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Recommendation ITU-R BT.1877-3
(12/2020)

Error-correction, data framing, modulation and emission methods and selection guidance for second generation digital terrestrial television broadcasting systems

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Broadcasting service (television)

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Note*: This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.*

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RECOMMENDATION ITU-R BT.1877-3*

Error-correction, data framing, modulation and emission methods and selection guidance for second generation digital terrestrial television broadcasting systems

(Questions ITU-R 132-5/6, 133-1/6)

(2010-2012-2019-2020)

Scope

This Recommendation defines error-correction, data framing, modulation and emission methods for the second generation of digital terrestrial television broadcasting transmission systems[1] (referred to, outside ITU-R, as a DVB-T2, ATSC 3.0, or DTMB-A system, respectively). Some of these systems have been developed such that they are compatible with the provisions of the GE06 Agreement. This Recommendation is intended for the digital terrestrial broadcasting transmission system, when high flexibility in the system configuration and broadcasting interactivity is of importance allowing for a wide-ranging trade-off between operation under minimal *C*/*N* levels or maximum transmission capacity[2].

Keywords

Data framing, Digital Terrestrial Television Broadcasting, emission methods, error correction, modulation characteristics, second generation

The ITU Radiocommunication Assembly,

considering

a) that the digital terrestrial television systems for use in broadcasting systems have been developed in Recommendation ITU-R BT.1306, which are referred to as the current systems;

b) that digital terrestrial television broadcasting (DTTB) is being introduced in the VHF/UHF bands by some administrations from 1997 and second generation systems are currently being deployed by some administrations;

c) that it may be desirable to support the simultaneous transmission of a hierarchy of nested quality levels (including low definition television (LDTV), high definition television (HDTV), ultra-high definition television (UHDTV), standard definition TV (SDTV), and supplementary data within a single channel;

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

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* Radiocommunication Study Group 6 made editorial amendments to this Recommendation in the year 2021 in accordance with Resolution ITU-R 1.

[1] The second generation of digital terrestrial television broadcasting transmission systems in this Recommendation is meant as systems offering higher bit rate capacity per Hz and better power efficiency in comparison to the systems described in Recommendation ITU-R BT.1306, and there is no general requirement for backward compatibility with first-generation systems.

[2] For the first-generation systems, information on planning parameters, protection ratios, etc. is already contained in relevant ITU-R Recommendations. For the second-generation systems, there is a need to study and include such information in the relevant ITU-R Recommendations.

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

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

g) that recent developments in the field of channel coding and modulation have produced new techniques with performances approaching the Shannon limit;

h) that these new digital techniques would offer better spectrum and/or power efficiency, in comparison to the current systems, whilst maintaining the possibility to be flexibly configured to cope with the specific broadcasting bandwidth and power resources;

i) that the recommended systems make use of such techniques and thus allow for a wide-ranging trade-off between operation under minimal *C*/*N* levels or maximum transmission capacity;

j) that the recommended systems would be capable to handle the variety of advanced audiovisual formats currently available and under definition, including immersive audio and ultra-high definition transmissions;

k) that the selection of a modulation option needs to be based on specific conditions such as spectrum resource, policy, coverage requirements, existing network structure, reception conditions, type of service required, cost to the consumer and broadcasters;

l) that advances in digital television transmission techniques are required to support content delivery to mobile devices;

m) that second generation systems may also support IMT-2020 data transport to supplement downlink capacity offload and provide flexibility and efficiencies for telecommunications platforms,

recommends

that administrations wishing to introduce the second generation DTTB systems may consider one of the families of error correction, framing, modulation and emission methods outlined within Annexes 1, 2 and 3, with the system selection guidelines provided in Annex 4.

Annex 1

DVB-T2

Currently two variants of the system are considered (referred to, outside ITU-R, as a DVB-T2 system) – for fixed and mobile reception of SDTV and HDTV services (referred to as the T2-Base profile or simply DVB-T2) and for reception by very low capacity applications such as mobile broadcasting (referred to as the T2-Lite profile). T2-Lite signals may also be received by conventional stationary DVB-T2 receivers.

Table 1 provides general data about the second-generation multi-carrier system with multiple physical layer pipes (PLP) covering both profiles. Notes 9 to 13 to Table 1 contain information on restrictions with respect to the T2-Base and T2-Lite profiles. Specifications and implementation guidelines for both profiles of this system are found in Attachment 1 to Annex 1.

TABLE 1

Parameters for the DVB-T2 DTTB transmission system
Second-generation multi-carrier system with multiple physical layer pipes (PLP)(1)

No.	Parameters	1.7 MHz multi-carrier (OFDM)(2)	5 MHz multi-carrier (OFDM)(2)	6 MHz multi-carrier (OFDM)	7 MHz multi-carrier (OFDM)	8 MHz multi-carrier (OFDM)	10 MHz multi-carrier (OFDM)(2)
1	Used bandwidth	1.54 MHz in normal mode	4.76 MHz in normal mode 4.82 MHz in extended mode (8k mode) 4.86 MHz in extended mode (16k and 32k mode)	5.71 MHz in normal mode 5.79 MHz in extended mode (8k mode) 5.83 MHz in extended mode (16k and 32k mode)	6.66 MHz in normal mode 6.75 MHz in extended mode (8k mode) 6.80 MHz in extended mode (16k and 32k mode)	7.61 MHz in normal mode 7.72 MHz in extended mode (8k mode) 7.77 MHz in extended mode (16k and 32k mode)	9.51 MHz in normal mode 9.65 MHz in extended mode (8k mode) 9.71 MHz in extended mode (16k and 32k mode)
2	Number of radiated carriers						
	1k mode(10)	853	853	853	853	853	853
	2k mode	1 705	1 705	1 705	1 705	1 705	1 705
	4k mode	3 409	3 409	3 409	3 409	3 409	3 409
	8k mode	6 817 (8k mode)	6 817 (8k mode) 6 913 (8k extended mode)	6 817 (normal mode) 6 913 (extended mode)	6 817 (normal mode) 6 913 (extended mode)	6 817 (normal mode) 6 913 (extended mode)	6 817 (8k mode) 6 913 (8k extended mode)
	16k mode		13 633 (16k mode) 13 921 (16k extended mode)	13 633 (normal mode) 13 921 (extended mode)	13 633 (normal mode) 13 921 (extended mode)	13 633 (normal mode) 13 921 (extended mode)	13 633 (16k mode) 13 921 (16k extended mode)
	32k mode(10)		27 265 (32k mode) 27 841 (32k extended mode)	27 265 (normal mode) 27 841 (extended mode)	27 265 (normal mode) 27 841 (extended mode)	27 265 (normal mode) 27 841 (extended mode)	27 265 (32k mode) 27 841 (32k extended mode)
3	Modulation modes	Constant coding and modulation (CCM)/variable coding and modulation (VCM)					

TABLE 1 (*continued*)

No.	Parameters	1.7 MHz multi-carrier (OFDM)(2)	5 MHz multi-carrier (OFDM)(2)	6 MHz multi-carrier (OFDM)	7 MHz multi-carrier (OFDM)	8 MHz multi-carrier (OFDM)	10 MHz multi-carrier (OFDM)(2)
4	Modulation method	QPSK, 16-QAM, 64-QAM, 256-QAM specific for each physical layer pipe					
5	Channel occupancy	To be defined(2)			See Rec. ITU-R BT.1206		To be defined(2)
6	Active symbol duration						
	1k mode(10)	554.99 µs	179.2 µs	149.33 µs	128 µs	112 µs	89.60 µs
	2k mode	1 109.98 µs	358.4 µs	298.67 µs	256 µs	224 µs	179.20 µs
	4k mode	2 219.97 µs	716.8 µs	597.33 µs	512 µs	448 µs	358.40 µs
	8k mode	4 439.94 µs	1 433.6 µs	1 194.67 µs	1 024 µs	896 µs	716.8 µs
	16k mode		2 867.2 µs	2 389.33 µs	2 048 µs	1 792 µs	1 433.6 µs
	32k mode(10)		5 734.40 µs	4 778.67 µs	4 096 µs	3 584 µs	2 867.2 µs
7	Carrier spacing						
	1k mode(10)	1 801.91 Hz	5 580.63 Hz	6 696.75 Hz	7 812.88 Hz	8 929 Hz	11 161.25 Hz
	2k mode	900.86 Hz	2 790 Hz	3 348 Hz	3 906 Hz	4 464 Hz	5 580.00 Hz
	4k mode	450.43 Hz	1 395 Hz	1 674 Hz	1 953 Hz	2 232 Hz	2 790.00 Hz
	8k mode	225.21 Hz	697.50 Hz	837 Hz	976 Hz	1 116 Hz	1 395.00 Hz
	16k mode		348.75 Hz	418.5 Hz	488.25 Hz	558 Hz	697.50 Hz
	32k mode(10)		174.38 Hz	209.25 Hz	244.125 Hz	279 Hz	348.75 Hz

TABLE 1 (*continued*)

No.	Parameters	1.7 MHz multi-carrier (OFDM)(2)	5 MHz multi-carrier (OFDM)(2)	6 MHz multi-carrier (OFDM)	7 MHz multi-carrier (OFDM)	8 MHz multi-carrier (OFDM)	10 MHz multi-carrier (OFDM)(2)
8	Guard interval duration(3)	1/128, 1/32, 1/16, 19/256, 1/8, 19/128, 1/4 of active symbol duration	1/128, 1/32, 1/16, 19/256, 1/8, 19/128, 1/4 of active symbol duration	1/128, 1/32, 1/16, 19/256, 1/8, 19/128, 1/4 of active symbol duration	1/128, 1/32, 1/16, 19/256, 1/8, 19/128, 1/4 of active symbol duration	1/128, 1/32, 1/16, 19/256, 1/8, 19/128, 1/4 of active symbol duration	1/128, 1/32, 1/16, 19/256, 1/8, 19/128, 1/4 of active symbol duration
	1k mode(10)	34.69, 69.37, 138.75 μs	11.2, 22.4, 44.8 μs	9.3, 18.6, 37.3 μs	8, 16, 32 μs	7, 14, 28 μs	5.6, 11.2, 22.4 μs
	2k mode	34.69, 69.37, 138.75, 277.50 μs	11.2, 22.4, 44.8, 89.6 μs	9.3, 18.6, 37.3, 74.6 μs	8, 16, 32, 64 μs	7, 14, 28, 56 μs	5.6, 11.2, 22.4, 44.8 μs
	4k mode	69.37, 138.75, 277.50, 554.99 μs	22.4, 44.8, 89.6, 179.2 μs	18.6, 37.3, 74.6, 149.3 μs	16, 32, 64, 128 μs	14, 28, 56, 112 μs	11.2, 22.4, 44.8, 89.6 μs
	8k mode	34.69, 138.75, 277.50, 329.53, 554.99, 659.05, 1 109.98 μs	11.2, 44.8, 89.6, 106.4, 179.2, 212.8, 358.4 μs	9.3, 37.3, 74.6, 88.6, 149.3, 177.3, 298.6 μs	8, 32, 64, 75.9, 128, 152, 256 μs	7, 28, 56, 66.5, 112, 133, 224 μs	5.6, 22.4, 44.8, 53.2, 89.6, 106.4, 179.2 μs
	16k mode		22.4, 89.6, 179.2, 212.8, 358.4, 425.6, 716.8 μs	18.6, 74.6, 149.3, 177.3, 298.6, 354.6, 597.3 μs	16, 64, 128, 152, 256, 304, 512 μs	14, 56, 112, 133, 224, 266, 448 μs	11.2, 44.8, 89.6, 106.4, 179.2, 212.8, 358.4 μs
	32k mode(10)		44.8, 179.2, 358.4, 425.6, 716.8, 851.2 μs	37.33, 149.33, 298.67, 354.67, 597.33, 709.33 μs	32, 128, 256, 304, 512, 608 μs	28, 112, 224, 266, 448, 532 μs	22.4, 89.6, 179.2, 212.8, 358.4, 425.6 μs
9	Overall symbol duration						
	1k mode(10)	589.68-4578.69 μs	190.4, 201.6, 224 μs	158.6, 168, 186.6 μs	136, 144, 160 μs	119, 126, 140 μs	95.20-112.00 μs
	2k mode	1 144.67-1 387.48 μs	369.6, 381, 403, 448 μs	308, 317, 336, 373.3 μs	264, 272, 288, 320 μs	231, 238, 252, 280 μs	184.80-224.00 μs
	4k mode	2 289.34-2 774.96 μs	739, 762, 806, 896 μs	616, 635, 672, 746.6 μs	527.9, 544, 576, 640 μs	462, 476, 504, 560 μs	369.60-448.00 μs
	8k mode	4 474.63-5 549.92 μs	1 444.8, 1 478.4, 1 523.2, 1 540, 1 612.8, 1 646.4, 1 792 μs	1 204, 1 232, 1 269.3, 1 283.3, 1 344, 1 372, 1 493.3 μs	1 032, 1 056, 1 088, 1 100, 1 152, 1 176, 1 280 μs	903, 924, 952, 962.5, 1 008, 1 29, 1 120 μs	722.4, 739.2, 761.6, 770, 806.4, 823, 896 μs
	16k mode		2 889, 2 956.8, 3 046.4, 3 080, 3 225.6, 3 292.8, 3 584 μs	2 408, 2 464, 2 538.6, 2 566.6, 2 686, 2 744, 2 986.6 μs	2 064, 2 112, 2 176, 2 200, 2 304, 2 352, 2 560 μs	1 806, 1 848, 1 904, 1 925, 2 016, 2 058, 2 240 μs	1 444.8, 1 478.4, 1 523.2, 1 540, 1 612.8, 1 646.4, 1 792 μs
	32k mode(10)		5 779.20-6 585.60 μs	4 816-5 488 μs	4 128-4 704 μs	3 612, 3 696, 3 808, 3 850, 4 032, 4 116 μs	2 889.6, 2 956.8, 3 046.4, 3 080, 3 225.6, 3 292.8 μs

TABLE 1 (*continued*)

No.	Parameters	1.7 MHz multi-carrier (OFDM)(2)	5 MHz multi-carrier (OFDM)(2)	6 MHz multi-carrier (OFDM)	7 MHz multi-carrier (OFDM)	8 MHz multi-carrier (OFDM)	10 MHz multi-carrier (OFDM)(2)
10	Transmission frame duration(6)	Frame starts with preamble and has a configurable number of symbols, with maximum duration of 250 ms. Minimum number of data symbols is 3 (32k mode) or 7 (other modes). Super-frame length is configurable, maximum 256 frames, 64 s					
11	Input stream format(4)	Either transport streams (TS) or generic streams (GS)					
12	System stream format	BB format(5)	BB format				
13	Mode adaptation code	CRC-8					
14	Channel coding(9)	LDPC/BCH code with block size of 64 800 (64 K)(10) or 16 200 (16 K) bits and code rates 1/3(9), 2/5(9), 4/9, 1/2, 3/5, 2/3, 11/15, 3/4(10), 4/5(10), 37/45(10), 5/6(10)					
15	Interleaving	Bit, cell and time interleaving separately for each physical layer pipe. Common frequency interleaving(1)					
16	Constellation rotation	None, 29 (QPSK), 16.8 (16-QAM), 8.6 (64-QAM) degrees or atn (1/16) (256-QAM)(10)					
17	Physical layer pipes (PLP)	Mode A with single PLP and mode B with multiple PLPs. Modulation, coding and time interleaving depth selectable separately for each PLP(1) (7)					
18	Data randomization/ energy dispersal	PRBS					
	Initial scan	Fast scan process with special preamble symbol P1					
19	Time/frequency synchronization	Preamble symbols P1 and P2. Scattered pilot carriers with 8 different pilot patterns available(13). Continual pilots					
20	MISO	An optional 2 × 1 Multiple Input Single Output (MISO) with Alamouti coding					
21	Receiver power consumption reduction	Physical layer pipes are organized as subslices in the frame. When receiving a single PLP only the preamble and relevant subslices are received and processed					
22	Layer 1 signalling	L1 signalling is carried by P2 symbols in the preamble. L1 pre-signalling is modulated with BPSK and coded with 1/4 16k LDPC. L1 post-signalling has configurable modulation and 1/2 16k LDPC coding. Option for in-band signalling within the PLP					
23	Layer 1 signalling	Either within the data PLPs or with special common PLP at the beginning of the frame					

TABLE 1 (*end*)

No.	Parameters	1.7 MHz multi-carrier (OFDM)(2)	5 MHz multi-carrier (OFDM)(2)	6 MHz multi-carrier (OFDM)	7 MHz multi-carrier (OFDM)	8 MHz multi-carrier (OFDM)	10 MHz multi-carrier (OFDM)(2)
24	PAPR (Peak-to-Average Power Ratio)	Active Constellation Extension (ACE) and Tone Reservation (TR) as options					
25	Future Extension Frames (FEF)	A super frame can include one or several FEF-parts. These can be used for future extensions of the system					
26	Net data rate	0.22-10.17 Mbit/s, depending on FFT-size, modulation, code rate, guard interval, pilot pattern, MISO, FEF, PAPR	3.01-31.55 Mbit/s, depending on FFT-size, modulation, code rate, guard interval, pilot pattern, MISO, FEF, PAPR	4.01-37.8 Mbit/s, depending on FFT-size, modulation, code rate, guard interval, pilot pattern, MISO, FEF, PAPR	4.68-44.1 Mbit/s, depending on FFT-size, modulation, code rate, guard interval, pilot pattern, MISO, FEF, PAPR	5.35-50.4 Mbit/s, depending on FFT-size, modulation, code rate, guard interval, pilot pattern, MISO, FEF, PAPR	5.93-63.23 Mbit/s, depending on FFT-size, modulation, code rate, guard interval, pilot pattern, MISO, FEF, PAPR
27	Carrier-to-noise ratio in an AWGN channel	Depending on modulation and channel code. –1 to 22 dB(8)					
28	Time interleaving memory	$2^{19}+2^{15}$ cells(11), 2^{18} cells(12)					

BCH: Bose – Chaudhuri – Hocquenghem multiple error correction binary block code.

LDPC: Low density parity check.

OFDM: Orthogonal frequency division multiplex.

PRBS: Pseudo-random binary sequence….0.

QAM: Quadrature amplitude modulation.

QPSK: Quaternary phase shift keying.

Notes to Table 1:

(1) Possibility for one or multiple PLP, each having its own specific modulation, coding and time interleaving depth, thus enabling service-specific robustness.

(2) Spectrum-shaping limits for digital terrestrial television systems using 5 MHz, 6 MHz and 10 MHz channels needs to be defined. The 1.7, 5 and 10 MHz channel variants are not normally used for TV-broadcasting purposes in the VHF III or UHF IV/V bands. The 7 and 8 MHz variants of the system are compatible with the GE06 Agreement with respect to spectrum usage. The 1.7 MHz variant is compatible with T-DAB frequency planning.

(3) All the fractions are not available for all FFT-modes.

(4) As defined in EN 302 755 (DVB-T2 standard), system support following input stream formats: GSE (Generic Stream Encapsulated format), GFPS (Generic Fixed-length Packetized Stream format), GCS (Generic Continuous Stream format) and MPEG-2 TS.

(5) Base band format, used in this second-generation broadcasting system.

(6) Values correspond to maximum frame length in OFDM symbols excluding P1 symbols. For 1k mode the maximum length is defined for guard interval duration of 1/16, 1/8 and 1/4. For 4k and 2k modes the maximum length is defined for 1/32, 1/16, 1/8 and 1/4. In the case of 32k mode non-applicable only 1/4 guard interval. For more information see EN 302 755 (DVB-T2 standard). Number of OFDM symbols for 1.7 MHz, 5 MHz, 6 MHz, 7 MHz, 10 MHz is to be defined.

(7) The system has a future option to spread the PLP subslices over multiple RF-channels within the frame. Time interleaving is applied over all these. Single profile receivers based on the first release of the specification do not support this.

(8) Simulated in Gaussian channels with BER 1×10^{-4} before BCH coding, without correction for pilot boosting (which is dependent on pilot pattern). The expected implementation loss due to real channel estimation needs also to be added to the figures. This will be significantly less than the corresponding figure for first-generation multi-carrier systems due to better optimization of the boosting and pattern densities for second-generation multi-carrier systems.

(9) Not used in T2-Base profile.

(10) Not used in T2-Lite profile.

(11) Applies to the T2-Base profile.

(12) Applies to the T2-Lite profile.

(13) T2-Lite profile has 7 pilot patters.

Attachment 1
to Annex 1

System standard

ETSI EN 302 755. Digital Video Broadcasting (DVB); Frame structure channel coding and modulation for a second generation digital terrestrial television broadcasting system (DVB-T2).

ETSI TR 102 831. Digital Video Broadcasting (DVB); Implementation guidelines for a second generation digital terrestrial television broadcasting system (DVB-T2).

Annex 2

ATSC 3.0

ATSC 3.0 is a suite of voluntary technical Standards and Recommended Practices that is fundamentally different from, and an operational replacement for, the predecessor ATSC Standard (known as ATSC 1.0), which was essentially limited to video and audio.

Compared to the current ATSC 1.0 standard, the ATSC 3.0 standard is intended to allow substantial improvements in performance, functionality and efficiency sufficient to warrant implementation of a non-backwards-compatible system. With higher capacity to deliver dramatically improved quality for video services, robust mobile reception on a wide range of devices, improved efficiency, IP transport, advanced emergency alerting, personalization features, and interactive capability, the ATSC 3.0 suite of standards provides much more capability than previous generations of terrestrial broadcasting in the same spectrum bandwidth. It also provides a means to integrate broadcast and broadband services and thus can be part of the 5G transmission ecosystem.

The ATSC 3.0 transmission system parameters are considered from very robust mobile reception to high-capacity fixed reception of SDTV, HDTV, and UHDTV services. Table 2 provides general data about the ATSC 3.0 system with multiple physical layer pipes (PLPs) covering both mobile and fixed receptions. Specifications and implementation guidelines of this system are found in Attachments 1 and 2 to Annex 2.

TABLE 2

Parameters for the ATSC 3.0 DTTB transmission system
Multi-carrier system with multiple physical layer pipes (PLP)(1)

No.	Parameters	1.7 MHz multi-carrier (OFDM)(2)	5 MHz multi-carrier (OFDM)(2)	6 MHz multi-carrier (OFDM)	7 MHz multi-carrier (OFDM)	8 MHz multi-carrier (OFDM)	10 MHz multi-carrier (OFDM)(2)
1	Used bandwidth Reduced coefficient (Cred_coeff)	NA	NA				NA
	0			5.832 MHz	6.804 MHz	7.777 MHz	
	1			5.751 MHz	6.710 MHz	7.669 MHz	
	2			5.670 MHz	6.615 MHz	7.561 MHz	
	3			5.589 MHz	6.521 MHz	7.453 MHz	
	4			5.508 MHz	6.426 MHz	7.345 MHz	
2	Number of radiated carriers	NA	NA				NA
	8k mode			6 913 (Cred_coeff=0) 6 817 (Cred_coeff=1) 6 721 (Cred_coeff=2) 6 625 (Cred_coeff=3) 6 529 (Cred_coeff=4)	6 913 (Cred_coeff=0) 6 817 (Cred_coeff=1) 6 721 (Cred_coeff=2) 6 625 (Cred_coeff=3) 6 529 (Cred_coeff=4)	6 913 (Cred_coeff=0) 6 817 (Cred_coeff=1) 6 721 (Cred_coeff=2) 6 625 (Cred_coeff=3) 6 529 (Cred_coeff=4)	
	16k mode			13 825 (Cred_coeff=0) 13 633 (Cred_coeff=1) 13 441 (Cred_coeff=2) 13 249 (Cred_coeff=3) 13 057 (Cred_coeff=4)	13 825 (Cred_coeff=0) 13 633 (Cred_coeff=1) 13 441 (Cred_coeff=2) 13 249 (Cred_coeff=3) 13 057 (Cred_coeff=4)	13 825 (Cred_coeff=0) 13 633 (Cred_coeff=1) 13 441 (Cred_coeff=2) 13 249 (Cred_coeff=3) 13 057 (Cred_coeff=4)	
	32k mode			27 649 (Cred_coeff=0) 27 265 (Cred_coeff=1) 26 881 (Cred_coeff=2) 26 497 (Cred_coeff=3) 26 113 (Cred_coeff=4)	27 649 (Cred_coeff=0) 27 265 (Cred_coeff=1) 26 881 (Cred_coeff=2) 26 497 (Cred_coeff=3) 26 113 (Cred_coeff=4)	27 649 (Cred_coeff=0) 27 265 (Cred_coeff=1) 26 881 (Cred_coeff=2) 26 497 (Cred_coeff=3) 26 113 (Cred_coeff=4)	

TABLE 2 (*continued*)

No.	Parameters	1.7 MHz multi-carrier (OFDM)(2)	5 MHz multi-carrier (OFDM)(2)	6 MHz multi-carrier (OFDM)	7 MHz multi-carrier (OFDM)	8 MHz multi-carrier (OFDM)	10 MHz multi-carrier (OFDM)(2)
3	Guard interval duration	NA	NA	192, 384, 512, 768, 1024, 1536, 2048, 2432, 3072, 3648, 4096, 4864 sample duration	192, 384, 512, 768, 1024, 1536, 2048, 2432, 3072, 3648, 4096, 4864 sample duration	192, 384, 512, 768, 1024, 1536, 2048, 2432, 3072, 3648, 4096, 4864 sample duration	NA
	8k mode			27.778, 55.556, 74.074, 111.111, 148.148, 222.222, 296.296 µs (192, 384, 512, 768, 1024, 1536, 2048 sample duration)	23.810, 47.619, 63.492, 95.238, 126.984, 190.476, 253.968 µs (192, 384, 512, 768, 1024, 1536, 2048 sample duration)	20.833, 41.667, 55.556, 83.333, 111.111, 166.667, 222.222 µs (192, 384, 512, 768, 1024, 1536, 2048 sample duration)	
	16k mode			27.778, 55.556, 74.074, 111.111, 148.148, 222.222, 296.296, 351.852, 444.444, 527.778, 592.593 µs (192, 384, 512, 768, 1024, 1536, 2048, 2432, 3072, 3648, 4096 sample duration)	23.810, 47.619, 63.492, 95.238, 126.984, 190.476, 253.968, 301.587, 380.952, 452.381, 507.937 µs (192, 384, 512, 768, 1024, 1536, 2048, 2432, 3072, 3648, 4096 sample duration)	20.833, 41.667, 55.556, 83.333, 111.111, 166.667, 222.222, 263.889, 333.333, 395.833, 444.444 µs (192, 384, 512, 768, 1024, 1536, 2048, 2432, 3072, 3648, 4096 sample duration)	
	32k mode			27.778, 55.556, 74.074, 111.111, 148.148, 222.222, 296.296, 351.852, 444.444, 527.778, 592.593, 703.704 µs (192, 384, 512, 768, 1024, 1536, 2048, 2432, 3072, 3648, 4096, 4864 sample duration)	23.810, 47.619, 63.492, 95.238, 126.984, 190.476, 253.968, 301.587, 380.952, 452.381, 507.937, 603.175 µs (192, 384, 512, 768, 1024, 1536, 2048, 2432, 3072, 3648, 4096, 4864 sample duration)	20.833, 41.667, 55.556, 83.333, 111.111, 166.667, 222.222, 263.889, 333.333, 395.833, 444.444, 527.778 µs (192, 384, 512, 768, 1024, 1536, 2048, 2432, 3072, 3648, 4096, 4864 sample duration)	

TABLE 2 (*continued*)

No.	Parameters	1.7 MHz multi-carrier (OFDM)(2)	5 MHz multi-carrier (OFDM)(2)	6 MHz multi-carrier (OFDM)	7 MHz multi-carrier (OFDM)	8 MHz multi-carrier (OFDM)	10 MHz multi-carrier (OFDM)(2)
4	Active symbol duration	NA	NA				NA
	8k mode			1 185.185 µs	1 015.873 µs	888.889 µs	
	16k mode			2 370.370 µs	2 031.746 µs	1 777.778 µs	
	32k mode			4 740.740 µs	4 063.492 µs	3 555.556 µs	
5	Carrier spacing	NA	NA				NA
	8k mode			843.75 Hz	984.375 Hz	1 125 Hz	
	16k mode			421.875 Hz	492.1875 Hz	562.5 Hz	
	32k mode			210.9375 Hz	246.09375 Hz	281.25 Hz	
6	Overall symbol duration	NA	NA				NA
	8k mode			1 212.963, 1 240.741, 1 259.259, 1 296.296, 1 333.333, 1 407.407, 1 481.481 µs	1 039.683, 1 063.492, 1 079.365, 1 111.111, 1 142.857, 1 206.349, 1 269.841 µs	909.722, 930.556, 944.445, 972.222, 1 000.000, 1 055.556, 1 111.111 µs	
	16k mode			2 398.148, 2 425.926, 2 444.444, 2 481.481, 2 518.518, 2 592.592, 2 666.666, 2 722.222, 2 814.814, 2 898.148, 2 962.963 µs	2 055.556, 2 079.365, 2 095.238, 2 126.984, 2 158.730, 2 222.222, 2 285.714, 2 333.333, 2 412.698, 2 484.127, 2.539.683 µs	1 798.611, 1 819.445, 1 833.334, 1 861.111, 1 888.889, 1 944.445, 2 000.000, 2 041.667, 2 111.111, 2 173.611, 2.222.222 µs	
	32k mode			4 768.518, 4 796.296, 4 814.814, 4 851.851, 4 888.888, 4 962.962, 5 037.036, 5 092.592, 5 185.184, 5 268.518, 5 333.333, 5 444.444 µs	4 087.302, 4 111.111, 4 126.984, 4 158.730, 4 190.476, 4 253.968, 4 317.460, 4 365.079, 4 444.444, 4 515.873, 4 571.429, 4 666.667 µs	3 576.389, 3 597.223, 3 611.112, 3 638.889, 3 666.667, 3 722.223, 3 777.778, 3 819.445, 3 888.889, 3 951.389, 4 000.000, 4 083.334 µs	

TABLE 2 (*continued*)

No.	Parameters	1.7 MHz multi-carrier (OFDM)(2)	5 MHz multi-carrier (OFDM)(2)	6 MHz multi-carrier (OFDM)	7 MHz multi-carrier (OFDM)	8 MHz multi-carrier (OFDM)	10 MHz multi-carrier (OFDM)(2)
7	Transmission frame duration	Frame starts with bootstrap and has a configurable number of preamble symbols and subframes. The minimum frame length is 50 ms and the maximum frame length is 5 seconds					
8	Frame length mode	Symbol-aligned, Time-aligned (5 ms unit)					
9	Input stream format	ATSC Link-Layer Protocol (ALP) Packet					
10	System stream format	Baseband Packet (BBP) format					
11	Channel coding	Inner code: LDPC code with block size of 64 800 (64 K) or 16 200 (16 K) bits and code rates 2/15, 3/15, 4/15, 5/15, 6/15, 7/15, 8/15, 9/15, 11/15, 12/15, 13/15 Outer code: BCH, CRC, None					
12	Modulation	QPSK, 16-NUC, 64-NUC, 256-NUC, 1024-NUC, 4096-NUC specific for each physical layer pipe					
13	Modulation modes	Constant coding and modulation (CCM)/variable coding and modulation (VCM)					
14	Interleaving Type	Bit Interleaver: separately for each physical layer pipe Time Interleaver: separately for each physical layer pipe Frequency Interleaver: OFDM symbol base					
15	Time Interleaving	Convolutional Time Interleaver Hybrid Time Interleaver (HTI): Cell Interleaver, Twisted Block Interleaver, Convolutional Delay Line					
16	Maximum Time interleaving memory	2^{19} cells for normal mode 2^{20} cells for extended interleaving mode (only for QPSK)					
17	Frequency Interleaving	Always applied to all of the Preamble symbol(s), but optional for data symbol					
18	Physical layer pipes (PLP)	Single PLP or multiple PLPs. Modulation, coding and time interleaving depth selectable separately for each PLP(1), (7)					
19	PLP Multiplexing	TDM, FDM, LDM, and combination of them (e.g. TFDM, LTDM, LFDM)					

TABLE 2 (*end*)

No.	Parameters	1.7 MHz multi-carrier (OFDM)(2)	5 MHz multi-carrier (OFDM)(2)	6 MHz multi-carrier (OFDM)	7 MHz multi-carrier (OFDM)	8 MHz multi-carrier (OFDM)	10 MHz multi-carrier (OFDM)(2)
20	Data randomization/ energy dispersal Initial scan	PRBS Fast scan process with bootstrap					
21	Time/frequency synchronization	Bootstrap and preamble symbol. Scattered pilot. Continual pilots. Edge pilots					
22	MISO	TDCFS (64 or 256 taps) as option					
23	Receiver power consumption reduction	Physical layer pipes are cell-multiplexed in the frame. When receiving a PLP, only the bootstrap, preamble, and relevant cells of the PLP are received and processed					
24	Layer 1 signalling	Bootstrap: Essential parameters enabling emergency alert wake up and decoding the L1-Basic portion of the preamble L1-Basic (fixed 200 bits) in preamble: Signalling parameters that enable the decoding of L1-Detail and the initial processing of the first subframe L1-Detail (variable length) in preamble: Signalling parameters that enable the decoding of the remaining subframes and each PLP L1-Basic has five error protection modes and L1-Detail has seven different error protection modes					
25	PAPR	Active Constellation Extension (ACE) and Tone Reservation (TR) as options					
26	Channel Bonding	Two RF channel bonding only as option					
27	MIMO	Cross-polarized MIMO only as option					
28	Future Extension Frames (FEF)	Bootstrap can indicate different version of frame. Non ATSC 3.0 frame can be used for future extensions of the system					
29	Net data rate	NA	NA	0.93-57.9 Mbit/s, depending on FFT-size, modulation, code rate, guard interval, pilot pattern, MISO, FEF, PAPR	1.08-67.5 Mbit/s, depending on FFT-size, modulation, code rate, guard interval, pilot pattern, MISO, FEF, PAPR	1.24-77.2 Mbit/s, depending on FFT-size, modulation, code rate, guard interval, pilot pattern, MISO, FEF, PAPR	NA
30	Carrier-to-noise ratio in an AWGN channel	Depending on modulation and channel code. –6 to 33 dB(3)					

Notes to Table 2:

AWGN: Additive white Gaussian noise

BCH: Bose – Chaudhuri – Hocquenghem multiple error correction binary block code

FDM: Frequency division multiplexing

LDM: Layered division multiplexing

LDPC: Low density parity check

LFDM: Layered frequency division multiplexing

LTDM: Layered time division multiplexing

MISO: Multiple input single output

MIMO: Multiple input multiple output

NUC: Non-uniform constellation

OFDM: Orthogonal frequency division multiplex

PAPR: Peak-to-average power ratio

PRBS: Pseudo-random binary sequence

QAM: Quadrature amplitude modulation

QPSK: Quaternary phase shift keying

TDCFS: Transmit diversity code filter sets

TDM: Time division multiplexing

TFDM : Time-frequency division multiplexing

(1) Possibility for one or multiple PLP, each having its own specific modulation, coding and time interleaving depth, thus enabling service-specific robustness.

(2) Spectrum-shaping limits for digital terrestrial television systems using 5 MHz, 6 MHz and 10 MHz channels needs to be defined. The 1.7, 5 and 10 MHz channel variants are not normally used for TV-broadcasting purposes in the VHF III or UHF IV/V bands. The 7 and 8 MHz variants of the system are compatible with the GE06 Agreement with respect to spectrum usage. ATSC 3.0 specification supports only 6 MHz, 7 MHz and 8 MHz bandwidths.

(3) Simulated in Gaussian channels with BER 1×10^{-6} after LDPC and BCH decoding, without correction for pilot boosting (which is dependent on pilot pattern). The expected implementation loss due to real channel estimation needs also to be added to the figures.

Attachment 1
to Annex 2

ATSC System standard reference documents

ATSC "ATSC System Discovery and Signaling," Doc. A/321:2016, Advanced Television System Committee, Washington, D.C., 23 March 2016.

ATSC "ATSC Physical Layer Protocol," Doc. A/322:2017, Advanced Television System Committee, Washington, D.C., 6 June 2017.

ATSC "Guidelines for the Physical Layer Protocol," Doc. A/327:2018, Advanced Television System Committee, Washington, D.C., 2 October 2018.

Attachment 2
to Annex 2

Brief presentation of the ATSC 3.0 digital transmission standard

1 Introduction

The Advanced Television Systems Committee is a non-profit organization developing voluntary standards for digital television. The ATSC's 130-plus member organizations represent the broadcast, broadcast equipment, motion picture, consumer electronics, computer, cable, satellite, and semiconductor industries.

ATSC 3.0 is a major version of the ATSC standards for digital television transmission over terrestrial, cable, and satellite networks. It is largely a replacement for the analogue NTSC standard, and like that standard, used mostly in the United States of America, Mexico, Canada and Korea. The new standard was created by the Advanced Television Systems Committee (ATSC). The standard reflects 25 sections including 21 Approved Standards and 4 Recommended Practices, which provide engineering guidance for implementation.

For reference purposes to this Recommendation, summaries of the key standards are reflected below.

A/300:2020 – ATSC 3.0 System

This Standard describes the entire suite of the ATSC 3.0 digital television system. ATSC 3.0 is a suite of voluntary technical Standards and Recommended Practices that is fundamentally different from predecessor ATSC systems and is therefore largely incompatible with them. This divergence from earlier design is intended to allow substantial improvements in performance, functionality, and efficiency sufficient to warrant implementation of a non-backwards-compatible system. With higher capacity to deliver Ultra High-Definition services, robust reception on a wide range of devices, improved efficiency, IP transport, advanced emergency alerting, personalization features and interactive capability, the ATSC 3.0 Standard provides much more capability than previous generations of terrestrial broadcasting.

In the fall of 2011, ATSC formed Technology Group 3 (TG-3) to design a next-generation broadcast system. TG-3 issued a Call for Input to solicit requirements for the system from a broad, international base of interests and organizations. Using this input, thirteen Usage Scenarios were developed, from which were derived a comprehensive set of system requirements. The system requirements established the capabilities of the overall system and thereby served as a guide in the preparation of the ATSC 3.0 suite of standards. The ATSC 3.0 Standard uses a layered architecture. Three layers are defined: Physical, Management and Protocols, and Application and Presentation. To facilitate flexibility and extensibility, different elements of the system are specified in separate Standards. The complete list and structure of these Standards is provided in Section 5.

Each ATSC 3.0 Standard is designed for maximum flexibility in its operation and is extensible to accommodate future adaptation. As a result, it is critical for implementers to use the most up-to-date revision of each Standard. The overall documentation structure also enables individual components of the system to be revised or extended without affecting other components. In some cases, multiple, fully parallel options are specified for certain operations, from which broadcasters can choose whichever method is more suitable to their operations or preferences. Examples include the use of either the MMT or ROUTE transport protocol, or the use of either the AC-4 or MPEG-H 3D Audio system.

Detailed Standard specifics are reflected at:

https://www.atsc.org/wp-content/uploads/2017/10/A300-2020-ATSC-3-System-Standard.pdf

A/321:2016 – System discovery and signalling

This document describes the system discovery and signalling architecture (the "bootstrap") for the ATSC 3.0 physical layer. Broadcasters anticipate providing multiple wireless-based services, in addition to conventional broadcast television in the future. Such services may be time-multiplexed together within a single RF channel. The bootstrap provides a universal entry point into a broadcast waveform. The bootstrap employs a fixed configuration (e.g. sampling rate, signal bandwidth, subcarrier spacing, time-domain structure) known to all receiver devices and carries information to enable processing and decoding the wireless service associated with a detected bootstrap. This capability ensures that broadcast spectrum can be adapted to carry new services and/or waveforms for public interest to continue to be served in the future.

Broadcasters anticipate providing multiple wireless-based services, in addition to just broadcast television, in the future. Such services may be time-multiplexed together within a single RF channel. As a result, there exists a need to indicate, at a low level, the type or form of a signal that is being transmitted during a particular time period, so that a receiver can discover and identify the signal, which in turn indicates how to receive the services that are available via that signal. To enable such discovery, a bootstrap signal can be used. This comparatively short signal precedes, in time, a longer transmitted signal that carries some form of data. New signal types, at least some of which have likely not yet even been conceived, could also be provided by a broadcaster and identified within a transmitted waveform through the use of a bootstrap signal associated with each particular time-multiplexed signal. Some future signal types indicated by a particular bootstrap signal may even be outside the scope of the ATSC.

The bootstrap provides a universal entry point into a broadcast waveform. The bootstrap employs a fixed configuration (e.g. sampling rate, signal bandwidth, subcarrier spacing, time-domain structure) known to all receiver devices and carries information to enable processing and decoding the signal associated with a detected bootstrap. This capability ensures that broadcast spectrum can be adapted to carry new signal types that are preceded by the universal entry point provided by the bootstrap, for public interest to continue to be served in the future. The bootstrap has been designed to be a very robust signal and detectable even at low signal levels. As a result of this robust encoding, individual signalling bits within the bootstrap are comparatively expensive in terms of the physical resources that they occupy for transmission. Hence, the bootstrap is generally intended to signal only the minimum amount of information required for system discovery (i.e. identification of the associated signal) and for initial decoding of the following signal.

The A/321:2016 Standard was approved and adopted by reference into the U.S. FCC Rules 47 CFR § 73.682. Detailed Standard specifics are reflected at:

https://www.atsc.org/wp-content/uploads/2016/03/A321-2016-System-Discovery-and-Signaling-3.pdf

A/322:2020 – Physical layer protocol

This Standard describes the RF/Transmission of a physical layer waveform. This waveform enables flexible configurations of physical layer resources to target a variety of operating modes. The intent is to signal the applied technologies and allow for future technology adaptation.

The ATSC physical layer protocol is intended to offer far more flexibility, robustness and efficient operations than the ATSC A/53 standard, and as a result it is non-backwards compatible with A/53. This physical layer allows broadcasters to choose from among a wide variety of physical layer parameters for personalized broadcaster performance that can satisfy many different broadcaster needs. There is the capability to have high-capacity/low-robustness and low-capacity/high robustness modes in the same emission. Technologies can be selected for special use cases like Single Frequency Networks, Multiple Input Multiple Output channel operation, channel bonding and more, well beyond a single transmitting tower. There is a large range of selections for robustness including, but not limited to, a wide range of guard interval lengths, forward error correction code lengths and code rates. Significant flexibility comes from a signalling structure that allows the physical layer to change technologies and evolve over time, while maintaining support of other ATSC systems. The starting point of this change is a physical layer offering highly spectral efficient operation with strong robustness across many different modes of operation.

Detailed Standard specifics are reflected at:

https://www.atsc.org/wp-content/uploads/2016/10/A322-2020-Physical-Layer-Protocol.pdf

A/327:2020 – Guidelines for the physical layer protocol

This document provides recommended practices for the ATSC 3.0 physical layer protocol standards specified by A/321 and A/322. The intent of this document is to make recommendations for physical layer operating modes so that readers can make informed decisions about physical layer configurations. Also, this document provides some implementation guidelines to aid with flexible configurations of physical layer design resources in transmitter and receiver manufacturers' equipment.

The ATSC 3.0 physical layer protocol is designed to provide a toolbox of technology that allows flexible operating modes for a variety of harsh channel conditions (e.g. indoor or mobile) while maintaining efficient use of spectrum resources. This document provides recommended parameter and technology choices in A/321 and A/322 so that broadcasters can optimally deliver intended service(s). It also contains detailed guidelines for transmitter and receiver design implementations based on engineering studies of the latest technologies in the ATSC 3.0 physical layer. Guidelines for broadcasters' mobile service(s) are provided with operating modes and parameter choices of A/322 in aspects of robustness and power consumption. The ATSC 3.0 system performance and recommended service examples cover aspects of real field experiences and are intended to provide practical guidance for all readers.

Detailed Recommended Practice specifics are reflected at:

https://www.atsc.org/wp-content/uploads/2020/08/A327-2020-Physical-Layer-RP.pdf

Annex 3

DTMB-A

Digital Television Terrestrial Multimedia Broadcasting-Advanced (DTMB-A) is the advanced version of digital television terrestrial broadcasting (DTTB) system (i.e. DTMB), which can support higher data throughput than that of DTMB with more robust performance. DTMB-A supports ultra-high definition, high-definition, standard-definition TV, and data broadcasting services under indoor/outdoor and fixed/mobile reception conditions and can be used for the large-area coverage within both multiple and single frequency networks. DTMB-A adopts multi-carrier modulation methods and advanced coding and modulation scheme with fast system synchronization, high receiving sensitivity, better performance against multi-path effect, high spectrum efficiency and the flexibility for the future extension.

Table 3 provides the system parameters about DTMB-A.

TABLE 3

Parameters for the digital television/terrestrial multimedia broadcasting – advanced

No.	Parameters		6 MHz multi-carrier (OFDM)	7 MHz multi-carrier (OFDM)	8 MHz multi-carrier (OFDM)
1	Used bandwidth		5.67 MHz with the roll off factor of 0.05, 5.83 MHz with the roll off factor of 0.025	6.62 MHz with the roll off factor of 0.05, 6.81 MHz with the roll off factor of 0.025	7.56 MHz with the roll off factor of 0.05, 7.78 MHz with the roll off factor of 0.025
2	Number of radiated carriers	4k mode	4 096	4 096	4 096
		8k mode	8 192	8 192	8 192
		32k mode	32 768	32 768	32 768
3	Modulation modes		Constant coding and modulation (CCM)/ variable coding and modulation (VCM)		
4	Modulation method		QPSK, 16-APSK, 64-APSK, 256-/APSK specific for each Service Channel		
5	Channel occupancy		See Recommendation ITU-R BT.1206		
6	Active symbol duration	4k mode	722.40 µs with the roll off factor of 0.05, 702.17 µs with the roll off factor of 0.025	619.20 µs with the roll off factor of 0.05, 601.86 µs with the roll off factor of 0.025	541.80 µs with the roll off factor of 0.05, 526.63 µs with the roll off factor of 0.025
		8k mode	1444.80 µs with the roll off factor of 0.05, 1404.34 µs with the roll off factor of 0.025	1238.40 µs with the roll off factor of 0.05, 1203.72 µs with the roll off factor of 0.025	1083.60 µs with the roll off factor of 0.05, 1053.26 µs with the roll off factor of 0.025
		32k mode	5779.19 µs with the roll off factor of 0.05, 5617.37 µs with the roll off factor of 0.025	4953.60 µs with the roll off factor of 0.05, 4814.89 µs with the roll off factor of 0.025	4334.40 µs with the roll off factor of 0.05, 4213.03 µs with the roll off factor of 0.025

TABLE 3 (*continued*)

No.	Parameters		6 MHz multi-carrier (OFDM)	7 MHz multi-carrier (OFDM)	8 MHz multi-carrier (OFDM)
7	Carrier spacing	4k mode	1 384 Hz with the roll off factor of 0.05, 1 424 Hz with the roll off factor of 0.025	1 615 Hz with the roll off factor of 0.05, 1 662 Hz with the roll off factor of 0.025	1 846 Hz with the roll off factor of 0.05, 1 899 Hz with the roll off factor of 0.025
		8k mode	692 Hz with the roll off factor of 0.05, 712 Hz with the roll off factor of 0.025	807 Hz with the roll off factor of 0.05, 831 Hz with the roll off factor of 0.025	923 Hz with the roll off factor of 0.05, 949 Hz with the roll off factor of 0.025
		32k mode	173 Hz with the roll off factor of 0.05, 178 Hz with the roll off factor of 0.025	202 Hz with the roll off factor of 0.05, 208 Hz with the roll off factor of 0.025	231 Hz with the roll off factor of 0.05, 237 Hz with the roll off factor of 0.025
8	Guard interval duration	4k mode (1/8, 1/4, 1/2)	90.3, 181, 361 µs with the roll off factor of 0.05. 87.8, 176, 351 µs with the roll off factor of 0.025	77.4, 155, 310 µs with the roll off factor of 0.05. 75.2, 150, 301 µs with the roll off factor of 0.025	67.7, 135, 271 µs with the roll off factor of 0.05. 65.8, 132, 263 µs with the roll off factor of 0.025
		8k mode (1/16, 1/8, 1/4)	90.3, 181, 361 µs with the roll off factor of 0.05. 87.8, 176, 351 µs with the roll off factor of 0.025	77.4, 155, 310 µs with the roll off factor of 0.05. 75.2, 150, 301 µs with the roll off factor of 0.025	67.7, 135, 271 µs with the roll off factor of 0.05. 65.8, 132, 263 µs with the roll off factor of 0.025
		32k mode (1/64, 1/32, 1/16)	90.3, 181, 361 µs with the roll off factor of 0.05. 87.8, 176, 351 µs with the roll off factor of 0.025	77.4, 155, 310 µs with the roll off factor of 0.05. 75.2, 150, 301 µs with the roll off factor of 0.025	67.7, 135, 271 µs with the roll off factor of 0.05. 65.8, 132, 263 µs with the roll off factor of 0.025
9	Overall symbol duration	4k mode	813, 903, 1 084 µs with the roll off factor of 0.05. 790, 878, 1 053 µs with the roll off factor of 0.025	679, 774, 929 µs with the roll off factor of 0.05. 677, 752, 903 µs with the roll off factor of 0.025	610, 677, 813 µs with the roll off factor of 0.05. 592, 658, 790 µs with the roll off factor of 0.025
		8k mode	1 535, 1 625, 1 806 µs with the roll off factor of 0.05. 1 492, 1 580, 1 755 µs with the roll off factor of 0.025	1 316, 1 393, 1 548 µs with the roll off factor of 0.05. 1 279, 1 354, 1 505 µs with the roll off factor of 0.025	1 151, 1 219, 1 354 µs with the roll off factor of 0.05. 1 119, 1 185, 1 317 µs with the roll off factor of 0.025
		32k mode	5 869, 5 960, 6 140 µs with the roll off factor of 0.05. 5 705, 5 793, 5 968 µs with the roll off factor of 0.025	5 031, 5 108, 5 263 µs with the roll off factor of 0.05. 4 890, 4 965, 5 116 µs with the roll off factor of 0.025	4 402, 4 470, 4 605 µs with the roll off factor of 0.05. 4 279, 4 345, 4 467 µs with the roll off factor of 0.025
10	Super frame duration		Super frame starts with super-frame synchronization channel and a control channel for service channel signalling. Each super-frame has configurable number of data signal frames, with maximum duration of 250 µs		

TABLE 3 (*end*)

No.	Parameters	6 MHz multi-carrier (OFDM)	7 MHz multi-carrier (OFDM)	8 MHz multi-carrier (OFDM)
11	Input stream format	Transport streams (TS)		
12	Channel coding	LDPC/BCH code with block size of 61 440 or 15 360 bits and code rates of 1/2, 2/3, 5/6		
13	Interleaving	Bit interleaving, bit permutation and time interleaving separately for each service channel		
14	Service Channel	Support for multiple service channels. Modulation, coding and time interleaving depth selectable separately for each service channel		
15	Data randomization/energy dispersal			
	Initial scan	Fast scan process with special super-frame synchronization channel		
16	Time/frequency synchronization	Super-frame synchronization channel and dual PN-MC symbols of each signal frame		
17	Multiple input single output (MISO)	An optional 2 × 1 MISO configuration with Alamouti coding in the space-frequency domain		
18	Receiver power consumption reduction	Service channels are organized in both time and frequency domains. When receiving a single service channel only the service channel signalling and relevant slices are received and processed		
19	Service channel signalling	Service channel signalling is carried by control channel in the super frame. The signal frame size for the control channel is 4096, and the PM-MC symbol length is 1024, modulated with QPSK and coded with punctured 2/3 15360 LDPC for OFDM.		
20	Peak-to-average power ratio (PAPR)	Special active constellation extension (ACE) for APSK constellation as options		
21	Extension Frame	A super frame can include extension frame. The extension frame can be used as NULL signals or for uplink services		
22	Payload	3.75-37 Mbit/s with the roll off factor of 0.05, 3.86-38 Mbit/s with the roll off factor of 0.025, depending on FFT-size, modulation, code rate, guard interval	4.38-43.1 Mbit/s with the roll off factor of 0.05, 4.5-44.4 Mbit/s with the roll off factor of 0.025, depending on FFT-size, modulation, code rate, guard interval	5.0-49.31 Mbit/s with the roll off factor of 0.05, 5.14-50.73 Mbit/s with the roll off factor of 0.025, depending on FFT-size, modulation, code rate, guard interval
23	Carrier-to-noise ratio over AWGN channel	Depending on modulation and channel code. 0.62-21.08 dB @ BER=1E-5, for the 7.56 MHz system bandwidth		

APSK: Amplitude and phase shift keying

BCH: Bose – Chaudhuri – Hocquenghem multiple error correction binary block code

LDPC: Low density parity check

OFDM: Orthogonal frequency division multiplex

PN-MC: Multi-carrier PN-sequence

PRBS: Pseudo-random binary sequence

QPSK: Quaternary phase shift keying

Attachment 1
to Annex 3

System standard

DTMB-A Chinese Standard GD/J 068-2015. Frame Structure, Channel Coding and Modulation for Digital Television/Terrestrial Multimedia Broadcasting-Advanced (DTMB-A).

Annex 4

System selection guidelines

The system selection requires the identification of requirements and performance parameters that are relevant to the requirements and circumstances of the administration or broadcaster wishing to choose a DTTB system, to be followed by an assessment of which system is most likely to meet the broadcaster's main requirements taking into account the prevailing technical/regulatory environment. Tables 4, 5 and 6 can be used to evaluate the respective characteristics of the systems in selecting a specific system.

Table 4 provides a list of broadcasting requirements and their relevancy to the system parameters and technical features.

Table 5 provides a list of system parameters of the second generation of digital terrestrial television broadcasting systems described in Annexes 1, 2 and 3.

Table 6 provides a list of technical features of the systems described in Annexes 1, 2 and 3 that concern several aspects relevant to implementation and deployment.

An assessment of the commercial and operational aspects may also be conducted to ascertain which of the systems is indeed the best solution overall. Such an assessment will take into account the required timescales to service implementation, cost and availability of equipment, interoperability within an evolving broadcasting environment, etc.

TABLE 4

Requirements and their relevancy to system parameters and technical features

	Requirements	Relevant system parameters in Table 5	Relevant technical features in Table 6
1	Compatibility with channel bandwidth	1	–
2	Minimum latency in channel-zapping	5, 6, 9	–
3	Maximum data rate in a Gaussian channel for a given *C*/*N* threshold	3, 4, 7, 8, 10, 12, 13	5
4	Maximum ruggedness against multipath interference(1)	3, 4, 7, 8, 9, 10, 11	1
5	Single frequency networks (SFNs)	3, 4	1, 3
6	Mobile reception(1)	2	2, 6
7	Simultaneous transmission of different quality levels (hierarchical transmission)	14	4
8	Independent decoding of data sub-blocks (for example, to facilitate sound broadcasting)	14	4
9	Maximum coverage from central transmitter at a given power in a Gaussian environment(2)	7, 8, 10, 13	–
10	Maximum ruggedness against impulse interference	7, 8, 9, 10, 11	–

(1) Tradable against bandwidth efficiency and other system parameters.

(2) For all systems in situations with coverage holes, gap filler transmitters will be required.

TABLE 5

System parameters supported by the systems

	Parameters	DVB-T2 (Annex 1)	ATSC 3.0 (Annex 2)	DTMB-A (Annex 3)
1	Used bandwidth/ Channel bandwidths	a) 1.54 MHz/1.7 MHz		
		b) 4.76-4.86 MHz/5 MHz		
		c) 5.71-5.83 MHz/6 MHz	a) 5.508-5.832 MHz/6 MHz	a) 5.67, 5.83 MHz/6 MHz
		d) 6.66-6.80 MHz/7 MHz	b) 6.426-6.804 MHz/7 MH	b) 6.62, 6.81 MHz/7 MHz
		e) 7.61-7.77 MHz/8 MHz	c) 7.345-7.777 MHz/8 MHz	c) 7.56, 7.78 MHz/8 MHz
		f) 9.51-9.71 MHz/10 MHz		
2	Subcarrier spacing	a) 1 801.91 Hz (1k mode) 900.86 Hz (2k mode) 450.43 Hz (4k mode) 225.21 Hz (8k mode)		
		b) 5 580.63 Hz (1k mode) 2 790 Hz (2k mode) 1 395 Hz (4k mode) 697.50 Hz (8k mode) 348.75 Hz (16k mode) 174.38 Hz (32k mode)		
		c) 6 696.75 Hz (1k mode) 3 348 Hz (2k mode) 1 674 Hz (4k mode) 837 Hz (8k mode) 418.5 Hz (16k mode) 209.25 Hz (32k mode)	a) 843.75 Hz (8k mode) 421.875 Hz (16k mode) 210.9375 Hz (32k mode)	a) 1 384, 1 424 Hz (4k mode) 692, 712 Hz (8k mode) 173, 178 Hz (32k mode)
		d) 7 812.88 Hz (1k mode) 3 906 Hz (2k mode) 1 953 Hz (4k mode) 976 Hz (8k mode) 488.25 Hz (16k mode) 244.125 Hz (32k mode)	b) 984.375 Hz (8k mode) 492.1875 Hz (16k mode) 246.09375 Hz (32k mode)	b) 1 615, 1 662 Hz (4k mode) 807, 831 Hz (8k mode) 202, 208 Hz (32k mode)
		e) 8 929 Hz (1k mode) 4 464 Hz (2k mode) 2 232 Hz (4k mode) 1 116 Hz (8k mode) 558 Hz (16k mode) 279 Hz (32k mode)	c) 1 125 Hz (8k mode), 562.5 Hz (16k mode) 281.25 Hz (32k mode)	c) 1 846, 1 899 Hz (4k mode) 923, 949 Hz (8k mode) 231, 237 Hz (32k mode)
		f) 11 161.25 Hz (1k mode) 5 580 Hz (2k mode) 2 790 Hz (4k mode) 1 395 Hz (8k mode) 697.50 Hz (16k mode) 348.75 Hz (32k mode)		

TABLE 5 (*continued*)

	Parameters	**DVB-T2 (Annex 1)**	**ATSC 3.0 (Annex 2)**	**DTMB-A (Annex 3)**
3	Active symbol duration	a) 554.99 µs (1k) 1 109.98 µs (2k) 2 219.97 µs (4k) 4 439.94 µs (8k)		
		b) 179.2 µs (1k) 358.4 µs (2k) 716.8 µs (4k) 1 433.6 µs (8k) 2 867.2 µs (16k) 5 734.4 µs (32k)		
		c) 149.33 µs (1k) 298.67 µs (2k) 597.33 µs (4k) 1 194.67 µs (8k) 2 389.33 µs (16k) 4 778.67 µs (32k)	a) 1 185.185 µs (8k) 2 370.370 µs (16k) 4 740.740 µs (32k)	a) 722.4, 702.17 µs (4k) 1 444.8, 1 404.34 µs (8k) 5 779.19, 5 617.37 µs (32k)
		d) 128 µs (1k) 256 µs (2k) 512 µs (4k) 1 024 µs (8k) 2 048 µs (16k) 4 096 µs (32k)	b) 1 015.873 µs (8k) 2 031.746 µs (16k) 4 063.492 µs (32k)	b) 619.2, 601.86 µs (4k) 1 238.4, 1 203.72 µs (8k) 4 953.6, 4 814.89 µs (32k)
		e) 112 µs (1k) 224 µs (2k) 448 µs (4k) 896 µs (8k) 1 792 µs (16k) 3 584 µs (32k)	c) 888.889 µs (8k) 1 777.778 µs (16k) 3 555.556 µs (32k)	c) 541.8, 526.63 µs (4k) 1 083.6, 1 053.26 µs (8k) 4 334.4, 4 213.03 µs (32k)
		f) 89.60 µs (1k) 179.20 µs (2k) 358.40 µs (4k) 716.8 µs (8k) 1 433.6 µs (16k) 2 867.2 µs (32k)		

TABLE 5 (*continued*)

	Parameters	DVB-T2 (Annex 1)	ATSC 3.0 (Annex 2)	DTMB-A (Annex 3)
4	Guard interval duration or guard interval ratio	1/128, 1/32, 1/16, 19/256, 1/8, 19/128, 1/4 of active symbol duration	192, 384, 512, 768, 1024, 1536, 2048, 2432, 3072, 3648, 4096, 4864 sample duration	512, 1024, 2048 sample duration
		a) 34.69-138.75 μs (1k) 34.69-277.50 μs (2k) 69.37-554.99 μs (4k) 34.69-554.99 μs (8k)		
		b) 11.2-44.8 μs (1k) 11.2-89.6 μs (2k) 22.4-179.2 μs (4k) 11.2-358.4 μs (8k) 22.4-716.8 μs (16k) 44.8-851.2 μs (32k)		
		c) 9.3-37.3 μs (1k) 9.3-74.6 μs (2k) 18.6-149.3 μs (4k) 9.3-298.6 μs (8k) 18.6-597.3 μs (16k) 37.33-709.33 μs (32k)	a) 27.778-296.296 μs (8k) 27.778-592.593 μs (16k) 27.778-703.704 μs (32k)	a) 87.771-361.2 μs (4k) 87.771-361.2 μs (8k) 87.771-361.2 μs (32k)
		d) 8-32 μs (1k) 8-64 μs (2k) 16-128 μs (4k) 8-256 μs (8k) 16-512 μs (16k) 32-608 μs (32k)	b) 23.810-253.968 μs (8k) 23.810-507.937 μs (16k) 23.810-603.175 μs (32k)	b) 75.233-309.6 μs (4k) 75.233-309.6 μs (8k) 75.233-309.6 μs (32k)
		e) 7-28 μs (1k) 7-56 μs (2k) 14-112 μs (4k) 7-224 μs (8k) 14-448 μs (16k) 28-532 μs (32k)	c) 20.833-222.222 μs (8k) 20.833-444.444 μs (16k) 20.833-527.778 μs (32k)	c) 65.829-270.9 μs (4k) 65.829-270.9 μs (8k) 65.829-270.9 μs (32k)
		f) 5.6-22.4 μs (1k) 5.6-44.8 μs (2k) 11.2-89.6 μs (4k) 5.6-179.2 μs (8k) 11.2-358.4 μs (16k) 22.4-425.6 μs (32k)		
5	Transmission unit (frame) duration	Frame starts with preamble and has a configurable number of symbols, with maximum duration of 250 ms. Minimum number of data symbols is 3 (32k mode) or 7 (other modes). Super-frame length is configurable, maximum 256 frames, 64 seconds	Frame starts with bootstrap and has a configurable number of preamble symbols and subframes. The minimum frame length is 50 ms and the maximum frame length is 5 seconds	Super frame starts with super-frame synchronization channel and a control channel for service channel signalling. Each super-frame has configurable number of data signal frames, with maximum duration of 250 μs

TABLE 5 (*end*)

	Parameters	**DVB-T2 (Annex 1)**	**ATSC 3.0 (Annex 2)**	**DTMB-A (Annex 3)**
6	Time/frequency synchronization	Preamble symbols P1 and P2. Scattered pilot carriers with 8 different pilot patterns available. Continual pilots	Bootstrap and preamble symbol. Scattered pilots. Continual pilots. Edge pilots, Subframe boundary pilots	Super-frame synchronization channel and dual PN-MC symbols of each signal frame
7	Modulation methods	QPSK, 16-QAM, 64-QAM, 256-QAM specific for each physical layer pipe	QPSK, 16-NUC, 64-NUC, 256-NUC, 1024-NUC, 4096-NUC specific for each physical layer pipe	QPSK, 16-APSK, 64-APSK, 256-APSK
8	Inner channel coding	LDPC code with block size of 64 800 (64 K) or 16 200 (16 K) bits and code rates 1/3, 2/5, 4/9, 1/2, 3/5, 2/3, 11/15, 3/4, 4/5, 37/45, 5/6	LDPC code with block size of 64 800 (64 K) or 16 200 (16 K) bits and code rates 2/15, 3/15, 4/15, 5/15, 6/15, 7/15, 8/15, 9/15, 10/15, 11/15, 12/15, 13/15	LDPC code with block size of 61 440 or 15 360 bits and code rates of 1/2, 2/3, 5/6
9	Inner interleaving	Cell, Time and Frequency interleaving	Time and Frequency interleaving	Bit interleaving, bit permutation and time interleaving separately for each service channel
10	Outer channel coding	BCH (64 800 or 16 200, x, t), there x – depends on LDPC code rate. Error correction capability t = 12 errors	BCH, CRC, None	BCH (30720,30512) for LDPC 1/2 BCH (40960,40752) for LDPC 2/3 BCH (51200,50992) for LDPC 5/6
11	Outer Interleaving	Bit (parity & column twist) interleaving	Bit (parity & Group-Wise & Block) interleaving	Symbol interleaving 240 rows and 4 096 columns
12	Net data rates	0.4-63.23 Mbit/s, depending on FFT-size, modulation, code rate, guard interval, pilot pattern, MISO, FEF, PAPR, used bandwidth (minimum/maximum net data rates are achieved with 1.54 MHz/9.71 MHz, respectively)	0.93-77.2 Mbit/s, depending on FFT-size, modulation, code rate, guard interval, pilot pattern, MISO, PAPR, used bandwidth (minimum/maximum net data rates are achieved with 5.508 MHz/7.777 MHz, respectively)	3.75-50.73 Mbit/s, depending on FFT-size, modulation, code rate, guard interval, MISO, frame header, used bandwidth (minimum/maximum net data rates are achieved with 5.67 MHz/7.78 MHz, respectively)
13	Carrier-to-noise ratio in an AWGN channel	Depending on modulation and channel code. –1 to 22 dB	Depending on modulation and channel code. –6 to 33 dB	Depending on modulation and channel code. 0.62 to 21.08 dB
14	Multiplexing scheme	PLP multiplexing with TDM	PLP multiplexing with TDM, FDM, LDM, and combination of them (e.g. TFDM, LTDM, LFDM)	PLP multiplexing with TDM

TABLE 6

Technical features of the systems

	Features	DVB-T2 (Annex 1)	ATSC 3.0 (Annex 2)	DTMB-A (Annex 3)
1	Multipath interference	Possibility of choice of 7 guard interval, 6 OFDM modes, 8 pilot patterns, P1 symbol availability, SISO/MISO modes providing high robustness in multipath environment	Possibility of choice of 12 guard interval, 3 OFDM modes, 16 pilot patterns, SISO/MISO modes providing high robustness in multipath environment	Possibility of choice of 6 guard interval, 3 OFDM modes, SISO/ MISO modes providing high robustness in multipath environment
2	Fading environments	Possibility of choice of different OFDM modes, different depth of interleaving and mechanisms of interleaving (approx. 5 stages of interleaving and some virtual interleaving) allowing for robust operation in fading condition	Possibility of choice of different OFDM modes, different depth of interleaving and mechanisms of interleaving (approx. 5 stages of interleaving and some virtual interleaving) allowing for robust operation in fading condition	Possibility of choice of different OFDM modes, different depth of interleaving and mechanisms of interleaving allowing for robust operation in fading condition
3	Single frequency networks	SFN cell radius is mostly dependent on the OFDM mode and selection of the guard interval duration	SFN cell radius is mostly dependent on the OFDM mode and selection of the guard interval duration	SFN cell radius is mostly dependent on the OFDM mode and selection of the guard interval duration
4	Simultaneous transmission of different quality levels (hierarchical transmission)	Depending on selected system configuration it is possible to choose different service error protection for one or multiple PLP, each having its own specific modulation, coding and time interleaving depth, thus enabling service specific robustness	Depending on selected system configuration it is possible to choose different service error protection for one or multiple PLP, each having its own specific modulation, coding and time interleaving depth, thus enabling service specific robustness	Support for multiple service channels. Modulation, coding and time interleaving depth selectable separately for each service channel
5	Spectrum efficiency (bit/s/Hz)[(1)]	From 0.25 bit/s/Hz (QPSK 1/2) to 6.51 bit/s/Hz (256-QAM 5/6)	From 0.16 bit/s/Hz (QPSK 2/15) to 9.92 bit/s/Hz (4096-QAM 13/15)	From 0.66 bit/s/Hz (QPSK 1/2) to 6.52 bit/s/Hz (256-APSK 5/6)
6	Power consumption for handheld receivers	T2 time slicing with PLP concept	Service channels are organized in time, frequency and power domains. When receiving a single service channel only the service channel signalling and relevant slices are received and processed	Service channels are organized in both time and frequency domains. When receiving a single service channel only the service channel signalling and relevant slices are received and processed

(1) Provided values of Spectral efficiency are calculated from minimum/maximum net data rates and used bandwidth in Table 5.