DVB and DVB-H Systems

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Contents

- DVB Broadcasting System
- DVB Broadcasting Standards
- DVB-S, DVB-C and DVB-T Channel Coding
- DVB-H Standards
- DVB-H System
- From DVB-T to DVB-H
  - Continual and TPS pilots, interleaver, etc.
  - Time Slicing
  - MPE-FEC
- IPDC
  - Standardization
  - Protocol stacks
- DVB-H Network Topology
- DVB-H Handover
- Homework
- References
DVB Broadcasting System

Satellite

DVB-S (QPSK) -> Multiplexing Scrambling

Scrambling Key

Multiplexing Scrambling

MPEG-2 Coding

Video Audio Data

DVB-T (COFDM) -> DVB-C (QAM)

DVB-C (QAM) -> Demultiplexing Descrambling

DVB-C (QAM) -> MPEG-2 Decoding

Data Audio Video

DVB-T (COFDM) -> DVB-S (QPSK)

DVB-S (QPSK) -> MPEG-2

10-Jan-2006
DVB Broadcasting Standards

Transmission
- EN 300 421 DVB Framing structure, channel coding and modulation for 11/12 MHz satellite service (DVB-S)
- EN 300 429 DVB Framing structure, channel coding and modulation for cable (DVB-C)
- EN 300 744 DVB Framing structure, channel coding and modulation for digital terrestrial television (DVB-T)

Audio-Video Coding
- MPEG-2: ISO 13818 Generic coding of moving pictures and associated audio information: Systems, video, audio, compliance testing, DSM-CC, etc.
  - Part1 Systems: Transport Stream, Program Specific Information (PSI), Part2 Video, Part3 Audio, Part6 DSM-CC Data Broadcasting on MPEG2
- MPEG-4: ISO 14496 Coding of audio-visual objects
  - Part1 System, Part2 Visual, Part3 Audio, etc.
- MPEG-4 AVC: ISO 14496 Coding of audio-visual object Part10 (ITU.T H.264)
- ITU.T H.263 Coding of moving video

Data Broadcasting
- EN 301 192 DVB specification for data broadcasting
  - MPE, INT, Time Slicing
- EN 301 468 (DVB-SI) DVB service information
  - NIT, Service Information
Error Correction in DVB System (Transmitter)

**DVB-T**
- RF modulation: OFDM
- Inner interleaver: Bit/Byte
- Inner coding (FEC): Convolutional Code
- Outer interleaver: DVB I = 12
- Outer coder: Reed Solomon RS(204, 188, T=8)
- Transport Stream

**DVB-C**
- RF modulation: 64 QAM
- Inner interleaver: Bit/Byte
- Inner coding (FEC): Convolutional Code
- Outer interleaver: DVB I = 12
- Outer coder: Reed Solomon RS(204, 188, T=8)
- Transport Stream

**DVB-S**
- RF modulation: QPSK
- Inner interleaver: Bit/Byte
- Inner coding (FEC): Convolutional Code
- Outer interleaver: DVB I = 12
- Outer coder: Reed Solomon RS(204, 188, T=8)
- Transport Stream
Requirements for Modulation in DVB Systems

- **Satellite reception (QPSK, Phase modulation)**
  - Carrier to noise ratio C/N can be very small (10 dB or less)
  - No reflections, but nonlinear transmission chain (C-class amplifiers in the satellites) leading to amplitude distortions
  - => constant amplitude modulation should be used (QPSK)

- **Cable reception (QAM, Amplitude and Phase modulation)**
  - C/N is quite high, generally over 30 dB
  - The signal can be effected by echoes due to impedance mismatches in the network
  - Amplitude modulation can be used, but echo cancellation is necessary

- **Terrestrial reception (COFDM, Coded Orthogonal Frequency Division Multiplex)**
  - Propagation conditions for signal are difficult, especially if mobile reception is required with simple antennas => variable echoes due to multipaths and signal level variations
  - => COFDM right choice
DVB Channel Coding: Randomization, energy dispersal

- All data in DVB channel is transmitted in fixed length packets; at this stage sync+187 data bytes
- Sync byte = 0x47
- Every 8th sync byte = 0xB8
- Bytes between sync bytes are randomized for energy dispersal

Initialization sequence:

```
| 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
```

Data input (MSB first): 1011000x x x x x x x x ....
PRBS sequence: 000000111 ....

PRBS period = 1503 bytes
DVB Channel Coding: Interleaver

1 byte per position

FIFO shift register

Interleaver I=12

Sync word route

De-interleaver I=12

17=M

17x2

17x3

17x11

17x1

17x3

17x2

17=M

17x11

17x1
DVB Channel Coding: Outer coding (RS), interleaving, framing

Figure 3a) MPEG-2 transport MUX packet

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

Figure 3c) Reed-Solomon RS (204,188, T=8) error protected packet

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
DVB-S Satellite Broadcasting (Transmitter Site Processing)

- **Modulation:**
  - QPSK (single carrier)

- **Convolutional code rates:**
  - $\frac{1}{2}$, 2/3, 3/4, 5/6, 7/8
DVB-C Cable Broadcasting (Transmitter Site Processing)

- **Modulation (single carrier):**
  - QAM-16
  - QAM-32
  - QAM-64
  - QAM-128 or
  - QAM-256

- **Inner Coder:**
  - Byte to m-tuple conversion
DVB-T Terrestrial Broadcasting
DVB-T Channel Coding: Inner Interleaver

Inner Coder and Inner Interleaver

- **Inner Coder (HP)**
  - Convolutional Encoder
  - Puncturing With Serial Output

- **Inner Coder (LP)**
  - Convolutional Encoder
  - Puncturing With Serial Output

- **Inner Interleaver (example for QAM-64)**

- **Modulation (multiple carriers):**
  - QPSK, QAM-16, QAM-64

- **Convolutional code rates:**
  - ½, 2/3, ¾, 5/6, 7/8

- **Inner interleaver**
  - See EN 300 744
DVB-T Modulation Method: COFDM (Coded Orthogonal Frequency Division Multiplexing)

8k mode (6817 carriers)

2k mode (1705 carriers)

Each carrier QPSK, 16 QAM, or 64 QAM modulated
DVB-T COFDM Carrier Arrangement
Synchronization Pilots for Receiver Locking

OFDM Frame (68 OFDM symbols)

FFT time windows for receivers
Maximum Speed vs. Frequency (DVB-T 2K & 8K and DAB)

- DAB III (192)
- DAB II (384)
- DAB IV (768)
- DAB I (1536)

- Channel 40
  - 626 MHz

Maximum speed:
- 10 km/h
- 100 km/h
- 1000 km/h
- 10 000 km/h

Frequency bands:
- Band III
- Band IV
- Band V

Modulation types:
- 2K 4QAM reg 1/2
- 2K 64QAM reg 2/3
- 8K 4QAM reg 1/2
- 8K 64QAM reg 2/3
DVB-H System (see EN 302 304!)

DVB-H IP-Encapsulator
- MPEG-2 TV Service

MUX
- MPE
- MPE-FEC
- Time Slicing

DVB-T Modulator
- 8k
- 2k
- DVB-H TPS

Channel

DVB-T Demodulator
- 8k
- 2k
- DVB-H TPS

DVB-H IP-Decapsulator
- Time Slicing
- MPE-FEC
- MPE

New to DVB-H
- Existing

Transmitter
- Receiver

IP

IP

10-Jan-2006
From DVB-T to DVB-H

- DVB-T as a physical transfer layer has been specified in ETS 300 744.
- With the introduction of DVB-H some new features have been added to the specification.
  - 4K mode, in-depth interleavers, DVB-H signalling, parameters for 5 MHz operation in non-broadcast bands.
  - Additions have been done in Annexes F and G.
  - Some references from the main text to new annexes.
  - Some editorial corrections in the main text.
  - Additions are not intended for fixed broadcasting.
- New DVB-H documents have been created
  - EN 302 304 Transmission System for Handheld Terminals
    - In just a short document referring to EN 300 744 and some other documents which have been updated during the process
  - TS 102 377 DVB-H Implementation Guidelines
    - 4K-mode and physical layer aspects
    - Time slicing principle explained
    - MPE-FEC functionality explained
    - DVB-H/DVB-T compatibility issues
    - DVB-H services
    - Hierarchical modulation
    - Handover
    - Etc.
DVB-H System Blocks Modified from DVB-T System

From DVB-H Transport Multiplexer

MPEG-TS “HP”

MUX adaptation Energy Dispersal

Outer Coder

Outer Interleaver

Inner Coder

Inner Interleaver

MPEG-TS “LP”

MUX adaptation Energy Dispersal

Outer Coder

Outer Interleaver

Inner Coder

Mapper

Frame Adaptation

OFDM

Guard Interval Insertion

D/A

Front End

Pilots & TPS signals

DVB-H Terrestrial Channel Adapter

To Aerial

= Affected blocks
4K-Mode is an Interpolation Between 2K- and 8K-Mode

The additional 4K DVB terrestrial transmission mode is an interpolation of the parameters defined for the 2K and 8K transmission modes.

It aims to offer an additional trade-off between transmission cell size and mobile reception capabilities, providing an additional degree of flexibility for network planning.

Features of 8K, 4K and 2K transmission modes:

- **8K transmission mode**
  - can be used both for single transmitter operation:
  - suitable for small, medium and large SFNs
  - allows high-speed reception

- **4K transmission mode**
  - can be used both for single transmitter operation
  - Suitable for small and medium SFNs
  - allowing very high speed reception

- **2K transmission mode**
  - can be used for single transmitter operation
  - suitable and for small SFNs with limited transmitter distances
  - allows extremely high speed reception
Bit interleaving block size is 126 bits and 24 blocks are needed to cover one OFDM symbol in 4K mode

In-depth interleaver goes over two symbol times so that impulse noise immunity is quasi-similar to 8K mode

The native 4K interleaver uses the same general structure as the 2K/8K interleavers; a new permutation table has been developed.
### DVB-H: Continual and TPS Pilots in 4K Mode

- **4K mode uses 89 continual pilots**
  - 8K: 177, 2K: 45

- **4K mode uses 34 TPS pilots**
  - 8K: 68, 2K: 17

- **4K mode uses 3024 data carriers**
  - 8K: 6048, 2K: 1512

<table>
<thead>
<tr>
<th>Continual pilots carrier positions for 4K mode (index number k)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
</tr>
<tr>
<td>432</td>
</tr>
<tr>
<td>873</td>
</tr>
<tr>
<td>1140</td>
</tr>
<tr>
<td>1845</td>
</tr>
<tr>
<td>2235</td>
</tr>
<tr>
<td>2646</td>
</tr>
<tr>
<td>3027</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TPS carrier indices for 4K mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>34</td>
</tr>
<tr>
<td>1262</td>
</tr>
<tr>
<td>2392</td>
</tr>
</tbody>
</table>
### DVB-H: Transmitter Parameter Signalling (TPS)

- TPS information contains 68 bits; one bit sent in every OFDM symbol
- In 4K mode there are 34 carriers for TPS bits
- TPS is defined over 68 consecutive OFDM symbols, referred as one OFDM frame
- Specially DVB-H related TPS bits are defined in Annex F of EN 300 744

<table>
<thead>
<tr>
<th>Bit number</th>
<th>Format</th>
<th>Purpose/Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>$s_0^L$</td>
<td>see clause 4.6.2.1</td>
<td>Initialization</td>
</tr>
<tr>
<td>$s_{1}$ to $s_{16}$</td>
<td>001101011101110110 or 1100101000010001</td>
<td>Synchronization word</td>
</tr>
<tr>
<td>$s_{17}$ to $s_{22}$</td>
<td>see clause 4.6.2.3</td>
<td>Length indicator (see annex F)</td>
</tr>
<tr>
<td>$s_{23}$, $s_{24}$</td>
<td>see table 10</td>
<td>Frame number</td>
</tr>
<tr>
<td>$s_{25}$, $s_{26}$</td>
<td>see table 11</td>
<td>Constellation</td>
</tr>
<tr>
<td>$s_{27}$, $s_{28}$, $s_{29}$</td>
<td>see table 12</td>
<td>Hierarchy information (see annex F)</td>
</tr>
<tr>
<td>$s_{30}$, $s_{31}$, $s_{32}$</td>
<td>see table 13</td>
<td>Code rate, HP stream</td>
</tr>
<tr>
<td>$s_{33}$, $s_{34}$, $s_{35}$</td>
<td>see table 13</td>
<td>Code rate, LP stream</td>
</tr>
<tr>
<td>$s_{36}$, $s_{37}$</td>
<td>see table 14</td>
<td>Guard interval</td>
</tr>
<tr>
<td>$s_{38}$, $s_{39}$</td>
<td>see table 15</td>
<td>Transmission mode (see annex F)</td>
</tr>
<tr>
<td>$s_{40}$ to $s_{47}$</td>
<td>see clause 4.6.2.10</td>
<td>Cell identifier</td>
</tr>
<tr>
<td>$s_{48}$ to $s_{53}$</td>
<td>all set to &quot;0&quot;</td>
<td>See annex F</td>
</tr>
<tr>
<td>$s_{54}$ to $s_{67}$</td>
<td>BCH code</td>
<td>Error protection</td>
</tr>
</tbody>
</table>
## DVB-H Dedicated TPS Bits

<table>
<thead>
<tr>
<th>Bit number</th>
<th>Format</th>
<th>Purpose/Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>$s_{17} - s_{22}$</td>
<td>see clause F.4.6.2.3</td>
<td>Length indicator</td>
</tr>
<tr>
<td>$s_{27}, s_{28}, s_{29}$</td>
<td>see clause F.4.6.2.6</td>
<td>Hierarchy information</td>
</tr>
<tr>
<td>$s_{38}, s_{39}$</td>
<td>see clause F.4.6.2.9</td>
<td>Transmission mode</td>
</tr>
<tr>
<td>$s_{40}, s_{49}$</td>
<td>see clause F.4.6.2.11</td>
<td>DVB-H signalling</td>
</tr>
<tr>
<td>$s_{50} - s_{53}$</td>
<td>all set to &quot;0&quot;</td>
<td>Reserved for future use</td>
</tr>
</tbody>
</table>

### In-depth Interleavers in Use

#### Bits $s_{27}, s_{28}, s_{29}$

<table>
<thead>
<tr>
<th>α value</th>
<th>Non hierarchical</th>
</tr>
</thead>
<tbody>
<tr>
<td>000</td>
<td>$\alpha = 1$</td>
</tr>
<tr>
<td>001</td>
<td>$\alpha = 2$</td>
</tr>
<tr>
<td>010</td>
<td>$\alpha = 4$</td>
</tr>
<tr>
<td>011</td>
<td>see annex F</td>
</tr>
<tr>
<td>100</td>
<td>see annex F</td>
</tr>
<tr>
<td>101</td>
<td>see annex F</td>
</tr>
<tr>
<td>110</td>
<td>see annex F</td>
</tr>
<tr>
<td>111</td>
<td>see annex F</td>
</tr>
</tbody>
</table>

#### Bits $s_{38}, s_{39}$

<table>
<thead>
<tr>
<th>Transmission mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
</tr>
<tr>
<td>01</td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td>11</td>
</tr>
</tbody>
</table>

### DVB-H Signalling

<table>
<thead>
<tr>
<th>$s_{48}$</th>
<th>$s_{49}$</th>
<th>DVB-H Signalling</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>x</td>
<td>Time Slicing is not used</td>
</tr>
<tr>
<td>1</td>
<td>x</td>
<td>At least one elementary stream uses Time Slicing</td>
</tr>
<tr>
<td>x</td>
<td>0</td>
<td>MPE-FEC not used</td>
</tr>
<tr>
<td>x</td>
<td>1</td>
<td>At least one elementary stream uses MPE-FEC</td>
</tr>
</tbody>
</table>

**NOTE:** "x" means whatever bit state.
Time Slicing Reasoning

- In normal DVB-T MPEG-2 and data transmissions the transport streams from the services are multiplexed together with high frequency on the TS-packet level.
- This means that the services are transmitted practically in parallel, each service having it’s share of the TS-packets.

For a DVB-T receiver it is impossible to receive only the wanted TS-packets due to the high multiplexing rate.
- All data must be received -> high power consumption.
In time slicing principle the IP-services take certain time slice of the MPE data service when the large portion of the channel capacity is reserved for that service:
- In this example time slice: 200 ms
- Full capacity of the MPE data service is reserved for one IP-service at a time
- After longer period, let’s say 4 seconds, the first service is again in transmission
- And so on …
- Timing slicing and transmission times can be configured and signalled dynamically to all receivers in the system.

The IPDC service is just another “MPE-data pipe” for the DVB-system and can be freely multiplexed with other transport streams.
Time Slicing Facts

- DVB-T is by default intended for continuous transmission
  - Synchronisation times are rather long: in the order of 200 ms.
  - Thus long time intervals have to be used to have full gain.

- The receiver has to know when to wake up
  - This is done by sending time difference to the next relevant burst
  - Real time signalling per elementary stream using Delta-T method.

- PSI/SI not Time Sliced
  - Not required for power saving

- Time Sliced and non-Time Sliced services in common multiplex
  - Only receiver switched off, transmitter on all the time
  - Support for Time Slicing not mandatory to receive Time Sliced service

- Buffer in terminal required for constant output rate

- Figure below: “Yellow Service” (Service 3) is of interest
MPE-FEC as Additional Data Protection: Transmission #1

1. Fill in the Application data table column-wise with IP datagrams
   - Fill in until the next IP does not fit
   - Or until delta-t period has passed
2. Add zero padding after the last IP datagram to the end of the table
3. Do the RS encoding for each row in the Application data table
4. Add the resulting 64 RS parity bytes to the corresponding row in the RS data table
   - Now both tables are ready
MPE-FEC as Additional Data Protection:
Transmission #2

5. Read out IP datagrams column-wise
6. Read out RS columns
7. Encapsulate IP datagrams into the MPE sections
8. Encapsulate RS columns into the MPE-FEC sections
9. Add real time parameters to the header of every section
10. Calculate CRC 32 to the end of the section
11. Write out the sections starting from MPE 1
   - Zero padding is not transmitted
Code Rate Adjustments in MPE-FEC

- Code rate $k/n$ can be decreased by having less information bytes ($k$) and increased by having less parity bytes ($n-k$)
- Higher code rate can be achieved with puncturing RS data columns after encoding
- Lower code rate can be achieved by adding zero padding columns to the application data area
- Normal code rate for MPE-FEC is $CR=191/255\approx 3/4$
- Examples for other rates:
  - $CR=1/2 \Rightarrow$ number of padding columns is 127
  - $CR=2/3 \Rightarrow$ number of padding columns is 63
  - $CR=5/6 \Rightarrow$ number of punctured columns is 26
IPDC Baseline Standardization - Services

- Video
  - H.263 and H.264 (MPEG-4 AVC)
  - IRD A 128kbps, QCIF-15fps
  - IRD B 384kbps, CIF-15fps => QVGA-15fps
  - IRD C 768kbps, CIF-30fps => QVGA-30fps

- File download
  - Use of FLUTE Protocol by default

- ESG (Electronic Service Guide)
  - Service announcement
  - IP addresses

- Baseline standardization going on in DVB-CBMS
IP Data casting (IPDC) over DVB-H: Protocol Stack

Transmitter

IPDC Baseline

<table>
<thead>
<tr>
<th>Video</th>
<th>File download</th>
<th>ESG</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTP</td>
<td>Flute</td>
<td></td>
</tr>
<tr>
<td>UDP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IPv6 /IPsec</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

DVB-H (IPDC Bearer)

PSI/SI

Priv. Sect

MPE/FEC Sect

MPEG2 TS

Mod.

Phys.

Receiver

<table>
<thead>
<tr>
<th>Video</th>
<th>File download</th>
<th>ESG</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTP</td>
<td>Flute</td>
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<td>UDP</td>
<td></td>
<td></td>
</tr>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

PSI/SI

Priv. Sect

MPE/FEC Sect

MPEG2 TS

Demod.

Phys.

Physical channel
DVB-H Protocol Stacks

- DVB-H defines the delivery of IP datagrams on DVB-T signal to a mobile terminal

DVB-H services

DVB-H services

IP

IP datagram

(40...4084 Bytes)

MPE section

(16...4095 Bytes)

transport packet

(188 bytes)

DVB-T

DVB-T carries a Transport Stream

- Transport Stream is a series of transport packets
  - 188 bytes, PID (Packet Identifier) in the header
- Sections carried on transport packet payload
  - Fragmenting may be required
- PSI/SI sections carry the signalling / announcements
- Payload of each MPE section carries a single IP datagram
- DVB-H services carried on IP
Multiplexer functionality (in a head end) builds a Transport Stream (TS) from multiple Elementary Streams (ES). One PID is allocated for each ES.

- Some PIDs are reserved for PSI/SI only
  - PSI/SI carries the mapping between the input streams and PIDs
- The output bitrate of a multiplexer (i.e. the bitrate of the TS) remains static
  - If input streams require less bandwidth, null-packets (PID = 0x1FFF) added
  - If input streams require more bandwidth, some transport packets dropped

By reading the PSI/SI, a receiver knows available input streams and used PIDs

De-multiplexer functionality (in a receiver) filters the requested input stream(s)
DVB-H Network Topology

DVB-H IPE
- Time Slicing
- MPE-FEC

DVB-T Tx
- 4k capable, if needed
- TPS

IP-backbone

Repeater
- Repeaters may be used.

DVB-H Time Slice Terminal
- Support for Time Slicing
- Power saving

Full DVB-H Terminal
- Support both TSL and MPE-FEC
- Power saving and performance

Dense SFN
- FFT-size selected according to planning requirements
- Some operators use 4k some 8k

10-Jan-2006
Case A, Basic Setup: TS-feed is taken to the site via fibre or radio link.
- SFN: SFN adapter is added between TS-adapter and DVB-T Modulator in case of Single Frequency Network (SFN)

Case B, IP Transmission (DVB-H): IP-encapsulator on site, IP-connection via 100BaseT.
- SFN: SFN adapter is added between TS-adapter and DVB-T Modulator in case of Single Frequency Network (SFN)
Gap Filler is a simple DVB-T transmitter which receives the signal from a main transmitter, filters, amplifies and re-radiates it.

- It does not include any modulator.
- It is a simple way of building SFNs.
- Output power is typically less than 50 W.

Isolation between antennas have to be high enough [70–80 dB].
The TS-stream (=IP) can be obtained by receiving the adjacent DVB-T cell with a DVB-T receiver. This is in general called relaying.

In digital systems relaying does not degrade the signal.

Relaying is cheaper than radio link.

The receiving and transmitting frequencies must be different ⇒ not suitable for SFN.
Handover Support in DVB-H

- Smooth handovers in regular DVB-T systems would require two front ends in the receiver.
- When receiver is in OFF state (not receiving a service) it can monitor neighbouring cells for possible soft handover.
- Soft handover, maintaining the service, is possible with minimal increase in power consumption.
- Example: Terminal Equipment #1 (TE#1) is receiving Service A from service cell F1. During OFF-time TE#1 can listen to adjacent cells F2 and F3.
1. List error correction methods used in each of the DVB transmission media: DVB-S, DVB-C and DVB-T/DVB-H.
2. Make a comparison table of the technical features of 2K, 4K and 8K modes in DVB-T/DVB-H?
3. For what purposes are TPS bits used in DVB-T/DVB-H?
References

1. EN 300 421 DVB Framing structure, channel coding and modulation for 11/12 MHz satellite service (DVB-S)
2. EN 300 429 DVB Framing structure, channel coding and modulation for cable (DVB-C)
3. EN 300 744 DVB Framing structure, channel coding and modulation for digital terrestrial television (DVB-T)
4. EN 302 304 DVB-H Transmission System
5. TS 102 377 DVB-H Implementation Guidelines
6. EN 301 192 DVB specification for data broadcasting
7. EN 301 468 (DVB-SI) DVB service information
8. TS 101 191 SFN Megaframe for SFN Synchronization