EUROPEAN
TELECOMMUNICATION
STANDARD

ETS 300 421

December 1994

Source: EBU/ETSI JTC

Reference: DE/JTC-DVB-6

ICS: 33.160.20, 33.060.140

Key words: Digital television broadcasting by satellite, modulation, channel coding

European Broadcasting Union   Union Européenne de Radio-Télévision

EBU
UER

Digital broadcasting systems for television,
sound and data services;
Framing structure, channel coding and modulation
for 11/12 GHz satellite services

ETSI

European Telecommunications Standards Institute

ETSI Secretariat

Postal address: F-06921 Sophia Antipolis CEDEX - FRANCE
Office address: 650 Route des Lucioles - Sophia Antipolis - Valbonne - FRANCE
X.400: c=fr, a=atlas, p=etsi, s=secretariat - **Internet:** secretariat@etsi.fr

Tel.: +33 92 94 42 00 - Fax: +33 93 65 47 16

New presentation - see History box

Contents

Blank page

Foreword

This European Telecommunication Standard (ETS) has been produced under the authority of the Joint Technical Committee (JTC) of the European Broadcasting Union (EBU) and the European Telecommunications Standards Institute (ETSI).

NOTE: The EBU/ETSI JTC was established in 1990 to co-ordinate the drafting of ETSs in the specific field of radio, television and data broadcasting.

The EBU is a professional association of broadcasting organisations 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
Case Postale 67
CH-1218 GRAND SACONNEX (Geneva)
Switzerland

Tel: +41 22 717 21 11
Fax: +41 22 717 24 81

This ETS describes framing structure, channel coding and modulation for digital television emission by satellite, it has been prepared by the Project Team PT-55V. The work of the Project Team was based on the studies carried out by European DVB Project under the auspices of the Ad hoc Group V4/MOD-B. This joint group of industry, operators and broadcasters provided the necessary information on all relevant matters to the Project Team, see DTVB 1110/GT V4/MOD 252/ DTVC 18 (bibliography).

This ETS is part of the complete "Multivision system" (the name "Multivision system" is currently under review) which covers the baseband image coding, baseband sound coding, baseband data service coding, multiplexing, channel coding and modulation for satellite services, channel coding and modulation for cable distribution and common scrambling system.

Blank page

1   Scope

This European Telecommunication Standard (ETS) describes the modulation and channel coding system (denoted the "System" for the purposes of this ETS) for satellite digital multi-programme Television (TV)/High Definition Television (HDTV) services to be used for primary and secondary distribution in Fixed Satellite Service (FSS) and Broadcast Satellite Service (BSS) bands. The System is intended to provide Direct-To-Home (DTH) services for consumer Integrated Receiver Decoder (IRD), as well as collective antenna systems (Satellite Master Antenna Television (SMATV)) and cable television head-end stations, with a likelihood of remodulation, see ETS 300 429 (bibliography).

The System uses Quaternary Phase Shift Keying (QPSK) modulation and concatenated error protection strategy based on a convolutional code and a shortened Reed-Solomon (RS) code.

The System is suitable for use on different satellite transponder bandwidths.

Compatibility with Moving Pictures Experts Group-2 (MPEG-2) coded TV services (see ISO/IEC DIS 13818-1 [1]), with a transmission structure synchronous with the packet multiplex, is provided. Exploitation of the multiplex flexibility allows the use of the transmission capacity for a variety of TV service configurations, including sound and data services. All service components are Time Division Multiplexed (TDM) on a single digital carrier.

This ETS:

-        gives a general description of the System for satellite digital TV transmission;

-        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 this ETS 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   Normative references

This ETS incorporates by dated and undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this ETS only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies.

[1]   ISO/IEC DIS 13818-1 (June 1994): "Coding of moving pictures and associated audio".

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

[3]   Intelsat Earth Station Standards (IESS) No. 308, revision 6 (26 October 1990): "Performance characteristics for Immediate Data Rate (IDR) digital carriers".

3 Symbols and abbreviations

3.1 Symbols

For the purposes of this ETS, the following symbols apply:

α	Roll-off factor
C/N	Signal-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
g(x)	RS code generator polynomial
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	Convolutional interleaver branch depth for j = 1, M = N/I
N	Error protected frame length (bytes)
p(x)	RS field generator polynomial
r_m	In-band ripple (dB)
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
R_u'	Bit rate after RS outer coder
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 this ETS, the following abbreviations apply:

AWGN	Additive White Gaussian Noise
BB	Baseband
BER	Bit Error Ratio
BSS	Broadcast Satellite Service
BW	Bandwidth
CCITT	International Telegraph and Telephone Consultative Committee
DTH	Direct To Home
EBU	European Broadcasting Union
ETS	European Telecommunication Standard
FDM	Frequency Division Multiplex
FEC	Forward Error Correction
FIFO	First-In, First-Out shift register
FIR	Finite Impulse Response
FSS	Fixed Satellite Service
HEX	Hexadecimal notation
HDTV	High Definition Television
IF	Intermediate Frequency
IMUX	Input Multiplexer - Filter
IRD	Integrated Receiver Decoder
ITU	International Telecommunications Union
MPEG	Moving Pictures Experts Group
MSB	Most Significant Bit
MUX	Multiplex
OBO	Output Back Off
OCT	Octal notation
OMUX	Output Multiplexer - Filter
P	Puncturing
PDH	Plesiochronous Digital Hierarchy
PSK	Phase Shift Keying

PRBS   Pseudo Random Binary Sequence
QEF   Quasi-Error-Free
QPSK   Quaternary PSK
R   Randomized sequence
RF   Radio Frequency
RS   Reed-Solomon
SMATV   Satellite Master Antenna Television
TBD   To Be Defined
TDM   Time Division Multiplex
TV   Television
TWTA   Travelling Wave Tube Amplifier

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 DIS 13818-1 [1]), to the satellite channel characteristics. The following processes shall be applied to the data stream (see figure 1):

-       transport multiplex adaptation and randomization for energy dispersal;

-       outer coding (i.e. Reed-Solomon);

-       convolutional interleaving;

-       inner coding (i.e. punctured convolutional code);

-       baseband shaping for modulation;

-       modulation.

The System functional description is given in annex B.

DTH services via satellite are particularly affected by power limitations, therefore, ruggedness against noise and interference, shall be the main design objective, rather than spectrum efficiency. To achieve a very high power efficiency without excessively penalizing the spectrum efficiency, the System shall use QPSK modulation and the concatenation of convolutional and RS codes. The convolutional code is able to be configured flexibly, allowing the optimization of the system performance for a given satellite transponder bandwidth (see annex C).

Although the System is optimized for single carrier per transponder Time Division Multiplex (TDM), it is able to be used for multi-carrier Frequency Division Multiplex (FDM) type applications.
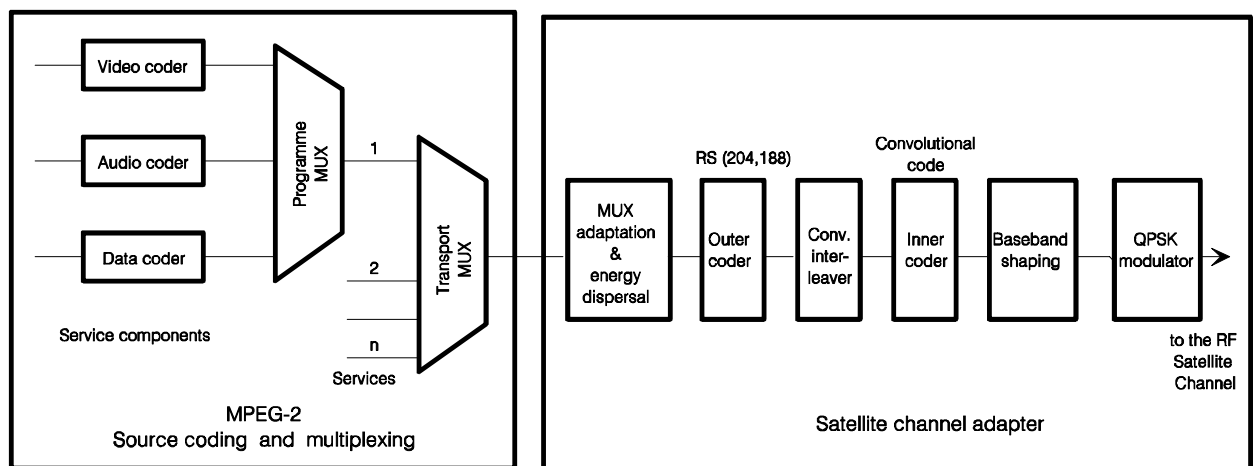

Figure 1: Functional block diagram of the System

The System is directly compatible with MPEG-2 coded TV signals (see ISO/IEC DIS 13818-1 [1]). The modem transmission frame is synchronous with the MPEG-2 multiplex transport packets.

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

Transmissions of digital multi-programme TV services will use satellites in both the FSS and the BSS bands. The choice of transponder bandwidth is a function of the satellite used and the data rates required by the service.

The symbol rate shall be matched to given transponder characteristics. Examples based on computer simulations for a hypothetical satellite chain, not including interference effects, are given in annex C.

4.3   Interfacing

The System, as defined in this ETS, 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] transport multiplex	from MPEG-2 multiplexer
	Output	70/140 MHz IF	to RF devices
Receive installation	Output	MPEG-2 transport multiplex	to MPEG-2 demultiplexer
	Input	TBD	from RF devices (indoor unit)

4.4   Channel coding

4.4.1   Transport multiplex adaptation and randomization for energy dispersal

The System input stream shall be organized in fixed length packets (see figure 3), following the MPEG-2 transport multiplexer (see ISO/IEC DIS 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}). 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 ITU Radio Regulations and to ensure adequate binary transitions, the data of the input MPEG-2 multiplex shall be randomized in accordance with the configuration depicted in figure 2.

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 2, 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 is bit-wise inverted from 47_{HEX} to $B8_{HEX}$. This process is referred to as the "Transport Multiplex Adaptation".

The first bit at the output of the PRBS generator shall be applied to the first bit (i.e. MSB) 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 shall continue, but its output shall be disabled, leaving these bytes unrandomized. Thus, the period of the PRBS sequence shall be 1 503 bytes.

The randomization process shall be active also when the modulator input bit-stream is non-existent, 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.
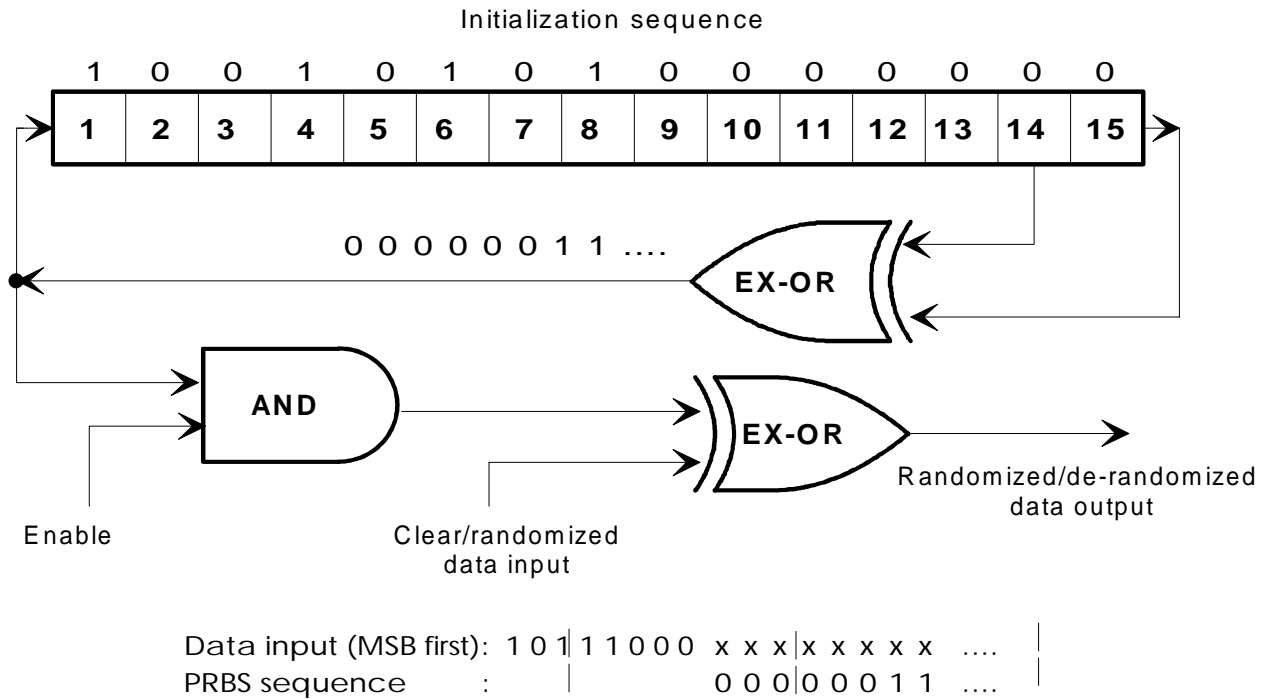
Initialization sequence

1	0	0	1	0	1	0	1	0	0	0	0	0	0	0
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

0 0 0 0 0 0 1 1 ....

EX-OR

AND

EX-OR

Randomized/de-randomized
data output

Enable

Clear/randomized
data input

Data input (MSB first): 1 0 1 1 1 0 0 0   x x x x x x x x   ....
PRBS sequence   :   0 0 0 0 0 0 1 1   ....

Figure 2: Randomizer/de-randomizer schematic diagram

4.4.2   Outer coding (RS), interleaving and framing

The framing organization shall be based on the input packet structure (see figure 3a).

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) of figure 3b to generate an error protected packet (see figure 3c). Reed-Solomon coding shall also be applied to the packet sync byte, either non-inverted (i.e. 47HEX) or inverted (i.e. B8HEX).

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

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

The shortened Reed-Solomon code may be implemented by adding 51 bytes, all set to zero, before the information bytes at the input of a (255,239) encoder. After the RS coding procedure these null bytes shall be discarded.

Following the conceptual scheme of figure 4, convolutional interleaving with depth I = 12 shall be applied to the error protected packets (see figure 3c). This results in an interleaved frame (see figure 3d).

The convolutional interleaving process shall be based on the Forney approach [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 inverted or non-inverted MPEG-2 [1] 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 (M j) 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 in the branch "0" of the interleaver (corresponding to a null delay).

NOTE: The de-interleaver is similar, in principle, to the interleaver, but the branch indexes are reversed (i.e. j = 0 corresponds to the largest delay). The de-interleaver synchronization can be carried out by routeing the first recognized sync byte in the "0" branch.
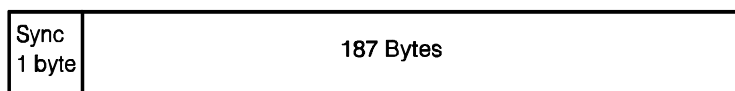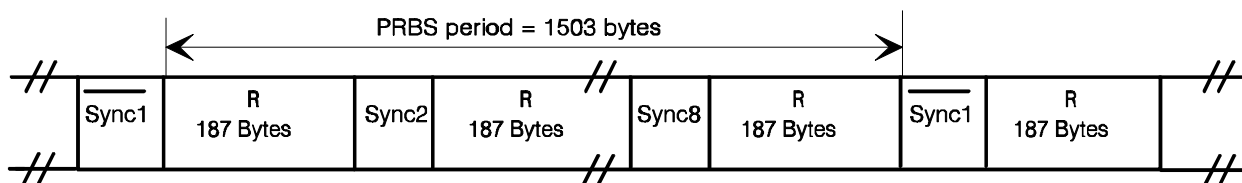
Sync 1 byte	187 Bytes

Figure 3a) MPEG-2 transport MUX packet

PRBS period = 1503 bytes

Sync1	R 187 Bytes	Sync2	R 187 Bytes	Sync8	R 187 Bytes	Sync1	R 187 Bytes

Figure 3b) Randomized transport packets: Sync bytes and randomized sequence R

204 bytes

Sync1 or Sync n	R 187 Bytes	RS(204,188,8)
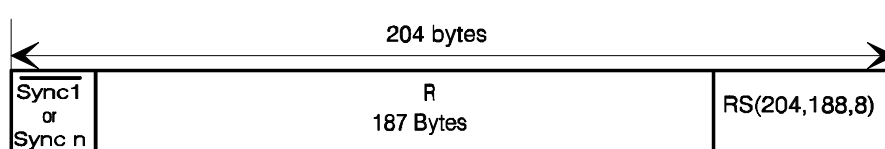
Figure 3c) Reed-Solomon RS (204,188, T=8) error protected packet

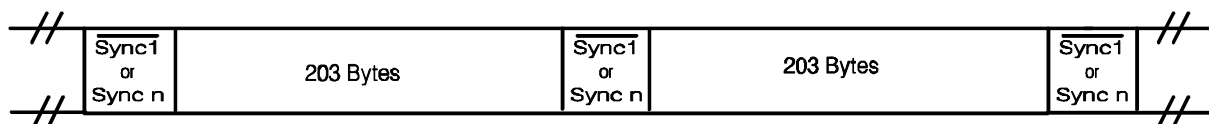| Sync1 or Sync n	203 Bytes	Sync1 or Sync n	203 Bytes	Sync1 or Sync n

Figure 3d) Interleaved frames; interleaving depth I=12 bytes

Sync1 = not randomized complemented sync byte
Sync n = not randomized sync byte, n = 2, 3, ..., 8

Figure 3: Framing structure

4.4.3   Inner coding (convolutional)

The System shall allow for a range of punctured convolutional codes, based on a rate 1/2 convolutional code with constraint length K = 7. 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.

The punctured convolutional code shall be used as given in table 2. See also figure 5.
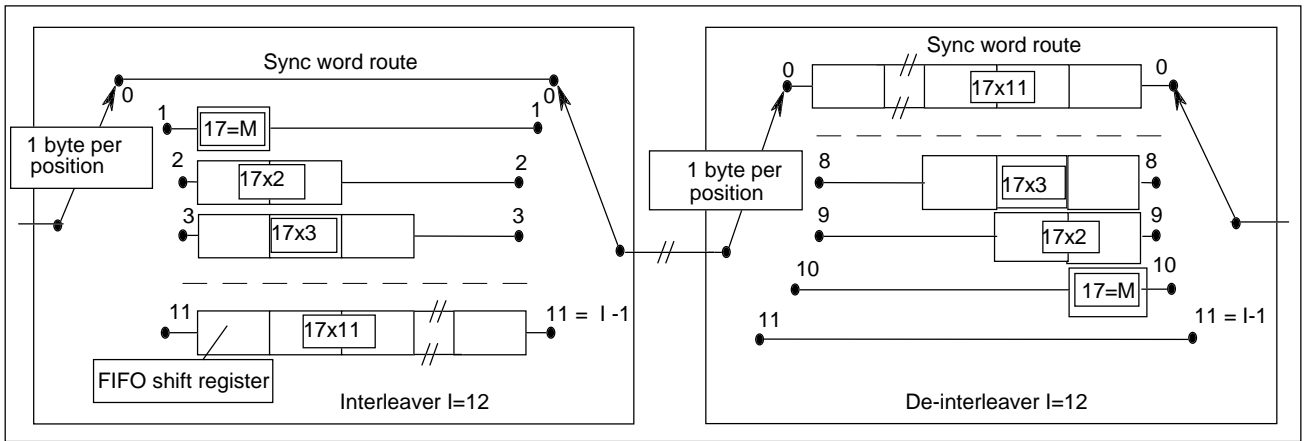
Figure 4: Conceptual diagram of the convolutional interleaver and de-interleaver

Table 2: Punctured code definition

Original code			Code rates										
			1/2		2/3		3/4		5/6		7/8		
K	G1 (X)	G2 (Y)	P	dfree	P	dfree	P	dfree	P	dfree	P	dfree
7	171_{OCT}	133_{OCT}	X: 1 Y: 1 I=X_1 Q=Y_1	10	X: 1 0 Y: 1 1 I=X_1 Y_2 Y_3 Q=Y_1 X_3 Y_4	6	X: 1 0 1 Y: 1 1 0 I=X_1 Y_2 Q=Y_1 X_3	5	X: 1 0 1 0 1 Y: 1 1 0 1 0 I=X_1 Y_2 Y_4 Q=Y_1 X_3 X_5	4	X: 1 0 0 0 1 0 1 Y: 1 1 1 1 0 1 0 I=X_1 Y_2 Y_4 Y_6 Q=Y_1 Y_3 X_5 X_7	3

NOTE: 1 = transmitted bit
         0 = non transmitted bit

4.5   Baseband shaping and modulation

The System shall employ conventional Gray-coded QPSK modulation with absolute mapping (no differential coding). Bit mapping in the signal space as given on figure 5 shall be used.

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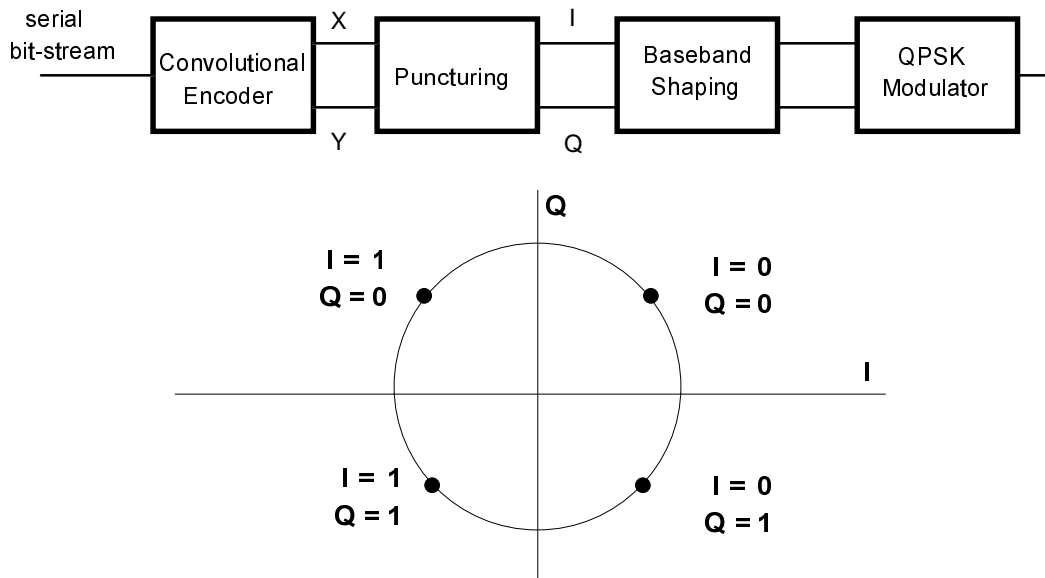

Figure 5: QPSK constellation

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

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

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

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

where

$$f_N = \frac{1}{2T_S} = \frac{R_S}{2} \text{ is the Nyquist frequency and}$$

α is the roll-off factor, $\alpha = 0,35$.

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 3.

Table 3: IF-Loop performance of the System

Inner code rate	Required E_b/N_o for BER = 2×10^{-4} after Viterbi QEF after Reed-Solomon
1/2	4,5
2/3	5,0
3/4	5,5
5/6	6,0
7/8	6,4

NOTE 1:   The figures of E_b/N_o refer to the useful bit-rate before RS coding and include a modem implementation margin of 0,8 dB and the noise bandwidth increase due to the outer code (10 log 188/204 = 0,36 dB).

NOTE 2:   Quasi-Error-Free (QEF) means less than one uncorrected error event per hour, corresponding to BER = 10^{-10} to 10^{-11} at the input of the MPEG-2 demultiplexer.

Indicative figures of the System performance by satellite are given in annex D.

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

Figure A.1 gives a template for the signal spectrum at the modulator output.

Figure A.1 also represents a possible mask for a hardware implementation of the Nyquist modulator filter as specified in subclause 4.5. The points A to S shown on figures A.1 and A.2 are defined in table A.1. 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.

Figures A.1 and A.2 are based on Intelsat Earth Station Standards (IESS) No. 308 [3], with slight modification due to different roll off.
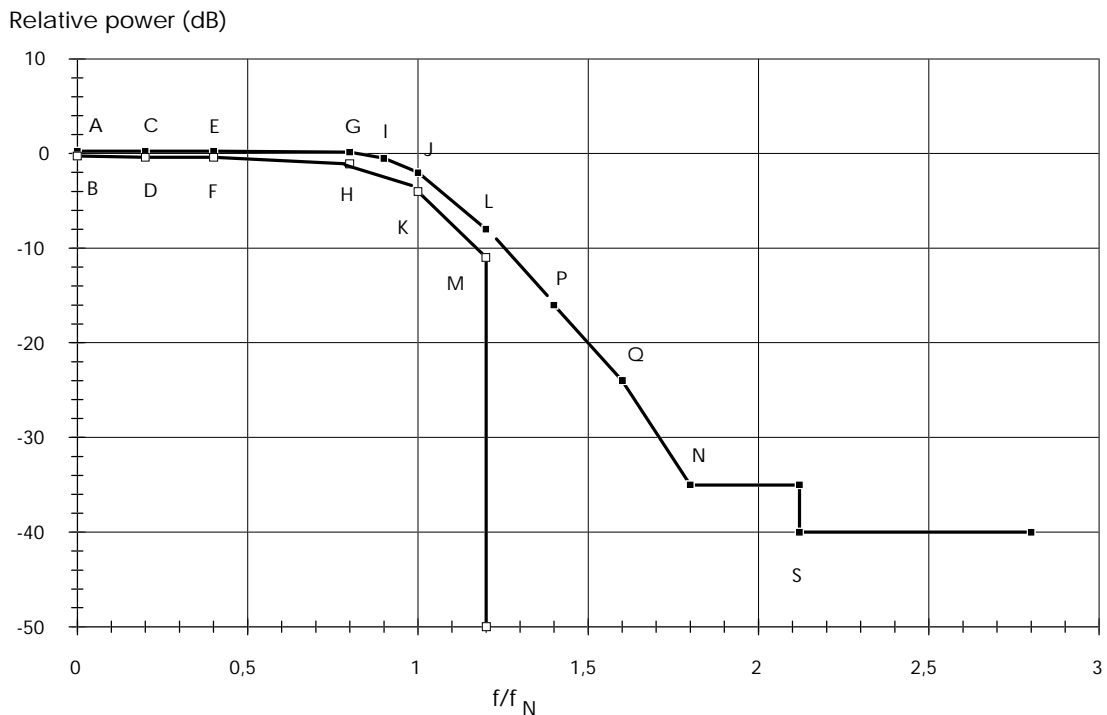
Figure A.1: Template for the signal spectrum mask at the modulator output represented in the baseband frequency domain
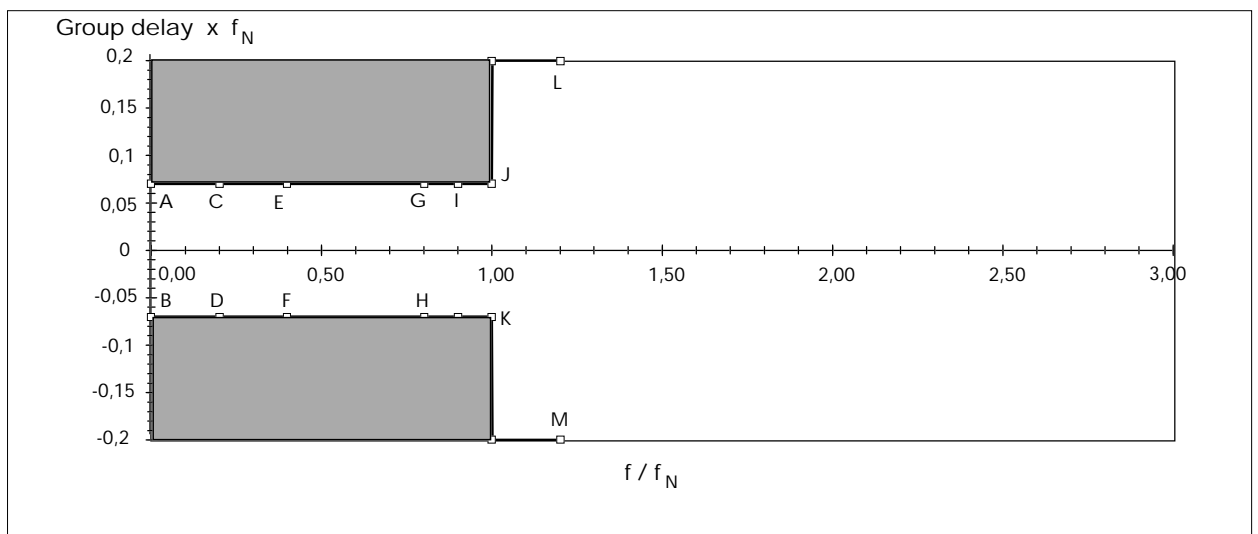
Figure A.2: Template of the modulator filter group delay

Table A.1: Definition of points given in figure A.1

Point	Frequency	Relative power (dB)	Group delay
A	0,0 f_N	+0,25	+0,07 / f_N
B	0,0 f_N	-0,25	-0,07 / f_N
C	0,2 f_N	+0,25	+0,07 / f_N
D	0,2 f_N	-0,40	-0,07 / f_N
E	0,4 f_N	+0,25	+0,07 / f_N
F	0,4 f_N	-0,40	-0,07 / f_N
G	0,8 f_N	+0,15	+0,07 / f_N
H	0,8 f_N	-1,10	-0,07 / f_N
I	0,9 f_N	-0,50	+0,07 / f_N
J	1,0 f_N	-2,00	+0,07 / f_N
K	1,0 f_N	-4,00	-0,07 / f_N
L	1,2 f_N	-8,00	-
M	1,2 f_N	-11,00	-
N	1,8 f_N	-35,00	-
P	1,4 f_N	-16,00	-
Q	1,6 f_N	-24,00	-
S	2,12 f_N	-40,00	-

Annex B (informative):   Conceptual System description

The modulator and demodulator may perform the functions indicated in the block diagrams of figure B.1.

Due to the similarity of the modulator and demodulator block diagrams, only the latter is described as follows:

- **IF interface and QPSK demodulator:** this unit performs the quadrature coherent demodulation function and the analogue to digital conversion, providing "soft decision" I and Q information to the inner decoder.

- **Matched filter:** this unit performs the complementary pulse shaping filtering of raised cosine type according to the roll-off. The use of a Finite Impulse Response (FIR) digital filter could provide equalization of the channel linear distortions in the IRD.

- **Carrier/clock recovery unit:** this device recovers the demodulator synchronization. The probability of slips generation over the full C/N range of the demodulator should be very low.

- **Inner decoder:** this unit performs first level error protection decoding. It should operate at an input equivalent "hard decision" BER in the order of between 10^{-1} and 10^{-2} (depending on the adopted code rate), and should produce an output BER of about 2×10^{-4} or lower. This output BER corresponds to QEF service after outer code correction. It is possible that this unit makes use of "soft decision" information. This unit is in a position to try each of the code rates and puncturing configurations until lock is acquired. Furthermore, it is in a position to resolve $\pi/2$ demodulation phase ambiguity.
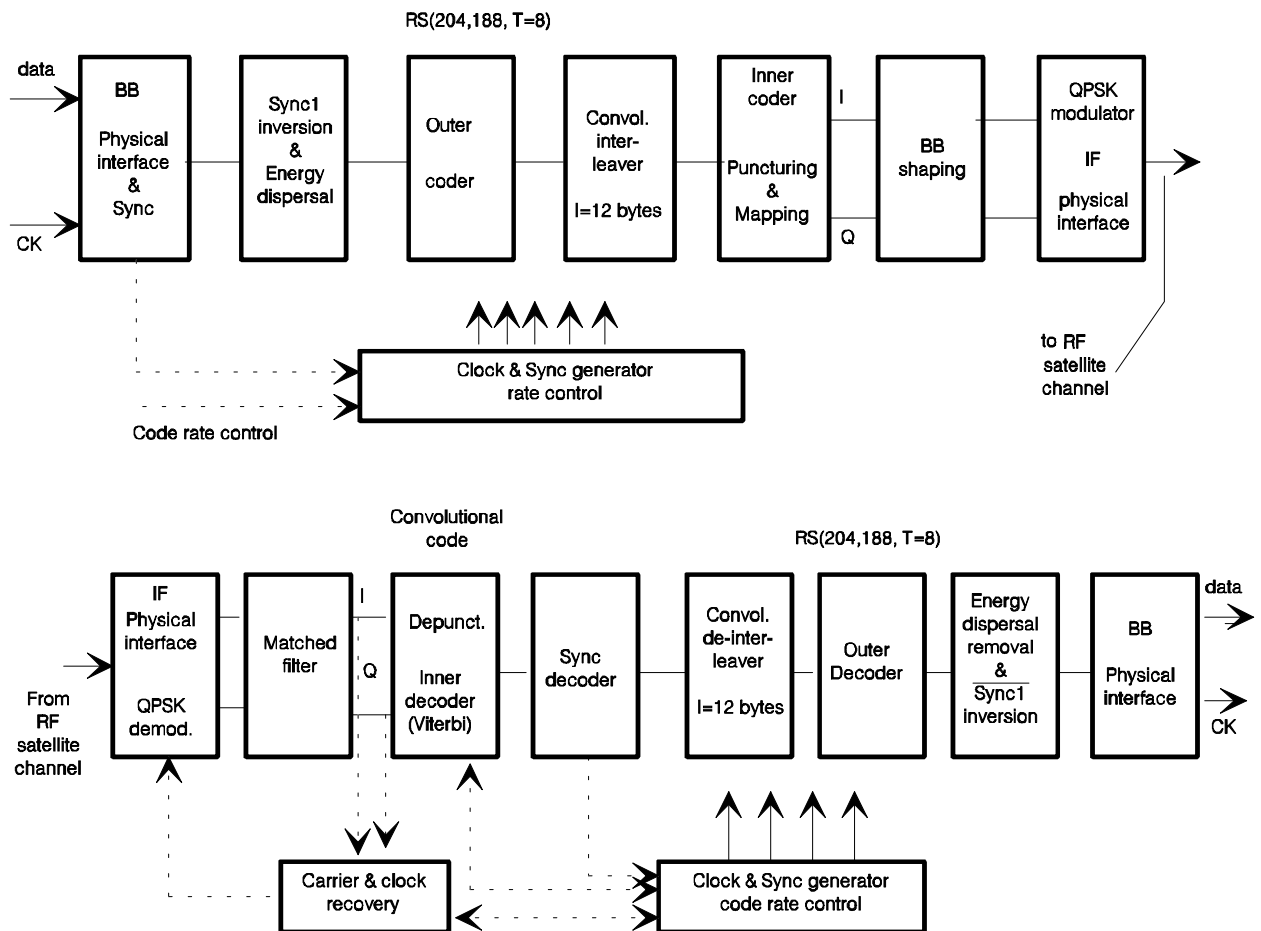

Figure B.1: Conceptual block diagram of the System at the transmitting and receiving side

- **Sync byte decoder:** by decoding the MPEG-2 [1] sync bytes, this decoder provides synchronization information for the de-interleaving. It is also in a position to recover π ambiguity of QPSK demodulator (not detectable by the Viterbi decoder).

- **Convolutional de-interleaver:** this device allows the error bursts at the output of the inner decoder to be randomized on a byte basis in order to improve the burst error correction capability of the outer decoder.

- **Outer decoder:** this unit provides second level error protection. It is in a position to provide QEF output (i.e. BER of about 10^{-10} to 10^{-11}) in the presence of input error bursts at a BER of about 7×10^{-4} or better with infinite byte interleaving. In the case of interleaving depth I = 12, BER = 2×10^{-4} is assumed for QEF.

- **Energy dispersal removal:** this unit recovers the user data by removing the randomizing pattern used for energy dispersal purposes and changes the inverted sync byte to its normal MPEG-2 sync byte value.

- **Baseband physical interface:** this unit adapts the data structure to the format and protocol required by the external interface.

    NOTE: A possibility is provided by the MPEG-2 [1] system to set on the error flag bit in the packet header if the correction capability of the outer code is exceeded.

Annex C (informative): Examples of bit rates versus transponder bandwidth

The transmission symbol rate R_S can be matched to given transponder characteristics, to achieve the maximum transmission capacity compatible with the acceptable signal degradation due to transponder bandwidth limitations. Table C.1 gives examples of the useful bit rate capacity R_u achievable on a satellite transponder with bandwidth BW corresponding to $BW/R_S = 1,28$.

Other BW/R_S values may be adopted for different service requirements, depending on the trade-off between transmission capacity and E_b/N_o degradation.

Figures C.1 and C.2 show the IMUX and OMUX filter characteristics adopted in the computer simulations, with a 33 MHz (-3dB) total bandwidth.

Figure C.3 gives an example of the E_b/N_o degradation on a computer simulated satellite transponder (Travelling Wave Tube Amplifier Output Back Off (TWTA OBO) = 0 dB) due to bandwidth limitations on IMUX and OMUX (see figures C.1 and C.2), for a ratio BW/Rs between 1 and 1,35. The reference 0 dB degradation refers to the case of a satellite transponder without bandwidth limitations (BW = ∞, TWTA OBO = 0 dB). The results are obtained by computer simulations, with inner code rates 2/3 and 7/8, at BER = 2×10^{-4}. Other results could be obtained for different transponder filter characteristics. When using the results of figure C.3, suitable margins should be allowed to take into account thermal and ageing instabilities of the transponder characteristics.

Table C.1: Examples of bit rates versus transponder bandwidth

BW (at -3 dB) [MHz]	BW' (at -1 dB) [MHz]	R_S (for BW/R_S=1.28) [Mbaud]	R_u (for QPSK + 1/2 convol) [Mbit/s]	R_u (for QPSK + 2/3 convol) [Mbit/s]	R_u (for QPSK + 3/4 convol) [Mbit/s]	R_u (for QPSK + 5/6 convol) [Mbit/s]	R_u (for QPSK + 7/8 convol) [Mbit/s]
54	48,6	42,2	38,9	51,8	58,3	64,8	68,0
46	41,4	35,9	33,1	44,2	49,7	55,2	58,0
40	36,0	31,2	28,8	38,4	43,2	48,0	50,4
36	32,4	28,1	25,9	34,6	38,9	43,2	45,4
33	29,7	25,8	23,8	31,7	35,6	39,6	41,6
30	27,0	23,4	21,6	28,8	32,4	36,0	37,8
27	24,3	21,1	19,4	25,9	29,2	32,4	34,0
26	23,4	20,3	18,7	25,0	28.1	31,2	32,8

NOTE 1: R_u stands for the useful bit rate after MPEG-2 MUX. R_S (symbol rate) corresponds to the -3dB bandwidth of the modulated signal.

NOTE 2: The figures of table C.1 correspond to an E_b/N_o degradation of 1,0 dB (with respect to AWGN channel) for the case of 0,35 roll-off and 2/3 code rate, including the effects of IMUX, OMUX and TWTA.
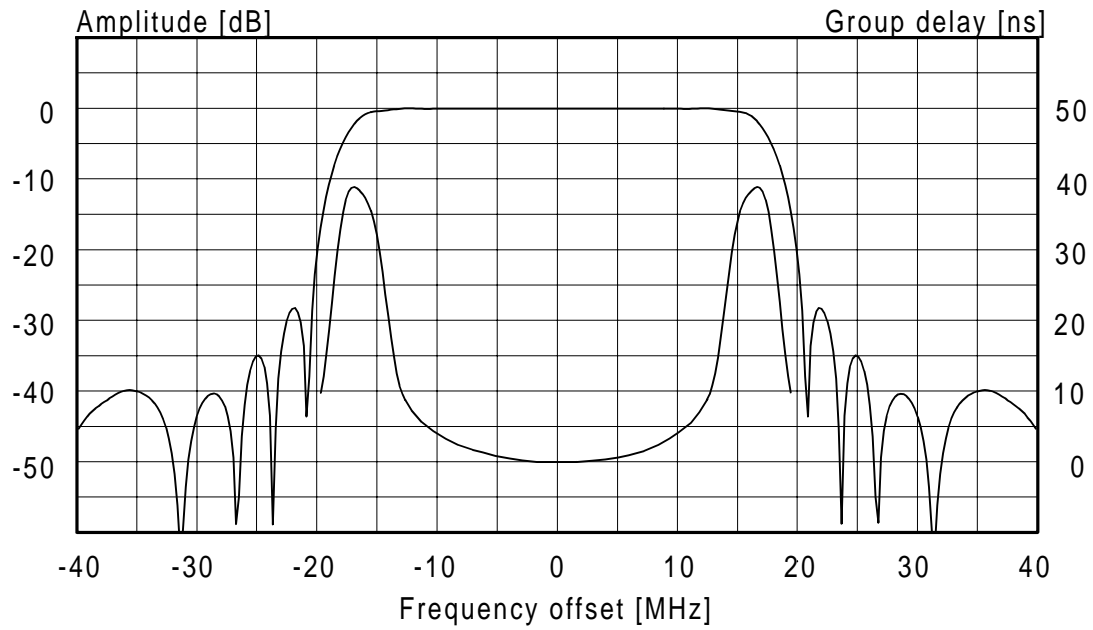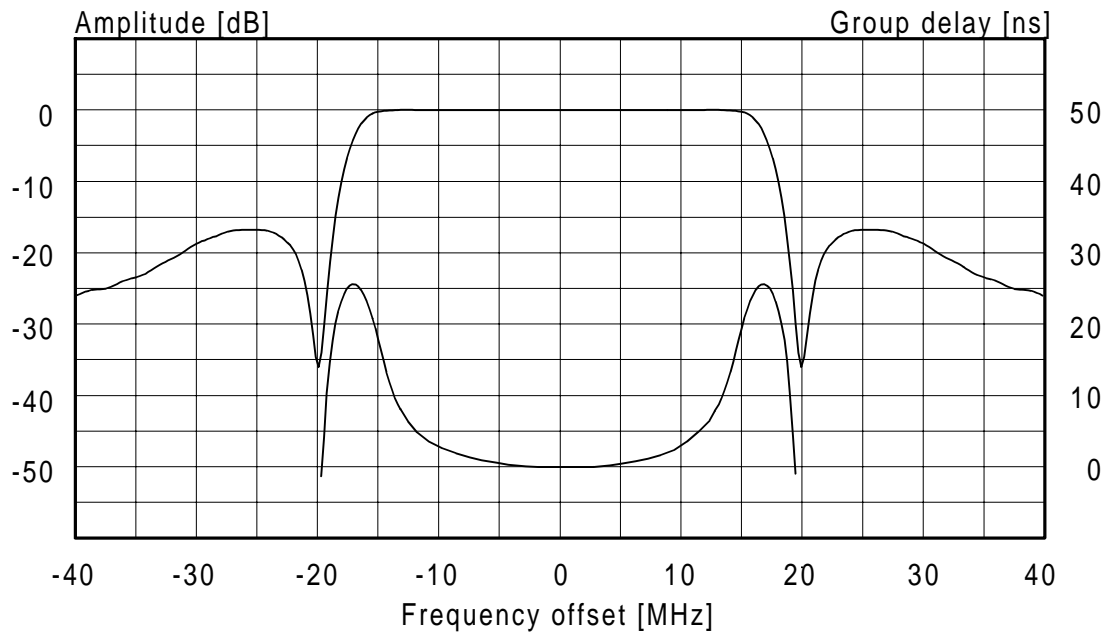
Figure C.1: Hypothetical IMUX filter characteristic

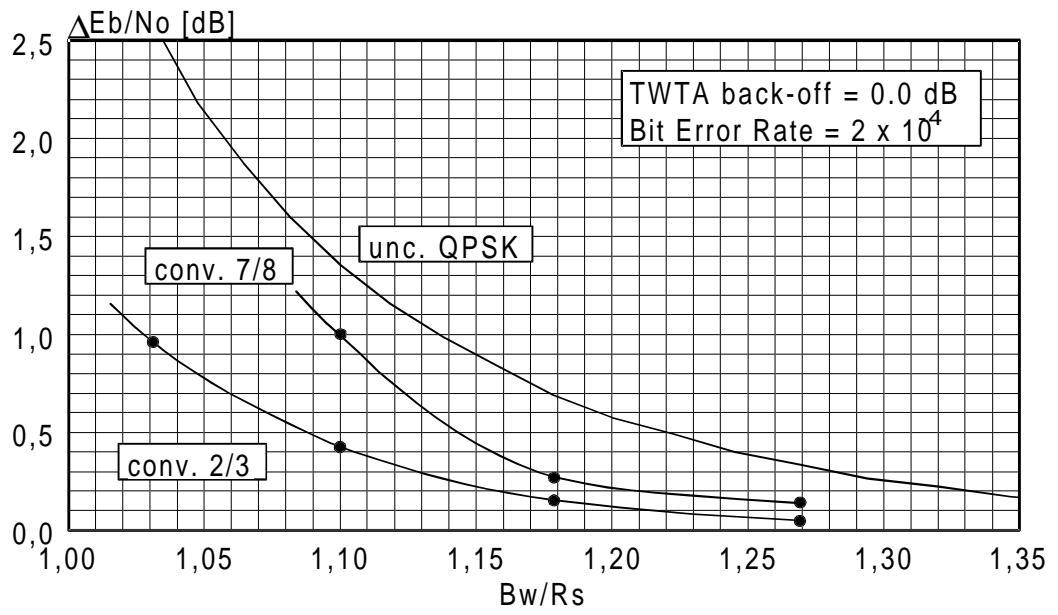**Figure C.2: Hypothetical OMUX filter characteristic**

Figure C.3: Example degradation due to transponder bandwidth limitation

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

Table D.1 considers possible examples of use of the System for a nominal transponder bandwidth (-3dB) of 33 MHz. Different inner code rates are given with the relevant bit rates.

Figure D.1 shows that the example highlighted in table D.1 with rate 2/3 inner code would be suitable for connection to a Plesiochronous Digital Hierarchy (PDH) terrestrial network at 34,368 Mbit/s, including the same Reed-Solomon error protection used by satellite.

Table D.1: Example of System performance over 33 MHz transponder

Bit Rate R_u (after MUX) [Mbit/s]	Bit Rate R'_u (after RS) [Mbit/s]	Symbol Rate [Mbaud]	Convolut. Inner Code Rate	RS Outer Code Rate	C/N (33 MHz) [dB]
23,754	25,776	25,776	1/2	188/204	4,1
31,672	**34,368**	**25,776**	**2/3**	**188/204**	**5,8**
35,631	38,664	25,776	3/4	188/204	6,8
39,590	42,960	25,776	5/6	188/204	7,8
41,570	45,108	25,776	7/8	188/204	8,4

NOTE 1:   The figures in table D.1 refer to computer simulation results achieved on a hypothetical satellite chain, including IMUX, TWTA and OMUX (see figures C.1 and C.2), with modulation roll-off of 0,35. The C/N figures are based on the assumption of soft-decision Viterbi decoding in the receiver. The ratio $BW/R_s = 1,28$ has been adopted.

NOTE 2:   The figures for C/N include a calculated degradation of 0,2 dB due to bandwidth limitations on IMUX and OMUX filters, 0,8 dB non-linear distortion on TWTA at saturation and 0,8 dB modem degradation. The figures apply to $BER = 2 \times 10^{-4}$ before RS(204,188), which corresponds to "Quasi Error Free" at the RS coder output. Degradation due to interference is not taken into account.
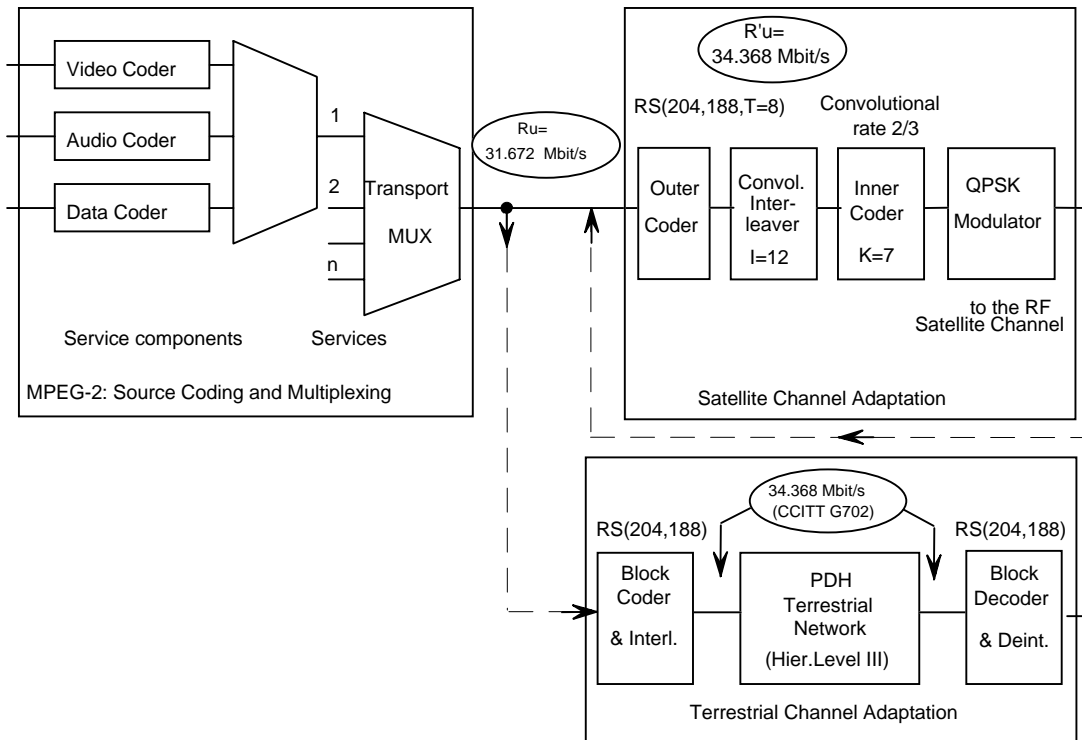

Figure D.1: Example of connection of the System with the terrestrial PDH network

Annex E (informative): Bibliography

For the purposes of this ETS, the following informative references apply:

1) DTVB 1163/GT V4/MOD 269 2nd revised version (November 1993): "Potential applications of the baseline modulation/channel coding system for digital multi-programme television by satellite" (Contribution from V4/MOD).

2) Reimers, U. NAB'93, (EBU V4/MOD 249): "The European perspectives on Digital Television Broadcasting".

3) Cominetti, M., Morello, A., Visintin; M. EBU Review - Technical, Summer '93, (EBU V4/MOD 235 rev.): "Satellite digital multi-programme TV/HDTV".

4) DTVB 1110/GT V4/MOD 252/ DTVC 18, 7th revised version, January 1994: "Baseline modulation/channel coding system for digital multi-programme television by satellite" (Contribution from V4/MOD-B).

5) ETS 300 429: "Digital broadcasting systems for television, sound and data services; Framing structure, channel coding and modulation for cable systems".

History

Document history	
December 1994	First Edition
December 1995	Converted into Adobe Acrobat Portable Document Format (PDF)