TRENDS IN BROADCASTING:
AN OVERVIEW OF DEVELOPMENTS

Report

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Trends in broadcasting: An overview of developments

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1 Introduction

Regulators, spectrum managers and broadcasters are faced with the question how to continue and extend the delivery of broadcasting services and introduce new broadcasting services in a frequency efficient and cost effective way, taking into account the following issues:

- local market requirements;
- existing transmission networks and receivers;
- alternative means of content delivery, including IP broadband, via mobile, fixed and satellite networks;
- regional and international regulatory requirements regarding the use of the frequency spectrum and in particular the impact of decisions adopted at the WRC-12[1];
- existing broadcasting transmission standards and future developments;
- demands of spectrum from other than broadcasting services.

This report is intended as a guide to deal with these issues by giving an overview of developments in broadcasting delivery technology and showing trends in the coming years. The emphasis of the report is on terrestrial broadcasting. The structure of the reports is summarized in Table 1.1.

Table 1.1: Structure of the report

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Two main developments in terrestrial broadcasting will determine the trends in audio and television broadcasting:

- The fast expansion of high capacity data networks, offering consumers broadband Internet access. The Internet will be an increasingly important means of delivery of audio-visual content, including broadcasting.
- The continuing evolution of digital broadcast technology, resulting in a considerable increase of the capacity in the transmitted bandwidth and enabling more services, better picture quality and improved coverage.

Section 2 sets out the milestones and timeframes with regard to the transition to digital broadcasting and the growth of broadband Internet access. Section 3 describes how broadband Internet access to a large part of the population offers an alternative means of broadcast delivery, and how it provides a means for enhanced broadcasting services. Section 4 and 5 reflect the trends and developments in broadcasting technology related to digital television and digital audio respectively. Finally Section 6 gives a summary of the conclusions and highlights the main trends toward the end of the decade.

[1] Final acts: www.itu.int/pub/R-ACT-WRC.9-2012/en

2 Broadcasting by the end of the decade

2.1 General

All players in the broadcasting value chain from content creators to device creators (see Figure 2.1) will be affected by the impact of the evolution of broadcast technology and the growth of broadband Internet access.

Figure 2.1: Digital broadcasting value chain

Source: ITU

These developments will result in the production of higher quality content and offer additional information and interactive services. Digital broadcasting networks will be modified due to:

- demand for more services of higher technical quality and with improved coverage;
- new technology with improved efficiency in the use of the spectrum;
- changed regulations on the use of the spectrum.

Receiving devices will appear on the market to enable high quality pictures and sound, able to handle integrated interactive services and to receive several delivery means including terrestrial broadcasting networks and broadband Internet. Such devices will range from large screens and multi-channel audio equipment to handheld devices like smart phones and tablet computers.

The market conditions and regulatory situation are different from country to country. The resulting situation by the end of the decade and beyond will therefore also differ in each country, but a number of milestones with general applicability and timeframes can be identified.

A principle condition for enjoying the benefit of digital technology is the transition from analogue to digital terrestrial television broadcasting. A milestone in the transition process is the completion of the digital switch-over (DSO) of terrestrial television broadcasting. The first national DSO was completed 2006. It is expected that by 2020 most countries have completed the DSO process. Another milestone is the worldwide allocation of International Mobile Services (IMT) in the 700 and 800 MHz range, expected to become effective in 2015. IMT services will provide mobile broadband Internet access. Together with fixed broadband Internet access, it will facilitate the development of broadcasting and multimedia services via the Internet to a large part of the population.

Section 2.2 sets out milestones and time frames for the transition to digital broadcasting. Section 2.3 describes the growth of broadband Internet access.

2.2 Transition to digital broadcasting

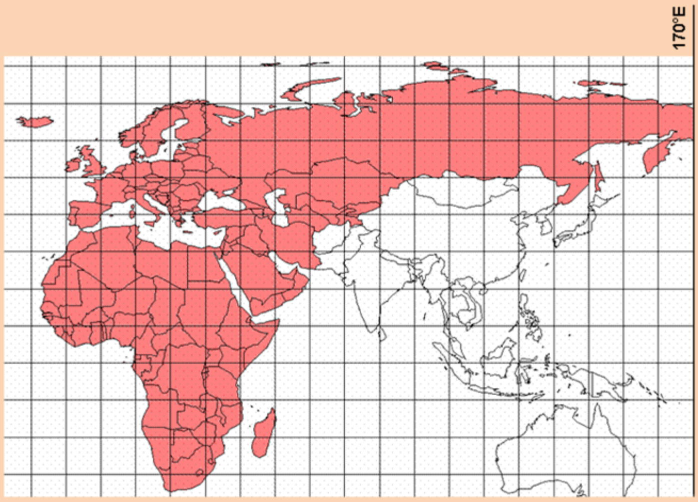
This section describes the developments in the transition to digital terrestrial television broadcasting (Section 2.2.1) and to digital terrestrial audio broadcasting (Section 2.2.2).

2.2.1 Transition to digital terrestrial television broadcasting (DTTB)

Many countries around the world are embarking on the digital switch-over (DSO) process. In parts of Region 1 and 3 (Figure 2.2), the Geneva 2006 Agreement (GE06) has set a time schedule for the transition:

- 17 June 2015: end of the transition period in Band IV/V and Band III, except in 35 countries in Africa and the Middle East[2];
- 17 June 2020: end of the transition period in Band III in the 35 countries in Africa and the Middle East.

Figure 2.2: GE06 planning area



Source: ITU

Many countries in other regions adapted time schedules for transition to digital television within the same timeframe. ITU promotes the transition to digital TV among others with the publication of the "Guidelines for the transition from analogue to digital broadcasting"[3]. These Guidelines are intended to provide information and recommendations on policy, regulation, technologies, network planning, customer awareness and business planning for the smooth introduction of digital terrestrial television and mobile television. Also the ITU-R BT.2140 report deals with the transition from analogue to digital broadcasting[4].

The transition to digital television results in a *Digital Dividend*. In addition to the use of the 800 MHz band (i.e. 790-862 MHz) in Region 1, the WRC-12 agreed on the allocation of the extension of the 800 MHz band, i.e., 694-790 MHz in Region 1 available from 2015 for sharing between broadcasting and mobile services (IMT). Subject to confirmation by WRC-15, this provides a worldwide mobile allocation and identification for IMT in all three regions in the band 698-862 MHz to become effective in 2015. To give an understanding of the *Digital Dividend* and its implications, ITU has published the report "Digital Dividend, insights for spectrum decisions"[5].

In countries where mobile services (IMT) will use a considerable part of the digital dividend it may be necessary to carry out major frequency planning activities and re-engineering of sites to accommodate

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[2] See footnote 7 to Article 12 of the Geneva 2006 Agreement

[3] www.itu.int/dms_pub/itu-d/opb/hdb/D-HDB-GUIDELINES.01-2010-R1-PDF-E.pdf

[4] ITU-R BT.2140-4 Transition from analogue to digital broadcasting

[5] www.itu.int/ITU-D/tech/digital_broadcasting/Reports/DigitalDividend.pdf

operational and planned TV broadcasting stations in a reduced frequency band. In many countries the objectives for digital switch-over include more services, extended coverage and better picture quality including HDTV and introduction of interactive services. Section 4 deals in more detail with the technological developments in digital terrestrial television broadcasting (DTTB) and the challenges to accommodate more services of higher quality in a limited amount of spectrum.

DTTB services are introduced in competition with other means of delivery such as satellite-TV, cable-TV, as well as via broadband networks through IPTV and streaming services on the open Internet. These other TV delivery means have the advantage of intrinsic higher capacity than DTTB. Digital satellite-TV and digital cable-TV have a higher multiplex capacity and also the number of multiplexes is higher than with terrestrial digital television. With IPTV the number of channels is not technically limited. Despite the lower capacity, DTTB is generally seen as the most important. This is stressed by a group of thirteen major broadcasting organisations from Region 1, 2 and 3, who took the initiative to collectively develop the next generation of terrestrial broadcasting standards, the so-called Future of Broadcast Television (FOBTV) initiative (see also Section 4.3.2). This group stated[6]:

> *"Terrestrial broadcasting is uniquely important because it is wireless (supports receivers that can move), infinitely scalable (point-to-multipoint and one-to-many architecture), local (capable of delivering geographically local content), timely (provides real time and non-real time delivery of content) and flexible (supports free-to-air and subscription services). The attribute of wireless delivery of media content to a potentially unlimited number of receivers makes terrestrial broadcasting a vital technology all over the world. Broadcasting is, in fact, the most spectrum-efficient wireless delivery means for popular real-time and file-based media content."*

2.2.2 Transition to digital terrestrial audio broadcasting (DTAB)

Contrary to DTTB, there are no international regulations that prescribe a time schedule for the transition from analogue to digital terrestrial audio broadcasting (DTAB). Furthermore there is a wide range of frequency bands for analogue and an even wider range for DTAB. Each band has its channel bandwidth requirements and propagation characteristics. Moreover, for each frequency band there are several DTAB standards that can be applied (Section 5.2, Table 5.1).

The main incentives for introduction of DTAB are:

- In the LF, MF and HF bands, with AM analogue broadcasting, digital audio broadcasting offers a considerable quality improvement.
- In the lower VHF broadcasting band (Band II)[7], with FM analogue audio broadcasting, the quality improvement of digital audio broadcasting is less apparent to most listeners. But in many countries the band is intensively used by FM transmissions, often in very competitive markets. In some areas the band is approaching its capacity limits and new services cannot be introduced without deteriorating existing coverage areas due to increasing interference levels. In order to accommodate more services, digital audio broadcasting will be required.

[6] Future of Broadcast Terrestrial Television Initiative Memorandum of Understanding; see also www.fobtv.org

[7] In some European countries the band 66 MHz to 72 or 74 MHz is also used for FM services. However, most of these countries have ceased using Band I for FM broadcasting services.

In the GE06 Agreement many countries have DTAB assignments or allotments in the upper VHF broadcasting band (Band III) with the T-DAB standard and will likely use these assignments or allotments for transmissions of T-DAB or related standards T-DAB+ and T-DMB, once analogue television in this band has been switched-off. Also countries outside the GE06 planning area have plans or implemented already DTAB services in Band III.

In a great number of countries DTAB services have been introduced or tests transmissions are carried out. However, the uptake is much slower than with digital television. The relative slow uptake of DTAB is among others caused by:

- the relatively good perceived reception quality of FM stations, hence listeners do not feel an immediate need to switch to digital to listen to existing FM services;
- the lack of attractive new services ;
- the very large base of low cost AM and FM receivers;
- confusion and fragmentation of the market due to the multitude of standards;
- the lack of low cost multi-standard receivers.

Only very few countries have announced to switch-off analogue radio completely. However, in many countries AM-transmitters in the LF, MF and HF bands have been switched off for cost reasons in cases where the services of these stations were duplicated by FM, DTAB or provided via the Internet.

Possible approaches for implementation of digital terrestrial audio broadcasting and phases of migration are described in the Final Report of ITU-D Study Group 2 related to Question 11-2/2[8].

In addition to terrestrial networks in LF, MF, HF and VHF, audio broadcasting services are also delivered as packages in digital television transmission, via cable and satellite as well as via the Internet. Digital radio by satellite shows limited prospects. An ambitious project to offer a package of digital radio services by satellite in the 1.5 GHz to Africa, Asia and America, called Worldspace, stopped a few years ago due to lack of interest. In North-America a subscription based satellite radio service is operated mainly directed to business, like hotels and retail chains.

Similarly as for digital terrestrial television broadcasting, digital terrestrial audio broadcasting is generally seen as the most important means of delivery of audio broadcasting services. This is stressed by the Electronic Communications Committee (EEC) of the CEPT, representing the European telecommunication administrations. The ECC states in ECC Report 177[9]:

> "*In most countries terrestrial radio is by far the most popular way of receiving radio services; most of the audience uses terrestrial as their primary means of reception. Although radio is available on other platforms, they are used only to a limited extent.*
>
> *Terrestrial distribution of radio offers a combination of many positive characteristics for listeners and broadcasters:*
>
> - *Potential to provide universal coverage;*
> - *Tailored coverage (local, regional, national);*

[8] See Section 9 of ITU-D report QUESTION 11-2/2: Examination of terrestrial digital audio and television broadcasting technologies and systems, including cost/benefit analyses, interoperability of digital terrestrial systems with existing analogue networks, and methods of migration from analogue terrestrial techniques to digital techniques; (2006-2010). www.itu.int/dms_pub/itu-d/opb/stg/D-STG-SG02.11.2-2010-PDF-E.pdf

[9] ECC Report 177 Possibilities for Future Terrestrial Delivery of Audio Broadcasting Services; April 2012. www.erodocdb.dk/docs/doc98/official/pdf/ECCRep177.pdf

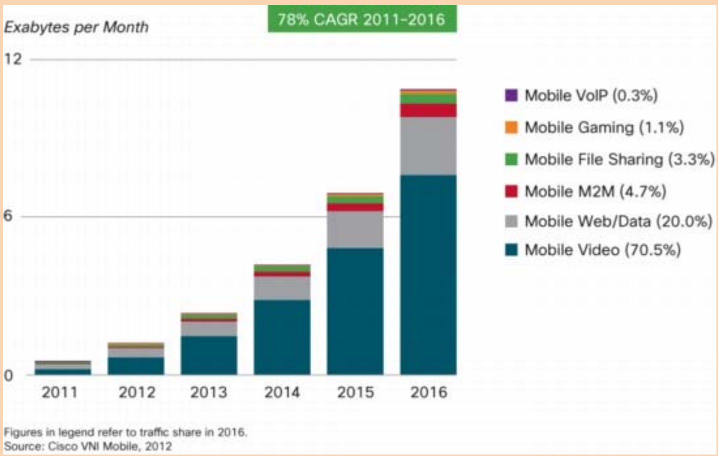
- *Free to air services;*
- *Fixed, portable (indoor) and mobile reception;*
- *Receivers which are agile in frequency tuning and simple to use;*
- *Reliable as a channel of information, especially in crises and catastrophes;*
- *An important medium for traffic information, shipping, mountain rescue, etc.;*
- *Audio quality and multi-media information is independent of the number of simultaneous listeners."*

2.3 Growth of broadband Internet access

Broadband Internet access enables delivery of IP broadcasting services. These kinds of services show a fast development. In particular Internet TV via the open Internet, like catch-up TV and social networking sites (such as YouTube), show high growth figures. Most broadcasters offer free Internet TV and radio services in professional quality, via their own Internet site and also via popular social networking sites.

The IMT allocation in the 700 MHz and 800 MHz frequency range and other frequency bands will facilitate the development of cost effective mobile Internet access in many parts of the world. A forecast shows an annual growth rate of mobile video of 90 per cent between 2011 and 2016, whereas the total annual mobile traffic growth is predicted at 78 per cent [10]. It is expected that by 2016 mobile video will generate over 70 per cent of the mobile data traffic (Figure 2.3).

Figure 2.3: Forecast of mobile data traffic



Source: Cisco Visual Networking Index

This increase is facilitated by the increase of the mobile network connection speed. Cisco forecasts that the average data rate will grow at an annual rate of 56 per cent and will exceed 2.9 Mbit/s in 2016. In many developing countries a growth rate above the average is expected (Table 2.1).

[10] Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2011–2016.

Table 2.1: Growth in mobile network connection speed

Region	Average speed (kbit/s) in 2011	Average speed (kbit/s) in 2016	Annual growth 2011-2016
Global	315	2 873	56%
Asia Pacific	337	2 608	51%
Latin America	125	1 627	67%
North America	1 138	6 785	43%
Western Europe	667	5 549	53%
Central and Eastern Europe	205	3 476	76%
Middle East and Africa	89	2 618	97%

Source: Cisco Visual Networking Index

The increase in data rate is due to the increasing application of 4G mobile connections, including Long-Term Evolution (LTE), an IMT implementation. Cisco expects that in 2016, 4G networks will represent 6 per cent of the connections and 36 per cent of the total traffic.

The LTE data rates are sufficient to distribute IP based radio services and TV services to smaller screen sizes. LTE support three kinds of delivery modes:

1. unicast, to deliver media content to individual users;
2. multicast, to deliver media content to groups of users;
3. broadcast, to deliver media content to anybody within reach of the transmitters.

The data rates of fixed broadband connections, either using ADSL or optical fibre, are sufficient to deliver high quality TV services, including HDTV, to large screens.

Wide spread broadband Internet access (mobile, fixed including WLAN extensions) will have a great impact on broadcasting services:

- On the one hand it is a competitive means to deliver radio and TV services compared to terrestrial, cable and satellite networks.
- On the other hand it is a supportive means of delivery for offering enhanced radio and television services.

Section 3 describes broadcasting service concepts including broadband Internet access.

3 Service concepts

3.1 General

Broadcasting services are by their nature downlink transmissions with programmes in a time sequence determined by the broadcaster (so called linear broadcasting). Enhanced broadcasting services complement the traditional broadcasting services and offer non-linear services (in an order and at time determined by the viewer) by means of interactivity, time-shifted viewing and continued reception at any location.

Enhanced broadcasting services could be offered by terrestrial broadcasting network, cable, IPTV and satellite networks in combination with broadband networks; so called hybrid broadcast-broadband (HBB) services. In addition, some delivery means can offer enhanced broadcasting to a certain extent. For instance DTTB can offer mobile and portable reception, MTV handheld reception and cable TV and IPTV may offer video-on-demand services.

Section 3.2 and 3.3 describe concepts of enhanced television broadcasting and audio broadcasting respectively. Section 3.4 summarizes the role of broadcast and broadband delivery on the services offered to viewer and listener.

3.2 Enhanced television broadcasting

Enhanced broadcasting services are developed around three concepts:

1. TV anytime, aiming at watching a specific programme at the time by choice of the viewer. Time shifted viewing is in particular of interest for shows, documentaries, movies etc., but a relative short time shift for sports and news programmes is also popular.
2. TV anywhere, aiming at watching the broadcast service not only in the living room, but also in other rooms, on the move, etc. Mobile devices like smart phones and tablet computers are used for this application.
3. Interactivity, aiming at contributing or reacting by the viewer to a specific programme, demanding for additional information regarding the programme or receiving programmes or information of particular interest.

These three concepts are described below.

TV anytime

Broadcast services are programmed in a linear way, but consumers may wish to watch the programmes at the time of their convenience, which could be time shifted from the broadcast transmission. There are basically three ways to realize time shifted viewing:

1. Personnel video recorder (PVR). Programmes can be recorded on a hard disk and watched later. The provision of an electronic programme guide (EPG) could facilitate the recording functions considerably.
2. Catch-up TV services via the open Internet. Catch-up TV services are watched at computers, smart phones and tablet computers, but also on television screens if the receiving set is equipped with facilities for Internet connection. So called connected TVs or hybrid broadcast-broadband (HBB) devices combine broadcast and broadband delivery in the TV receiver and offer among others catch-up services (see also the section below on interactivity). Public fixed and mobile networks in combination with domestic WLAN networks will be necessary for uplink and downlink transmission of the catch-up services.
3. Catch-up TV services as part of a video-on demand offer. Providers of digital cable TV services and IPTV services may offer also catch-up TV services as part of a video-on-demand offer.

TV anywhere

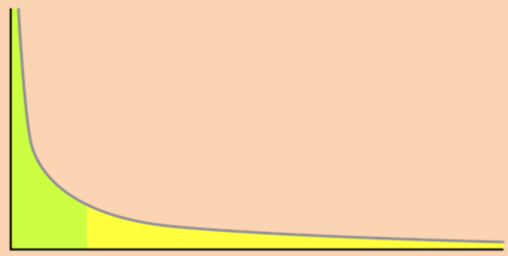
Consumers may wish to watch their favourite programmes anywhere, on route, in the living room and in other rooms. In addition to the main TV set, second sets and other types of receivers such as pc, smart phone and tablet computer are used. Reception of the programme on the latter two devices is realized by means of IPTV and broadband TV via public fixed and mobile networks in combination with domestic WLAN networks. Alternatively, DTTB or dedicated mobile TV networks (MTV) could be used if the devices are equipped with the appropriate systems.

Interactivity

Consumers may wish to participate actively in the programme by means of voting, giving comments, receiving additional information or wish to receive video-on-demand programmes. Also programme independent information may be offered such as news, e-government and e-learning services as well as commercial applications for ordering good or services. For this kind of interactive services, a return path (upload) is necessary and often also a second download path to distribute the requested information.

Hybrid broadcast-broadband (HBB) solutions are suitable for offering interactive services. A package of 20 to 30 popular TV services of interest to most of the viewers could be transmitted by digital broadcasting network. The broadband network could provide the uplink for reactions to the programme and selection of additional services, while the downlink of the broadband network is used to deliver the individual information such as video-on demand services. The latter services are also called "long tail" services (Figure 3.1). This refers to a statistical distribution describing the retail strategy of selling a large number of products with small quantities per product (in this case individually requested TV services), in addition to selling low numbers of popular products in large quantities (in this case distribution of TV services via broadcast networks to the general public).

Figure 3.1: Long tail curve



Source: Wikipedia

The broadband connection can also be used for selecting and downloading other information like catch-up TV services, programme related information, news and commercial services through specially designed web pages that can be navigated by means of a remote control[11].

Interactivity is realized by means of "middleware" in the TV receiver or set-top-box. Several proprietary and open standards exist. Examples of the latter category are DVB related MHEG5 (e.g. in the UK) and MHP (e.g. in Italy) and the ISDB-T related Ginga (e.g. in Brazil and Angola) and BML (e.g. in Japan). New standards related to DVB are HbbTV currently in use in France and Germany and other European countries and YouView in the UK.

Modern broadcast receivers are often offered with Internet connectivity; two kinds of TV sets with Internet connection exist:

1. TV sets using the "middleware" as indicated above;
2. TV sets with manufacturer-specific brand names offering content based "apps".

With HBB applications and other interactive systems, interactive services are searched and received via applications displayed on the main TV screen and operated with the remote control device of the TV set or set-top-box. This is sometimes referred to as "over the top TV" (OTT).

Another approach to interactivity is the use of "second screen", also called "companion screen". Search and display of the interactive service is performed a by separate device connected to the Internet, such as a smart phone or a tablet computer. This kind of interactivity is potentially attractive if there are many smart phones and tablet computers in the market. Special software for operation of the interactive

[11] Examples of such kind of HBB services can been seen at www.hbbtv.org.

services has to be provided by the broadcaster for downloading to and installation on the second screen device.

The second screen approach has a number of advantages, such as:

- a normal digital TV receiver or set-top-box without "middleware" can be used;
- the viewing experience of the main (first) screen is not disturbed, as no windows with additional information appear on the screen;
- the second screen device (pc, smart phone or tablet computer) are optimized for data entry and have a keyboard.

Summary of enhanced television broadcasting concepts

A summary of the enhanced television broadcasting concepts is shown on Table 3.1.

Table 3.1: Summary of enhanced television broadcasting concepts

Enhanced broadcasting	Delivery	Terminal devices (must be equipped to receive the corresponding transmission standard)
TV anytime	• Broadcast (DTTB) • Hybrid broadcast-broadband • Broadband	• PVR/TV set • TV set *); tablet computer; smart phone • PC; tablet computer; smart phone
TV anywhere	• Broadcast (DTTB) • Broadcast (MTV) • Broadband	• TV set; car TV set; tablet computer; smart phone • Car TV set; tablet computer; smart phone • PC; tablet computer; smart phone
Interactivity	• Broadcast (DTTB) • Broadcast (MTV) • Hybrid broadcast-broadband • Broadband	• TV set (local interactivity) • Tablet computer; smart phone • TV set *); tablet computer; smart phone • PC; tablet computer; smart phone
		*) With Internet connection

3.3 Enhanced audio broadcasting

The service concepts in audio broadcasting follow similar patterns as in television broadcasting. However, the "anywhere" concept is much more developed in audio broadcasting. Reception of analogue audio broadcasting in FM and AM and DTAB takes place almost everywhere: with portable receivers or high-end audio-sets in every room in the house, with car radios while driving, outside and in public places with small pocket radios and mobile phones and in waiting rooms and shopping centres by means of central audio installations.

Streaming via the Internet is becoming a very important means of delivery. Thousands of radio stations from all over the world can be received in good quality with radio receivers equipped with Internet access, or with mobile phones and computers.

Interactivity and hybrid broadcast-broadband (HBB) is also developing in audio broadcasting. HBB radio receivers with a screen for displaying additional personalised information appear on the market.

RadioDNS (Domain Name Service) is an initiative to help broadcasters to offer HBB services with the aim that the listener is unaware that the linear broadcasting services and the personalised broadband services are combined. This is achieved by making use of existing identifiers of the radio station used with, e.g. FM-RDS, DAB, DRM or IBOC and to locate the IP delivered services of that station[12].

A summary of the enhanced audio broadcasting concepts is shown on Table 3.2.

Table 3.2: Summary of enhanced audio broadcasting concepts

Enhanced broadcasting	Delivery	Terminal devices (must be equipped to receive the corresponding transmission standard)
Radio anytime	• Broadcast (DTAB) • Hybrid broadcast-broadband • Broadband (broadcaster's website)	• PVR/ audio set • Radio set*); tablet computer; smart phone • PC; tablet computer; smart phone
Radio anywhere	• Broadcast (AM/FM) • Broadcast (DTAB) • Broadcast (MTV) • Broadband	• Any radio set: Hifi audio set, portable radio, car radio, tablet computer, smart phone, simple mobile phone • Any radio set • Car radio; tablet computer; smart phone • PC; tablet computer; smart phone
Interactivity	• Broadcast (FM) • Broadcast (DTAB) • Broadcast (MTV) • Hybrid broadcast-broadband • Broadband	• FM radio with RDS (local interactivity) • Radio set (local interactivity) • Car radio; tablet computer; smart phone • Radio set*); tablet computer; smart phone • PC; tablet computer; smart phone
		*) With Internet connection

3.4 Broadcast and broadband delivery

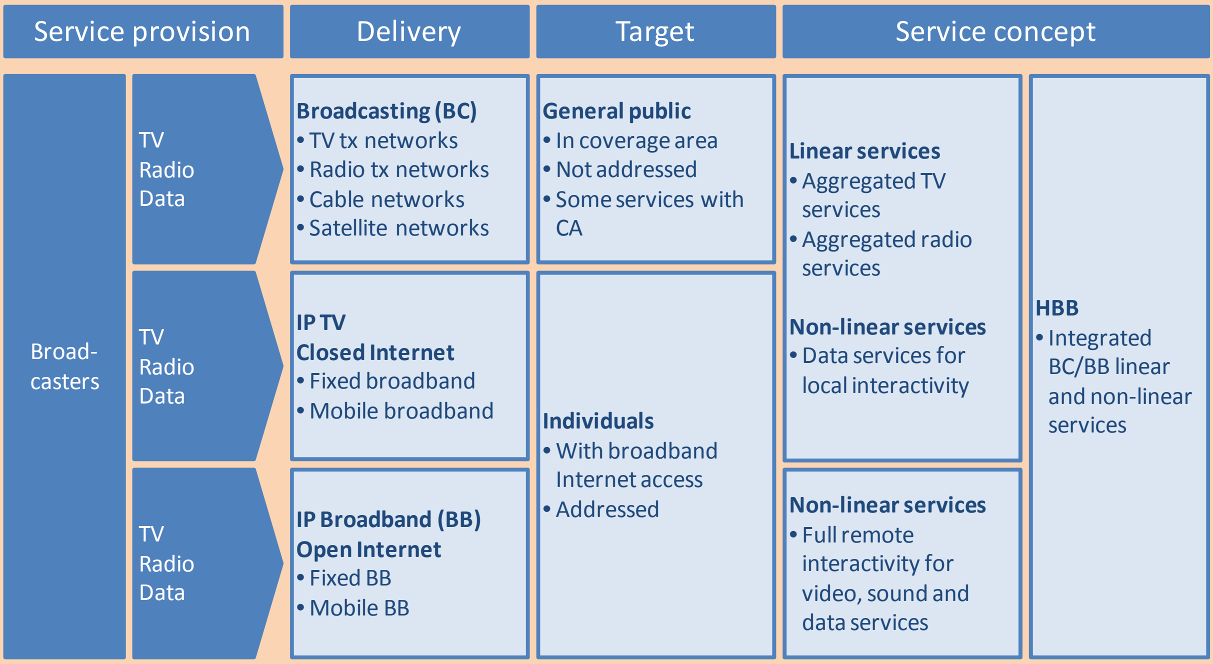
It is expected that linear broadcasting services aimed at reception by the general public in a country or region will be enhanced with individualized services delivered by fixed (including domestic distribution by WLAN) and mobile networks. When broadband connections are available to a large part of the population, broadband will not only be the main means of delivery for individual non-linear broadcasting, but could also deliver linear broadcasting to the general public.

The relative importance of broadcasting and broadband delivery will be different from country to country depending on the market conditions and the regulatory situation. It may also be different for audio broadcasting and television services.

Figure 3.2 shows in a matrix the position of broadcast (BC) and broadband (BB) delivery with regard to the linear and non-linear broadcasting services.

[12] More information can be found in EBU Tech Review 2010 RadioDNS — the hybridisation of Radio; 17 March 2010.

Figure 3.2: Position of broadcast (BC) and broadband (BB) delivery



Source: ITU

The importance of broadband delivery is expected to increase and will enable integrated hybrid broadcast-broadband (HBB) services. It is not expected that broadband will replace broadcast as the main means of delivery for linear broadcasting to the general public, but it cannot be excluded on the long term[13]. It will depend on national market conditions and regulatory situation.

4 Television broadcast technology

4.1 General

As indicated in Section 2, one of the main developments in terrestrial broadcasting is the continuing evolution of digital broadcast technology, resulting in a considerable increase of the capacity in the transmitted bandwidth and enabling more services, better picture quality and improved coverage.

There are two main directions of these developments:

1. increased picture quality by means of HDTV, 3DTV and Ultra-HDTV (Section 4.2);
2. more efficient compression and transmission systems (Section 4.3).

It is expected that by 2020 most countries have completed the switch-over to digital television. In many countries the objectives for digital switch-over include more services, extended coverage and better picture quality including HDTV. The challenge to accommodate more services of higher quality in limited amount of spectrum is described in Section 4.4.

[13] In EBU Technical Report 013 The future of Terrestrial Broadcasting; Geneva November 2011, three scenarios are described for the future of terrestrial broadcasting. The scenarios are called: expansion, reduction and phase out.

4.2 HDTV and beyond

Broadcasters in many countries are distributing HDTV services; others are preparing for it, or have included HDTV production and transmission in their future plans. In the meantime, technical developments take place to improve picture quality beyond the quality that is currently achieved with HDTV.

The demand for HD services is to a great extent driven by the growing number of households with flat panel displays, able to present HD. It is expected that in future all television services will be in HD.

Developments on the television presentation formats are taking place in three areas:

1. Improved HDTV (1080p/50 or 60);
2. Stereoscopic 3DTV;
3. Ultra High Definition Television.

The developments concentrate currently on standards for programme production and programme exchange. Broadcast delivery of these systems are expected. These developments are described below.

Improved HDTV

In principle HDTV production should be performed at the highest quality, in order to avoid artefacts and leave room for processing of the signal without quality degradation at delivery. Until recently the highest quality HDTV for production was a horizontal resolution of 1920 bits and a vertical resolution of 1080 lines, using progressive scanning (p) with the half of the frame frequency, 25 Hz or 30 Hz. This is termed as 1080p/25 or 1080p/30. After compression, coding and modulation the HDTV services are broadcast in 1080i/25 (i stands for interlaced) or 720p/50, respective 1080i/30 and 720p/60[14]. It should be noted that broadcasting in 720p is 10 to 20 per cent (depending on type of content) more efficient in transmission capacity than in 1080i, while giving a comparable picture quality[15]. These formats are considered sufficient for display sizes up to about 50 inch.

An improved scanning format is now available: 1080p/50[16] or 1080p/60. Professional and consumer equipment for production of HDTV with this format is already on the market. It is expected that many broadcasters will use 1080p/50-60 for production and contribution.

Distribution in 1080p/50-60 lays further ahead, but is in principle possible in existing DTTB networks. The HDTV format 1080p/50 does not require a higher data rate than 1080i/25, while a considerably better picture quality is achieved using large screens[17]. Compared to 720p/50 a 15 to 20 per cent higher data rate would be needed.

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[14] More information can be found in EBU Technical Report 005 Information Paper on HDTV Formats; Geneva, February 2010.

[15] See EBU Recommendation R124, Choice of HDTV Compression Algorithm and Bitrate for Acquisition, Production & Distribution; Geneva, December 2008.

[16] More information can be found in EBU Technical Report 014 What follows HDTV, a status report on 1080p/50 and '4k'; Geneva, June 2012.

[17] See Section 3.1.2 of EBU Technical Report 014 What follows HDTV, a status report on 1080p/50 and '4k'; Geneva; June 2012.

Modern large screens can normally display 1080p/50 or 1080p/60 images, but a new set-top-box would be needed to decode the signal. A solution with a combined 1080p/50-60 and 720p/50-60 or 1980i/50-60 signal is possible giving backwards compatibility, but at the cost of 20 to 30 per cent additional capacity[18].

As HDTV 1080p/50-60 distribution would in particular be directed towards screens of more than 50 inch, it seems, for the time being, a niche market. The service may better fit in the "long tail" as a service on demand by viewers that possess the appropriate set-top-box or integrated TV set.

3DTV

With 3DTV, images are displayed that are filtered for perception by the left and the right eye. Two methods exist that accomplish the stereoscopic effect:

1. Near the viewers' eyes, by means of a binocular optical device (3D glasses/spectacles);
2. At the screen, by the light source directing the images into the viewers' left and right eye. In this method no glasses are required.

For watching 3DTV in most cases 3D glasses are needed (first method). However, there are also 3DTV sets in which the second method is applied. It is not expected that eventually 3DTV will replace the usual two-dimensional television; 3DTV will be used for specific programmes. Currently a limited number of broadcasters provide 3DTV services and it is not expected that by the end of the decade 3DTV will form a substantial part of the service bouquet of most broadcasters.

It should be noted that watching 3DTV may cause eye discomfort and headache with some viewers.

Recently a number of Draft New Recommendations on 3DTV has been agreed in ITU-R, dealing with:

- Performance requirements and criteria that should be used worldwide for the production, international exchange and broadcasting of stereoscopic 3DTV, including references to some of the production requirements necessary to achieve a comfortable, high quality 3DTV viewing experience[19];
- The digital image systems that should be used worldwide for the production and international exchange of stereoscopic 1280 × 720 3DTV programmes for broadcasting[20].
- Methodologies for the assessment of stereoscopic 3DTV systems including general test methods, the grading scales and the viewing conditions[21].

Systems for 3DTV have a certain degree of backward interoperability with existing HD services. In this way 3DTV programmes can be watched as a 2D service on a HDTV screen.

As with HDTV in 1080p/50-60 format, distribution of 3DTV seems for the time being a niche market. The service may better fit in the "long tail" as a service on demand by viewers that possess the appropriate set-top-box or integrated TV set.

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[18] See Section 3.1.2 of EBU Technical Report 014 What follows HDTV, a status report on 1080p/50 and '4k'; Geneva; June 2012.

[19] Draft New Recommendation ITU-R BT.[3DTV-REQS] Performance requirements for the production, international exchange and broadcasting of 3DTV Programmes.

[20] Draft New Recommendation ITU-R BT.[3D-VID_2] 1280 × 720 digital image systems for the production and international exchange of 3DTV programs for broadcasting.

[21] Draft New Recommendation ITU-R BT.[3DTV SUBMETH] Subjective methods for the assessment of stereoscopic 3DTV systems.

UHDTV

Ultra High Definition television (UHDTV) aims at providing viewers at home and in public places with an enhanced visual experience by means of a wide viewing angle of up to 100 degrees, while with HDTV the viewing angle is no more than 30 degrees. UHDTV also has an improved colour and audio representation.

Two image formats have been specified with UHDTV:

- UHDTV1 with 3840 x 2160 pixels (also referred to as the 4k system);
- UHDTV2 with 7689 x 4320 pixels (also referred to as the 8k system).

The very high resolution (about 8 megapixels at UHDTV1 and about 32 megapixels at UHDTV2) gives viewers a spectacular viewing experience. For comparison: current HDTV broadcasts have a resolution of 1 to 2 megapixels. UHDTV is considered as the next big quality step, comparable with the experience in changing from SDTV to HDTV.

Recently a draft new Recommendation has been proposed in ITU-R[22]. This Recommendation specifies UHDTV image system parameters for production and international programme exchange.

The first UHDTV implementations are expected in China and Japan in the coming years. UHDTV trials were carried out by the BBC during the London Olympics in the summer of 2012, and transmitted to cinema-size screens in London, Glasgow, Bradford and venues in Tokyo, Fukushima and Washington DC.

UHDTV broadcasting via terrestrial digital television networks is not expected in the near future. The capacity requirements (8 Megapixels with UHDTV1) are such that with current technology (DVB-T2 with MPEG4 compression) one UHDTV service can be transmitted in the Transport Stream. More efficient compression and transmission systems would be needed before large scale UHDTV broadcasting will be a reality.

Summary of HD developments

A summary of HD developments is shown on Table 4.1

Table 4.1: Summary of HD developments

System	Production format	Picture resolution (megapixel)	Viewing distance (relative to picture height)[23]	Delivery options
HDTV	1920 x 1080	≈ 2	3 times	Broadcast incl. DTTB, Broadband
UHDTV1	3840 x 160	≈ 8	1.5 times	Not yet, improved compression system required
UHDTV2	7689 x 4320	≈ 32	0.75 times	Not yet, improved compression system required

4.3 More efficient television broadcasting systems

Since the developments in digital television started in the early 1990s, a number of DTTB transmission standards have been adopted. DTTB transmission systems can be divided in first generation systems and

[22] Draft New Recommendation ITU-R BT. [IMAGE-UHDTV] Parameter values for UHDTV systems for production and international programme exchange.

[23] Recommendation ITU-R BT. 1769 - Parameter values for an expanded hierarchy of LSDI image formats for production and international programme exchange. www.itu.int/dms_pubrec/itu-r/rec/bt/R-REC-BT.1769-0-200607-I!!PDF-E.pdf (Appendix 2)

the more efficient second generation systems. Section 4.3.2 describes the developments of these systems.

The DTTB systems allow reception with fixed, portable or mobile receiving installations. Some of the systems have special features to optimize reception to handheld receiving devices, such as smart phones. There are also dedicated systems for reception with handheld devices. Broadcasting to handheld devices is sometimes referred to as Mobile Television (MTV). Section 4.3.3 describes the MTV developments.

All standards make use of the compression system MPEG2 or its successor, the more efficient MPEG4. A new even more efficient compression system is under development, this system is called High Efficiency Video Codec (HEVC). Section 4.3.1 describes the developments of video compression systems.

4.3.1 Compression systems

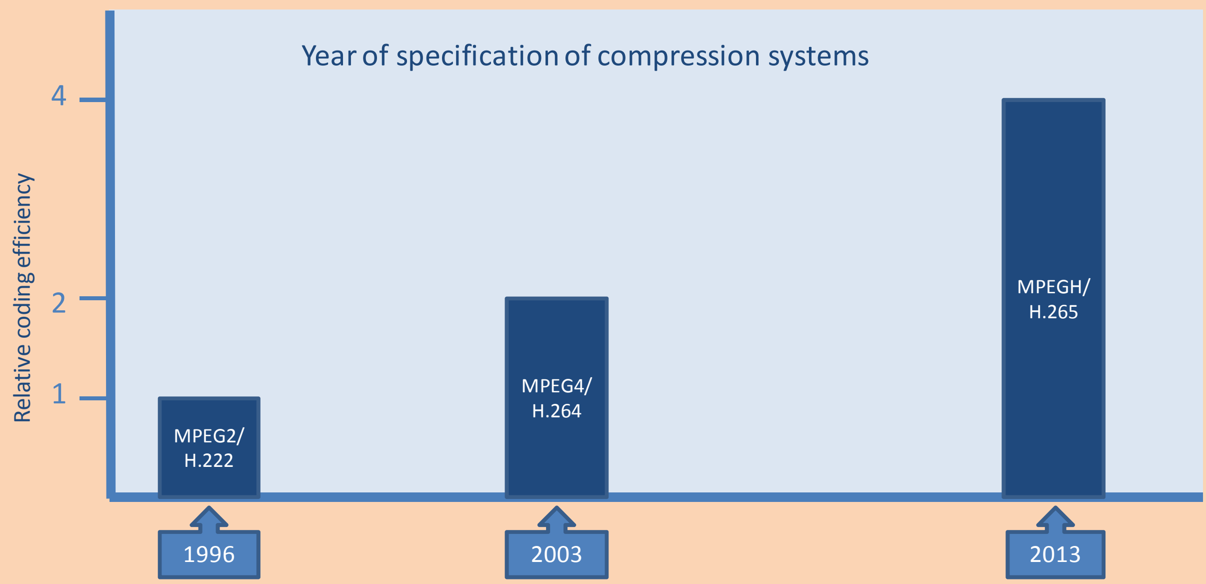
The first DTTB implementations used MPEG2, also referred to as ITU-T H.222, as video compression system. MPEG2 has been succeeded by MPEG4, also referred to as MPEG-AVC, MPEG-4 part 10 and ITU-T H.264. MPEG4 has been implemented in many countries and the technology is considered to be mature. MPEG4 is about two times more efficient than MPEG2.

Standardization of a third generation video compression system is nearing completion. This new video compression standard, called High Efficiency Video Coding (HEVC), is being jointly developed by ISO/IEC MPEG and ITU-T VCEG. These two standardization bodies also developed MPEG2/H.222 and MPEG4/H.264. The new compression standard aims at a factor two improvement in compression efficiency compared to the MPEG4/H.264.

Completion of the new HEVC standard is planned by January 2013. It is then intended to be published by ISO/IEC as MPEG-H and by ITU-T as H.265. The first services using HEVC/MPEG-H/H.265 may be launched in 2015. HEVC may give the opportunity to broadcast UHDTV.

Figure 4.1 summarise the developments of compression system by showing the year of specification of the systems and the relative coding efficiency relative MPEG2.

Figure 4.1: Compression system developments



Source: ITU

It should be noted that new generation compression systems are not backwards compatible with the former generations of systems. Therefore existing set-top-boxes have to be replaced when a new generation system is introduced. Existing integrated digital TV receivers will need a set-top-box with the new system. Receivers with the improved system can normally receive the old system as well. It is likely that a transition period will be needed to avoid service interruptions.

4.3.2 First and second generation DTTB systems and beyond

Television broadcasting systems are divided in first and second generation systems. The first generation systems are described in Recommendation ITU-R BT.1306[24]. These systems can be divided in single carrier and multicarrier systems. All systems can be used in 6, 7 and 8 MHz channel arrangements.

The main distinctive features are:

- Single carrier standards provide a higher bit rate at given C/N in a Gaussian channel[25].
- Multi-carrier standards provide maximum ruggedness against multipath interference. This is important in case of reception with simple antennas; a means of reception commonly used in many countries. Furthermore multi-carrier standards allow the use of single frequency networks.

Recommendation ITU-R BT.1877[26] describes second generation television broadcasting systems. These systems offer a higher data rate capacity per Hertz and better power efficiency in comparison to first generation systems. Currently one second generation system is recommended: DVB-T2. Other second generation systems are being developed, for instance ATSC 2.0, which is expected to be completed by the end of 2012.

Table 4.2 shows an overview of first and second generation standards currently recommended by ITU.

Table 4.2: First and second generation DTTB systems

Standard	ITU-R Recommendation	Technology	Payload in an 8 MHz channel
ATSC	Rec. BT.1306-6 System A	Single carrier	6.0-27.5 Mbit/s
DVB-T	Rec. BT.1306-6 System B	Multi-carrier (OFDM)	5.0-31.7 Mbit/s
ISDB-T	Rec. BT.1306-6 System C	Multi-carrier (segmented OFDM)	4.9-31.0 Mbit/s
DTMB	Rec. BT.1306-6 System D	Single carrier or multi-carrier (OFDM)	4.8-32.5 Mbit/s
DVB-T2*	Rec. BT.1877	Multi-carrier (OFDM)	5.4-50.4 Mbit/s

** Second generation standard.*

Information on protection ratios regarding all standards, including protection ratios of one standard interfered by another is shown in Recommendation ITU-R BT.1368[27]. Work is in progress on a new ITU

[24] Recommendation ITU-R BT.1306-6 Error-correction, data framing, modulation and emission methods for digital terrestrial television broadcasting.

[25] A Gaussian channel is a propagation mode when only the wanted signal with no delayed signals is present at the receiver input, but taking into account the Gaussian noise only.

[26] Recommendation ITU-R BT.1877 Error-correction, data framing, modulation and emission methods for second generation of digital terrestrial television broadcasting systems.

[27] Recommendation ITU-R BT.1368-9 Planning criteria, including protection ratios, for digital terrestrial television services in the VHF/UHF bands.

Recommendation regarding planning criteria for second generation DTTB standards. However, a detailed description of the technical features of the standard and information on frequency and network planning is given in a Draft New Report[28].

All first and second generation systems are flexible in their application. By choosing the appropriate system variant, the payload (net data rate of the multiplex) and the C/N value (determining the power of the transmitter for a given coverage area) can be varied. As indicated in Section 4.4, a trade-off needs to be made between transmitter power, multiplex capacity and coverage area. This applies to both first and second generation systems; however the ranges with second generation systems are much larger.

With a given transmitter power and a given coverage area, the payload of a DTTB transmission using a second generation system is larger than with a first generation system. For instance in the application in the UK the payload increased from 24 Mbit/s with DVB-T to 40 Mbit/s with DVB-T2, while transmitter power and coverage area remained the same.

Alternatively, with a given transmitter power and a given payload, the coverage area of a 2nd generation DTTB transmission is larger. Instead of a larger coverage area, the higher efficiency can also be used in reducing the power of the transmitter, while keeping the coverage area the same.

Implementation of the second generation systems are in particular of interest in situations where a need exists to:

- broadcast a high data rate, e.g. for HDTV services or a great number of SDTV services and the available spectrum is limited;
- reduce transmitter powers as much as possible.

In November 2011 the Future of Broadcast Television (FOBTV)[29] initiative was started with the aim to collaborate towards the development of a single global DTTB standard. The goals of FOBTV are:

a. develop future ecosystem models for terrestrial broadcasting taking into account business, regulatory and technical environments;
b. develop requirements for next generation terrestrial broadcast systems;
c. foster collaboration of DTV development laboratories;
d. recommend major technologies to be used as the basis for new standards;
e. request standardization of selected technologies (layers) by appropriate standards development organizations (ATSC, DVB, ARIB, TTA, etc.).

FOBTV expects that within five years a new standard could emerge.

4.3.3 MTV systems

MTV networks provide multimedia broadcasting services for handheld receiving devices, using a dedicated MTV transmission standard, or a decided part of the DTTB transmission. Examples of dedicated MTV standards are DVB-H, DVB-NGH (an improved version of DVB-H), DVB-SH, T-DMB, MediaFlo and ATSC-M/H. DTTB standards offering the possibilities for a mobile service within the DTTB multiplex are:

[28] Draft New Report ITU-R BT.[DVBT2PLAN] Frequency and network planning aspects of DVB-T2 (See input document 6/43 of ITU Study Group 6). This report provides guidance on frequency and network planning of DVB-T2. It has been developed by EBU Members involved in planning of DVB-T2 networks. It is intended to help broadcast network operators in their planning and Administrations in defining the most suitable set of parameters from the large possibilities offered by the DVB-T2 system.

[29] Future of Broadcast Terrestrial Television Initiative Memorandum of Understanding; see also www.fobtv.org

- ISDB-T, with the option to use 1 RF segment (of the 13 segments in the multiplex) with a rugged modulation and code rate for MTV services;
- DVB-T2, with the option to use one the physical layer pipes with a rugged modulation and code rate for MTV services. DVB-T2-Lite contains a subset of the DVB-T2 specifications and some extensions and is meant for implementation in handheld receiving devices.

Recommendation ITU-R BT.1833 [30] describes user requirements of MTV systems and system characteristics related to the user requirements of eight of MTV systems. The draft revision to this recommendation describes a ninth system. In Recommendation ITU-R BT.2016[31] a number of systems are recommended for introduction of multimedia broadcasting for mobile reception using handheld receivers. An overview of the systems is given in Table 4.3.

Table 4.3: MTV systems

Standard	ITU-R Recommendation	Characteristic
T-DMB	Rec. BT 1833 System A Rec. BT.2016 System A	Terrestrial multimedia services based on the T-DAB system
AT-DMB	Rec. BT.2016 System A	Enhanced version of T-DMB, two times more efficient, backward compatible
ATSC-M/H	Rec. BT 1833 System B	Terrestrial multimedia services; enhancement of the ATCS system
ISDB-T 1seg	Rec. BT.1833 System C	Terrestrial multimedia services; part of ISDB-T multiplex
-	Rec. BT.1833 System E	Terrestrial component to satellite multimedia services in 2.6 GHz band. Satellite system known as system E in Recommendation ITU-R BO.1130[32]
ISDB-T	Rec. BT.1833 System F Rec. BT.2016 System F	Terrestrial multimedia services
DVB-H	Rec. BT.1833 System H	Terrestrial multimedia services; enhancement of the DVB-T system
DVB-SH	Rec. BT.1833 System I Rec. BT.2016 System I	Terrestrial component to satellite multimedia services 2.2 GHz.
MediaFLo	Rec. BT.1833 System M	Terrestrial multimedia services
DVB-T2-lite	Draft revision Rec. BT.1833-1 System T2	Terrestrial multimedia services based on the DVB-T2 system

Another system, currently not described in ITU recommendations, is called RAVIS (Real-time AudioVisual Information System)[33]. RAVIS is a digital terrestrial broadcasting system for use in the VHF broadcasting bands I and II with a channel bandwidth of 100, 200 or 250 kHz. The system is intended to deliver audio, video and multimedia services for fixed, mobile and portable reception. The system has been tested in Russia.

[30] Recommendation ITU-R BT.1833-1 Broadcasting of multimedia and data applications for mobile reception by handheld receivers.

[31] Recommendation ITU-R BT.2016 Error-correction, data framing, modulation and emission methods for terrestrial multimedia broadcasting for mobile reception using handheld receivers in VHF/UHF bands.

[32] Recommendation ITU-R BO.1130-4 Systems for digital satellite broadcasting to vehicular, portable and fixed receivers in the bands allocated to BSS (sound) in the frequency range 1 400-2 700 MHz.

[33] Section 2.8 and Annex 5 of Report ITU-R 2049-5 Broadcasting of multimedia and data applications for mobile reception.

The international market prospective of MTV is variable. MTV services are successfully implemented in Korea and Japan using the T-DMB and ISDB-T 1-seg standard respectively. However, in Europe a number of countries started MTV services using the DVB-H standard. Due to limited market take up, these DVB-H services were stopped or will stop soon. Also in the USA MTV transmissions using MediaFlo were stopped. However, multimedia services via Mobile communication networks (3G and 4G) show very high growth figures (Figure 2.2).

4.4 More, better and larger coverage of services

In many countries the objectives for digital switch-over include more services, extended coverage and better picture quality including HDTV. It is often a challenge to accommodate more services of higher quality in a limited amount of spectrum.

In network planning, the network and station characteristics have to be chosen on the basis of the service proposition (including the number and type of services) and business plan and within the limitations of available budget, spectrum regulations and adopted technology.

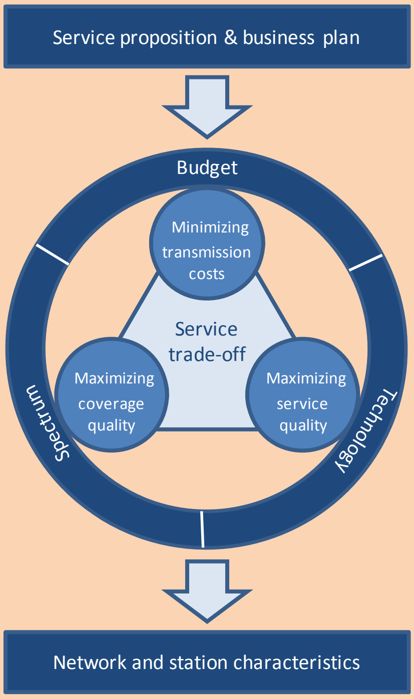
In making the choice a trade-off has to be made between[34]:

- transmission costs, which depend to a great extent on the number of transmitting stations and the radiation characteristics;
- service quality, the net data rate of the multiplex and the number of services in the multiplex determine the data rate per service and consequently picture and sound quality;
- coverage quality depending on the kind of receiving installation (fixed, portable, mobile or handheld) for which the service is planned and the required probability for reception of the service.

The trade-off is illustrated in Figure 4.2.

[34] Chapter 4.3 of the ITU Guidelines for the transition from analogue to digital broadcasting gives information and guidance regarding network planning for digital terrestrial television. www.itu.int/dms_pub/itu-d/opb/hdb/D-HDB-GUIDELINES.01-2010-R1-PDF-E.pdf

Figure 4.2: Service trade-off



Source: ITU

The choice of the network and station characteristics following from the service trade-off (inner triangle in Figure 4.2) will need review if the service proposition or business plan changes, or if the conditions in the outer ring of Figure 4.2 are changing. For instance if spectrum regulation changes or if new technology standards become available a new service trade-off has to made performed which may result in modifications to the network.

As indicated in Section 2, at WRC-12 it was decided to allocate in all three Regions, in addition to broadcasting, mobile services (IMT) in the frequency range 698-862MHz. In particular in Region 1 and 3 it may therefore be necessary to carry out frequency planning activities and reconsider the technology choices in order to accommodate operational and planned TV broadcasting stations in a reduced frequency band.

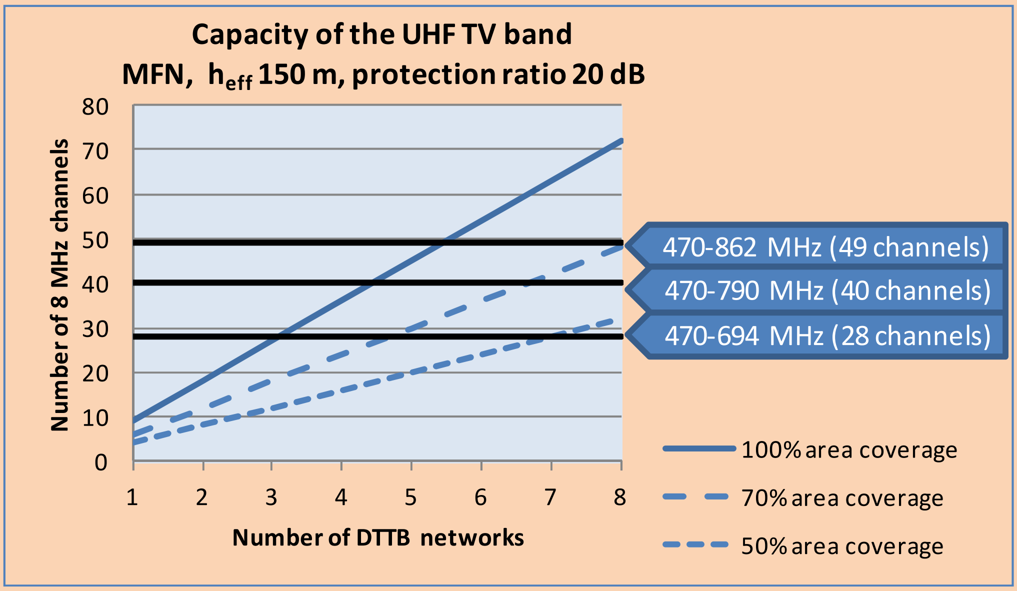
In Figure 4.3 an example is given of the number of multi frequency networks (MFN) with national coverage that can theoretically be accommodated in the UHF TV band in an 8 MHz channelling arrangement. In this example the transmitting antennas have an effective antenna height of 150m. Three curves are shown, a curve to achieve complete (100 per cent) geographical coverage and a curve to achieve 70 per cent and 50 per cent geographical coverage. The curves are based on the results of theoretical studies carried out in the EBU[35].

If the frequency band is reduced from 862 MHz to 694 MHz and the number of networks and transmitters is maintained, the coverage reduces considerably (in the example of Figure 4.3 from 100 per cent to less than 70 per cent). The reduction of the frequency band can be compensated by reducing the number of networks and applying compression and transmission systems with higher efficiency. In the example of Figure 4.3 the degree of coverage is maintained if the number of networks is reduced from 5 to 3 in case

[35] EBU – BPN 038 Report from ad-hoc group B/CAI-FM24 to B/MDT and FM PT24 on spectrum requirements for DVB-T implementation, March 2001.

of 100 per cent area coverage and from 8 to 5 in case of 70 per cent area coverage; resulting reduction about 40 per cent. The use of a second generation DTTB transmission system would in the example increase the payload of a multiplex from 24 Mbit/s to 40 Mbit/s, an increase of 40 per cent, hence reduction of band capacity has been compensated, while the coverage has been maintained.

Figure 4.3: Number of MFNs with effective antenna heights of 150m to achieve national coverage (based on EBU Report BPN 038)



Source: ITU

The estimations shown in Figure 4.3 give an indication of the capacity of the UHF TV band under various assumptions based on theoretical calculations for MFNs with effective antenna heights of 150m. In practice the capacity may differ. The results of the EBU studies also indicate that in general more efficient use of the spectrum (higher band capacity) is made with:

1. larger coverage areas (high antenna heights in MFNs, large area SFNs), compared to smaller coverage areas;
2. fixed reception (directional antenna on the top of the roof) compared to portable reception;
3. SFN compared to MFN.

A further increase in capacity of the frequency is needed when HDTV is introduced. It is often indicated that a package of 20 to 30 services is needed for an attractive DTTB offer. Some countries require more services in particular in main cities. For examples, to transmit 30 HDTV services, six transmitters per site using MPEG4 and DVB-T2 may be needed. From the examples above it is clear that in order to be prepared for the HD future the most spectrum efficient transmission standard and the most spectrum efficient network architecture principles should be chosen.

The implementation of different network architecture and a different (second generation) transmission system will affect the viewer, because the antenna installation may need to be adapted and a new set-top-box has to be bought and installed. A second transition period (after the first transition period from analogue to digital television) may be required. Similar aspects as with the first transition have to be addressed, including:

- simulcasting of the old and new system;
- re-engineering of transmitter sites;
- communication campaigns to the public.

5 Audio broadcasting technology

5.1 General

A number of DTAB systems have been specified for different frequency bands and different transmission capacities. Some systems can be used in combination with an analogue system on the same channel, others only in digital mode. The choice of a system depends very much on the service requirements and the available frequency bands. It could happen that more than one system will be in operation in the same country. The availability of multi-standard receivers is therefore an important condition for the development of digital audio broadcasting.

Section 5.2 gives an overview of the digital audio broadcasting systems. Considerations on the application of systems are given in Section 5.3.

5.2 Digital audio broadcasting systems

DTAB systems are divided by frequency range. Systems recommended for use between 30 and 3000 MHz are described in Recommendation ITU-R BS.1114[36] and systems recommended for use below 30 MHz are described in Recommendation ITU-R BS.1514-2[37].

An overview of the standards currently recommended by ITU is shown in Table 5.1.

Table 5.1: Digital audio broadcasting systems in VHF and UHF

Standard	ITU-R Recommendation	Audio compression	Transmission technology	RF bandwidth	Frequency range	Note
DAB	Rec. BS.1114-7; System A	MPEG-layer II	Multi-carrier (OFDM)	1.5 MHz	Band III 1.5 GHz	
DAB+	Rec. BS.1114-7; System A	HE-AAC	Multi-carrier (OFDM)	1.5 MHz	Band III 1.5 GHz	
ISDB-TSB	Rec. BT.1114-7; System F	MPEG Layer II Dolby AC-3 and HE-AAC	Multi-carrier (segmented OFDM)	0.5 MHz or 1.5 MHz	Band III 2.6 GHz	1
IBOC	Rec. BT.1114-7; System C	HD-codec	Multi-carrier (OFDM)	400 kHz	Band II	2
IBOC	Rec. BT.1514-2	HE-AAC	Multi-carrier (OFDM)	20 or 30 kHz	MF	2
DRM30	Rec. BT.1514-2	HE-AAC	Multi-carrier (OFDM)	9 or 10 kHz and multiples	LF/MF/HF	3
DRM+	Rec. BT.1114-7 System G	HE-AAC	Multi-carrier (OFDM)	100 kHz	Band I Band II Band III	3

[36] Recommendation ITU-R BS.1114-7 Systems for terrestrial digital audio broadcasting to vehicular, portable and fixed receivers in the frequency range 30-3 000 MHz.

[37] Recommendation ITU-R BS.1514-2 System for digital audio broadcasting in the broadcasting bands below 30 MHz.

Notes to the table:

1. ISDB-TSB can be used either as a single transmission with a bandwidth of about 0.5 MHz or 1.5 MHz or as part of a full channel ISDB-T transmission in a 6, 7 or 8 MHz channel.
2. IBOC can be used either in combination with an analogue signal in the same channel or OFDM only, in the LF/MF bands the bandwidth is 30 kHz in the hybrid AM-OFDM mode and 20 kHz in all OFDM mode.
3. DRM30 and DRM+ in can be used either in combination with an analogue signal in the same channel, or OFDM only.

The audio compression system MPEG4 HE-AAC (version 2) (High Efficiency - Advanced Audio Coding) was standardized in 2006. Together with other coding techniques such a spectrum band replication (SBR) a considerable improvement in the efficiency of the audio coding has been achieved. The WorldDMB consortium indicates that with DAB+ (using HE-AAC and SBR) about 40 kbit/s is needed for good quality audio, comparable to 128 kbit/s with DAB, using MPEG layer II audio compression[38]. A DAB+ multiplex could contain e.g. 28 services at 40 kbit/s plus 1 at 32 kbit/s compared to a DAB multiplex with nine services at 128 kbit/s. It is expected that countries introducing DAB now, will implement DAB+ with HE-AACv2. Eventually all DAB transmissions will be using HE-AACv2. However, HE-AACv2 is not compatible with MPEG layer II compression and new receivers will be needed if the change is made to HE-AACv2. A transition period with (costly and frequency spectrum demanding) simulcasting of DAB and DAB+ may therefore be necessary.

It should be noted that not in all the frequency ranges indicated in Table 5.1 digital audio broadcasting systems are implemented in practice and not for all combinations of systems and frequency bands planning parameters are recommended by ITU. Information on planning parameters including protection ratios and minimum field strength values are shown in Recommendation ITU-R BT.1615[39] for frequencies below 30 MHz and in Recommendation ITU-R BT.1660[40] for the VHF band.

Table 5.2 shows which systems and frequency bands planning parameters are given by these recommendations. The white blocks in the table indicate frequency bands for which the related system is not recommended according to Recommendations ITU-R BT.1114-7 and BT.1514-2 (see Table 5.1). Indication "-" means that, although the system is recommended for use in the indicated frequency band, no planning parameters are described in Recommendation ITU-R BT.1615 or BT.1660.

Table 5.2: Systems and frequency band with recommended planning parameters

System	LF	MF	HF	VHF (Band I)	VHF (Band II)	VHF (Band III)	UHF 1.5 GHz range	UHF 2.6 GHz range
DAB (+)						BT.1660-5	-	
ISDB-TSB					BT.1660-5	BT.1660-5		-
IBOC		BT.1615-1			-			
DRM30	BT.1615-1	BT.1615-1	BT.1615-1					
DRM+				BT.1660-5	BT.1660-5	BT.1660-5		

[38] WorldDMB report DAB+; The additional audio coding in DAB, March 2008.

[39] Recommendation ITU-R BT.1615-1 "Planning parameters" for digital sound broadcasting at frequencies below 30 MHz.

[40] Recommendation ITU-R BT.1660-5 Technical basis for planning of terrestrial digital sound broadcasting in the VHF band.

Table 5.3 gives an overview of the ITU agreements in the frequency bands indicated in Table 5.1 and 5.2 and an indication if the related systems are permitted under the relevant agreements.

Table 5.3: Applicability of digital audio broadcasting systems under ITU agreements

Frequency band	Agreement	Area	Application of digital systems under the current Agreements	Note
LF/MF	GE75	Region 1 and 3	• DRM30 with a nominal bandwidth of 9 kHz permitted, provided the radiation is reduced by at least 7 dB in all directions, compared to the radiation of the AM modulated frequency assignment in the Plan**;** • IBOC not permitted without revision of the Agreement.	1
MF	RJ81	Region 2	• DRM30 not permitted without revision of the Agreement; • IBOC not permitted without revision of the Agreement.	1
MF (1605 – 1705 kHz)	RJ88	Region 2	• DRM30 with a nominal bandwidth of 10 kHz permitted if conditions in No. 3.2 of Annex 2 to the RJ88 Agreement are satisfied; • IBOC not permitted without revision of the Agreement.	1
HF	Radio Regulation Article 12	All regions	• Permitted under the condition of Radio • Regulations Resolution 517 (rev. WRC-07).	2
Band I	RRC-06-Rev ST61	European Broadcasting Area	• DRM+ not permitted without revision of the Agreement; Agreement permits analogue TV only.	
Band I	RRC-06-Rev GE89	African Broadcasting Area	• DRM+ not permitted without revision of the Agreement; Agreement permits analogue TV only.	
Band II	GE84	Region 1 and part of Region 3	• DRM+ permitted provided that is does not cause more interference and does not require higher protection (Section 3.1 of Chapter 3 to Annex 2 of the GE84 Agreement); • ISDB-TSB not permitted; does not fit in channel arrangement; • IBOC not permitted; does not fit in channel arrangement.	3
Band III	GE06	Parts of Regions 1 and 3	• DAB and DAB+ permitted under T-DAB assignments or allotments; • ISDB-TSB (in full channel mode) permitted if the conditions of Article 5.1.3 of the GE06 Agreement are satisfied; • DRM+ permitted if the conditions of Article 5.1.3 of the GE06 Agreement are satisfied	
1.5 GHz range	No ITU plan	-	-	4
2.6 GHz range	No ITU plan	-	-	

Notes to the table:

1. See ITU Circular letter CCRR/20 of 6 September 2002 and Section 5.1 of Report ITU-R BS.2144[41].
2. In provision 5.134 of the Radio Regulations administrations are encouraged to use a number of HF broadcasting bands to facilitate the introduction of digitally modulated emissions in accordance with the provisions of Resolution 517 (Rev.WRC-07).
3. The ECC of the CEPT notes that there may be a need for some Rules of Procedure in relation to the GE-84 Agreement in order to take into account digital system parameters[42].
4. The MA02revCO07 provides the regional special arrangement within CEPT for the introduction of DAB and mobile multimedia broadcasting in the frequency range 1452 to 1479.5 MHz.

5.3 Application of digital audio broadcasting systems

The choice of a digital audio broadcasting system will depend on:

- the market requirements;
- the available frequency bands (ranging from about 150 kHz to 2.6 GHz);
- the capacity of the system;
- the propagation characteristics of the frequency band;
- receiver price and availability.

For example, in some countries digital audio broadcasting in the LF and MF range, using DRM30, is the only viable way to serve vast areas with low population density. Other countries prefer to use part of the band 174-230 MHz (Band III) after analogue television has been switched-off to cover large or small areas with a package of a high number of services of high technical quality using DAB or DAB+. Also the frequency range 47 to 68 MHz (Band I) could in principle be used for digital audio broadcasting using DRM+[43], but there is no regulatory framework in place and there are no implementations in practice.

The HF bands are mainly used for international broadcasting, making use of ionospheric propagation. The 26 MHz band is not much used for international broadcasting and could be used with DRM30 for local broadcasting with tropospheric propagation[44], but there are no implementations in practice.

In many countries the lower VFH broadcasting band (Band II) is intensively used for FM transmissions. In some areas the band is approaching its capacity limits. Introduction of digital broadcasting in this band (e.g. using DRM+ or IBOC) is in these situations impossible without affecting the existing services. The use of the upper VHF broadcasting band (Band III) for digital audio broadcasting is often preferred in this case.

Both DRM+ and IBOC have the possibility to transmit an analogue and a digital signal on the same channel. Care should be taken that the existing FM signal quality and coverage is not affected[45]. It should be noted that the channelling arrangements in a frequency band are not always the same in all regions. Therefore systems designed for a specific bandwidth and channel arrangement may not be applied

[41] Report ITU-R BS.2144 Planning parameters and coverage for Digital Radio Mondiale (DRM) broadcasting at frequencies below 30 MHz.

[42] Section 7.2.4 of ECC Report 177 Possibilities for Future Terrestrial Delivery of Audio Broadcasting Services; April 2012.

[43] Report ITU-R BS.2208 Possible use of VHF Band I for digital sound broadcasting services.

[44] Draft new report ITU-R BS.[DRM26local] Digital Radio Mondiale (DRM) in the 26 MHz band (25 670-26 100 kHz).

[45] See also Section 4.8 of REPORT ITU-R BS.2144 Planning parameters and coverage for Digital Radio Mondiale (DRM) broadcasting at frequencies below 30 MHz.

satisfactorily in countries with different channels arrangements due to unacceptable adjacent channel interference.

Originally in Europe it was envisaged to use Band II for DAB after the FM transmissions have been switched-off. There are no signs that the band will be vacated by FM transmissions in the foreseeable future. However, in principle it could be a long term option to use DAB in Band II.

Digital audio broadcasting in the upper UHF broadcasting bands (1.5 GHz with DAB and 2.6 GHz with ISDB-TSB) is also an option. In Europe a frequency plan has been agreed for use of DAB in the 1.5 GHz[46], but DAB implementation in this band is very limited. For that reason CEPT is currently reviewing the use of the 1.5 GHz range in Europe.

The systems for use in the lower frequency bands (e.g. DRM) have a lower capacity than the systems for use in the higher frequency ranges (e.g. DAB). Low capacity systems are sometimes more attractive to broadcasters than high capacity systems, for example to local broadcasters with only a few services, or to broadcasters not wishing to share a multiplex with many others because coverage requirements (or obligations) are different.

6 Conclusions

Two main developments in terrestrial broadcasting will determine the trends in audio and television broadcasting in the coming years:

1. The fast expansion of high capacity data networks, offering consumers broadband Internet access. The Internet will be an increasingly important means of delivery of audio-visual content, including broadcasting.
2. The continuing evolution of digital broadcast technology, resulting in a considerable increase of the capacity in the transmitted bandwidth and enabling more services, better picture quality and improved coverage.

A summary of the conclusions and main trends towards to end of the decade is given below.

Broadcasting by the end of the decade

a) Many countries in all regions will have completed the DSO process regarding their television services, or will be in an advanced stage in the process.

b) The number of digital audio broadcasting services, in particular via the Internet, will increase.

c) For cost reasons more analogue LF, MF and HF stations will be closed for which coverage is also provided by FM, digital audio broadcasting or via the Internet.

d) FM will remain an important means of delivery of audio broadcasting. In general switch-off of FM stations lies far ahead, but a few countries may have switched-off analogue radio.

e) Mobile networks will on average provide a data rate of more than 3 Mbit/s (sufficient for good quality pictures at not too large screen sizes) and mobile video will take more than 70 per cent of the total mobile data traffic. Together with fixed broadband Internet access, mobile networks will facilitate the development of broadcasting and multimedia services via the Internet to a large part of the population.

[46] The Maastricht 2002, Special Arrangement, as revised in Constanţa, 2007 (MA02revCO07).

Services concepts

a) Wide spread broadband Internet access (mobile, fixed including WLAN extensions) will have a great impact on broadcasting services:

- on the hand it is a competitive means to deliver radio and TV services compared to terrestrial, cable and satellite networks;
- on the other hand, it is a supportive means of delivery for offering enhanced radio and television services.

b) Interactive television services will be realized by hybrid broadcast-broadband (HBB) solutions; either by presentation of the requested information on the main TV screen and operation via the remote control of the TV-set, or by means of a second screen (e.g. tablet computer or smart phone).

c) The relative importance of broadcasting and broadband delivery will be different from country to country depending on the market conditions and the regulatory situation. It may also be different for audio broadcasting and television services. In all cases, it expected that HBB services, offering linear programmes intended for the general public together with individualized services, will be of great demand.

d) It is not expected that broadband will replace broadcast as main means of delivery for linear broadcasting to the general public, but it cannot be excluded on the very long term in some markets.

Audio broadcasting developments

a) Many countries will introduce digital audio broadcasting for national and regional coverage in parts of the frequency band 174-230 MHz (Band III), when vacated by analogue television. Countries with DAB assignments or allotments in the Geneva 2006 Agreement will use these as a basis.

b) In addition in many countries also digital audio broadcasting stations will be introduced in the LF, MF and HF bands in order to satisfy specific market requirements, such as coverage in low populated areas, international broadcasting and local broadcasting.

c) More than one digital audio broadcasting system in different frequency bands or in the same frequency band may be in operation in the same country in order to satisfy the various market requirements. The availability of multi-standard and multi-band receivers is therefore an important condition for the development of digital audio broadcasting.

d) An increasing number of digital audio broadcasting implementations will make use high efficiency source coding (e.g. DAB+). Eventually all transmissions with less efficient source coding will be replaced.

Television broadcasting development

a) In an increasing number of countries all TV services will be in HD quality.

b) Screen sizes will increase and for large screens (> 50 inch) the presentation format 1080p/50 or 60 may be implemented on some DTTB networks.

c) UHDTV will be implemented in some countries, with advanced compression systems. Implementation on DTTB networks is not expected.

d) A new, twice as efficient compression system called HEVC/MPEG-H/H.265 will be available. The system will have a two times higher coding efficiency than MPEG4. Initially it may be used with UHDTV services. It is also likely to be included in the specifications of DTTB standards.

e) Second generation transmission systems will be implemented in more and more countries to provide sufficient capacity on the DTTB networks in order to:

- deliver an attractive HDTV service package;
- compensate the reduction of the UHF TV band, due to the introduction on IMT services.

f) A single global new generation of standard, referred to as FOBTV, has been developed with the aim to achieve compatible DTTB standards worldwide.

g) The MTV market prospective is variable. Many systems exist, either as dedicated MTV system, or as part of a DTTB transmission. In addition, multimedia services via mobile communication networks (3G and 4G) show very high growth figures.

h) More services, with better picture quality (including HDTV) and better reception quality will be implemented on the terrestrial platform. In countries where the UHF TV band will be limited to 694 MHz, the following activities may take place:

- major frequency re-plannning to accommodate the transmission of the services into a reduce frequency band;
- application of second generation transmission standards;
- re-engineering of transmitting stations;
- organizing a transition period to allow viewers to buy new receivers;
- communication campaigns to inform the public about the required changes in receiving installations.

Annex

Glossary of abbreviations

1080i/25 or 30	HDTV with 1080 vertical lines, interlaced scanning and 25 or 30 fields per second
1080p/25 or 30	HDTV with 1080 vertical lines, progressive scanning and 25 or 30 fields per second
1080p/50 or 60	HDTV with 1080 vertical lines, progressive scanning and 50 or 60 fields per second
2D	Two dimensional
3DTV	Three dimensional television
3G	Third generation mobile communication networks
4G	Fourth generation mobile communication networks
720p/50 or 60	HDTV with 720 vertical lines, progressive scanning and 50 or 60 fields per second
AC-3	Dolby Digital Audio Codec
ADSL	Asymmetric Digital Subscriber Line
AM	Amplitude modulation
ARIB	Association of Radio Industries and Businesses in Japan
AT-DMB	Advanced Terrestrial Digital Multimedia Broadcasting (MTV standard)
ATSC	Advanced Television Systems Committee (DTTB standard)
ATSC-M/H	Advanced Television Systems Committee - Mobile/Handheld (MTV standard)
AVC	Advanced Video Coding
BB	Broadband
BBC	British Broadcasting Corporation
BC	Broadcasting
BML	Broadcast Markup Language (middleware standard)
C/N	Carrier to Noise ratio
CA	Conditional Access
CEPT	European Conference of Postal and Telecommunications Administrations
DAB	Digital Audio Broadcasting (digital audio broadcasting standard)
DAB+	Digital Audio Broadcasting, improved system (digital audio broadcasting standard)
dB	Decibel
DNS	Domain Name Service
DRM	Digital Radio Mondiale
DRM+	Digital Radio Mondiale for use in the VHF band (digital audio broadcasting standard)
DRM30	Digital Radio Mondiale for use below 30 MHz (digital audio broadcasting standard)

DSO	Digital Switch Over
DTMB	Digital Terrestrial Multimedia Broadcast (DTTB standard)
DTTB	Digital Terrestrial Television Broadcasting (synonym to DTV)
DTV	Digital Terrestrial Television (synonym to DTTB)
DVB	Digital Video Broadcasting
DVB-H	Digital Video Broadcasting – Handheld (MTV standard)
DVB-NGH	Digital Video Broadcasting - Next Generation Handheld (MTV standard)
DVB-SH	Digital Video Broadcasting - Satellite Services to Handhelds (MTV standard)
DVB-T	Digital Video Broadcasting – Terrestrial (DTTB standard)
DVB-T2	Digital Video Broadcasting – Terrestrial 2nd generation (DTTB standard)
EBU	European Broadcasting Union
ECC	Electronic Communications Committee in Europe
EPG	Electronic Programme Guide
FM	Frequency Modulation
FOBTV	Future of Broadcast Television
GE06	Geneva 2006 Agreement (Digital broadcasting plan in VHF and UHF in parts of Region 1 and 3)
GE75	Geneva 1975 Agreement (MF plan in Region 1 and 3)
GHz	Gigahertz
HBB	Hybrid Broadcast-Broadband
HbbTV	Hybrid Broadcast-Broadband Television system
HD	High Definition
HDTV	High Definition Television
HE-AAC	High-Efficiency Advanced Audio Coding
Heff	Effective antenna height
HF	High Frequency bands (3 - 30 MHz)
IBOC	In-band on-channel (digital audio broadcasting standard)
IMT	International Mobile Telecommunications
IP	Internet Protocol
IPTV	Internet Protocol Television
ISBD-T	Integrated Services Digital Broadcasting – Terrestrial (DTTB standard)
ISDB-T 1seg	One radio-frequency segment of Integrated Services Digital Broadcasting – Terrestrial (MTV standard)
ISDB-TSB	Integrated Services Digital Broadcasting (digital audio broadcasting standard)

ISO/IEC	International Organization for Standards/International Electrotechnical Commission
ITU	International Telecommunication Union
ITU-D	ITU – Telecommunication Development Sector
ITU-R	ITU – Radiocommunication Sector
ITU-T	ITU – Telecommunication Standardization Sector
kbit/s	Kilobits per second
LF	Low frequency bands (30 - 300 kHz)
LTE	Long Term Evolution, often marketed as 4G (mobile communication standard)
MA02revCO07	Maastricht 2002, Special Arrangement, as revised in Constanţa, 2007 (European DAB plan in the 1.5 GHz range)
Mbit/s	Megabits per second
MediaFlo	Media Forward Link Only (MTV standard)
MF	Medium frequency bands (300 – 3000 kHz)
MFN	Multi Frequency Network
MHEG	Multimedia and Hypermedia Experts Group (middleware standard)
MHP	Multimedia Home Platform; middleware standard
MHz	Megahertz
MPEG	Moving Picture Expert Group
MTV	Mobile Television
OFDM	Orthogonal Frequency Division Multiplex
OTT	Over-the-Top TV; broadcast service provider via the Internet
PC	Personnel Computer
PVR	Personnel Video Recorder
RAVIS	Real-time AudioVisual Information System (Digital audio and multimedia standard)
RDS	Radio Data System
RJ81	Rio de Janeiro 1981 Agreement (MF plan in Region 2)
RJ88	Rio de Janeiro 1988 Agreement (1605 – 1705 kHz plan in Region 2)
RRC-06-Rev GE89	Regional Radio Conference 2006 for the revision of the Geneva 1989 Agreement (Analogue TV plan in Band I in the African Broadcasting Area)
RRC-06-Rev ST61	Regional Radio Conference 2006 for the revision of the Stockholm 1961 Agreement (Analogue TV plan in Band I in the European Broadcasting Area)
SBR	Spectrum Band Replication system
SDTV	Standard Definition Television
SFN	Single Frequency Network

T-DAB	Terrestrial - Digital Audio Broadcasting (digital audio broadcasting standard)
T-DAB+	Terrestrial - Digital Audio Broadcasting, improved system (digital audio broadcasting standard)
T-DMB	Terrestrial - Digital Multimedia Broadcasting (MTV standard)
TTA	Telecommunications Technology Association in Korea
UHDTV	Ultra High Definition Television
UHF	Ultra High Frequencies (300 – 3000 GHz)
USA	United States of America
VCEG	Video Coding Experts Group
VHF	Very High Frequencies (30 -300 MHz)
WLAN	Wireless Local Area Network
WRC-07	World Radiocommunication Conference in 2007
WRC-12	World Radiocommunication Conference in 2012
WRC-15	World Radiocommunication Conference in 2015

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