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Collection of field trials of UHDTV over DTT networks

BT Series

Broadcasting service (television)

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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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Collection of field trials of UHDTV over DTT networks

(2015)

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1 Introduction

Ultra high definition television (UHDTV) is one of the major applications of next-generation digital terrestrial broadcasting. Several countries have already started studies on digital terrestrial broadcasting transmission systems that have significantly expanded their transmission capacities by means of, for example, high multilevel modulation technology. Moreover, some countries have already carried out UHDTV field experiments on digital terrestrial broadcasting to demonstrate the feasibility of these systems. The compilation of a summary of these experiments will offer useful information to administrations and broadcasters wishing to introduce or consider UHDTV broadcasting in the future, as well as to manufacturers wishing to engage with this.

UHDTV production of big live events has already started, notably the 2014 FIFA World Cup in Brazil where three games hosted in the Epic Maracana Stadium were officially produced and distributed worldwide in 4k UHDTV. The EBU, by means of its operational branch (EUROVISION), ensured the worldwide delivery of the three games over its satellite and fibre network.

In Japan, 8K UHDTV field transmission experiments with 4096-QAM and dual-polarized multiple input multiple output (MIMO) technology were conducted in January 2014.

In the Annexes, the Report presents an overview of the experiments, key technologies, and the results conducted in various countries.

The intent of this Report is to provide evidence about the suitability of terrestrial television networks to deliver UHDTV services to consumers on a large scale.

2 Status of standardization of UHDTV

2.1 Standardization within ITU

The standardization of parameters for Ultra High Definition is underway at ITU-R and different Recommendations and Reports have been published, for example:

- Recommendation ITU-R BT.2020-1 (06/14) – Parameter values for ultra-high definition television systems for production and international programme exchange.
- Recommendation ITU-R BS.2051-0 (02/14) – Advanced sound system for programme production.
- Report ITU-R BT.2246-3 (2014) – The present state of ultra-high definition television.

Other standardization activities on UHDTV are ongoing in ITU-R and ITU-T.

2.2 Standardization within DVB

The standardization process is also well underway at the DVB level, with the Standard TS 101 154 V2.1.1 recently published (07/2014) as DVB Blue Book A157 ‘Specification for the use of Video and Audio Coding in Broadcasting Applications based on the MPEG-2 Transport Stream’ and which is expected to be published by ETSI in the coming months.

2.3 Standardization within TTA[1]

On August 30, 2013, the scenarios for 4K-UHDTV service were described in the Report “TTAR-07.0011: A Study on the UHDTV Service Scenarios and its Considerations”.

[1] In Korea, the standardization process goes through the TTA, the authority responsible for information and communications technology (ICT) standardization. http://www.tta.or.kr/English/

On May 22, 2014, the technical report "TTAR-07.0013: Terrestrial 4K UHDTV Broadcasting Service" was published.

On October 13, 2014, an interim standard – "TTAI.KO-07.0123: Transmission and Reception for Terrestrial UHDTV Broadcasting Service" – was published based on HEVC encoding, with MPEG-2 TS, and DVB-T2 serving as the standards.

3 Field Studies of Terrestrial UHDTV

Annex 1 shows details of trials conducted for UHDTV over terrestrial television networks.

The following Table summarizes the trials and indexes the Annex.

Summary of UHDTV trials on terrestrial television networks

Annex	Country	Transmitter site	Covering	ERP	DTT System	Channel bandwidth	Transmission mode	Multiplex capacity	Signal bit rate	Video encoding standard	Picture standard	Audio encoding standard	Frequency used
A1.1	**Japan**	Hitoyoshi	City of Hitoyoshi	140W(H) 135W(V)	ISDB-T[2]	6 MHz	32k *GI* = 1/32 4096QAM, FEC 3/4 dual-polarized MIMO	91.8 Mb/s	91Mb/s	MPEG-4 AVC/H.264	7 680×4 320p 59.94frame/s 8 bits/pixel	MPEG-4 AAC 384 kb/s	671 MHz (Ch 46 in Japan)
A1.2	**Korea (Republic of)[3]**	Kwan-Ak Mountain	South Metropolitan area of Seoul	36.7 kW	DVB-T2	6 MHz	32k, extended mode, *GI* = 1/16, PP4, 256 QAM, FEC 3/4, 4/5, 5/6	< 35.0 Mb/s	Variable (some trials at 25~34 Mb/s)	HEVC Main10 Level 5.1, Max 28 Mb/s	3 840×2 160p 60 frames/s, 8 bits or 10 bits/pixel	MPEG-4 AAC-LC or Dolby AC-3, Max 5.1Ch, Max 600 kb/s	713 MHz (Ch 54 in Korea)
				12.9 kW									701 MHz (Ch 52 in Korea)
				40.0 kW									707 MHz (Ch 53 in Korea)
		Nam Mountain	Central area of Seoul	2.2 kW									713 MHz (Ch 54 in Korea)
		Yong-Moon Mountain	West Metropolitan area of Seoul	8.3 kW									707 MHz (Ch 53 in Korea)
A1.3	**France**	Eiffel Tower	City of Paris	1kW	DVB-T2	8 MHz	32k, extended mode, *GI* = 1/128, 256QAM, FEC2/3, PP7	40.2 Mb/s	Two programmes carried: one at 22.5 Mb/s, one at 17.5 Mb/s	HEVC	3 840×2 160p 50 frames/s 8 bits/pixel	HE-AAC 192 kb/s	514 MHz (Ch26 in Region 1)
A1.4	**Spain**	ETSI Tele-comunicación	Ciudad Universitaria, Madrid	125W	DVB-T2	8 MHz	32k, extended mode, *GI* = 1/128, 64QAM, FEC5/6, PP7	36.72 Mb/s	35 Mb/s (other bit rates also tested)	HEVC	3 840×2 160p 50 frames/s 8 bits/pixel	E-AC-3 5.1	754 MHz (Ch56 in Region 1)

[2] Some parameters are extended from conventional ISDB-T system (System C of Recommendation ITU-R BT.1306).

[3] Details for Korea in Table 1 correspond to Phase 3 of the trials. See § A1.2 for more details of Phases 1 and 2.

Annex	Country	Transmitter site	Covering	ERP	DTT System	Channel bandwidth	Transmission mode	Multiplex capacity	Signal bit rate	Video encoding standard	Picture standard	Audio encoding standard	Frequency used
A1.5	**Sweden**	Stockholm Nacka	City of Stockholm	35 kW	DVB-T2	8 MHz	32k, extended mode, *GI* = 19/256, 256QAM, FEC 3/5, PP4	31.7 Mb/s	24 Mb/s	HEVC	3 840×2 160p 29.97 frames/s 8 bits/pixel		618 MHz (Ch 39 in Region 1)
A1.6	**UK**	Crystal Palace	Greater London (serving over 4.5 Million households)	40 kW	DVB-T2	8 MHz	32k, extended mode, *GI* = 1/128, 256QAM, FEC 2/3, PP7	40.2 Mb/s	Variable (some trials at 35 Mb/s)	HEVC	Mixture of 3 840×2 160p 50 frames/s and 3 840×2 160p 59.94 frames/s Most of the trial at 8 bits/pixel, some at 10 bits/pixel		586 MHz (Ch 35 in Region 1)
		Winter Hill	North-west of England, including Manchester and Liverpool (serving 2.7 Million households)	22.5 kW		8 MHz							602 MHz (Ch 37 in Region 1)
		Black Hill	Central Scotland, including Glasgow and Edinburgh (serving 1 Million households)	39 kW		8 MHz							586 MHz (Ch 35 in Region 1)

GI = guard intervals

Annex 1

Field Experiments of UHDTV Terrestrial Transmission

A1.1 Japan

A1.1.1 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 ultra-multilevel (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.

A1.1.2 8K-UHDTV field experiments in Hitoyoshi

Japan has installed an experimental transmitting station in Hitoyoshi city, Kumamoto prefecture that uses dual-polarized MIMO and ultra-multilevel OFDM technologies. Two 8K field experiments were conducted there: a transmission test and field measurements at 52 points around Hitoyoshi.

Here, Japan reports the results of these experiments, including the required field strength when using 4096-QAM carrier modulation and a channel response analysis of dual-polarized MIMO transmission.

A1.1.2.1 Transmission parameters and experiment area

Table A1.1 lists the specifications of the 8K field experiments in the Hitoyoshi area and Fig. A1.1 shows the area in which the experiments were conducted.

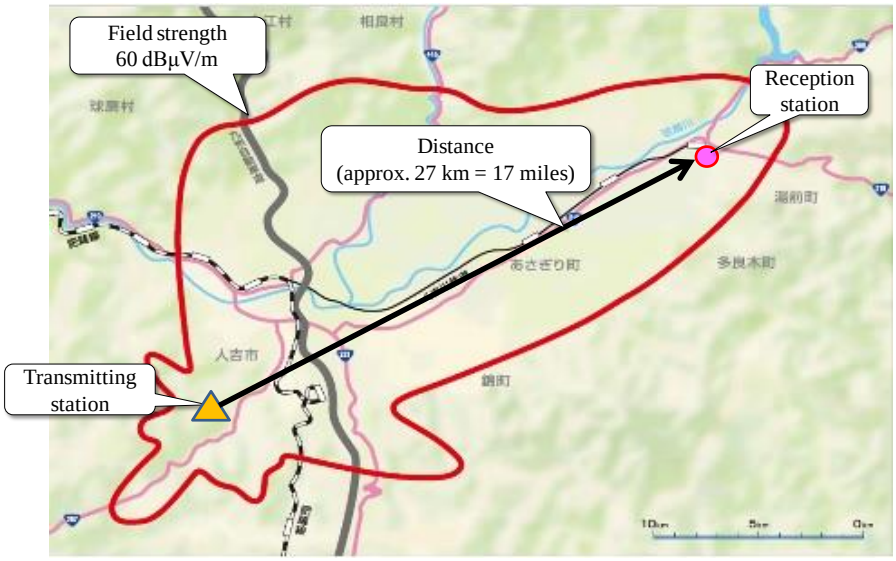
TABLE A1.1

Specifications of 8K field experiments in Hitoyoshi

Modulation method	OFDM
Occupied bandwidth	5.57 MHz
Transmission frequency	671.142857 MHz (UHF ch46)
Transmission power	Horizontal polarized waves: 10 W, ERP: 140 W Vertical polarized waves: 10 W, ERP: 135 W
Carrier modulation	4096-QAM
FFT size (number of radiated carriers)	32k (22,465)
Guard interval ratio (guard interval duration)	1/32 (126 μs)
Error-correcting code	Inner: LDPC, code rate = 3/4 Outer: BCH
Transmission capacity	91.8 Mb/s
Video coding	MPEG-4 AVC/H.264 (to be replaced by HEVC)
Audio coding	MPEG-4 AAC
Transmitting station	Established at NHK Hitoyoshi TV relay station
Height of transmitting antenna	632 m above sea level (21 m above ground level)
Receiving station	Nousonkankyoukaizen Center, Yunomae Town, Kumamoto Prefecture – approx. 27 km from the test transmitting station
Height of receiving antenna	211 m above sea level (10 m above ground level)

FIGURE A1.1

Area of 8K field experiments in Hitoyoshi



A1.1.2.2 Transmitting and receiving station equipment

Table A1.2 shows the requirements for selecting the field experiment locations. The Hitoyoshi area fulfils these requirements and so it was chosen as the place to set up the experimental transmitting station.

Figure A1.2 shows the transmitting station and equipment and Fig. A1.3 shows the receiving station and equipment. An 85-inch 8K monitor was used to display the 8K signal. Both the dual-polarized transmitting antenna and the dual-polarized receiving antenna were developed.

Figure A1.4 is a block diagram of the modulator and demodulator used in the experiments. The input signal is coded with BCH code and low density parity check (LDPC) code, bit interleaved and mapped onto the constellation. After that, the signal is divided into two signals (one for horizontal polarization and the other for vertical) with 3D interleave (time, frequency and inter-polarization). The signals are then converted into time domain signals by inverse fast Fourier transform (IFFT) and guard intervals (*GI*) are added.

The signals from the modulator are converted into RF signals of the same frequency by using up-converters (U/C). The signals are then amplified with a power amplifier (PA) to the desired power level and transmitted as horizontal and vertical polarized waves from a dual-polarized antenna.

The transmitted signals are received by a dual-polarized Yagi antenna. Each received signal is filtered by a band-pass filter (BPF) and input to a variable attenuator (ATT). The signals are then amplified using low noise amplifiers (LNA) and converted into IF signals with a down converter (D/C). The IF signals are then input to the demodulator.

In the demodulator, the active symbol period is extracted from the received signals, which are then converted into frequency domain signals by fast Fourier transform (FFT). The frequency domain signals are de-multiplexed, equalized by MIMO detection, 3D de-interleaved, and used to calculate the log likelihood ratio (LLR). LLRs are de-interleaved and input to the LDPC decoder. Finally, BCH decoding is applied to obtain the output signal.

In the transmission test, compressed 8K signals were transmitted over a single UHF-band channel (6 MHz bandwidth). The distance between the transmitting station and receiving station was 27 km, a typical distance for current digital terrestrial broadcasting.

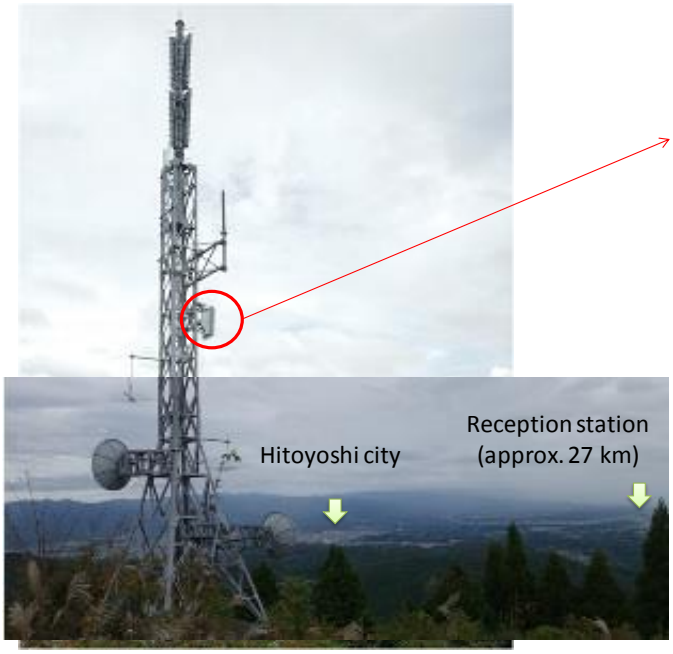
TABLE A1.2

Location requirements for 8K field experiments

1	The place should have a vacant UHF single channel for 8K transmission.
2	To analyse the channel response of dual-polarized MIMO transmission, the experiment should be able to be conducted over a large area and over long distances (e.g. transmissions over 20 km).
3	The place should support a current DTTB system.
4	The place should be free of mutual interference from other areas.

FIGURE A1.2

Transmitting station and equipment



Transmitting antenna gain	Over 10dBd
Cross-polarization discrimination	Over 15 dB (in half power angle)
VSWR	Under 1.20

VSWR: Voltage Standing Wave Ratio

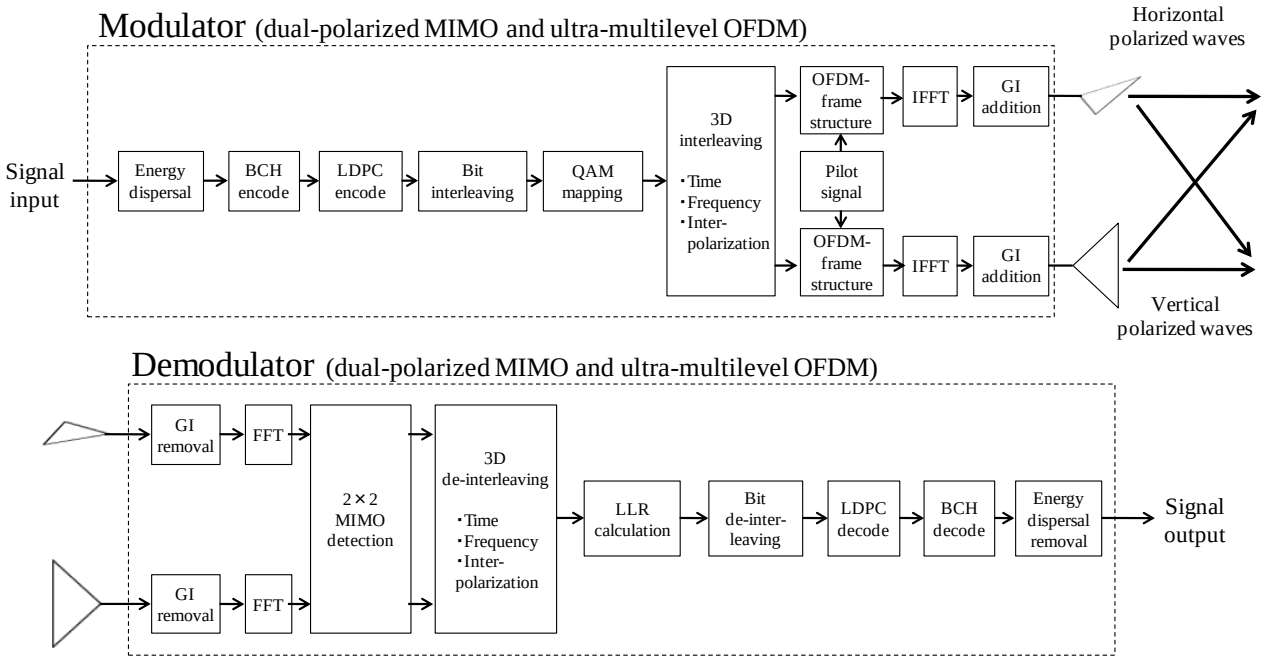
FIGURE A1.3

Receiving station and equipment

Antenna type	8 element dual-polarized Yagi antenna
Frequency	597－674 MHz (UHF 33 ch – 46 ch)
Gain	9.0 dBd
Front to back ratio	Over 13 dB
Cross-polarization discrimination	Over 25 dB (Boresight)

FIGURE A1.4

Block diagram of 8K experiments

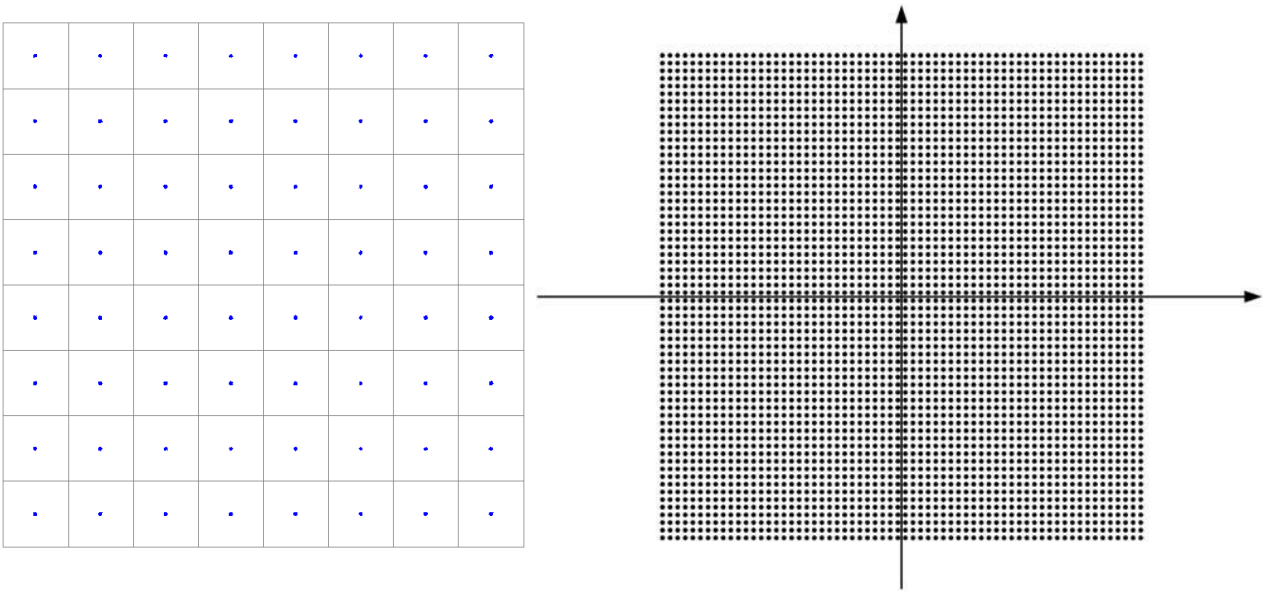


A1.1.2.3 Key technologies

Ultra-multilevel OFDM is a technology that applies a greater number of signal points to data symbols. Carrier modulation schemes up to 64-QAM can be used in current ISDB-T, but up to 4096-QAM can be implemented in the prototype equipment. Figure A1.5 shows the constellations of 64-QAM and 4096-QAM. 64-QAM can transmit six bits of data per carrier symbol, while 4096-QAM can transmit 12 bits per carrier symbol, which is twice as many as 64-QAM.

FIGURE A1.5

Constellations of 64-QAM (left) and 4096-QAM (right)

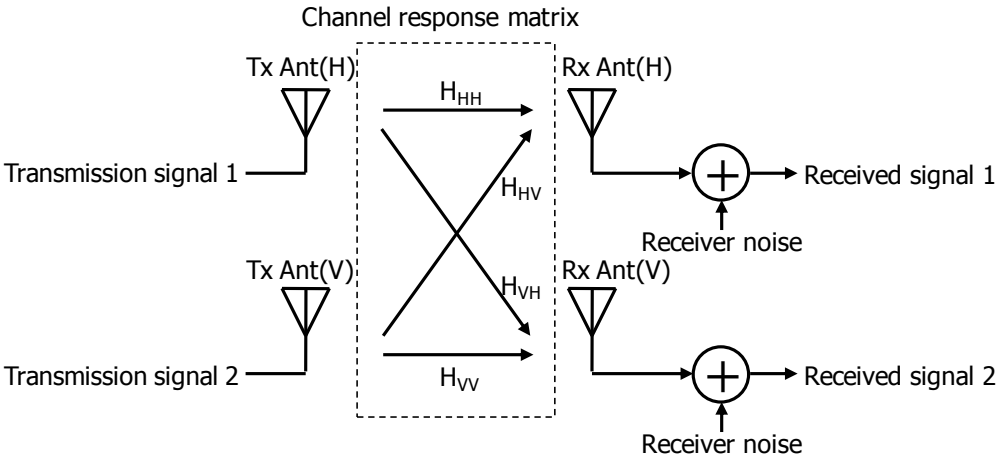


Dual-polarized MIMO is a technology configuring MIMO with two orthogonal polarizations. This technology was used to expand the transmission capacity, and namely each of the two polarized waves

transmitted different data. A dual-polarized MIMO using horizontally and vertically polarized waves can be used as the model, as shown in Fig. A1.6.

FIGURE A1.6

MIMO transmission model



A1.1.2.4 Field measurement results

For the field test, 52 reception points in the Hitoyoshi area that were 1.3 km to 36.7 km from the transmitter were selected (Fig. A1.7). MIMO propagation measurements were conducted at all 52 points and the BER (after the BCH decoding) and receiving margin were measured at each carrier modulation at 30 points.

FIGURE A1.7

Location of reception points

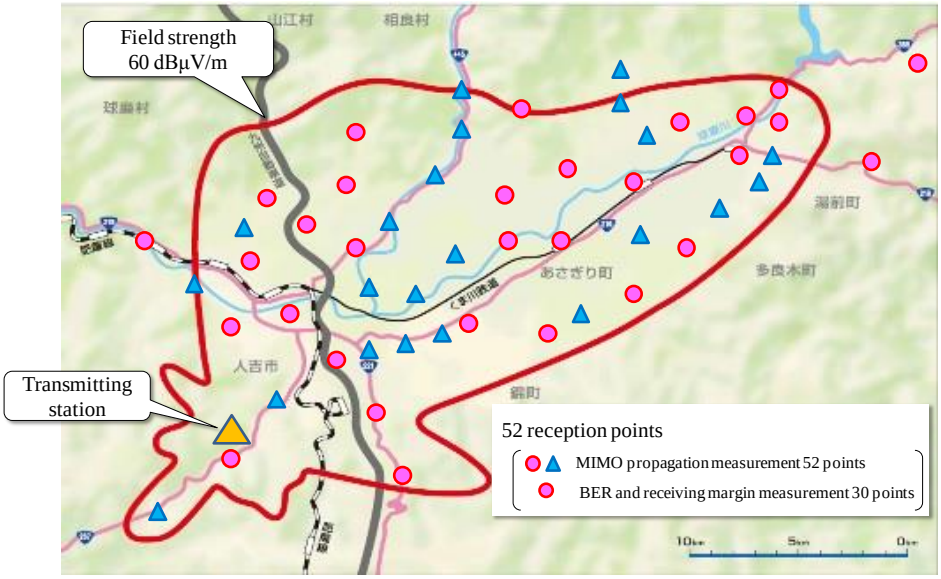
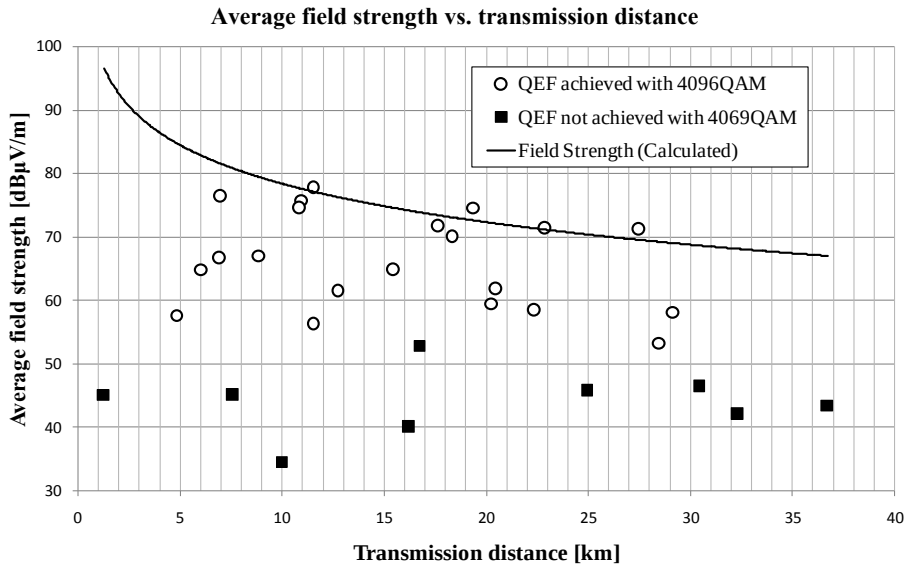


Figure A1.8 plots the average field strength of the BER and receiving margin measurements at the 30 reception points. The horizontal axis is the transmission distance (km) and the vertical axis is the average field strength of both polarized waves. These results indicate that quasi error free (QEF) transmission is possible with the 4096-QAM carrier modulation scheme. In this Annex, the QEF is defined that there is no error for a measurement time of two minutes.

FIGURE A1.8



The required field strength, which is defined as the lowest field strength for QEF transmission, was determined by decreasing the input signal level of the LNA by using the ATT.

Table A1.3 lists the average required field strengths, which were calculated by averaging the horizontal and vertical polarized waves. The average required field strength increased by about 5 dB as a result of quadrupling the number of signal points in the constellation.

TABLE A1.3

Average required field strength for QEF

Carrier modulation scheme	Average required field strength (dBμV/m)	Number of QEF points
256-QAM	42.4	23
1024-QAM	47.3	22
4096-QAM	52.3	21

The transmission characteristics were analysed at all 52 points of the MIMO propagation measurement. The propagation environment was classified into four categories: line of sight (LoS), non-line of sight (NLOS) with a strong field strength (over 60 dBμV/m), NLOS with a moderate field strength (40-60 dBμV/m), and NLOS with a weak field strength (under 40 dBμV/m).

Figure A1.9 shows an example of the MIMO channel responses of NLOS with a moderate field strength. An example of the distribution of the condition numbers of the four categories is presented in Fig. A1.10.

The analysis indicates that the MIMO propagation qualities became worse starting with LoS and followed by NLOS with a strong field strength, NLOS with a moderate field strength, and NLOS with a weak field strength. This order is attributed to the increase of the cross polarized wave components. It was also shown that the condition number increased and the distribution of the condition number spread out in the same order as above.

FIGURE A1.9

Example of MIMO channel responses of NLOS with a moderate field strength

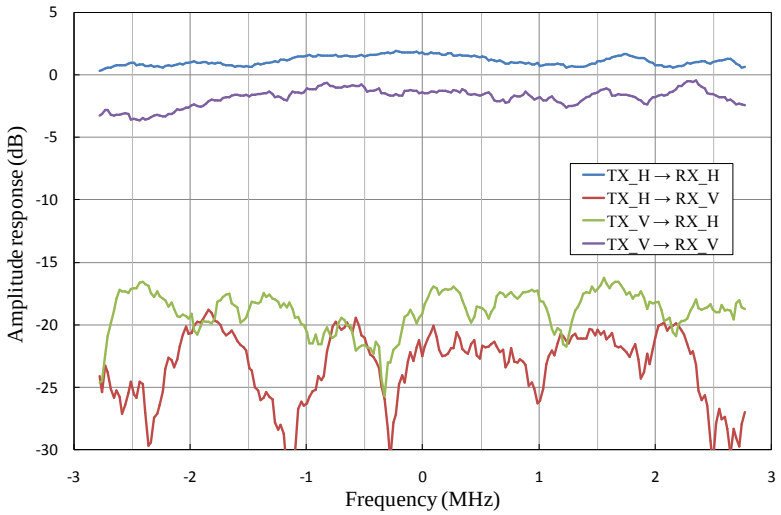
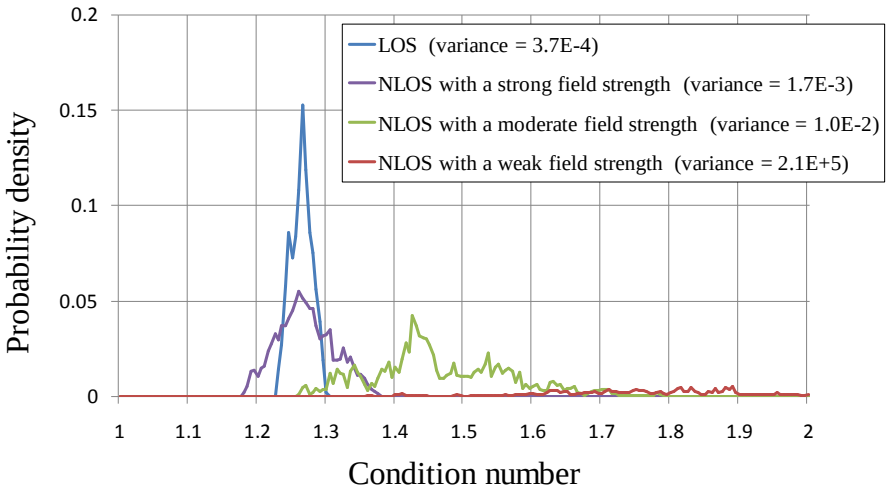


FIGURE A1.10

Example of distribution of condition number of four categories



A1.1.3 Summary

In the field of broadcasting, UHDTV can be the successor to HDTV.

Japan installed an experimental station for 8K transmissions in Hitoyoshi city, Kumamoto prefecture that uses dual-polarized MIMO and ultra-multilevel OFDM technologies. Field experiments carried out there in January 2014 were the world's first 8K terrestrial transmissions (91 Mbps) over a long distance (27 km) using only one UHF channel (6 MHz). This paper reported the results of these field experiments, specifically, the required field strength of the 256-QAM, 1024-QAM, and 4096-QAM carrier modulation and the channel response analysis of dual-polarized MIMO transmission.

It is noted that this experiment showed the feasibility of the terrestrial 8K transmission using some key technologies including dual-polarized MIMO and 4096-QAM carrier modulation. UHDTV system in Japan will be decided upon further considerations and examinations of various technical possibilities as well as future trends.

A1.2 Republic of Korea

The world's first terrestrial UHDTV trial through the DTT platform in Korea was made possible by the strong resolve of two government bodies in Korea: the Korean Communications Commission (KCC) and the Ministry of Science, ICT and Future Planning (MSIP). They granted permissions and provided support to execute the UHDTV experimental broadcast. This trial was also facilitated by the memorandum of understanding (MOU) signed in April 2012, which confirmed the cooperation of major terrestrial broadcasters in Korea, i.e. KBS, MBC, SBS and EBS, for experimental broadcasts.

Furthermore, most uncertainties regarding the implementation of 4K-UHDTV service within a 6 MHz bandwidth have been resolved and the date for launching 4K-UHDTV via terrestrial broadcast networks can be brought forward. Moreover, the capability of participating broadcasters to produce 4K-UHDTV content has been enhanced up to live production.

Phase 1: September 1 - December 31, 2012

KBS, on behalf of four terrestrial broadcasters, carried out the world's first terrestrial 4K broadcast at 30fps using approximately 32~35 Mb/s. The transmission was conducted at Kwan-Ak in the south of Seoul.

Phase 2: May 10 - October 15, 2013

Following license renewal, KBS increased the frame rate of 4K contents from 30 to 60 fps at approximately 26~34 Mb/s. The transmissions continued at Kwan-Ak.

The goal during these phases was to confirm the feasibility of delivering a terrestrial 4K-UHDTV contents using only 6 MHz of channel bandwidth. Thus, the HEVC compression technique, to fit high volumes of 4K video data rates into limited bandwidth, and the DVB-T2 standards, to improve the robustness of over-the-air transmission, were adopted.

Kwan-Ak Mountain Transmission Site

During Phase 1 and 2, KBS operated the Kwan-Ak site only using the parameters shown in Table A2.1. For the field test, 15 and 10 reception points located 5 km to 52 km, respectively, from the transmitter were selected as shown in Fig. A1.11.

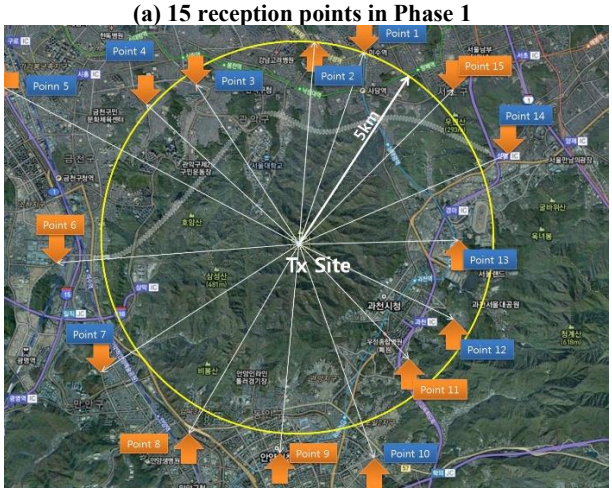
– In Phase 1, the field test was conducted at 15 points with an almost identical radial distance of 5 km from the transmission site. We attempted to maintain an equal angle interval for each measuring point, as shown in Fig. A1.11(a).

– In Phase 2, the field test was conducted at 10 points at distance 10 km to 52 km from the transmission site as shown in Fig. A1.11(b).

FIGURE A1.11

Location of reception points during Phase 1 and Phase 2

(a) 15 reception points in Phase 1



(b) 10 reception points in Phase 2

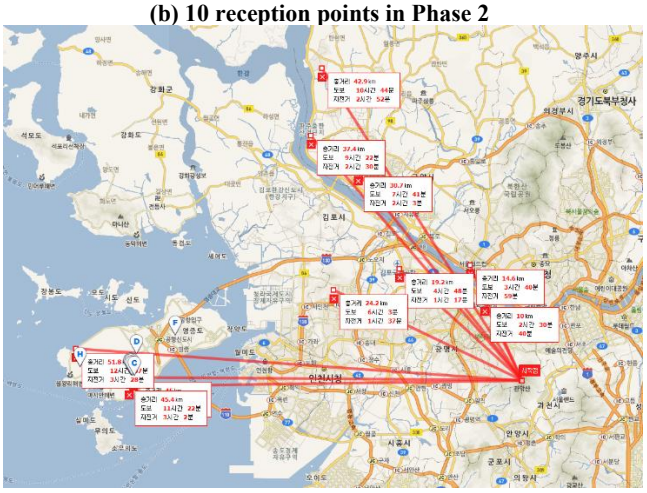


TABLE A1.4

Specifications of transmission system during Phase 1 and 2

	Phase 1			Phase 2	
Transmitter site	Kwan-Ak Mountain				
Covering	The Metropolitan area of Seoul				
Nominal power (Antenna gain)	100 W (6.01 dBi)				
DTT System	DVB-T2				
Transmission mode	32k, extended mode, *GI* = 1/128, PP7				
Modulation	256 QAM			64 QAM	256 QAM
Number of FEC blocks in interleaving frame	163			123	165
FEC code rate	3/4	4/5	5/6	4/5	5/6
Multiplexing capacity	32.8 Mb/s	35.0 Mb/s	36.5 Mb/s	26.5 Mb/s	36.9 Mb/s
Signal bit rate	32.0 ~ 35.0 Mb/s			26.0 ~ 34.0 Mb/s	
Video encoding standard	HEVC				
Picture standard	3 840×2 160p, 8 bits/pixel 30 fps			3 840×2 160p, 8 bits/pixel 60 fps	
Frequency used	785 MHz (Ch 66 in Korea)				

Phase 3: March 24, 2014 - March 31, 2015

In Phase 3, in addition to KBS, MSIP granted permission to MBC and SBS for experimental broadcast. KBS and SBS deployed a single frequency network (SFN) for live 4K-UHDTV experiments as listed in Table A1.5.

TABLE A1.5

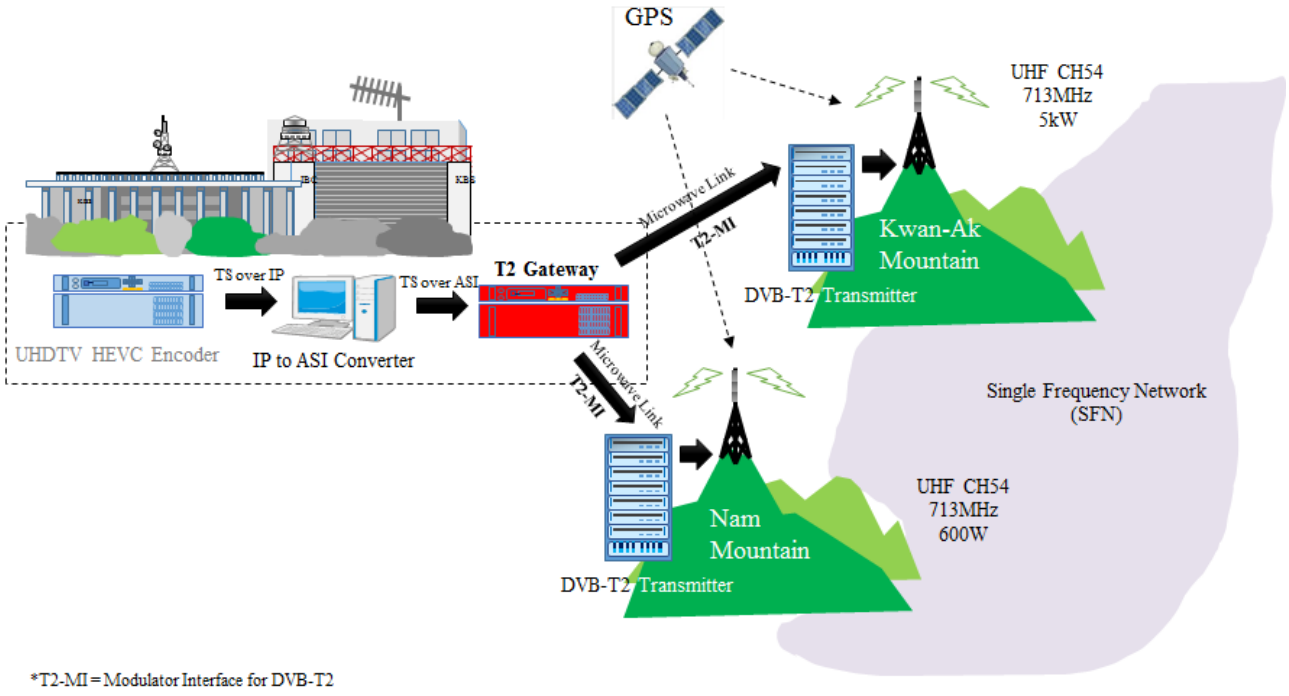
Transmitting power and used channels of transmitter site during Phase 3

Broadcaster Center frequency (Channel number)	KBS 713 MHz (Ch 54)	MBC 701 MHz (Ch 52)	SBS 707 MHz (Ch 53)
Kwan-Ak mountain	5 kW	2.5 kW	5 kW
Nam mountain	600 W	–	–
Yong-Moon mountain	–	–	1 kW

The detailed parameters of the 4K signal transmitted on the DTT platform are listed in Table A1. The experimental broadcast chain of KBS, including content production, encoding, microwave link, is shown in Fig. A1.12.

FIGURE A1.12

Transmission chain of the SFN deployed by KBS for 4K-UHDTV experiments in Phase 3



The remarkable feature of Phase 3 was that it involved live 4K-UHDTV experimental broadcasting over an SFN, which was possible due to the development of a real-time encoder for 4K-UHDTV content. KBS hence carried out the world's first live 4K terrestrial broadcast over SFN, of the 2014 Korean Basketball League (KBL) Final.

It also should be emphasized that the release of the DVB-T2 demodulator with the HEVC decoder chipset-embedded 4K-UHDTV at an affordable price has made it easier for people in Seoul to watch 4K programs through the direct reception using the antenna. That is, anyone who has a 4K-UHD TV can watch 4K contents through the DTT platform.

2014 KBL Final Match

On April 5, 2014, KBS carried out the world's first terrestrial 4K live broadcast. The target of the 4K live broadcast was the final of the KBL in Ulsan in south-eastern Korea, as shown in Fig. A1.13(a).

Alongside the terrestrial 4K live broadcasting, a public viewing event was also held in Seoul Station, the largest and busiest railway station in Korea. Figure A1.14 shows the event. The 4K UHDTVs in Fig. A1.13(b) had a built-in DVB-T2 tuner with the HEVC decoder, which enabled the direct reception of the 4K terrestrial signal to the station.

FIGURE A1.13

4K live broadcast of the 2014 KBL Final

(a) Image of the 4K live broadcast **(b) People watching the game at Seoul Station**

2014 FIFA World Cup in Brazil

In an attempt to give wider publicity to terrestrial 4K-UHDTV, the following three World Cup matches were broadcast live in 4K-UHD, as shown in Fig. A1.14. 4K live was fed from Brazil via AsiaSat5, a communications satellite, as shown in Fig. A1.14.

– Round of 16: Colombia vs. Uruguay
– The Quarterfinal: France vs. Germany
– The Final: Germany vs. Argentina

Images from Brazil were delivered in real-time through the AsiaSat5 communication satellite. The Korean Research Environment Open Network (KREONET) was used to deliver live 4K contents for public viewing events to other provinces.

In order to increase live service coverage of the 4K-UHDTV, two provinces were chosen for the public viewing, Daejeon and Jeju Island, in addition to the metropolitan area of Seoul, as shown in Fig. A1.15:

– Daejeon is fifth largest metropolis of Korea and approximately 167 km from Seoul. The reception system for the public viewing was set up in the lobby of the KBS's Daejeon station building.
– Jeju is 450 km south of Seoul, and is the largest island in Korea. The reception system for public viewing there was set up in the lobby of the KBS Jeju station building.

FIGURE A1.14

Transmission configuration established by KBS for the nationwide 4K live broadcast

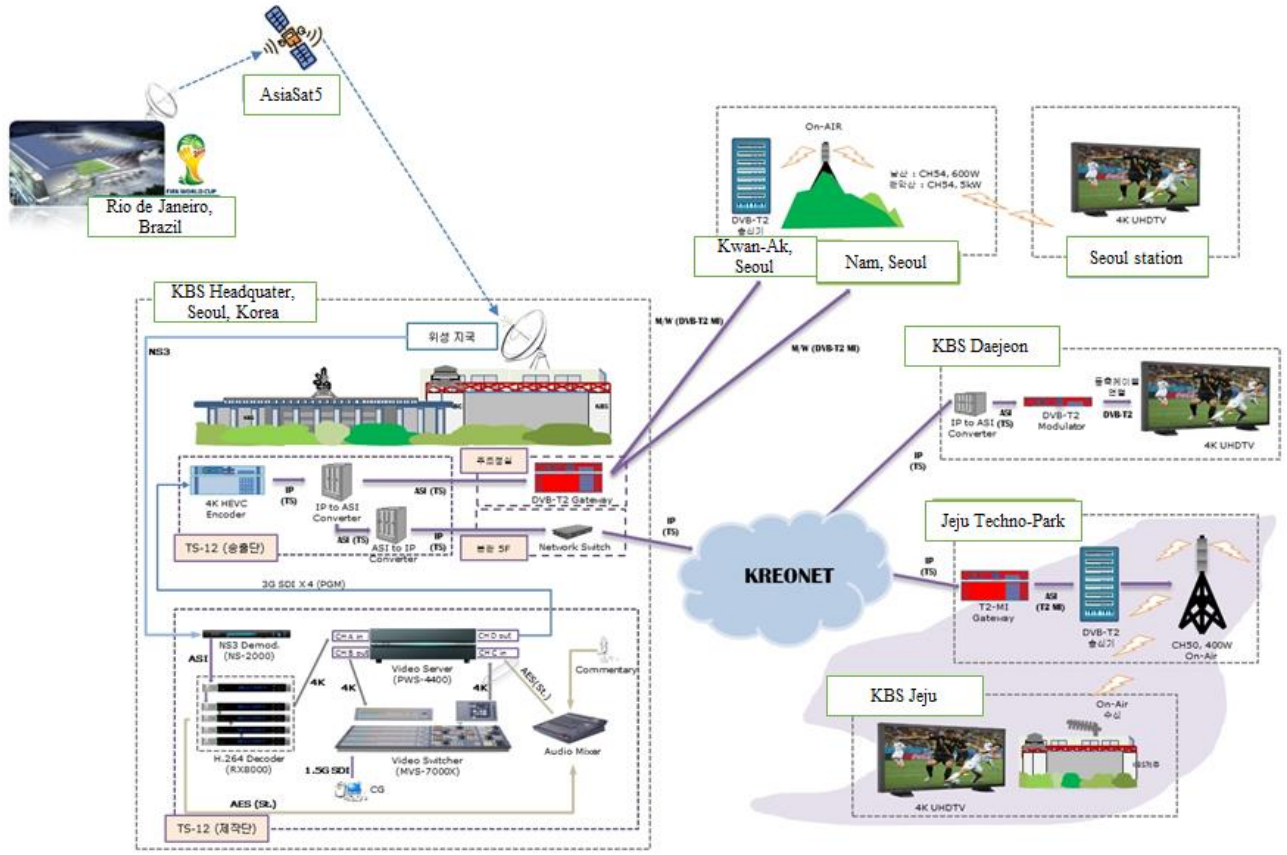


FIGURE A1.15

4K live broadcast of the 2014 FIFA World Cup

A scene of the location for public viewing at (a) the lounge in Seoul Station, (b) the lobby of the KBS Daejeon station building, and (c) the lobby of KBS's Jeju station building

2014 Incheon Asian Games

With the government's cooperation in support 4K live coverage of the 2014 Incheon Asian Games, each broadcaster picked sporting events that suited its interests:

– KBS chose men and women's volleyball. (see Fig. A1.16).

– MBC chose track-and-field events, as well as the opening and closing ceremonies.

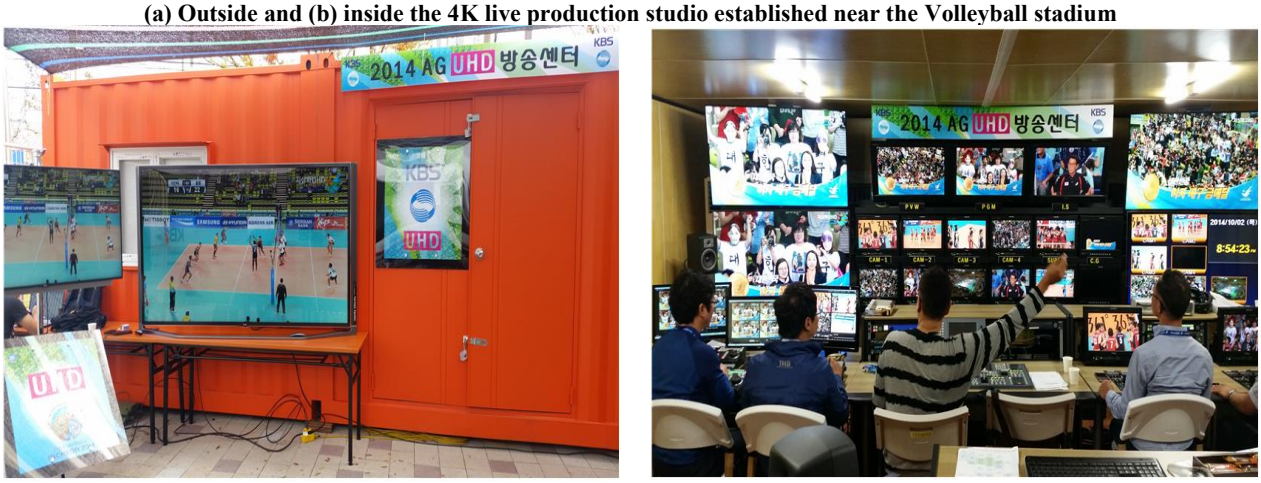
– SBS picked beach volleyball.

There were no public viewing events, because 4K UHD TVs with built-in DVB-T2 tuners along with the HEVC decoder had become widely available by then, and anybody in the metropolitan area of Seoul could have watched the Incheon Asian Games live on 4K UHDTV.

FIGURE A1.16

4K live broadcast of the 2014 Incheon Asian Games

(a) Outside and (b) inside the 4K live production studio established near the Volleyball stadium



ITU Plenipotentiary Conference 2014 (PP-14)

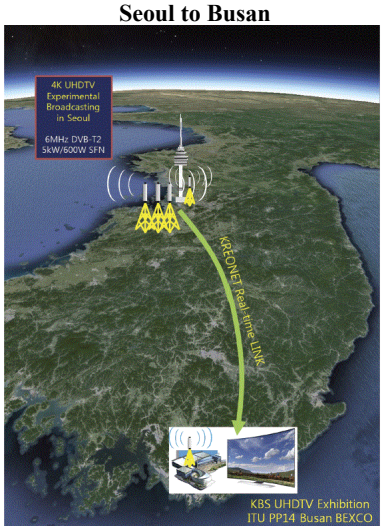
During the ITU PP-14 held at the Busan Exhibition and Convention Center (BEXCO) in Busan, Korea, a local on-air demonstration was watched by several delegates from the Member States as well as Sector Members of the ITU.

A 4K stream was delivered by KREONET from Seoul to Busan, as shown in Fig. A1.17(a). Consequently, the same 4K contents were broadcasted in both Seoul and BEXCO. The 4K stream was fed into a transmitter installed in BEXCO, and the radio frequency (RF) signal produced by the transmitter was sent to the 4K UHDTV by covering the indoor, as shown in Fig. A1.17(b).

FIGURE A1.17

Local on-air demonstration at ITU PP-14 held in Busan, Korea

(a) Configuration for delivering 4K contents live from Seoul to Busan



(b) Equipment including transmitting antenna for local on-air transmission and the 4K-UHDTV with integrated tuner.

A1.3 France

A1.3.1 Introduction

The objective of this experiment was to implement an experimental platform for transmitting linear ultra-high definition television (UHDTV) from the Eiffel Tower with a data rate of 40.215 Mb/s, aiming at testing the associated new technologies (HEVC encoding of UHD profile, DVB-T2 broadcasting and interoperability with TVs), understanding the possible technical difficulties in this context and demonstrating the corresponding services.

The current DTTB SD&HDTV platform, which is the major platform transmitting linear TV in France, in order to remain attractive, should evolve towards a connected and interactive platform, offering at the present more programs in high definition (HD) and later in ultra-high definition (UHD).

A1.3.2 4K-UHDTV field experiment conducted in France

For maximizing the throughput during this experiment, a UHD DVB-T2 multiplex was transmitted from the Eiffel Tower (Paris) according to a MFN (Multi-frequency Network) profile with GI = 1/128.

The reception of DVB-T2 multiplex was possible at any point in the DTTB coverage area, having a radius of about (25 km), via a standard fixed rake antenna and a TV set equipped with a DVB-T2 tuner and HEVC chipset set up to decode the UHD programs.

A1.3.2.1 System parameters and coverage area

The system parameters used in the experiment of 4K UHDTV terrestrial transmission conducted in France are presented in Table A1.6. The coverage of the transmitter is depicted in Fig. A1.18.

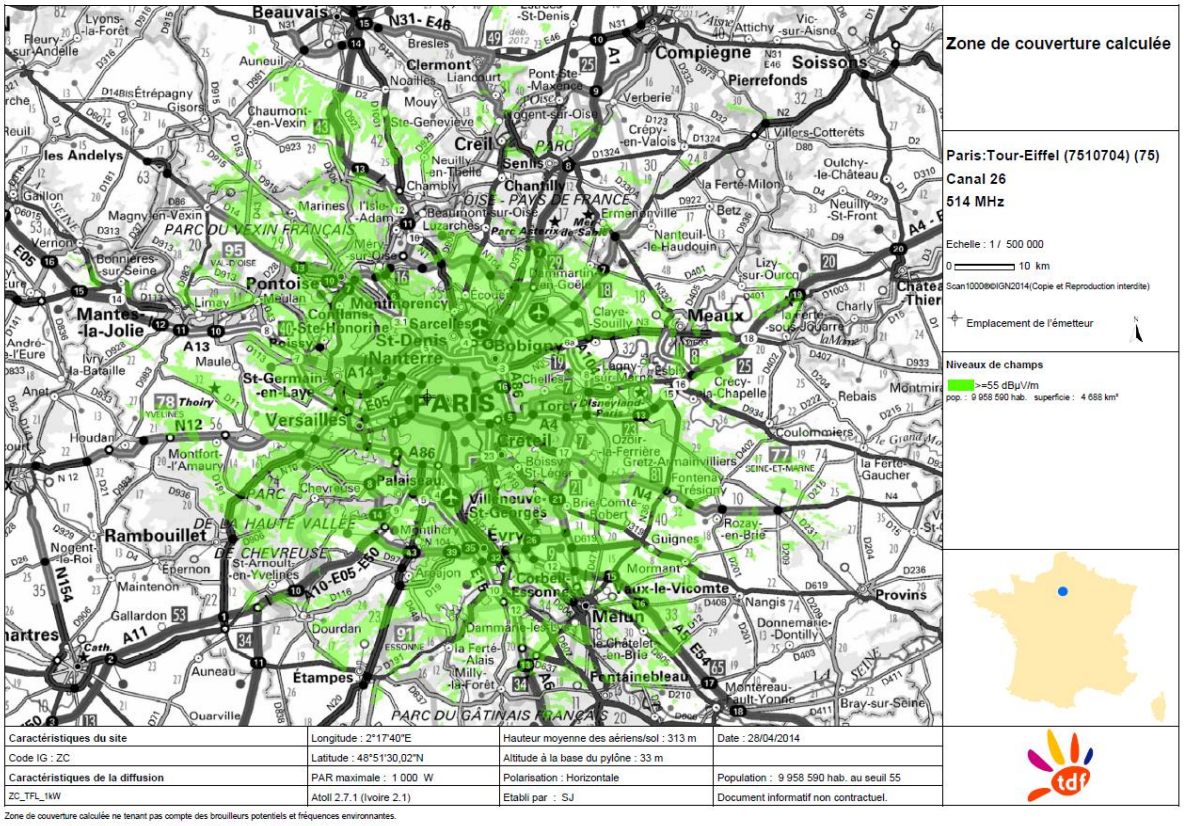
TABLE A1.6

System parameters of 4K UHDTV field experiment in France

Network topology	MFN (DTTB)
Modulation method	OFDM
Channel bandwidth / Occupied bandwidth	8 / 7.77 MHz
Transmission frequency	514.167 MHz (UHF ch26)
Transmission power	100 W, ERP: 1000 W
Transmission mode	SISO
Carrier modulation	256-QAM
C/N (for Rician channel)	19.7 dB
FFT size (number of radiated carriers)	32k (22,465)
Guard interval ratio (guard interval duration)	1/128 (28 μs)
Pilot profile	PP7
# OFDM symbols	60
Error-correcting code	Inner: LDPC, code rate = 2/3 Outer: BCH
Data rate	40.215 Mb/s
Video coding	HEVC (2160p[(1)] UHD-1 phase 1, 8 bit, 50 fps)
Transmitting station	Eiffel Tower
Height of transmitting antenna	313 m
Height of receiving antenna	10 m
Coverage radius	(25 km)
Minimum median field strength	55 dBμV/m at 10 m
[1] 3 840×2 160 (4K)	

FIGURE A1.18

Coverage area of 4K UHDTV field experiments in Paris (France)



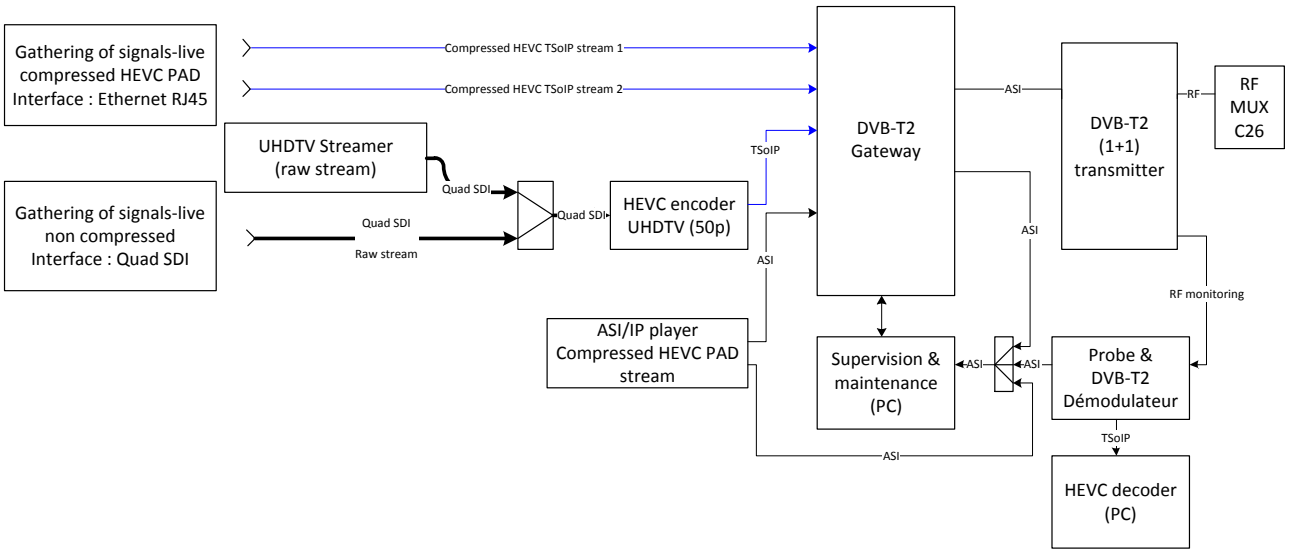
ERP = 1 kW
Coverage radius ≈ 25 km
Minimum median field strength = 55 dBµV/m,

A1.3.2.2 Implementation of 4K UHDTV terrestrial transmission platform

The implementation of 4K UHDTV terrestrial transmission platform was based on a set of technical links and units most of them being new and requiring specific tests to be able to run the transmission link from the starting point to the end – from the capture of UHD images to the reception on an integrated UHD-1 phase1 TV set. The technical description of the platform is depicted in Fig. A1.19.

FIGURE A1.19

Technical description of 4K UHDTV terrestrial transmission platform



A1.3.2.3 Live 4K UHDTV terrestrial transmission of the "French Open" International tennis tournament (2014)

Live transmission as well as transmission of pre-recorded and encoded footages were performed during the experiment. Here we only focus on live transmission of "French Open" international tennis tournament.

The implementation of 4K-UHDTV platform for live transmission (50 fps) of the "French Open" tournament was a technological challenge. The experiment has demonstrated the feasibility of such broadcasting in DVB-T2 with three different integrated UHD-TV with first embedded HEVC decoding chipset. For the duration of the tournament, two full afternoons (3 and 4 June) were dedicated for broadcasting in live on UHD Program 1 by means of 4 moving UHD cameras (actual UHD production). For the rest of the tournament, a fixed UHD camera installed on the main court was used for broadcasting in live on UHD program 1. A second UHD program (Program 2), pre-encoded UHD film (sea, waves with storm, fisher boats), was broadcasted on Brittany:

- UHD Program 1: 22.5 Mb/s real-time encoding for live transmission.
- UHD Program 2: 17.5 Mb/s pre-recorded and off line encoded.

These two values have been defined for several reasons:

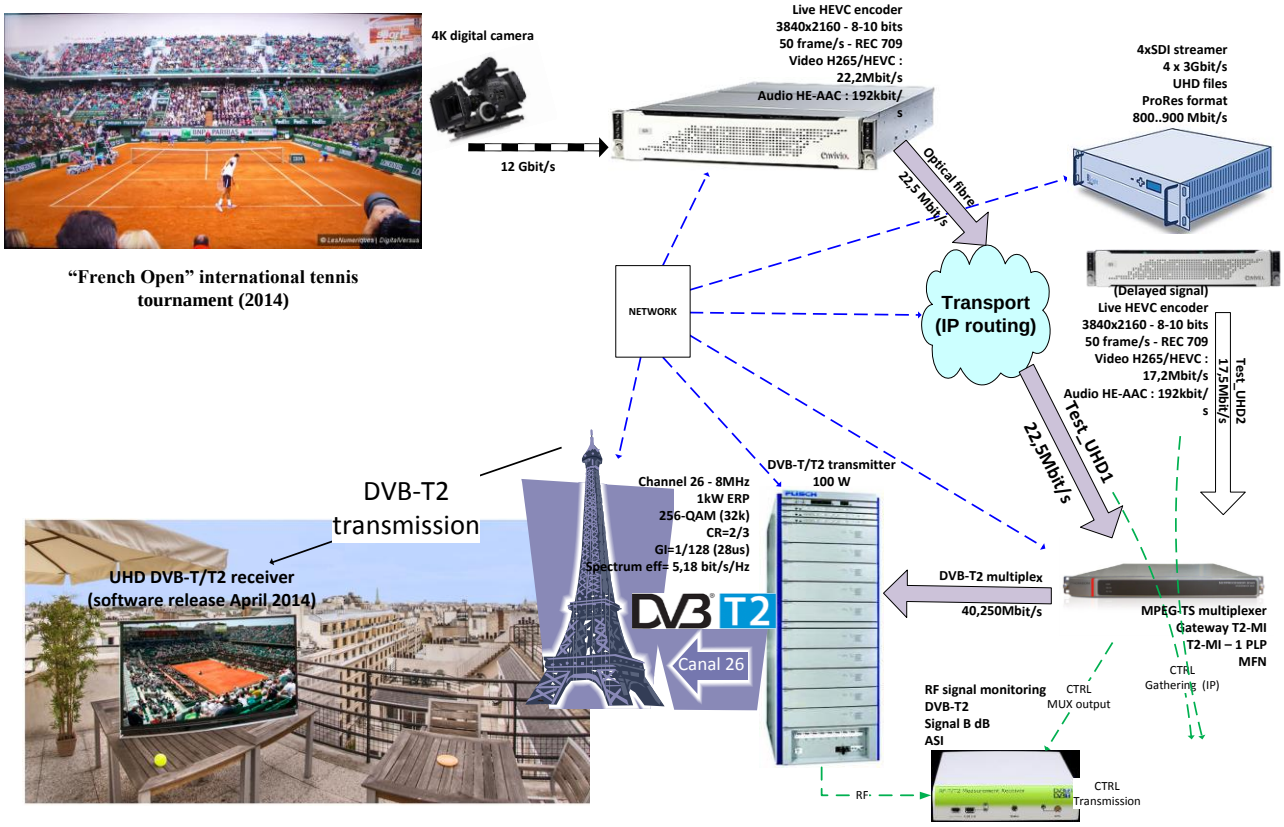
- Off line encoding uses additional HEVC tools that are not implemented in the first generation of real time encoder (no more details from encoder manufacturers at this time) and it represents next versions that will be implemented in live encoders.
- Pre-recorded files represent the same quality of current live encoder at a different bit rate.
- 17 Mb/s represents the quality of two UHDTV channels in a SFN T2 multiplex of 36 Mb/s.
- 22 Mb/s has been set in order to show the impact of an additional 5Mb/s on UHDTV quality.

Moreover, two days were devoted to the production of UHDTV images shot by four UHDTV cameras and two HD cameras upscaled to UHD. These two days have permitted the comparison of the quality of image of UHD, HD (1 920×1 080i/25) and SD (720×576i/25) programs on the same UHDTV screen.

The block diagram of live 4K UHDTV terrestrial transmission platform is depicted in Fig. A1.20.

FIGURE A1.20

Live UHDTV terrestrial transmission of the "French Open" tournament



The experiment permitted, through simulcasting DTTB including images of "French Open" tournament, to compare the perceived quality of UHD, HD and SD programs, images being presented on the same UHDTV screen.

Demonstrations were performed to have the opinion of professionals as well as home users, some of them discovering UHDTV images for the first time. They were invited to watch TV in the same conditions as in a living room sitting at a distance suitable for a UHDTV screen, which was about 1.5 times the height of the 65 inches TV display. Most of them (about 60 to 70 visitors) felt that the image quality of UHDTV programs was fairly better than that of SD and HD programs due to the fact that we could recognize people in the stands even with wide view angle, which is impossible in HD and many other feedbacks: "it is so realistic, like if we look through a window".

A1.3.3 Conclusion

This experiment was an important step towards the introduction of the terrestrial UHDTV in France. It demonstrated the feasibility of live 4K UHDTV terrestrial transmission based on UHDTV (phase 1) specifications and 256 QAM OFDM modulation with two programs in a DTT Multiplex for the first version of live UHDTV encoders. It also demonstrated the step of quality of UHDTV programs compared to HD programs (1 920×1 080i/25).

Consequently, it is concluded that UHDTV will surely be the successor to high definition television (HDTV). Based on this conclusion the aforementioned 4K UHDTV terrestrial transmission platform is maintained in use aiming at supporting the undergoing developments of UHDTV and preparing the introduction of the terrestrial UHDTV in France.

Moreover, based on the currently available information on the issue, from a technical and economical point of view, it can be concluded that it will be possible to transmit three UHDTV (phase 1) programs in a DVB-T2 multiplex in France by 2017.

A1.4 Spain

RTVE, the Spanish public service broadcaster, together with Universidad Politécnica de Madrid (UPM) and other relevant Spanish companies, undertook an Ultra High Definition TV trial in 2014. RTVE provided a documentary about the Prado Museum, titled "The Passion of the Prado", produced using 4K resolution (3 840×2 160-pixel images) video.

Along the duration of this initiative, different encoding specifications and sets of transmission parameters were used. Meanwhile, manufacturers started to integrate the capacity to decode HEVC/H.265 video in their new flat-screens. As soon as this feature was available, it was used in the trial.

First tests were based on AVC/H.264 video encoding and 25p frame rate. After that, HEVC/H.265 at 50p frames per second was used to get smoother movements. Several bitrates were also tested from 20 Mb/s to 35 Mb/s. In all the cases, the transmission was based on DVB-T2 to ensure a higher spectral efficiency. Since DVB-T2 admits useful bitrates of around 50 Mb/s, the bitrate of the deployed signal (until 35 Mb/s) is low enough to integrate more programs in future tests. The trial covered the area of Ciudad Universitaria (north-west of Madrid city) from a transmitter in the Telecommunication Engineering School (ETSI de Telecomunicación – UPM).

The trial was presented in a technical event in the RTVE Institute on 24th June, 2014. The table below shows the technical parameters involved in this demonstrator.

Transmission standard	DVB-T2
Bandwidth	8 MHz
Frequency	754 MHz (Ch. 56 in region 1; central frequency)
Power	ERP: 125 W (H)
Carrier modulation	64 QAM
FFT size	32k extended
Guard interval ratio (guard interval duration)	1/128
DVB-T2 FEC	5/6
Pilot pattern	PP7
Theoretical capacity	36.72 Mb/s
Video coding	HEVC/H.265
Audio coding	E-AC-3 5.1
Total used bitrate	35 Mb/s
Transmitting station	ETSI de Telecomunicación (UPM).

Further trials are planned to be carried out in this frequency channel where the multiplex will remain in operation until the Rio de Janeiro 2016 Olympic Games. The trials will be consistent with the principles stated in EBU TR 028 "EBU Policy Statement on Ultra High Definition Television"[4] and, in particular, will test those parameters (or a combination of them) that provide a more immersive viewing experience, such as improved frame rate, dynamic range, colour gamut and enhanced audio.

A1.5 Sweden

The transmission was primarily made for the Teracom customer event "TV-Puls" January 23rd 2014, but was on air the week before and two weeks after this date. Two encoded streams were alternately broadcast during this period. Stream 1 was offline encoded. Stream 2 was supplied by a manufacturer, meaning that the parameters of this stream are not known.

The 4k signal was transmitted in the DTT platform with the parameters in Table 1.

A1.6 United Kingdom

The ready availability of 4k material for two major sporting events of great public interest in the summer of 2014 (the FIFA World Cup in Brazil, and the Commonwealth Games in Glasgow) allowed the BBC to run a series of trials concerning distribution of this material. As well as trials of streaming the content online (via DVB-DASH), the BBC's transmission network operator, Arqiva, operated a network of three high-power DTT transmitters broadcasting a multiplex containing one UHDTV service.

The 4k signal was transmitted in the DTT platform with the parameters in Table 1.

The transmissions were successfully received and decoded for a series of public and private demonstrations in all three service area.

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4 https://tech.ebu.ch/webdav/site/tech/shared/techreports/tr028.pdf