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European Standard (Telecommunications series)

**Digital Video Broadcasting (DVB);
Framing structure, channel coding and modulation
for Digital Satellite News Gathering (DSNG)
and other contribution applications by satellite**

European Broadcasting Union



Union Européenne de Radio-Télévision

DVB
Digital Video
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Contents

Intellectual Property Rights.....	4
Foreword	4
1 Scope.....	5
2 References.....	6
3 Symbols and abbreviations	7
3.1 Symbols	7
3.2 Abbreviations.....	7
4 Transmission system.....	8
4.1 System definition	8
4.2 Adaptation to satellite transponder characteristics.....	9
4.3 Interfacing.....	9
4.4 Channel coding for QPSK modes	9
4.4.1 Transport multiplex adaptation and randomization for energy dispersal.....	10
4.4.2 Outer coding (RS), interleaving and framing	10
4.4.3 Inner coding (convolutional).....	10
4.5 Bit mapping, baseband shaping and modulation for QPSK modes.....	11
4.5.1 Bit mapping to QPSK constellation	11
4.5.2 Baseband shaping and quadrature modulation	12
4.6 Channel coding for the optional 8PSK and 16QAM modes	12
4.6.1 Transport multiplex adaptation and randomization for energy dispersal (8PSK and 16QAM modes)	12
4.6.2 Outer coding (RS), interleaving and framing (8PSK and 16QAM modes)	12
4.6.3 Inner coding ("pragmatic" trellis coding type) (8PSK and 16QAM modes).....	12
4.7 Bit mapping, baseband shaping and modulation for the optional 8PSK and 16QAM modes.....	15
4.7.1 Bit mapping to constellations (8PSK and 16QAM modes).....	15
4.7.1.1 Inner coding and constellation for 8PSK 2/3 (2CBPS)	16
4.7.1.2 Inner coding and constellation for 8PSK 5/6 and 8/9 (1CBPS).....	17
4.7.1.3 Inner coding and constellation for 16QAM 3/4 and 7/8 (2CBPS).....	18
4.7.2 Baseband shaping and modulation (8PSK and 16QAM modes).....	20
5 Error performance requirements	21
Annex A (normative): Signal spectrum at the modulator output	22
Annex B (normative): Transmission setups for interoperability tests and emergency situations.....	24
Annex C (normative): Implementation of the "optional" modes.....	25
Annex D (normative): SI implementation for DSNG and other contribution applications	26
Annex E (informative): Examples of possible use of the System.....	28
Bibliography	31
History	32

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Foreword

This European Standard (Telecommunications series) has been produced by the Joint Technical Committee Broadcast of the European Broadcasting Union (EBU), Comité Européen de Normalisation ELEctrotechnique (CENELEC) and the European Telecommunications Standards Institute (ETSI), and is now submitted for the Public Enquiry phase of the ETSI standards Two-step Approval Procedure.

The work was based on the studies carried out by the European DVB Project under the auspices of the Ad Hoc Group on DSNG of the DVB Technical Module. This joint group of industry, operators and broadcasters provided the necessary information on all relevant technical matters (see bibliography).

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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Digital Video Broadcasting (DVB) Project

Founded in September 1993, the DVB Project is a marked-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 marked-led systems, which meet the real needs, and economic circumstances, of the consumer electronics and the broadcast industry.

Proposed national transposition dates	
Date of latest announcement of this EN (doa):	3 months after ETSI publication
Date of latest publication of new National Standard or endorsement of this EN (dop/e):	6 months after doa
Date of withdrawal of any conflicting National Standard (dow):	6 months after doa

1 Scope

The present document describes the modulation and channel coding system (denoted the "System" for the purposes of the present document) for Digital Satellite News Gathering (DSNG) and other contribution applications by satellite.

According to ITU-R Recommendation SNG.770-1 [12], SNG is defined as "Temporary and occasional transmission with short notice of television or sound for broadcasting purposes, using highly portable or transportable uplink earth stations...". The equipment should be capable of uplinking the video programme (or programmes) with its associated sound or sound programme signals. Optionally it should be capable of providing two-way co-ordination (communication) circuits and data transmission according to EN 301 222 (see bibliography). The equipment should be capable of being set up and operated by a crew of no more than two people within a reasonably short time. Limited receiving capability should be available in the uplink terminal to assist in pointing the antenna and to monitor the transmitted signal, where possible.

Digital television contribution applications by satellite consist of point-to-point or point-to-multipoint transmissions, connecting fixed or transportable uplink and receiving stations, not intended to be received by the general public.

Although these applications often transmit a single TV service, the Transport Stream multiplex flexibility also allows multi-programme TV services with associated sound, including commentary sound channels and data services; in this case multiple service components are Time Division Multiplexed (TDM) on a single digital carrier.

Maximum commonality with EN 300 421 [3] is maintained, such as Transport Stream multiplexing [1], scrambling for energy dispersal, concatenated error protection strategy based on Reed-Solomon coding, convolutional interleaving and inner convolutional coding. The baseline System compatibly includes (as a subset) all the transmission formats specified by EN 300 421 [3], based on Quaternary Phase Shift Keying (QPSK) modulation and is suitable for DSNG services as well as for other contribution applications by satellite. Nevertheless, other optional (annex C explains the meaning of "optional" within the present document) transmission modes are added, using Eight Phase Shift Keying (8PSK) modulation and Sixteen Quadrature Amplitude Modulation (16QAM), in order to fulfil specific application requirements. These optional modes can be very efficient in certain contribution applications by satellite.

The following warnings should be taken into account while using the high spectrum efficiency modes, 8PSK and 16QAM:

- they require higher transmitted EIRPs and/or receiving antenna diameters, because of their intrinsic sensitivity to noise and interferences;
- they are more sensitive to linear and non-linear distortions; in particular 16QAM cannot be used on transponders driven near saturation;
- they are more sensitive to phase noise, especially at low symbol rates; therefore high quality frequency converters should be used (see annex E);
- the System modulation/coding schemes are not rotationally-invariant, so that "cycle-slips" and "phase snaps" in the chain can produce service interruptions; therefore frequency conversions and demodulation carrier recovery systems should be designed to avoid cycle-slips and phase snaps.

The System is suitable for use on different satellite transponder bandwidths, either in single carrier per transponder or in multiple carriers per transponder (Frequency Division Multiplex, FDM) configuration. Annex E gives examples of possible use of the System.

The present document:

- gives a general description of the System;
- specifies the digitally modulated signal in order to allow compatibility between pieces of equipment developed by different manufacturers. This is achieved by describing in detail the signal processing principles at the modulator side, while the processing at the receive side is left open to different implementation solutions. However, it is necessary in the present document to refer to certain aspects of reception;
- identifies the global performance requirements and features of the System, in order to meet the service quality targets.

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, subsequent revisions do apply.
- 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: "Information technology; Generic coding of moving pictures and associated audio information: Systems".
- [2] ISO/IEC 13818-2: "Information technology; Generic coding of moving pictures and associated audio information: Video".
- [3] EN 300 421: "Digital Video Broadcasting (DVB); Framing structure, channel coding and modulation for 11/12 GHz satellite services".
- [4] EN 50083-9: "Cabled distribution systems for television, sound and interactive multimedia signals; Part 9: Interfaces for CATV/SMATV headends and similar professional equipment for DVB/MPEG-2 transport streams".
- [5] ETR 154: "Digital Video Broadcasting (DVB); Implementation guidelines for the use of MPEG-2 Systems, Video and Audio in satellite, cable and terrestrial broadcasting applications".
- [6] Void.
- [7] Void.
- [8] EN 300 468: "Digital Video Broadcasting (DVB); Specification for Service Information (SI) in DVB systems".
- [9] ETS 300 327: "Satellite Earth Stations and Systems (SES); Satellite News Gathering (SNG) Transportable Earth Stations (TES) (13-14/11-12 GHz)".
- [10] ETS 300 673 (1997): "Radio Equipment and Systems (RES); ElectroMagnetic Compatibility (EMC) standard for 4/6 GHz and 11/12/14 GHz Very Small Aperture Terminal (VSAT) equipment and 11/12/13/14 GHz Satellite News Gathering (SNG) Transportable Earth Station (TES) equipment".
- [11] TBR 30: "Satellite Earth Stations and Systems (SES); Satellite News Gathering (SNG) Transportable Earth Stations (TES) operating in the 11-12/13-14 GHz frequency bands".
- [12] ITU-R Recommendation SNG.770-1: "Uniform operational procedures for Satellite News Gathering (SNG)".

3 Symbols and abbreviations

3.1 Symbols

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

α	Roll-off factor
C/N	Carrier-to-noise ratio
d_{free}	Convolutional code free distance
E_b/N_0	Ratio between the energy per useful bit and twice the noise power spectral density
f_N	Nyquist frequency
G_1, G_2	Convolutional code generators
I	Interleaving depth [bytes]
I, Q	In-phase, Quadrature phase components of the modulated signal
j	Branch index of the interleaver
K	Convolutional code constraint length
m	number of transmitted bits per constellation symbol
M	Convolutional interleaver branch depth for $j = 1$, $M = N/I$
N	Error protected frame length (bytes)
R_s	Symbol rate corresponding to the bilateral Nyquist bandwidth of the modulated signal
R_u	Useful bit rate after MPEG-2 [1] transport multiplexer, referred to the 188 byte format
T	Number of bytes which can be corrected in RS error protected packet
T_s	Symbol period
X,Y	Di-bit stream after rate 1/2 convolutional coding

3.2 Abbreviations

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

16QAM	Sixteen Quadrature Amplitude Modulation
1CBPS	1 Coded Bit Per Symbol
2CBPS	2 Coded Bits Per Symbol
8PSK	Eight Phase Shift Keying
AWGN	Additive White Gaussian Noise
BER	Bit Error Ratio
BS	Bandwidth of the frequency Slot allocated to a service
BW	Bandwidth (at -3 dB) of the transponder
CBPS	Coded Bits Per Symbol
DSNG	Digital Satellite News Gathering
FDM	Frequency Division Multiplex
FEC	Forward Error Correction
HEX	Hexadecimal notation
IF	Intermediate Frequency
IRD	Integrated Receiver Decoder
MCPC	Multiple Channels Per Carrier transmission
MPEG	Moving Pictures Experts Group
MUX	Multiplex
OBO	Output Back Off
OCT	Octal notation
P	Puncturing
PDH	Plesiochronous Digital Hierarchy
PSK	Phase Shift Keying
QEF	Quasi-Error-Free
QPSK	Quaternary PSK
RF	Radio Frequency
RS	Reed-Solomon
SCPC	Single Channel Per Carrier transmission
SI	Service Information

SMATV	Satellite Master Antenna Television
SNG	Satellite News Gathering
TCM	Trellis Coded Modulation
TDM	Time Division Multiplex
TSDT	Transport Stream Descriptor Table
TV	Television

4 Transmission system

4.1 System definition

The System is defined as the functional block of equipment performing the adaptation of the baseband TV signals, from the output of the MPEG-2 transport multiplexer (see ISO/IEC 13818-1 [1]), to the satellite channel characteristics. The System is designed to support source coding as defined in [1], [2], [5].

The System transmission frame is synchronous with the MPEG-2 multiplex transport packets (see [1]).

The System shall use QPSK modulation, and optionally (annex C explains the meaning of "optional") 8PSK and 16QAM modulations, and the concatenation of convolutional and RS codes. For 8PSK and 16QAM, "pragmatic" trellis coding shall be applied, optimizing the error protection of the convolutional code defined in EN 300 421 [3]. The convolutional code is able to be configured flexibly, allowing the optimization of the system performance for a given satellite transponder bandwidth (see annex E).

Digital television transmissions via satellite can be affected by power limitations, therefore ruggedness against noise and interference has been one of the design objectives of the System. On the other hand, when larger power margins are available, spectrum efficiency can be increased to reduce the cost of the space segment. Therefore the System offers many transmission modes (inner coding and modulations), giving different trade-offs between power and spectrum efficiency. For some specific contribution applications, some modes (QPSK and 8PSK) thanks to their quasi-constant envelope, are appropriate for operation with saturated satellite power amplifiers, in single carrier per transponder configuration. All the modes (including 16QAM) are appropriate for operation in quasi-linear satellite channels, in multi-carrier Frequency Division Multiplex (FDM) type applications.

The following processes shall be applied to the data stream (see figure 1):

- transport multiplex adaptation and randomization for energy dispersal (according to EN 300 421 [3]);
- outer coding (i.e. Reed-Solomon) (according to EN 300 421);
- convolutional interleaving (according to EN 300 421);
- inner coding:
 - punctured convolutional coding (according to EN 300 421);
 - "pragmatic" trellis coding associated with 8PSK and 16QAM (optional);
- bit mapping into constellations:
 - QPSK (according to EN 300 421);
 - 8PSK (optional);
 - 16QAM (optional);
- squared-root raised-cosine baseband shaping:
 - roll-off factor $\alpha=0,35$ according to EN 300 421 for QPSK, 8PSK and 16QAM;
 - additional optional roll-off factor $\alpha=0,25$ (for the optional modulations 8PSK and 16QAM);
- quadrature modulation (according to EN 300 421).

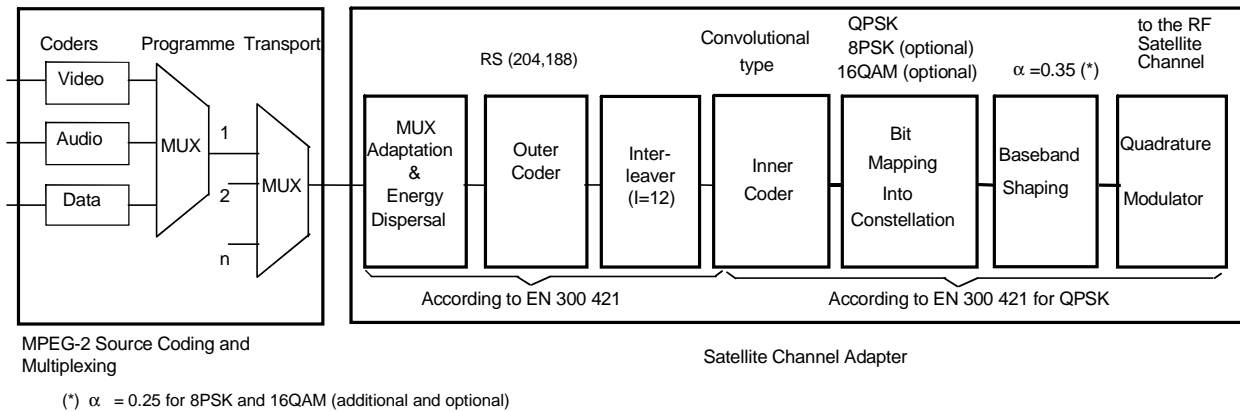


Figure 1: Functional block diagram of the System

If the received signal is above C/N and C/I threshold, the Forward Error Correction (FEC) technique adopted in the System is designed to provide a "Quasi Error Free" (QEF) quality target. The QEF means less than one uncorrected error-event per transmission hour, corresponding to Bit Error Ratio (BER) = 10^{-10} to 10^{-11} at the input of the MPEG-2 demultiplexer.

4.2 Adaptation to satellite transponder characteristics

The symbol rate shall be matched to given transponder characteristics, and, in the case of multiple carriers per transponder (FDM), to the adopted frequency plan. Examples of possible use of the System are given in annex E.

4.3 Interfacing

The System, as defined in the present document, shall be delimited by the following interfaces given in table 1.

Table 1: System interfaces

Location	Interface	Interface type	Connection
Transmit station	Input	MPEG-2 [1], [2], [4] transport multiplex (note 1)	from MPEG-2 multiplexer
	Output	70/140 MHz IF, L-band IF, RF	to RF devices
Receive installation	Output	MPEG-2 transport multiplex [1], [2], [4] (note 1)	to MPEG-2 demultiplexer
	Input	70/140 MHz IF, L-band IF	from RF devices

NOTE 1: For interoperability reasons, the Asynchronous Serial Interface (ASI) with 188 bytes format, data burst mode (bytes regularly spread over time) is recommended.

NOTE 2: The 70 MHz IF may imply limitation on the maximum symbol rate.

4.4 Channel coding for QPSK modes

The information on QPSK modulation summarized here is only partial. Refer to EN 300 421 [3] for the complete specification.

4.4.1 Transport multiplex adaptation and randomization for energy dispersal

This processing shall be in accordance with EN 300 421, as summarized in the following.

The System input stream shall be organized in fixed length packets, following the MPEG-2 transport multiplexer (see ISO/IEC 13818-1 [1]). The total packet length of the MPEG-2 transport Multiplex (MUX) packet is 188 bytes. This includes 1 sync-word byte (i.e. 47_{HEX}). In order to comply with ITU Radio Regulations and to ensure adequate binary transitions, the data of the input MPEG-2 multiplex shall be randomized. To provide an initialization signal for the descrambler, the MPEG-2 sync byte of the first transport packet in a group of eight packets is bit-wise inverted from 47_{HEX} to $B8_{\text{HEX}}$. This process is referred to as the "Transport Multiplex Adaptation".

4.4.2 Outer coding (RS), interleaving and framing

This processing shall be in accordance with EN 300 421, as summarized in the following.

Reed-Solomon RS (204,188, T = 8) shortened code, from the original RS(255,239, T = 8) code, shall be applied to each randomized transport packet (188 bytes) to generate an error protected packet. Reed-Solomon coding shall also be applied to the packet sync byte, either non-inverted (i.e. 47_{HEX}) or inverted (i.e. $B8_{\text{HEX}}$).

Convolutional interleaving with depth I = 12 shall be applied to the error protected packets. This results in an interleaved frame, composed of overlapping error protected packets and delimited by inverted or non-inverted MPEG-2 [1] sync bytes (preserving the periodicity of 204 bytes).

4.4.3 Inner coding (convolutional)

Processing of the convolutional encoder shall be in accordance with EN 300 421, as summarized in the following.

The System shall allow for a range of punctured convolutional codes, based on a rate 1/2 mother convolutional code with constraint length K = 7 corresponding to 64 trellis states (figure 2). This will allow selection of the most appropriate level of error correction for a given service or data rate. The System shall allow convolutional coding with code rates of 1/2, 2/3, 3/4, 5/6 and 7/8.

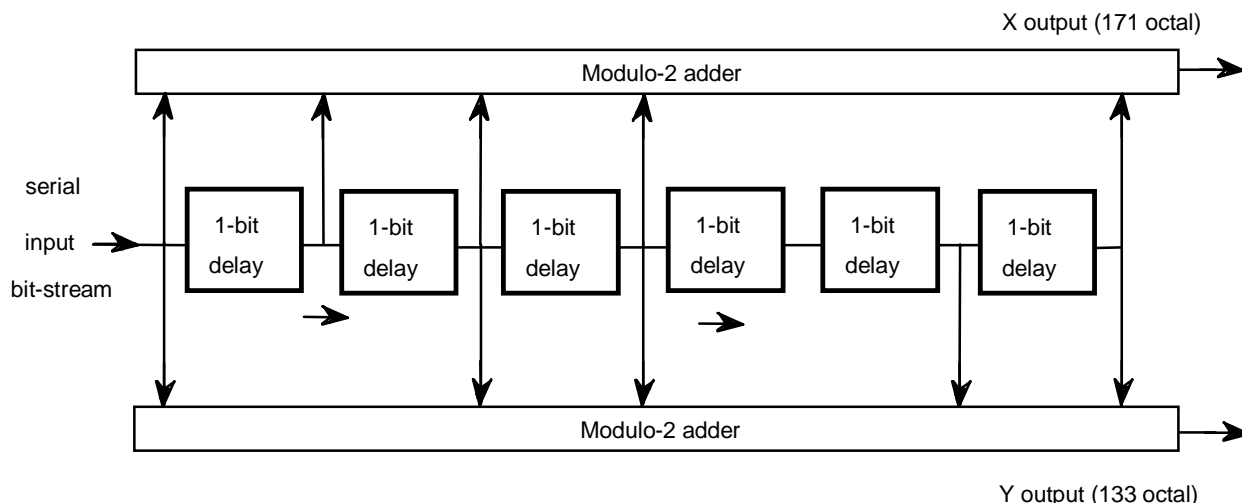


Figure 2: Convolutional code of rate 1/2

The punctured convolutional code shall be used as given in table 2, according to EN 300 421.

NOTE: At the receiver, each of the code rates and puncturing configurations is in a position to be tried until lock is acquired. Phase ambiguity in the demodulator is able to be resolved by decoding the MPEG-2 [1] sync byte delimiting the interleaved frame. Automatic receiver synchronization is an important feature in DSNG applications, to simplify and accelerate the satellite connection setup.

Table 2: Punctured code definition

Original code			Code rates									
			1/2		2/3		3/4		5/6		7/8	
K	G ₁ (X)	G ₂ (Y)	P	d _{free}	P	d _{free}	P	d _{free}	P	d _{free}	P	d _{free}
7	171 _{OCT}	133 _{OCT}	X: 1 Y: 1 C1=X ₁ C2=Y ₁	10	X: 1 0 Y: 1 1 C1=X ₁ Y ₂ Y ₃ C2=Y ₁ X ₃ Y ₄	6	X: 1 0 1 Y: 1 1 0 C1=X ₁ Y ₂ C2=Y ₁ X ₃	5	X: 1 0 1 0 1 Y: 1 1 0 1 0 C1=X ₁ Y ₂ Y ₄ C2=Y ₁ X ₃ X ₅	4	X: 1 0 0 0 1 0 1 Y: 1 1 1 1 0 1 0 C1=X ₁ Y ₂ Y ₄ Y ₆ C2=Y ₁ Y ₃ X ₅ X ₇	3
NOTE: 1 = transmitted bit 0 = non transmitted bit												

4.5 Bit mapping, baseband shaping and modulation for QPSK modes

4.5.1 Bit mapping to QPSK constellation

For QPSK, inner coding and mapping into constellation shall be in accordance with EN 300 421, as summarized in the following.

The serial input stream (see figures 2 and 3) shall be directly fed into the convolutional encoder. The outputs C1 and C2 of the punctured convolutional encoder shall be directly sent to the QPSK mapper.

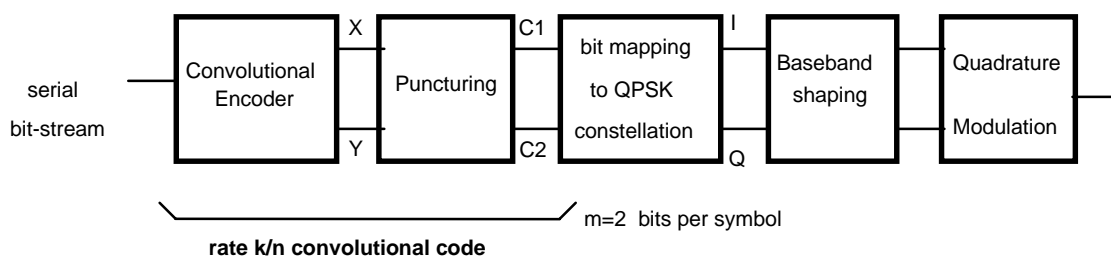


Figure 3: Inner coding principle for QPSK

The System shall employ conventional Gray-coded QPSK modulation with absolute mapping (no differential coding). Bit mapping in the QPSK constellation shall follow figure 4. If the normalization factor $1/\sqrt{2}$ is applied to the I and Q components, the corresponding average energy per symbol becomes equal to 1.

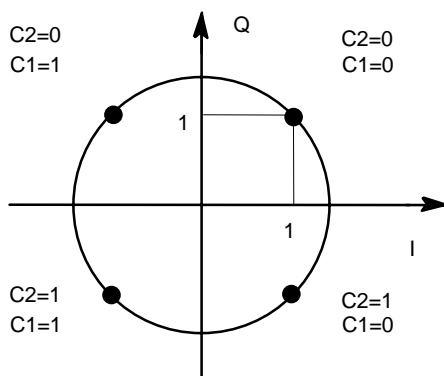


Figure 4: Bit mapping into QPSK constellation

4.5.2 Baseband shaping and quadrature modulation

Prior to modulation, the I and Q signals (mathematically represented by a succession of Dirac delta functions, multiplied by the amplitudes I and Q, spaced by the symbol duration $T_s = 1/R_s$) shall be square root raised cosine filtered. The roll-off factor shall be $\alpha = 0,35$.

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

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

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

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

where

$$f_N = \frac{1}{2T_s} = \frac{R_s}{2} \text{ is the Nyquist frequency and } \alpha \text{ is the roll-off factor.}$$

A template for the signal spectrum at the modulator output is given in annex A.

4.6 Channel coding for the optional 8PSK and 16QAM modes

Some details on QPSK are also repeated in the following for completeness.

4.6.1 Transport multiplex adaptation and randomization for energy dispersal (8PSK and 16QAM modes)

This processing shall be in accordance with EN 300 421 (see subclause 4.4.1).

4.6.2 Outer coding (RS), interleaving and framing (8PSK and 16QAM modes)

This processing shall be in accordance with EN 300 421 (see subclause 4.4.2).

4.6.3 Inner coding ("pragmatic" trellis coding type) (8PSK and 16QAM modes)

The inner coding schemes produce pragmatic Trellis Coded Modulations (TCM) (see bibliography), which are an extension of the coding method adopted in EN 300 421 (see subclause 4.4.3). The pragmatic trellis coded modulations shall be produced by the principle scheme shown in figure 5 and by tables 3 and 4. The byte-parallel stream (P0 to P7 in figure 5) at the output of the convolutional interleaver shall be conveyed to a parallel-to-parallel converter (note 1), which shall split the input bits into two branches, depending on the selected modulation / inner coding mode.

NOTE 1: The schemes of the parallel-to-parallel converters have been selected in order to reduce, on average, the byte error-ratio at the input of the Reed-Solomon decoder (high concentration of bit-errors in bytes). Therefore the bit error ratio (BER) after RS correction is reduced. Furthermore some MPEG sync-bytes are regularly convolutionally encoded.

The parallel-to-parallel converter is synchronized in such a way that the MPEG sync-bytes, in the normal form (47_{HEX}) or bit-wise inverted form (B8_{HEX}), regularly appear in byte **A** (see table 3). When an MPEG sync byte (47_{HEX}) is transmitted, the **A** byte shall be coded as follows: **A** = (A7, ..., A0) = 01000111.

The signal **NE** of the non-encoded branch shall generate, through the Symbol Sequencer, a sequence of signals **U**, each to be transmitted in a modulated symbol. These bits generate parallel transitions in the trellis code, and are only protected by a large Euclidean distance in the signal space (see bit mapping to constellation). The signal **E** in the encoded branch shall be processed by the punctured convolutional encoder according to EN 300 421 (see subclause 4.4.3). These bits shall generate, through the Symbol Sequencer, a sequence of signals **C**, each to be transmitted in a modulated symbol. The specific coding scheme for each constellation and coding rate shall follow the specification given in subclauses 4.7.1.1 to 4.7.1.3. A pragmatic trellis code characterized by c Coded Bits Per Symbol ($c = 1$ or 2) will be indicated in the following with the notation c CBPS (note 2).

NOTE 2: The 1CBPS schemes require lower processing speed of the TCM decoder compared to 2CBPS schemes. The selections have been carried-out on the basis of the best performance in the presence of AWGN.

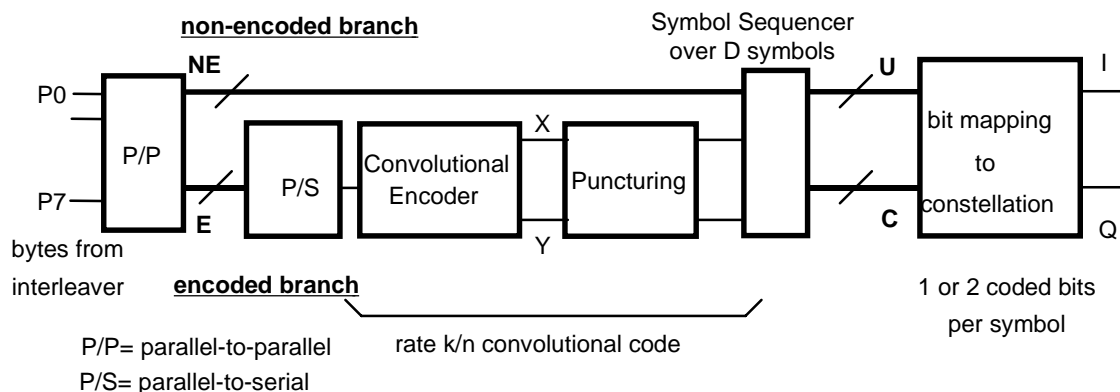


Figure 5: Inner trellis coder principle

NOTE 3: The QPSK modes described in subclause 4.5 can be generated by the TCM scheme of figure 5, without non-encoded bits.

The input parallel-to-parallel conversion shall be defined by table 3. The generic input bytes **P** = (P7, ..., P0) are taken from the sequence **A** (first), **B**, **D**, **F**, **G**, **H**, **L** (last) (the letters **C**, **E**, **I**, **J**, **K** are not used to avoid notation conflicts). For QPSK, the parallel-to-parallel converter reduces to a parallel-to-serial converter.

Table 3: Parallel-to-parallel conversion

MODE	Input P								Output
	LAST							FIRST	
QPSK	A0	A1	A2	A3	A4	A5	A6	A7	⇒ E1
8PSK - 2/3	B0	B1	B2	B3	B4	B5	B6	B7	⇒ NE1
	A0	A1	A2	A3	A4	A5	A6	A7	⇒ E1
8PSK - 5/6	G3	G7	F3	F7	D3	D7	B3	B7	⇒ NE4
	G2	G6	F2	F6	D2	D6	B2	B6	⇒ NE3
	G1	G5	F1	F5	D1	D5	B1	B5	⇒ NE2
	G0	G4	F0	F4	D0	D4	B0	B4	⇒ NE1
	A0	A1	A2	A3	A4	A5	A6	A7	⇒ E1
8PSK - 8/9					F5	F7	B1	B7	⇒ NE6
					F4	F6	B0	B6	⇒ NE5
					F3	D3	D7	B5	⇒ NE4
					F2	D2	D6	B4	⇒ NE3
					F1	D1	D5	B3	⇒ NE2
					F0	D0	D4	B2	⇒ NE1
					A1	A3	A5	A7	⇒ E2
16QAM - 3/4					A0	A2	A4	A6	⇒ E1
	D1	D3	D5	D7	B1	B3	B5	B7	⇒ NE2
	D0	D2	D4	D6	B0	B2	B4	B6	⇒ NE1
16QAM - 7/8	A0	A1	A2	A3	A4	A5	A6	A7	⇒ E1
	L3	L7	G3	G7	D3	D7	B3	B7	⇒ NE4
	L2	L6	G2	G6	D2	D6	B2	B6	⇒ NE3
	L1	L5	G1	G5	D1	D5	B1	B5	⇒ NE2
	L0	L4	G0	G4	D0	D4	B0	B4	⇒ NE1
	H2	H5	F0	F3	F6	A1	A4	A7	⇒ E3
	H1	H4	H7	F2	F5	A0	A3	A6	⇒ E2
H0	H3	H6	F1	F4	F7	A2	A5	⇒ E1	

The parallel-to-serial converter in figure 5 shall output first the E bit associated with highest index. The parallel-to-serial converter and the convolutional encoder shall introduce no relative delay between the coded and non-coded branches (i.e., the bit timing between non-encoded and encoded branches as indicated in table 4 shall be preserved).

The puncturing and symbol sequencer functions shall follow the definition given in table 4.

Table 4: Puncturing and Symbol sequencer definition

MODE	LAST SYMBOL			FIRST SYMBOL		Output
QPSK - 1/2				Y1	⇒	C2
				X1	⇒	C1
QPSK - 2/3		Y4	X3	Y1	⇒	C2
		Y3	Y2	X1	⇒	C1
QPSK - 3/4			X3	Y1	⇒	C2
			Y2	X1	⇒	C1
QPSK - 5/6		X5	X3	Y1	⇒	C2
		Y4	Y2	X1	⇒	C1
QPSK - 7/8	X7	X5	Y3	Y1	⇒	C2
	Y6	Y4	Y2	X1	⇒	C1
8PSK - 2/3				NE1	⇒	U1
				Y1	⇒	C2
				X1	⇒	C1
8PSK - 5/6			NE2	NE4	⇒	U2
			NE1	NE3	⇒	U1
			Y1	X1	⇒	C1
8PSK - 8/9		NE2	NE4	NE6	⇒	U2
		NE1	NE3	NE5	⇒	U1
		Y2	Y1	X1	⇒	C1
16QAM - 3/4				NE2	⇒	U2
				NE1	⇒	U1
				Y1	⇒	C2
				X1	⇒	C1
16QAM - 7/8			NE2	NE4	⇒	U2
			NE1	NE3	⇒	U1
			X3	Y1	⇒	C2
			Y2	X1	⇒	C1

4.7 Bit mapping, baseband shaping and modulation for the optional 8PSK and 16QAM modes

4.7.1 Bit mapping to constellations (8PSK and 16QAM modes)

Bit mapping into constellations is carried out by associating the m input bits (U , C in figure 5) with the corresponding vector in the Hilbert signal space belonging to the chosen constellation. The possible constellations are 8PSK ($m=3$ bit) and 16QAM ($m=4$ bit). Optimum mapping of coded and uncoded bits into constellation is different in the cases of 1CBPS or 2CBPS schemes. The Cartesian representation of each vector will be indicated by I , Q (i.e., the in-phase and quadrature components).

4.7.1.1 Inner coding and constellation for 8PSK 2/3 (2CBPS)

For 8PSK rate 2/3, inner coding shall comply with the principle of figure 6.

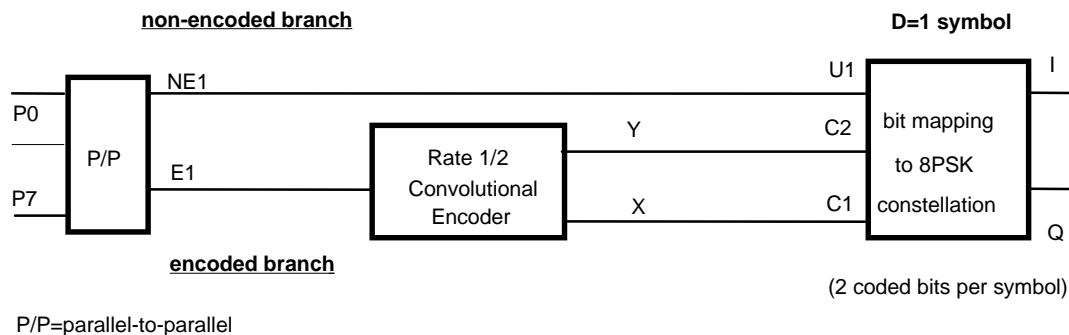


Figure 6: Inner coding principle for 8PSK rate 2/3 (2CBPS)

For rate 2/3, bit mapping in the 8PSK constellation shall follow figure 7. If the normalization factor $1/\sqrt{2}$ is applied to the I and Q components, the corresponding average energy per symbol becomes equal to 1.

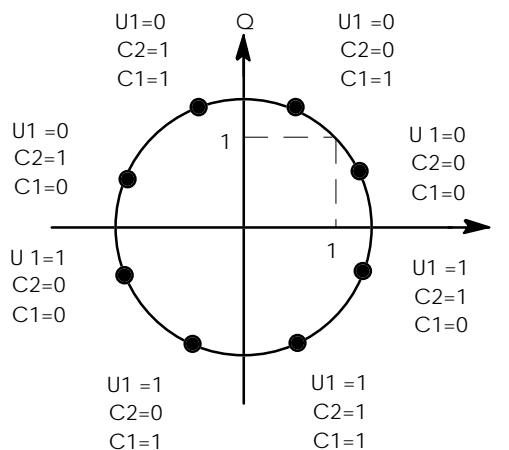


Figure 7: Bit mapping into 8PSK constellation for rate 2/3 (2CBPS)

4.7.1.2 Inner coding and constellation for 8PSK 5/6 and 8/9 (1CBPS)

For 8PSK rate 5/6 inner coding shall comply with the principle of figure 8.

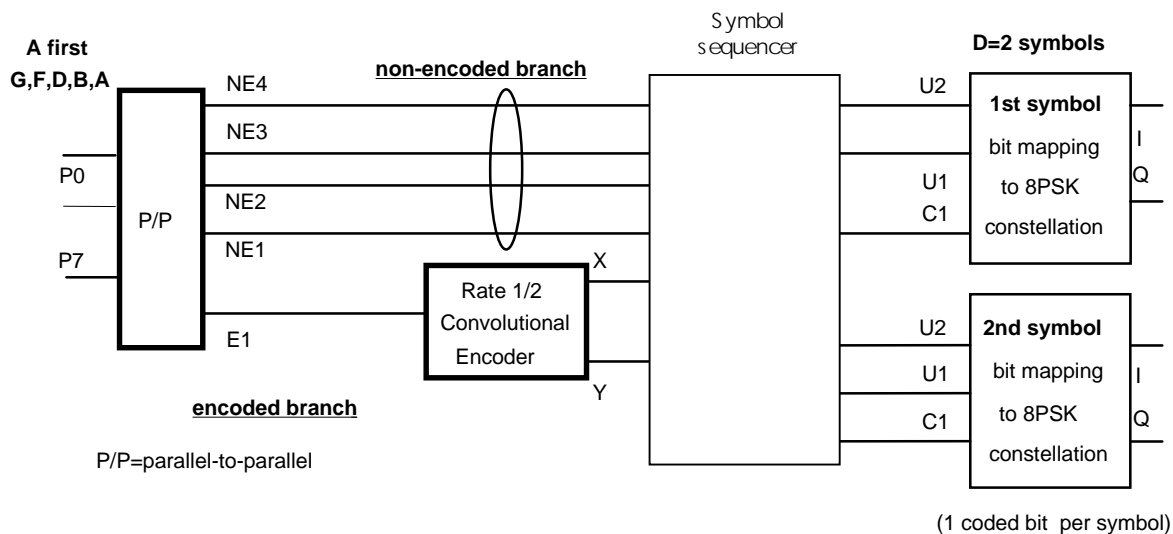


Figure 8: Inner coding principle for 8PSK rate 5/6 (1CBPS)

For 8PSK rate 8/9, inner coding shall comply with the principle of figure 9.

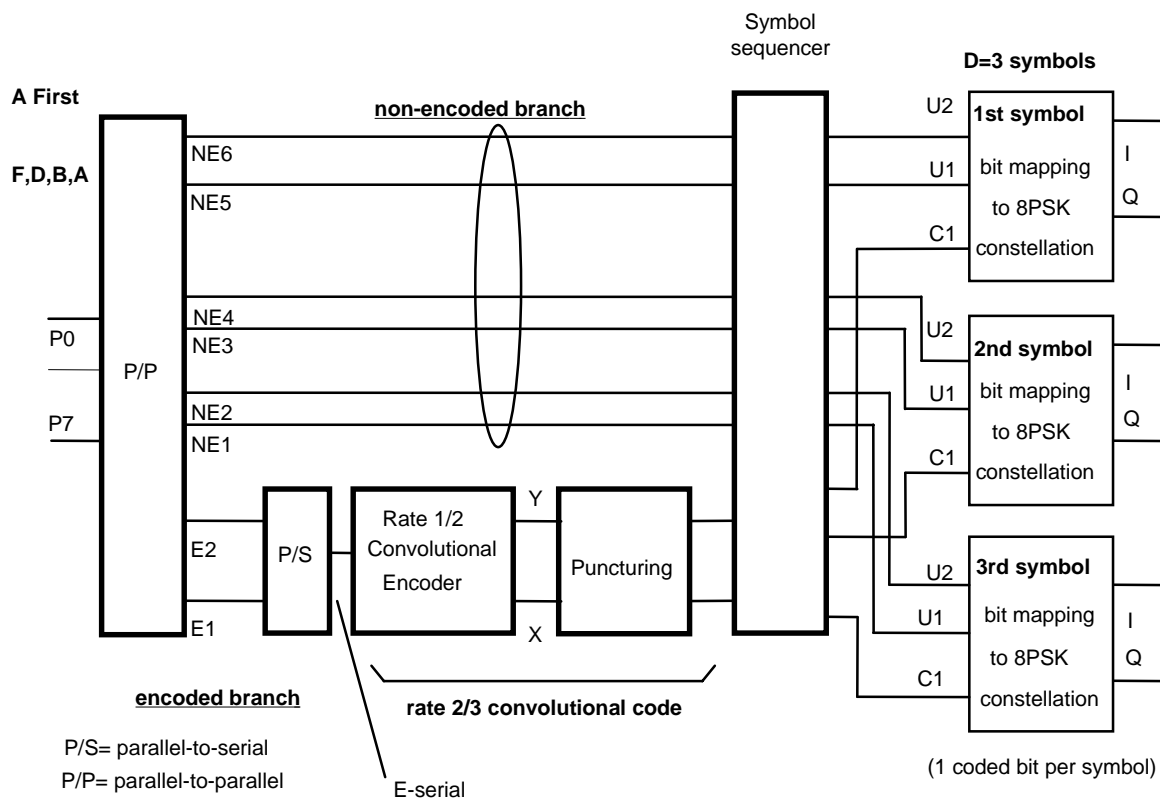
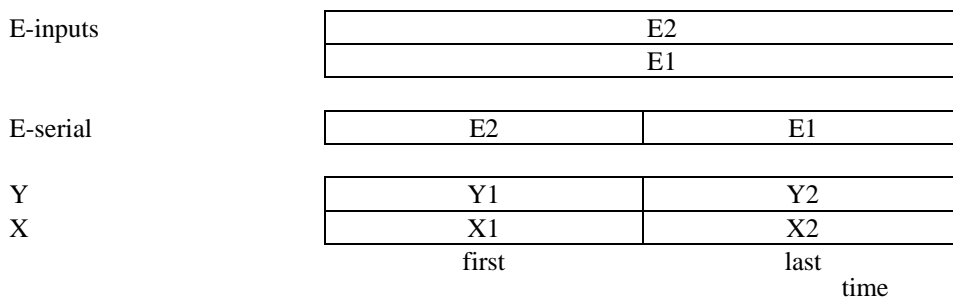


Figure 9: Inner coding principle for 8PSK rate 8/9 (1CBPS)

For 8PSK rate 8/9 the timing of the P/S converter and convolutional encoder shall follow the principle scheme as follows:



For rates 5/6 and 8/9, bit mapping in the 8PSK constellation shall comply with figure 10. If the normalization factor $1/\sqrt{2}$ is applied to the I and Q components, the corresponding average energy per symbol becomes equal to 1.

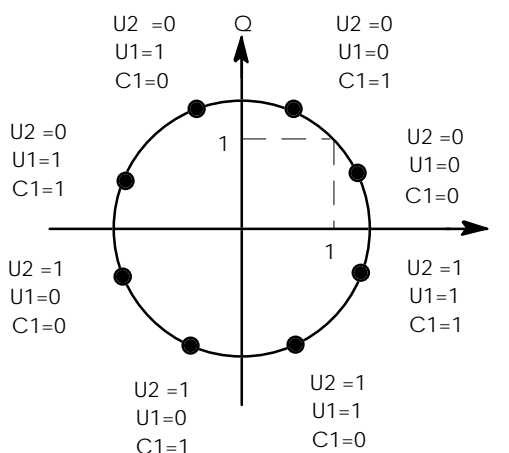


Figure 10: Bit mapping into 8PSK constellation for rates 5/6 and 8/9 (1CBPS)

4.7.1.3 Inner coding and constellation for 16QAM 3/4 and 7/8 (2CBPS)

16QAM modes are suitable for quasi-linear transponders.

For 16QAM rate 3/4 inner coding shall comply with the principle of figure 11.

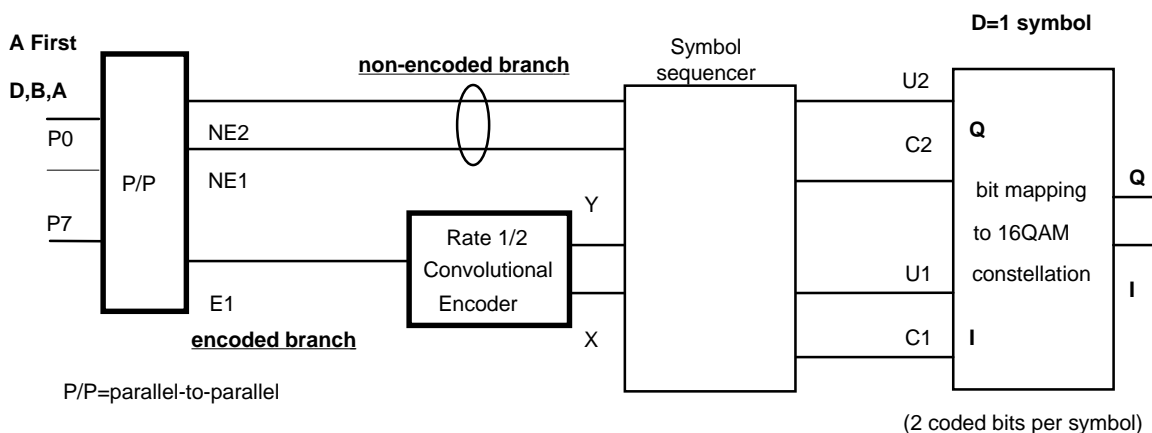


Figure 11: Inner coding principle for 16QAM rate 3/4 (2CBPS)

For 16QAM rate 7/8, inner coding shall comply with the principle of figure 12.

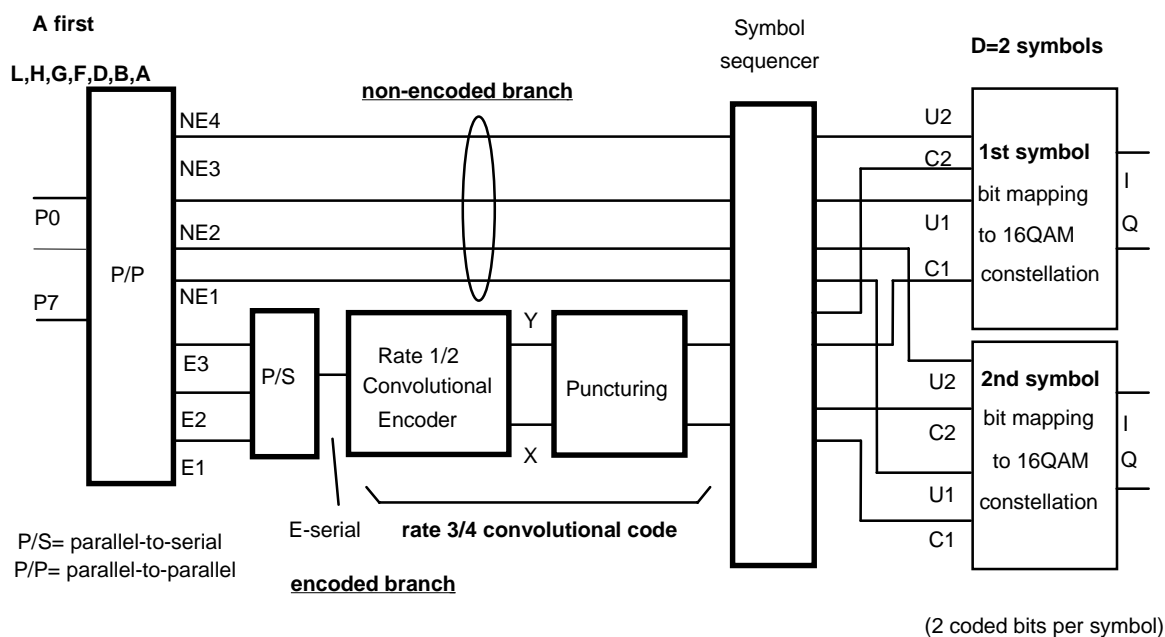


Figure 12: Inner coding principle for 16QAM rate 7/8 (2CBPS)

For 16QAM rate 7/8 the timing of the P/S converter and convolutional encoder shall comply with the principle scheme as follows:

E-inputs	E3		
	E2		
	E1		
E-serial	E3	E2	E1
Y	Y1	Y2	Y3
X	X1	X2	X3
	first		last

For rates 3/4 and 7/8, bit mapping in the 16QAM constellation shall comply with figure 13. If the normalization factor $1/\sqrt{10}$ is applied to the I and Q components, the corresponding average energy per symbol becomes equal to 1.

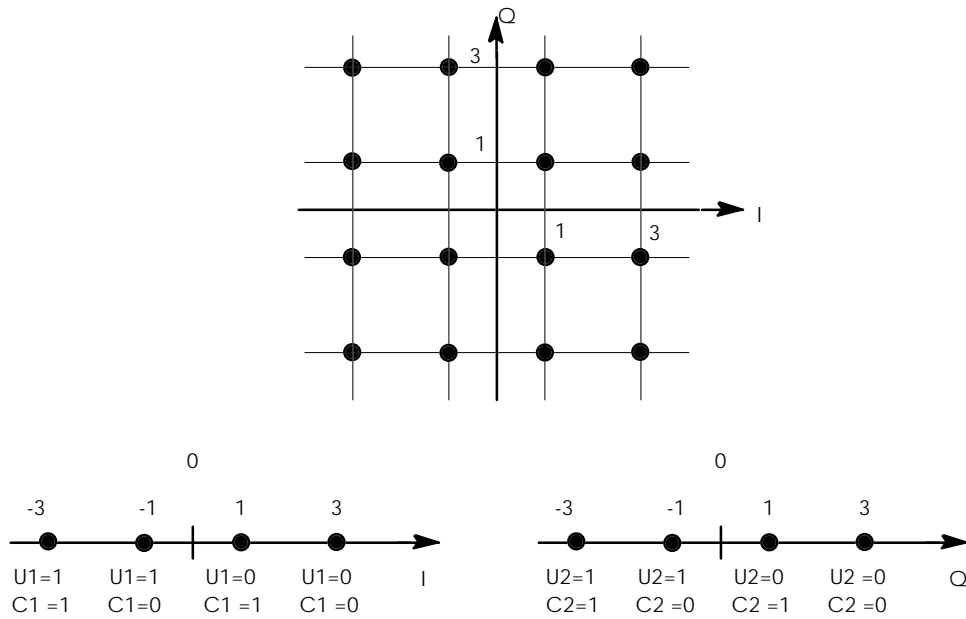


Figure 13: Bit mapping into I and Q axes for 16QAM constellation, rates 3/4 and 7/8 (2CBPS)

4.7.2 Baseband shaping and modulation (8PSK and 16QAM modes)

Prior to modulation, the I and Q signals (mathematically represented by a succession of Dirac delta functions, multiplied by the amplitudes I and Q, spaced by the symbol duration $T_s = 1/R_s$) shall be square root raised cosine filtered (see subclause 4.5.2). The roll-off factor shall be $\alpha = 0,35$ for 8PSK and 16QAM.

In addition to $\alpha = 0,35$, for 8PSK and 16QAM the narrow roll-off factor $\alpha = 0,25$ can optionally be used (see annex E).

A template for the signal spectrum at the modulator output is given in annex A.

5 Error performance requirements

The modem, connected in the IF loop, shall meet the BER versus E_b/N_o performance requirements given in table 5.

Table 5: IF-Loop performance of the System

Modulation	Inner code rate	Spectral efficiency (bit/symbol)	Modem implementation margin (dB)	Required E_b/N_o (note 1) for BER = 2×10^{-4} before RS QEF after RS (dB)
QPSK	1/2	0,92	0,8	4,5
	2/3	1,23	0,8	5,0
	3/4	1,38	0,8	5,5
	5/6	1,53	0,8	6,0
	7/8	1,61	0,8	6,4
8PSK (optional)	2/3	1,84	1,0	6,9
	5/6	2,30	1,4	8,9
	8/9 (note 3)	2,46	1,5	9,4
16QAM (optional)	3/4 (note 3)	2,76	1,5	9,0
	7/8	3,22	2,1	10,7

NOTE 1: The figures of E_b/N_o are referred to the useful bit-rate R_U (188 byte format, before RS coding) (so takes account of the factor $10 \log 188/204 \approx 0,36$ dB due to the Reed-Solomon outer code) and include the modem implementation margins. For QPSK the figures are derived from EN 300 421 [1]. For 8PSK and 16QAM, modem implementation margins which increase with the spectrum efficiency are adopted, to cope with the larger sensitivity associated with these schemes.

NOTE 2: Quasi-Error-Free (QEF) means approximately less than one uncorrected error event per hour at the input of the MPEG-2 demultiplexer. Other residual error rate targets could be defined for "contribution quality" transmissions. The bit error ratio (BER) of 2×10^{-4} before RS decoding corresponds approximately to a byte error ratio between 7×10^{-4} and 2×10^{-3} depending on the coding scheme.

NOTE 3: 8PSK 8/9 is suitable for satellite transponders driven near saturation, while 16QAM 3/4 offers better spectrum efficiency for quasi-linear transponders, in FDMA configuration.

Examples of possible use of the System are given in annex E.

Annex A (normative): Signal spectrum at the modulator output

For QPSK modulation, the signal spectrum at the modulator output shall be in accordance with EN 300 421, relevant to a roll-off factor $\alpha=0,35$.

For the optional modulations 8PSK and 16QAM, the signal spectrum at the modulator output shall be in accordance with EN 300 421, relevant to a roll-off factor $\alpha=0,35$. As an option, the signal spectrum can correspond to a narrower roll-off factor $\alpha=0,25$.

Figure A.1 gives a template for the signal spectrum at the modulator output for a roll-off factor $\alpha=0,35$.

Figure A.1 also represents a possible mask for a hardware implementation of the Nyquist modulator filter as specified in subclauses 4.5.2 and 4.7.2. The points A to S shown on figures A.1 and A.2 are defined in table A.1 for roll-off factors $\alpha=0,35$ and $\alpha=0,25$. The mask for the filter frequency response is based on the assumption of ideal Dirac delta input signals, spaced by the symbol period $T_s = 1/R_s = 1/2f_N$, while in the case of rectangular input signals a suitable $x/\sin x$ correction shall be applied on the filter response.

Figure A.2 gives a mask for the group delay for the hardware implementation of the Nyquist modulator filter.

Relative power (dB)

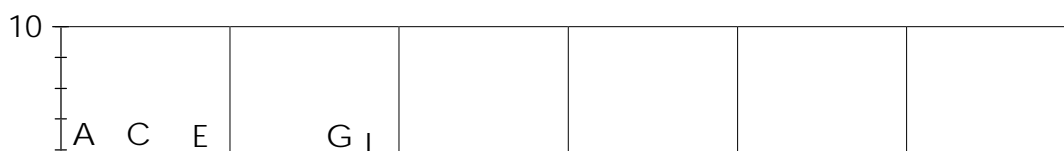


Figure A.1: Template for the signal spectrum mask at the modulator output represented in the baseband frequency domain (roll-off factor $\alpha=0,35$)

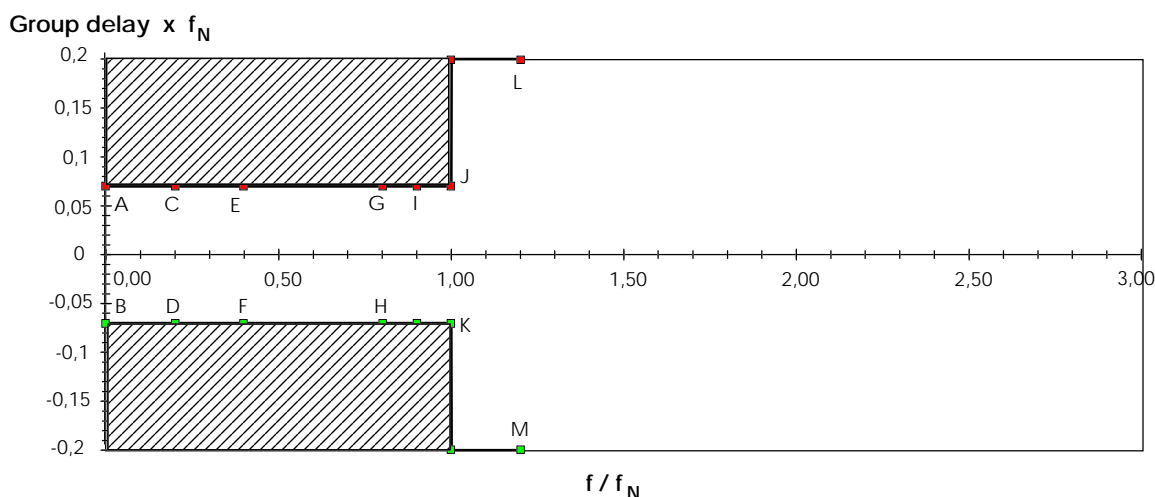


Figure A.2: Template of the modulator filter group delay (roll-off factors $\alpha=0,35$ and $\alpha=0,25$)

Table A.1: Definition of points given in figures A.1 and A.2

Point	Frequency for $\alpha=0,35$	Frequency for $\alpha=0,25$ (note)	Relative power (dB)	Group delay
A	$0,0 f_N$	$0,0 f_N$	+0,25	$+0,07 / f_N$
B	$0,0 f_N$	$0,0 f_N$	-0,25	$-0,07 / f_N$
C	$0,2 f_N$	$0,2 f_N$	+0,25	$+0,07 / f_N$
D	$0,2 f_N$	$0,2 f_N$	-0,40	$-0,07 / f_N$
E	$0,4 f_N$	$0,4 f_N$	+0,25	$+0,07 / f_N$
F	$0,4 f_N$	$0,4 f_N$	-0,40	$-0,07 / f_N$
G	$0,8 f_N$	$0,86 f_N$	+0,15	$+0,07 / f_N$
H	$0,8 f_N$	$0,86 f_N$	-1,10	$-0,07 / f_N$
I	$0,9 f_N$	$0,93 f_N$	-0,50	$+0,07 / f_N$
J	$1,0 f_N$	$1,0 f_N$	-2,00	$+0,07 / f_N$
K	$1,0 f_N$	$1,0 f_N$	-4,00	$-0,07 / f_N$
L	$1,2 f_N$	$1,13 f_N$	-8,00	-
M	$1,2 f_N$	$1,13 f_N$	-11,00	-
N	$1,8 f_N$	$1,60 f_N$	-35,00	-
P	$1,4 f_N$	$1,30 f_N$	-16,00	-
Q	$1,6 f_N$	$1,45 f_N$	-24,00	-
S	$2,12 f_N$	$1,83 f_N$	-40,00	-

NOTE: The roll-off factor $\alpha=0,25$ is optional and applicable to 8PSK and 16QAM only

Annex B (normative): Transmission setups for interoperability tests and emergency situations

At least one user definable setup shall be provided by the DSNG equipment to be able to cope with interoperability tests and emergency situations. This setup shall be easily selectable in the equipment.

Table B.1 shows possible examples of Transmission Setups which can be used for interoperability tests and emergency situations. Other examples may be derived from table E.1 of annex E.

Table B.1: Possible examples of Transmission Setups

MPEG 2 Coding profile	Bit Rate R_U (after MUX) (Mbit/s)	Modulation	Code rate	Symbol Rate R_S (Mbaud)	Total bandwidth $1,35 R_S$ (MHz)
MP@ML	3,0719	QPSK	3/4	2,222	3,000
MP@ML	4,6078	QPSK	3/4	3,333	4,500
MP@ML	6,3120	QPSK	3/4	4,566	6,160
MP@ML	8,2941	QPSK	3/4	6,000	8,100
MP@ML	8,4480	QPSK	3/4	6,1113	8,250
422P@ML	21,5030	QPSK	7/8	13,3332	18,000

NOTE: For bit-rates and symbol rates, typical accuracy is ± 10 ppm.

Tables B.2 and B.3 show example Coding Setups for $R_U=8,448$ Mbit/s and for $R_U=21,5030$ Mbit/s which can be used for interoperability tests and emergency situations.

Table B.2: Example Coding Setups for MP@ML at 8,448 Mbit/s

Components	No. of channels	Bit rate (Elementary Stream)	Coding	Video Resolution and Audio Sampling Rate	
				Video frame rate 25 Hz	Video frame rate 29,97 Hz
Video	1	7,60 Mbit/s	No Low delay	720 x 576	720 x 480
Audio	1 Stereo pair	256 kbit/s	MPEG1 Layer 2	48 kHz	48 kHz
Data	Not used				
VBI data	Not used				

Table B.3: Example Coding Setups for 422@ML at 21,503 Mbit/s

Components	No. of channels	Bit rate (Elementary Stream)	Coding	Video Resolution and Audio Sampling Rate	
				Video frame rate 25 Hz	Video frame rate 29,97 Hz
Video	1	20,00 Mbit/s	No Low delay	720 x 576	720 x 480
Audio	1 Stereo pair	384 kbit/s	MPEG1 Layer 2	48 kHz	48 kHz
Data	Not used				
VBI data	Not used				

NOTE 1: It would be desirable that the Transport Stream at the input of the Modulator is not scrambled (no conditional access).

NOTE 2: I, B or P picture type are allowed in the coded video stream.

Annex C (normative): Implementation of the "optional" modes

Within the present document, a number of modes and mechanisms have been defined as "Optional".

For example, trellis coded 8PSK and 16QAM modes are optional.

Modes and mechanisms explicitly indicated as "optional" within the present document need not be implemented in the equipment to comply with the present document. Nevertheless, when an "optional" mode or mechanism is implemented, it shall comply with the specification as given in the present document.

Annex D (normative): SI implementation for DSNG and other contribution applications

In DSNG transmissions, editing of the SI tables in the field may be impossible due to operational problems. Therefore, only the following MPEG2-defined SI tables PAT, PMT and Transport Stream Descriptor Table (TSDT) are mandatory.

The first descriptor in the TSDT descriptor loop shall contain the descriptor which identifies the Transport Stream as of type 'CONA' (with reference to the "CONtribution" Application).

Syntax **no. of bits****identifier**

```
transport-stream-descriptor (){
    descriptor_tag          8    uimsbf
    descriptor_length      8    uimsbf
    for (i=0;i<N;i++){
        byte                8    uimsbf
    }
}
```

Semantics for the Transport Stream Descriptor:

The descriptor_length field shall be set to the value 0x04.

byte: This in an 8-bit field. The four bytes shall contain the values 0x43, 0x4F, 0x4E, 0x41 (ASCII: "CONA").

In DSNG transmissions, the TSDT descriptor loop shall also contain a second descriptor, the DSNG descriptor, with the following syntax:

Syntax **no. of bits****identifier**

```
DSNG-descriptor (){
    descriptor_tag          8    uimsbf
    descriptor_length      8    uimsbf
    for (i=0;i<N;i++) {
        station_identification_char  8    uimsbf
    }
}
```

Descriptor_tag: 0x68

Semantics for the DSNG descriptor:

station_identification_char: Is a field containing a string used for fast identification of the uplink station transmitting the Transport Stream. The characters in the string are coded in ASCII.

Guidelines for the usage of the Transport Stream Description Table (TSDT) within DVB-DSNG streams are given in EN 301 222 (see bibliography).

TSDTs shall be repeated at least every 10 seconds.

The *station_identification_char* field shall contain the following items, comma-separated and in the following order:

- The usual station-code.
- The SNG Headquarter.
- The SNG provider.

The usual station-code is the code assigned to the station by the Satellite Operator with which the station is most frequently used.

The SNG Headquarter (operating during the transmission period) is the control centre through which the station can uniquely be identified (by giving its usual station code) and quickly located. The SNG provider is the owner of the SNG station.

DSNG IRDs shall be able to decode and interpret the TSDT and the descriptors specified.

Guidelines to achieve (optional) compatibility with consumer IRDs

If compatibility with consumer IRDs is required, the TSDT shall contain three descriptors:

- the first descriptor is a Transport Stream descriptor [0x67] containing the ASCII string "DVB".
The presence of this descriptor implies that all SI tables shall be present according to EN 300 468 [8].
- the second descriptor is the Transport Stream descriptor [0x67] containing the ASCII string "CONT".
The presence of this descriptor indicates that the transmission is of contribution nature.
- for DSNG transmissions, the third descriptor is the DSNG-descriptor [0x68].

Annex E (informative): Examples of possible use of the System

In single carrier per transponder configurations, the transmission symbol rate R_s can be matched to given transponder bandwidth BW (at -3 dB), to achieve the maximum transmission capacity compatible with the acceptable signal degradation due to transponder bandwidth limitations. To take into account possible thermal and ageing instabilities, reference can be made to the frequency response mask of the transponder.

In the multi-carrier FDM configuration, R_s can be matched to the frequency slot BS allocated to the service by the frequency plan, to optimize the transmission capacity while keeping the mutual interference between adjacent carriers at an acceptable level.

Table E.1 gives examples of the maximum useful bit rate capacity R_u achievable by the System versus the allocated bandwidths BW or BS. The figures for very low and very high bit-rates may be irrelevant for specific applications. In these examples the adopted BW/R_s or BS/R_s ratios are $\eta = 1 + \alpha = 1,35$ where α is the roll-off factor of the modulation. This choice allows to obtain a negligible E_b/N_0 degradation due to transponder bandwidth limitations, and also to adjacent channel interference on a linear channel. Higher bit-rates can be achieved with the narrow roll-off factor $\alpha = 0,25$ (optional for 8PSK and 16QAM) and BW/R_s or BS/R_s equal to $\eta = 1 + \alpha = 1,25$.

Table E.1: Examples of maximum bit rates versus transponder bandwidth BW or frequency slot BS, for BW/R_s or $BS/R_s = \eta = 1,35$

BW or BS (MHz)	$R_s =$ BW/1,35 (Mbaud)	R_u (Mbit/s)									
		QPSK					8PSK			16QAM	
		rate 1/2	rate 2/3	rate 3/4	rate 5/6	rate 7/8	rate 2/3	rate 5/6	rate 8/9	rate 3/4	rate 7/8
72	53,333	49,1503	65,5338	73,7255	81,9172	86,0131	98,3007	122,876	131,068	147,451	172,026
54	40,000	36,8627	49,1503	55,2941	61,4379	64,5098	73,7255	92,1568	98,3007	110,588	129,020
46	34,074	31,4016	41,8688	47,1024	52,3360	54,9528	62,8032	78,5040	83,7376	94,2047	109,906
41	30,370	27,9884	37,3178	41,9826	46,6473	48,9797	55,9768	69,971	74,6357	83,9651	97,9593
36	26,666	24,5752	32,7669	36,8627	40,9586	43,0065	49,1503	61,4379	65,5338	73,725	86,0131
33	24,444	22,5272	30,0363	33,7908	37,5454	39,4227	45,0545	56,3181	60,0726	67,5817	78,8453
30	22,222	20,4793	27,3057	30,7190	34,1322	35,8388	40,9586	51,1983	54,6115	61,4379	71,6776
27	20,000	18,4314	24,5752	27,6471	30,7190	32,2549	36,8627	46,0784	49,1503	55,2941	64,5098
18	13,333	12,2876	16,3834	18,4314	20,4793	21,5033	24,5752	30,7190	32,7669	36,8627	43,0065
15	11,111	10,2397	13,6529	15,3595	17,0661	17,9194	24,5752	25,5991	27,3057	30,7190	35,8388
12	8,888	8,1917	10,9223	12,2876	13,6529	14,3355	16,3834	20,4793	21,8446	24,5752	28,6710
9	6,666	6,1438	8,1917	9,2157	10,2397	10,7516	12,2876	15,3595	16,3834	18,4314	21,5033
6	4,444	4,0959	5,4611	6,1438	6,8264	7,1678	8,1917	10,2396	10,9223	12,2876	14,3355
4,5	3,333	3,0719	4,0959	4,6078	5,1198	5,3758	6,1438	7,6797	8,1917	9,2157	10,7516
3	2,222	2,0480	2,7306	3,0719	3,4132	3,5839	4,096	5,1198	5,4611	6,1438	7,1678
1,5	1,111	1,0240	1,3653	1,5359	1,7066	1,7919	2,048	2,5599	2,7306	3,0719	3,5839

NOTE 1: R_u stands for the useful bit rate (188 byte format) after MPEG-2 MUX. R_s (symbol rate) corresponds to the -3dB bandwidth of the modulated signal. $R_s(1+\alpha)$ corresponds to the theoretical total signal bandwidth after the modulator.

NOTE 2: 8PSK 8/9 is suitable for satellite transponders driven near saturation, while 16QAM 3/4 offers better spectrum efficiency for quasi-linear transponders, in FDMA configuration.

NOTE 3: BW/R_s or BS/R_s ratios different from $1+\alpha$ may be adopted for different service requirements. For example the MP-setup (see annex B) can be transmitted in a 9 MHz frequency slot with 750 kHz bandwidth margin. The adoption of BS/R_s figures significantly lower than $1+\alpha$ (e.g. $BS/R_s = 1,21$ associated with $\alpha=0,35$), to improve the spectrum exploitation, should be carefully studied on a case-by-case basis, since severe performance degradations may arise due to bandwidth limitations and/or adjacent channel interference, especially with 8PSK and 16QAM modulations and high coding rates (e.g. 5/6 or 7/8).

Table E.2 considers possible examples of use of the System in the single carrier per transponder configuration. Different modulation and inner code rates are given with the relevant bit rates. According to typical practical applications, a BW/R_s ratio equal to 1,31 is considered, offering a slightly better spectrum efficiency than the examples of table E.1 for the same modulation/coding schemes. The considered transponder bandwidth of 36 MHz is wide enough to allow high quality 422P@ML Single Channel Per Carrier (SCPC) transmissions, as well as MP@ML and 422P@ML Multiple Channels Per Carrier (MCPC) transmissions.

**Table E.2: Examples of System configurations by satellite:
single carrier per transponder**

Satellite BW (at -3 dB)	System mode	Symbol Rate R_s (Mbaud)	Bit Rate R_u (after MUX) (Mbit/s)	E_b/N_o (specification) (dB)
36	QPSK 3/4	27,500	38,015	5,5
36	8PSK 2/3	27,500	50,686	6,9

NOTE 4: The E_b/N_o figures refer to the IF loop specification for Quasi-Error-Free (QEF) (see clause 5). Overall linear, non-linear and interference performance degradations by satellite should be evaluated on a case-by-case basis; typical figures are of the order of 0,5 to 1,5 dB.

NOTE 5: Quasi-constant envelope modulations, such as QPSK and 8PSK, are power efficient in single carrier per transponder configuration, since they can operate on transponders driven near saturation. Conversely, 16QAM is not power efficient since it can only operate on quasi-linear transponders (i.e., with large Output-Back-Off, OBO). The use of the narrow roll-off $\alpha=0,25$ with 8PSK can produce a larger non-linear degradation by satellite.

Table E.3 considers possible examples of use of the System in the multi-carrier FDM configuration and in SCPC (Single Channel Per Carrier) mode. Different modulation/coding modes are given with the relevant bit rates.

**Table E.3: Examples of System configurations by satellite:
multi-carrier FDM transmissions, SCPC mode**

Satellite BW (MHz)	Slot BS (MHz)	Number of Slots in BW	Video Coding	System mode	Symbol Rate (Mbaud)	BS/R_s (Hz/Baud)	Bit Rate R_u (Mbit/s)	E_b/N_o (specification) (dB)
36	9	4	MP@ML	QPSK 3/4	6,1113	1,47	8,4480	5,5
36	18	2	422P@ML	QPSK 7/8	13,3332	1,35	21,5030	6,4
36	12	3	422P@ML	8PSK 5/6	9,3332	1,28	21,5030	8,9
36	9	4	422P@ML	16QAM 7/8	6,6666	1,35	21,5030	10,7
72	18	4	422P@ML	QPSK 7/8	13,3332	1,35	21,5030	6,4

NOTE 6: The E_b/N_o figures refer to the IF loop specification for Quasi-Error-Free (QEF) (see clause 5). Overall linear, non-linear and interference degradations by satellite should be evaluated on a case-by-case basis; typical figures are of the order of 0,5 dB to 1,5 dB.

NOTE 7: In the FDM configuration, the satellite transponder must be quasi-linear (i.e., with large Output-Back-Off, OBO) to avoid excessive intermodulation interference between signals. Therefore 16QAM may be used.

The system, when operating in 8PSK and 16QAM modes, is more sensitive to phase noise than in QPSK modes. Figure E.1 shows an example transmit phase noise mask for carriers with information rates $< 2\,048$ Mbit/s, taken from the Intelsat IESS-310 specification for pragmatic trellis coded 8PSK modulations (see bibliography).

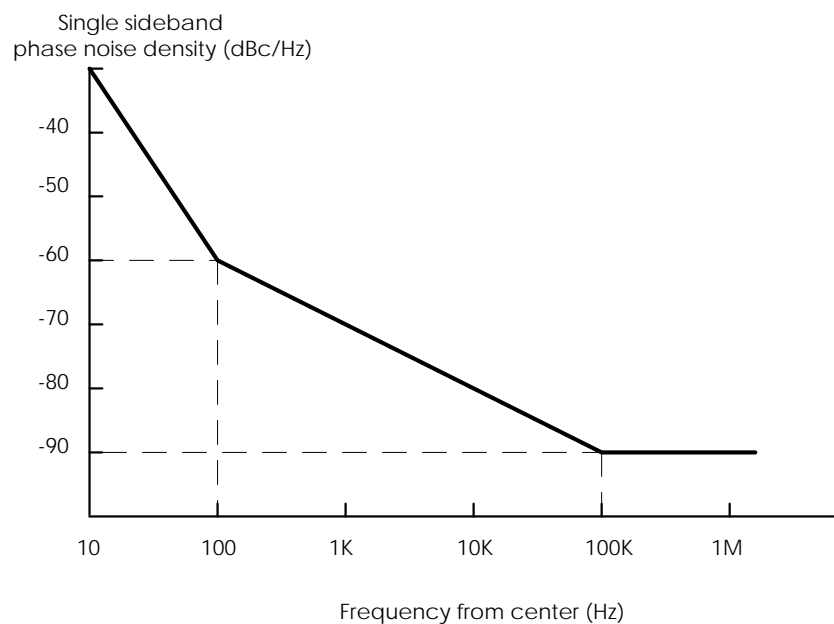


Figure E.1: Example of continuous single sideband phase noise mask (for carriers with information rates less than or equal to 2 048 Mbit/s)

NOTE 8: Equipment designers should take account of the total system phase noise requirements, that is arising in the modulator, up/down converters, satellite and the receiver oscillators.

Bibliography

The following material, though not specifically referenced in the body of the present document, gives supporting information.

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History

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