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Digital terrestrial broadcasting systems

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Foreword

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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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REPORT ITU-R BT.2295-0

Digital terrestrial broadcasting systems

(2013)

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1 Introduction

This Report reviews the general characteristics of the systems for digital terrestrial sound, multimedia and TV broadcasting for fixed, portable and mobile reception. The Report deals with the systems included into ITU-R Recommendations and Reports.

There is an increasing worldwide demand for suitable means of broadcasting high-quality sound, multimedia and TV programmes to vehicular, portable and fixed receivers.

Digital terrestrial broadcasting offers the potential for new and improved services to consumers. Digital terrestrial broadcasting has such advantages as high reliability of service for practically unlimited number of users, free-to-air access, possibility of fixed and mobile reception, etc.

Digital terrestrial broadcasting systems have been implemented in many countries or they are planned to be introduced. It may be necessary for digital terrestrial broadcasting services to coexist with analogue transmissions for a temporary period.

ITU-R Study Group 6 has developed and adopted a set of Recommendations comprising description of various digital terrestrial broadcasting systems – sound, multimedia, TV – that may be used in different frequency bands. These Recommendations are aimed to provide the Administrations with the guidance for the choice of national and regional broadcasting systems providing technical and service requirements to various possible systems.

Recommendation ITU-R BS.1514 describes systems for digital terrestrial sound broadcasting in frequency bands below 30 MHz. Recommendation ITU-R BS.1114 describes systems for digital terrestrial sound broadcasting in frequency range 30-3 000 MHz. Recommendation ITU-R BT.2016 describes systems for digital terrestrial multimedia broadcasting in VHF/UHF frequency bands. Recommendations ITU-R BT.1306 and ITU-R BT.1877 describe first and second generation systems for digital terrestrial TV broadcasting. Recommendation ITU-R BT.1368 defines planning criteria for various methods of providing digital terrestrial television services in the VHF/UHF bands. Recommendation ITU-R BT.2036 establishes characteristics of a reference television receiving system used as a basis for frequency planning.

The interoperability between digital TV, multimedia and sound broadcasting systems may be desired.

The division of broadcasting systems into sound, multimedia and TV becomes more and more relative in present-day conditions. For example, even digital narrowband sound broadcasting systems are able to transmit video information in frequency bands below 30 MHz. Additionally, digital TV broadcasting systems are used for sound programmes also. Some digital broadcasting systems (for example, ISDB-T) may be used for both TV, multimedia and sound broadcasting, depending on different operating modes.

Availability of receivers in the market, that are capable of receiving all or multiple digital radio systems that are used currently or will be offered in future, would meet the interests of users at best, in particular for reception during travelling. Availability of such receivers will allow intersystem interoperability of information services in disaster and emergency situations, navigation, safety, etc. This issue is under study of ITU-R Study Group 6 according to ITU-R Question 136-1/6 – Worldwide broadcasting roaming.

Service requirements for digital terrestrial sound broadcasting systems in frequency bands below 30 MHz are outlined in Recommendation ITU-R BS.1348. Service requirements for digital terrestrial sound broadcasting systems in VHF/UHF frequency bands are outlined in Recommendation ITU-R BS.774. Requirements for enhanced multimedia services for digital terrestrial broadcasting in VHF bands are outlined in Recommendation ITU-R BS.1892.

Digital terrestrial TV broadcasting should fit into existing 6, 7, 8 MHz channels intended for analogue television transmission.

Modern digital terrestrial broadcasting receivers implement interactivity, broadband access, content delivery from Internet, record of content for further presentation, playback of local content (so called smart receivers). Modern digital terrestrial broadcasting receivers have programmable functions and allow for software update.

The choice of broadcasting system should depend on specific conditions such as spectrum availability, regulation policy, coverage requirements, structure of existing network, reception conditions, types of required services and cost for customers and broadcasters.

This Report reviews the following systems:

- ATSC (Recommendations ITU-R BT.1306, ITU-R BT.1368, ITU-R BT.1833, ITU-R BT.2036);
- DAB (Recommendations ITU-R BS.1114, ITU-R BS.1660, Report ITU-R BS.1203);
- DRM (Recommendations ITU-R BS.1114, ITU-R BS.1514, ITU-R BS.1615, ITU-R BS.1660, Reports ITU-R BS.2144, ITU-R BS.2208, ITU-R BS.2214, ITU-R BS.2251);
- DTMB (Recommendations ITU-R BT.1306, ITU-R BT.1368);
- DVB-T, DVB-H, DVB-SH (Recommendations ITU-R BT.1306, ITU-R BT.1368, ITU-R BT.1833, ITU-R BT.2016, ITU-R BT.2036, Report ITU-R BT.2049);
- DVB-T2 (Recommendations ITU-R BT.1833, ITU-R BT.1877, ITU-R BT.2016, ITU-R BT.2033, ITU-R BT.2036, Report ITU-R BT.2254);
- IBOC (Recommendations ITU-R BS.1114, ITU-R BS.1514, ITU-R BS.1615, Report ITU-R BS.1203);
- ISDB-T, ISDB-TSB, ISDB-T multimedia systems (Recommendations ITU-R BS.1114, ITU-R BT.1306, ITU-R BT.1368, ITU-R BS.1660, ITU-R BT.1833, ITU-R BT.2016, ITU-R BT.2036, Report ITU-R BT.2049);
- RAVIS (Reports ITU-R BS.2214, ITU-R BT.2049);
- T-DMB, AT-DMB (Recommendations ITU-R BT.1833, ITU-R BT.2016, Report ITU-R BT.2049).

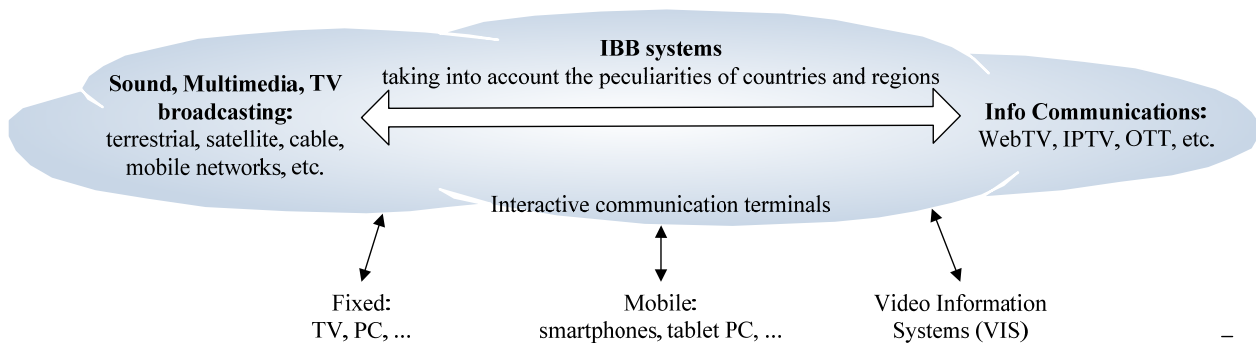
Mobile telecommunication systems with advanced information technologies are under implementation in many countries. In many cases there is a need for interoperability between the mobile telecommunication services and interactive digital broadcasting services.

There are telecommunication systems not explicitly dedicated to broadcasting services, such as Multimedia Broadcast/Multicast Services (MBMS), as shown in Appendix 1, that fulfil the requirements for interoperability between mobile telecommunication services and interactive digital broadcasting services.

Currently ITU-R Study Group 6 is carrying out the study of Integrated Broadcast-Broadband (IBB) systems: Report ITU-R BT.2267 and Recommendation ITU-R BT.2037 have been adopted, draft new Recommendation (Annex 2 to Document 6B/128) is under development. Such systems will integrate both traditional broadcasting (terrestrial, satellite, cable) and broadcasting in mobile networks as well as other types of broadcasting taking into account the peculiarities of countries and regions (see Fig. 1).

FIGURE 1

The media and the means for transmission and reception of information and interactive services of sound, multimedia and television broadcasting



2 General characteristics of digital terrestrial broadcasting systems

Key characteristics of digital terrestrial broadcasting systems are represented in Table 1.

Table 1 can be used for the evaluation of the respective characteristics of the systems and selecting a specific system.

TABLE 1

Key characteristics of digital terrestrial broadcasting systems

Characteristics	ATSC	DAB	DRM	DTMB	DVB-T, DVB-H, DVB-SH	DVB-T2		IBOC	ISDB-T family	RAVIS	T-DMB, AT-DMB
Reception modes: – Fixed – Portable – Portable handheld – Mobile	+	+	+	+	+	+		+	+	+	+
Net data rates	Depending on modulation code rate: a) 4.23-19.39 Mbit/s b) 4.72-21.62 Mbit/s c) 5.99-27.48 Mbit/s	0.576 to 1.728 Mbit/s	Depending on modulation, code rate, robustness mode, channel bandwidth: 1) Modes A, B, C, D – 5-72 kbit/s 2) Mode E – 37-186 kbit/s	Depending on modulation, code and frame header: a) 3.610-24.436 Mbit/s b) 4.211-28.426 Mbit/s c) 4.813-32.486 Mbit/s	a) 0.42 to 3.447 Mbit/s ³ b) 1.332 to 10.772 Mbit/s ³ ; 2.33 to 14.89 Mbit/s ⁴ c) 1.60 to 12.95 Mbit/s ³ ; 2.80 to 23.5 Mbit/s ⁴ d) 1.868 to 15.103 Mbit/s ³ ; 3.27 to 27.71 Mbit/s ⁴ e) 2.135 to 17.257 Mbit/s ³ ; 3.74 to 31.67 Mbit/s ⁴	7.5-50.5 Mbit/s		Depending on band, modulation, code rate: a) 20 to 40 kbit/s b) 98 to 147 kbit/s c) 147 to 294 kbit/s	n × a) 0.281 to 1.787 Mbit/s b) 0.328 to 2.085 Mbit/s c) 0.374 to 2.383 Mbit/s	Depending on modulation and code rate for different channel bandwidth: a) 100 kHz-75-341 kbit/s b) 200 kHz-155-703 kbit/s c) 250 kHz-196-888 kbit/s	T-DMB: 0.576 to 1.728 Mbit/s AT-DMB: 0.864 to 2.304 Mbit/s at BPSK over DQPSK AT-DMB: 1.152 to 2.88 Mbit/s at QPSK over DQPSK
Spectrum efficiency (bit/s/Hz)	0.55-1.48	0.38-1.1	1) Modes A, B, C, D – 1.1-3.73 kbit/s 2) Mode E – 0.39-1.9 kbit/s	0.64-4.30	0.28-2.44 ³ 0.46-1.86 ⁴	0.98-6.50		a) 0.55-4.1 b) 0.73-1.4	0.66-4.17	0.77-3.64	T-DMB: 0.38-1.13 AT-DMB: 0.56-1.88

TABLE 1 (continued)

Characteristics	ATSC	DAB	DRM	DTMB	DVB-T, DVB-H, DVB-SH	DVB-T2		IBOC	ISDB-T family	RAVIS	T-DMB, AT-DMB
Single frequency networks		Supported	Supported	Supported	Supported	Supported		Supported	Supported	Supported	Supported
Broadcasting types: – sound – multimedia – TV	+ +	+	+	+ +	+ +	+ +		+ +	+ +	+ +	+
Transmission data/service types	Video, audio, data	Audio, data	Audio, data	Video, audio, data	Video, audio, data	Video, audio, data		Audio, images/pictures, data (traffic, news, weather, alerts)	Video, audio, data	Video, audio, still pictures, presentations, traffic data, etc.	Video, audio, data
Frequency bands	VHF, UHF	VHF, UHF	LF, MF, HF (Modes A, B, C, D), VHF (Mode E)	VHF, UHF	VHF, UHF	VHF, UHF		MF, VHF	VHF, UHF	VHF bands I, II	UHF
Channel bandwidth	a) 6 MHz b) 7 MHz c) 8 MHz	1.712 MHz	4.5, 5, 9, 10, 18, 20 kHz (Modes A, B, C, D); 100 kHz (Mode E)	a) 6 MHz b) 7 MHz c) 8 MHz	a) 1.7 MHz ³ b) 5 MHz c) 6 MHz d) 7 MHz e) 8 MHz	a) 1.7 MHz b) 5 MHz c) 6 MHz d) 7 MHz e) 8 MHz		a) 5, 10, 20, 30 kHz b) 70, 100, 140, 170, 200 kHz c) 400 kHz	1/14 × n of a) 6 MHz b) 7 MHz c) 8 MHz n ≥ 1 ¹	a) 100 kHz b) 200 kHz c) 250 kHz	1.712 MHz

TABLE 1 (continued)

Characteristics	ATSC	DAB	DRM	DTMB	DVB-T, DVB-H, DVB-SH	DVB-T2		IBOC	ISDB-T family	RAVIS	T-DMB, AT-DMB
Used bandwidth	At -3 dB: a) 5.38 MHz b) 6.00 MHz c) 7.00 MHz	1.536 MHz	4.4, 4.8, 8.7, 9.8, 17.3, 19.4 kHz (Modes A, B, C, D); 96 kHz (Mode E)	a) 5.67 MHz b) 6.62 MHz c) 7.56 MHz	a) 1.52 MHz ³ b) 4.75 MHz c) 5.71 MHz d) 6.66 MHz e) 7.61 MHz TDM ³ : a) 1.368 MHz b) 4.27 MHz c) 5.13 MHz d) 5.18 MHz e) 6.838 MHz	a) 1.52 MHz b) 4.75 MHz c) 5.71 MHz d) 6.66 MHz e) 7.61 MHz		a) 4.9, 9.8, 14.2, 18.9, 28.4 kHz b) 69.4, 97, 139, 166.4, 194, c) 397.2 kHz	Subcarrier spacing + $1/14 \times n \times$ a) 6 MHz b) 7 MHz c) 8 MHz $n \geq 1$ ¹	a) 96.0 kHz b) 185.6 kHz c) 246.2 kHz	1.536 MHz
Number of segments	1	1	1	1	Configurable number of time slices per bandwidth ³	Configurable		a) 1 to 6 b) 1 to 6 c) 1 to 10	$n \geq 1$ ¹	1	1
Number of subcarriers per segment	1	192 384 768 1 536	Mode A: 101 (4.5 kHz), 113 (5 kHz), 205 (9 kHz), 229 (10 kHz), 413 (18 kHz), 461 (20 kHz) Mode B: 91 (4.5 kHz), 103 (5 kHz), 183 (9 kHz), 207 (10 kHz), 367 (18 kHz), 411 (20 kHz) Mode C: 139 (10 kHz), 281 (20 kHz) Mode D: 89 (10 kHz), 179 (20 kHz) Mode E: 213	1 (single-carrier mode) 3 780 (multi-carrier mode)	853 (1k mode) ³ 1 705 (2k mode) 3 409 (4k mode) 6 817 (8k mode)	1 705 (2k mode) 3 409 (4k mode) 6 817 (8k mode) 13 633 (16k mode)		a) 25 to 27 b) 38 to 191	108 (Mode 1) 216 (Mode 2) 432 (Mode 3)	a) 215 b) 439 c) 553	192 384 768 1 536

TABLE 1 (continued)

Characteristics	ATSC	DAB	DRM	DTMB	DVB-T, DVB-H, DVB-SH	DVB-T2	IBOC	ISDB-T family	RAVIS	T-DMB, AT-DMB
Subcarrier spacing	–	a) 8 kHz b) 4 kHz c) 2 kHz d) 1 kHz	750/18 Hz (Mode A), 750/16 Hz (Mode B), 750/11 Hz (Mode C), 750/7 Hz (Mode D), 4000/9 Hz (Mode E)	Multi-carrier mode: a) 1.5 kHz b) 1.75 kHz c) 2.0 kHz	a) 1 786 kHz (1k) ³ b) 5 580.322 Hz (1k) ³ , 2 790.179 Hz (2k), 1 395.089 Hz (4k), 697.545 Hz (8k) c) 6 696.42 Hz (1k) ³ , 3 348.21 Hz (2k), 1 674.11 Hz (4k), 837.05 Hz (8k) d) 7 812 Hz (1k) ³ , 3 906 Hz (2k), 1 953 Hz (4k), 976 Hz (8k) e) 8 929 Hz (1k) ³ , 4 464 Hz (2k), 2 232 Hz (4k), 1 116 Hz (8k)	a) 901 Hz (2k mode), 450 Hz (4k mode), 225 Hz (8k mode), 113 Hz (16k mode) b) 2 790 Hz (2k mode), 1 395 Hz (4k mode), 698 Hz (8k mode), 349 Hz (16k mode) c) 3 348 Hz (2k mode), 1 674 Hz (4k mode), 837 Hz (8k mode), 419 Hz (16k mode) d) 3 906 Hz (2k mode), 1 953 Hz (4k mode), 977 Hz (8k mode), 488 Hz (16k mode) e) 4 464 Hz (2k mode), 2 232 Hz (4k mode), 1 116 Hz (8k mode), 558 Hz (16k mode)	a) 181.7 Hz b) 363.4 Hz	a) 3.968 kHz (Mode 1) ² , 1.984 kHz (Mode 2), 0.992 kHz (Mode 3) b) 4.629 kHz (Mode 1), 2.314 kHz (Mode 2), 1.157 kHz (Mode 3) c) 5.291 kHz (Mode 1), 2.645 kHz (Mode 2), 1.322 kHz (Mode 3)	4000/9 Hz	a) 8 kHz b) 4 kHz c) 2 kHz d) 1 kHz

TABLE 1 (continued)

Characteristics	ATSC	DAB	DRM	DTMB	DVB-T, DVB-H, DVB-SH	DVB-T2	IBOC	ISDB-T family	RAVIS	T-DMB, AT-DMB
Active symbol duration	a) 92.9 ns b) 83.3 ns c) 71.4 ns	a) 156 μ s b) 312 μ s c) 623 μ s d) 1 246 μ s	24 ms (Mode A), 21.33 ms (Mode B), 14.66 ms (Mode C), 9.33 ms (Mode D), 2.25 ms (Mode E)	a) 0.176 μ s (single-carrier mode) 666.67 μ s (multi-carrier mode) b) 0.151 μ s (single-carrier mode) 571.43 μ s (multi-carrier mode) c) 0.132 μ s (single-carrier mode) 500 μ s (multi-carrier mode)	a) 560 μ s (1k) ³ b) 179.2 μ s (1k) ³ , 358.40 μ s (2k), 716.80 μ s (4k), 1 433.60 μ s (8k) c) 149.33 μ s (1k) ³ , 298.67 μ s (2k), 597.33 μ s (4k), 1 194.67 μ s (8k) d) 2 128 μ s (1k) ³ , 256 μ s (2k), 512 μ s (4k), 1 024 μ s (8k) e) 112 μ s (1k) ³ , 224 μ s (2k), 448 μ s (4k), 896 μ s (8k)	a) 1 109.98 μ s (2k), 2 219.97 μ s (4k), 4 439.94 μ s (8k) b) 358.4 μ s (2k), 716.8 μ s (4k), 1 433.6 μ s (8k), 2 867.2 μ s (16k) c) 298.67 μ s (2k), 597.33 μ s (4k), 1 194.67 μ s (8k), 2 389.33 μ s (16k) d) 256 μ s (2k), 512 μ s (4k), 1 024 μ s (8k), 2 048 μ s (16k) e) 224 μ s (2k), 448 μ s (4k), 896 μ s (8k), 1 792 μ s (16k)	a) 5.504 ms b) 2.752 ms	a) 252 μ s (Mode 1) ² , 504 μ s (Mode 2), 1 008 μ s (Mode 3) b) 216 μ s (Mode 1), 432 μ s (Mode 2), 864 μ s (Mode 3) c) 189 μ s (Mode 1), 378 μ s (Mode 2), 756 μ s (Mode 3)	2.25 ms	a) 156 μ s b) 312 μ s c) 623 μ s d) 1 246 μ s
Guard interval duration/ ratio	–	a) 31 μ s b) 62 μ s c) 123 μ s d) 246 μ s	1/9 (Mode A), 1/4 (Mode B), 4/11 (Mode C), 11/14 (Mode D), 1/9 (Mode E)	Frame header 1/9, 1/6, 1/4 of frame body: a) 74.07, 104.94, 166.67 μ s b) 63.49, 89.95, 142.86 μ s c) 55.56, 78.70, 125.00 μ s	1/32, 1/16, 1/8, 1/4	1/128, 1/32, 1/16, 19/256, 1/8, 19/128, 1/4	7/128	1/32, 1/16, 1/8, 1/4	1/8	a) 31 μ s b) 62 μ s c) 123 μ s d) 246 μ s

TABLE 1 (continued)

Characteristics	ATSC	DAB	DRM	DTMB	DVB-T, DVB-H, DVB-SH	DVB-T2		IBOC	ISDB-T family	RAVIS	T-DMB, AT-DMB
Frame duration	a) 48.4 ms b) 43.4 ms a) 37.2 ms	96 ms 48 ms 24 ms	Mode A: 400 ms (15 OFDM symbols) Mode B: 400 ms (15 OFDM symbols) Mode C: 400 ms (20 OFDM symbols) Mode D: 400 ms (24 OFDM symbols) Mode E: 100 ms (40 OFDM symbols)	a) 740.74, 771.60, 833.33 μ s b) 634.92, 661.38, 714.29 μ s c) 555.56, 578.70, 625.00 μ s	68 OFDM symbols. One super-frame consists of 4 frames TDM ³ : 476 physical layer slots, each of them comprising 2 176 symbols	Flexible with possibility of changing on frame-by-frame basis. Max 250 ms		a) Sub-frame 92.88 ms b) frame 1.486 s	204 OFDM symbols	103.78125 ms (41 OFDM symbols)	96 ms 48 ms 24 ms
Time/frequency synchronization	Segment sync, pilot carrier; Frame sync	Null symbol and centre frequency and phase reference symbol	Guard interval/Pilot carriers	PN sequence as the frame header of signal frame	Guard interval/Pilot carriers TDM ³ : Pilot symbols	P1 symbol/Guard interval/Pilot carriers		Guard interval/pilot carriers	Pilot carriers	Guard interval/Pilot carriers	Null symbol and centre frequency and phase reference symbol
Modulation methods	8-VSB	4-DQPSK	16-QAM, 64-QAM (Modes A, B, C, D) 4-QAM, 16-QAM (Mode E)	4-QAM-NR, 4-QAM, 16-QAM, 32-QAM, 64-QAM	QPSK, 16-QAM, 64-QAM ⁴ , MR-16-QAM ⁴ , MR-64-QAM ⁴ TDM ³ : QPSK, 8-PSK, 16-APSK	QPSK, 16-QAM, 64-QAM with or without constellation rotation specific for each physical layer pipe		a) BPSK, QPSK, 16-QAM, 64-QAM b) BPSK, QPSK	DQPSK, QPSK, 16-QAM, 64-QAM	QPSK, 16-QAM, 64-QAM	T-DMB: DQPSK AT-DMB: DQPSK BPSK over DQPSK QPSK over DQPSK
Inner FEC	2/3 trellis, concatenated 1/2 or 1/4 trellis	Convolution code (1/4 to 3/4)	Multilevel punctured convolutional code with mother code rate 1/6 and constraint length 7 (0.25, 0.33, 0.4, 0.41, 0.45, 0.48, 0.5, 0.55, 0.57, 0.58, 0.6, 0.62, 0.67, 0.71, 0.72, 0.78)	LDPC code 0.4 (7 488, 3 008), 0.6 (7 488, 4 512), 0.8 (7 488, 6 016)	a) Convolution code, mother rate 1/2 with 64 states. Puncturing to rate 2/3, 3/4, 5/6, 7/8 ⁴ b) Turbo Code from 3GPP2 with mother information block size of 12 282 bits. Rates obtained by puncturing: 1/5, 2/9, 1/4, 2/7, 1/3, 2/5, 1/2, 2/3 ³	LDPC code with code rates 1/3, 2/5, 1/2, 3/5, 2/3, 3/4		Convolution code 2/11 to 5/6	Convolution code, Mother rate 1/2 with 64 states. Puncturing to rate 2/3, 3/4, 5/6, 7/8	LDPC code with approximate code rates 1/2, 2/3, 3/4	T-DMB: Convolution code (1/4 to 3/4) AT-DMB: Convolution code + Turbo code (1/4 to 1/2)

TABLE 1 (continued)

Characteristics	ATSC	DAB	DRM	DTMB	DVB-T, DVB-H, DVB-SH	DVB-T2		IBOC	ISDB-T family	RAVIS	T-DMB, AT-DMB
Inner interleaving	Independently encoded streams interleaved in time: a) 12 b) 24 c) 28	Time interleaving and frequency interleaving	Bit interleaving, cell interleaving	In frequency domain inside one signal frame (multi-carrier mode)	a) Bit interleaving, combined with native or in-depth symbol interleaving ⁴ b) Frequency interleaving; Time interleaving (Forney with 48 branches QPSK: 320/9 600 ms 16-QAM:160/4 800 ms) ³	Cell, time and frequency interleaving		Time interleaving and frequency interleaving	Frequency interleaving: Intra and inter segments interleaving Time interleaving: Symbol-wise convolutional interleaving 0, 380, 760, 1 520, 3 040 symbols (Mode 1) ² 0, 190, 380, 760, 1 520 symbols (Mode 2) 0, 95, 190, 380, 760 symbols (Mode 3)	Bit, cell, time and frequency interleaving	Time interleaving and frequency interleaving
Outer FEC	RS (207,187, T = 10), concatenated RS (184,164, T = 10)	–	–	BCH (762, 752) derived from BCH (1 023, 1 013)	Outer Code: RS (204, 188, T = 8) ⁴ IP outer channel code: MPE-FEC RS (255,191) ³	BCH (16 200, x, t), there x – depends on LDPC code rate. Error correction capability t = 12 errors		RS (96, 88, 4) RS (255, 223, 16) RS (255, 191, 32)	RS (204, 188, T = 8)	BCH (n, k, t); n, k depend on channel bandwidth, LDPC code rate; error correction capability t = 10 errors (for main service channel)	RS (204, 188, T=8) code for video service and scalable video service
Outer interleaving	52 segment convolutional byte interleaved, concatenated 46 segment byte interleaved	–	–	Convolutional interleaving in time domain, number of interleaving branches B = 52, interleaving depth M = 240, 720	Byte-wise convolutional interleaving, I = 12 ³	Bit (parity & column twist) interleaving		Up to 64 code words	Byte-wise convolutional interleaving, I = 12	–	Convolutional interleaving for video service and scalable video service
Data randomization/energy dispersal	16 bit PRBS	16 bit PRBS	16 bit PRBS	PRBS	16 bit PRBS	16 bit PRBS		13 bit PRBS	PRBS	16 bit PRBS	16 bit PRBS

TABLE 1 (end)

Characteristics	ATSC	DAB	DRM	DTMB	DVB-T, DVB-H, DVB-SH	DVB-T2		IBOC	ISDB-T family	RAVIS	T-DMB, AT-DMB
Hierarchical transmission	–	–	+	–	+	–		+	+	–	–
Transmission parameter signalling	Mode symbols in frame sync	Phase reference symbol	Control cells	Carried by 36 system information symbol per signal frame	TPS pilot carriers	Preamble symbol P1		32 bit information sequence provided cyclically	TMCC pilot carriers	4 subcarriers per OFDM symbol, 41 bit per OFDM frame	Phase reference symbol

¹ The number of segments “*n*” is determined by the available bandwidth.

² Modes 1, 2 and 3 can be selected by the scale of the single frequency network (SFN) and the types of service reception such as fixed or mobile. Mode 1 can be used for single transmission operation, or for small single frequency network. This mode is suitable for mobile reception. Mode 3 can be used for large single frequency network. This mode is suitable for fixed reception. Mode 2 offers an additional trade-off between transmission area size and mobile reception capabilities. The mode should be selected by taking the applied radio frequency, the scale of SFN, and the type of service reception into consideration.

³ Available for DVB-SH.

⁴ Available for DVB-T, DVB-H.

3 Summaries of digital terrestrial broadcasting systems and references to ITU-R Recommendations and Reports

3.1 Summary of ATSC system

ATSC standards are a set of standards developed by the Advanced Television Systems Committee for digital television transmission over terrestrial, cable, and satellite networks.

ATSC Mobile DTV is an enhancement of the ATSC system to provide multimedia services including video, audio, and interactive data service delivery to small (power efficient) receivers, for fixed, handheld and vehicular environments. The system uses IP-based mechanism with control of time synchronized delivery via buffer modelling for an end-to-end broadcast system including enablement of a return path to facilitate delivery of any type of digital content and service.

Recommendation ITU-R BT.1306-6 (12/2011) provides transmission parameters (Table 1 Part a) and bibliography (Appendix 1 to Annex 1) for ATSC system standard (System A).

Recommendation ITU-R BT.1368-10 (01/2013) provides planning criteria for ATSC system (Annex 1). Planning criteria includes protection ratios (ATSC signal interfered with by ATSC signal, ATSC signal interfered with by analogue TV signal, analogue TV signal and TV sound signal interfered with by ATSC signal) and minimum field strengths.

Recommendation ITU-R BT.2036 (07/2013) establishes characteristics (Annexes 1 and 2) for a reference ATSC television receiving system to be used as a basis for frequency planning.

Recommendation ITU-R BT.1833-2 (08/2012) provides user requirements (Table 2a) and normative references (Table 3a) for ATSC Mobile DTV (Multimedia system B) for mobile reception by handheld receivers, summary (Part 4.6) and description (Annex 6) of ATSC Mobile DTV, transmission parameters (Table 6a) and technical performance (Table 7a) of ATSC Mobile DTV for mobile reception.

More information about the system and standards can be found at <http://www.atsc.org/>.

3.2 Summary of DAB system

DAB system, also known as the Eureka 147 digital audio broadcasting (DAB) system, has been developed for both satellite and terrestrial broadcasting applications in order to allow a common low-cost receiver to be used. The system has been designed to provide vehicular, portable and fixed reception with low gain omni-directional receive antennas located at 1.5 m above ground. DAB system allows for complementary use of satellite and terrestrial broadcast transmitters resulting in better spectrum efficiency and higher service availability in all receiving situations. It especially offers improved performance in multipath and shadowing environments which are typical of urban reception conditions by the use of on-channel terrestrial repeaters to serve as gap-fillers. DAB system is capable of offering various levels of sound quality up to high quality sound comparable to that obtained from consumer digital recorded media. It can also offer various data services and different levels of conditional access and the capability of dynamically re-arranging the various services contained in the multiplex.

Recommendation ITU-R BS.1114-7 (12/2011) provides performance (Table 1) of DAB system (Digital system A), summary (Annex 1 Part 1) and description (Annex 2) of the system, including spectrum mask and RF performance characteristics in AWGN and Rayleigh channels.

Recommendation ITU-R BS.1660-6 (08/2012) gives the technical basis for planning of terrestrial digital sound broadcasting (T-DAB) in the VHF band (Annex 1), including minimum wanted field strength used for planning, spectrum masks for T-DAB out-of-band emissions, position of

frequency blocks in Band III (Wiesbaden 1995 Special Arrangement), T-DAB reference network, protection ratios (T-DAB interfered with by T-DAB, T-DAB interfered with by analogue sound broadcasting, T-DAB interfered with by digital terrestrial television broadcasting, T-DAB interfered with by analogue terrestrial television broadcasting, T-DAB interfered with by services other than broadcasting), and bibliography.

Report ITU-R BS.1203-1 (1994) gives DAB system description (Annex 1-A), system experimental evaluations (1988-1993) (Annex 1-B), applicable propagation/channel characteristics and related experimental results (Annex 1-C), computer simulations of coverage concepts (Annex 1-D), computer simulations of system performance (Annex 1-E).

More information about the system and standards can be found at <http://www.worlddab.org/>.

3.3 Summary of DRM system

Digital Radio Mondiale (DRM) system has been developed for terrestrial broadcasting applications in all the frequency bands allocated worldwide for analogue sound broadcasting. It respects the ITU-defined spectrum masks, allowing a smooth transition from analogue to digital broadcasting. The system is designed as a digital-only system. In the bands above 30 MHz, it defines Robustness Mode E (also known as DRM+) to offer audio quality comparable to that obtained from consumer digital recorded media. In addition, DRM system also offers various data services, including images and electronic programme guides, and the capability of dynamically rearranging the various services contained in the multiplex without loss of audio.

Recommendation ITU-R BS.1114-7 (12/2011) provides performance (Table 1) of DRM system Mode E (Digital system G), summary (Annex 1 Part 4) and description (Annex 5) of the system, including simulated system performance.

Recommendation ITU-R BS.1514-2 (03/2011) provides summary description of DRM system for operation below 30 MHz (Modes A, B, C, D) (Annex 1) and summary of DRM system performance below 30 MHz (Annex 4).

Recommendation ITU-R BS.1615-1 (05/2011) provides planning parameters DRM sound broadcasting below 30 MHz including minimum usable field strengths (Annex 1) and RF protection ratios (Annex 2).

Recommendation ITU-R BS.1660-6 (08/2012) gives the technical basis for planning of DRM terrestrial digital sound broadcasting in the VHF band (Annex 3), including minimum wanted field strength used for planning, out-of-band spectrum masks, protection ratios (DRM interfered with by DRM, DRM interfered with by analogue FM in Band II, DRM interfered with by DAB in Band III, DRM interfered with by DVB-T in Band III, analogue FM interfered with by DRM in Band II, DAB interfered with by DRM in Band III), and bibliography.

Report ITU-R BS.2144 (05/2009) gives planning parameters and coverage for DRM broadcasting at frequencies below 30 MHz, including DRM system aspects, required S/N ratios for DRM reception, minimum usable field-strength values for planning, RF protection ratios, simulcast aspects, examples of SFN and international regulation aspects.

Report ITU-R BS.2208 (10/2010) considers possible use of VHF Band I for digital sound broadcasting using in particular DRM system.

Report ITU-R BS.2214 (05/2011) gives planning parameters for DRM broadcasting in VHF bands I, II and III (Annex 1), such as minimum median field-strength level, position of DRM frequencies, out-of-band spectrum mask and protection ratios (for DRM, for broadcasting systems interfered with by DRM, for other services interfered with by DRM).

Report ITU-R BS.2251-1 (10/2012) gives some aspects of using DRM broadcasting in the 26 MHz band (25 670-26 100 kHz).

More information about the system and standards can be found at <http://www.drm.org/>.

3.4 Summary of DTMB system

DTMB (Digital Terrestrial Multimedia Broadcast) is the TV standard for mobile and fixed terminals. Besides the basic functions of traditional television service, the DTMB allows additional services. DTMB system is compatible with fixed reception (indoor and outdoor) and mobile digital terrestrial television. Mobile reception is compatible with standard definition digital TV broadcasting, digital audio broadcasting, multimedia broadcasting and data broadcasting service. Fixed reception in addition to the previous services also supports high definition digital TV broadcasting.

Recommendation ITU-R BT.1306-6 (12/2011) provides transmission parameters (Table 1 Part d) and bibliography (Appendix 4 to Annex 1) for DTMB system standard (System D).

Recommendation ITU-R BT.1368-10 (01/2013) provides planning criteria for DTMB system (Annex 4). Planning criteria includes protection ratios for DTMB wanted digital terrestrial television signals, protection ratios for wanted analogue terrestrial television signals interfered with by unwanted DTMB 8 MHz signals, minimum field strengths for DTMB fixed reception, minimum median field strength for mobile DTMB reception.

3.5 Summary of DVB-T, DVB-H, DVB-SH systems

DVB-T is the standard for the broadcast transmission of digital terrestrial television. The system transmits compressed digital audio, digital video and other data in an MPEG transport stream, using COFDM modulation. DVB-H and DVB-SH systems are end-to-end broadcast systems for delivery of any types of digital content and services using IP-based mechanisms optimized for devices with limitations on computational resources and battery. They consist of a unidirectional broadcast path that may be combined with a bidirectional mobile cellular (2G/3G) interactivity path. The broadcast path of DVB-SH system uses combined or integrated satellite and terrestrial networks. Both DVB-H and DVB-SH are platforms that can be used for enabling the convergence of services from broadcast/media and telecommunications domains (e.g. mobile/cellular).

Recommendation ITU-R BT.1306-6 (12/2011) provides transmission parameters (Table 1 Part b) and bibliography (Appendix 2 to Annex 1) for DVB-T system standard (System B).

Recommendation ITU-R BT.1368-10 (01/2013) provides planning criteria for DVB-T system (Annex 2). Planning criteria includes:

- protection ratios for DVB-T wanted signals (DVB-T signal interfered with by digital terrestrial television signal, DVB-T signal interfered with by analogue terrestrial TV signal, DVB-T signal interfered with by CW or FM signals, DVB-T signal interfered with by T-DAB signals, DVB-T signal interfered with by wideband signals other than terrestrial broadcasting);
- protection ratios for wanted analogue terrestrial TV signals interfered with by unwanted DVB-T signals;
- protection ratios for sound signals of wanted analogue terrestrial television signals interfered with by unwanted DVB-T signals;
- correction factors for different wanted DVB-T system variants and different reception conditions;
- protection ratios for a T-DAB signal interfered with by an unwanted DVB-T signal;

- minimum field strengths for DVB-T signal (fixed reception);
- minimum median field strength for mobile DVB-T reception;
- minimum median field strength for handheld pedestrian indoor, pedestrian outdoor and mobile DVB-H reception.

Recommendation ITU-R BT.2036 (07/2013) establishes characteristics (Annexes 1 and 2) for a reference DVB-T television receiving system to be used as a basis for frequency planning.

Recommendation ITU-R BT.1833-2 (08/2012) provides user requirements (Table 2b) and normative references (Table 3b) for DVB-H (Multimedia system H) and DVB-SH (Multimedia system I) for mobile reception by handheld receivers, summary (Part 4.4) and description (Annex 4) of DVB-H and DVB-SH systems, transmission parameters (Table 6b) and technical performance (Table 7b) of DVB-H and DVB-SH systems for mobile reception.

Recommendation ITU-R BT.2016-1 (01/2013) provides error-correction, data framing, modulation and emission methods for terrestrial multimedia broadcasting for mobile reception using handheld receivers in VHF/UHF bands, particularly for DVB-H (Multimedia system H) and DVB-SH (Multimedia system I). The Recommendation includes the parameters for emission for the systems (Table 1), technical features of the systems (Table 2), description and bibliography for DVB-SH system (Appendix 3 to Annex 1), description and bibliography for DVB-H system (Appendix 4 to Annex 1).

Report ITU-R BS.2049-5 (05/2011) gives service requirements for DVB-H (Part 2.4) and DVB-SH (Part 2.7) use cases, transmission mechanisms for IP-based services delivery over DVB-H (Part 5.2), transmission mechanisms of DVB-SH (Part 5.5), overview of DVB-H standard (Appendix 3) and overview of DVB-SH standard (Appendix 6).

More information about the system and standards can be found at <http://www.dvb.org/>.

3.6 Summary of DVB-T2 system

DVB-T2 is a 2nd generation terrestrial broadcast transmission system developed since 2006. The main purpose was to increase capacity, ruggedness and flexibility to the DVB-T system. The first version was published in 2009.

DVB-T2 Lite profile is designed to make use of the same reliable features we are familiar with from DVB-T2, but by a careful selection of a sub-set of modes, allows for receivers to be implemented using much smaller and more efficient silicon chips. So T2-Lite will efficiently deliver TV and radio to mobile devices such as phones and tablets (for which power consumption is an important issue) and in-car at the same time as providing services to existing fixed receivers.

Recommendation ITU-R BT.1833-2 (08/2012) provides user requirements (Table 2b) and normative references (Table 3b) for DVB-T2 Lite profile (Multimedia system T2) for mobile reception by handheld receivers, summary (Part 4.7) and description (Annex 7) of DVB-T2 Lite profile, transmission parameters (Table 6b) and technical performance (Table 7b) of DVB-T2 Lite profile for mobile reception.

Recommendation ITU-R BT.1877-1 (08/2012) provides error-correction, data framing, modulation and emission methods for DVB-T2 system. The Recommendation includes general transmission parameters of the system (Table 1) and references to system standards (Appendix 1 to Annex 1).

Recommendation ITU-R BT.2016-1 (01/2013) provides error-correction, data framing, modulation and emission methods for terrestrial multimedia broadcasting for mobile reception using handheld receivers in VHF/UHF bands, particularly for DVB-T2 Lite profile (Multimedia system T2). The Recommendation includes the parameters for emission for the systems (Table 1), technical features

of the systems (Table 2), short description and bibliography for DVB-T2 Lite profile (Appendix 5 to Annex 1).

Recommendation ITU-R BT.2033 (01/2013) provides planning criteria, including protection ratios, for DVB-T2 system in the VHF/UHF bands, particularly:

- protection ratios and overload thresholds for DVB-T2 wanted digital terrestrial television signals (interfered with by DVB-T2 signal, interfered with by LTE base station and user equipment signals);
- minimum field strengths for DVB-T2 terrestrial digital television.

Recommendation ITU-R BT.2036 (07/2013) establishes characteristics (Annexes 1 and 3) for a reference DVB-T2 television receiving system to be used as a basis for frequency planning.

Report ITU-R BT.2254 (09/2012) gives frequency and network planning aspects of DVB-T2, including system properties, receiver properties, sharing and compatibility, network planning parameters, new planning features (SFN extension, degradation beyond guard interval, MISO, time-frequency slicing, time slicing, physical layer pipes, PAPR reduction techniques, future extension frames), implementation scenarios and references. The Report consider DVB-T2 Lite profile also (Annex 5).

More information about the system and standards can be found at <http://www.dvb.org/>.

3.7 Summary of IBOC system

In-band on-channel (IBOC) digital sound broadcasting (DSB) system was designed to provide vehicular, portable and fixed reception using terrestrial transmitters. Although IBOC system can be implemented in unoccupied spectrum, a significant feature of the system is its ability to offer simulcasting of analogue and digital signals in the existing AM and FM sound broadcasting bands. The system offers improved performance in multipath environments resulting in greater reliability than is offered by existing analogue AM and FM operations. IBOC system offers enhanced audio quality comparable to that obtained from consumer digital recorded media, new data-casting services in addition to the enhanced audio programming. In addition, the system allows for allocation of bits between audio and data-casting capacity to maximize the data-casting capabilities.

Recommendation ITU-R BS.1114-7 (12/2011) provides performance (Table 1) of IBOC system in VHF band (Digital system C), summary (Annex 1 Part 3) and description (Annex 4) of the system, including simulated system performance.

Recommendation ITU-R BS.1514-2 (03/2011) provides summary description of IBOC system for operation below 30 MHz (Annex 2) and summary of IBOC system performance below 30 MHz (Annex 5).

Recommendation ITU-R BS.1615-1 (05/2011) provides planning parameters IBOC sound broadcasting below 30 MHz including measured RF protection ratios in the MF band (Annex 3).

Report ITU-R BS.1203-1 (1994) gives IBOC system description (Annex 2).

More information about the system and standards can be found at <http://www.ibiquity.com/>.

3.8 Summary of ISDB-T systems family

The ISDB-T family (ISDB-T, ISDB-TSB, ISDB-T multimedia systems) was designed on the basis of the OFDM band-segmented transmission scheme. One OFDM segment corresponds to 1/13 of the bandwidth of a television channel. The number of segments can be chosen in accordance with the available bandwidth and application; 13 for television service, 1 or 3 for sound service, and 1 or more determined by the available bandwidth for multimedia service. The ISDB-T family of

terrestrial broadcasting systems of sound, television, and multimedia has commonality and interoperability.

Recommendation ITU-R BS.1114-7 (12/2011) provides performance (Table 1) of ISDB-TSB system (Digital system F), summary (Annex 1 Part 2) and description (Annex 3) of the system, including RF performance characteristics.

Recommendation ITU-R BT.1306-6 (12/2011) provides transmission parameters (Table 1 Part c) and bibliography (Appendix 3 to Annex 1) for ISDB-T system standard (System C).

Recommendation ITU-R BT.1368-10 (01/2013) provides planning criteria for ISDB-T system (Annex 3). Planning criteria includes:

- protection ratios for ISDB-T wanted signals (ISDB-T signal interfered with by digital terrestrial television signal, ISDB-T signal interfered with by analogue terrestrial TV signal);
- protection ratios for wanted analogue terrestrial TV signals interfered with by unwanted ISDB-T signals;
- protection ratios for sound signals of wanted analogue terrestrial television signals interfered with by unwanted ISDB-T signals;
- minimum field strengths for ISDB-T signal (fixed reception);
- minimum median field strength for handheld pedestrian indoor, pedestrian outdoor and mobile ISDB-T reception.

Recommendation ITU-R BS.1660-6 (08/2012) gives the technical basis for planning of ISDB-TSB terrestrial digital sound broadcasting in the VHF band (Annex 2), including spectrum masks for out-of-band emissions, frequency conditions, minimum usable field strengths, protection of ISDB-TSB (protection ratios for ISDB-TSB interfered with by ISDB-TSB, protection ratios for ISDB-TSB interfered with by analogue television (NTSC), protection ratios for analogue television (NTSC) interfered with by ISDB-TSB, maximum interfering field strength density interfered with by services other than broadcasting).

Recommendation ITU-R BT.1833-2 (08/2012) provides user requirements (Table 2a) and normative references (Table 3a) for ISDB-TSB (Multimedia system C) and ISDB-T (Multimedia system F) for mobile reception by handheld receivers, summary (Part 4.1) and description (Annex 2) of ISDB-T system, transmission parameters (Table 6a) and technical performance (Table 7a) of ISDB-T system for mobile reception.

Recommendation ITU-R BT.2016-1 (01/2013) provides error-correction, data framing, modulation and emission methods for terrestrial multimedia broadcasting for mobile reception using handheld receivers in VHF/UHF bands, particularly for ISDB-T (Multimedia system F). The Recommendation include the parameters for emission for the system (Table 1), technical features of the system (Table 2), description and bibliography for ISDB-T system (Appendix 2 to Annex 1).

Recommendation ITU-R BT.2036 (07/2013) establishes characteristics (Annexes 1 and 2) for a reference ISDB-T television receiving system to be used as a basis for frequency planning.

Report ITU-R BS.2049-5 (05/2011) gives service requirements for ISDB-T use cases (Part 2.3), transmission mechanisms of ISDB-T (Part 5.1), overview of ISDB-T multimedia broadcasting for mobile reception (Appendix 1).

More information about the system and standards can be found at <http://www.dibeg.org/>.

3.9 Summary of RAVIS system

Digital terrestrial sound and multimedia broadcasting system RAVIS have been developed for the purpose of efficiency enhancement of utilization of spectrum bands used now for audio FM broadcasting, i.e. VHF Bands I and II. RAVIS allows to deliver digital data with bit rates from 150 to 900 kbit/s through one 100, 200 or 250 kHz bandwidth radio-frequency channel. RAVIS provides for steady mobile reception (up to 250 km/h) in urban environment, in the districts with difficult topography, in mountainous and dense forested areas, in water areas, that is under conditions characterized by multipath propagation, without direct visibility of transmitting antenna and so forth.

Report ITU-R BS.2214 (05/2011) gives planning parameters for RAVIS broadcasting in VHF bands I and II (Annex 2), such as minimum field-strength requirements, out-of-band spectrum mask and protection ratios (FM interfered with by RAVIS, RAVIS interfered with by RAVIS, RAVIS interfered with by FM).

Report ITU-R BS.2049-5 (05/2011) gives service requirements for RAVIS use cases (Part 2.8), transmission mechanisms of RAVIS (Part 5.6), overview of RAVIS system (Appendix 5).

More information about the system and standards can be found at <http://www.ravis-radio.com/>.

3.10 Summary of T-DMB, AT-DMB systems

Terrestrial digital multimedia broadcasting (T-DMB) system is the extended system compatible with digital sound broadcasting system T-DAB, which enables video services using T-DAB networks for handheld receivers in a mobile environment. T-DMB provides multimedia services including video, audio, and interactive data.

AT-DMB is the extended system of guaranteeing backward compatibility with T-DMB, which increases channel capacity of T-DMB by applying hierarchical modulation mechanism. AT-DMB provides a scalable video service as well as all kinds of T-DMB services.

Recommendation ITU-R BT.1833-2 (08/2012) provides user requirements (Table 2a) and normative references (Table 3a) for T-DMB and AT-DMB (Multimedia system A) for mobile reception by handheld receivers, summary (Part 4.3) and description (Annex 3) of T-DMB and AT-DMB, transmission parameters (Table 6a) and technical performance (Table 7a) of T-DMB and AT-DMB for mobile reception.

Recommendation ITU-R BS.2016-1 (01/2013) provides error-correction, data framing, modulation and emission methods for T-DMB and AT-DMB (Multimedia system A) for mobile reception using handheld receivers in VHF/UHF bands, including parameters for emission (Table 1), technical features (Table 2), description of the systems and bibliography (Appendix 1 to Annex 1).

Report ITU-R BS.2049-5 (05/2011) gives service requirements for T-DMB use cases (Part 2.5), transmission mechanisms of T-DMB (Part 5.3), current status of T-DMB and AT-DMB services (Appendix 2).

More information about the systems and standards can be found at <http://www.worlddab.org/>.

Appendix 1

Summary of MBMS system (the telecom network based Multimedia Broadcast/Multicast Services)

There are telecommunication systems not explicitly dedicated to broadcasting services, such as Multimedia broadcast/multicast services (MBMS), that fulfils the requirements for interoperability between mobile telecommunication services and interactive digital broadcasting services. The MBMS system is intended to work within services other than broadcasting.

Recommendation ITU-R BT.1833-2 (08/2012) includes informative Appendix 1 that provides:

- MBMS key characteristics;
 - MBMS requirements;
 - MBMS Broadcast Multicast Service Centre description;
 - MBMS user equipment handheld terminal capabilities;
 - MBMS service and application types;
 - MBMS radio bearer implementation description;
 - performance of MBMS for mobile reception;
 - specifications of MBMS for mobile reception; and
 - informative references.
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