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## SIST EN 300 744 V1.1.2:2005

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**Digitalna videoradiodifuzija (DVB) – Struktura okvirov, kodiranje kanalov in modulacija za digitalno prizemno televizijo (DVB-T)**

Digital Video Broadcasting (DVB); Framing structure, channel coding and modulation for digital terrestrial television

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# EN 300 744 V1.1.2 (1997-08)

*European Standard (Telecommunications series)*

## Digital Video Broadcasting (DVB); Framing structure, channel coding and modulation for digital terrestrial television

European Broadcasting Union

EBU
UER

Union Européenne de Radio-Télévision

**DVB** Digital Video Broadcasting

ETSI

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# Foreword

This second edition, previously as an ETS now an EN, contains changes of an entirely editorial nature as follows:

1) add the DVB logo to the front page of the deliverable;
2) change the title from: "Digital broadcasting systems for television, sound and data services; etc." to "Digital Video Broadcast (DVB); etc.";
3) add in the foreword the DVB acknowledgement.

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 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 *.

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**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.

| Proposed national transposition dates | |
|---|---|
| Date of adoption of ETS 300 744: | 28 February 1997 |
| Date of latest announcement of ETS 300 744 (doa): | 30 June 1997 |
| Date of latest publication of new National Standard or endorsement of ETS 300 744 (dop/e): | 31 December 1997 |
| Date of withdrawal of any conflicting National Standard (dow): | 31 December 1997 |

# 1 Scope

The present document describes a baseline transmission system for digital terrestrial TeleVision (TV) broadcasting.
It specifies the channel coding/modulation system intended for digital multi-programme LDTV/SDTV/EDTV/HDTV
terrestrial services.

The scope is as follows:

- it gives a general description of the Baseline System for digital terrestrial TV;

- it identifies the global performance requirements and features of the Baseline System, in order to meet the service
  quality targets;

- it 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 at the modulator side,
  while the processing at the receiver side is left open to different implementation solutions.
  However, it is necessary in this text to refer to certain aspects of reception.

# 2 Normative 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 Part 1, 2, 3 (November 1994): "Coding of moving pictures and associated audio".

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

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

# 3        Definition, symbols and abbreviations

## 3.1        Definition

For the purposes of the present document, the following definition applies:

**constraint length:** Number of delay elements +1 in the convolutional coder.

## 3.2        Symbols

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

| | |
|---|---|
| $A(e)$ | output vector from inner bit interleaver e |
| $a_{e,w}$ | bit number w of inner bit interleaver output stream e |
| $\alpha$ | constellation ratio which determines the QAM constellation for the modulation for hierarchical transmission |
| $B(e)$ | input vector to inner bit interleaver e |
| $b_{e,w}$ | bit number w of inner bit interleaver input steam e |
| $b_{e,do}$ | output bit number do of demultiplexed bit stream number e of the inner interleaver demultiplexer |
| $c_{m,l,k}$ | complex cell for frame m in OFDM symbol l at carrier k |
| $C'_k$ | Complex modulation for a reference signal at carrier k |
| $C'_{l,k}$ | Complex modulation for a TPS signal at carrier k in symbol l |
| $C/N$ | Carrier-to-noise ratio |
| $\Delta$ | time duration of the guard interval |
| $d_{free}$ | convolutional code free distance |
| $f_c$ | centre frequency of the emitted signal |
| $G_1, G_2$ | convolutional code Generator polynomials |
| $g(x)$ | Reed-Solomon code generator polynomial |
| $h(x)$ | BCH code generator polynomial |
| $H(q)$ | inner symbol interleaver permutation |
| $H_e(w)$ | inner bit interleaver permutation |
| $i$ | priority stream index |
| $I$ | Interleaving depth of the outer convolutional interleaver |
| $I0,I1,I2,I3,I4,I5$ | inner Interleavers |
| $j$ | branch index of the outer interleaver |
| $k$ | carrier number index in each OFDM symbol |
| $K$ | number of active carriers in the OFDM symbol |
| $K_{min}, K_{max}$ | carrier number of the lower and largest active carrier respectively in the OFDM signal |
| $l$ | OFDM symbol number index in an OFDM frame |
| $m$ | OFDM frame number index |
| $m'$ | OFDM super-frame number index |
| $M$ | convolutional interleaver branch depth for $j = 1$, $M = N/I$ |
| $n$ | transport stream sync byte number |
| $N$ | length of error protected packet in bytes |
| $N_{max}$ | inner symbol interleaver block size |
| $p$ | scattered pilot insertion index |
| $p(x)$ | RS code field generator polynomial |
| $P_k(f)$ | Power spectral density for carrier k |
| $P(n)$ | interleaving Pattern of the inner symbol interleaver |
| $r_i$ | code rate for priority level i |
| $s_i$ | TPS bit index |
| $t$ | number of bytes which can be corrected by the Reed-Solomon decoder |
| $T$ | elementary Time period |
| $T_S$ | duration of an OFDM symbol |
| $T_F$ | Time duration of a frame |
| $T_U$ | Time duration of the useful (orthogonal) part of a symbol, without the guard interval |
| $u$ | bit numbering index |
| $v$ | number of bits per modulation symbol |

| $w_k$ | value of reference PRBS sequence applicable to carrier k |
| $x_{di}$ | input bit number di to the inner interleaver demultiplexer |
| $x'_{di}$ | high priority input bit number di to the inner interleaver demultiplexer |
| $x''_{di}$ | low priority input bit number di to the inner interleaver demultiplexer |
| Y | output vector from inner symbol interleaver |
| Y' | intermediate vector of inner symbol interleaver |
| $y_q$ | bit number q of output from inner symbol interleaver |
| $y'_q$ | bit number q of intermediate vector of inner symbol interleaver |
| z | complex modulation symbol |

## 3.3     Abbreviations

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

| ACI | Adjacent Channel Interference |
| AFC | Automatic Frequency Control |
| BCH | Bose - Chaudhuri - Hocquenghem code |
| BER | Bit Error Ratio |
| D/A | Digital-to-Analogue converter |
| DBPSK | Differential Binary Phase Shift Keying |
| DFT | Discrete Fourier Transform |
| DVB | Digital Video Broadcasting |
| DVB-T | DVB-Terrestrial |
| EDTV | Enhanced Definition TeleVision |
| ETS | European Telecommunication Standard |
| FEC | Forward Error Correction |
| FFT | Fast Fourier Transform |
| FIFO | First-In, First-Out shift register |
| HDTV | High Definition TeleVision |
| HEX | HEXadecimal notation |
| HP | High Priority bit stream |
| IF | Intermediate Frequency |
| IFFT | Inverse Fast Fourier Transform |
| LDTV | Limited Definition TeleVision |
| LO | Local Oscillator |
| LP | Low Priority bit stream |
| LSB | Least Significant Bit |
| MPEG | Moving Picture Experts Group |
| MSB | Most Significant Bit |
| MUX | MUltipleX |
| NICAM | Near-Instantaneous Companded Audio Multiplex |
| OCT | OCTal notation |
| OFDM | Orthogonal Frequency Division Multiplexing |
| PAL | Phase Alternating Line |
| PCR | Program Clock Reference |
| PID | Program IDentifier |
| PRBS | Pseudo-Random Binary Sequence |
| QAM | Quadrature Amplitude Modulation |
| QEF | Quasi Error Free |
| QPSK | Quaternary Phase Shift Keying |
| RF | Radio Frequency |
| RS | Reed-Solomon |
| SDTV | Standard Definition TeleVision |
| SECAM | Système Sequentiel Couleur A Mémoire |
| SFN | Single Frequency Network |
| TPS | Transmission Parameter Signalling |
| TV | TeleVision |
| UHF | Ultra-High Frequency |
| VHF | Very-High Frequency |

# 4        Baseline system

## 4.1        General considerations

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, to the terrestrial 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 code);

-    outer interleaving (i.e. convolutional interleaving);

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

-    inner interleaving;

-    mapping and modulation;

-    Orthogonal Frequency Division Multiplexing (OFDM) transmission.

The system is directly compatible with MPEG-2 coded TV signals ISO/IEC 13818 [1].

Since the system is being designed for digital terrestrial television services to operate within the existing UHF (see note) spectrum allocation for analogue transmissions, it is required that the System provides sufficient protection against high levels of Co-Channel Interference (CCI) and Adjacent-Channel Interference (ACI) emanating from existing PAL/SECAM services. It is also a requirement that the System allows the maximum spectrum efficiency when used within the UHF bands; this requirement can be achieved by utilizing Single Frequency Network (SFN) operation.

NOTE:        I.e. 8 MHz channel spacing. An adaptation of the present document for 7 MHz channels can be achieved by scaling down all system parameters according to a change of the system clock rate from 64/7 MHz to exactly 8,0 MHz. The frame structure and the rules for coding, mapping and interleaving are kept, only the data capacity of the system is reduced by a factor 7/8 due to the respective reduction of signal bandwidth.

To achieve these requirements an OFDM system with concatenated error correcting coding is being specified. To maximize commonality with the Satellite baseline specification (see EN 300 421 [2]) and Cable baseline specifications (see EN 300 429 [3]) the outer coding and outer interleaving are common, and the inner coding is common with the Satellite baseline specification. To allow optimal trade off between network topology and frequency efficiency, a flexible guard interval is specified. This will enable the system to support different network configurations, such as large area SFN and single transmitter, while keeping maximum frequency efficiency.

Two modes of operation are defined: a "2k mode" and an "8k mode". The "2k mode" is suitable for single transmitter operation and for small SFN networks with limited transmitter distances. The "8k mode" can be used both for single transmitter operation and for small and large SFN networks.

The system allows different levels of QAM modulation and different inner code rates to be used to trade bit rate versus ruggedness. The system also allows two level hierarchical channel coding and modulation, including uniform and multi-resolution constellation. In this case the functional block diagram of the system shall be expanded to include the modules shown dashed in figure 1. The splitter separates the incoming transport stream into two independent MPEG transport streams, referred to as the high-priority and the low-priority stream. These two bitstreams are mapped onto the signal constellation by the Mapper and Modulator which therefore has a corresponding number of inputs.

To guarantee that the signals emitted by such hierarchical systems may be received by a simple receiver the hierarchical nature is restricted to hierarchical channel coding and modulation without the use of hierarchical source coding. A programme service can thus be "simulcast" as a low-bit-rate, rugged version and another version of higher bit rate and lesser ruggedness. Alternatively, entirely different programmes can be transmitted on the separate streams with different ruggedness. In either case, the receiver requires only one set of the inverse elements: inner de-interleaver, inner decoder, outer de-interleaver, outer decoder and multiplex adaptation. The only additional requirement thus placed on the receiver is the ability for the demodulator/de-mapper to produce one stream selected from those mapped at the sending end.

The price for this receiver economy is that reception can not switch from one layer to another (e.g. to select the more rugged layer in the event of reception becoming degraded) while continuously decoding and presenting pictures and sound. A pause is necessary (e.g. video freeze frame for approximately 0,5 seconds, audio interruption for approximately 0,2 seconds) while the inner decoder and the various source decoders are suitably reconfigured and reacquire lock.
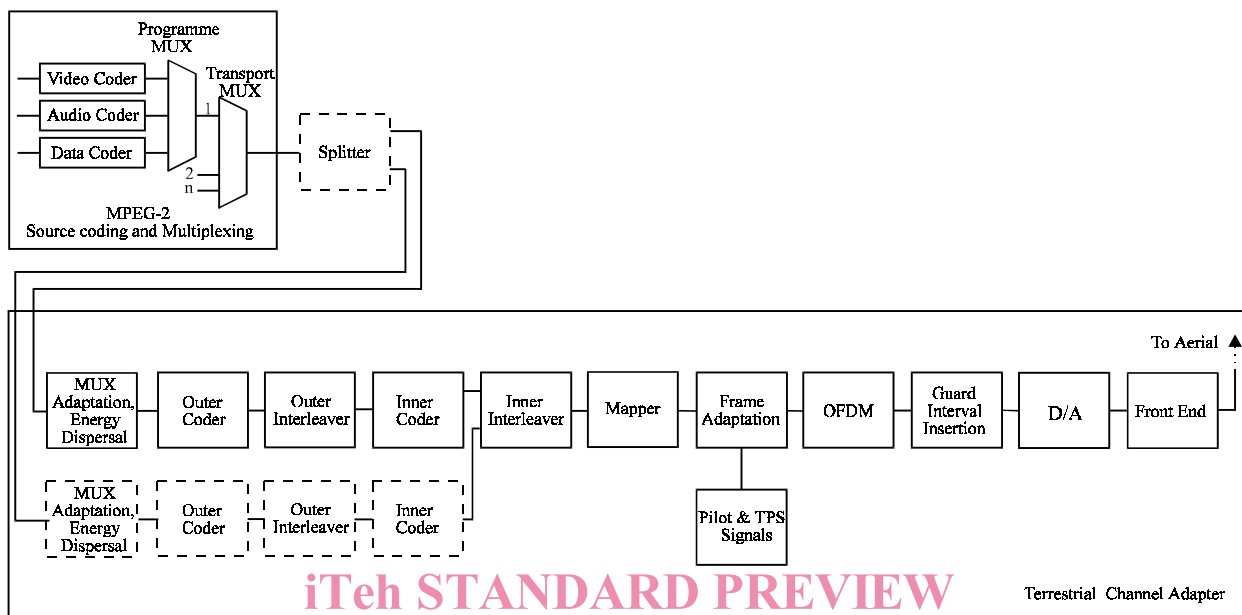


**Figure 1: Functional block diagram of the System**

## 4.2 Interfacing

The Baseline System as defined in the present document is delimited by the following interfaces:

**Table 1: Interfaces for the Baseline System**

| Location | Interface | Interface type | Connection |
|---|---|---|---|
| Transmit Station | Input | MPEG-2 transport stream(s) multiplex | from MPEG-2 multiplexer |
| | Output | RF signal | to aerial |
| Receive Installation | Input | RF | from aerial |
| | Output | MPEG-2 transport stream multiplex | to MPEG-2 demultiplexer |

## 4.3 Channel coding and modulation

### 4.3.1 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. 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. 01 000 111). In order to ensure adequate binary transitions, the data of the input MPEG-2 multiplex shall be randomized in accordance with the configurations depicted in figure 2.
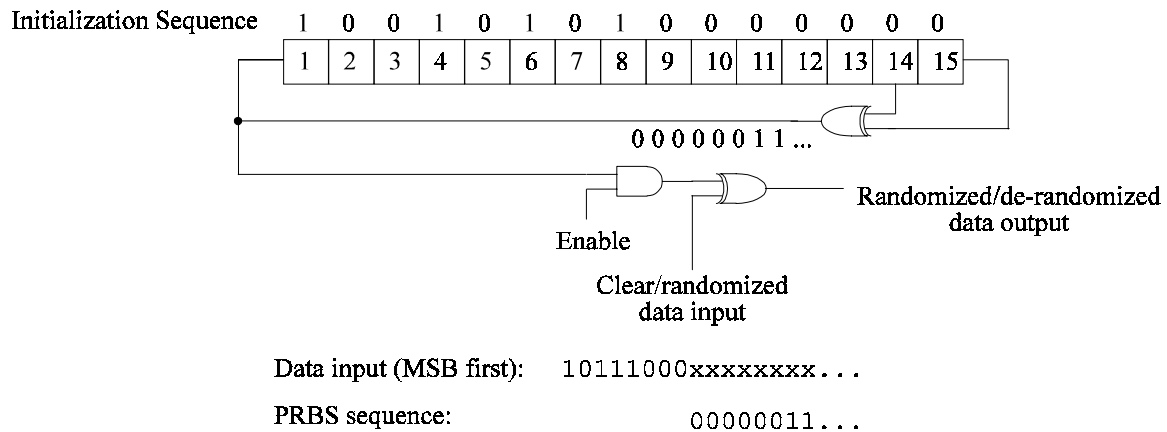
Initialization Sequence



Data input (MSB first): `10111000xxxxxxxx...`

PRBS sequence: `00000011...`

**Figure 2: Scrambler/descrambler schematic diagram**

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

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

NOTE: The polynomial description given here is in the form taken from the Satellite baseline specification EN 300 421 [2]. Elsewhere, in both the Satellite baseline specification and in the present document, a different polynomial notation is used which conforms with the standard textbook of Peterson and Weldon (Error correcting codes, second edition, MIT Press, 1972).

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 $47_{HEX}$ (SYNC) to $B8_{HEX}$ ($\overline{\text{SYNC}}$). This process is referred to as "transport multiplex adaptation" (see figure 3b).

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).

## 4.3.2 Outer coding and outer interleaving

The outer coding and interleaving shall be performed on the input packet structure (see figure 3a).

Reed-Solomon RS (204,188, t = 8) shortened code (see note 1), derived from the original systematic RS (255,239, t = 8) code, shall be applied to each randomized transport packet (188 byte) 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. $47_{HEX}$) or inverted (i.e. $B8_{HEX}$).

NOTE 1: The Reed-Solomon code has length 204 bytes, dimension 188 bytes and allows to correct up to 8 random erroneous bytes in a received word of 204 bytes.

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 an RS (255,239, t = 8) encoder. After the RS coding procedure these null bytes shall be discarded, leading to a RS code word of N = 204 bytes.

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