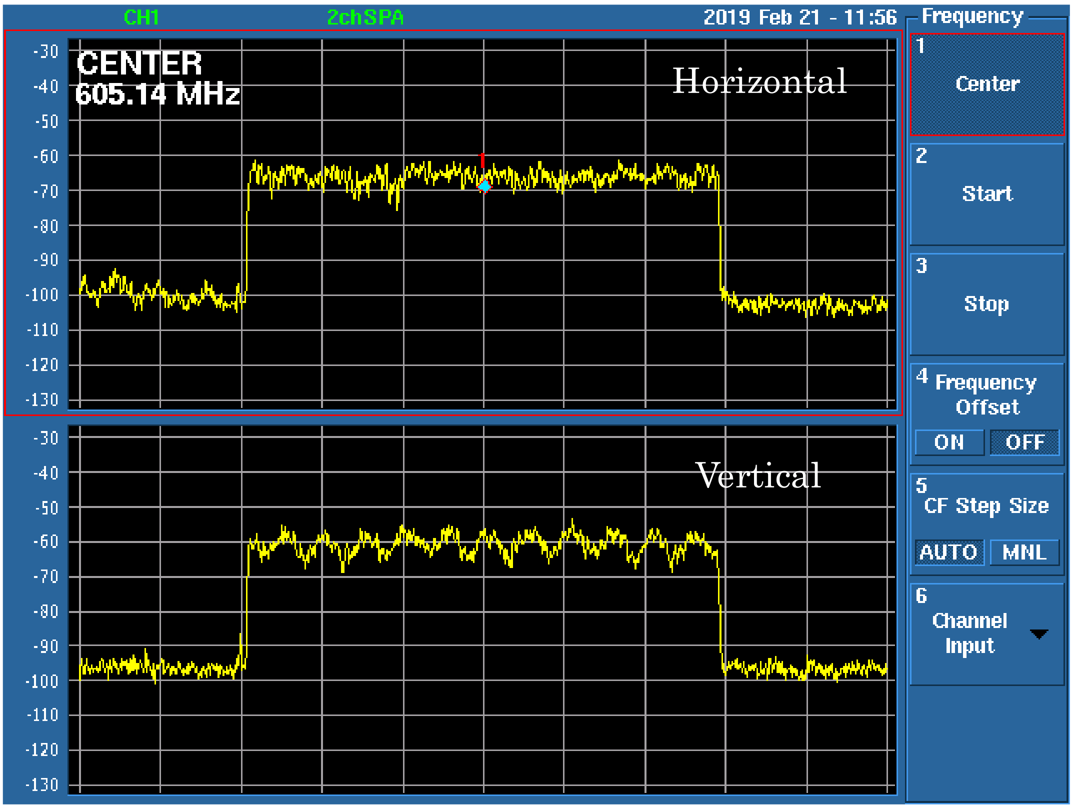


Figure 2.1.9 Spectrum of received signals at Nagoya port building (MIMO)

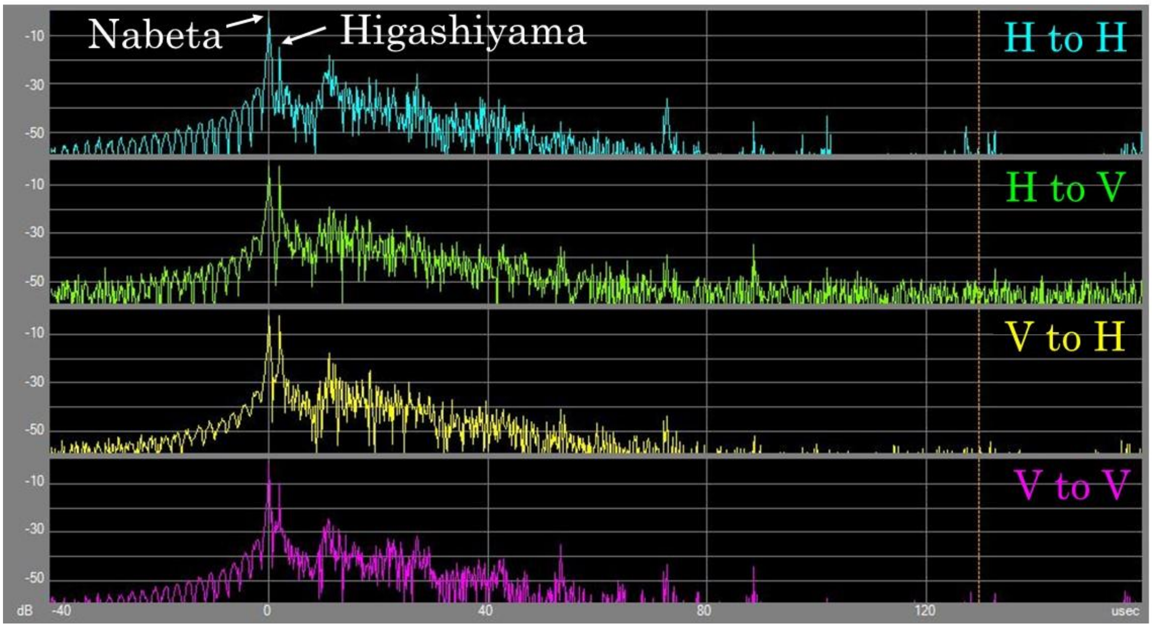
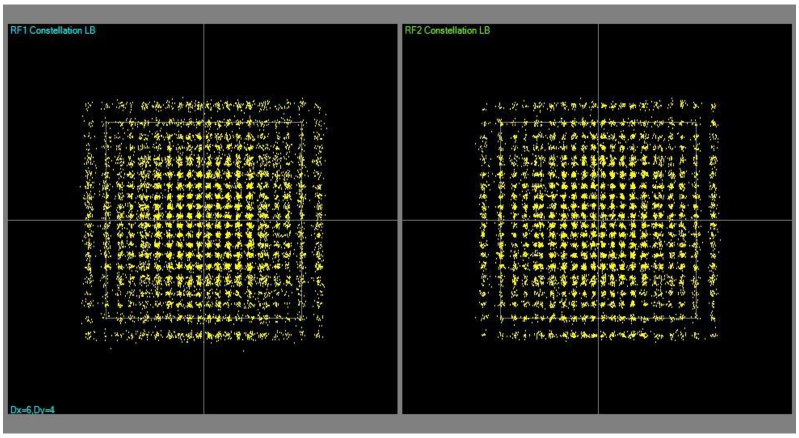


Figure 2.1.10 Delay profile of received signals at Nagoya port building (MIMO)

(a) 1024 NUC QAM for UHDTV (Horizontal) (b) 1024 NUC QAM for UHDTV (Vertical)



(c) 64 NUC QAM for HDTV (Horizontal) (d) 64 NUC QAM for HDTV (Vertical)

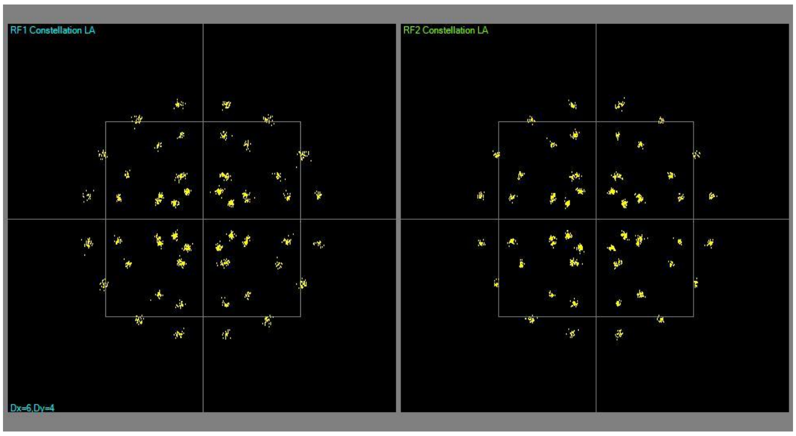


Figure 2.1.11 Constellations of received signals at Nagoya port building (MIMO)

Transmission performance of the advanced system is being verified assuming a fixed rooftop reception with a reception antenna at a height of 10 metres and a mobile reception with vehicular external aerials at a height of 2 metres in the Tokyo and Nagoya areas.
The plan is to evaluate the transmission characteristics not only of single-input single-output (SISO), but also MIMO to confirm the gain in the capacity and required C/N achieved with the advanced system in actual urban reception environments.

2.1.3. Overview of advanced ISDB-T specifications and evaluation of their transmission characteristics

With the aim of improving the quality and expanding the functions of digital terrestrial television broadcasting services, advanced transmission systems have been developed that inherit the key functions of integrated services digital broadcast-terrestrial (ISDB-T) systems, which employs hierarchical transmission based on frequency division multiplexing (FDM) and a segment structure. The advanced ISDB-T system has a new signal frame structure that enables bandwidth to be flexibly allocated to multiple services for different reception scenarios, such as fixed reception and mobile reception, compared with ISDB-T. Currently, verification of the transmission method is in progress.

The following are documents to help you get more information about the advanced ISDB-T:

A Study on the Transmission System of an Advanced ISDB-T
https://ieeexplore.ieee.org/document/8971915
This report describes an overview of the transmission system for a next-generation DTTB called the advanced ISDB-T and its basic transmission performance.

Transmission System Design of UHD-1/4K and UHD-2/8K Terrestrial Television Broadcasting and its Performance Proof by Large-Scaled Field Experiments
https://ieeexplore.ieee.org/document/9136826
This paper presents the concept and specifications of the proposed system. The verification results of a computer simulation, and laboratory and large-scale field experiments are also described.

Fixed Reception Performance of FDM-based Transmission System for Advanced ISDB-T
https://www.set.org.br/ijbe/ed6/Artigo1.pdf
This paper provides a BICM selection guideline based on the simulation results for fixed reception scenarios toward the practical application of advanced ISDB-T.

2.1.4. 8K-UHDTV field experiments with channel bonding

Channel bonding technologies use two or more radio frequency (RF) channels to transmit data from a single physical layer pipe (PLP) that exceeds the capacity of a single RF channel. These multiple RF channels may be located at any channel frequency and may not necessarily be adjacent to each other. To verify the channel bonding technology, an 8K-UHDTV field experiment of the channel bonding was conducted using two RF channels.

2.1.4.1 Transmission parameter and equipment

A field experiment was conducted with channel bonding using two RF channels based on the advanced system described in § 2.1.2. The transmission parameters are presented in Table 10. Each transmitting station for the two individual RF channels was composed of two transmitters for horizontal and vertical polarized waves. A dual-polarized dipole antenna was used for transmitting antennas. Simultaneous transmission of a UHDTV service for fixed reception and an HDTV service for mobile reception was assumed using FDM. A block diagram of the transmitting side is presented in Fig. 2.1.12.

TABLE 2.1.3 Parameters for field experiments of channel bonding

Transmitter site	Kinuta, Tokyo		
Transmission frequency	599.143 (UHF Ch 34)	581.143 MHz (UHF Ch 31)	
Transmission power	Horizontal: 1 W, e.r.p.: 1.3 W Vertical: 1 W, e.r.p.: 1.45 W	Horizontal: 1 W, e.r.p.: 9.3 W Vertical: 1 W, e.r.p.: 9.3 W	
Transmitting antenna height	104 m above sea level (74 m above ground level)	126 m above sea level (96 m above ground level)	
Modulation method	OFDM		
Occupied bandwidth	5.57 MHz	5.57 MHz	
Reception scenario	Fixed (Rooftop)		Mobile (Car-mounted)
Number of segments	33	24	9
Carrier modulation	1024 NUC QAM		16 NUC QAM
FFT size (number of radiated carriers)	16 k (15 121)		
Guard interval ratio (guard interval duration)	800/16 384 (126 µs)		
Error-correcting code	Inner: LDPC, code rate = 9/16 Outer: BCH		Inner: LDPC, code rate = 7/16 Outer: BCH
Transmission capacity (each)	52.4 Mbit/s (MIMO)	38.0 Mbit/s (MIMO)	4.4 Mbit/s (MIMO)
Transmission capacity(total)	90.4 Mbit/s (MIMO)		
Video coding	HEVC		
Video format	7 680 × 4 320/60/P (8K)		1 920 × 1 080/60/P (2K)
Video bit rate	MIMO: 80 Mbit/s (8K)		MIMO: 4.0 Mbit/s (2K)

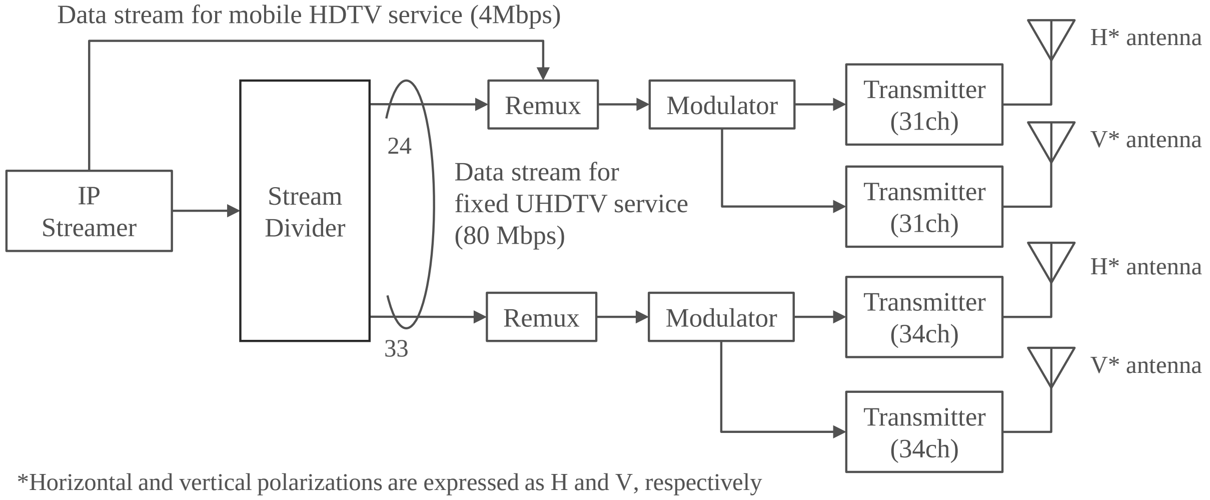


FIGURE 2.1.12 Block diagram of transmitter site

2.1.4.2 Field measurement

The transmitted signals were received at a line-of-site point located 4.5 km from the transmitter site. A block diagram of the receiving side is illustrated in Fig. 2.1.13. A dual-polarized Yagi-antenna was used to receive both the horizontal and vertical signals. Each signal transmitted in Ch 31 and Ch 34 was demodulated individually. The spectrum, constellations, and bit error rate (BER)s of the received signals are presented in figures 2.1.14, 2.1.15 and 2.1.16 respectively. The output data streams from the demodulators for the fixed reception UHDTV service were combined and fed to an MPEG media transport (MMT) /high-efficiency video encoding (HEVC) decoder, and the data stream for mobile reception HDTV service was fed to another MMT/HEVC decoder. The decoded UHDTV and HDTV images are displayed in Fig. 2.1.17.

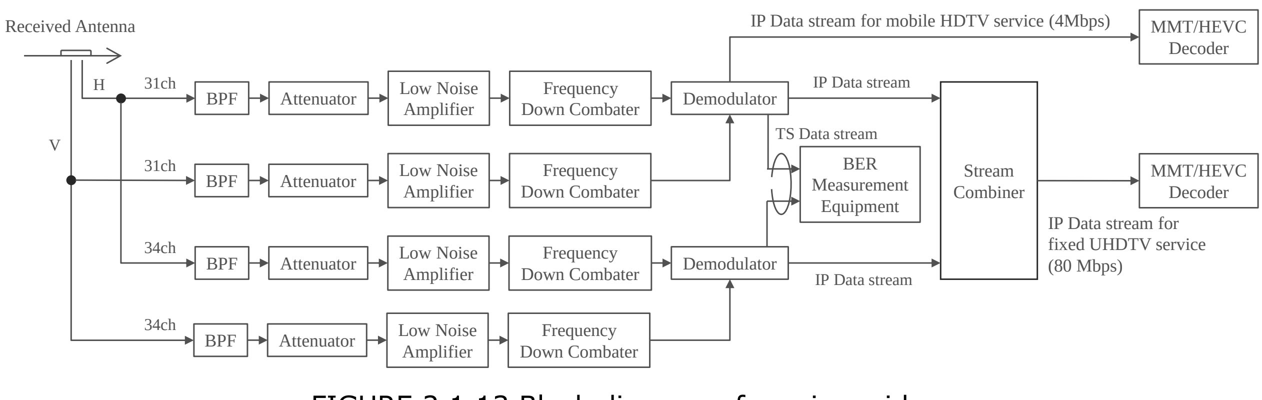


FIGURE 2.1.13 Block diagram of receiver side

(a) Horizontal (b) Vertical

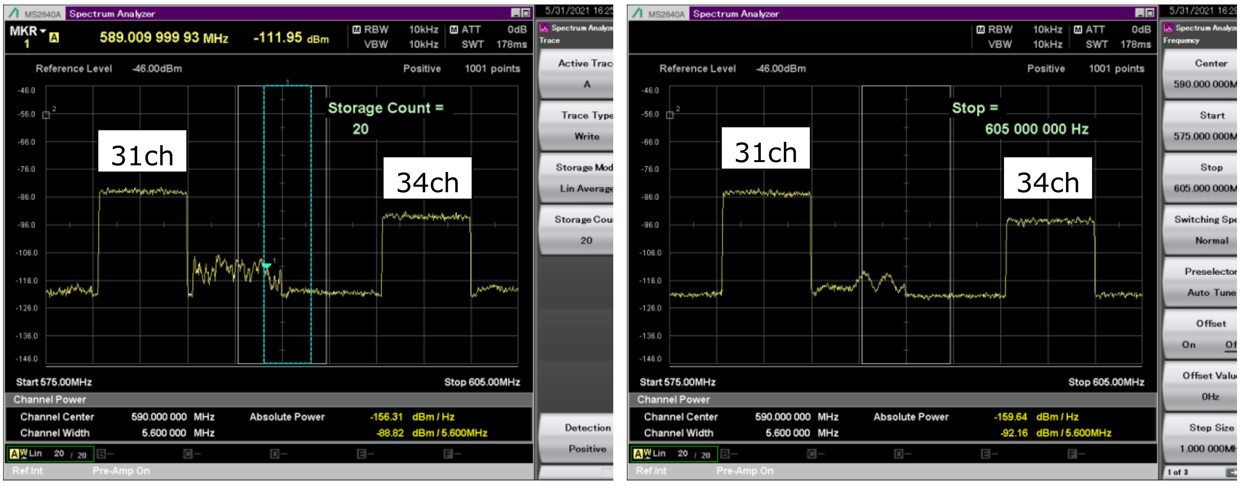
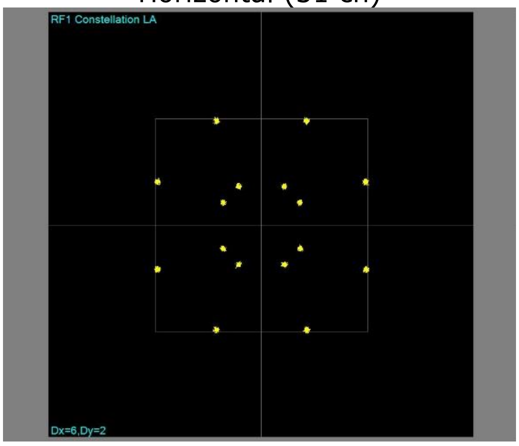


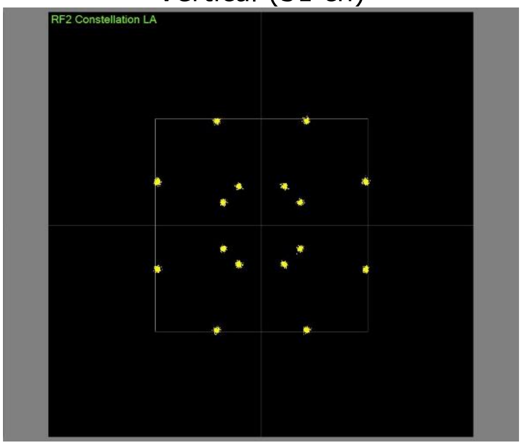
FIGURE 2.1.14 Spectrum of received signals

(a) Mobile reception layer
Horizontal (31 ch)



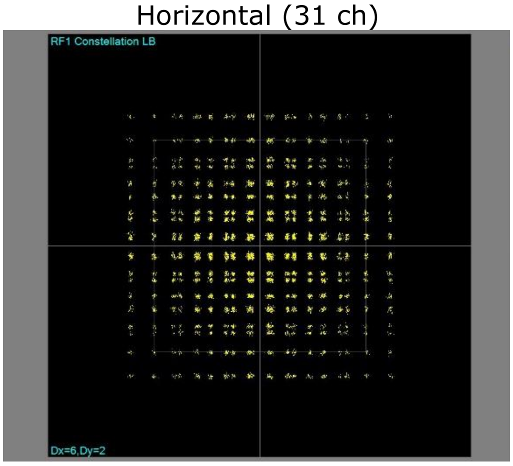
MER = 33.8 dB

(b) Mobile reception layer
Vertical (31 ch)



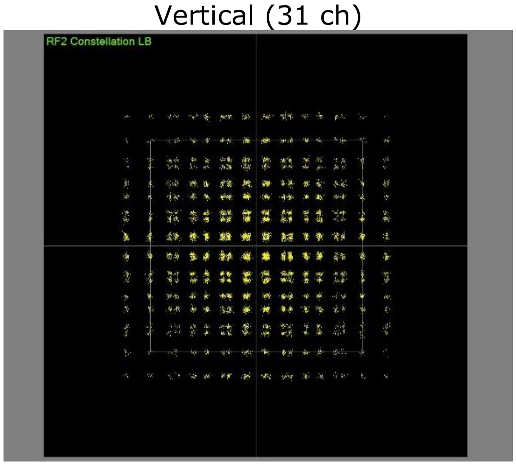
MER = 33.5 dB

(c) Fixed reception layer
Horizontal (31 ch)



MER = 34.3 dB

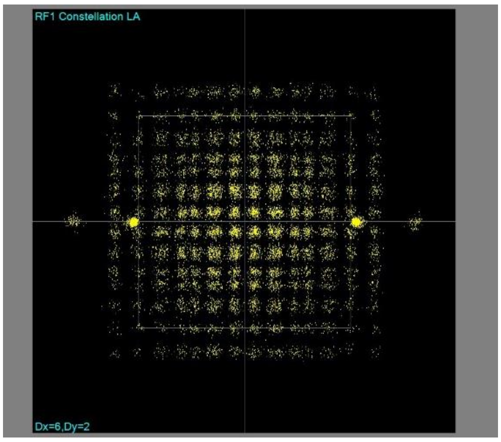
(d) Fixed reception layer
Vertical (31 ch)



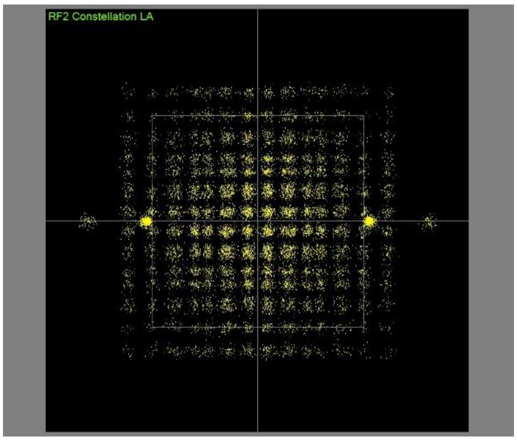
MER = 34.0 dB

(e) Fixed reception layer
Horizontal (34 ch)

(f) Fixed reception layer
Vertical (34 ch)



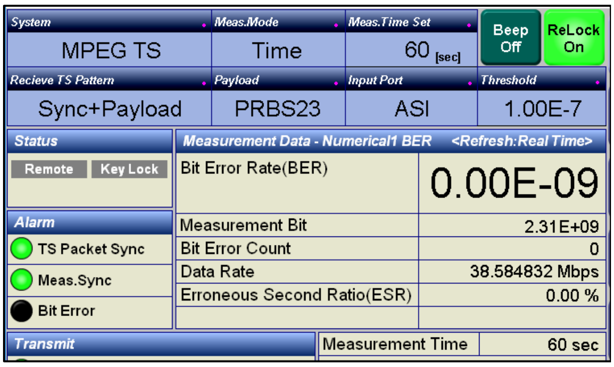
MER = 27.2 dB



MER = 27.0 dB

FIGURE 2.1.15 Constellation of received signals

(a) Fixed reception layer – 31 ch



(b) Fixed reception layer – 34 ch

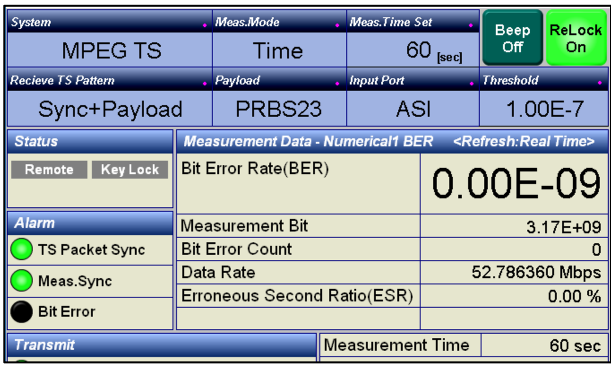


FIGURE 2.1.16 Measurement results of bit error rates

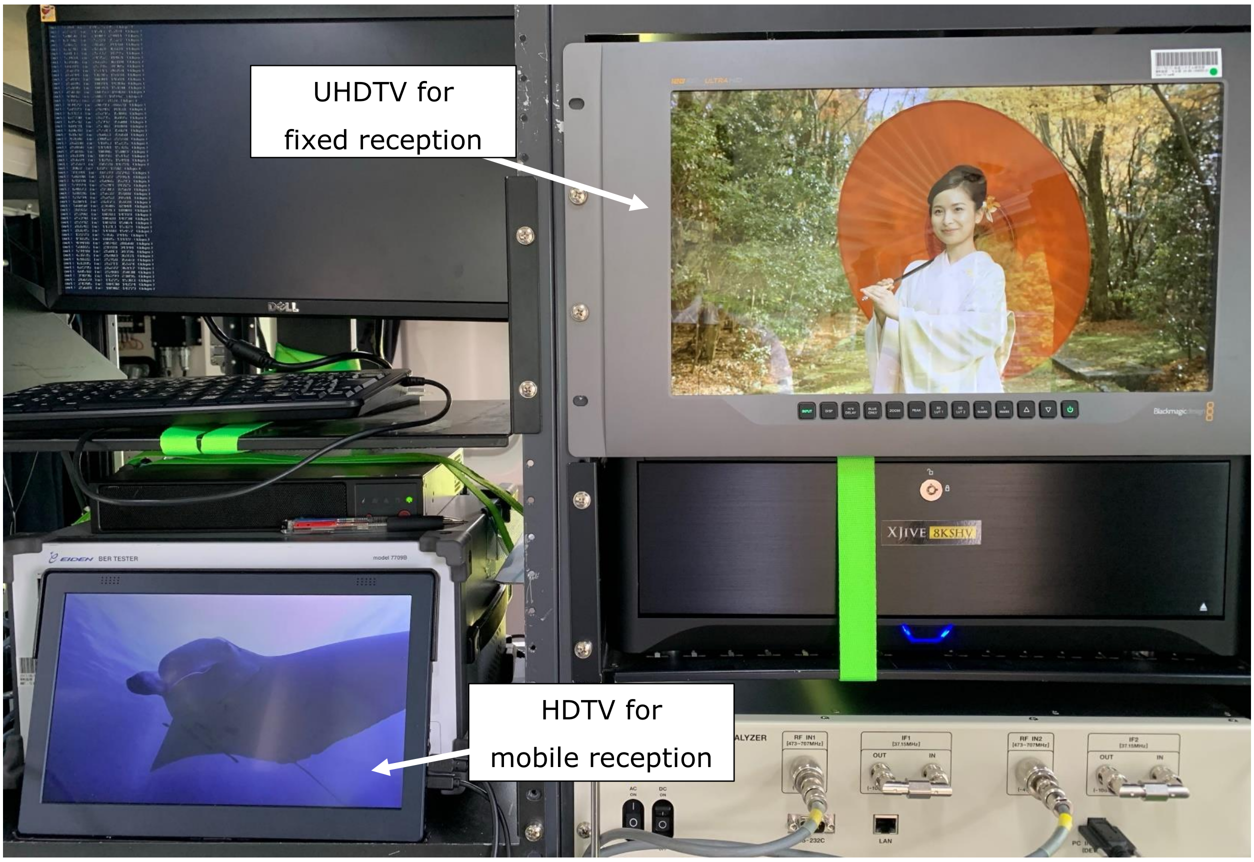


FIGURE 2.1.17 Received video of UHDTV and HDTV

2.1.4. Summary

In the field of broadcasting, UHDTV has the potential to succeed HDTV.

Japan has launched an R&D project aiming at developing an advanced DTTB system and evaluating its performance through field trials in large-scale experimental environments constructed in urban areas.

These field experiments will show the feasibility of terrestrial UHDTV transmission using several key technologies, including dual-polarized MIMO, 4096-QAM carrier modulation, LDPC code, NUC and channel bonding. The UHDTV system to be used in Japan will be selected on the basis of further consideration and examination of various technical possibilities and future trends.

More information such as transmission parameters, experimental results was described in the Rep. ITU-R BT.2343-7. (http://www.itu.int/pub/R-REP-BT.2343)

2.2. Development of ATSC 3.0 & 5G-Broadcast Transmission Technique in the Republic of Korea

KBS continued to develop ATSC 3.0 standard transmission and reception technology, and successfully launched the first domestic 5G-Broadcast test radio wave based on the 3GPP Release 16/17 standard. All developments are being done by the 'KBS Gyeonggi Gamaksan UHDTV Experiment Station.'

2.2.1. Configuring KBS 1-channel multi-channel/mobile/interactive service

1) UHD 1 channel (fixed reception) + HD 2 channels (mobile reception) + disaster warning message (data) configuration

On July 23, last year, KBS started multi-channel mobile broadcasting through the ATSC 3.0 broadcasting network before the Tokyo Summer Olympics. Two HD channels have been newly added, and channel 9-2 is organized and operated as an Olympic-specific channel during the Olympics, and continues to be operated as a disaster-specific broadcasting channel after the Olympics.

Channel 9-3 is 'Visual KBS 1 Radio' and is broadcasted simultaneously with FM radio, which is designated as a medium for disaster mitigation and relief in Korea. The screen part of channel 9-3 can be used to provide a variety of public information, and currently provides finding missing children, weather and fine dust information as shown in Figure 2.2.1.

n, weather and fine dust information as shown in Figure 2.2.1.

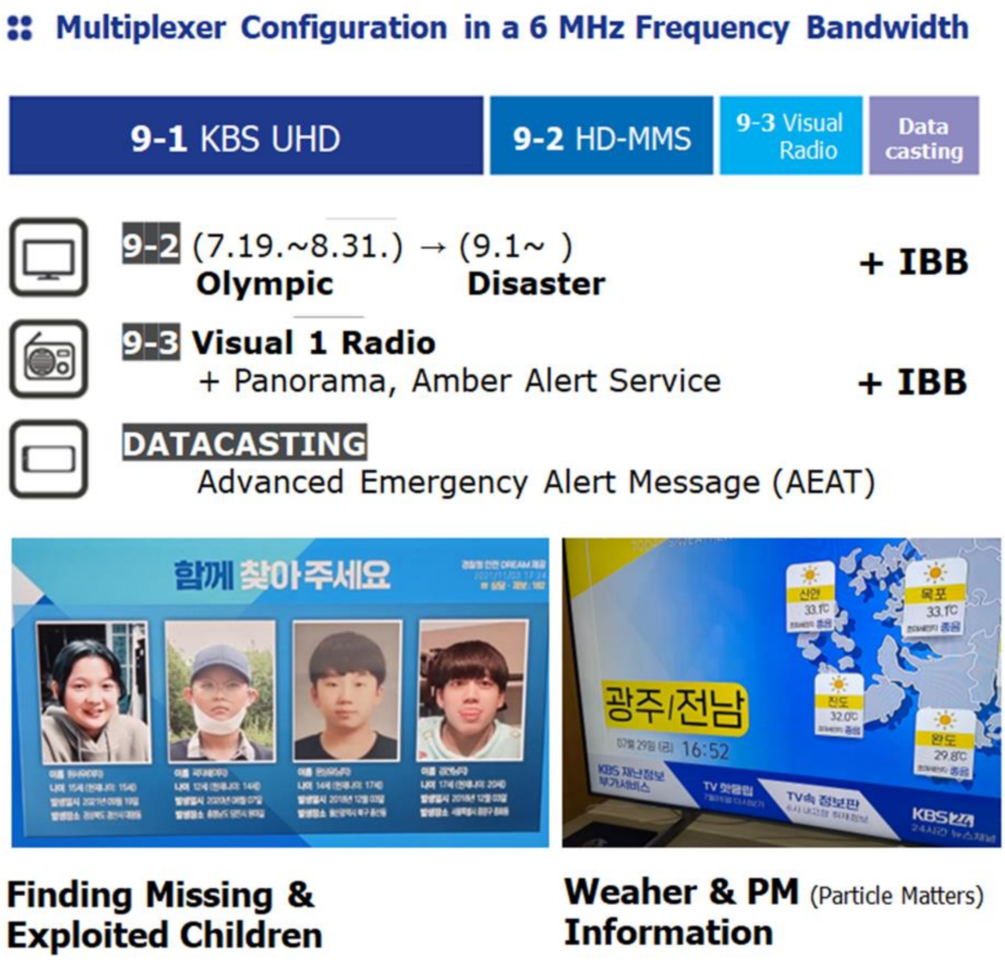


Figure 2.2.1 (up) Channel configuration within 6 MHz bandwidth (down) Finding missing children, weather and dust information services provided via the screen part of channel 9-3

In addition, as a data service, a disaster warning message is delivered according to the ATSC 3.0 AEAT standard, and the disaster message is displayed on public signage in a city bus or on the street quickly and accurately without any traffic bottleneck.

Figure 2.2.2 Disaster warning message displayed on a special receiver installed in Seoul city bus and public signage on the street equipped with ATSC 3.0 direct reception function

2) Securing mobile reception service coverage and terminals

The 9-1 UHD channel can support only fixed reception, while the newly added channels 9-2 and 9-3 can receive the signal under mobile condition. At first, we developed a vehicle test receiver, and conducted field tests in the Seoul metropolitan area to confirm how much service coverage was obtained.

Figure 2.2.3 (left) An ATSC 3.0 vehicle receiver prototype capable of mobile reception with up to 4 antennas Diversity (right) Field test results of mobile reception success rate in Seoul metropolitan area when one or four reception antennas are used

To build a mobile reception environment that the viewers can experience, it is essential to make commercial receivers available in the market, so we are promoting an atmosphere by sharing development status through demonstrations.

In March 2022, KBS and ETRI jointly demonstrated the Mark One Smartphone direct reception with the world's first ATSC 3.0 chipset built-in, widely announcing that mobile broadcasting is near at hand.

In June 2022, Madeleine Noland, President of the ATSC, officially said, South Korean auto parts manufacturer Hyundai MOBIS has developed, tested the first ATSC 3.0 receiver-equipped vehicles and these will be on the road in the United States by 2023 during opening remarks at ATSC NextGen Broadcast Conference in Detroit. It is expected that the ATSC 3.0 mobile reception environment will be improved significantly in the United States, and if the same vehicles are released in South Korea, Korean viewers will be able to experience mobile direct reception more.

Also, during KOBA Show 2022, KBS inserted the 'begin and end' time of programme on Channel 9-3, and vehicle receivers replaced a disaster clip video customized to the region based on their location during that period. As a result, it was proven that the technique, location-based dynamic disaster spot insertion, is possible to provide disaster information suitable for local disaster situations.

Figure 2.2.4 (left) ATSC 3.0 mobile direct reception demonstration using the Mark One smartphone held in March 2020. (right) ATSC 3.0 vehicle receiver demonstrated during KOBA 2022 event. The location-based dynamic disaster spot insertion was demonstrated by installing a receiver on a vehicle near the convention venue, and it was promoted to visitors through detailed configuration and explanatory materials in the booth inside the venue.

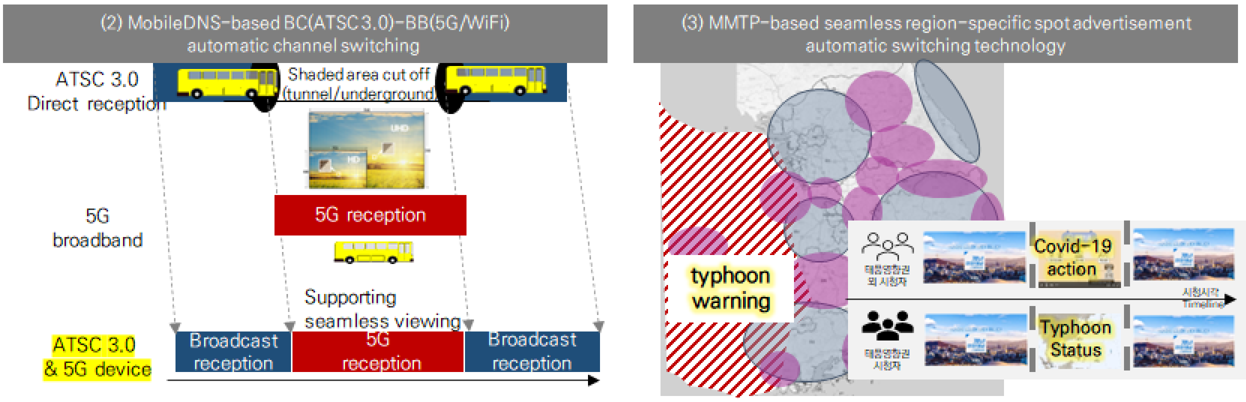


Figure 2.2.4 (left) Seamless Handoff between 9-2 channel 5G broadband network and ATSC 3.0 broadcast network in mobile reception environment (right) Disaster information service according to receiver position

3) Standardization and technical development of Handoff technique for seamless mobile reception

To build a mobile reception environment, it is essential to develop technology that enables seamless viewing, such as handoff, in addition to the spread of mobile receivers. In Korea, domestic TTA standardization was completed in December 2020 and based on this, handoff technique was verified within and between service coverages. For instance, in October 2022, the mobile DNS-based 'BC-BB heterogeneous network interworking technique' developed by KBS R&D was technically verified through the 9-2 channel in Jeju Island, and it proved that disaster information channels could be viewed anytime, anywhere.

2.2.2. Development of RF transmission technology based on KBS Gyeonggi Gamaksan Experiment Station

KBS is carrying out a national research project to implement all the functions of the ATSC 3.0 standard jointly with ETRI, developing MIMO technology based on the ATSC 3.0 standard. Also, in collaboration with ETRI, we are developing 5G-Broadcast technology based on the 3GPP standard for direct smartphone reception without embedding ATSC 3.0 chipset. We are conducting technical development and verification in both directions.

1) The center of development and verification of new transmission technologies in South Korea, KBS Gyeonggi Gamaksan UHDTV Experiment Station

KBS Gyeonggi Gamaksan UHDTV Experiment Station is mainly called the 'KBS Bukgamak Experiment Station'. Currently, one ATSC 3.0 MIMO transmitter capable of 300W transmission, one ATSC 3.0 transmitter and one 3GPP 5G-Broadcast transmitter capable of 900W transmission through a SISO antenna are installed and operating. Transmitters use UHF CH 56 (786MHz) as an experimental frequency channel officially licensed by the Korean government. The station is located near the DMZ, and the test antenna was installed only in the north direction, to minimize the problem of interference in the metropolitan area due to test radio waves.

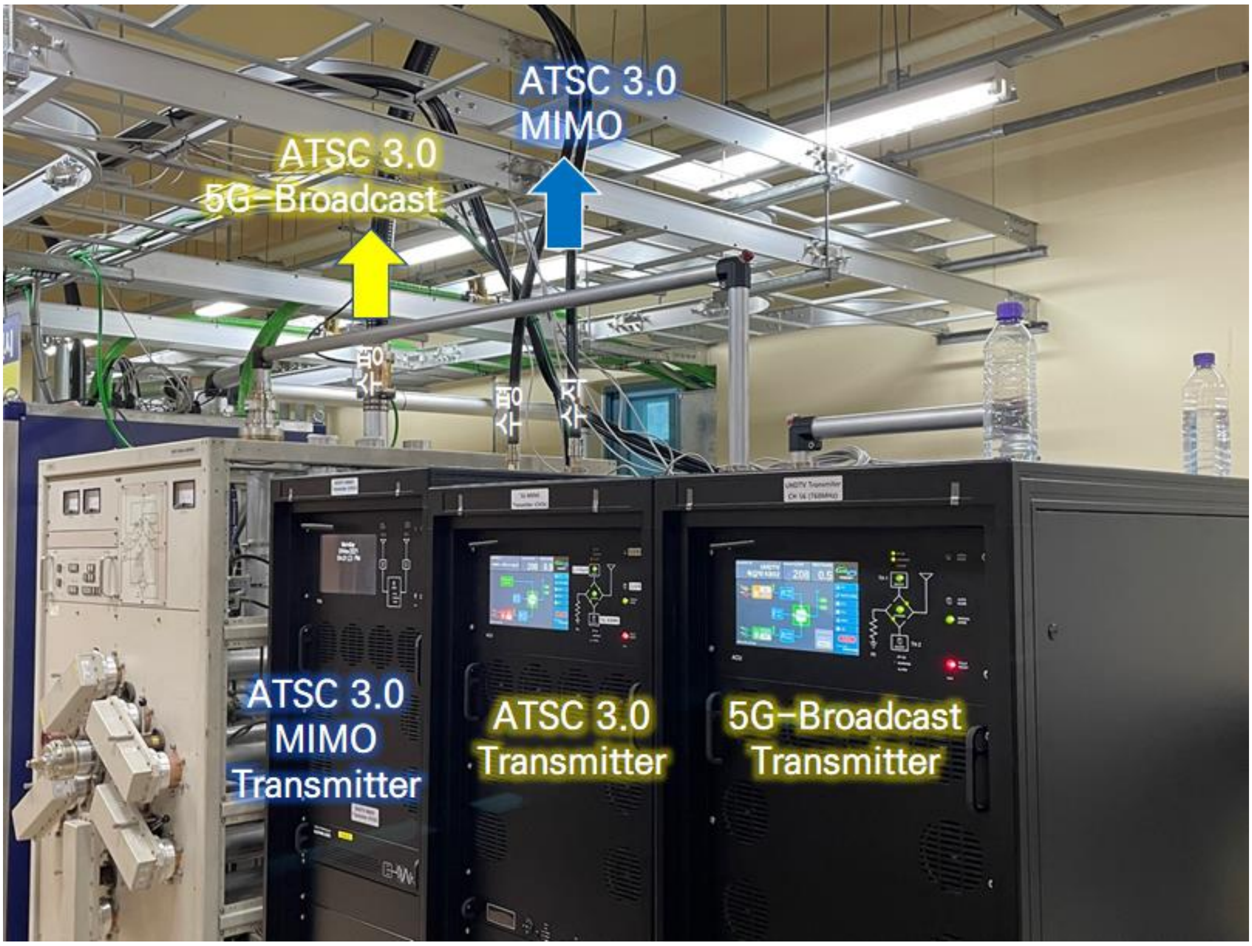


Figure 2.2.5 Experimental transmitters installed at the Bukgamak Experiment Station. ATSC 3.0 MIMO Transmitter capable of transmitting 300W on the left. ATSC 3.0 SISO Transmitter capable of transmitting 900W each in the middle and 5G-Broadcast Transmitter on the right.

2) Development of ATSC 3.0 2x2 MIMO transmitter and receiver for 4K-UHD multi-channel transmission test

The maximum data rate that can be obtained through the SISO ATSC 3.0 transmitter while maintaining the current ATSC 1.0 service coverage is about 25 Mbps. However, it was confirmed when MIMO technology is used, that it is possible to obtain a transmission rate of 50 Mbps. The main purpose of the technology development is to verify whether it can transmit four 12.5 Mbps UHD channels compressed by the HEVC codec.

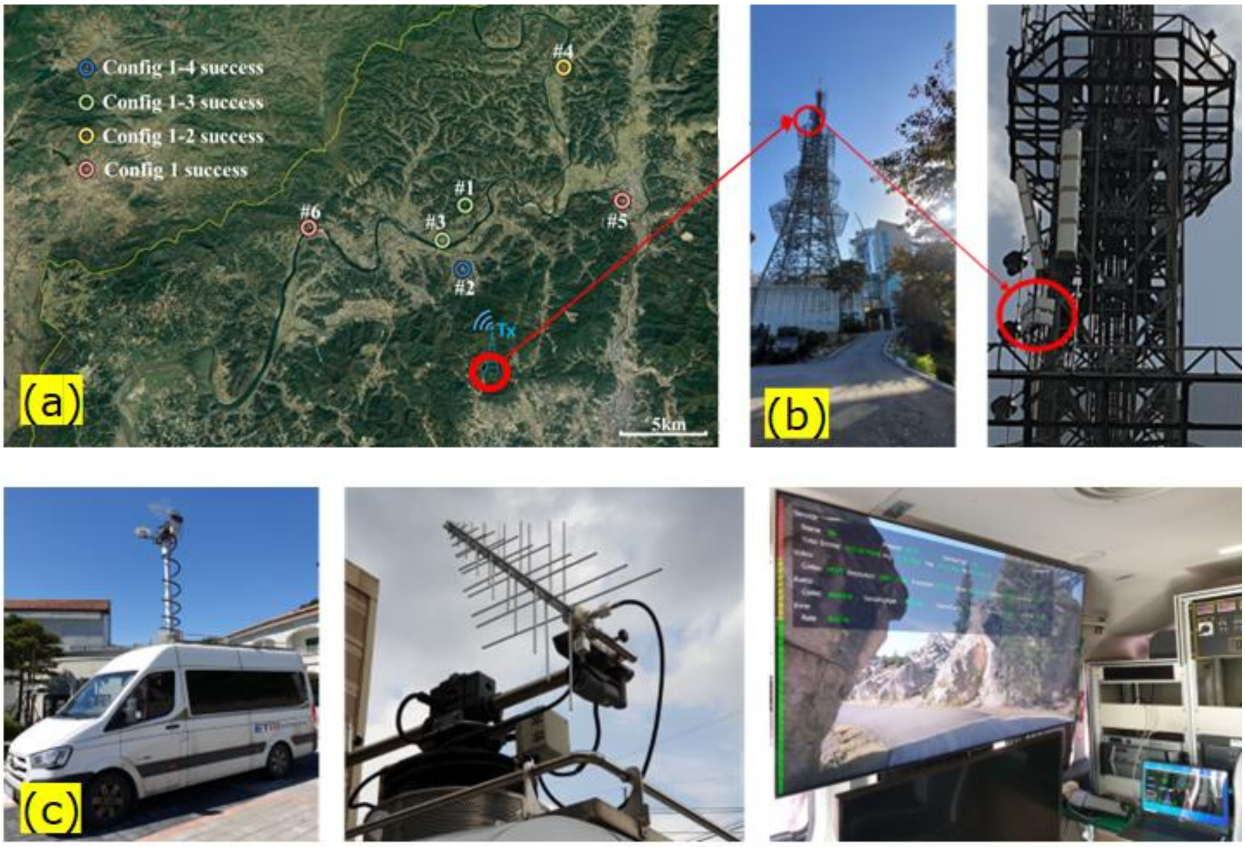


Figure 2.2.6 (a) Six field measurement locations and the corresponding results (b) ATSC 3.0 MIMO transmission tower (c) ATSC 3.0 MIMO measurement test vehicle. A dual-polarized antenna is placed at the top of the vehicle. The maximum height of the receiving antenna is 9 m and 2 m from the ground for fixed and moving measurement, respectively.

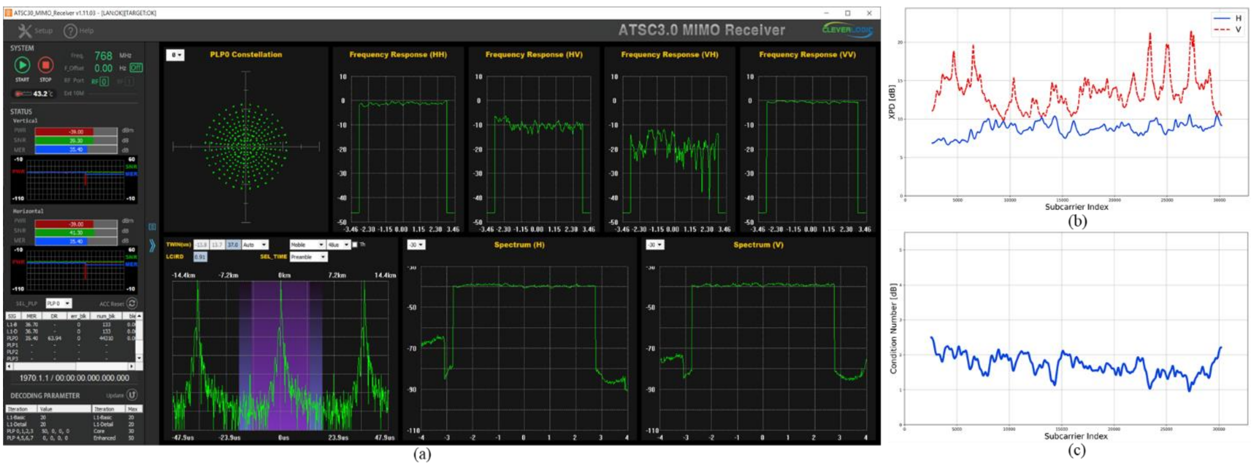


Figure 2.2.7 (a) ATSC 3.0 MIMO demodulator GUI (b) Cross-polarization discrimination (XPD) measurement results and (c) Condition numbers at the measurement point #3

3) Development of 3GPP 5G-Broadcast transmitter/receiver and first test radio launch

In parallel with the development of ATSC 3.0 technology, 3GPP 5G Broadcast technology, which is being actively studied in Europe, is also being developed to support the consumption of broadcast content through smartphones, which is becoming increasingly important every day. Especially, in November 2021, the experimental radio wave was successfully transmitted for the first time in South Korea through the KBS Bukgamak Experimental Station. Currently, based on the 3GPP Release 16 standard, a transmitter with the 6/7/8 MHz bandwidth setting defined in Release 17 and an FPGA-based receiver for validation check was implemented. Currently, only fixed reception is possible, through the continuous on-air validation and verification process, the technology level will be raised to a level that can be used under mobile receiving conditions.

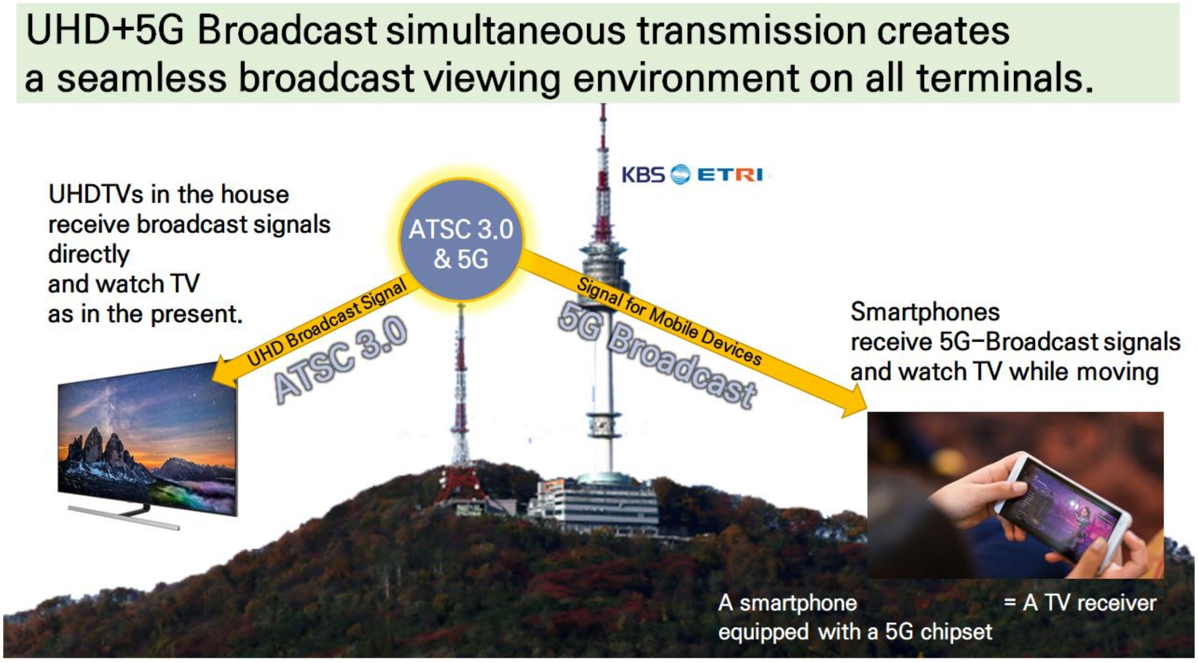


Figure 2.2.8 Development of ATSC 3.0 direct reception environment targeted to fixed and vehicle receiver, and 5G-Broadcast direct reception environment targeted to smartphone that enables direct reception without installing a separate ATSC 3.0 reception chipset. Through parallel research on both technologies, the ultimate goal is to create an environment where viewers can conveniently watch anytime, anywhere, and further raise the competitiveness of the terrestrial platform.

2.2.3. Summary and Further Plans

By expanding the ATSC 3.0 MIMO technology that uses only one 6MHz channel, we'd like to verify the environment in which multi-channel 8K-UHD transmission is possible by implementing and applying channel bonding technique using two 6MHz channels. Of course, we plan to conduct field tests through the KBS Bukgamak Experiment Station. In addition, we would like to compare and verify the difference in ATSC 3.0 and 5G-Broadcast reception performance under the same output and same transmission speed conditions and collect and collate the basic data necessary for analyzing the broadcasting network expansion in the future.

Annex 3

Project: Integrated Broadcast-Broadband and OTT (T/IBBOTT)

Project Manager: **Dr. Go OHTAKE** (NHK, Japan)
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Dr. Shinya Abe (NHK, Japan)
Mrs. Zhang Dingjing (ABS, China)
Zhang Yu (ABS, China)
Zhang Wei (ABS, China)
He Jing (ABS, China)
Wang Lei (ABS, China)
Mr. A K Mangalgi (DDI, India)
Mr. A K Srivastava (India)

3. Status report

This clause describes recent updates on IBB and OTT standards and related technologies identified and studied by this project. And it describes also recent update on standards and technologies of information security for broadcasting services and cyber security in broadcasting industry for protecting the broadcasting systems.

3.1 Standardization of Integrated Broadcast-Broadband System in Japan

IPTV Forum Japan standardizes specifications of Hybridcast in Japan. Technical specification of Hybridcast is composed of two technical standards and an operational guideline listed below and the latest versions are published in November 2020.

- IPTVFJ STD-0010 'Integrated Broadcast-Broadband System Specification', version 2.3
- IPTVFJ STD-0011 'HTML5 Browser Specification', version 2.6
- IPTVFJ STD-0013 'Hybridcast Operational Guideline', version 2.9

In the revision in November 2020 several new features were added to the Hybridcast technical specifications. Major updates are as follows:

- Addition of the new application type named "Broadcast-independent managed application"
  An application of this type runs in the state that no broadcast channel is being tuned so that service providers can offer application services regardless of their broadcasting area.
- Enhancement to the streaming video playback function
  The CMAF[*1] is added as a supported container format of streaming video, including low-latency playback features. Support for stream event delivery mechanisms such as an 'event message' (emsg) box and an 'Event' XML element of MPEG DASH[*2] are

also added.

- Enhancement to the companion device function
  UHDTV broadcasting services, i.e. 4K and 8K satellite broadcasting in Japan, are added to the available channels for tuning from a companion device.
- Addition of the three-dimensional audio codec support
  The enhanced AC-3[*3] is added to the available audio codecs for video streaming.

*1 ISO/IEC 23000-19 "Multimedia application format (MPEG-A) — Part 19: Common media application format (CMAF) for segmented media".
*2 ISO/IEC 23009-1 "Dynamic adaptive streaming over HTTP (DASH) — Part 1: Media presentation description and segment formats".
*3 ETSI TS 102 366 "Digital Audio Compression (AC-3, Enhanced AC-3) Standard".

3.2 Studies in ITU-R

ITU-R WP6B is working for the study on IBB systems. The working party is now studying on harmonization of IBB systems by making comparison of Hybridcast (Japan), HbbTV2.0 (Europe), TOPSmedia (South Korea) and Ginga (Brazil).
At the meeting held in April 2019 in Geneva, the working party developed the comparison of application life-cycle and application transition of the IBB systems, and revised Report ITU-R BT.2267 "Integrated broadcast-broadband systems" to add a new part on the harmonization of Integrated Broadcast-Broadband (IBB) systems' applications. To allow the exchange of services covered by the IBB systems and to deploy these services in an area where other systems are used, it is important to harmonize the IBB systems, to ensure compatibility with the IBB applications and interoperability across systems.
At the meeting, the working party revised Report ITU-R BT.2342 to replace information on TTML Text and Image Profiles for Internet Media Subtitles and Captions 1.0 (IMSC1.0) with the updated IMSC1.1 and to update a list of current EBU specifications pertinent to the content of the Report.

At the meeting held in July 2019 in Geneva, the working party revised Report BT.2267 to add the companion application to execute the application on a receiver. The working party also developed the new use cases of IBB system which provides object-based sound services via MPEG-DASH streams.
The working party also developed the global platform. The working party revised Report ITU-R BT.2400 "Usage scenarios, requirements and technical elements of a global platform for the broadcasting service" to add the specific reference to the ATSC 3.0 standard and some examples to show its Internet Protocol-based capabilities to integrate broadcast and broadband services. New digital terrestrial transmission standards such as the ATSC 3.0 system can help effectuate a converged broadcast and broadband platform, which is an important aspect of a global platform for broadcasting services.

At the meeting held in October 2020, the working party revised Recommendation ITU-R BT.2075 "Integrated broadcast-broadband system" to update an application execution mechanism of Hybridcast, with which a companion device sends a command to a receiver to tune to a designated channel and launch a Hybridcast application.

At the meeting held in March 2021, the working party prepared a revised draft report of Recommendation BT.2075 by adding information regarding commonality among IBB systems and equivalency of their functions as described in Report BT.2267 Part 3. The working party also prepared a draft revision to report BT.2267 on IBB systems to align with Recommendation ITU-T J.208 on harmonization of applications between IBB systems.

At the meeting held in September 2022, the working party revised Recommendation ITU-R BT.2075 "Integrated broadcast-broadband system" and Report BT.2267 "Integrated broadcast-broadband systems" to add a Broadcast-independent managed application, that is an application launched when broadcast services are not selected but still authenticated by broadcasters.

3.3 Studies in ITU-T

ITU-T SG9 is also working for the study on IBB system applied to Cable Digital TV. At the meeting held in November 2018 in Bogota, Colombia, the Study Group started the work to revise IBB system Recommendation (ITU-T Recommendation J.207 "Specification for integrated broadcast and broadband digital television application control framework") to add the function of device collaboration with companion devices in Hybridcast. Recommendation J.207 is a twin of IBB system Recommendations in ITU; Recommendation ITU-R BT.2075 is another twin on this topic. So, the Study Group continue to work to revise the Recommendation according to revision of Recommendation ITU-R BT.2075. The Study Group is studying the work of smart TV operating system for hybrid cable Digital TV services including IBB DTV service provided by cable television operators and third-party providers. At the Bogota meeting, the study group make progress the work of the architecture of smart TV operating system. The study group consent the Recommendation of "The functional requirements of smart TV operating system" as ITU-T Recommendation J.1201.

At the meeting held in June 2019 in Geneve, the study group consent Recommendation J.207 to add the function of device collaboration in Hybridcast. The study group also make progress the work of drafting new Recommendation "Harmonization of Integrated Broadcast-Broadband DTV application control framework". As for the smart TV operating system, the study group consent the Recommendation of "The architecture of smart TV operating system" as ITU-T Recommendation J.1202. In addition, making a new

Recommendation for the specification of smart TV operating system was started in the study group.

At the meeting held in July 2020, the study group reached the AAP consent for the draft new Recommendation ITU-T J.1204. It is now approved and is part of a set of already approved Recommendations as follows:

- J.1201: Functional requirements of a smart TV operating system
- J.1202: The architecture of a smart TV operating system
- J.1203: The specification of a smart TV operating system
- J.1204: The security framework of a smart TV operating system

The group also consent new Recommendation ITU-T J.208 "Harmonization of Integrated Broadcast-Broadband DTV application control framework" at its November 2020 meeting. The recommendation is created based on Report ITU-R BT.2067 which defines the methods to harmonize IBB systems by identifying commonalities across the IBB systems.

3.4 Cyber Security in USA

Sinclair Broadcast Group, which has 185 television stations in 86 markets, became the target of a ransomware attack that disrupted operations at several television stations on Friday, October 15th, 2021. Ransomware hackers often launch their attacks at the beginnings of weekends in the hope that victims will be short-staffed. Sinclair began investigating Saturday and by Sunday had discovered that several of its servers and workstations were encrypted with ransomware. Hackers also took unspecified data. Shares traded down nearly 3%.

The company did not address questions regarding how widespread the service disruptions were, but at least a half-dozen of its stations used social media to inform audiences of the outages. They include KHQA (Channel 7) in Hannibal, Mo.; KOMO News in Seattle; WLUK Fox 11 in Wisconsin; CBS (Channel 6) in Albany, N.Y.; and KATU (Channel 2) in Portland, Ore. For example, at WBFF in Baltimore, Sinclair's flagship station, Monday's midday newscasts aired without any of the usual graphics or accompaniments. Some of the usually live segments were clearly pretaped. The problems largely hindered local live programming, like the newscasts that typically air for multiple hours a day. Some stations struggled to produce newscasts on Sunday without writing, editing or scheduling software. Some journalists continued to deliver broadcasts through Facebook Live and video clips on Twitter, sharing updates on local news, traffic and weather.

Source:

https://abcnews.go.com/Politics/sinclair-broadcast-group-hit-ransomware-attack/story?id=80646308
https://www.washingtonpost.com/business/2021/10/18/sinclair-broadcasting-ransomware-attack/
https://www.nbcnews.com/tech/security/ransomware-attack-hits-owner-dozens-news-stations-rcna3180
https://edition.cnn.com/2021/10/18/media/sinclair-ransomware/index.html

Annex 4

Project: Satellite Broadcasting (T/SB)

Project Manager: **Mr. Masashi Kamei** (NHK, Japan)
Co-project Manager: **Mr. K. K. Rao** (India)
TRT, IRIB

4.0 Objectives

This clause describes technologies on the latest satellite systems for UHDTV broadcasting and specifications of the latest satellite broadcasting systems. And it describes also the latest topics on advanced satellite broadcasting technologies using Ka-band, etc.

4.1 ITU-R documents related to satellite broadcasting systems

4.1.1 Radio Regulations

ARTICLE 23 Section 2 "Broadcasting-satellite services"

APPENDIX 30 "Provisions for all services and associated Plans and List for the broadcasting-satellite service in the frequency bands 11.7-12.2 GHz (in Region 3), 11.7-12.5GHz (in Region 1) and 12.2-12.7 GHz (in Region 2)

APPENDIX 30A "Provisions and associated Plans and List for feeder links for the broadcasting-satellite service (11.7-12.5GHz in Region 1, 12.2-12.7 GHz in Region 2 and 11.7-12.2 GHz in Region 3) in the frequency bands 14.5-14.8 GHz and 17.3-18.1 GHz in Regions 1 and 3, and 17.3-17.8 GHz in Region 2

RESOLUTION 506 "Use by space stations in the broadcasting-satellite service operating in the 12 GHz frequency bands allocated to the broadcasting-satellite service of the geostationary-satellite orbit and no other"

RESOLUTION 507 "Establishment of agreements and associated plans for the broadcasting-satellite service"

RESOLUTION 528 "Introduction of the broadcasting-satellite service (sound) systems and complementary terrestrial broadcasting in the frequency bands allocated to these services within the range 1-3 GHz."

RESOLUTION 536 "Operation of broadcasting satellites serving other countries."

RESOLUTION 548 "Application of the grouping concept in Appendices 30 and 30A in Regions 1 and 3"

RESOLUTION 552 "Long-term access to and development in the frequency band 21.4-22 GHz in Regions 1 and 3"

RESOLUTION 553 "Additional regulatory measures for broadcasting-satellite networks in the frequency band and 21.4-22 GHz in Regions 1 and 3 for the enhancement of equitable access to this frequency band"

RESOLUTION 554 "Application of pfd masks to coordination under No. 9.7 for broadcasting-satellite service networks in the band 21.4-22 GHz in Regions 1 and 3"

RESOLUTION 555 "Additional regulatory provisions for broadcasting-satellite service networks in the frequency band 21.4-22 GHz in Regions 1 and 3 for the enhancement of equitable access to this frequency band"

RESOLUTION 557 "Consideration of possible revision of Annex 7 to Appendix 30 of the Radio Regulations"

4.1.2 Recommendations (https://www.itu.int/rec/R-REC-BO/en)

BO.1213 "Reference receiving Earth station antenna pattern for the broadcasting-satellite service in the 11.7-12.75 GHz band"

BO.1408 "Transmission system for advanced multimedia services provided by integrated services digital broadcasting in a broadcasting-satellite channel"

BO.1516 "Digital multiprogramme television systems for use by satellites operating in the 11/12 GHz frequency range"

BO.1659 "Mitigation techniques for rain attenuation for broadcasting-satellite service systems in frequency bands between 17.3 GHz and 42.5 GHz"

BO.1696 "Methodologies for determining the availability performance for digital multi-programme BSS systems, and their associated feeder links operating in the planned bands"

BO.1724 "Interactive satellite broadcasting systems (television, sound and data)"

BO.1774 "Use of satellite and terrestrial broadcast infrastructures for public warning, disaster mitigation and relief"

BO.1784 "Digital satellite broadcasting system with flexible configuration (television, sound and data)"

BO.1900 "Reference receive earth station antenna pattern for the broadcasting-satellite service in the band 21.4-22 GHz in Regions 1 and 3"

BO.2063 "Alternative BSS earth station antenna radiation pattern for 12 GHz BSS bands with effective apertures in the range 55-75 cm"

BO.2098 "Transmission system for UHDTV satellite broadcasting"

4.1.3 Reports (https://www.itu.int/pub/R-REP-BO/en)

BO.2007 "Considerations for the introduction of broadcasting-satellite service of high-definition television and ultra-high-definition television systems in the band 21.4-22 GHz"

BO.2071 "Broadcasting-satellite service system parameters between 17.3 GHz and 42.5 GHz and associated feeder links"

BO.2101 "Digital satellite broadcasting system (television, sound and data) with flexible configuration"

BO.2102 "Multiple-feed BSS receiving antennas"

BO.2397 "Satellite transmission for UHDTV satellite broadcasting"

4.2 Latest topics on satellite broadcasting

4.2.1 Update of Report ITU-R BO.2397 "Satellite transmission for UHDTV satellite broadcasting"

Report ITU-R BO.2397 "Satellite transmission for UHDTV satellite broadcasting" has been updated at ITU-R Study Group 4 meeting in Sep. 2022. It reflects the latest developments of UHDTV satellite broadcasting in Japan in Annex 1 and to create new Annex 2 dealing with satellite transmission techniques for APSK modulation signals to improve link margin by considering a trade-off between the output power and the transmission performance of TWTA as follows.

Satellite transmission techniques for APSK modulation signals

1 Background

APSK modulation increases transmission capacity, but it is also more susceptible to non-linear characteristics of the RF components in the broadcasting satellite network because its peak to average power (PAPR) is larger than PSK modulation. In particular, non-linear distortion of a traveling wave tube amplifier (TWTA) in a satellite transponder is a dominant factor for the transmission performance of APSK modulation when considering conventional receivers with an adaptive linear equalizer. It is desirable for the TWTA to operate at or near the saturation point to achieve high output power and high power efficiency. On the other hand, it is desirable for the transmission performance to operate in the near-linear region to reduce the deterioration due to non-linear distortion. There is therefore a trade-off for the TWTA operations between the output power and the transmission performance.

2 Relationship between operating point of satellite transponder and transmission performance

A TWTA is often used in high-frequency satellite transponders because it has the capability of high output power and high power efficiency, However, since its non-linearity affects the transmission performance, it is desirable to operate in the near-linear region especially for APSK transmission which is sensitive to non-linear distortion. The operating point of the satellite transponder using a TWTA is defined by an output back-off (OBO) [dB] that indicates the reduction of the average output power level compared to the saturation power. The OBO at saturation is set as 0 dB, and any increase in the OBO indicates a drop in the output power. Figure 11 shows the relationship between the OBO and the constellation of APSK signals. When the OBO is small (operating point A), the constellation is dispersed because the high-power portion of the signal in the saturation range of the AM/AM characteristic is clipped, and the constellation suffers from non-linear distortion as a result. On the other hand, when the OBO is large (operating point B), the constellation is less dispersed because most of the signal is in the linear range of the AM/AM characteristic. The greater the dispersion in the constellation, the higher the required C/N (dB). The relationship between the OBO (dB) and the required C/N (dB) is thus a trade-off.

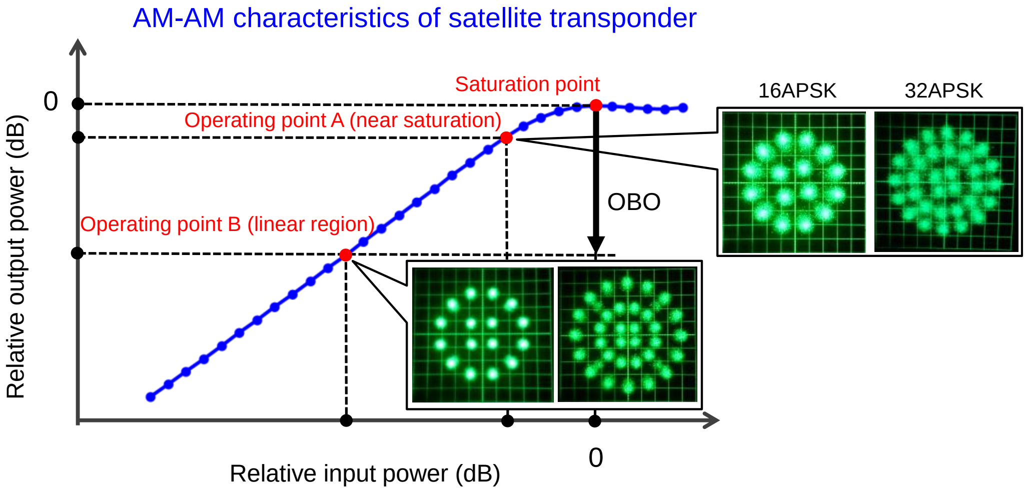
Therefore, an evaluation formula for the overall performance which can analyze the link margin is proposed as follows:

$$\mathrm{OBO} + \mathrm{Required\ C/N} \quad (dB)$$

Here, the link margin is maximized when the above value is set to minimized.

FIGURE 11

Relationship between OBO and transmission performance of APSK modulation



3 Transmission experiment for improvement of link margin

3.1 Overview

Transmission experiments were conducted to analyze the overall performance on the basis of the link-margin evaluation formula by using an indoor satellite transponder model [9] and an actual broadcasting satellite. In the experiments, 16-APSK (7/9) and 32-APSK (3/4) of the ISDB-S3 system shown in Table 1 in Annex 1 were used by applying a symbol rate of 33.7561 Mbaud.

3.2 Experiment using indoor satellite transponder model

The indoor experiment was conducted by using a 12 GHz-band satellite transponder model consisting of input/output filters and TWTA. Figures 12 and 13 show the experimental system and AM/AM characteristics of the satellite transponder model, respectively. Seven different OBOs were used in the range of 1.20 to 2.40 dB for 16-APSK (7/9) and of 1.80 to 3.00 dB for 32-APSK (3/4), with the variable attenuator inserted in the front section of the TWTA.

Figure 14 shows *C/N* vs. BER measurements of 16-APSK (7/9) and 32-APSK (3/4) for each OBO through the satellite transponder model. The IF loopback indicates the performance when the transmitter and receiver are directly connected. The experiment results show that the required *C/Ns* increase (degrade) as the OBOs become smaller (the output powers become higher). This means that the transmission signals suffer from the non-linear distortion occurring in the saturation range, thereby the transmission performance was deteriorated.

The evaluation formula for the overall performance was applied to evaluate the link margins. Table 4 summarizes the values for the OBO, the required *C/N*, the evaluation formula, and the degradation. In the case of 16-APSK (7/9), the value of the evaluation formula was minimized when the OBO was set to 1.8 dB. This point was the optimal OBO considering the trade-off between the OBO and the required *C/N*. When compared with the optimal OBO, in the case of the OBO of 1.20 dB which was 0.60 dB higher power, the required *C/N* was 12.71 dB which was increased by 0.97 dB. Therefore, the overall performance degraded by 0.37 dB due to the increase in non-linear distortion even though the output power was higher. Moreover, in the case of the OBO of 2.40 dB which was 0.6dB lower power, the required *C/N* was 11.43 dB which was decreased by 0.31 dB. However the overall performance also degraded by 0.29 dB.

Similarly, in the case of 32-APSK (3/4), the optimal OBO based on the evaluation formula was 2.60 dB considering the trade-off between the OBO and the required *C/N*.

The result indicates that there is the optimal OBO to improve the link margin in accordance with modulation scheme. Moreover, the optimal OBO for 32-APSK (3/4) is larger than that for 16-APSK (7/9) due to susceptibility to non-linear distortion.

FIGURE 12

Indoor experiment system

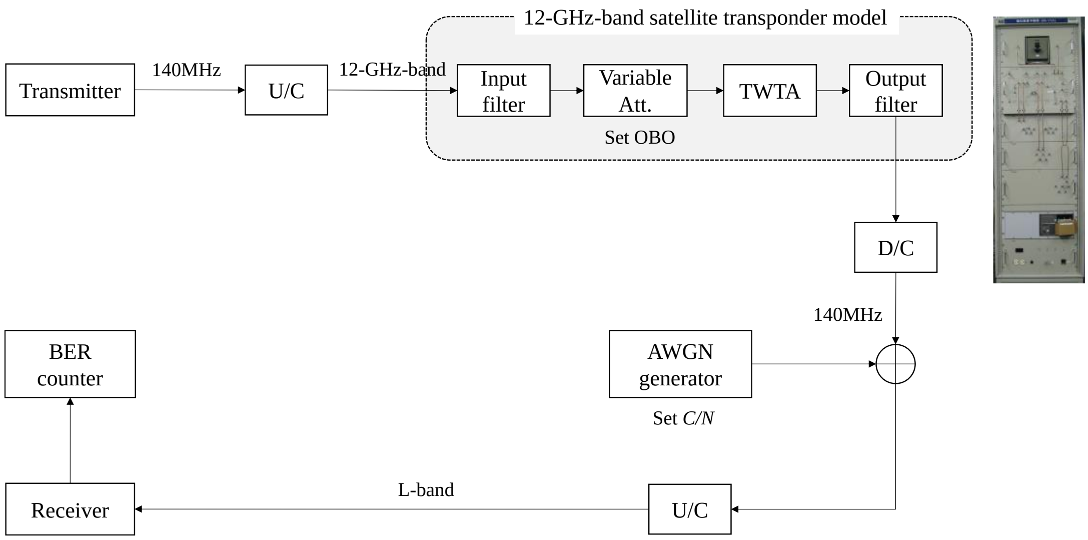


FIGURE 13

AM/AM characteristics of satellite transponder model in indoor experiment

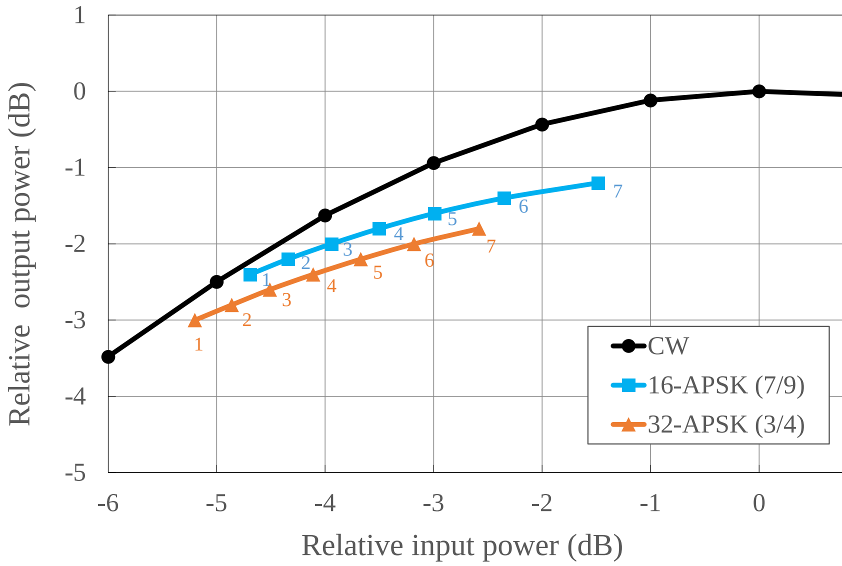


FIGURE 14

***C/N* vs. BER measurements for each OBO in indoor experiment**
(a) 16-APSK (7/9), (b) 32-APSK (3/4)

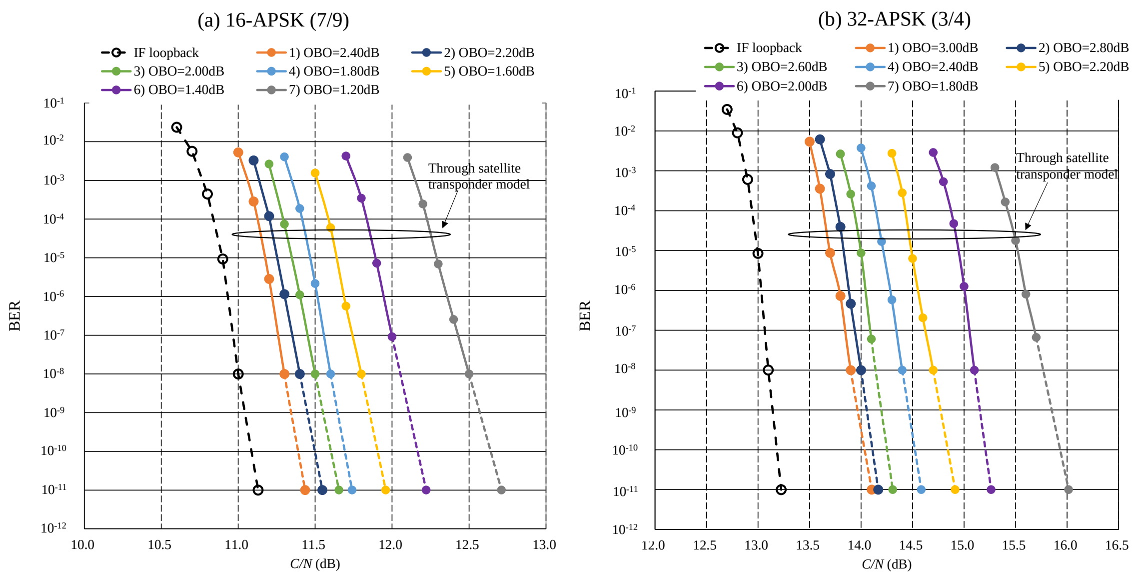


TABLE 4

Application of the evaluation formula to indoor experiment

(a) 16-APSK (7/9)

Point	**IF loopback**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
A) OBO (dB)	-	2.40	2.20	2.00	1.80	1.60	1.40	1.20
B) Req.*C/N* (dB)	11.13	11.43	11.55	11.65	11.74	11.96	12.22	12.71
Evaluation formula A) + B) (dB)	-	13.83	13.75	13.65	13.54	13.56	13.62	13.91
Degradation (dB)	-	0.29	0.21	0.11	0.00	0.02	0.08	0.37

(b) 32-APSK (3/4)

Point	**IF loopback**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
A) OBO (dB)	-	3.00	2.80	2.60	2.40	2.20	2.00	1.80
B) Req.*C/N* (dB)	13.23	14.10	14.17	14.31	14.59	14.91	15.26	16.01
Evaluation formula A) + B) (dB)	-	17.10	16.97	16.91	16.99	17.11	17.26	17.81
Degradation (dB)	-	0.19	0.06	0.00	0.08	0.12	0.35	0.90

3.3 Experiment using broadcasting satellite transponder

An outdoor experiment using the broadcasting satellite BSAT-4b was conducted to analyze the overall performance on the basis of the evaluation formula. Figure 15 shows the experimental system. Five different OBOs were used for 16-APSK (7/9) and six OBOs for 32-APSK (3/4). The OBO is defined as the relative value (relative OBO) compared with each maximum power among the setting points (five in 16-APSK (7/9) or six in 32-APSK (3/4)). Figure 16 shows *C/N* vs. BER measurements of 16-APSK (7/9) and 32-APSK (3/4) for each relative OBO, respectively. Similar to the indoor experiment, the required *C/Ns* tend to increase (degrade) as the OBOs become smaller (the output powers become higher).

Table 5 summarizes the values for the relative OBO, the required *C/N*, the evaluation formula, and the degradation. It also indicates the trade-off between the relative OBO and the required *C/N*. The optimal relative OBOs were 0.32 and 1.14 dB for 16-APSK (7/9) and 32-APSK (3/4), respectively. The results indicate that the optimal relative OBO that improve the link margin can be obtained by the evaluation formula in satellite transmission.

FIGURE 15

Outdoor experiment system using BSAT-4b

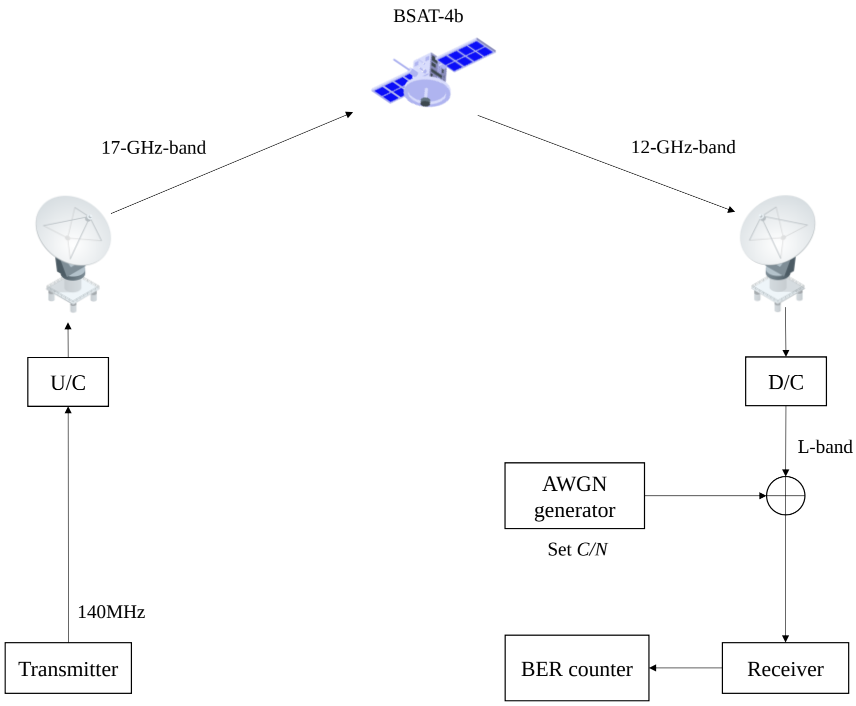


FIGURE 16

***C/N* vs. BER measurements for each OBO through BSAT-4b**
(a) 16-APSK (7/9), (b) 32-APSK (3/4)

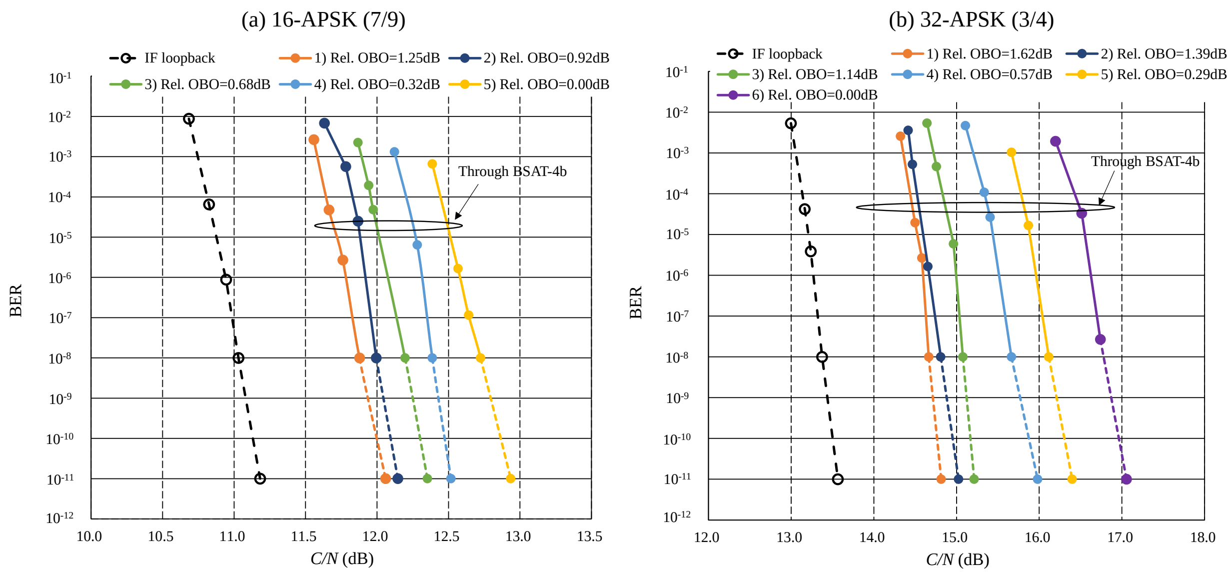


TABLE 5

Evaluation results for finding optimal relative OBO through BSAT-4b

(a) 16-APSK (7/9)

Point	IF loopback	1	2	3	4	5
A) OBO (dB)	-	1.25	0.92	0.68	0.32	0.00
B) Req.*C/N* (dB)	11.13	12.06	12.15	12.35	12.52	12.93
Evaluation formula A) + B) (dB)	-	13.31	13.07	13.03	12.84	12.93
Degradation (dB)	-	0.47	0.23	0.19	0.00	0.09

(b) 32-APSK (3/4)

Point	IF loopback	1	2	3	4	5	6
A) OBO (dB)	-	1.62	1.39	1.14	0.57	0.29	0.00
B) Req.*C/N* (dB)	13.23	14.81	15.02	15.21	15.98	16.40	17.05
Evaluation formula A) + B) (dB)	-	16.43	16.41	16.35	16.55	16.69	17.05
Degradation (dB)	-	0.08	0.06	0.00	0.20	0.34	0.70

4 Summary

Satellite transmission for APSK modulation signals was studied considering non-linear distortion of TWTA in a satellite transponder. It was found that there is a trade-off for TWTA operations between the output power and the transmission performance. An evaluation formula for the overall performance was proposed to maximize the link margin considering the OBO and the required *C/N*. Indoor and outdoor experiments were conducted to analyze the overall performance on the basis of the evaluation formula. The experimental results show that there is a trade-off between the OBO and that the required *C/N* and the evaluation formula enables the detection of the optimal OBO that maximize the link margin in accordance with each modulation scheme.