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European Standard (Telecommunications series)

Digital Video Broadcasting (DVB); Framing structure, channel coding and modulation for cable systems

European Broadcasting Union

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ETSI

Postal address

F-06921 Sophia Antipolis Cedex - FRANCE

Office address

650 Route des Lucioles - Sophia Antipolis
Valbonne - FRANCE
Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16
Siret N° 348 623 562 00017 - NAF 742 C
Association à but non lucratif enregistrée à la
Sous-Préfecture de Grasse (06) N° 7803/88

Internet

secretariat@etsi.fr
http://www.etsi.fr
http://www.etsi.org

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Foreword

This European Standard (Telecommunications series) has been produced by the Joint Technical Committee (JTC) of the European Broadcasting Union (EBU), Comité Européen de Normalisation ELECtrotechnique (CENELEC) and the European Telecommunications Standards Institute (ETSI).

NOTE: The EBU/ETSI JTC was established in 1990 to co-ordinate the drafting of standards in the specific field of broadcasting and related fields. Since 1995 the JTC 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 *.

* European Broadcasting Union
CH-1218 GRAND SACONNEX (Geneva)
Switzerland
Tel: +41 22 717 21 11
Fax: +41 22 717 24 81

Digital Video Broadcasting (DVB) Project

Founded in September 1993, the DVB Project is a market-led consortium of public and private sector organizations in the television industry. Its aim is to establish the framework for the introduction of MPEG-2 based digital television services. Now comprising over 200 organizations from more than 25 countries around the world, DVB fosters market-led systems, which meet the real needs, and economic circumstances, of the consumer electronics and the broadcast industry.

National transposition dates	
Date of adoption of this EN:	17 April 1998
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1 Scope

The present document only adds 128 and 256 QAM to the specification.

The present document describes the framing structure, channel coding and modulation (denoted "the System" for the purposes of the present document) for a digital multi-programme television distribution by cable. The aim of the present document is to present a harmonized transmission standard for cable and satellite, based on the MPEG-2 System Layer ISO/IEC 13818-1 [1], with the addition of appropriate Forward Error Correction (FEC) technique.
This System can be used transparently with the modulation/channel coding system used for digital multi-programme television by satellite (see EN 300 421 [3]). The System is based on Quadrature Amplitude Modulation (QAM).
It allows for 16, 32, 64, 128 or 256-QAM constellations.

The System FEC is designed to improve Bit Error Ratio (BER) from 10^{-4} to a range, 10^{-10} to 10^{-11}, ensuring "Quasi Error Free" (QEF) operation with approximately one uncorrected error event per transmission hour.

2 References

References may be made to:

a) specific versions of publications (identified by date of publication, edition number, version number, etc.), in which case, subsequent revisions to the referenced document do not apply; or

b) all versions up to and including the identified version (identified by "up to and including" before the version identity); or

c) all versions subsequent to and including the identified version (identified by "onwards" following the version identity); or

d) publications without mention of a specific version, in which case the latest version applies.

A non-specific reference to an ETS shall also be taken to refer to later versions published as an EN with the same number.

[1] ISO/IEC 13818-1: "Coding of moving pictures and associated audio".

[2] IEEE Trans. Comm. Tech., COM-19, pp. 772-781, (October 1971) Forney, G.D.: "Burst-correcting codes for the classic bursty channel".

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

3 Symbols and abbreviations

3.1 Symbols

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

α	Roll-off factor
A_k, B_k	Most Significant Bits at the output of the Byte to m-tuple converter
f_0	Channel centre frequency
f_N	Nyquist frequency
g(x)	RS code generator polynomial
HEX	Hexadecimal
I	Interleaving depth (bytes)
I, Q	In-phase, Quadrature phase components of the modulated signal
j	Branch index
k	Number of bytes mapped into n symbols

m	Power of 2^m-level QAM: 4,5,6,7,8 for 16-QAM, 32-QAM, 64-QAM, 128-QAM, 256-QAM respectively
M	Convolutional interleaver branch depth for j = 1, M = N/I
n	Number of symbols mapped from k bytes
N	Error protected frame length [bytes]
p(x)	RS field generator polynomial
r_m	In-band ripple (dB)
R	Randomized sequence
R_s	Symbol rate corresponding to the bilateral Nyquist bandwidth of the modulated signal
R_u	Useful bit rate after MPEG-2 transport multiplexer
$R_{u'}$	Bit rate after RS outer coder
q	Number of bits: 2,3,4,5,6 for 16-QAM, 32-QAM, 64-QAM, 128-QAM, 256-QAM respectively
T	Number of bytes which can be corrected in RS error protected packet
T_s	Symbol period

3.2 Abbreviations

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

BB	Baseband
BER	Bit Error Ratio
DTVC	Digital Television by Cable
FEC	Forward Error Correction
FIFO	First In First Out
IF	Intermediate Frequency
IRD	Integrated Receiver Decoder
LSB	Least Significant Bit
MPEG	Moving Pictures Experts Group
MSB	Most Significant Bit
MUX	Multiplex
PDH	Plesiochronous Digital Hierarchy
PRBS	Pseudo Random Binary Sequence
QAM	Quadrature Amplitude Modulation
QEF	Quasi Error Free
RF	Radio Frequency
RS	Reed-Solomon
SMATV	Satellite Master Antenna Television
TDM	Time Division Multiplex
TV	Television

4 Cable System concept

The cable System shall be defined as the functional block of equipment performing the adaptation of the baseband TV signals to the cable channel characteristics (see figure 1). In the cable head-end, the following TV baseband signal sources can be considered:

- satellite signal(s);
- contribution link(s);
- local program source(s).

The processes in the following subclauses shall be applied as shown in figure 1.

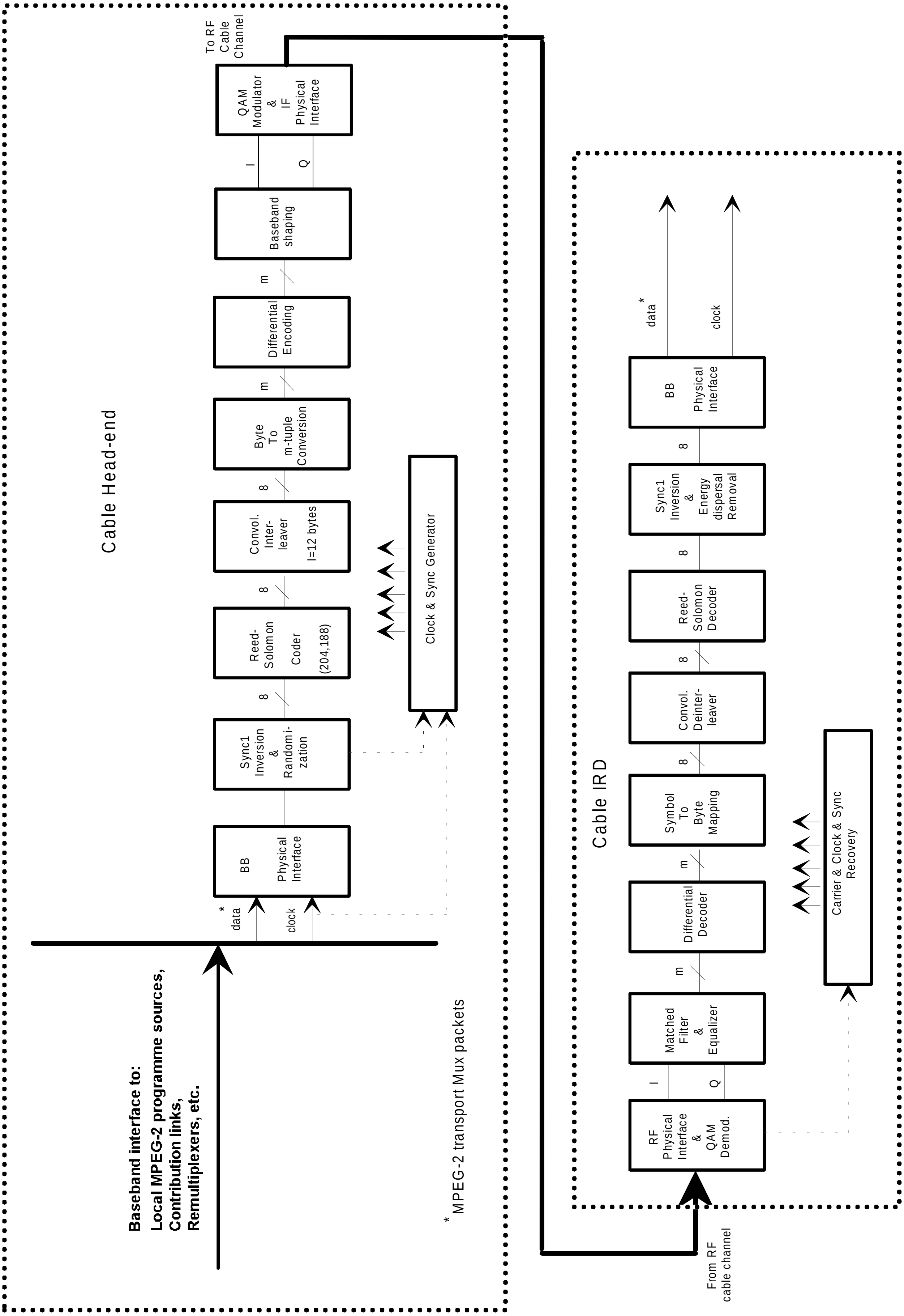


Figure 1: Conceptual block diagram of elements at the cable head-end and receiving site

4.1 Baseband interfacing and sync

This unit shall adapt the data structure to the format of the signal source. The framing structure shall be in accordance with MPEG-2 transport layer including sync bytes.

NOTE: Interfaces are not part of the present document.

4.2 Sync 1 inversion and randomization

This unit shall invert the Sync 1 byte according to the MPEG-2 framing structure, and randomizes the data stream for spectrum shaping purposes.

4.3 Reed-Solomon (RS) coder

This unit shall apply a shortened Reed-Solomon (RS) code to each randomized transport packet to generate an error-protected packet. This code shall also be applied to the Sync byte itself.

4.4 Convolutional interleaver

This unit shall perform a depth I = 12 convolutional interleaving of the error-protected packets. The periodicity of the sync bytes shall remain unchanged.

4.5 Byte to m-tuple conversion

This unit shall perform a conversion of the bytes generated by the interleaver into QAM symbols.

4.6 Differential encoding

In order to get a rotation-invariant constellation, this unit shall apply a differential encoding of the two Most Significant Bits (MSBs) of each symbol.

4.7 Baseband shaping

This unit performs mapping from differentially encoded m-tuples to I and Q signals and a square-root raised cosine filtering of the I and Q signals prior to QAM modulation.

4.8 QAM modulation and physical interface

This unit performs QAM modulation. It is followed by interfacing the QAM modulated signal to the Radio Frequency (RF) cable channel.

4.9 Cable receiver

A System receiver shall perform the inverse signal processing, as described for the modulation process above, in order to recover the baseband signal.

5 MPEG-2 transport layer

The MPEG-2 Transport Layer is defined in ISO/IEC 13818-1 [1]. The Transport Layer for MPEG-2 data is comprised of packets having 188 bytes, with one byte for synchronization purposes, three bytes of header containing service identification, scrambling and control information, followed by 184 bytes of MPEG-2 or auxiliary data.

6 Framing structure

The framing organization shall be based on the MPEG-2 transport packet structure. The System framing structure is shown on figure 2.

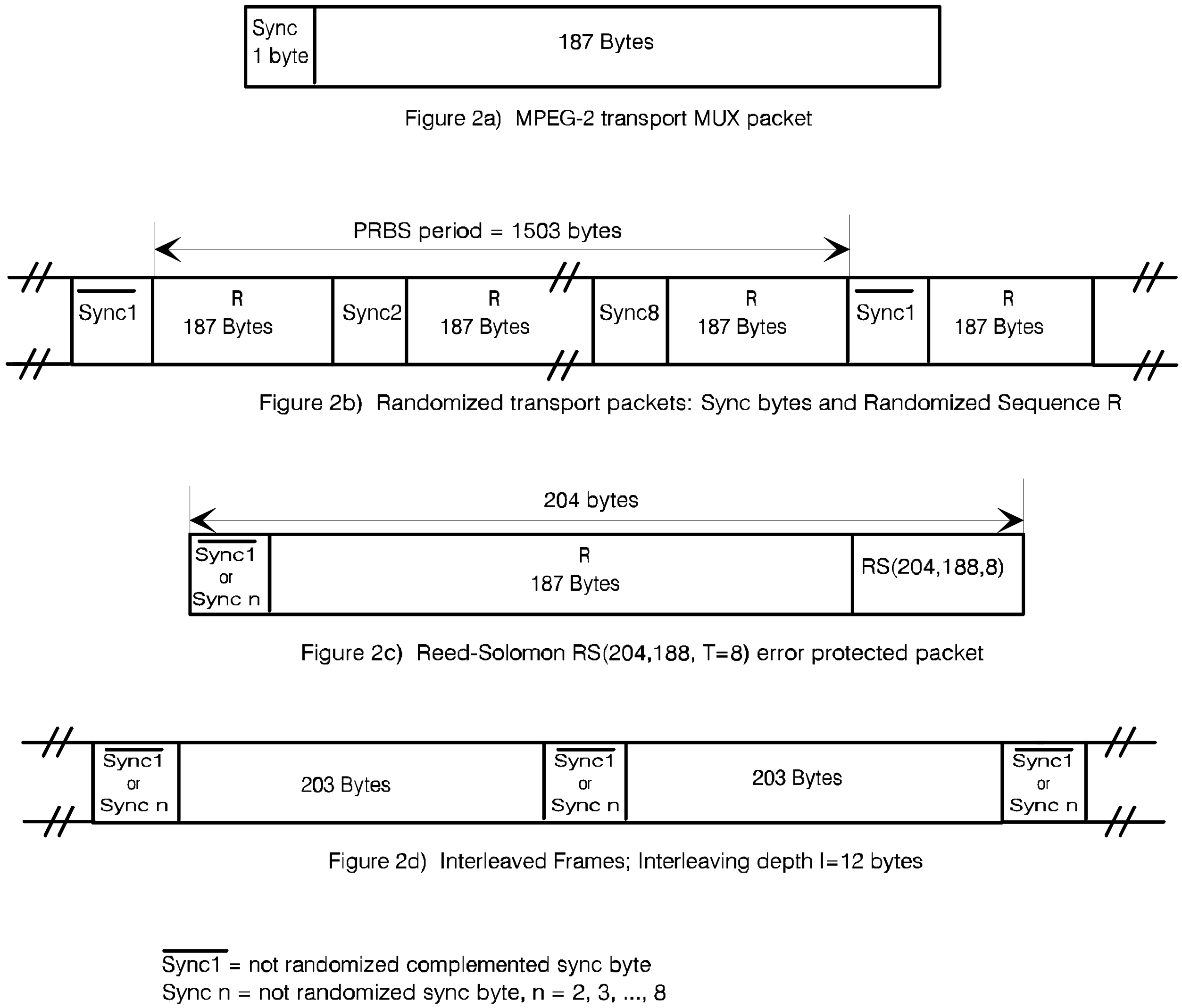


Figure 2: Framing structure

7 Channel coding

To achieve the appropriate level of error protection required for cable transmission of digital data, a FEC based on Reed-Solomon encoding shall be used. In contrast to the Baseline System for satellite described in ETS 300 421 [3], no convolutional coding shall be applied to cable transmission. Protection against burst errors shall be achieved by the use of byte interleaving.

7.1 Randomization for spectrum shaping

The System input stream shall be organized in fixed length packets (see figure 2), following the MPEG-2 transport multiplexer. The total packet length of the MPEG-2 transport MUX packet is 188 bytes. This includes 1 sync-word byte (i.e. 47_{HEX}). The processing order at the transmitting side shall always start from the MSB (i.e. 0) of the sync word-byte (i.e. 01000111).

In order to comply with the System for satellite in ETS 300 421 [3] and to ensure adequate binary transitions for clock recovery, the data at the output of the MPEG-2 transport multiplex shall be randomized in accordance with the configuration depicted in figure 3.

The polynomial for the Pseudo Random Binary Sequence (PRBS) generator shall be:

$$1 + X^{14} + X^{15}$$

Loading of the sequence "100101010000000" into the PRBS registers, as indicated in figure 3, shall be initiated at the start of every eight transport packets. To provide an initialization signal for the descrambler, the MPEG-2 sync byte of the first transport packet in a group of eight packets shall be bitwise inverted from 47_{HEX} to $B8_{HEX}$.

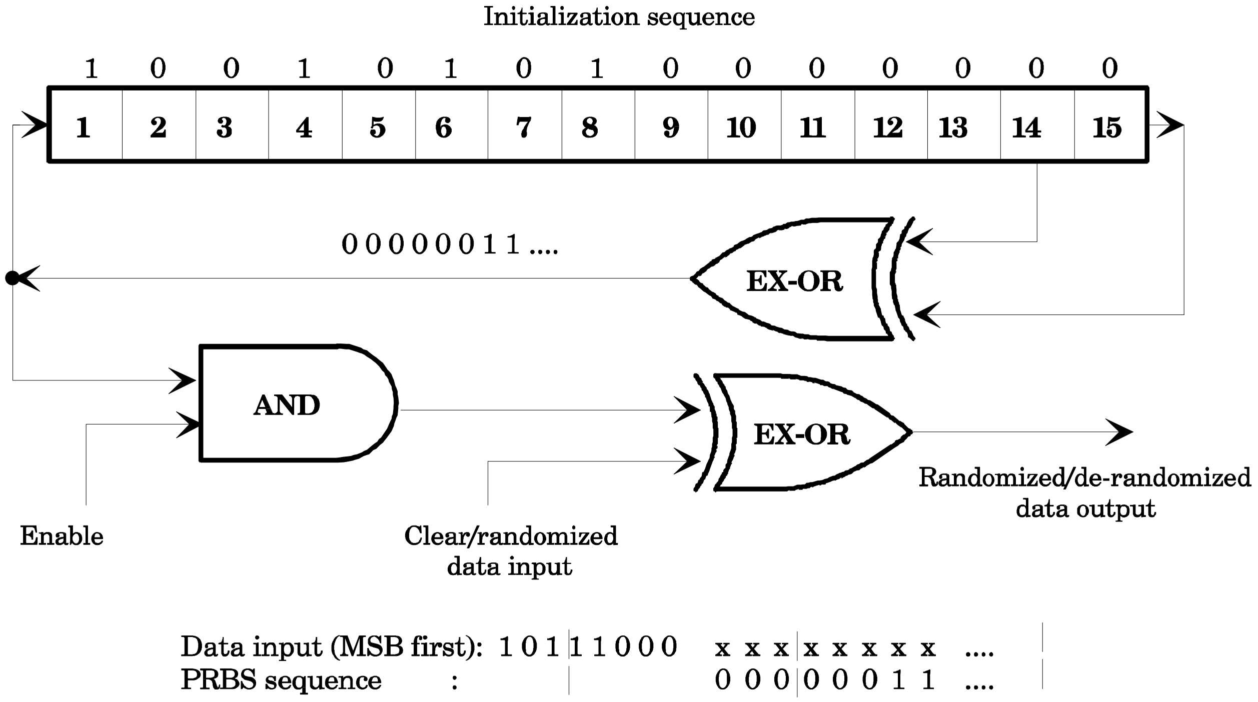


Figure 3: Scrambler/descrambler schematic diagram

The first bit at the output of the PRBS generator shall be applied to the first bit of the first byte following the inverted MPEG-2 sync byte (i.e.$B8_{HEX}$). To aid other synchronization functions, during the MPEG-2 sync bytes of the subsequent 7 transport packets, the PRBS generation continues, but its output shall be disabled, leaving these bytes unrandomized. The period of the PRBS sequence shall therefore be 1 503 bytes.

The randomization process shall be active also when the modulator input bit-stream is non-existant, or when it is non-compliant with the MPEG-2 transport stream format (i.e. 1 sync byte + 187 packet bytes). This is to avoid the emission of an unmodulated carrier from the modulator.

7.2 Reed-Solomon coding

Following the energy dispersal randomization process, systematic shortened Reed-Solomon encoding shall be performed on each randomized MPEG-2 transport packet, with T = 8. This means that 8 erroneous bytes per transport packet can be corrected. This process adds 16 parity bytes to the MPEG-2 transport packet to give a codeword (204,188).

NOTE: RS coding shall also be applied to the packet sync byte, either non-inverted (i.e. 47_{HEX}) or inverted (i.e. $B8_{HEX}$).

Code Generator Polynomial: $g(x) = (x+\lambda^0)(x+\lambda^1)(x+\lambda^2) \ldots (x+\lambda^{15})$, where $\lambda = 02_{HEX}$

Field Generator Polynomial: $p(x) = x^8 + x^4 + x^3 + x^2 + 1$

The shortened Reed-Solomon code shall be implemented by appending 51 bytes, all set to zero, before the information bytes at the input of a (255,239) encoder; after the coding procedure these bytes are discarded.

7.3 Convolutional interleaving

Following the scheme of figure 4, convolutional interleaving with depth I = 12 shall be applied to the error protected packets (see figure 2c). This results in an interleaved frame (see figure 2d).

The convolutional interleaving process shall be based on the Forney approach (see Burst-correcting codes for the classic bursty channel in IEEE Trans. Comm. Tech., COM-19 [2]) which is compatible with the Ramsey type III approach, with I = 12. The Interleaved Frame shall be composed of overlapping error protected packets and shall be delimited by MPEG-2 sync bytes (preserving the periodicity of 204 bytes).

The interleaver may be composed of I = 12 branches, cyclically connected to the input byte-stream by the input switch. Each branch shall be a First In First Out (FIFO) shift register, with depth (Mj) cells (where M = 17 = N/I, N = 204 = error protected frame length, I = 12 = interleaving depth, j = branch index). The cells of the FIFO shall contain 1 byte, and the input and output switches shall be synchronized.

For synchronization purposes, the sync bytes and the inverted sync bytes shall be always routed into the branch "0" of the interleaver (corresponding to a null delay).

NOTE: The deinterleaver is similar, in principle, to the interleaver, but the branch indexes are reversed (i.e. j = 0 corresponds to the largest delay). The deinterleaver synchronization can be carried out by routeing the first recognized sync byte into the "0" branch.

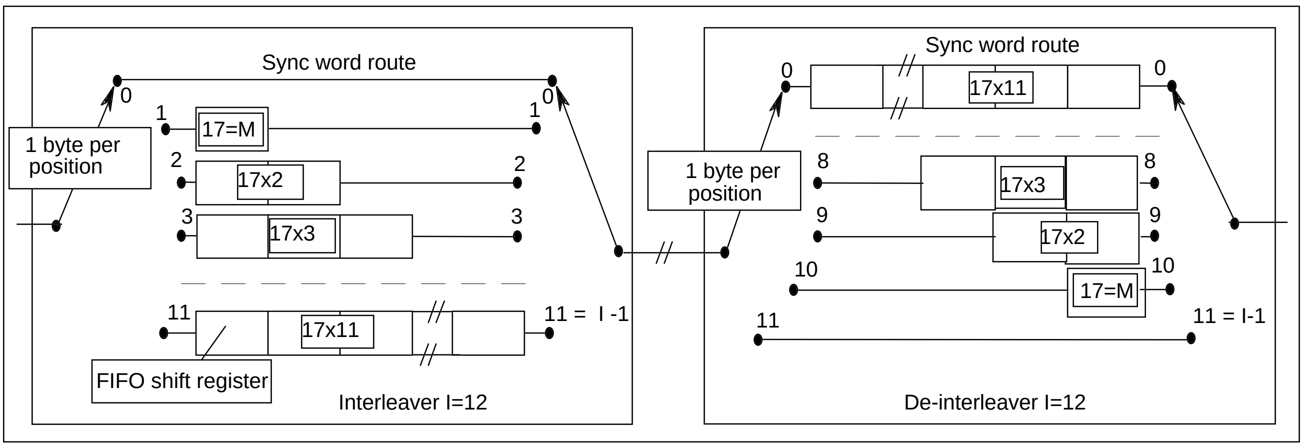


Figure 4: Conceptual diagram of the convolutional interleaver and de-interleaver

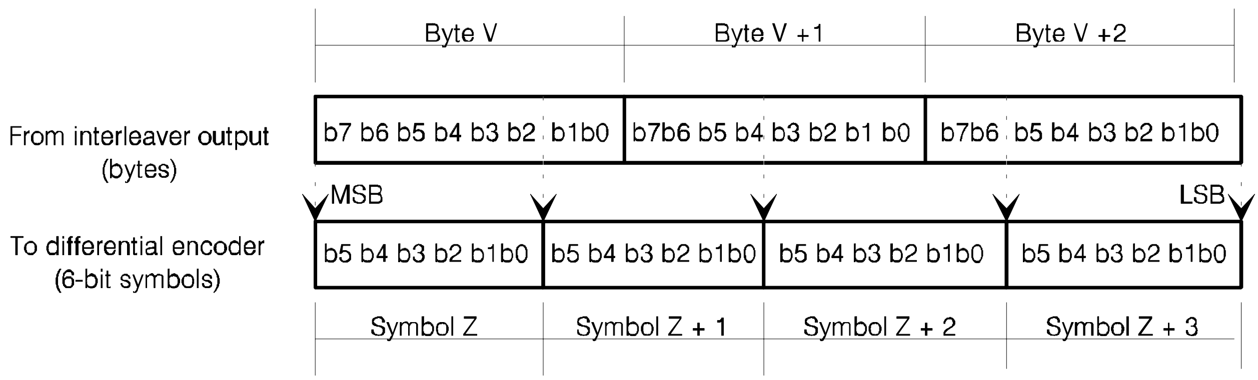
8 Byte to symbol mapping

After convolutional interleaving, an exact mapping of bytes into symbols shall be performed. The mapping shall rely on the use of byte boundaries in the modulation system.

In each case, the MSB of symbol Z shall be taken from the MSB of byte V. Correspondingly, the next significant bit of the symbol shall be taken from the next significant bit of the byte. For the case of 2^m-QAM modulation, the process shall map **k** bytes into **n** symbols, such that:

$8\ k = n \times m$

The process is illustrated for the case of 64-QAM (where m = 6, k = 3 and n = 4) in figure 5:



NOTE 1: b0 shall be understood as being the Least Significant Bit (LSB) of each byte or m-tuple.

NOTE 2: In this conversion, each byte results in more than one m-tuple, labelled Z, Z+1, etc. with Z being transmitted before Z+1.

Figure 5: Byte to m-tuple conversion for 64-QAM

The two most significant bits of each symbol shall then be differentially coded in order to obtain a $\pi/2$ rotation-invariant QAM constellation. The differential encoding of the two MSBs shall be given by the following Boolean expression:

$$I_k = \overline{(A_k \oplus B_k)}.(A_k \oplus I_{k-1}) + (A_k \oplus B_k).(A_k \oplus Q_{k-1})$$

$$Q_k = \overline{(A_k \oplus B_k)}.(B_k \oplus Q_{k-1}) + (A_k \oplus B_k).(B_k \oplus I_{k-1})$$

NOTE: For the above Boolean expression "$\oplus$" denotes the EXOR function, "+" denotes the logical OR function, "**.**" denotes the logical AND function and the overbar denotes inversion.

Figure 6 gives an example of implementation of byte to symbol conversion.

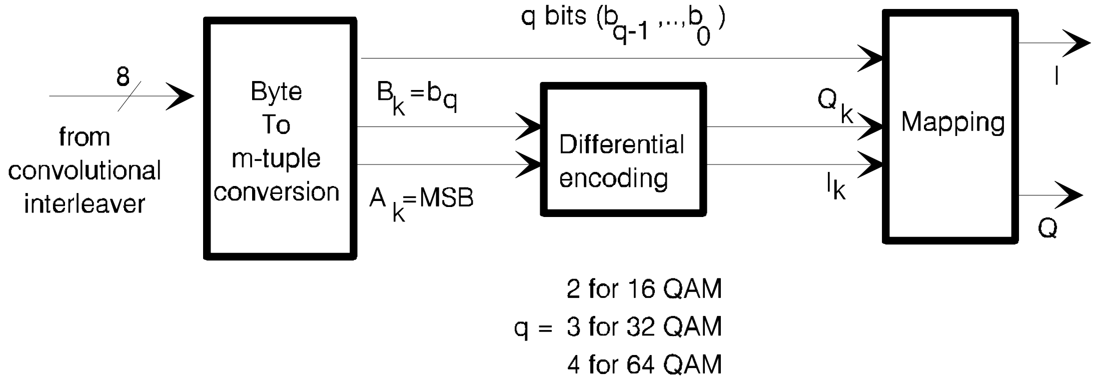


Figure 6: Example implementation of the byte to m-tuple conversion and the differential encoding of the two MSBs

9 Modulation

The modulation of the System shall be Quadrature Amplitude Modulation (QAM) with 16, 32, 64, 128 or 256 points in the constellation diagram.

The System constellation diagrams for 16-QAM, 32-QAM and 64-QAM are given in figure 7. The System constellation diagrams for 128-QAM and 256-QAM are given in figure 8. These constellation diagrams represent the signal transmitted in the cable system.

As shown in figure 7, the constellation points in Quadrant 1 shall be converted to Quadrants 2, 3 and 4 by changing the two MSB (i.e. I_k and Q_k) and by rotating the q LSBs according to the following rule given in table 1:

Table1: Conversion of constellation points of quadrant 1 to other quadrants of the constellation diagram given in figure 7

Quadrant	MSBs	LSBs rotation
1	00	
2	10	$+ \pi/2$
3	11	$+ \pi$
4	01	$+ 3\pi/2$

Receivers shall support at least 64-QAM modulation.

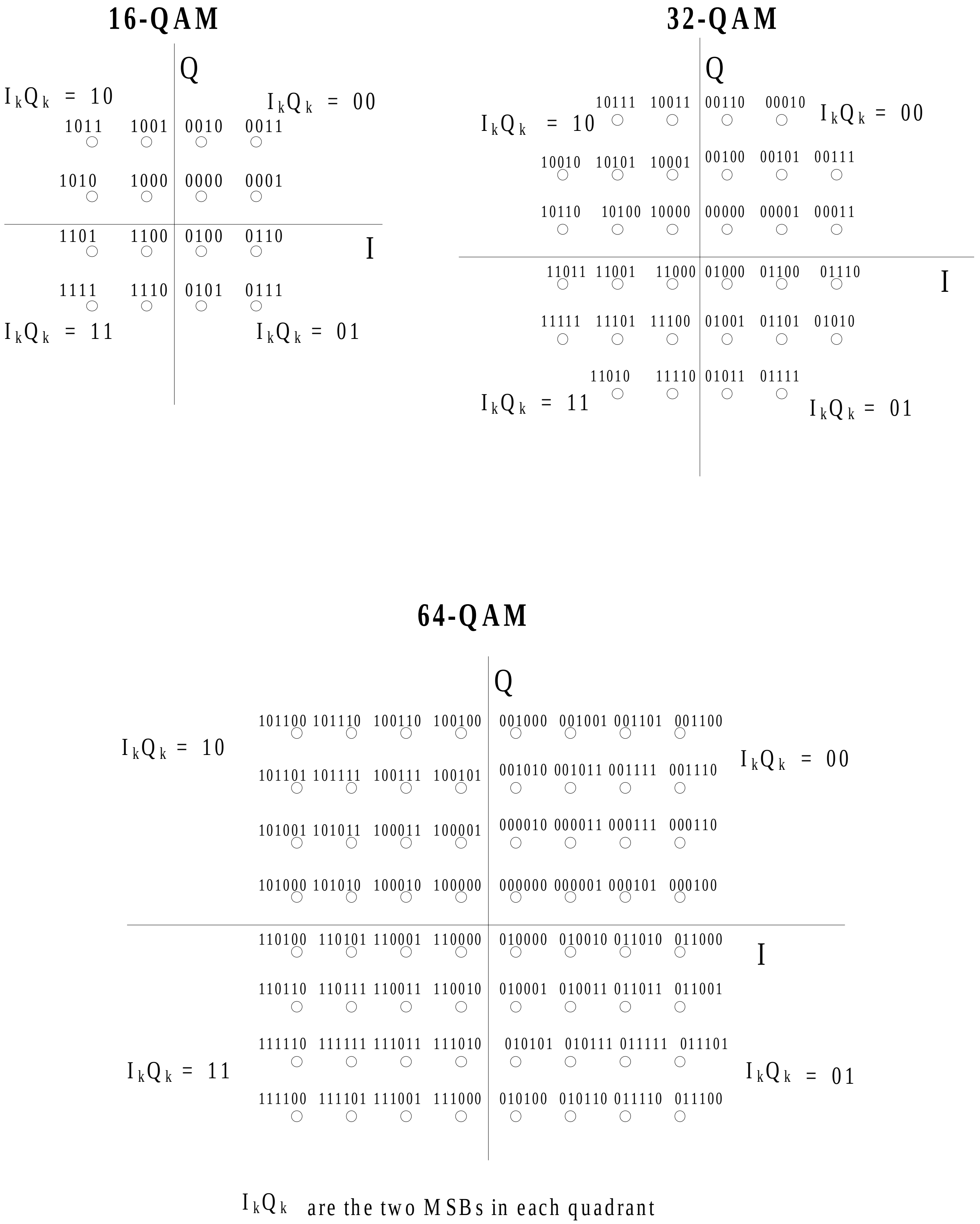
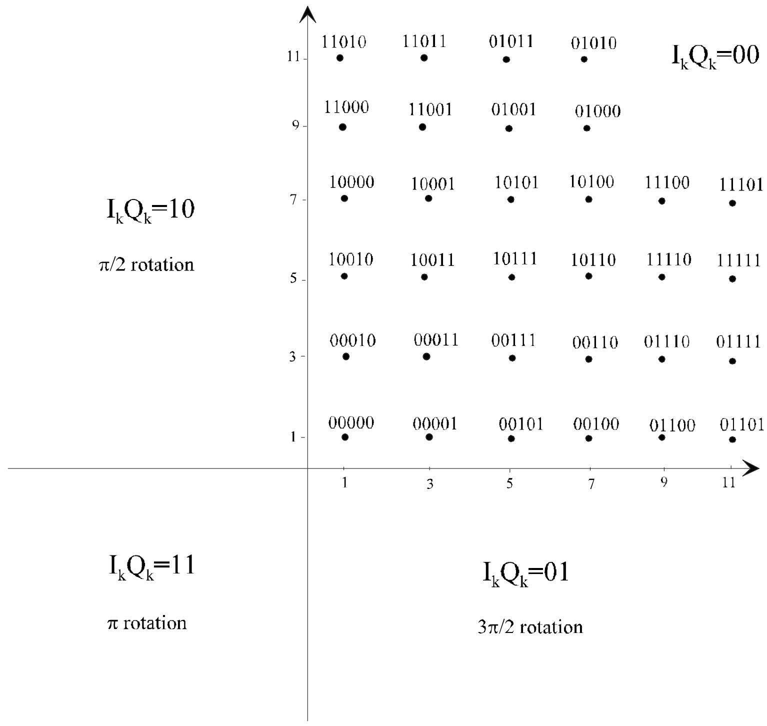


Figure 7: Constellation diagrams for 16-QAM, 32-QAM and 64-QAM



256 QAM

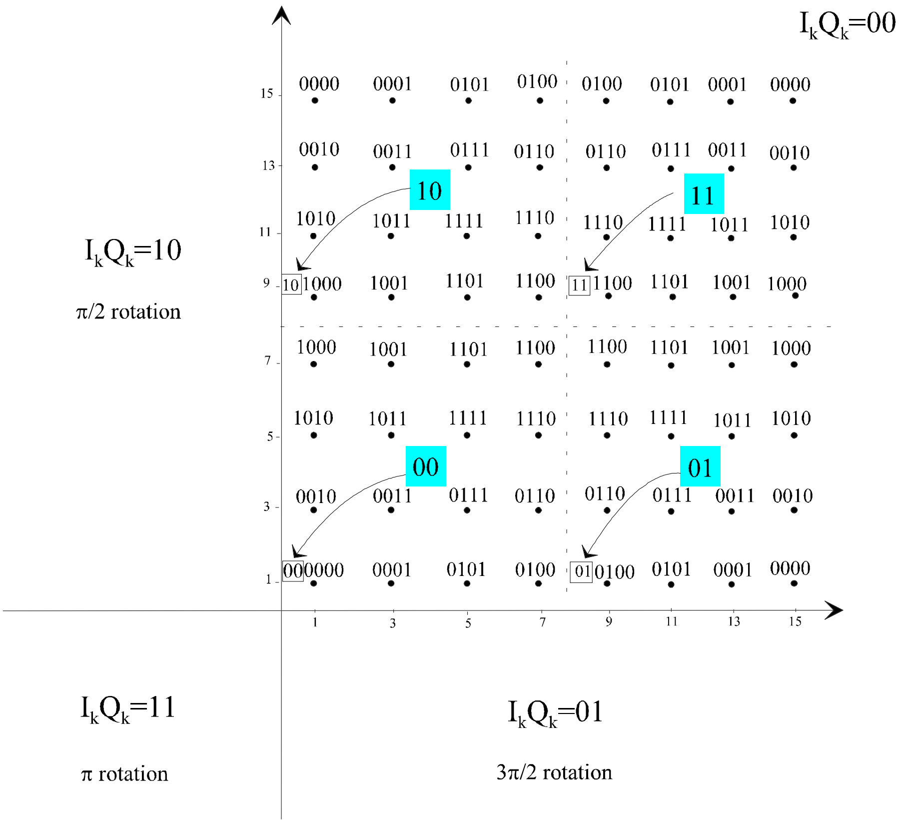


Figure 8: Constellation diagrams for 128-QAM and 256-QAM

Prior to modulation, the I and Q signals shall be square-root raised cosine filtered. The roll-off factor shall be 0,15.

Examples of transparent cable transmissions are given in table B.1.

The square-root raised cosine filter shall have a theoretical function defined by the following expression:

$$H(f) = 1 \text{ for } |f| < f_N(1-\alpha)$$

$$H(f) = \left\{ \frac{1}{2} + \frac{1}{2} \sin \frac{\pi}{2 f_N} \left[\frac{f_N - |f|}{\alpha} \right] \right\}^{1/2} \quad \text{for } f_N(1-\alpha) \le |f| \le f_N(1+\alpha)$$

$$H(f) = 0 \text{ for } |f| > f_N(1+\alpha)$$

where

$f_N = \frac{1}{2T_S} = \frac{R_S}{2}$ is the Nyquist frequency and roll-off factor $\alpha = 0{,}15$.

The transmitter filter characteristic is given in annex A.

Annex A (normative): Baseband filter characteristics

The template given in figure A.1 shall be used as a minimum requirement for hardware implementation of the Nyquist filter. This template takes into account not only the design limitations of the digital filter, but also the artefacts coming from the analogue processing components of the System (e.g. D/A conversion, analogue filtering, etc.).

The value of in-band ripple r_m in the pass-band up to 0,85 f_N as well as at the Nyquist frequency f_N shall be lower than 0,4 dB. The out-band rejection shall be greater than 43 dB.

The filter shall be phase linear with the group delay ripple $\leq$ 0,1 T_s (ns) up to f_N

where, $T_s = 1/R_s$ is the symbol period.

NOTE: The values for in-band ripple and out of band rejection given in this annex are subject to further study.

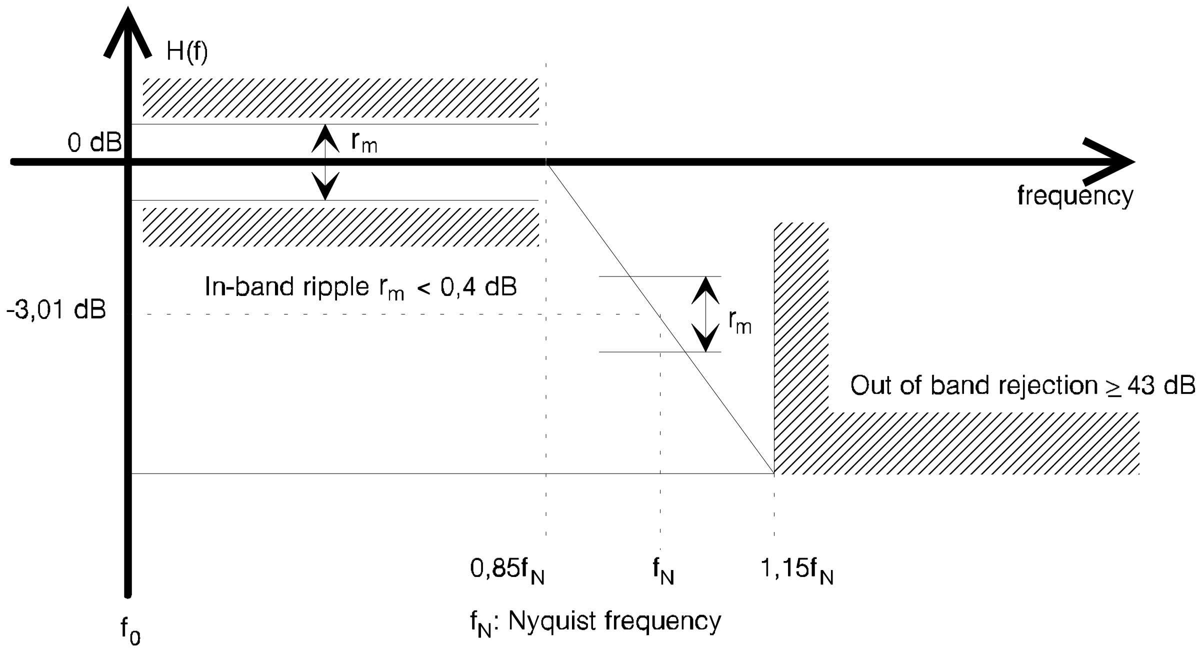


Figure A.1: Half-Nyquist baseband filter amplitude characteristics

Annex B (informative): Transparency of cable networks

In order to achieve a transparent re-transmission of different services on cable systems, the limitations imposed by the System for cable transmission in 8 MHz cable channel bandwidth should be taken into account. With a roll-off factor of 0,15, the theoretical maximum symbol rate in an 8 MHz channel is 6,96 MBaud.

Table B.1 of this annex gives examples of the wide range of possible cable symbol rates and occupied bandwidths for different useful bit rates considering 16-QAM, 32-QAM and 64-QAM constellations.

For full transparency, the same useful bit rate (**excluding** RS coding) should be used on the contributing system and the cable network for secondary distribution.

In the upper part of table B.1, an example of a transparent transmission of the satellite rate of 38,1 Mbit/s, which may be potentially used by many existing satellites (EN 300 421 [3]), is given. This bit rate can be re-transmitted very efficiently in an 8 MHz cable channel by using 64-QAM. A bit rate compatible with terrestrial Plesiochronous Digital Hierarchy (PDH) networks can be re-transmitted in an 8 MHz channel by using 32-QAM.

As shown in the lower part of table B.1, network performance limitations, service requirements (e.g. additional data/audio services), characteristics of the primary distribution system (e.g. satellite, fibre) or other constraints may lead to different usages of the System to appropriately suit various applications.

NOTE: Examples of satellite useful bit rates R_u are taken from EN 300 421 [3].

Table B.1: Examples of useful bit rates R_u and total bit rates R_u' for transparent re-transmission and spectrum efficient use on cable networks

Useful bit rate R_u (MPEG-2 transport layer) [Mbit/s]	Total bit rate R_u' incl. RS(204,188) [Mbit/s]	Cable symbol rate [MBaud]	Occupied bandwidth [MHz]	Modulation scheme
38,1	41,34	6,89	7,92	64-QAM
31,9	34,61	6,92	7,96	32-QAM
25,2	27,34	6,84	7,86	16-QAM
31,672 PDH	34,367	6,87	7,90	32-QAM
18,9	20,52	3,42	3,93	64-QAM
16,0	17,40	3,48	4,00	32-QAM
12,8	13,92	3,48	4,00	16-QAM
9,6	10,44	1,74	2,00	64-QAM
8,0	8,70	1,74	2,00	32-QAM
6,4	6,96	1,74	2,00	16-QAM

Annex C (informative): Bibliography

For the purposes of the present document, the following informative references apply:

- DTVB 1190/DTVC 38, 3rd revised version, February 1994 (Contribution from DTVC), document: "Specification of modulation, channel coding and framing structure for the Baseline System for digital multi-programme television by cable".
- DTVB 1110/GT V4/MOD 252/ DTVC 18, 7th revised version, January 1994 (Contribution from V4/MOD-B), document: "Specification of the "Baseline modulation/channel coding system" for digital multi-programme television by satellite".
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- Reimers, U. NAB'93, document GT V4/MOD 249: "The European perspectives on Digital Television Broadcasting".

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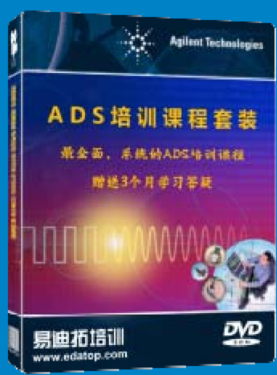
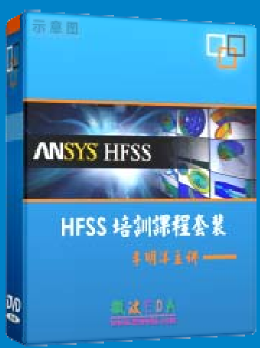
该套装是迄今国内最全面、最权威的 ADS 培训教程，共包含 10 门 ADS 学习培训课程。课程是由具有多年 ADS 使用经验的微波射频与通信系统设计领域资深专家讲解，并多结合设计实例，由浅入深、详细而又全面地讲解了 ADS 在微波射频电路设计、通信系统设计和电磁仿真设计方面的内容。能让您在最短的时间内学会使用 ADS，迅速提升个人技术能力，把 ADS 真正应用到实际研发工作中去，成为 ADS 设计专家...



课程网址： http://www.edatop.com/peixun/ads/13.html

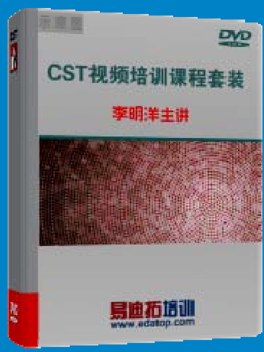


HFSS 学习培训课程套装

该套课程套装包含了本站全部 HFSS 培训课程，是迄今国内最全面、最专业的 HFSS 培训教程套装，可以帮助您从零开始，全面深入学习 HFSS 的各项功能和在多个方面的工程应用。购买套装，更可超值赠送 3 个月免费学习答疑，随时解答您学习过程中遇到的棘手问题，让您的 HFSS 学习更加轻松顺畅…

课程网址：http://www.edatop.com/peixun/hfss/11.html

CST 学习培训课程套装



该培训套装由易迪拓培训联合微波 EDA 网共同推出，是最全面、系统、专业的 CST 微波工作室培训课程套装，所有课程都由经验丰富的专家授课，视频教学，可以帮助您从零开始，全面系统地学习 CST 微波工作的各项功能及其在微波射频、天线设计等领域的设计应用。且购买该套装，还可超值赠送 3 个月免费学习答疑…

课程网址：http://www.edatop.com/peixun/cst/24.html

HFSS 天线设计培训课程套装

套装包含 6 门视频课程和 1 本图书，课程从基础讲起，内容由浅入深，理论介绍和实际操作讲解相结合，全面系统的讲解了 HFSS 天线设计的全过程。是国内最全面、最专业的 HFSS 天线设计课程，可以帮助您快速学习掌握如何使用 HFSS 设计天线，让天线设计不再难…

课程网址：http://www.edatop.com/peixun/hfss/122.html

13.56MHz NFC/RFID 线圈天线设计培训课程套装

套装包含 4 门视频培训课程，培训将 13.56MHz 线圈天线设计原理和仿真设计实践相结合，全面系统地讲解了 13.56MHz 线圈天线的工作原理、设计方法、设计考量以及使用 HFSS 和 CST 仿真分析线圈天线的具体操作，同时还介绍了 13.56MHz 线圈天线匹配电路的设计和调试。通过该套课程的学习，可以帮助您快速学习掌握 13.56MHz 线圈天线及其匹配电路的原理、设计和调试…

详情浏览：http://www.edatop.com/peixun/antenna/116.html

我们的课程优势：

※ 成立于 2004 年，10 多年丰富的行业经验，

※ 一直致力并专注于微波射频和天线设计工程师的培养，更了解该行业对人才的要求

※ 经验丰富的一线资深工程师讲授，结合实际工程案例，直观、实用、易学

联系我们：

※ 易迪拓培训官网：http://www.edatop.com

※ 微波 EDA 网：http://www.mweda.com

※ 官方淘宝店：http://shop36920890.taobao.com