RECOMMENDATION ITU-R BT.1306

ERROR-CORRECTION, DATA FRAMING, MODULATION AND EMISSION METHODS FOR DIGITAL TERRESTRIAL TELEVISION BROADCASTING

(Question ITU-R 121/11)

(1997)

The ITU Radiocommunication Assembly,

considering

a) that digital terrestrial television broadcasting (DTTB) will be introduced in the VHF/UHF bands by some administrations from 1997;

b) that DTTB should fit into existing channels intended for analogue television transmission;

c) that it may be desirable to support the simultaneous transmission of a hierarchy of nested quality levels (including HDTV, EDTV and SDTV) within a single channel;

d) that it may be necessary for DTTB services to coexist with existing analogue television transmissions for a temporary period;

e) that many types of interference, including co-channel and adjacent channel, ignition noise, multipath and other signal distortions exist in the VHF/UHF bands;

f) that commonalities with alternative media, such as cable and satellite, could be advantageous at the level of outer coding scheme;

g) that it is necessary that the frame synchronization be capable of robustness in channels subject to transmission errors;

h) that it is desirable that the frame structure be adapted to different bit rate channels;

j) that both single carrier and multi-carrier modulation methods may be introduced;

k) that it is desirable that there be maximum commonality of characteristics between systems;

l) that it is desirable that there be maximum commonality between digital terrestrial television transmissions that are required to coexist with existing analogue television transmissions and those that are not,

recommends

1 that administrations wishing to introduce DTTB should use one of the families of error correction, framing, modulation and emission methods outlined in Annex 1.

NOTE 1 – Annex 2 provides preliminary information about systems still under development and which may be of interest to administrations having longer term plans regarding the introduction of digital terrestrial television services. When these systems are developed, they can be considered for inclusion in Annex 1.

ANNEX 1

Table 1 provides information on the developed systems as of November 1996.

Table 1a) provides data for single carrier systems, while Table 1b) provides data about multi-carrier systems. Specifications for Systems A and B are found in Appendices 1 and 2.

TABLE 1

Parameters for DTTB transmission systems

(**Bold** text indicates demonstrated systems as of November, 1996. Normal text indicates proposed extensions of the family)

a) Single carrier systems

	Parameters	**6 MHz**		7 MHz	8 MHz
1	Used bandwidth	**5.38 MHz (–3 dB)**		6.00 MHz (–3 dB)	7.00 MHz (–3 dB)
2	Number of radiated carriers	**1**		1	1
3	Modulation method	**8-VSB**		8-VSB	8-VSB
4	Spectrum shaping function	**Root raised cosine roll off** $R = 5.8\%$		Root raised cosine roll off $R = 8.3\%$	Root raised cosine roll off $R = 7.1\%$
5	Channel occupancy	**See Rec. ITU-R BT.1206**		–	–
6	Active symbol duration	**92.9 ns**		83.3 ns	71.4 ns
7	Overall symbol or segment duration	**77.3 μs (segment)**		69.3 μs (segment)	59.4 μs (segment)
8	Transmission frame duration	**48.4 ms**		43.4 ms	37.2 ms
9	Channel equalization				
10	Inner interleaving	**12 (independently encoded streams interleaved in time)**		24 (independently encoded streams interleaved in time)	28 (independently encoded streams interleaved in time)
11	Outer channel Reed-Solomon (RS) code	**RS (207,187, $T = 10$)**		RS (207,187, $T = 10$)	RS (207,187, $T = 10$)
12	Outer interleaving	**52 segment convolutional byte interleaved**		52 segment convolutional byte interleaved	52 segment convolutional byte interleaved
13	Data randomization/energy dispersal	**16 bit PRBS**		16 bit PRBS	16 bit PRBS
14	Time/frequency synchronization	**Segment sync, pilot carrier**		Segment sync, pilot carrier	Segment sync, pilot carrier
15	Frame synchronization	**Frame sync**		Frame sync	Frame sync
16	Data equalization	**Frame sync, PN.511 and 3 × PN.63**		Frame sync, PN.511 and 3 × PN.63	Frame sync, PN.511 and 3 × PN.63
17	Transmission mode identification	**Mode symbols in frame sync**		Mode symbols in frame sync	Mode symbols in frame sync
18	Net data rate	**19.39 Mbit/s**		21.62 Mbit/s	27.48 Mbit/s
19	Carrier-to-noise ratio in an additive white Gaussian noise (AWGN)	**15.19 dB(1)**		15.19 dB	15.19 dB

TABLE 1 (*continued*)

b) Multi-carrier systems

	Parameters	6 MHz multi-carrier (OFDM)		**7 MHz multi-carrier (OFDM)**	**8 MHz multi-carrier (OFDM)**
1	Used bandwidth	5.64 MHz		**6.66 MHz**	**7.61 MHz**
2	Number of radiated carriers	1 705 (2k mode)(2) 6 817 (8k mode)		**1 705 (2k mode)(2)** **6 817 (8k mode)**	**1 705 (2k mode)(2)** **6 817 (8k mode)**
3	Modulation method	QPSK, 16-QAM, 64-QAM, MR-16-QAM, MR-64-QAM(3)		**QPSK, 16-QAM, 64-QAM, MR-16-QAM, MR-64-QAM(3)**	**QPSK, 16-QAM, 64-QAM, MR-16-QAM, MR-64-QAM(3)**
4	Channel occupancy			**See Rec. ITU-R BT.1206**	**See Rec. ITU-R BT.1206**
5	Active symbol duration	– 301.889 μs (2k mode) 1 207.556 μs (8k mode)		**– 256 μs (2k mode)** **1 024 μs (8k mode)**	**224 μs (2k mode)** **896 μs (8k mode)**
6	Carrier spacing	3 312.477 Hz (2k mode) – 828.119 Hz (8k mode)		**3 906 Hz (2k mode)** **– 976 Hz (8k mode)**	**4 464 Hz (2k mode)** **1 116 Hz (8k mode)**
7	Guard interval duration	1/4, 1/8, 1/16, 1/32 of active symbol duration 9.43, 18.87, 37.74, 75.47 μs (2k mode) 37.74, 75.47, 150.94, 301.89 μs (8k mode)		**1/4, 1/8, 1/16, 1/32 of active symbol duration** **8, 16, 32, 64 μs (2k mode)** **32, 64, 128, 256 μs (8k mode)**	**1/4, 1/8, 1/16, 1/32 of active symbol duration** **7, 14, 28, 56 μs (2k mode)** **28, 56, 112, 224 μs (8k mode)**
8	Overall symbol duration	311.32, 320.76, 339.63, 377.36 μs (2k mode) 1 245.29, 1 283.03, 1 358.50, 1 509.45 μs (8k mode)		**264, 272, 288, 320 μs (2k mode)** **1 048, 1 088, 1 152, 1 280 μs (8k mode)**	**231, 238, 252, 280 μs (2k mode)** **924, 952, 1 008, 1 120 μs (8k mode)**
9	Transmission frame duration	68 OFDM symbols. One super frame consists of 4 frames		**68 OFDM symbols.** **One super-frame consists of 4 frames**	**68 OFDM symbols.** **One super-frame consists of 4 frames**
10	Inner channel code	Convolutional code, mother rate 1/2 with 64 states. Puncturing to rate 2/3, 3/4, 5/6, 7/8		**Convolutional code, mother rate 1/2 with 64 states. Puncturing to rate 2/3, 3/4, 5/6, 7/8**	**Convolutional code, mother rate 1/2 with 64 states. Puncturing to rate 2/3, 3/4, 5/6, 7/8**
11	Inner interleaving	Bit interleaving, depth 126, combined with symbol interleaving (frequency interleaving)		**Bit interleaving, depth 126, combined with symbol interleaving (frequency interleaving)**	**Bit interleaving, depth 126, combined with symbol interleaving (frequency interleaving)**
12	Outer channel Reed-Solomon (RS) code	RS(204,188, $T = 8$)		**RS(204,188, $T = 8$)**	**RS(204,188, $T = 8$)**
13	Outer interleaving	Bytewise convolutional interleaving, $I = 12$		**Bytewise convolutional interleaving, $I = 12$**	**Bytewise convolutional interleaving, $I = 12$**
14	Data randomization/energy dispersal	PRBS		**PRBS**	**PRBS**
15	Time/frequency synchronization	Pilot carriers(4)		**Pilot carriers(4)**	**Pilot carriers(4)**
16	Transmission parameter signalling TPS(5)	Carried by TPS pilot carriers		**Carried by TPS pilot carriers**	**Carried by TPS pilot carriers**

TABLE 1 (*continued*)

b) Multi-carrier systems (*continued*)

	Parameters	6 MHz multi-carrier (OFDM)		**7 MHz multi-carrier (OFDM)**	**8 MHz multi-carrier (OFDM)**
17	Net data rate	Depending on modulation, code rate and guard interval (3.69-23.5 Mbit/s for non-hierarchical modes)(6)		**Depending on modulation, code rate and guard interval (4.35-27.71 Mbit/s for non-hierarchical modes) (6)**	**Depending on modulation, code rate and guard interval (4.98-31.67 Mbit/s for non-hierarchical modes) (6)**
18	Carrier-to-noise ratio in an AWGN channel	Depending on modulation and channel code. 3.1-20.1 dB(7)		**Depending on modulation and channel code. 3.1-20.1 dB(7)**	**Depending on modulation and channel code. 3.1-20.1 dB(7)**

PRBS: pseudo-random binary sequence

VSB: vestigial side band

OFDM: Orthogonal Frequency Division Multiplex

(1) Measured value. After RS decoding, error rate 3×10^{-6}.

(2) 2k mode can be used for single transmitter operation, for single frequency gap-fillers and for small single frequency network. The 8k mode can be used for the same network structures and also for large single frequency network.

(3) 16-QAM, 64-QAM, MR-16-QAM and MR-64-QAM (MR-QAM: non-uniform QAM constellations), may be used for hierarchical transmission schemes. In this case two layers of modulation carry two different MPEG-2 transport streams. The two layers may have different code rates and can be decoded independently.

(4) Pilot carriers are continual pilots, carried by 45 (2k mode) or 177 (8k mode) carriers on all OFDM symbols, and scattered pilots, spread in time and frequency.

(5) Transmission parameter signalling carry information on modulation, code rate and other transmission parameters.

(6) The choice of modulation, code rate and guard interval depends on service requirements and planning environment.

(7) Simulated with perfect channel estimation, non-hierarchical modes. Error rate before RS decoding 2×10^{-4}, error rate after RS decoding 1×10^{-11}.

APPENDIX 1

TO ANNEX 1

System A Standard

BIBLIOGRAPHY

ATSC [September, 1995] Standard A/53. Digital television Standard. The United States Advanced Television Systems Committee.

ATSC [December, 1995] Standard A/52. Digital audio compression standard (AC-3). The United States Advanced Television Systems Committee.

ATSC [January, 1996] Standard A/55. Program guide for digital television. The United States Advanced Television Systems Committee.

ATSC [January, 1996] Standard A/56. System information for digital television. The United States Advanced Television Systems Committee.

ATSC [August, 1996] Standard A/57. Program/episode/version identification. The United States Advanced Television Systems Committee.

ATSC [September, 1996] Standard A/58. Recommended practice; Harmonization with DVB SI in the use of the ATSC digital television standard. The United States Advanced Television Systems Committee.

APPENDIX 2

TO ANNEX 1

System B Standard

BIBLIOGRAPHY

ETSI [May, 1995] ETS 300 472. Digital broadcasting systems for television, sound and data services; Specification for conveying ITU-R System B Teletext in Digital Video Broadcasting (DVB) bitstreams. European Telecommunications Standards Institute, Sophia Antipolis, F-06291 Valbonne Cedex, France.

ETSI [October, 1995] ETR 162. Digital broadcasting systems for television, sound and data services; Allocation of Service Information (SI) codes for Digital Video Broadcasting (DVB) systems. European Telecommunications Standards Institute, Sophia Antipolis, F-06291 Valbonne Cedex, France.

ETSI [May, 1996] ETR 154. Digital Video Broadcasting (DVB); Implementation guidelines for the use of MPEG-2 systems, video and audio in satellite and cable broadcasting applications. European Telecommunications Standards Institute, Sophia Antipolis, F-06291 Valbonne Cedex, France.

ETSI [May, 1996] ETR 211. Digital Video Broadcasting (DVB); Guidelines on implementation and usage of DVB service information. European Telecommunications Standards Institute, Sophia Antipolis, F-06291 Valbonne Cedex, France.

ETSI [October, 1996] ETR 289. Digital Video Broadcasting (DVB); Support for use of scrambling and Conditional Access (CA) within digital broadcasting systems. European Telecommunications Standards Institute, Sophia Antipolis, F-06291 Valbonne Cedex, France.

ETSI [October, 1996] ETS 300 468. Edition 2, Digital Video Broadcasting (DVB); Specification for Service Information (SI) in DVB Systems. European Telecommunications Standards Institute, Sophia Antipolis, F-06291 Valbonne Cedex, France.

ETSI [August, 1997] EN 300 744. Edition 1.1.2, DE/JTC-DVB-8 Digital Video Broadcasting (DVB); Framing structure, channel coding and modulation for digital terrestrial television. European Telecommunications Standards Institute, Sophia Antipolis, F-06291 Valbonne Cedex, France.

ETSI [September 1997] ETS 300 743. Edition 1, DE/JTC-DVB-17 Digital Video Broadcasting (DVB); Subtitling systems. European Telecommunications Standards Institute, Sophia Antipolis, F-06291 Valbonne Cedex, France.

ANNEX 2

Systems under development

(as at November, 1996)

Parameters	COFDM-6 6 MHz channel	6 MHz BST-OFDM[1]	7 MHz BST-OFDM[2]	8 MHz BST-OFDM[2]
Used bandwidth	5.6 MHz	5.6 MHz	6.6 MHz	7.6 MHz
Number of frequency segments		56[1]	66[1]	76[1]
Number of radiated carriers	3 060 (4k mode) 6 120 (8k mode)	1 400 (MODE 1) 5 600 (MODE 2)[2]	1 650 (MODE 1) 6 600 (MODE 2)[2]	1 900 (MODE 1) 7 600 (MODE 2)
Modulation method	64-QAM	DQPSK, 16-QAM and/or 64-QAM[3]		
Channel occupancy	See Rec. ITU-R BT.1206	See Rec. ITU-R BT.1206		
Active symbol duration	– 555.179 μs (4k mode) 1 101.607 μs (8k mode)	250 μs (MODE 1) —1 ms (MODE 2)		
Carrier spacing	1 801.2 Hz (4k mode) – 907.8 Hz (8k mode)	4 kHz (MODE 1) 1 kHz (MODE 2)		
Guard interval duration	25.752 μs (4k mode) 64.0094 μs (8k mode)	1/4, 1/8, 1/16, 1/32 of active symbol duration: 62.5, 31.25, 15.625, 7.8125 μs (MODE 1) 250, 125, 62.5, 31.25 μs (MODE 2)		

Parameters	COFDM-6 6 MHz channel	6 MHz BST-OFDM[1]	7 MHz BST-OFDM[2]	8 MHz BST-OFDM[2]
Overall symbol or segment duration	580.254 μs (4k mode) 1 165.6164 μs (8k mode)	312.5, 281.25, 265.625, 257.8 125 μs (MODE 1) 1 250, 1 125, 1 062.5, 1 031.25 μs (MODE 2)		
Transmission frame duration	102 data symbols + 3 reference symbols	280 symbols		
Inner channel code		Convolutional code, mother rate 1/2 with 64 states. Puncturing to rate 3/4, 7/8[3]		
Inner interleaving	Frequency interleaving	Frequency and time interleaving: depending on the number of carriers and the modulation method		
Outer channel Reed-Solomon (RS) code	RS (255,239, $T = 8$)	RS (204,188, $T = 8$)		
Outer interleaving		Bytewise convolutional interleaving, $I = 12$		
Data randomization/ energy dispersal	PRBS	PRBS		
Time/frequency synchronization		Pilot symbols and pilot carriers (TMCC)[4]		
Frame synchronization		Pilot symbols		
Data equalization		Pilot symbols and pilot carriers (TMCC)[4]		
Transmission parameter signalling/transmission mode identification		Carried by pilot carriers (TMCC)[4]		
Net data rate	≈ 19 Mbit/s	Depending on modulation, code rate and guard interval (3.85-24.50 Mbit/s)	Depending on modulation, code rate and guard interval (4.54-28.87 Mbit/s)	Depending on modulation, code rate and guard interval (5.22-33.25 Mbit/s)
Carrier-to-noise ratio in an AWGN channel	15.7 dB	Depending on modulation and channel code. 6.0 dB (DQPSK, 1/2) – 20 dB (64-QAM, 7/8)[5]		

COFDM: coded orthogonal frequency division multiplex

BST-OFDM: band segmented transmission-orthogonal frequency division multiplex

(1) The bandwidth of a frequency segment (BST-segment) is 100 kHz, which consists of 25 carriers for MODE 1 or 100 carriers for MODE 2.

(2) MODE 1 accommodates fixed and mobile reception in small or regional single frequency networks (SFNs). MODE 2 can be used for large SFNs.

(3) The modulation scheme and the code rate for the error correcting code can be set independently for each BST-segment.

(4) TMCC (transmission and multiplexing configuration control) is transmitted by the centre carriers of each BST-segment.

(5) Error rate before RS decoding 2×10^{-4}, error rate after RS decoding 1×10^{-11}. Simulated with perfect channel estimation in the case of 64-QAM.

NOTE 1 – BST-OFDM provides the capability of bandwidth flexibility and mobile reception.