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EUROPEAN STANDARD

Digital Video Broadcasting (DVB);
Frame structure channel coding and modulation
for a second generation digital transmission system
for cable systems (DVB-C2)

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Foreword

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NOTE: The EBU/ETSI JTC Broadcast was established in 1990 to co-ordinate the drafting of standards in the specific field of broadcasting and related fields. Since 1995 the JTC Broadcast became a tripartite body by including in the Memorandum of Understanding also CENELEC, which is responsible for the standardization of radio and television receivers. The EBU is a professional association of broadcasting organizations whose work includes the co-ordination of its members' activities in the technical, legal, programme-making and programme-exchange domains. The EBU has active members in about 60 countries in the European broadcasting area; its headquarters is in Geneva.

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The Digital Video Broadcasting Project (DVB) is an industry-led consortium of broadcasters, manufacturers, network operators, software developers, regulatory bodies, content owners and others committed to designing global standards for the delivery of digital television and data services. DVB fosters market driven solutions that meet the needs and economic circumstances of broadcast industry stakeholders and consumers. DVB standards cover all aspects of digital television from transmission through interfacing, conditional access and interactivity for digital video, audio and data. The consortium came together in 1993 to provide global standardization, interoperability and future proof specifications.

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Modal verbs terminology

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Introduction

Since 1994 enhanced digital transmission technologies have evolved somewhat:

- New channel coding schemes, combined with higher order modulation, promise more powerful alternatives to the DVB-C coding and modulation schemes. The result is a capacity gain in the order of 30 % at a given cable channel bandwidth and CATV network performance.
- Variable Coding and Modulation (VCM) may be applied to provide different levels of error protection to different services (e.g. SDTV and HDTV, audio, multimedia).
- In the case of interactive and point-to-point applications, the VCM functionality may be combined with the use of return channels, to achieve Adaptive Coding and Modulation (ACM). This technique provides more exact channel protection and dynamic link adaptation to propagation conditions, targeting each individual receiving terminal.
- DVB-C is strictly focused on a unique data format, the MPEG Transport Stream (ISO/IEC 13818-1 [i.1] or a reference to it). Extended flexibility to cope with other input data formats (such as multiple Transport Streams, or generic data formats) is now possible without significant complexity increase.

Version 1.2.1 of the present document defines a "second generation" modulation and channel coding system (denoted the "C2 System" or "DVB-C2" for the purposes of the present document) to make use of the improvements listed above. DVB-C2 is a single, very flexible standard, covering a variety of applications by cable, as described below. It is characterized by:

- a flexible input stream adapter, suitable for operation with single and multiple input streams of various formats (packetized or continuous);
- a powerful FEC system based on LDPC (Low-Density Parity Check) codes concatenated with BCH (Bose Chaudhuri Hocquenghem) codes, allowing Quasi Error Free operation close to the Shannon limit, depending on the transmission mode (AWGN channel, modulation constrained Shannon limit);
- a wide range of code rates (from 2/3 up to 9/10); 5 constellations, ranging in spectrum efficiency from 1 to 10,8 bit/s/Hz, optimized for operation in cable networks;
- Adaptive Coding and Modulation (ACM) functionality, optimizing channel coding and modulation on a frame-by-frame basis.

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DVB-C [i.4] was introduced as a European Norm in 1994. It specifies single carrier QAM modulation and Reed-Solomon channel coding and is used today by many cable operators worldwide for television and data broadcasting as well as for forward channel transmission of the Data Over Cable System defined in [i.7].

Version 1.3.1 of this specification (the present document) made a number of clarifications and corrections to the wording. No changes have been made to existing features. Three new technical features have been added:

- Early Warning System signalling
- DVB-C2 version number
- Additional MODCOD 4/5 for 4096-QAM

The new features are defined backward compatible. This means that receivers compliant to version 1.2.1 are not affected when receiving a 1.3.1 compliant signal, which does not include additional MODCOD 4/5 for 4096-QAM or extended PLP Bundling over several C2-Systems.

New signalling elements (EWS and C2-versioning) are deemed to be ignored by 1.2.1 compliant receivers.

Further details of the specification of PLP bundling have been added in annex F, especially addressing the optimization of the buffer size, both at transmitter and at receiver side. Furthermore a new mechanism is defined to allow PLP bundling also over several **C2_Systems**.

1 Scope

The present document describes a second generation baseline transmission system for digital television broadcasting via Hybrid Fibre Coax (HFC) cable networks and Master Antenna Television (MATV) installations. It specifies the channel coding, modulation and lower layer signalling protocol system intended for the provision of digital television services and generic data streams.

The scope is as follows:

- it gives a general description of the Baseline System for digital cable TV;
- it specifies the digital signal processing in order to establish compatibility between pieces of equipment developed by different manufacturers. This is achieved by describing in detail the signal processing at the transmitting side, while the processing at the receiving side is left open to individual implementations. However, for the purpose of securing interoperability it is necessary in this text to refer to certain implementation aspects of the receiving end.

2 References

2.1 Normative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the reference document (including any amendments) applies.

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[1] ETSI TS 101 162: "Digital Video Broadcasting (DVB); Allocation of identifiers and codes for Digital Video Broadcasting (DVB) systems".

2.2 Informative references

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The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] ISO/IEC 13818-1: "Information technology - Generic coding of moving pictures and associated audio information: Systems".

[i.2] ETSI TS 102 606: "Digital Video Broadcasting (DVB); Generic Stream Encapsulation (GSE) Protocol".

[i.3] ETSI EN 302 307: "Digital Video Broadcasting (DVB); Second generation framing structure, channel coding and modulation systems for Broadcasting, Interactive Services, News Gathering and other broadband satellite applications (DVB-S2)".

[i.4] ETSI EN 300 468: "Digital Video Broadcasting (DVB); Specification for Service Information (SI) in DVB systems".

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[i.5] ETSI EN 300 429: "Digital Video Broadcasting (DVB); Framing structure, channel coding and modulation for cable systems".

[i.6] 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)".

[i.7] CENELEC EN 50083-2:2006: "Cable networks for television signals, sound signals and interactive services - Part 2: Electromagnetic compatibility for equipment".

[i.8] ETSI EN 300 421: "Digital Video Broadcasting (DVB); Framing structure, channel coding and modulation for 11/12 GHz satellite services".

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

⊕: Exclusive OR / modulo-2 addition operation

0xkk: digits 'kk' should be interpreted as a hexadecimal number

active cell: OFDM Cell carrying a constellation point for L1 signalling or a PLP

auxiliary data: sequence of cells carrying data of as yet undefined modulation and coding, which may be used for stuffing Data Slices or stuffing Data Slice Packets

BBFrame: signal format of an input signal after mode and stream adaptation

BBHeader: header in front of a baseband data field

NOTE: See clause 5.1.

BUFS: maximum size of the requested receiver buffer to compensate delay variations

BUFSTAT: actual status of the receiver buffer

C2 frame: fixed physical layer TDM frame that is further divided into variable size Data Slices

NOTE: C2 Frame starts with one or more Preamble Symbol.

C2 system: complete transmitted DVB-C2 signal, as described in the L1-part2 block of the related Preamble

common PLP: special PLP, which contains data shared by multiple PLPs (Transport Stream)

data cell: OFDM Cell which is not a pilot or tone reservation cell

data PLP: PLP carrying payload data

data slice: group of OFDM Cells carrying one or multiple PLPs in a certain frequency sub-band

NOTE: This set consists of OFDM Cells within a fixed range of consecutive cell addresses within each Data Symbol and spans over the complete C2 Frame, except the Preamble Symbols.

data slice packet: XFECFrame including the related FECFrame Header

data symbol: OFDM Symbol in a C2 Frame which is not a Preamble Symbol

div: integer division operator, defined as:

$$x \operatorname{div} y = \left\lfloor \frac{x}{y} \right\rfloor$$

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dummy cell: OFDM Cell carrying a pseudo-random value used to fill the remaining capacity not used for L1 signalling, PLPs or Auxiliary Data

elementary period: time period which depends on the channel raster and is used to define the other time periods in the C2 System

FECFrame: set of N_{LDPC} (16 200 or 64 800) bits of one LDPC encoding operation

NOTE: In case of Data Slices carrying a single PLP and constant modulation and encoding is applied, FECFrame Header information may be carried in Layer1 part2 and the Data Slice Packet is identical with the XFECFrame.

FFT size: nominal FFT size for a DVB-C2 receiver is 4K

NOTE: Further details are discussed in clause 10.1.

for i=0..xxx-1: when used with the signalling loops, this means that the corresponding signalling loop is repeated as many times as there are elements of the loop

NOTE: If there are no elements, the whole loop is omitted.

Im(x): Imaginary part of x

Layer 1 (L1): name of the first layer of the DVB-C2 signalling scheme (signalling of physical layer parameters)

L1 block: set of L1-part2 COFDM Cells, cyclically repeated in the frequency domain

NOTE: L1 Blocks are transmitted in the Preamble.

L1-part1: signalling carried in the header of the Data Slice Packets carrying modulation and coding parameters of the related XFECFrame

NOTE: L1-part1 parameters may change per XFECFrame.

L1-part2: Layer 1 Signalling cyclically transmitted in the preamble carrying more detailed L1 information about the C2 System, Data Slices, Notches and the PLPs

NOTE: L1-part2 parameters may change per C2 Frame.

Layer 2 (L2): name of the second layer of the DVB-C2 signalling scheme (signalling of transport layer parameters)

mod: modulo operator, defined as:

$$x \bmod y = x - y\left\lfloor \frac{x}{y} \right\rfloor$$

mode adapter: input signal processing block, delivering BBFrames at its output

nn_D: digits 'nn' should be interpreted as a decimal number

notch: set of adjacent OFDM Cells within each OFDM Symbol without transmitted energy

null packet: MPEG Packet with the Packet_ID 0x1FFF, carrying no payload data and intended for padding

OFDM cell: modulation value for one OFDM carrier during one OFDM Symbol, e.g. a single constellation point

OFDM symbol: waveform Ts in duration comprising all the active carriers modulated with their corresponding modulation values and including the guard interval

Physical Layer Pipe (PLP): logical channel carried within one or multiple Data Slice(s)

NOTE 1: All signal components within a PLP share the same transmission parameters such as robustness, latency.

NOTE 2: A PLP may carry one or multiple services. In case of PLP Bundling a PLP may be carried in several Data Slices. Transmission parameters may change each XFECFrame.

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PLP bundling: transmission of one PLP via multiple Data Slices

PLP_ID: this 8-bit field identifies uniquely a PLP within a C2 transmission signal

preamble header: fixed size signalling transmitted in the first part of the Preamble, carrying the length and Interleaving parameters of Layer 1 part 2 data

preamble symbol: one or multiple OFDM Symbols, transmitted at the beginning of each C2 Frame, carrying Layer 1 part 2 signalling data

Re(x): Real part of x

reserved for future use: value of any field indicated as "reserved for future use", which has to be set to "0" unless otherwise defined

START_FREQUENCY: index of lowest used OFDM subcarrier of a C2 System. The value of START_FREQUENCY has to be a multiple of D_X

***x**:** Complex conjugate of *x*

XFECFrame: FECFrame mapped onto QAM constellations:

- $\lfloor x \rfloor$: round towards minus infinity: the most positive integer less than or equal to x.
- $\lceil x \rceil$: round towards plus infinity: the most negative integer greater than or equal to x.

3.2 Symbols

For the purposes of the present document, the following symbols apply:

Δ	Absolute guard interval duration
Λ	LDPC codeword of size N_{ldpc}
λ_i	LDPC codeword bits
λ^{RM}	32 output bits of Reed-Muller encoder
λ_i^{RM}	Bit number of index *i* of 32 bit long output bits of Reed-Muller encoder
η_{MOD}, $\eta_{MOD}(i)$	Number of transmitted bits per constellation symbol (for PLP *i*)
π_{p}	Permutation operator defining parity bit groups to be punctured for L1 signalling
π_s	Permutation operator defining bit-groups to be padded for L1 signalling
$A_{m,l}$	Output vector of the frequency interleaver of OFDM Symbol *l* and C2 Frame *m*
A_{CP}	Amplitude of the continual pilot cells
A_{SP}	Amplitude of the scattered pilot cells
$a_{m,l,q}$	Frequency-Interleaved cell value, cell index *q* of symbol *l* of C2 Frame *m*
$B(n)$	Location of the first Data Cell of symbol l allocated to Data Slice *n* in the frequency interleaver
b	16 bit long FECFrame signalling data vector
$b_{e,do}$	Output from the demultiplexer, depending on the demultiplexed bit sub-stream number *e* and the input bit number d_i of the bit interleaver demultiplexer
b_i	Bit number of index *i* of 16 bit long FECFrame signalling data vector
C/N	Carrier-to-noise power ratio
$C/N+I$	Carrier-to-(Noise+Interference) ratio
C_i	Column of index *i* of time interleaver
c_i	Column of index *i* of bit interleaver
$c(x)$	Equivalent BCH codeword polynomial
$c_{m,l,k}$	Cell value for carrier *k* of symbol *l* of C2 Frame *m*
DFL	Data field length
D_{P}	Difference in carrier index between adjacent preamble-pilot-bearing carriers
D_{x}	Difference in carrier index between adjacent scattered-pilot-bearing carriers

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D_y	Difference in symbol number between successive scattered pilots on a given carrier
$d(x)$	Remainder of dividing message polynomial by the generator polynomial $g(x)$ during BCH encoding
d_i	Input bit number d_i of the bit interleaver demultiplexer
d_o	Bit number of a given stream at the output of the demultiplexer of the bit interleaver
e	Demultiplexed bit sub stream number ($0 \le e < N_{substreams}$), depending on input bit number d_i of the bit interleaver demultiplexer
f_q	Constellation point normalized to mean energy of 1
G	Reed-Muller encoder matrix
$g(x)$	BCH generator polynomial
$g_1(x), g_2(x), \ldots, g_{12}(x)$	Polynomials to obtain BCH code generator polynomial
g_q	Complex cell of index q of a Data Slice Packet
$H(q)$	Frequency interleaver permutation function, element q
I	Output codeword of BCH encoder
i_j	BCH codeword bits which form the LDPC information bits
j	$\sqrt{-1}$
K_{bch}	Number of bits of BCH uncoded Block
K_i	L1 signalling part 2 parameter selected as $N_{L1part2}(K_i) <= N_{L1part2\_Cells} \times \eta_{MOD}$
K_{ldpc}	Number of bits of LDPC uncoded Block
K_{L1}	3408 (number of OFDM carriers per L1 block)
$K_{L1\_PADDING}$	Length of L1_PADDING field
$K_{L1part2}$	Length of L1-part2 signalling field including the padding field
$K_{L1part2\_ex\_pad}$	Number of information bits in L1-part2 signalling excluding the padding field
$K_{N,min}$	Lowest frequency carrier index of a frequency Notch
$K_{N,max}$	Highest frequency carrier index of a frequency Notch
K_{sig}	Number of signalling bits per FEC block for L1 signalling part 2
K_{min}	Lowest frequency carrier index of a C2 signal, which has to be identical to the START_FREQUENCY and which has to be a multiple of D_X
K_{max}	Highest frequency carrier index of a C2 signal, which has to be a multiple of D_X
K_{total}	Number of OFDM carriers per OFDM symbol
k	Absolute OFDM carrier index
L_{data}	Number of data OFDM Symbols per C2 Frame (excluding Preamble)
L_F	Number of OFDM Symbols per C2 Frame including excluding preamble
L_P	Number of preamble OFDM Symbols within the C2 Frame
l	Index of OFDM Symbol within the C2 Frame
l_d	Index of data OFDM Symbol within the C2 Frame
l_P	Index of preamble OFDM Symbol in C2 Frame
m	C2 Frame number
$m(x)$	Message polynomial within BCH encoding
m_i	Input bit of index i from uncoded bit vector M before BCH encoder
M	Uncoded bit vector before BCH encoder
M_{max}	Maximum Sequence length for the frequency interleaver
N_{bch}	Number of bits of BCH coded Block
N_{bch_parity}	Number of BCH parity bits
N_c	Number of columns of bit or time interleaver
N_{data}	Number of Data Cells in a Data Slice in frequency interleaver
N_{DP}	Number of complex cells per Data Slice Packet
N_{group}	Number of bit-groups for BCH shortening
$N_{L1part2}$	Length of punctured and shortened LDPC codeword for L1-part2 signalling
$N_{L1part2\_Cells}$	Number of available cells for L1 signalling part 2 in one OFDM Symbol
$N_{L1part2\_FEC\_Block}$	Number of LDPC blocks for the L1 signalling part 2
$N_{L1part2\_max\_per\_Symbol}$	Maximum number of L1 information bits for transmitting the encoded L1 signalling part 2 through one OFDM Symbol

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Full standard:
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$N_{L1\_TI\_Depth}$	Time interleaving depth for L1 signalling part 2
$N_{L1part2\_temp}$	Intermediate value used in L1 puncturing calculation
N_{ldpc}	Number of bits of LDPC coded Block
$N_{MOD\_per\_Block}$	Number of modulated cells per FEC block for the L1-part2 signalling
N_{MOD_Total}	Total number of modulated cells for the L1-part2 signalling
N_{pad}	Number of BCH bit-groups in which all bits will be padded for L1-part2 signalling
N_{punc}	Number of LDPC parity bits to be punctured
N_{punc_groups}	Number of parity groups in which all parity bits are punctured for L1 signalling
N_{punc_temp}	Intermediate value used in L1 puncturing calculation
N_r	Number of bits in Frequency Interleaver sequence
N_r	Number of rows of bit or time interleaver
N_{RT}	Number of reserved carriers
$N_{substreams}$	Number of substreams produced by the bit-to-sub-stream demultiplexer
n	Data slice number
$P_k(f)$	Power spectral density
p_i	LDPC parity bits
Q_{ldpc}	Code-rate dependent LDPC constant
q	Data Cell index within the OFDM Symbol prior to frequency interleaving and pilot insertion
$R_{eff\_16K\_LDPC\_1\_2}$	Effective code rate of 16K LDPC with nominal rate ½
$R_{eff\_L1part2}$	Effective code rate of L1-part2 signalling
R_i	Row of index i of time interleaver
R_i	Value of element i of the frequency interleaver sequence following bit permutations
R'_i	Value of element i of the frequency interleaver sequence prior to bit permutations
r_i	Row of index i of bit interleaver
r_k	DBPSK modulated pilot reference sequence
S_0	List of reserved carriers
T	Elementary period
T_{Ci}	Column-twist value for column C of time interleaver
T_{CH}	Component set of carrier indices for reserved carriers
T_F	Duration of one C2 Frame
T_P	Time interleaving period
T_S	Total OFDM Symbol duration
T_U	Useful OFDM Symbol duration
t	BCH error correction capability
t_c	Column-twist value for column c of bit interleaver
U	Parity interleaver output
UPL	User Packet Length
u_i	Parity-interleaver output bits
u^{RM}	32 bit output vector of the cyclic delay block in the FECFrame header encoding
$u_{(i+2)mod32}{}^{RM}$	Output of the cyclic delay block for input bit i in the FECFrame header encoding
V	Column-twist interleaver output
v_i	Column-twist interleaver output bits
$v_{m,l,i}$	Output vector of frequency interleaver, starting at carrier index i (= Data slice start carrier) of the current OFDM Symbol l and C2 Frame m
v^{RM}	Scrambled output sequence in the lower branch of the FECFrame header encoder
v_i^{RM}	Bit i of scrambled output sequence in the lower branch of the FECFrame header encoder
w_i	Bit i of the data scrambling sequence
w^{RM}	32 bit scrambling sequence in the lower branch of the FECFrame header encoder
w_i^{RM}	Bit i of scrambling sequence in the lower branch of the FECFrame header encoder
w^p	Pilot synchronization sequence, build out of w_i and w'
w_k^p	Bit of index k of pilot synchronization sequence

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Full standard:
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2a1e-b2c1138c0bcc69/etsi-en-302-769-v1.3.1-2015-10