EBU Workshop on Frequency and Network Planning
Aspects of DVB-T2
Part 2

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System Properties

Why DVB-T2?
- More flexibility / frequency planning
- More flexibility / specific to services
- Higher robustness
- More capacity
- Improved SFN performance

Flexibility
- More bandwidths available
- Scattered pilot patterns variable

Robustness
- Time interleaving
- Improved channel coding
- Rotated constellation

Capacity
- Additional modulation schemes
- Bandwidth extension

Further parameters
- C/N values, protection ratios
- Available net data rates

SFN performance
- Additional guard interval sizes
- Additional FFT sizes
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Overview Part 2

- Network Planning Parameters
- Network Planning Objectives
- Implementation Scenarios
- SFN Extension
- Receiver Modelling
- Note on General Planning Methods, Criteria and Parameters
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Network Planning Parameters

Minimum signal input levels

Signal levels for planning
- Bands III and IV/V
- Fixed rooftop reception
- Portable indoor/outdoor reception
- Mobile reception
- Handheld portable/mobile reception

Protection ratios
- DVB-T2 vs. DVB-T/DVB-T2
- DVB-T2 vs. Other Services (LTE etc.)

Overload thresholds
- DVB-T2 vs. Other Services (LTE etc.)
Partly available yet
Signal Levels for Planning

Required signal levels are basic network planning parameters

Information required on:
  Robustness: C/N
  Receiver: Receiver noise figure, antenna gain, feeder loss
  Receiver site: Man-made noise, penetration loss, height loss
      (transmission channel characteristics in C/N)
  Coverage quality: Reception mode, location probability

Methodology identical to known digital broadcasting systems
(DVB-T and T-DAB)

Details are collected in Annex 1 of EBU Tech 3348
### Signal Levels for Planning

Examples described in EBU Tech 3348 for Band III and Band IV/V:

<table>
<thead>
<tr>
<th>Reception mode</th>
<th>Example DVB-T2 variant</th>
<th>C/N [dB]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed reception</td>
<td>256-QAM, FEC 2/3, 32k, PP7</td>
<td>20.0</td>
</tr>
<tr>
<td>Portable outdoor reception / urban (Class A)</td>
<td>64-QAM, FEC 2/3, 32k, PP4</td>
<td>17.9</td>
</tr>
<tr>
<td>Portable indoor reception / urban (Class B)</td>
<td>64-QAM, FEC 2/3, 16k, PP1</td>
<td>18.3</td>
</tr>
<tr>
<td>Mobile reception / rural</td>
<td>16-QAM, FEC 1/2, 8k, PP1</td>
<td>10.2</td>
</tr>
<tr>
<td>Handheld portable outdoor reception (Class H-A)</td>
<td>16-QAM, FEC 1/2, 16k, PP3</td>
<td>9.8</td>
</tr>
<tr>
<td>Handheld mobile reception (Class H-D) (i.e. terminals are used within a moving vehicle)</td>
<td>16-QAM, FEC 1/2, 8k, PP2</td>
<td>10.2</td>
</tr>
</tbody>
</table>
Network and Frequency Planning Aspects of DVB-T2

Signal Levels for Planning

Simplified table from EBU Tech 3348 for two cases in Band IV/V:

<table>
<thead>
<tr>
<th>DVB-T2 in Band IV/V</th>
<th>Fixed</th>
<th>Portable indoor/urban</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency Freq MHz 650</td>
<td>650</td>
<td></td>
</tr>
<tr>
<td>Minimum C/N required by system C/N dB 20.0</td>
<td>18.3</td>
<td></td>
</tr>
<tr>
<td>System variant (example) 256-QAM FEC 2/3, 32k, PP7 Extended</td>
<td>64-QAM FEC 2/3, 16k, PP1 Extended</td>
<td></td>
</tr>
<tr>
<td>Bit rate (indicative values) Mbit/s 35-40</td>
<td>23-28</td>
<td></td>
</tr>
<tr>
<td>Receiver Noise Figure F dB 6</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Feeder loss Lf dB 4</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Antenna gain relative to half dipole Gd dB 11</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Min equivalent field strength at receiving location Emin dBµV/m 45.3</td>
<td>50.6</td>
<td></td>
</tr>
<tr>
<td>Allowance for man-made noise Pmmn dB 0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Penetration loss (building or vehicle) Lb, Lh dB 0</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Location probability % 70</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td>Minimum median equivalent field strength at reception height; 50% time and 50% locations Emed dBµV/m 48.2</td>
<td>66.8</td>
<td></td>
</tr>
<tr>
<td>Location probability % 95</td>
<td>95</td>
<td></td>
</tr>
<tr>
<td>Minimum median equivalent field strength reception height; 50% time and 50% locations Emed dBµV/m 54.3</td>
<td>75.9</td>
<td></td>
</tr>
</tbody>
</table>
Protection Ratios / Overload Thresholds

All PRs for reference DVB-T2 mode from Draft [2NDDTTBPlan]

DVB-T2 vs. DVB-T / DVB-T2
Co-channel PR: Identical with C/N (for appropriate transmission channel)
Adjacent channel PR: from Draft [2NDDTTBPlan]
Extended bandwidth mode: Identical with normal mode
Into DVB-T: Identical with interference from DVB-T

DVB-T2 vs. other broadcasting systems (T-DAB, Analogue TV, etc.)
Co-channel and Adjacent channel PR: not available yet
Into T-DAB, AnTV, etc.: Identical with DVB-T figures

DVB-T2 vs. non-broadcasting systems (LTE, …)
For LTE Base Station and LTE Terminal
Co-channel PR: not available yet
Adjacent channel PR: from Draft [2NDDTTBPlan]
Protection Ratios / Overload Thresholds

Protection ratios for other DVB-T2 modes
Simple adaption method: Use respective difference from C/N figures
(Comment: Is rough approximation; measurements preferable)

Overload Thresholds: DVB-T2 vs. DVB-T2
Adjacent channel $O_{th}$: from Draft [2NDDTTBPlan]

Overload Thresholds:
DVB-T2 vs. non-broadcasting systems (LTE, ...)
For LTE Base Station and LTE Terminal
Adjacent channel $O_{th}$: from Draft [2NDDTTBPlan]
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Network Planning Objectives

Number of programmes: Capacity of DVB-T/T2 MUX
Quality of programmes: Capacity of DVB-T/T2 MUX
Quality of coverage: Robustness of DVB-T/T2 mode
Frequency efficiency: MFN/SFN performance

Trade-off between capacity and robustness

Costs
(Economic aspect which rules the technical choice)
### MUX Capacity - Example

MFN Rooftop reception (UK case)
Same coverage area for both DVB-T and DVB-T2

<table>
<thead>
<tr>
<th>DVB-T Parameters</th>
<th>DVB-T2 Parameters</th>
<th>Gain in data rate: 16 Mbit/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bandwidth: 8 MHz</td>
<td>Bandwidth: 8 MHz</td>
<td></td>
</tr>
<tr>
<td>FFT size: 2k</td>
<td>FFT size: 32k</td>
<td></td>
</tr>
<tr>
<td>Carrier mode: N/A</td>
<td>Carrier mode: extended</td>
<td></td>
</tr>
<tr>
<td>Scattered Pilot Pattern: N/A</td>
<td>Scattered Pilot Pattern: PP7</td>
<td></td>
</tr>
<tr>
<td>Guard interval: 1/32 (7 µs)</td>
<td>Guard interval: 1/128 (28 µs)</td>
<td></td>
</tr>
<tr>
<td>Modulation: 64-QAM</td>
<td>Modulation: 256-QAM</td>
<td></td>
</tr>
<tr>
<td>Code rate: 2/3</td>
<td>Code rate: 2/3</td>
<td></td>
</tr>
<tr>
<td>C/N (Rice): 20.1 dB</td>
<td>C/N (Rice): 20.0 dB</td>
<td></td>
</tr>
<tr>
<td>Resulting data rate: 24.1 Mbit/s</td>
<td>Resulting data rate: 40.2 Mbit/s</td>
<td></td>
</tr>
</tbody>
</table>

Usable for: More programmes or better picture quality
Overview on MUX data capacity in Annex 2 of EBU Tech 3348
Robustness - Example

SFN Portable reception
Same data rate for both DVB-T and DVB-T2

<table>
<thead>
<tr>
<th>DVB-T Parameters</th>
<th>DVB-T2 Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bandwidth:</td>
<td>8 MHz</td>
</tr>
<tr>
<td>FFT size:</td>
<td>8k</td>
</tr>
<tr>
<td>Carrier mode:</td>
<td>N/A</td>
</tr>
<tr>
<td>Scattered Pilot Pattern:</td>
<td>N/A</td>
</tr>
<tr>
<td>Guard interval:</td>
<td>1/4 (224 µs)</td>
</tr>
<tr>
<td>Modulation:</td>
<td>16-QAM</td>
</tr>
<tr>
<td>Code rate:</td>
<td>2/3</td>
</tr>
<tr>
<td>C/N (Rayleigh):</td>
<td>17.2 dB</td>
</tr>
<tr>
<td>Resulting data rate:</td>
<td>13.3 Mbit/s</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DVB-T2 Parameters</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Bandwidth:</td>
<td>8 MHz</td>
</tr>
<tr>
<td>FFT size:</td>
<td>16k</td>
</tr>
<tr>
<td>Carrier mode:</td>
<td>extended</td>
</tr>
<tr>
<td>Scattered Pilot Pattern:</td>
<td>PP3</td>
</tr>
<tr>
<td>Guard interval:</td>
<td>1/8 (224 µs)</td>
</tr>
<tr>
<td>Modulation:</td>
<td>16-QAM</td>
</tr>
<tr>
<td>Code rate:</td>
<td>1/2</td>
</tr>
<tr>
<td>C/N (Rayleigh):</td>
<td>9.8 dB</td>
</tr>
<tr>
<td>Resulting data rate:</td>
<td>13.1 Mbit/s</td>
</tr>
</tbody>
</table>

Gain in C/N: 7 dB

Usable for: Less transmitter power or Larger coverage area or Improved reception mode
SFN Performance

SFN performance is restricted by self-interference

Limitation on inter-transmitter distance and size of SFN

Crucial parameter: Guard interval GI

Larger GI -> Larger inter-transmitter distance / size of SFN

Rule of thumb: GI length x c = inter-transmitter distance

Trade-off between data capacity and GI length

higher FFT/same GI: higher MUX capacity

higher FFT/same MUX capacity: larger SFN

Figure 2.12: Guard interval overhead reduction with larger FFT size
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Implementation Scenarios

Which combination of DVB-T2 parameters for a specific purpose?

**Fixed rooftop reception**

**Scenarios:**

1. Same coverage as DVB-T, Transition period
2. SFN, maximum coverage
3a. SFN, limited areas
3b. SFN, large areas

**Portable & mobile reception**

**Scenarios:**

4. Maximum data rate
5. Maximum coverage
6. Optimal spectrum usage
7. Mobile reception, small bandwidth
8. Common MUX usage, Different services
## Fixed Rooftop Reception

<table>
<thead>
<tr>
<th>Implementation</th>
<th>Scenario</th>
<th>1</th>
<th>2</th>
<th>3a</th>
<th>3b</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed rooftop reception</td>
<td></td>
<td>Fixed rooftop reception</td>
<td>Fixed rooftop reception</td>
<td>Fixed rooftop reception</td>
<td>Fixed rooftop reception</td>
</tr>
<tr>
<td>MFN (UK mode)</td>
<td></td>
<td>(maximum coverage area extension)</td>
<td>Limited area SFN</td>
<td>Large area SFN</td>
<td></td>
</tr>
</tbody>
</table>

| Bandwidth                                           | 8 MHz    | 8 MHz    | 8 MHz    | 8 MHz    |
| FFT mode                                            | 32K      | 32K      | 32K      | 32K      |
| Carrier mode                                        | Extended | Extended | Extended | Extended |
| Scattered Pilot Pattern                             | PP7      | PP2      | PP4      | PP2      |
| Guard interval                                      | 1/128    | 1/8      | 1/16     | 1/8      |
|                                                     | (28 µs)  | (448 µs) | (224 µs) | (448 µs) |
| Modulation                                          | 256 QAM  | 16QAM    | 256 QAM  | 256 QAM  |
| Code rate                                           | 2/3      | 2/3      | 2/3      | 2/3      |
| C/N                                                 | 20.0 dB  | 11.6 dB  | 20.8 dB  | 21.2 dB  |
| Data rate                                           | 40.2 Mbit/s | 16.7 Mbit/s | 37.0 Mbit/s | 33.4 Mbit/s |

Table 5.1: Overview of the Rooftop Implementation Scenarios
# Portable and Mobile Reception

<table>
<thead>
<tr>
<th>Scenario</th>
<th>4a</th>
<th>4b</th>
<th>5</th>
<th>6</th>
<th>7a</th>
<th>7b</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Implementation</td>
<td>portable reception (maximum date rate)</td>
<td>portable reception (maximum date rate, alternative)</td>
<td>portable reception (maximum coverage area extension)</td>
<td>portable reception (optimum spectrum usage)</td>
<td>mobile reception Band III</td>
<td>mobile reception Band III (alternative)</td>
<td>portable and mobile reception (common usage of MUX by different services)</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>8 MHz</td>
<td>8 MHz</td>
<td>8 MHz</td>
<td>8 MHz</td>
<td>1,7 MHz</td>
<td>1,7 MHz</td>
<td>8 MHz</td>
</tr>
<tr>
<td>FFT mode</td>
<td>16K</td>
<td>32K</td>
<td>16K</td>
<td>16K</td>
<td>4K</td>
<td>4K</td>
<td>8K</td>
</tr>
<tr>
<td>Carrier mode</td>
<td>Extended</td>
<td>Extended</td>
<td>Extended</td>
<td>Extended</td>
<td>Normal</td>
<td>Normal</td>
<td>Extended</td>
</tr>
<tr>
<td>Scattered Pilot Pattern</td>
<td>PP3</td>
<td>PP4</td>
<td>PP3</td>
<td>PP1</td>
<td>PP2</td>
<td>PP1</td>
<td>PP1</td>
</tr>
<tr>
<td>Guard interval</td>
<td>1/8 (224 µs)</td>
<td>1/16 (224 µs)</td>
<td>1/8 (224 µs)</td>
<td>1/4 (448 µs)</td>
<td>1/8 (278 µs)</td>
<td>1/4 (555 µs)</td>
<td>1/4 (224 µs)</td>
</tr>
<tr>
<td>Modulation</td>
<td>64 QAM</td>
<td>64 QAM</td>
<td>64 QAM</td>
<td>64 QAM</td>
<td>64 QAM</td>
<td>64 QAM</td>
<td>64 QAM</td>
</tr>
<tr>
<td>Code rate</td>
<td>2/3</td>
<td>2/3</td>
<td>1/2</td>
<td>2/3</td>
<td>1/2</td>
<td>1/2</td>
<td>2/3</td>
</tr>
<tr>
<td>C/N</td>
<td>17.9 dB</td>
<td>17.9 dB</td>
<td>9.8 dB</td>
<td>18.3 dB</td>
<td>10.2 dB</td>
<td>10.2 dB</td>
<td>18.3 dB</td>
</tr>
<tr>
<td>Data rate</td>
<td>26,2 Mbit/s</td>
<td>27,7 Mbit/s</td>
<td>13,1 Mbit/s</td>
<td>22,6 Mbit/s</td>
<td>2,5 Mbit/s</td>
<td>2,2 Mbit/s</td>
<td>22,4 Mbit/s (max)</td>
</tr>
</tbody>
</table>

Table 5.2: Overview of the Portable and Mobile Implementation Scenarios
Overview Part 2

- Network Planning Parameters
- Network Planning Objectives
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- SFN Extension
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- Note on General Planning Methods, Criteria and Parameters
Scenario 3b: Rooftop Reception
SFN, Large Area

Planning exercise in Finland (Progira)
3 transmitter network, fixed rooftop reception, channel 6 (VHF)

DVB-T
- 8k, 64QAM–2/3
- GI 1/4 (256 μs)
- C/N = 19.5 dB
- 17.4 Mbit/s

DVB-T2
- 32k, 256QAM–2/3
- GI 1/8 (512 μs)
- C/N = 20.2 dB
- 31.4 Mbit/s
Scenario 6: Portable reception
Optimal Spectrum Usage

Planning exercise in Bavaria (IRT)
10 transmitter network, portable outdoor reception (UHF), (Map: 300 km x 300 km)

DVB-T
8k, 16QAM–2/3
GI 1/4 (224 µs)
C/N = 17.2 dB
13.3 Mbit/s

DVB-T2
16k, 64QAM–2/3
GI 1/4 (448 µs)
C/N = 17.5 dB
22.6 Mbit/s
Network and Frequency Planning Aspects of DVB-T2
Implementation Scenarios / SFN extension

Mixture of Scenarios:
Maximum Data Rate / Maximum Coverage Area

Planning exercise in northern part of Germany (NDR)
4 transmitter network, portable outdoor reception, channel 47 (UHF)

DVB-T
8k, 16QAM–2/3
GI 1/4 (224 µs)
C/N = 17.2 dB
13.3 Mbit/s

DVB-T2
16k, 64QAM–3/5
GI 19/128 (266 µs)
C/N = 15.5 dB
23.0 Mbit/s
Scenario 3b: for portable reception (with 64QAM) SFN, Large Area

Planning exercise in Finland (Progira)
3 transmitter network, portable outdoor reception, channel 6 (VHF)
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Synchronisation of Useful Signals

In multipath environment (SFN or/and echoes) signals arrive at different times. This requires synchronisation strategy for FFT evaluation window.

Description of synchronisation strategies, e.g., in EBU BPN066.

Performance beyond Guard Interval

Useful signals beyond guard interval degrade gradually. This gradual degradation is restricted by Nyquist limit given by pilot pattern choice and interpolation mode: Interval of correct equalisation.

Receiver modelling is an issue for a network planning tool.
Interval of Correct Equalisation

Figure 3.1: Weighting function $w_i(t)$ (with an equalization interval $EI$ starting at $t = -t_a$)

Table 3.10: Calculation of interval of correct equalization for two DVB-T2 modes

<table>
<thead>
<tr>
<th>MODE</th>
<th>UHF 2 (Large area SFN-Rooftop)</th>
<th>UHF 4 (Large area SFN–Portable)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulation</td>
<td>256-QAM</td>
<td>16-QAM</td>
</tr>
<tr>
<td>FFT size</td>
<td>32k</td>
<td>16k</td>
</tr>
<tr>
<td>Code rate</td>
<td>3/4</td>
<td>1/2</td>
</tr>
<tr>
<td>Pilot Pattern</td>
<td>PP2</td>
<td>PP3</td>
</tr>
<tr>
<td>Guard interval fraction</td>
<td>1/8</td>
<td>1/8</td>
</tr>
<tr>
<td>$T_g$ (µs)</td>
<td>448</td>
<td>224</td>
</tr>
<tr>
<td>$T_u$ (µs)</td>
<td>3584</td>
<td>1792</td>
</tr>
<tr>
<td>Nyquist limit as fraction of $T_u$</td>
<td>1/6</td>
<td>1/6</td>
</tr>
<tr>
<td>Nyquist limit (µs)</td>
<td>597</td>
<td>299</td>
</tr>
<tr>
<td>Equalisation factor</td>
<td>57/64</td>
<td>57/64</td>
</tr>
<tr>
<td>$T_p$ time (µs)</td>
<td>532</td>
<td>266</td>
</tr>
</tbody>
</table>

Table of Nyquist time for frequency and time interpolation vs. guard interval is given in Annex 3 of EBU Tech 3348
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General Planning Methods, Criteria and Parameters

Many general frequency and network planning aspects for DVB-T2 are identical or (very) similar to DVB-T:

- Reception modes: Fixed, Portable, Mobile, Handheld
- Coverage definitions, Location percentage
- Calculation of signal levels:
  - Antenna gain, Feeder loss, Man-made noise, Height loss
  - Building penetration loss, Vehicle entry loss

Information collected in Annex 1 of EBU Tech 3348
Documents and References

EBU:
- BPN005ed.3: Terrestrial Digital Television – Planning and Implementation Considerations
- BPN066: Guide on SFN Frequency Planning and Network Implementation
- Tech 3348: Frequency and Network Planning Aspects of DVB-T2
- Tech 3317: Planning parameters for hand-held reception

ETSI:
- ETSI TS 102 831 V1.1.1 (2010-10): Implementation Guideline

ITU-R:
- Rec BT.1306, BT.1877, BT.1368, BT.[2NDDTTBPLAN],
- Rec P.1546, P.372, SM.1875 etc.
- Technical Annex GE06 Agreement
Thank you for your attention

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