



Report ITU-R BT.2485-1
(03/2022)

**Advanced network planning and
transmission methods for enhancements
of digital terrestrial television broadcasting**

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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(2021-2022)

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Acronyms

ADM	Audio definition model
AdvSS	Advanced sound system
AIAV	Advanced immersive audio-visual
AR	Augmented reality
ATSC	Advanced Television Systems Committee
ATSC 3.0	Advanced Television Systems Committee next generation
BICM	Bit-interleaved coding and modulation
C/N	Carrier-to-noise ratio
CSS	Cascading style sheets
DIDO	Distributed input, distributed output
DTTB	Digital terrestrial television broadcasting
DTV	Digital television
DVB-T	Digital video broadcasting – terrestrial
DVB-T2	Digital video broadcasting – terrestrial second generation
FDM	Frequency division multiplexing
FEC	Forward error correction
FEF	Future extension frame
FFT	Fast Fourier transform
HARQ	Hybrid automatic repeat request
HBBTV	Hybrid broadcast broadband television

HD	High definition
HDR	Higher dynamic range
HDTV	High definition television
HFR	Higher frame rate
HLG	Hybrid-log gamma
HTML	Hypertext markup language
IoT	Internet of Things
IP	Internet protocol
IPDC	Internet protocol data cast
IPTV	Internet protocol television
IRA	Irregular repeat-accumulate
LDPC	Low density parity check
LDM	Layer-division multiplexing
LOS	Line of sight
M2M	Machine to machine
MET	Multi-EDGE TYPE
MFN	Multi-frequency network
MIMO	Multiple input, multiple output
NUC	Non uniform constellation
OAM	Orbital angular momentum
PC	Personal computer
PLP	Physical layer pipe
PQ	Perceptual quantization
QAM	Quadrature amplitude modulation
QoS	Quality of service
QPSK	Quadrature phase-shift keying
RF	Radio frequency
RoD	Redundancy on demand
SD	Standard definition
SDTV	Standard definition television
SDR	Standard dynamic range
SFN	Single frequency network
SISO	Single input, single output
SNR	Signal-to-noise ratio
STB	Set-top box
TCP-IP	Transmission Control Protocol/Internet Protocol

TDM	Time-division multiplexing
TS	Transport stream
TV	Television
UHD	Ultra high definition
UHDTV	Ultra high definition television
UHF	Ultra high frequency
VR	Virtual reality
VRTV	Virtual reality television
WiB	Wideband re-use 1

Introduction

To meet the increasing user requirements for quality of broadcast content and maintain the competitiveness of digital terrestrial broadcasting with respect to other platforms, a number of advanced content delivery formats and applications should be introduced in broadcasting networks. This means introduction of high-definition (HD) and ultra-high definition (UHD), high frame-rate (HFR), high dynamic range (HDR), augmented/virtual reality (AR/VR), multi-screen and ultra-wide angle television, multi-channel immersive audio providing presence effect, associated and additional content delivery and many others.

The aim of this Report is to consider a number of improved techniques of frequency planning and advanced methods of transmission for broadcasting networks to provide necessary additional data capacity to introduce new and upcoming broadcast applications, audio and picture formats using the limited number of channels within heavily occupied and extensively used radio spectrum environment.

1 Advanced broadcast applications and formats

1.1 High definition television (HDTV) and ultra high definition television (UHDTV)

Recommendation ITU-R BT.709 specified the parameters for high-definition television (HDTV). It is expected that HDTV will replace standard definition television (SDTV) as the mainstream standard for picture resolution in broadcast networks. HDTV resolution now widely supported in modern television production equipment and consumer television receivers.

Ultra-high definition television (UHDTV) provides viewers with an enhanced visual experience primarily by having a wide field of view both horizontally and vertically with appropriate screen sizes relevant to usage at home and in public places. UHDTV applications require system parameters that go beyond the levels of HDTV. Recommendation ITU-R BT.2020 provides parameters for UHDTV. Two levels of spatial resolutions are specified, 4K UHDTV (3 840×2 160) and 8K UHDTV (7 680×4 320).

Transmission of HDTV and UHDTV images requires significant increase in the data volume transferred within a broadcast channel with respect to SDTV transmission. There are various estimations of necessary data capacity, due to divergence of test methods, picture content, subjective quality requirements, equipment used in tests, etc. If the video compression (H.264/H.265) is applied, increase in the bitrate for UHDTV transmission becomes lower than relevant increase in the number of picture elements (pixels); nevertheless, it remains substantial. As a rule, transmission of HD images requires several times larger bitrate than SD transmission, and demands from 5 to 14 Mbit/c

depending on a compression method, picture frame rate, content type and user tolerance to distortions of small details or fast-moving objects. Transmission of 4K UHD images typically require bitrate from 20 to 50 Mbit/c, depending on the similar conditions.

1.2 High frame rate television

High frame rate (HFR) television provides viewers with an enhanced visual experience by providing images that look more essentially and sharper when a motion in captured scene take place.

HFR television offers smoother motion with less ‘motion blur’, the effect where for example an object moving across the screen looks out of focus or blurred but becomes much sharper when static and implementation of HFR across production chain would provide a more realistic image for scenes with motion, without massive loss of details.

In addition to increased resolution, HFR options up to 120 Hz are specified in Recommendations ITU-R BT.2020 for UHDTV and ITU-R BT.2100 for HDR-TV.

Implementation of HFR for all production chain should help to provide more realistic live picture for scenes with motion, without massive loss of details. Some increase in the necessary data capacity in the broadcast channel will be a payment for it. Effect of HFR application on bitrate requirements will vary depending on dynamics, amount of motion and other characteristics of a picture. For a sport content in a high definition format (HD) the necessary addition may be up to 20%.

1.3 High dynamic range television

High Dynamic Range Television (HDR-TV) provides viewers with an enhanced visual experience by providing images that have been produced to look correct on brighter displays, that provide much brighter highlights, and that provide improved detail in dark areas.

Recommendation ITU-R BT.2100 specifies HDR-TV image parameters for use in production and international programme exchange using the Perceptual Quantization (PQ) and Hybrid Log-Gamma (HLG) methods. These define progressive image formats with spatial characteristics of $1\,920 \times 1\,080$, $3\,840 \times 2\,160$ and $7\,680 \times 4\,320$ pixels with bit depths of either 10 bits or 12 bits, and with frame frequencies ranging between 24 Hz and 120 Hz. The system colorimetry is identical to that of Recommendation ITU-R BT.2020.

HLG allows to encode in one signal both SDR and HDR images, and it is quite probably that SDR-TVs may have an opportunity to display an HDR-content after software update. HDR-video will be used not only in UHD television: HD also included in the list of supported resolutions. It is important to note what 10- or 12-bit colour depth to be used for HDR. Transmission of additional colour bits for HDR representation will definitely require some additional data capacity in TV transmission downstream. Taking into account latest developments in the field, standardization and implementation of new HDR technologies are expected to continue.

1.4 Advanced Immersive television applications

Report ITU-R BT.2420 – Collection of usage scenarios and current status of advanced immersive audio-visual systems (AIAV-Systems), points out that Advanced immersive audio-visual systems allow a user to have immersive experiences with an unprecedented degree of presence. By tricking the low-level perceptual systems of the user’s brain, AIAV systems can make the user believe to be somewhere else and/or somebody else. This is achieved by (re)creating audio-visual realities and allowing the user to naturally interact with these virtual environments.

These systems rely on the combination of high resolution images, ‘3D sound’ (see § 1.5) and for interaction, minimal latency.

The success of future immersive audio-visual applications will depend on presenting each eye with sufficient resolution that the participant (more than just a viewer) can suspend disbelief and become part of a 360° experience. Recommendation ITU-R BT.2123-0 specifies spatial resolutions of $30\,720 \times 15\,360$ (30K $\times$ 15K) for 360° images.

Due to a large amount of data required, delivery of high-quality advanced immersive streams will be a challenging task for all types of telecommunication networks. Extended broadcast applications may provide such possibility with a small additional cost at broadcaster side using one of advanced ‘layered’ modulation techniques described in § 3.

1.5 Advanced Sound System (AdvSS)

The Advanced Sound System is capable of providing listeners with an immersive audio experience by reproducing sound using three-dimensional loudspeaker layouts. AdvSS can provide audio services adapted to listener’s preferences and listening environments, using an audio renderer that makes use of audio-related metadata.

Recommendation ITU-R BS.2051 specifies loudspeaker configurations supporting up to 24 loudspeakers for advanced sound production and supports channel-based, object-based or scene-based input sound signals, or a combination of them, with accompanying metadata. The number of input sound signals maybe larger than the number of reproduction audio channels or loudspeakers, in which case they are converted to reproduction loudspeaker signals based on audio-related metadata by the audio renderer.

Recommendation ITU-R BS.2127-0, specifies the reference renderer for use, including for programme exchange, with the advanced sound systems specified in Recommendation ITU-R BS.2051-2, and the XML based audio-related metadata specified by the Audio Definition Model (ADM) in Recommendation ITU-R BS.2076-1.

The audio renderer converts a set of audio signals with associated metadata to a different configuration of audio signals and metadata, based on the provided content metadata and local environmental metadata.

1.6 Multiscreen and ultra-wide angle panoramic television

Conventional TV systems designed to display with limited area-of-view. A viewer typically watches a television at the distance about two to three metres from the display. For HDTV and UHDTV home use, a large screen application normally considered to be essential. At the same time, in many cases installation of a large screen TV in particular household is not feasible due to some practical constraints or considerations. So, in many cases typical viewing distance is enough to neglect the effect of even large-size display – viewing angle is still not big enough to consider wide-angle panoramic television content application.

Both multiscreen and panoramic ultra-wide angle television aimed to provide better user experience.

Multiscreen service provides the picture for additional displays, and the content of these additional views in simplest system to be selected by production team. In more advanced systems, consumer can select the content for additional displays from wider preset of cameras, or even freely select points of view taken from larger ultra-wide angle or panoramic view. Combination of real-time choice between different points of view (for example, panoramic cameras in some locations) and field of view selection (for currently used panoramic camera) capable to give to end-user something close to ‘virtual presence’ experience.

Another way to extend user experience is the panoramic or ultra-wide-angle TV, which delivers panoramic or ultra-wide-angle image (or a set of conventional size images intended to form ultra-wide-angle picture) directly to the screen (or screens) at end-user side. One simple example of

ultra-wide-angle view system is a multiscreen set using a number of adjacent displays, preferably models with curved screens and thin frames. Multi-element screen has to be of enough size and to stay in proper position for being capable to provide the aerial effect.

If user equipment supports virtual and augmented reality (VR/AR) applications, multiscreen or ultra-wide-angle panoramic TV content may also be applied for rendering VR/AR scenes in receiver.

1.7 Virtual Reality (VR)

Virtual Reality application have to handle great volume of visual information to render a three-dimensional scene what will create the effect of presence using moving portable displays or personal 3D viewing equipment what also provide control information what affect the rendered image, like a change in direction of human look, head and body movements, etc.

With respect to VR application in Broadcasting service (VRTV), most probable approach is to deliver all necessary visual information to user equipment (PC, STB, etc.) and perform required operations to render VR in user equipment. This approach overcomes latency and QoS issues relevant for conventional simulcast IP network. To achieve UHD quality when looking at particular direction, and to provide at least HD quality 2x-3x zoom, spherical panoramic image must be much larger and have better resolution than UHD TV.

VR applications also offer certain forms of interactivity, allowing the user to affect somehow the content of the displayed environment. In the simplest case, a system permits the user to be moved freely to new points of presence, becoming the witness of various events or watching the same event from different locations. Real-time interactivity requires even larger volume of data being transferred to receiver when the downlink/broadcast approach is adopted.

1.8 Augmented Reality (AR)

The term ‘augmented reality’ reflects the feature of real-time local interaction between visualized content and real environment, based on broadcasting transmission. This form of local interaction includes detection of user position, movement, gaze direction. This data is used to display the content in such a way that provides precise alignment with the surrounding visible environment. Visualization of such augmented image carried out by mobile display, is capable to precisely identify a movement and its position in space (smart phones, pads, 3D-helmets or glasses).

Example of similar system is the system of the mixed reality ‘Augmented TV’. Users can see objects and characters in TV programmes, which are falling outside the limits the TV screen when looking at the pad connected to TV service provider. The 2D-image in the TV set and the 3D-image on the pad are synchronized, reference points for alignment of the images are set up by recognition of TV picture appearing in the pad backward camera sensor, in combination with pad angle movement sensor data.

Augmented reality applications require additional information to be transmitted in broadcast channel, including information on the spatial binding of the augmented reality content, the content itself, additional data for the proper content representation (time and subject relevance, etc.). In given above example delivering image that goes beyond the margins of TV screen, it is required to transmit an additional image, which in size and quality can be comparable with or even exceed the main image. If this system is implemented by means of a TV broadcasting network, an additional extended image with reference to the coordinate system must be transmitted as part of the broadcast multiplex or in a separate channel.