About 15 years have passed since the start of digital terrestrial television broadcasting in Japan in December 2003. Research and development on advanced terrestrial broadcasting technology for realizing next-generation terrestrial broadcasting, such as terrestrial “Super Hi-Vision” (4K/8K) broadcasting, is progressing.

In our development of a next-generation terrestrial broadcasting system, while we are inheriting the features of ISDB-T (Integrated Services Digital Broadcasting-Terrestrial), which is the current transmission system for digital terrestrial television broadcasting, we aim to create a system that adopts the latest technology, has higher frequency-utilization efficiency, is capable of large-capacity transmission, and has excellent transmission robustness. We have been advancing research to increase the capacity of terrestrial broadcasting, developed a transmission method that can simultaneously provide Super Hi-Vision broadcasting and mobile broadcasting services on one channel, and produced experimental equipment on a trial basis. In this report, considering the global trends in next-generation terrestrial broadcasting, our research and development towards next-generation advanced terrestrial broadcasting is explained.

1. Trends in next-generation terrestrial broadcasting

About 15 and 20 years have respectively passed since the start of digital terrestrial television broadcasting in Japan and in Europe and the United States, and at this point in time, global widespread adoption of next-generation terrestrial broadcasting is being considered. The digital terrestrial television broadcasting systems widely used throughout the world are ISDB-T, DVB-T (Digital Video Broadcasting – Terrestrial), ATSC (Advanced Television Systems Committee), and DTMB (Digital Terrestrial Multimedia Broadcast), which were developed in Japan, Europe, the USA, and China, respectively. In recent years, technical specifications for next-generation systems have been studied, and some countries have already put them to practical use.

In Europe, the standardization of DVB-T2, which was
developed from DVB-T, was completed in April 2009, and regular broadcasting began in the UK in December 2009. Like DVB-T, DVB-T2 uses OFDM (orthogonal frequency-division multiplexing) as a digital modulation scheme. Regarding the error correction code, by using concatenated codes, namely, the LDPC (low-density parity check) code and BCH (Bose–Chaudhuri–Hocquenghem) code, and using 256QAM (quadrature amplitude modulation) for the carrier modulation scheme, it is possible to improve transmission capacity by about 45% compared with that possible with DVB-T (compared with transmission parameters used in current broadcasting).

In the UK and Sweden, broadcasting uses DVB-T and DVB-T2 in combination, and multiple SD (standard-definition) programs are broadcast on the DVB-T channel, while multiple HD (high-definition) programs are broadcast on the DVB-T2 channel. In the UK, although demonstration experiments on terrestrial 4K broadcasts were conducted around 2014, since then such broadcasts have not been considered in a concrete manner.

In Germany, since March 2017, efforts to complete the transition from DVB-T to DVB-T2 have been underway, and broadcasting of HD programs by using DVB-T2 has started in some areas. In Italy, the transition from DVB-T to DVB-T2 will start from January 2020. In France, programs with SD/HD picture quality are currently being broadcast by DVB-T; however, discussions on the transition to 4K broadcasts using DVB-T2 and HEVC (high-efficiency video coding) - targeting the Paris Olympic Games in 2024 - have started.

In the United States, standardization work of the next-generation terrestrial broadcasting system ATSC3.0 started in 2012. Basic standardization was completed by June 2017, and the first edition of the technical specification was released in January 2018. The multiplexing scheme used is IP (Internet Protocol) taken from the conventional MPEG-2 (Moving Picture Experts Group-2) TS (Transport Stream) standard, and the error correction codes are concatenated codes of LDPC and BCH codes. Moreover, the carrier modulation (OFDM) schemes used cover QPSK to 4096QAM.

Broadcasting using ATSC3.0 started in Seoul, South Korea, in May 2017, expanded to some major cities of Korea in December 2017, and will be expanded to cover the whole country by 2021. 4K programs are included in the broadcasts, and the composition ratio of 4K programs is scheduled to be gradually increased from 5% in 2017 to 10% in 2018 and 15% in 2019.

In Japan, an advanced version of ISDB-T (hereafter referred to as “advanced ISDB-T”) is being studied. The study on this system is explained in detail in Section 3.

The above-mentioned, next-generation digital terrestrial television broadcasting systems are compared in Table 1. As the signal structure, TDM (time-division multiplexing)
is used for DVB-T2 and ATSC3.0, and FDM (frequency-division multiplexing) is used for advanced ISDB-T. In addition, for both ATSC3.0 and advanced ISDB-T, the signal structure can handle LDM (layered division multiplexing), which multiplexes two layers with different powers. Regarding error correction codes, in all systems, transmission efficiency is increased by using concatenated codes of LDPC and BCH codes. With regard to the carrier modulation scheme, DVB-T2 can handle up to 256QAM, ATSC3.0 and advanced ISDB-T can handle up to 4096QAM, those multi-level modulations enable the increase in the transmission capacity.

2. Approach to broadcast mode taken by 3GPP (3rd-Generation Partnership Project)\(^1\)

As well as approaches based on broadcasting systems, approaches based on communication systems can be considered with next-generation terrestrial broadcasting systems. In particular, in Europe, sometimes the infrastructure for broadcasting and communication is operated by the same company, and the “Broadcast mode”\(^2\) based on wireless communication standards for 4G and 5G is being studied. The transition of the broadcast mode of wireless communication standards is shown in Fig. 1.

For LTE (Long-Term Evolution) broadcast mode Release 9 launched in 2009, although the MBMS (Multimedia Broadcast and Multicast Service) specification (for simultaneous broadcasts based on LTE) was standardized, the time rate of the downlink that can be used for broadcasting was restricted. Furthermore, other restrictions, namely, short guard-interval (GI) length and small cells (reception areas) in a similar manner to mobile-phone base stations, are imposed, and no examples actually linked to services have been reported.

In Release 14 launched in 2017, some functions of MBMS were revised on the basis of the completed technical specification LTE Advanced Pro. The whole signal was made available for broadcasting and the maximum GI length became 200 μs, so the idea of incorporating a large cell for broadcasting was considered; however, problems such as the small GI length of the control signal (called the “cell acquisition subframe”) remained to be solved. At the 3GPP meeting in June 2018, the 5G broadcast mode handling the downlink only (under the assumption of a fixed service area and bit rate) was agreed as a study item, and study to formulate the technical specification of Release 16 will start at the end of 2019.

3. Development of next-generation terrestrial-broadcasting systems

We have also promoted R&D aimed at advanced terrestrial broadcasting. In 2007, we began R&D aimed at increasing the capacity of terrestrial broadcasting, and we have been developing high-order modulation OFDM and polarization MIMO (multiple-input multiple-output) technology\(^3\). In 2013, we undertook a research project outsourced by the Ministry of Internal Affairs and Communications titled “Research and Development of Basic Technology Encouraging Effective Utilization of Frequency for the Next Generation Broadcasting System.” and in January 2014, we achieved 8K long-distance transmission (with a transmission capacity of 91.8 Mbps over a transmission distance of 27 km) in the Hitoyoshi district of Kumamoto Prefecture\(^4\). From 2014 to 2016, we were entrusted with a project called “Research and Development of Technology Encouraging Effective Utilization of Frequency for Ultra High Definition Satellite and Terrestrial Broadcasting.” During that period, we conducted experiments on technology for effective frequency utilization; for example, we performed experiments on a coded SFN (single-frequency network), and we studied transmission characteristics of high-order modulation OFDM\(^5\).

Considering the results of these investigations, we have been studying provisional specifications aimed at future terrestrial broadcasting systems. In particular, we aim to boost capacity by incorporating ISDB-T-based technologies in these specifications\(^6\).

Since 2016, NHK, receiver manufacturers, a university, and another organization have been entrusted with the research project “Research and Development for Advanced Digital Terrestrial TV Broadcasting System”\(^7\), and we are working in cooperation with them on developing advanced technologies for terrestrial broadcasting.

The research items (“technologies” hereafter) stated in “Research and Development for Advanced Digital Terrestrial TV Broadcasting System” are shown in Fig. 2. The goal of this R&D is to further promote the utilization of radio waves and establish technologies that enable services including ultrahigh-definition terrestrial broadcasting such as 4K and 8K (Super Hi-Vision broadcasting) by improving transmission efficiency while inheriting the features

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\(^1\) An organization in which seven worldwide communication standardization bodies gather and discuss next-generation communication standards. From Japan, the ARIB (Association of Radio Industries and Businesses) and the TTC (Telecommunication Technology Committee) are participating members.

\(^2\) Based on wireless communication standards such as LTE, 4G, and 5G, a mode specialized for one-way unidirectional transmission (broadcasting).
Purpose
Achieving more effective use of radio waves and establishing technologies that enable services such as ultrahigh-definition terrestrial broadcasting by inheriting the features of the current terrestrial television broadcasting system and by improving transmission efficiency.

Implementation period
Fiscal year 2016 - 2018 (three years)

Research institutes
NHK (Japan Broadcasting Corporation), Sony Corporation, Panasonic Corporation, Tokyo University of Science, NHK Integrated Technology Inc.

Technology A: Advanced technology for terrestrial broadcasting
- Improve transmission efficiency, develop a transmission scheme\(^1\) and a video-coding scheme\(^2\) that can simultaneously provide 4K/8K and mobile services on one channel, and prototype the developed equipment.

Technology B: Advanced technology for mobile services
- Evaluate the mobile reception characteristics of the transmission method developed via Technology A and develop technology for improving reception.

Technology C: Transmission technology for large-scale stations
- Establish a large-scale station and evaluate the transmission characteristics of the schemes developed via Technology A by field experiments.

Technology D: Relay technology based on SFNs compliant with advanced ISDB-T
- Develop technologies for synchronizing transmission waveforms from multiple transmission stations so that SFN can be created with IP signals.
- Establish SFN experimental stations and evaluate transmission characteristics by field experiments.

Figure 2: Research and Development for Advanced Digital Terrestrial television Broadcasting System

of the current digital terrestrial television broadcasting. The research is split into four technologies: “A: advanced technology for terrestrial broadcasting,” “B: advanced technology for mobile services,” “C: transmission technology for large-scale stations,” and “D: relay technology based on SFNs compliant with advanced ISDB-T”. NHK is focused on addressing technologies A, C, and D.

For technology A (advanced technology for terrestrial broadcasting), we developed (i) a transmission scheme—based on the provisional specifications we have been studying—that can simultaneously provide Super Hi-Vision and mobile services on one channel and (ii) a video-coding scheme that improves coding efficiency, and we have prototyped equipment utilizing these schemes. To improve transmission efficiency, we are using high-order modulation technology, extending the signal bandwidth and FFT (fast Fourier transform) size\(^3\), and introducing

\(^1\) High-order modulation, error correction code, etc.
\(^2\) Noise elimination, band-limited HEVC, etc.
\(^3\) Number of FFT samples used for OFDM signal modulation/demodulation processing.
new error correction codes\(^9\). In addition, we are studying technologies for eliminating coding noise and limiting the video band to improve video-coding efficiency, which are important tasks in regard to advanced ISDB-T (which has smaller transmission capacity than satellite broadcasting)\(^9\).

For technology C (transmission technology for large-scale stations), we plan to evaluate the transmission specifications of large-scale experimental test stations, improve these facilities, and evaluate the transmission characteristics in field experiments\(^10\). Moreover, while extending the signal bandwidth, we are also investigating sharing conditions with ISDB-T\(^11\).

For technology D (relay technology based on SFNs compliant with advanced ISDB-T), we are developing relay technology based on SFNs (which broadcast radio waves with the same frequency from multiple transmitting stations).

To create SFNs using IP signals, we have started to develop a technology for synchronizing waveforms transmitted from multiple transmitting stations, develop SFN experimental testing stations, and evaluate their transmission characteristics in field experiments in the autumn of 2018.

In this way, regarding the development of the advanced ISDB-T, we are targeting a system that adopts the latest technology while inheriting the features of ISDB-T; as a result, it will provide superior transmission robustness while enabling higher-capacity transmission and higher

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**Table 2: Specifications of transmission by experimental stations**

<table>
<thead>
<tr>
<th>Transmission location</th>
<th>Tokyo Area</th>
<th>Nagoya area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmission location</td>
<td>Shiba (Tokyo Tower)</td>
<td>Higashiyama (main station)</td>
</tr>
<tr>
<td>Transmission frequency</td>
<td>563.143 MHz, 563.210 MHz (UHF 28ch)</td>
<td>605.143 MHz, 605.210 MHz (UHF 35ch)</td>
</tr>
<tr>
<td>Polarization</td>
<td>Horizontal, vertical (Dual-polarized MIMO)</td>
<td></td>
</tr>
<tr>
<td>Transmission power</td>
<td>1 kW</td>
<td>1 kW</td>
</tr>
<tr>
<td>Effective radiated power (ERP)</td>
<td>2.1 kW</td>
<td>980 W</td>
</tr>
<tr>
<td>Transmission height above sea level</td>
<td>280 m</td>
<td>203 m</td>
</tr>
</tbody>
</table>

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[Figure 3: Experimental stations and area guidelines](#)
frequency-utilization efficiency. Moreover, toward the development of a next-generation terrestrial broadcasting system in Japan, in addition to developing the above-described advanced ISDB-T, we are also investigating methods of multiplexing new signals with those of the current digital terrestrial television broadcasts and aiming to create terrestrial 4K broadcasting\(^2\).

4. Experimental testing stations to evaluate advanced ISDB-T

The large-scale experimental testing stations for carrying out these experiments are outlined as follows.

To evaluate the transmission scheme in various receiving environments, the radio waves of the experimental testing stations must reach a wide range, so we established transmission specifications targeting transmission power as the current key station. The transmission specifications of the experimental testing stations in the Tokyo and Nagoya areas are listed in Table 2. In the Tokyo area, the key-station-scale transmission technology was evaluated, and transmission tests were executed in an urban area. In the Nagoya area, a transmission network was established by setting up a key station and a relay station, the synchronization technology was verified by using the IP between transmitting stations, and transmission experiments were executed under an SFN environment.

The transmission center frequency can be selected from the following two types: a frequency with an offset of 0.143 MHz (similar to that of the current digital terrestrial television broadcasting) or a frequency with an offset of 0.21 MHz so that the balance between upper adjacent channel interference and lower adjacent channel interference is satisfactory (according to the results of interference experiments in which the signal bandwidth was extended).

Rough estimates of the experimental test areas (i.e., the range in which the field strength is 60 dBμV/m or more) calculated on the basis of the transmission specifications listed in Table 2 are shown in Fig. 3. In these test areas, transmission characteristics in various receiving environments, such as urban areas, suburbs, and highways, can be evaluated. Transmission specifications of the advanced ISDB-T are described in the subsequent article “Transmission system for advanced digital TV broadcasting” and the results of the experiments will soon be reported at international conferences.

5. Concluding remarks

In this article, global trends towards the advancement of terrestrial broadcasting were described, and the advanced ISDB-T being developed in Japan by NHK and other organizations, and large-scale experimental testing stations were outlined.

The author hopes readers will get an understanding of the various initiatives aiming to create a terrestrial-broadcast advancement system that can simultaneously provide Super Hi-Vision broadcasting and mobile broadcasting services.

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