EBU – TECH 3348

# Frequency and Network Planning Aspects of DVB-T2

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# Frequency and Network Planning Aspects of DVB-T2

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## 1. Introduction

DVB-T2 is the 2nd generation standard for digital terrestrial TV, offering significant benefits compared to DVB-T.

The emergence of DVB-T2 is motivated by the higher spectral efficiency going along with DVB-T2 – be it for a transition from analogue TV to DVB-T2, be it for a transition from DVB-T to DVB-T2. Higher spectral efficiency means that with the same amount of spectrum a larger number of programmes can be broadcast or the same number of programmes broadcast with a higher audio/video quality or coverage quality.

If in addition improved source coding (MPEG-4) is employed, the gain in broadcast transmission is remarkable. For example, in [BG2009] it is shown that a doubling of the number of programmes that can be accommodated in one multiplex is possible (while keeping the same audio/video quality). Also the transmission of more programmes in HD quality would become possible.

Alternatively, the coverage area of a DTT transmitter can be largely increased while keeping constant the transmitter characteristics as well as the reception mode, video quality and number of programmes.

### *1.1 Commercial requirements for DVB-T2*

The commercial requirements for DVB-T2 [TS 102 831] included:

- DVB-T2 transmissions must be able to use existing domestic receive antenna installations and must be able to re-use existing transmitter infrastructures. This requirement ruled out the consideration of MIMO techniques which would involve both new receive and transmit antennas.
- DVB-T2 should primarily target services to fixed and portable receivers.
- DVB-T2 should provide a minimum of 30% capacity increase over DVB-T working within the same planning constraints and conditions as DVB-T.
- DVB-T2 should provide for improved single frequency network (SFN) performance compared with DVB-T.
- DVB-T2 should have a mechanism for providing service-specific robustness; i.e. it should be possible to give different levels of robustness to some services compared to others. For example, within a single 8 MHz channel, it should be possible to target some services for

rooftop reception and target other services for reception on portables.

- DVB-T2 should provide for bandwidth and frequency flexibility.
- There should be a mechanism defined, if possible, to reduce the peak-to-average-power ratio of the transmitted signal in order to reduce transmission costs.

## 1.2 DVB-T and DVB-T2; what is the difference?

Compared to DVB-T, DVB-T2 COFDM parameters have been extended to include:

- New generation FEC (error protection) and higher constellations (256-QAM) resulting in a capacity gain of 25-30%, approaching the Shannon limit.
- OFDM carrier increase from 8k to 32k. In SFN, the guard interval of 1/16 instead of 1/4 resulting in an overhead gain of ~18%.
- New Guard interval fractions: 1/128, 19/256, 19/128.
- Scattered Pilot optimization according to the guard interval (GI), continual pilot minimization resulting in an overhead reduction of ~10%.
- Bandwidth extension: e.g., for 8 MHz bandwidth, 7.77 MHz instead of 7.61 MHz (2% gain).
- Extended interleaving including bit, cell, time and frequency interleaving.

The extended range of COFDM parameters allows very significant reductions in overhead to be achieved by DVB-T2 compared with DVB-T, which taken together with the improved error-correction coding allows an increase in capacity of up to nearly 50% to be achieved for MFN operation and even higher for SFN operation.

DVB-T2 also allows for three new signal bandwidths: 1.7 MHz, 5 MHz and 10 MHz.

The DVB-T2 system also provides a number of new features for improved versatility and ruggedness under critical reception conditions such as:

- rotated constellations, which provide a form of modulation diversity, to assist in the reception of higher code-rate signals in demanding transmission channels,
- special techniques to reduce the peak-to-average power ratio (PAPR) of the transmitted signal resulting in a better efficiency of high power amplifiers Multiple transmit antennas,
- MISO transmission mode using a modified form of Alamouti encoding.

At the physical layer, time slicing is included enabling power saving and allowing different physical layer pipes to have different levels of robustness. Sub-slicing within a frame is also possible which increases time diversity/interleaving depth without increasing de-interleaving memory.

## 1.3 Notes on this report

The purpose of this report is to collect information relevant to network and frequency planning for DVB-T2. It is complementary information to the ETSI system specification [EN 302 755] and implementation guideline [TS 102 831] and the corresponding DVB Blue Books [A122, A133]. Some of the information in these system documents is inevitably repeated here.

**Annex 1** covers planning aspects that are not specific to DVB-T2 but which are nonetheless required for frequency and network planning. **Annexes 2** and **3** deal with some technical details of DVB-T2 and **Annex 4** is a collection of reports about the introduction of DVB-T2 in different European countries.

At the time of writing (Spring 2011) system specification and implementation guidelines for DVB-T2 have been finalized, DVB-T2 field trials are being performed in several countries, and first implementations of regular DVB-T2 DTT services have been started. Nonetheless, for several of the parameters and criteria required for network and frequency planning, no consolidated experience or data is publicly available. This is particularly the case for C/N values in Rayleigh channels and for intra- and inter-protection ratios related to DVB-T2, but also for network implementation aspects particular to DVB-T2 and the DVB-T2 receiver behaviour and performance in SFNs. Therefore, in the present report these aspects are either omitted or are not covered in detail. It is intended to prepare a revision of this report to include this missing or incomplete information when it becomes available.

Similarly, the feasibility of DVB-T2 for audio broadcasting is not dealt with in detail in this report. Also this aspect is intended to be covered in a future revision.

A short and concise overview of the DVB-T2 system parameters is given in ITU-R Recommendation BT.1877 [BT1877]. A general textbook on DVB-T2 is, e.g. [F2010], where information on frequency and network planning aspects of DVB-T2 can also be found.

# 2. System properties

Compared with DVB-T, the DVB-T2 standard offers a bigger choice of the OFDM parameters and modulation schemes. The available bandwidths are increased, too. Combining various modulation schemes with FFT sizes and guard intervals allows construction of MFN and SFN networks designed for different applications: from low bit-rate but robust mobile reception to the high bit-rate fixed reception for domestic and professional use.

This section gives a short overview of the DVB-T2 system parameters. More information on DVB-T and DVB-T2 system parameters can be found in [TR 102 831, EN 302 755, EN 300 744].

## *2.1 Bandwidth*

There are three additional bandwidths available as compared to DVB-T, see **Table 2.1**.

**Table 2.1: Channel bandwidths for DVB-T and DVB-T2**

| DVB-T | DVB-T2 |
|---|---|
| - | 1.7 MHz |
| - | 5 MHz |
| 6 MHz | 6 MHz |
| 7 MHz | 7 MHz |
| 8 MHz | 8 MHz |
| - | 10 MHz |

## *2.2 FFT size*

While for DVB-T two FFT sizes, 2k and 8k, are specified, DVB-T2 comprises 1k, 2k, 4k, 8k, 16k and 32k FFT sizes. **Table 2.2** shows the available FFT sizes for the 8 MHz variant.

**Table 2.2: FFT size parameters for DVB-T2 / 8 MHz (from [EN 302 755])**

| Parameter | | 1k mode | 2k mode | 4k mode | 8k mode | 16k mode | 32k mode |
|---|---|---|---|---|---|---|---|
| Number of carriers $K_{total}$ | normal carrier mode | 853 | 1,705 | 3,409 | 6,817 | 13,633 | 27,265 |
| | extended carrier mode | NA | NA | NA | 6,913 | 13,921 | 27,841 |
| Value of carrier number $k_{min}$ | normal carrier mode | 0 | 0 | 0 | 0 | 0 | 0 |
| | extended carrier mode | NA | NA | NA | 0 | 0 | 0 |
| Value of carrier number $k_{max}$ | normal carrier mode | 852 | 1,704 | 3,408 | 6,816 | 13,632 | 27,264 |
| | extended carrier mode | NA | NA | NA | 6,912 | 13,920 | 27,840 |
| Number of carriers added on each side in extended carrier mode $K_{ext}$ (see Note 2) | | 0 | 0 | 0 | 48 | 144 | 288 |
| Duration $T_U$ | | 1024T | 2048T | 4096T | 8192T | 16384T | 32768T |
| Duration $T_U$ ms (see Note 3) | | 112 | 224 | 448 | 896 | 1792 | 3584 |
| Carrier spacing $1/T_U$ (Hz) (see notes 1 and 2) | | *8,929* | *4,464* | *2,232* | *1,116* | *558* | *279* |
| Spacing between carriers $k_{min}$ and $k_{max}$ $(K_{total}-1)/T_U$ (see Note 3) | normal carrier mode | *7.61 MHz* | *7.61 MHz* | *7.61 MHz* | *7.61 MHz* | *7.61 MHz* | *7.61 MHz* |
| | extended carrier mode | NA | NA | NA | *7.71 MHz* | *7.77 MHz* | *7.77 MHz* |

*Note 1: Numerical values in italics are approximate values.*

*Note 2: This value is used in the definition of the pilot sequence in both normal and extended carrier mode.*

*Note 3: Values for 8 MHz channels.*

In **Table 2.2** the parameters which are bandwidth dependent are given as a function of TU which is a function of the elementary period T. Explicitly shown are the values for the 8 MHz variant. **Table 2.3** gives the absolute values of T for all the available bandwidths. With these the parameter values for the other bandwidths can be calculated.

**Table 2.3: Elementary period as a function of bandwidth (from [EN 302 755])**

| **Bandwidth** | 1.7 MHz | 5 MHz | 6 MHz | 7 MHz | 8 MHz | 10 MHz (see Note) |
|---|---|---|---|---|---|---|
| **Elementary period T** | 71/131 µs | 7/40 µs | 7/48 µs | 1/8 µs | 7/64 µs | 7/80 µs |

*Note: This configuration is only intended for professional applications and is not expected to be supported by domestic receivers.*

## *2.3 Modulation scheme and guard interval*

In DVB-T2, the additional modulation scheme 256-QAM is available, see **Table 2.4**. The new error protection techniques allow the usage of such high modulation schemes.

**Table 2.4: Modulation schemes for DVB-T and DVB-T2**

| DVB-T | DVB-T2 |
|---|---|
| **QPSK** | **QPSK** |
| **16-QAM** | **16-QAM** |
| **64-QAM** | **64-QAM** |
| **-** | **256-QAM** |

**Table 2.5: Length of guard interval for DVB-T2 in an 8 MHz channel raster**

| | | GI-Fraction | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | **1/128** | **1/32** | **1/16** | **19/256** | **1/8** | **19/128** | **1/4** |
| | | | | | | | | |
| **FFT** | **$T_U$ [ms]** | **GI [µs]** | | | | | | |
| 32k | 3.584 | 28 | 112 | 224 | 266 | 448 | 532 | NA |
| 16k | 1.792 | 14 | 56 | 112 | 133 | 224 | 266 | 448 |
| 8k | 0.896 | 7 | 28 | 56 | 66,5 | 112 | 133 | 224 |
| 4k | 0.448 | NA | 14 | 28 | NA | 56 | NA | 112 |
| 2k | 0.224 | NA | 7 | 14 | NA | 28 | NA | 56 |
| 1k | 0.112 | NA | NA | 7 | NA | 14 | NA | 28 |

**Table 2.6: Length of guard interval for DVB-T2 in a 7 MHz channel raster**

| | | GI-Fraction | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | **1/128** | **1/32** | **1/16** | **19/256** | **1/8** | **19/128** | **1/4** |
| | | | | | | | | |
| **FFT** | **$T_U$ [ms]** | **GI [µs]** | | | | | | |
| 32k | 4.096 | 32 | 128 | 256 | 304 | 512 | 608 | NA |
| 16k | 2.048 | 16 | 64 | 128 | 152 | 256 | 304 | 512 |
| 8k | 1.024 | 8 | 32 | 64 | 76,0 | 128 | 152 | 256 |
| 4k | 0.512 | NA | 16 | 32 | NA | 64 | NA | 128 |
| 2k | 0.256 | NA | 8 | 16 | NA | 32 | NA | 64 |
| 1k | 0.128 | NA | NA | 8 | NA | 16 | NA | 32 |

Also additional guard interval fractions are available in DVB-T2. A suitable combination of symbol length (i.e. FFT mode) and guard interval fraction allows for the minimisation of the overhead implied by the guard interval.

In **Tables 2.5 – 2.7** the various guard interval fractions are described for an 8, 7 and 1.7 MHz bandwidth.

**Table 2.7: Length of guard interval for DVB-T2 in a 1.7 MHz channel raster**

| | | GI-Fraction | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | **1/128** | **1/32** | **1/16** | **19/256** | **1/8** | **19/128** | **1/4** |
| | | | | | | | | |
| **FFT** | **$T_U$ [ms]** | **GI [µs]** | | | | | | |
| 8k | 4.440 | 34.7 | 138.7 | 277.5 | 329.5 | 555.0 | 659.1 | 333.0 |
| 4k | 2.220 | NA | 69.4 | 138.7 | NA | 277.5 | NA | 166.5 |
| 2k | 1.110 | NA | 34.7 | 69.4 | NA | 138.7 | NA | 83.2 |
| 1k | 0.555 | NA | NA | 34.7 | NA | 69.4 | NA | 41.6 |

## *2.4 Available data rate*

As seen in **Tables 2.5, 2.6** and **2.7** there are a large number of possible modes in DVB-T2. Some of the 2k and 8k modes are the same as in DVB-T. The main difference is the addition of 16k and 32k FFT.

**Table 2.8: Maximum bit-rate and recommended configurations for 8 MHz, 32k 1/128, PP7 (from [TS 102 831])**

| Modulation | Code rate | Absolute maximum bit-rate | | | Recommended configuration | | |
|---|---|---|---|---|---|---|---|
| | | Bitrate Mbit/s | Frame length $L_F$ | FEC blocks per frame | Bitrate Mbit/s | Frame length $L_F$ | FEC blocks per frame |
| QPSK | 1/2 | 7.49255 | 62 | 52 | 7.4442731 | 60 | 50 |
| | 3/5 | 9.003747 | | | 8.9457325 | | |
| | 2/3 | 10.01867 | | | 9.9541201 | | |
| | 3/4 | 11.27054 | | | 11.197922 | | |
| | 4/5 | 12.02614 | | | 11.948651 | | |
| | 5/6 | 12.53733 | | | 12.456553 | | |
| 16-QAM | 1/2 | 15.03743 | 60 | 101 | 15.037432 | 60 | 101 |
| | 3/5 | 18.07038 | | | 18.07038 | | |
| | 2/3 | 20.10732 | | | 20.107323 | | |
| | 3/4 | 22.6198 | | | 22.619802 | | |
| | 4/5 | 24.13628 | | | 24.136276 | | |
| | 5/6 | 25.16224 | | | 25.162236 | | |
| 64-QAM | 1/2 | 22.51994 | 46 | 116 | 22.481705 | 60 | 151 |
| | 3/5 | 27.06206 | | | 27.016112 | | |
| | 2/3 | 30.11257 | | | 30.061443 | | |
| | 3/4 | 33.87524 | | | 33.817724 | | |
| | 4/5 | 36.1463 | | | 36.084927 | | |
| | 5/6 | 37.68277 | | | 37.618789 | | |
| 256-QAM | 1/2 | 30.08728 | 68 | 229 | 30.074863 | 60 | 202 |
| | 3/5 | 36.15568 | | | 36.140759 | | |
| | 2/3 | 40.23124 | | | 40.214645 | | |
| | 3/4 | 45.25828 | | | 45.239604 | | |
| | 4/5 | 48.29248 | | | 48.272552 | | |
| | 5/6 | 50.34524 | | | 50.324472 | | |

This will result in a two and four times longer "useful" symbol time compared to the 8k case, i.e. at UHF (8 MHz channel raster) 2 and 4 times 896 μs (1792 μs and 3584 μs).

The very long symbol time will, in principle, result in a poorer Doppler performance, due to the short inter-carrier distance in the OFDM signal. The 32k mode is therefore aimed mainly at fixed rooftop reception. Currently it seems unlikely that the 32k mode can be used to provide mobile (vehicular) reception at UHF. However, future laboratory and field tests have to give a clearer answer.

Even in a portable (indoor or outdoor pedestrian) receiving environment with relatively low Doppler frequencies it needs to be confirmed that the 32k mode is suitable. The Doppler performance is however up to 4 times better at VHF compared to UHF Band V. This fact may make VHF Band III frequencies interesting for providing mobile services using the DVB-T2 system.

One additional difference between DVB-T and DVB-T2 is the increased number of GI fraction using 1/128, 19/256 and 19/128, which gives further possibilities to adopt the length of the guard interval to the size of the SFN.

As an example, **Table 2.8** and **Figure 2.1** show the maximum bit-rate and recommended configurations for the system variant 8 MHz, 32k 1/128, PP7.

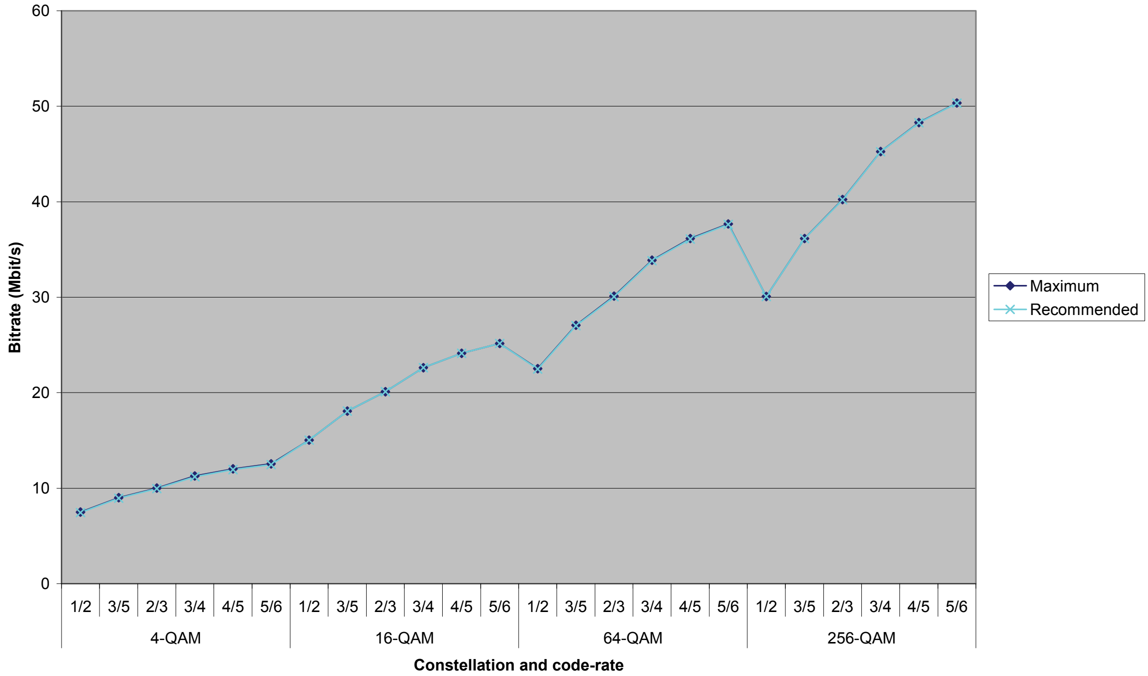



**Figure 2.1: Maximum bit rate and bit rate for recommended configuration with 8 MHz bandwidth and 32k PP7 (from [TS 102 831])**

A more comprehensive overview of the available data rates for the various DVB-T2 configurations is given in **Annex 2**.

Two parameters of the transmitted signal related to the FFT size of the OFDM modulation can influence planning of the DVB-T2 network:

- inter-carrier spacing;
- symbol duration.

Increasing the FFT size results in a narrower sub-carrier spacing and consequently in a longer symbol duration.

Further considerations on the suitable choice of a DVB-T2 configuration are described in **§ 2.11**.

## 2.5 C/N values

C/N values characterize the robustness of transmission systems with regard to noise. Usually, it is distinguished between C/N values for a Gaussian, Rice or Rayleigh channel according to the nature of the transmission channel. More detailed classifications like static or time-variant Rayleigh channels, channels with or without erasures, 0 dB echo channel, etc. are possible.

In this section C/N values for the various DVB-T2 variants as derived from software simulations are presented. They are taken from the DVB-T2 implementation guideline [TS 102 831]. Different channel models and simulation parameters have been applied which means that the results are not always directly comparable.

**Table 2.9: Required raw $(C/N)_0$ to achieve a BER = $1 \times 10^{-7}$ after LDPC decoding LDPC block length: 64,800 bits (from [TS 102 831])**

| | | | Required $(C/N)_0$ (dB) for BER = $1 \times 10^{-7}$ after LDPC decoding | | | |
|---|---|---|---|---|---|---|
| Constel-lation | Code rate | Spectral Efficiency (see Note 2) | Gaussian Channel (AWGN) | Ricean channel ($F_1$) | Rayleigh channel ($P_1$) | 0 dB echo channel @ 90 % GI |
| QPSK | 1/2 | *0.99* | *1.0* | *1.2* | *2.0* | *1.7* |
| QPSK | 3/5 | *1.19* | *2.3* | *2.5* | *3.6* | *3.2* |
| QPSK | 2/3 | *1.33* | *3.1* | *3.4* | *4.9* | *4.5* |
| QPSK | 3/4 | *1.49* | *4.1* | *4.4* | *6.2* | *5.7* |
| QPSK | 4/5 | *1.59* | *4.7* | *5.1* | *7.1* | *6.6* |
| QPSK | 5/6 | *1.66* | *5.2* | *5.6* | *7.9* | *7.5* |
| 16-QAM | 1/2 | *1.99* | *6.0* | *6.2* | *7.5* | *7.2* |
| 16-QAM | 3/5 | *2.39* | *7.6* | *7.8* | *9.3* | *9.0* |
| 16-QAM | 2/3 | *2.66* | *8.9* | *9.1* | *10.8* | *10.4* |
| 16-QAM | 3/4 | *2.99* | *10.0* | *10.4* | *12.4* | *12.1* |
| 16-QAM | 4/5 | *3.19* | *10.8* | *11.2* | *13.6* | *13.4* |
| 16-QAM | 5/6 | *3.32* | *11.4* | *11.8* | *14.5* | *14.4* |
| 64-QAM | 1/2 | *2.98* | *9.9* | *10.2* | *11.9* | *11.8* |
| 64-QAM | 3/5 | *3.58* | *12.0* | *12.3* | *14.0* | *13.9* |
| 64-QAM | 2/3 | *3.99* | *13.5* | *13.8* | *15.6* | *15.5* |
| 64-QAM | 3/4 | *4.48* | *15.1* | *15.4* | *17.7* | *17.6* |
| 64-QAM | 4/5 | *4.78* | *16.1* | *16.6* | *19.2* | *19.2* |
| 64-QAM | 5/6 | *4.99* | *16.8* | *17.2* | *20.2* | *20.4* |
| 256-QAM | 1/2 | *3.98* | *13.2* | *13.6* | *15.6* | *15.7* |
| 256-QAM | 3/5 | *4.78* | *16.1* | *16.3* | *18.3* | *18.4* |
| 256-QAM | 2/3 | *5.31* | *17.8* | *18.1* | *20.1* | *20.3* |
| 256-QAM | 3/4 | *5.98* | *20.0* | *20.3* | *22.6* | *22.7* |
| 256-QAM | 4/5 | *6.38* | *21.3* | *21.7* | *24.3* | *24.5* |
| 256-QAM | 5/6 | *6.65* | *22.0* | *22.4* | *25.4* | *25.8* |

*Note 1:* *Figures in italics are approximate values.*

*Note 2:* *Spectral efficiency does not take into account loss due to signalling / synchronization / sounding and guard interval.*

*Note 3:* *The BER targets are discussed in more detail in [TS 102 831].*

*Note 4:* *The expected implementation loss due to real channel estimation needs to be added to the above Figures. This value will be significantly less than the corresponding Figure for DVB-T in some cases, due to better optimisation of the boosting and pattern densities for DVB-T2.*

*Note 5:* *Entries shaded blue are results from a single implementation. All other results are confirmed by multiple implementations.*

The DVB-T2 OFDM parameters used for these simulations were chosen to be as similar as possible to those for DVB-T. These parameters are as follows: the FFT size is 8k with a guard interval of 1/32, and the bandwidth is 8 MHz with normal carrier mode. Rotated constellations were used and PAPR (Peak to Average Power Ratio) techniques were not applied. The simulations assumed ideal conditions, i.e. ideal synchronization and ideal channel estimation.

**Table 2.10: Required raw (C/N)0 to achieve a BER = 1 x 10-7 before BCH decoding. LDPC block length: 16 200 bits (from [TS 102 831])**

| | | | Required $(C/N)_0$ (dB) for BER = 1 × $10^{-7}$ after LPDC decoding | | | | |
|---|---|---|---|---|---|---|---|
| Constel-lation | Code rate | Effective Code Rate | Spectral Efficiency (see Note 2) | Gaussian Channel (AWGN) | Ricean Channel ($F_1$) | Rayleigh Channel ($P_1$) | 0 dB echo channel @ 90% GI |
| QPSK | 1/2 | 4/9 | *0.87* | *0.7* | *0.9* | *2.0* | *1.6* |
| QPSK | 3/5 | 3/5 | *1.18* | *2.5* | *2.7* | *4.1* | *3.7* |
| QPSK | 2/3 | 2/3 | *1.31* | *3.4* | *3.6* | *5.3* | *4.8* |
| QPSK | 3/4 | 11/15 | *1.45* | *4.3* | *4.6* | *6.6* | *6.2* |
| QPSK | 4/5 | 7/9 | *1.53* | *4.9* | *5.3* | *7.4* | *7.0* |
| QPSK | 5/6 | 37/45 | *1.62* | *5.5* | *5.9* | *8.3* | *7.9* |
| 16-QAM | 1/2 | 4/9 | *1.74* | *5.5* | *5.7* | *6.9* | *6.6* |
| 16-QAM | 3/5 | 3/5 | *2.36* | *7.9* | *8.2* | *9.6* | *9.3* |
| 16-QAM | 2/3 | 2/3 | *2.63* | *9.1* | *9.4* | *11.1* | *10.8* |
| 16-QAM | 3/4 | 11/15 | *2.89* | *10.3* | *10.7* | *12.8* | *12.5* |
| 16-QAM | 4/5 | 7/9 | *3.07* | *11.1* | *11.5* | *13.9* | *13.8* |
| 16-QAM | 5/6 | 37/45 | *3.25* | *11.7* | *12.2* | *15.0* | *15.0* |
| 64-QAM | 1/2 | 4/9 | *2.60* | *9.2* | *9.5* | *11.0* | *10.8* |
| 64-QAM | 3/5 | 3/5 | *3.54* | *12.3* | *12.6* | *14.4* | *14.3* |
| 64-QAM | 2/3 | 2/3 | *3.94* | *13.8* | *14.1* | *16.1* | *15.9* |
| 64-QAM | 3/4 | 11/15 | *4.34* | *15.5* | *15.8* | *18.2* | *18.0* |
| 64-QAM | 4/5 | 7/9 | *4.60* | *16.4* | *16.8* | *19.5* | *19.5* |
| 64-QAM | 5/6 | 37/45 | *4.87* | *17.1* | *17.6* | *20.6* | *20.9* |
| 256-QAM | 1/2 | 4/9 | *3.47* | *12.6* | *12.9* | *14.6* | *14.6* |
| 256-QAM | 3/5 | 3/5 | *4.72* | *16.9* | *17.2* | *19.0* | *19.3* |
| 256-QAM | 2/3 | 2/3 | *5.25* | *18.1* | *18.4* | *20.5* | *20.9* |
| 256-QAM | 3/4 | 11/15 | *5.78* | *20.3* | *20.6* | *22.9* | *23.3* |
| 256-QAM | 4/5 | 7/9 | *6.14* | *21.6* | *22.0* | *24.5* | *25.1* |
| 256-QAM | 5/6 | 37/45 | *6.49* | *22.4* | *22.9* | *25.8* | *26.6* |

*Note 1: Figures in italics are approximate values.*

*Note 2: Spectral efficiency does not take into account loss due to signalling / synchronization / sounding and Guard interval.*

*Note 3: The BER targets are discussed in more detail in [TS 102 831].*

*Note 4: The expected implementation loss due to real channel estimation needs to be added to the above Figures. This value will be significantly less than the corresponding Figure for DVB-T in some cases, due to better optimisation of the boosting and pattern densities for DVB-T2.*

*Note 5: All the results in this table are from a single implementation and are therefore shaded blue.*

The results are given at a BER of $10^{-7}$ after LDPC, corresponding to approximately $10^{-11}$ after BCH.

The channel models used for the simulation are described in detail in [TS 102 831, § 14.2].

**Tables 2.9** and **2.10** give $(C/N)_0$ values for LDPC block lengths of 64,800 and 16,200, respectively. The results for the two block lengths differ between 0.1 and 0.8 dB.

In **Table 2.10** the third column gives “effective code rates”. These code rates are the actual code rates of the respective variants; the code rates given in the second column are to be understood only as labels in order to keep a formal correspondence with DVB-T.

Since these Figures are results of software simulations they need confirmation by laboratory and field measurements. However, yet there are only few and preliminary results of measurements available. From the experience with DVB-T simulations, correction factors of 1 dB to 3 dB (or even m ore in the case of a time-variant Rayleigh channel) are to be expected. Such corrections include effects from different FFT sizes and pilot patterns, from real channel estimation, implementation margins, etc. However, see Note 4 in **Tables 2.9** and **2.10**.

The C/N values are denoted by $(C/N)_0$ indicating that they are “raw” values since they have still to be corrected for the effect resulting from the presence of boosted pilots which depends on the chosen pilot pattern. The specification gives correction factors which vary between about 0.3 and 0.5 dB. Pilot patterns are explained in more detail in **§ 2.7**.

All results of the above described simulations are achieved under the assumption that the receiver has a perfect, noiseless knowledge of the channel. In practice this will not be the case, and therefore, in order to take this effect in account, additional corrections to the C/N values have to be applied. The implementation guideline [TS 102 831, § 14.4] gives an estimation of these corrections, amounting to roughly 0.5 dB to 2.0 dB depending on the chosen pilot pattern.

As mentioned before, it has to be kept in mind that the results of **Tables 2.9** and **2.10** are results from simulations and have to be confirmed by measurements. Therefore, they rather may serve as an indication of the Figures that eventually are to be used for planning purposes.

For the progress of this document, however, certain assumptions with regard to C/N values have to be made in order to calculate minimum median field strengths, describe implementation scenarios, etc. Therefore, in order to be definite, the following is assumed:

As a reference the raw C/N values of **Table 2.9** are chosen. Averaged correction factors, derived from the values given in the implementation guideline [TS 102 831] are used which depend on the choice of the scattered pilot pattern. **Table 2.11** gives the details.

**Table 2.11: Averaged correction factors for raw C/N [in dB] used in this document**

| Pilot Pattern | PP1 | PP2 | PP3 | PP4 | PP5 | PP6 | PP7 | PP8 |
|---|---|---|---|---|---|---|---|---|
| **Pilot Boost Correction** | 0.4 | 0.4 | 0.5 | 0.5 | 0.5 | 0.5 | 0.3 | 0.3 |
| **Real Channel Estimation** | 1.5 | 1.5 | 1.0 | 1.0 | 0.5 | 0.5 | 0.5 | 0.5 |
| **Total** | 1.9 | 1.9 | 1.5 | 1.5 | 1.0 | 1.0 | 0.8 | 0.8 |

These correction factors are added to the raw C/N values of **Table 2.9**.

For fixed roof-top reception the Rice channel Figures are applied and for portable and mobile reception the Rayleigh channel Figures are applied.

As additional information, in **Table 2.12** C/N values for a memoryless Rayleigh channel with erasures are given. This channel model is used to simulate the behaviour of the ‘bit interleaved coding and modulation’ (BICM) module of the DVB-T2 system over multipath channels as an equivalent flat fading channel. This channel is often used by theorists because it is one of the simplest noisy channels to analyze. Erasure probabilities K = 0.1 to 0.2 are regarded as representative for multipath channels with large delay times as they are encountered in SFN.

The results given in **Table 2.12** may serve as an indication for C/N values to be applied in time-variant Rayleigh channels. However, no measurement results are available yet for a comparison. A later version of this document may provide Figures for this transmission channel.

It should be noted that the target BERs in Table 2.12 are different from those applied for the simulations of Tables 2.9 and 2.10.

**Table 2.12: C/N values for simulated performance in Memoryless Rayleigh channel with erasures LDPC block length 64,800 bits (from [TS 102 831])**

| Constellation | Code rate | Spectral Efficiency (see Note 2) | Gaussian Channel (AWGN channel) | Memoryless Rayleigh Channel K=0 | Memoryless Rayleigh channel K=0.1 | Memoryless Rayleigh Channel K=0.2 |
|---|---|---|---|---|---|---|
| QPSK | 1/2 | *0.99* | *1.0* | *2.8* | *3.5* | *4.5* |
| QPSK | 3/5 | *1.19* | *2.2* | *4.7* | *5.7* | *7.8* |
| QPSK | 2/3 | *1.33* | *3.1* | *5.9* | *7.2* | *9.9* |
| QPSK | 3/4 | *1.49* | *4.1* | *7.6* | *9.8* | *17.4* |
| QPSK | 4/5 | *1.59* | *4.7* | *8.9* | *12.2* | - |
| QPSK | 5/6 | *1.66* | *5.2* | *9.8* | *14.6* | - |
| 16-QAM | 1/2 | *1.99* | *6.2* | *8.1* | *9.0* | *10.2* |
| 16-QAM | 3/5 | *2.39* | *7.6* | *10.1* | *11.3* | *13.4* |
| 16-QAM | 2/3 | *2.66* | *8.9* | *11.5* | *13.0* | *15.8* |
| 16-QAM | 3/4 | *2.99* | *10.0* | *13.3* | *15.7* | *24.0* |
| 16-QAM | 4/5 | *3.19* | *10.8* | *14.7* | *18.2* | - |
| 16-QAM | 5/6 | *3.32* | *11.3* | *15.6* | *20.6* | - |
| 64-QAM | 1/2 | *2.98* | *10.5* | *12.6* | *13.6* | *15.0* |
| 64-QAM | 3/5 | *3.58* | *12.3* | *14.7* | *16.0* | *18.3* |
| 64-QAM | 2/3 | *3.99* | *13.6* | *16.2* | *17.8* | *20.9* |
| 64-QAM | 3/4 | *4.48* | *15.1* | *18.2* | *20.8* | *29.6* |
| 64-QAM | 4/5 | *4.78* | *16.1* | *19.7* | *23.4* | - |
| 64-QAM | 5/6 | *4.99* | *16.7* | *20.7* | *260* | - |
| 256-QAM | 1/2 | *3.98* | *14.4* | *16.5* | *17.7* | *19.4* |
| 256-QAM | 3/5 | *4.78* | *16.7* | *19.0* | *20.6* | *23.2* |
| 256-QAM | 2/3 | *5.31* | *18.1* | *20.6* | *22.6* | *25.9* |
| 256-QAM | 3/4 | *5.98* | *20.0* | *22.9* | *25.8* | *35.3* |
| 256-QAM | 4/5 | *6.38* | *21.3* | *24.6* | *28.6* | - |
| 256-QAM | 5/6 | *6.65* | *22.0* | *25.6* | *31.2* | - |

*Note 1:* *Figures in italics are approximate values.*

*Note 2:* *Spectral efficiency does not take into account loss due to signalling/synchronization/sounding and guard interval.*

*Note 3:* *AWGN channel results are at BER=$10^{-6}$ (after BCH). BCH is just emulated, with a minimum of 50 erroneous FEC blocks required to achieve target BER. The BER of $10^{-6}$ has been used to keep simulation times reasonable. Rayleigh channel results are at BER=$10^{-4}$ (after LDPC with no BCH). It is expected that the target packet error rate of the T2 system will be $10^{-7}$.*

*Note 4:* *Rotated constellations are off, perfect CSI is assumed, conventional demapping (not Genie-aided) is used.*

*Note 5:* *Entries shaded blue are results from a single implementation. All other results are confirmed by multiple implementations.*

## 2.6 *Rotated constellation*

### 2.6.1 Concept

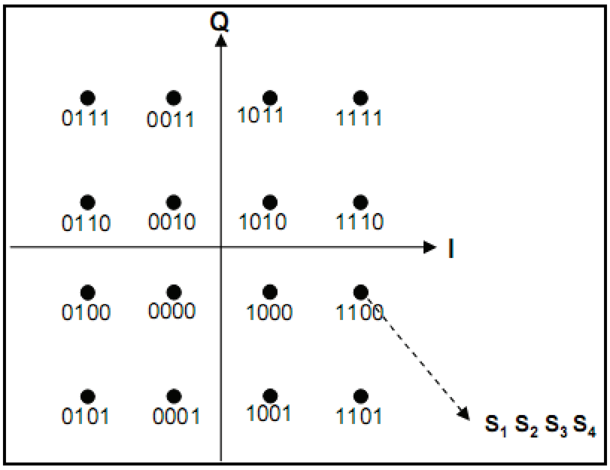
In DVB-T2 a performance improvement with regard to DVB-T is achieved by treating the constellation diagram of the channel symbols in a more flexible way. A rotation of the constellation diagram is applied which yields an improvement. Here, the description of this approach follows the presentation given by [ND2007, ND2008].

### 2.6.2 Constellation Diagram

In DVB-T2 modulation, an information frame is encoded via a binary outer Forward Error Correcting (FEC) code, then processed by a bit interleaver and the resulting sequence is mapped to a succession of complex channel symbols. Such a channel symbol is composed of an in-phase (I) and a quadrature (Q) component, represented in a constellation diagram as shown in **Figure 2.2**. A symbol carries m bits according to the chosen $2^m$-ary constellation characteristics. In QPSK a symbol carries two bits, in 16-QAM it carries 4 bits, in 64-QAM it carries 6 bits, etc.

**Figure 2.2:**
**Constellation diagram for 16-QAM modulation**

**(Figure taken from [ND2008])**




There are various ways of attributing the bits to the symbols. Best results are achieved if only one bit is changed when going from one symbol to the next closest symbol. In this way only one bit is mistaken when a symbol mismatch occurs with the next closest symbol. This coding is called Gray mapping. **Figure 2.2** shows a Gray mapping constellation.

### 2.6.3 Rotation of the constellation diagram

Gray mapping implies an independence of I and Q components of the symbol. As a consequence, all constellation points need both I and Q components to be identified. I contains no information about Q and vice versa. One way of avoiding this independence is to rotate the constellation diagram, as shown in **Figure 2.3**. Now each single m-bit has an individual I and Q component.

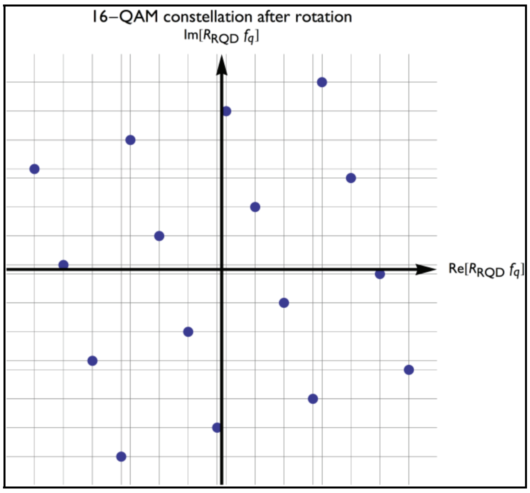



**Figure 2.3:**
**Rotated constellation diagram for 16-QAM modulation**

**(from [TS 102 831])**

### 2.6.4 Rotation angle

In order to determine the optimal rotation angle various aspects have to be considered. Generally, the projection of the constellation points on one axis should have equal distance to gain the best performance. This is best achieved with the rotation angles given in **Table 2.13**.

**Table 2.13: Values of the rotation angle**

| Constellation | Rotation angle (in degree) |
|---|---|
| QPSK | 29.0 |
| 16-QAM | 16.8 |
| 64-QAM | 8.6 |
| 256-QAM | 3.6 |

### 2.6.5 Time delay between I and Q

Rotated constellations do not, however, give a remarkable improvement should I and Q suffer from an identical loss in a fading channel. To overcome this difficulty the so-called Q-delay is introduced. With this delay the Q value is not transmitted in the same cell as the I value, but it is shifted (delayed) to a different cell. Frequency and time interleaving schemes which follow after this modulator stage ensure that the corresponding I and Q values are transmitted in a well separated way in time and frequency. **Figure 2.4** illustrates the process.

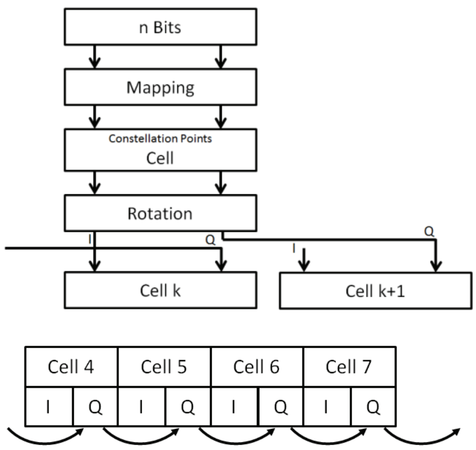



**Figure 2.4: Structure of bit interleaved coded modulation with rotated-QAM mapper and delay**

**(Figure taken from [F2010])**

A cell is the result of mapping a later carrier. In contrast to DVB-T, mapping is not carried out after all interleaving processes but relatively early, after the error protection and after the bit interleaver. However, this is still followed by the cell interleaver, the time interleaver and the frequency interleaver which is the reason why the mapping result cannot yet be allocated to a carrier and why the term “cell” was introduced. A cell is, therefore, a complex number consisting of an I-component and a Q-component, i.e. a real part and an imaginary part. For more details see [F2010].

### 2.6.6 Improvement of performance

For a 16-QAM modulation, code rate 4/5 and 64,800-bit frames, simulations indicate that the application of a rotated constellation diagram provides an improvement of performance of about 0.5 dB for a flat fading Rayleigh channel without erasures, relevant for an MFN. This is not a remarkable improvement. However, for a flat fading Rayleigh channel with erasures (15% assumed), relevant for SFN, an improvement of about 6 dB is predicted, which would be remarkable, see **Table 2.14**.

Constellation rotation and Q-delay imply that the binary information of each constellation point is transmitted twice. This allows for the application of an additional technique, iterative demapping, which may additionally improve the performance by another 0.4 dB for a flat fading Rayleigh channel without erasures and 1.2 dB for a flat fading Rayleigh channel with erasures, see **Table 2.14**.

**Table 2.14: Improvement of performance with rotated constellation diagram, time delay and iterative demapping for 16-QAM, code rate 4/5, 64.800-bit frames**

| Channel | Rotated constellation diagram and time delay | Iterative demapping | Sum |
|---|---|---|---|
| flat fading Rayleigh channel without erasures (MFN case) | 0.5 dB | 0.4 dB | 0.9 dB |
| flat fading Rayleigh channel with erasures (15%) (SFN case) | 6.0 dB | 1.2 dB | 7.2 dB |

For a 64-QAM modulation, code rate 9/10, 64,800-bit rate, the improvement would amount to about 1.2 dB for a flat fading Rayleigh channel without erasures, to about 3.4 dB for 5% erasures, and the improvement vanishes if the occurrence of erasure events exceeds the coding rate, e.g., for 15% erasures there is no improvement at all since the chosen modulation scheme is too vulnerable.

## *2.7 Scattered pilot patterns*

Pilots are carriers which do not contain net information but serve for transmission purposes such as channel estimation, equalization, Common-Phase-Error correction, synchronization. Different kinds of pilots are used for this: continual, scattered, P2 and frame-closing pilots.

Scattered pilots are used by the DVB-T2 receiver to make measurements of the channel and to estimate the channel response for every OFDM cell. The measurements need to be sufficiently dense that they can follow channel variations as a function of both frequency and time.

In DVB-T2, a choice of 8 different pilot patterns is possible, PP1 to PP8, which gives the possibility to adapt to particular channel scenarios. An overview is given in **Table 2.15**. The choice depends on the FFT size and impacts the Doppler performance and the performance regarding self-interference. The pilot patterns PP2, 4 and 6 repeat every second OFDM symbols ($D_y$), they therefore show the best Doppler performance. The small distance ($D_x$) of the pilots in PP1 proves this pattern as most robust against inter-symbol interference, whereas PP6 and 7 are most vulnerable to it.

Pilot pattern PP8 is regarded as suitable for fixed reception but not for portable and mobile reception because PP8 works not or only very limited with time interleaving.

When choosing a certain pilot pattern the trade-off between performance and data capacity has to be considered.

A comprehensive overview of the various combinations of systems variants and pilot patterns and the corresponding data rates can be found in **Annex 2**.

**Table 2.15: Comparison of Scattered Pilot patterns (from [TS 102 831])**

| | PP1 | PP2 | PP3 | PP4 | PP5 | PP6 | PP7 | PP8 | Interpretation |
|---|---|---|---|---|---|---|---|---|---|
| $D_X$ | 3 | 6 | 6 | 12 | 12 | 24 | 24 | 6 | Separation of pilot-bearing carriers |
| $D_Y$ | 4 | 2 | 4 | 2 | 4 | 2 | 4 | 16 | Length of sequence in symbols |
| $1/D_XD_Y$ | 8.33% | 8.33% | 4.17% | 4.17% | 2.08% | 2.08% | 1.04% | 1.04% | Scattered pilots overhead |

## *2.8 Time interleaving*

A further important improvement of DVB-T2 as compared to DVB-T is the introduction of time interleaving which significantly increases the robustness of the system against impulsive noise and time selective fading. The interleaving time may range from a few milliseconds up to some seconds. A typical value is 70 ms.

Time interleaving also improves the Doppler behaviour of the system. **Figure 2.5** compares the required C/N for DVB-T and DVB-T2 as a function of the velocity of the mobile receiver. The simulation is made for a 16-QAM modulation at 600 MHz and a time interleaving depth for DVB-T2 of 100 ms. The limit for the maximum velocity is shifted from 90 km/h for DVB-T to 125 km/h for DVB-T2. The Figure also shows the performance of DVB-T2 at 200 MHz, 500 MHz and 800 MHz.

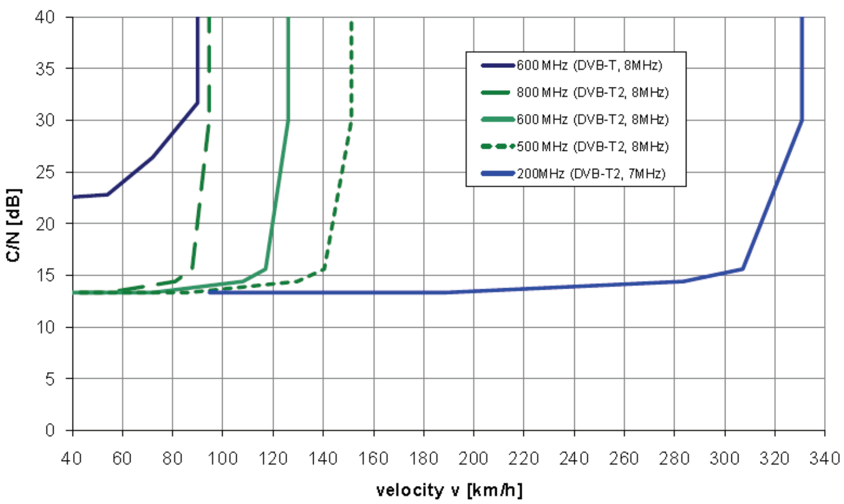



**Figure 2.5: Required C/N for DVB-T and DVB-T2 as a function of the velocity of the mobile receiver, 8k FFT (from [AFM2010])**

It has, however, to be taken into account that there is a trade-off between a large time interleaving depth (if >250 ms) and the time of receiver lock and recovery which also is a criterion of reception quality.

## *2.9 Bandwidth extension*

DVB-T2 allows for the extension of the number of used carriers for the 8k, 16k and 32k mode while at the same time keeping the bandwidth limits of the RF channel. This mode is called the Extended Carrier Mode. **Figure 2.6** shows the spectral density of the extended carrier mode for the various FFT modes.

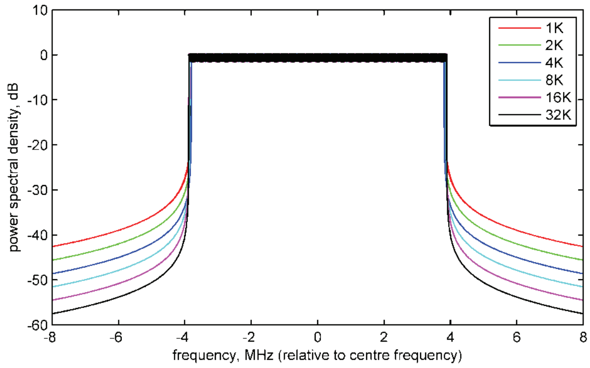


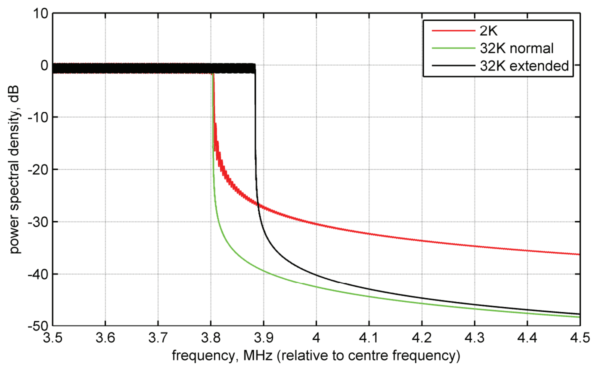

**Figure 2.6:**
**Theoretical DVB-T2 signal spectrum for guard interval fraction 1/8 (for 8 MHz channels and with extended carrier mode for 8k, 16k and 32k)**

**(from [EN 302 755)]**

**Figure 2.7** compares the normal and the extended carrier mode for the 32k FFT.

**Figure 2.7:**
**Detail of theoretical DVB-T2 spectrum for guard-interval fraction 1/8 (for 8 MHz channels)**

**(from [EN 302 755)]**




Because of its higher number of usable carriers the extended carrier mode has an increased data capacity as the normal carrier mode. **Table 2.16** gives the gain of the extended carrier mode for the different FFT modes.

**Table 2.16: Gain of data capacity for the Extended Carrier Mode**

| | carrier mode | | |
|---|---|---|---|
| FFT | normal | extended | |
| Size | carriers | carriers | Gain |
| 1k | 853 | - | 0.00% |
| 2k | 1,705 | - | 0.00% |
| 4k | 3,409 | - | 0.00% |
| 8k | 6,817 | 6,913 | 1.41% |
| 16k | 13,633 | 13,921 | 2.11% |
| 32k | 27,265 | 27,841 | 2.11% |

## *2.10 Phase noise*

Phase noise impairs the DVB-T2 performance by two mechanisms: common phase error (CPE) and inter-carrier interference (ICI). CPE produces a common rotation of all the constellations in an OFDM symbol, and since it is common to all carriers it can be compensated for and therefore introduces no additional degradation. ICI, a form of cross-talk between carriers, cannot be compensated for and therefore produces additional noise.

ICI increases, in general, with larger FFT size, i.e., smaller carrier spacing. However, in the implementation guideline [TS 102 831] it is stated that the experience from DVB-T shows that the difference between 2k and 8k modes is small. Based on this experience and based on software simulations it is expected that 16k and 32k modes will not be significantly worse than 2k and 8k. In the meantime this has been confirmed by laboratory tests.

## 2.11 *Choice of System Parameters*

### 2.11.1 Choice of FFT size

The results of choosing a certain FFT size are well known: an increased FFT size will give a greater delay tolerance for the same fractional guard interval, allowing larger Single Frequency Networks (SFNs) to be constructed. Alternatively, a larger FFT size allows the same delay tolerance to be achieved with a smaller overhead due to the guard interval.

A larger FFT size implies a longer symbol duration, which means that the guard-interval fraction is smaller for a given guard interval duration in time (see **Figure 2.8**). This reduction in overhead leads to an increase in throughput ranging from 2.3% to 17.6%.

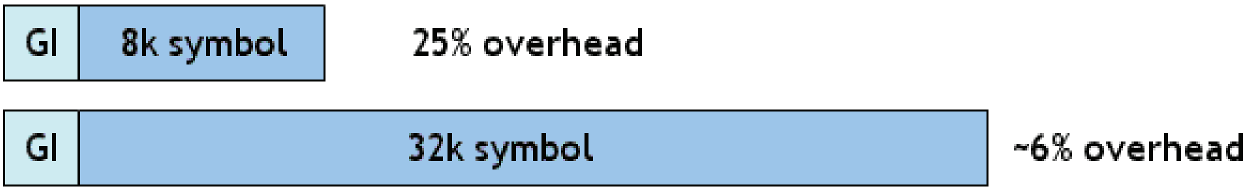



**Figure 2.8: Guard interval overhead reduction with larger FFT size (from [TS 102 831])**

For mobile reception in UHF Band IV/V, or higher bands, smaller FFT sizes should be used as they offer better Doppler performance. The 1k FFT mode which offers the highest Doppler performance is intended primarily for operation in the L-band (about 1.5 GHz), or higher, using a nominal occupied bandwidth of 1.7 MHz. Given that the fundamental sampling rate is lower, the carrier spacing will be correspondingly smaller than it would be in an 8 MHz channel.

For delivering high-bit-rate services to fixed rooftop antennas, in VHF or UHF, the 32k FFT mode is more appropriate. In this situation the time variations in the channel are minimized, and 32k offers the very highest bit rates achievable using DVB-T2.

For a given FFT size, constellation and code rate, the Doppler performance is roughly proportional to the RF bandwidth (halving the bandwidth will halve the carrier spacing resulting in half the Doppler performance) and inversely proportional to the RF frequency and therefore higher frequencies are more vulnerable to fast time-varying channels, having poorer Doppler performance.

Therefore, roughly the same Doppler performance should be expected for mobile applications in VHF Band III (about 200 MHz) using the 32k mode as when using the 8k mode at 800 MHz, so 32k may be an option even at VHF using 7 MHz RF bandwidth. The performance in time-varying channels can also be affected by the choice of pilot pattern.

On the other hand, increasing the FFT size would proportionally decrease the Doppler performance of the system.

### 2.11.2 Selection of DVB-T2 mode for SFNs

When selecting a transmission mode for DVB-T2 the actual choice (as in the case of DVB-T) depends upon the networks requirements. As always a trade-off between capacity and robustness needs to be made.

One approach for selecting a mode for SFN operation would be to select the length of the guard interval according to the physical size of the SFN or the SFN's intra transmitter separation distances, noting of course that it may be possible to have larger transmitter separations than the guard interval depending on practical considerations such as terrain, propagation and system robustness etc. Additionally, optimisation of coverage by modification of antenna diagrams, transmitter powers, antenna heights, transmitter timing etc, may allow larger transmitter distances in the SFN than the guard interval. However in such cases detailed coverage simulations need to be made.

Together with the selection of the length of the guard interval, the guard interval fraction also needs determination. The GI fraction involves consideration of the FFT size which is related to the reception scenario: fixed rooftop, portable or mobile reception. In the case of fixed rooftop reception it would seem desirable to use 32k or 16k FFT as a larger FFT size would reduce the GI fraction and increase the available capacity. For portable and mobile reception a lower FFT size such as 16k, 8k or even 4k may need to be considered, in particular for mobile reception when Doppler is a limitation.

The choice of modulation determines the bit rate (capacity), but it also has a large impact upon the robustness of the system; higher order modulation schemes that offer more capacity are more fragile. It should however be noted that due to the more efficient channel coding, rotated constellation etc. used in DVB-T2, compared with DVB-T, 256-QAM will require C/N values in the same order of magnitude as those previously required for 64-QAM, that is, values in the order of 17 – 20 dB depending on the code rate used, see **Tables 2.9** to **2.12**.

Increased system robustness will also have a large impact upon SFN performance since a lower required C/N will reduce the susceptibility for SFN self-interference. DVB-T2 will give the possibility to provide much higher data rates than current DVB-T networks designed for portable or mobile reception.

Additionally, there are several Scattered Pilot Patterns (PP) available in DVB-T2, PP1 to PP8. They are described in more detail in **§ 2.7**. The choice of pilot patterns will determine the performance for delayed signals arriving outside the guard interval as given by the Nyquist limit. Exceeding this Nyquist limit means that channel equalisation is incorrect even if the fraction of inter-symbol interference (ISI) is small.

# 3. Receiver properties, sharing and compatibility, network planning parameters

For frequency and network planning of DVB-T2 knowledge of receiver properties, sharing and compatibility criteria and network planning parameters is required. Many of the network planning parameters and methods are well known from DVB-T and DVB-H planning. They comprise definition of coverage and reception modes, method of calculation of minimum median equivalent field strengths, treatment of antenna gain, feeder loss, man made noise and building penetration loss, or the definition of location percentage requirements. All these are given in **Annex 3**.

In this section, aspects particular to DVB-T2 are described such as minimum receiver input levels, signal levels for planning, or protection ratios.

## *3.1 Minimum receiver signal input levels*

To illustrate how the C/N ratio influences the minimum signal input level for the receiver, the latter has been calculated for five representative C/N ratios. They are given in **Table 3.1**. For other values simple linear interpolation can be applied.

The receiver noise Figure has been chosen as 6 dB for the frequency Bands III, IV and V. Previously a number of different noise Figure values ranging from 5 – 7 dB has been used. The EBU planning guideline for DVB-T [BPN005] suggests the value 7 dB. However, it is believed that improvements in digital receiver design will justify this small modification. Using the same receiver noise Figure for all frequency bands will mean that the minimum receiver input signal level is independent of the transmitter frequency. If other noise Figures are used in practice, the minimum receiver input signal level will change correspondingly by the same amount.

The minimum receiver input signal levels calculated here are used in **§ 3.3** to derive the minimum power flux densities and corresponding minimum median equivalent field strength values for various frequency bands and reception modes.

***Definitions:***

| | |
|---|---|
| B | : Receiver noise bandwidth [Hz] |
| C/N | : RF signal to noise ratio required by the system [dB] |
| F | : Receiver noise Figure [dB] |
| $P_n$ | : Receiver noise input power [dBW] |
| $P_{s\ min}$ | : Minimum receiver signal input power [dBW] |
| $U_{s\ min}$ | : Minimum equivalent receiver input voltage into $Z_i$ [dBμV] |
| $Z_i$ | : Receiver input impedance (75Ω) |

***Constants:***

| | |
|---|---|
| k | : Boltzmann's Constant = 1.38*10-23 Ws/K |
| $T_0$ | : Absolute temperature = 290 K |

***Formulas used:***

| | |
|---|---|
| $P_n$(in dBW) | = F + 10 log (k*$T_0$*B) |
| $P_{s\ min}$ (in dBW) | = $P_n$ + C/N |
| $U_{s\ min}$ (in dBμV) | = $P_{s\ min}$ + 120 + 10 log ($Z_i$) |

**Table 3.1: Minimum required input signal levels for 8 MHz versions and different C/N values**

| Frequency Band III, IV, V - 8 MHz channels | | | | | | |
|---|---|---|---|---|---|---|
| **Normal carrier mode; 1k, 2k, 4k, 8k, 16k, 32k modes** | | | | | | |
| **Equivalent noise bandwidth** | **B [Hz]** | $7.61*10^6$ | $7.61*10^6$ | $7.61*10^6$ | $7.61*10^6$ | $7.61*10^6$ |
| **Receiver noise Figure** | **F [dB]** | 6 | 6 | 6 | 6 | 6 |
| **Receiver noise input power** | **$P_n$ [dBW]** | -129.2 | -129.2 | -129.2 | -129.2 | -129.2 |
| **RF signal/noise ratio** | **C/N [dB]** | 8.0 | 12.0 | 16.0 | 20.0 | 24.0 |
| **Min. receiver signal input power** | **$P_{s\ min}$ [dBW]** | -121.7 | -117.7 | -113.7 | -111.2 | -108.2 |
| **Min. equivalent receiver input voltage, 75Ω** | **$U_{s\ min}$ [dBμV]** | 17.5 | 21.5 | 25.5 | 29.5 | 33.5 |

***Note***: *This table provides a derivation of <u>minimum</u> required signal levels;* ***§ 3.3*** *provides information on the <u>minimum median</u> values of signal levels required in practical situations.*

For the extended carrier mode 8k (with an equivalent noise bandwidth of 7.71 MHz) and the extended carrier modes 16k, 32k (with an equivalent noise bandwidth of 7.77 MHz), the Figures of required signal power and voltage for the normal carrier modes should be used because the small increase in the equivalent noise bandwidth has a negligible impact on the final value.

For other channel bandwidths B' (1.7, 5, 6, 7 or 10 MHz), the Figures of minimum required signal power and voltage could be derived from **Table 3.1** by adding the correction factor 10 log(B'/8).

## *3.2 Signal levels for planning*

In **§ 3.1** the minimum signal levels to overcome noise are given as the minimum receiver input power and the corresponding minimum equivalent receiver input voltage. No account is taken of any propagation effect. However, it is necessary to consider these effects when considering reception in a practical environment.

In defining coverage, it is indicated that due to the very rapid transition from near perfect to no reception at all, it is necessary that the minimum required signal level is achieved at a high percentage of locations. These percentages have been set at 95% for "good" and 70% for "acceptable" portable reception. For mobile reception the percentages defined were 99% and 90%, respectively, see **Annex 1**.

In **§ 3.3** minimum median power flux densities and equivalent field strengths are presented which are needed for practical planning considerations. Six different reception modes are described which are listed in **Table 3.2**.

**Table 3.2: Reception modes, example DVB-T2 variants, C/N values**

| Reception mode | Example DVB-T2 variant | C/N [dB] |
|---|---|---|
| Fixed reception | 256-QAM, FEC 2/3, 32k, PP7 | 18.9 |
| Portable outdoor reception / urban (Class A) | 64-QAM, FEC 2/3, 32k, PP3 | 17.1 |
| Portable indoor reception / urban (Class B) | 64-QAM, FEC 2/3, 16k, PP3 | 17.1 |
| Mobile reception / rural | 16-QAM, FEC 1/2, 8k, PP2 | 9.4 |
| Handheld portable outdoor reception (Class H-A) | 16-QAM, FEC 2/3, 16k, PP3 | 12.3 |
| Handheld mobile reception (Class H-D)<br>(i.e. terminals are used within a moving vehicle) | 16-QAM, FEC 1/2, 8k, PP3 | 9.0 |

The calculations are performed for two frequencies representing Band III (200 MHz) and Bands IV and V (650 MHz) and a bandwidth of 7 MHz in Band III and 8 MHz in Bands IV and V. For Band III the “mobile/rural” reception mode is calculated for the 1.7 MHz bandwidth and the “handheld class H-D” reception mode is calculated for both 1.7 MHz and 7 MHz bandwidth. Values for other frequencies or bandwidths may be calculated as described in **§ 3.1** and **Annex 1**.

Suitable DVB-T2 variants are chosen for the reception modes, see **Table 3.2**. They are to be understood as examples for the respective reception modes, since the large variety of DVB-T2 system variants always allows for a choice out of several possible variants. In **§ 5** a more detailed treatment of possible system variants for the various reception modes and implementation scenarios is given.

In order to calculate the minimum median power flux densities and equivalent field strengths the C/N Figures for the different DVB-T2 variants are needed. They are given in the third column of **Table 3.2** and calculated from **Tables 2.9** and **2.11** as described in **§ 2.5**.

The values for other reception modes or other DVB-T2 variants may be derived from these six representative cases.

More details are given in **Annex 1**.

## *3.3 Examples of signal levels for planning*

The following **sections 3.3.1** and **3.3.2** give the details of the calculation for the cases listed in **§ 3.2**.

The DVB-T2 variants indicated in the tables are examples for a possible choice of the variant. For each reception mode there are several DVB-T2 variants available with their respective bit rates. In addition, the choice of the guard interval affects the bit rate but does not change the required C/N. Therefore, in the tables, for the available net bit rate a range is given.

In the tables, the reception height is 10 m above ground level (a.g.l.) for fixed reception and 1.5 m a.g.l. for the other reception modes.

### 3.3.1 DVB-T2 in Band III

| | | | Fixed | Portable outdoor/urban | Portable indoor/urban | Mobile/rural | Handheld portable outdoor | Handheld mobile Class H-D/ integrated antenna | Handheld mobile Class H-D/ integrated antenna |
|---|---|---|---|---|---|---|---|---|---|
| Frequency | Freq | MHz | 200 | 200 | 200 | 200 | 200 | 200 | 200 |
| Minimum C/N required by system[1] | C/N | dB | 18.9 | 17.1 | 17.1 | 9.4 | 12.3 | 9 | 9 |
| System variant (example) | | | 256-QAM FEC 2/3, 32k, PP7 Normal | 64-QAM FEC 2/3, 32k, PP3 Normal | 64-QAM FEC 2/3, 16k, PP3 Normal | 16-QAM FEC 1/2, 8k, PP2 Normal | 16-QAM FEC 2/3, 16k, PP3 Normal | 16-QAM FEC 1/2, 8k, PP3 Normal | 16-QAM FEC 1/2, 8k, PP3 Normal |
| Bit rate (indicative values) | | Mbit/s | 28-35 | 20-25 | 20-25 | 2.2-2.8 | 13-16 | 2.3-2.9 | 10-12 |
| Receiver Noise Figure | F | dB | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| Equivalent noise band width | B | MHz | 6.66 | 6.66 | 6.66 | 1.54 | 6.66 | 1.54 | 6.66 |
| Receiver noise input power | Pn | dBW | -129.7 | -129.7 | -129.7 | -136.1 | -129.7 | -136.1 | -129.7 |
| Min. receiver signal input power | Ps min | dBW | -110.8 | -112.6 | -112.6 | -126.7 | -117.4 | -127.1 | -120.7 |
| Min. equivalent receiver input voltage, 75Ω | Umin | dBμV | 27.9 | 26.1 | 26.1 | 12.0 | 21.3 | 11.6 | 18.0 |
| Feeder loss | Lf | dB | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| Antenna gain relative to half dipole | Gd | dB | 7 | -2.2 | -2.2 | -2.2 | -17 | -17 | -17 |
| Effective antenna aperture | Aa | $dBm^2$ | 1.7 | -7.5 | -7.5 | -7.5 | -22.3 | -22.3 | -22.3 |
| Min Power flux density at receiving location | Φmin | $dB(W)/m^2$ | -110.5 | -105.1 | -105.1 | -119.2 | -95.1 | -104.8 | -98.4 |
| Min equivalent field strength at receiving location | Emin | dBμV/m | **35.3** | **40.7** | **40.7** | **26.6** | **50.7** | **41.0** | **47.4** |
| Allowance for man-made noise | Pmmn | dB | 2 | 8 | 8 | 5 | 0 | 0 | 0 |
| Penetration loss (building or vehicle) | Lb, Lh | dB | 0 | 0 | 9 | 0 | 0 | 8 | 8 |
| Standard deviation of the penetration loss | | dB | 0 | 0 | 3 | 0 | 0 | 2 | 2 |
| Diversity gain | Div | dB | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Location probability | | % | 70 | 70 | 70 | 90 | 70 | 90 | 90 |
| Distribution factor | | | 0.5244 | 0.5244 | 0.5244 | 1.28 | 0.5244 | 1.28 | 1.28 |
| Standard deviation | | | 5.5 | 5.5 | 6.3 | 5.5 | 5.5 | 5.9 | 5.9 |
| Location correction factor | Cl | dB | 2.8842 | 2.8842 | 3.30372 | 7.04 | 2.8842 | 7.552 | 7.552 |
| Minimum median power flux density at reception height[2]; 50% time and 50% locations | Φmed | $dB(W)/m^2$ | -105.6 | -94.2 | -84.8 | -107.1 | -92.2 | -89.2 | -82.9 |
| Minimum median equivalent field strength at reception height[2]; 50% time and 50% locations | Emed_1.5m | dBμV/m | **40.2** | **51.6** | **61.0** | **38.7** | **53.6** | **56.6** | **62.9** |
| Location probability | | % | 95 | 95 | 95 | 99 | 95 | 99 | 99 |
| Distribution factor | | | 1.6449 | 1.6449 | 1.6449 | 2.3263 | 1.6449 | 2.3263 | 2.3263 |
| Standard deviation | | | 5.5 | 5.5 | 6.3 | 5.5 | 5.5 | 5.9 | 5.9 |
| Location correction factor | Cl | dB | 9.04695 | 9.04695 | 10.36287 | 12.79465 | 9.04695 | 13.72517 | 13.72517 |
| Minimum median power flux density at reception height[2]; 50% time and 50% locations | Φmed | $dB(W)/m^2$ | -99.5 | -88.1 | -77.8 | -101.4 | -86.1 | -83.1 | -76.7 |
| Minimum median equivalent field strength at reception height[2]; 50% time and 50% locations | Emed_1.5m | dBμV/m | **46.3** | **57.7** | **68.0** | **44.4** | **59.7** | **62.7** | **69.1** |

[1] Raw C/N values; they do not include implementation margin

[2] 10m for fixed reception and 1.5m for the other reception modes

## 3.3.2 DVB-T2 in Band IV/V

| | | | Fixed | Portable outdoor/urban | Portable indoor/urban | Mobile/rural | Handheld portable outdoor | Handheld mobile Class H-D/ integrated antenna |
|---|---|---|---|---|---|---|---|---|
| Frequency | Freq | MHz | 650 | 650 | 650 | 650 | 650 | 650 |
| Minimum C/N required by system[1] | C/N | dB | 18.9 | 17.1 | 17.1 | 9.4 | 12.3 | 9 |
| System variant (example) | | | 256-QAM FEC 2/3, 32k, PP7 Extended | 64-QAM FEC 2/3, 32k, PP3 Extended | 64-QAM FEC 2/3, 16k, PP3 Extended | 16-QAM FEC 1/2, 8k, PP2 Extended | 16-QAM FEC 2/3, 16k, PP3 Extended | 16-QAM FEC 1/2, 8k, PP3 Extended |
| Bit rate (indicative values) | | Mbit/s | 33-40 | 23-29 | 23-29 | 11-13 | 15-19 | 12-14 |
| Receiver Noise Figure | F | dB | 6 | 6 | 6 | 6 | 6 | 6 |
| Equivalent noise band width | B | MHz | 7.77 | 7.77 | 7.77 | 7.71 | 7.77 | 7.71 |
| Receiver noise input power | Pn | dBW | -129.1 | -129.1 | -129.1 | -129.1 | -129.1 | -129.1 |
| Min. receiver signal input power | Ps min | dBW | -110.2 | -112.0 | -112.0 | -119.7 | -116.8 | -120.1 |
| Min. equivalent receiver input voltage, 75 ohm | Umin | dBμV | 28.6 | 26.8 | 26.8 | 19.0 | 22.0 | 18.6 |
| Feeder loss | Lf | dB | 4 | 0 | 0 | 0 | 0 | 0 |
| Antenna gain relative to half dipole | Gd | dB | 11 | 0 | 0 | 0 | -9.5 | -9.5 |
| Effective antenna aperture | Aa | $dBm^2$ | -4.6 | -15.6 | -15.6 | -15.6 | -25.1 | -25.1 |
| Min Power flux density at receiving location | Φmin | $dB(W)/m^2$ | -101.6 | -96.4 | -96.4 | -104.1 | -91.7 | -95.0 |
| Min equivalent field strength at receiving location | Emin | dBμV/m | 44.2 | 49.4 | 49.4 | 41.7 | 54.1 | 50.8 |
| Allowance for man-made noise | Pmmn | dB | 0 | 1 | 1 | 0 | 0 | 0 |
| Penetration loss (building or vehicle) | Lb, Lh | dB | 0 | 0 | 11 | 0 | 0 | 8 |
| Standard deviation of the penetration loss | | dB | 0 | 0 | 6 | 0 | 0 | 2 |
| Diversity gain | Div | dB | 0 | 0 | 0 | 0 | 0 | 0 |
| Location probability | | % | 70 | 70 | 70 | 90 | 70 | 90 |
| Distribution factor | | | 0.5244 | 0.5244 | 0.5244 | 1.28 | 0.5244 | 1.28 |
| Standard deviation | | | 5.5 | 5.5 | 8.1 | 5.5 | 5.5 | 5.9 |
| Location correction factor | Cl | dB | 2.8842 | 2.8842 | 4.24764 | 7.04 | 2.8842 | 7.552 |
| Minimum median power flux density at reception height[2]; 50% time and 50% locations | Φmed | $dB(W)/m^2$ | -98.7 | -92.5 | -80.2 | -97.1 | -88.8 | -79.5 |
| Minimum median equivalent field strength at reception height[2]; 50% time and 50% locations | Emed_1.5m | dBμV/m | 47.1 | 53.3 | 65.6 | 48.7 | 57.0 | 66.3 |
| Location probability | | % | 95 | 95 | 95 | 99 | 95 | 99 |
| Distribution factor | | | 1.6449 | 1.6449 | 1.6449 | 2.3263 | 1.6449 | 2.3263 |
| Standard deviation | | | 5.5 | 5.5 | 8.1 | 5.5 | 5.5 | 5.9 |
| Location correction factor | Cl | dB | 9.04695 | 9.04695 | 13.32369 | 12.79465 | 9.04695 | 13.72517 |
| Minimum median power flux density at reception height[2]; 50% time and 50% locations | Φmed | $dB(W)/m^2$ | -92.6 | -86.4 | -71.1 | -91.4 | -82.7 | -73.3 |
| Minimum median equivalent field strength reception height[2]; 50% time and 50% locations | Emed_1.5m | dBμV/m | 53.2 | 59.4 | 74.7 | 54.4 | 63.1 | 72.5 |

[1] Raw C/N values; they do not include implementation margin
[2] 10m for fixed reception and 1.5m for the other reception modes

## 3.4 Protection ratios

Protection ratios are required for compatibility considerations with regard to other radio systems. These cover intra-protections ratios (DVB-T2 vs. DVB-T2) and inter-protection ratios (DVB-T2 vs. other non-T2 radio systems, broadcasting as well as non-broadcasting), co-channel as well as adjacent channel protection ratios.

Up to the time of the preparation of this report, few protection ratios measurements have been published, and similarly little information is available with regard to C/N measurements. The C/N values which are presented in **§ 2** of this report result from software simulations and remain to be confirmed by laboratory and field measurements. This holds in particular for Rice and (static and time-variant) Rayleigh transmission channels which are regarded as the relevant channels for broadcasting applications.

Therefore, limited information is presented in this document; subsequent versions may provide more details.

As usual for OFDM systems, it is expected that DVB-T2 intra-protection ratios (DVB-T2 vs. DVB-T2) are identical to the respective C/N values. The same holds for the protection ratios DVB-T vs. DVB-T2.

First results of laboratory measurements [IRT-2011-1] give the following indication:

C/N values for a Gaussian transmission channel are slightly higher by 0.5 to 1.0 dB as compared to the simulation results given in the ETSI guideline [TS 102 831].

C/N values for a static Rayleigh transmission channel are by 0.5 to 2.0 dB higher as compared to the simulation results given in the ETSI guideline [TS 102 831].

C/N values for a time-variant Rayleigh transmission channel are by 3 to 4 dB higher than for a static Rayleigh channel.

These first preliminary results are quite similar to the experience that was made with DVB-T when simulated C/N values have been compared with measurement results. The Figures are slightly smaller than the corrected C/N Figures derived in **§ 2.5** and which are used for the calculation of the minimum median field strengths in **§ 3.3** and the description of the implementation scenarios in **§ 5**.

A particular aspect, specific to DVB-T2, is the question whether the extended bandwidth mode of DVB-T2 imposes a higher interference to other DVB-T or DVB-T2 implementations than the normal mode. First available results [IRT2011-2] indicate that an increase of only 0.2 to 0.3 dB is to be expected which would - in first approximation –be a negligible difference.

For a detailed compilation the following protection ratios are intended to be collected in a subsequent version of this report:

- Protection ratios DVB-T2 interfered with by DVB-T2
- Protection ratios DVB-T2 interfered with by DVB-T and vice versa
- Protection ratios DVB-T2 interfered with by T-DAB and vice versa
- Protection ratios DVB-T2 interfered with by Analogue TV systems and vice versa
- Protection ratios DVB-T2 interfered with by Other services and vice versa

# 4. New planning features

## 4.1 SFN Extension

DVB-T2 allows for the implementation of large area SFNs with a high data rate because of the possibility of choosing larger guard intervals. An example is:

32k modes using 256-QAM using CR 3/5 requiring a raw C/N (Rice) of about 16 dB (about 18 dB with implementation margin)

- GI 1/16 (GI 224 µs)➔up to 34.1 Mbit/s using extended carrier mode
- GI 19/256 (GI 266 µs) ➔ up to 33.7 Mbit/s
- GI 1/8 (448 µs)➔ up to 32.2 Mbit/s
- GI 19/128 (532 µs)➔ up to 31.6 Mbit/s

It is interesting to note the large increase in capacity relative to a DVB-T mode requiring the same C/N. SFN performance will be significantly improved when using very robust system variants of DVB-T offering relatively low capacity.

In the following **Figures 4.1** and **4.2** an example is given showing an SFN with transmitter distances above 100 km. In can be seen that coverage can be significantly improved by using DVB-T2, since the SFN self-interference is reduced.

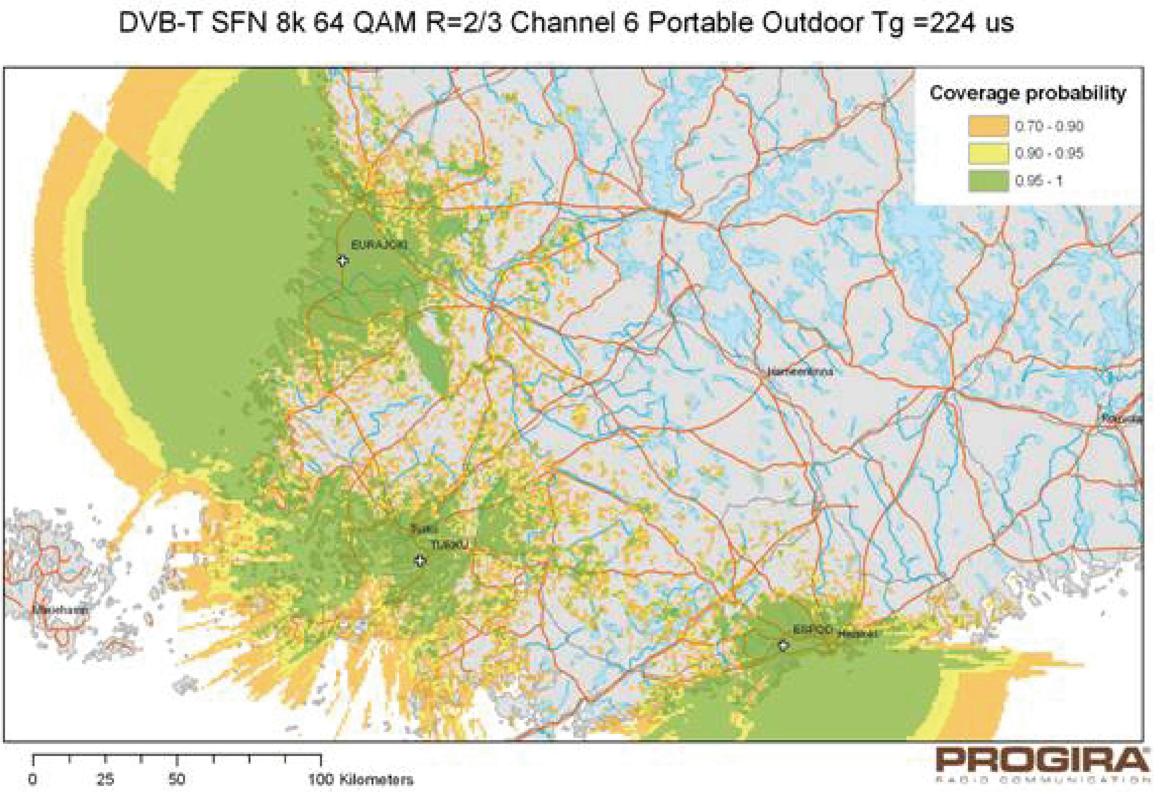



**Figure 4.1: DVB-T SFN**

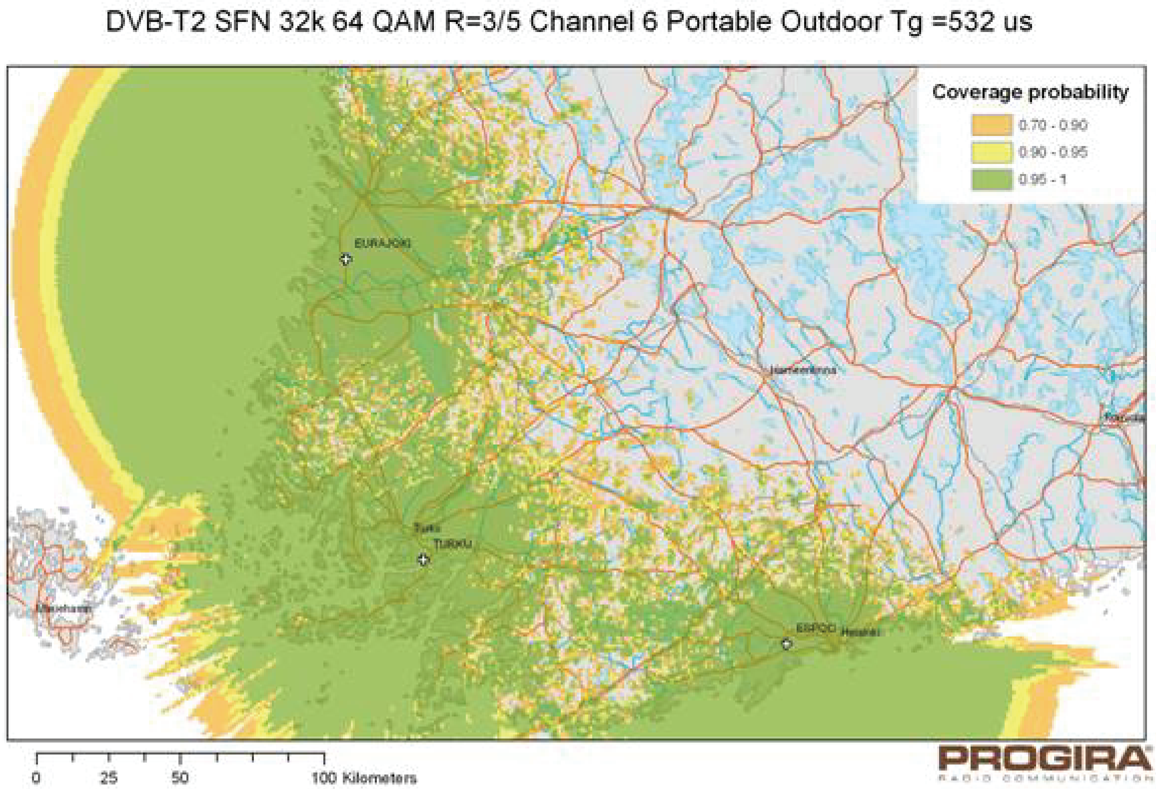



**Figure 4.2: DVB-T2 SFN**

## *4.2 Degradation beyond guard interval*

The length of the guard interval, as mentioned in **§ 4.1**, is the most significant and obvious improvement when it comes to handling long delayed echoes in SFNs. However handling of signals arriving outside the guard also has a significant effect upon the SFN performance.

The performance of DVB-T2 system outside the guard interval is mainly determined by two factors which are essentially the same as in the case of DVB-T. They are:

- The symbol time: longer symbol time, when using higher (e.g. 16k or 32k) FFT, will improve performance outside the guard interval since guard interval fraction becomes smaller when using the same length of the guard interval
- Interval of correct equalisation

These two factors are discussed separately in the following sections.

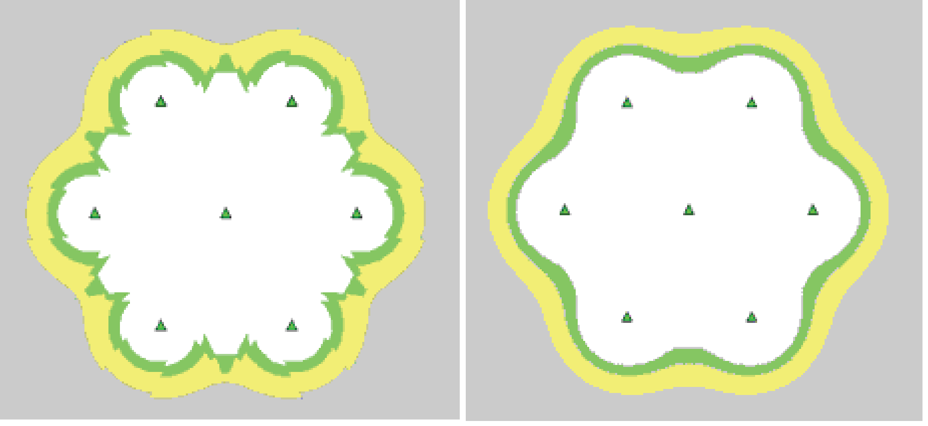
### 4.2.1 Use of higher FFT modes

The choice of a higher FFT mode with an accordingly larger symbol length includes an additional SFN coverage improvement which results from the fact that SFN self-interference, resulting from time delays beyond the guard interval, scales with the symbol length. Whereas the effect of a larger guard interval is discussed in **§ 4.1** the effect of a larger symbol length is discussed in this section. However, it has to be noted that is latter effect is secondary, less important than the former one. The effect is described in more detail in [EDP089].

Signals with time delays beyond the guard interval contribute destructively, with increasing weight for increasing time delays. This deleterious effect scales with the symbol length. As an example, a hexagon network with the corresponding coverage area for an 8k and a 32k FFT was investigated. The network parameters are given in **Table 4.1**. **Figure 4.3** compares the coverage areas of the two scenarios and **Figure 4.4** shows the difference in coverage.

**Table 4.1: Network parameters**

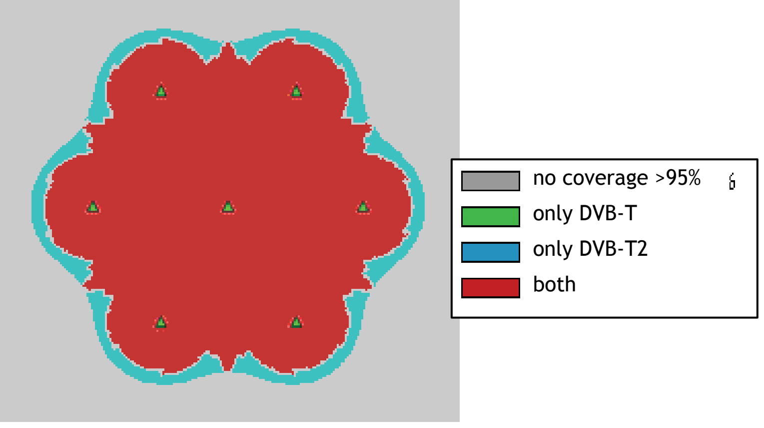
| | |
|---|---|
| Transmitters | 7, hexagon |
| $T_x$ distance | 50 km |
| Antenna height | 150 m, nd |
| $T_x$ power | 100 kW |
| DVB-T2 variant | 16-QAM 5/6 |
| 8k FFT GI | 1/4 (224 µs) |
| 32k FFT GI | 1/16 (224 µs) |
| C/N | ~ 16.4 dB |
| Reception mode | portable outdoor |



8k FFT 32k FFT

**Figure 4.3: Comparison of the coverage areas for the 8k and the 32k FFT mode**

**Figure 4.4:**
**Difference in coverage**




It can be seen that the difference is effective at the fringe of the coverage area and the increase of the symbol length may help to fill some coverage deficiencies caused by self-interference. However, the effect is not suited to heal larger coverage gaps due to self-interference. Moreover, in order to benefit from the effect it is to be ensured that receivers behave approximately in the theoretical manner. It is well known that in the past many receivers had abrupt cliff-edge behaviour at or very close to the edge of the guard interval.

### 4.2.2 DVB-T2 equalisation interval, EI

The handling of echoes outside the guard interval for DVB-T2 should in principle be determined in the same way as in the case of DVB-T. However, for DVB-T2 the length and position of EI the interval during which signals can be correctly equalized, must first be calculated as it is pilot pattern dependant. In DVB-T the pilot pattern was fixed which, for a given FFT size, also fixes the length of the EI.

Neglecting other interference sources, the equivalent total available C/(N+I) [dB] in a given location can be determined by the formula below. To aid understanding the formula is illustrated in **Figure 4.5**.

$$w_i = \begin{cases} 0 & \text{if} \quad t \notin EI \\ \left(\dfrac{T_u + t}{T_u}\right)^2 & \text{if} \quad t \in EI \,\&\, t < 0 \\ 1 & \text{if} \quad t \in EI \,\&\, 0 \le t \le T_g \\ \left(\dfrac{(T_u + T_g) - t}{T_u}\right)^2 & \text{if} \quad t \in EI \,\&\, t > T_g \end{cases}$$

$$C = \sum_i w_i C_i$$
$$I = \sum_i (1 - w_i) C_i$$

where:

$C_i$ is the power contribution from the i[th] signal at the receiver input

$C$ is the total power of the effective useful signal

$I$ is the total effective interfering power

$w_i$ is the weighting coefficient for the i[th] component

$T_u$ is the useful symbol length

$T_g$ is the guard interval length

$t$ is the signal arrival time relative to the beginning of the FFT window

EI is the equalisation **interval** during which signals can be correctly equalised and therefore usefully contribute

$T_P$ is the length of the equalisation interval EI

It should be noted that EI is an interval and not a value and can be considered to be an "equalisation window". The length of EI (which is $T_p$) is dependent upon the pilot pattern, but the positioning of this interval/window is chosen by the receiver. As long as the time between the first and the last received paths is less than $T_p$ correct equalisation is in principle possible. When this condition is not fulfilled the interference effect is accounted for by the equations above (zero $w_i$ term for certain paths).

For a given length of the EI the optimum positioning of the EI depends on the impulse response of the channel. In some cases the Equalisation Interval may start at t=0, but in other cases it may be better for it to start before or after t=0. In the general case the EI does *not* therefore have to be symmetric with respect to the FFT window, as shown in Figure 4.5 where the point $t = -t_a$ shows the starting point of the EI. Further information about the positioning of EI can be found in the DVB-T2 implementation guideline.

The receiver can operate satisfactorily in a given location when the aggregate available C/(N+I) is larger or equal to the required C/N.

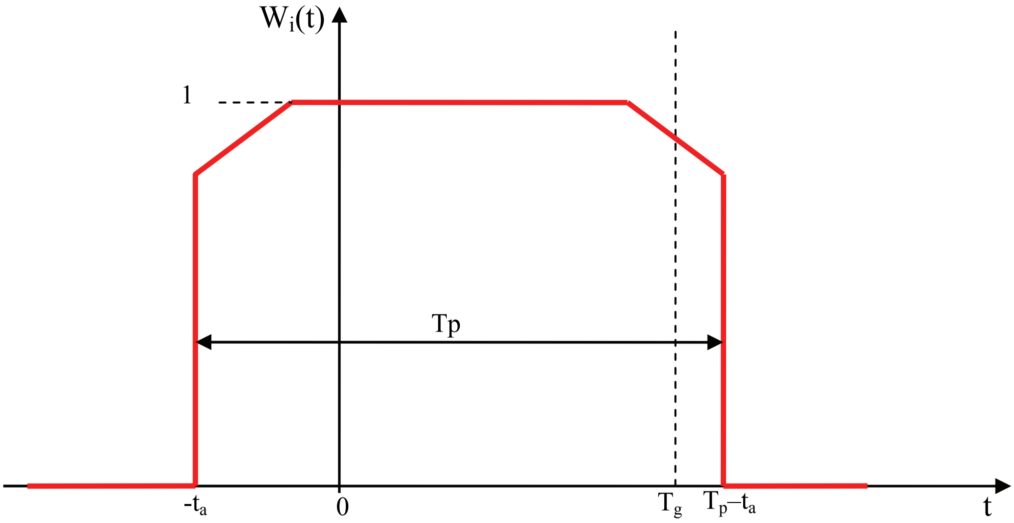



**Figure 4.5: Weighting function $w_i(t)$ (with an equalization interval EI starting at t = $-t_a$)**

DVB-T2 receivers can equalise the channel by performing a 2-dimensional interpolation (time/frequency). This interpolation may either be fixed, independently of the particular channel or be adapted to the particular characteristics of the channel. In practice all receivers support combined time/frequency interpolation. Receivers with adaptive interpolation may use frequency-only interpolation in cases where there is a need for better Doppler performance and where the echoes are short enough in relation to the used FFT size and pilot pattern. For fixed reception, where Doppler performance is normally not a problem, combined time/frequency interpolation is normally used.

Combined time and frequency interpolation allows for the use of transmission modes with less dense pilot patterns, and therefore a greater payload.

**Table 4.2: Nyquist limits for t-only and t-and-f-interpolation [from TS 102 831]**

| Pilot Pattern | $D_X$ (Separation of pilot-bearing carriers) | $D_Y$ (No. of symbols forming one Scattered Pilot sequence) | Nyquist limit as fraction of $T_U$, for *f*-only interpolation | Nyquist limit as fraction of $T_U$, for *t*- and *f*-interpolation |
|---|---|---|---|---|
| **PP1** | 3 | 4 | 1/12 | 1/3 |
| **PP2** | 6 | 2 | 1/12 | 1/6 |
| **PP3** | 6 | 4 | 1/24 | 1/6 |
| **PP4** | 12 | 2 | 1/24 | 1/12 |
| **PP5** | 12 | 4 | 1/48 | 1/12 |
| **PP6** | 24 | 2 | 1/48 | 1/24 |
| **PP7** | 24 | 4 | 1/96 | 1/24 |
| **PP8** | 6 | 16 | 1/96 | 1/6 |

In order to determine $T_p$ the Nyquist limit must first be determined. **Table 4.2** shows the Nyquist limit as a fraction of $T_u$, the useful symbol length, for the different DVB-T2 pilot patterns. $T_u$ is provided for frequency only interpolation as well as combined time and frequency interpolation.

More detailed information regarding the Nyquist limit for the available combinations of guard intervals and scattered pilot patterns is provided in **Annex A3**.

For network planning purposes it can be assumed that a DVB-T2 receiver is able to correctly equalize the signal for echoes up to 57/64 (= 89.1%) of the Nyquist time for the scattered pilots (after time interpolation) for a particular FFT size, pilot pattern and RF bandwidth. Note that the factor of 57/64 depends only upon the pilot pattern and not the guard interval.

$T_p$ can then be calculated but the real positioning of this "equalization window" depends on the actual distribution of the received signals which arrive along different paths. **Table 4.3** contains examples for some DVB-T2 modes based upon using both time and frequency interpolation.

*Note: For UHF 5 (in **Table 4.3** below) with the combination 32k FFT size, pilot pattern PP7 and 1/128 GI-fraction, the receiver cannot be assumed to perform the combined time/frequency interpolation since it would require more memory in the receivers. Since the guard interval is very short for this mode, frequency-only interpolation will work well.*

**Table 4.3: Calculation of interval of correct equalization for some DVB-T2 modes**

| MODE | UHF 1 (Medium area SFN-Rooftop) | UHF 2 (Large area SFN-Rooftop) | UHF3 (Medium area SFN-Rooftop) | UHF 4 (Large area SFN-Portable) | UHF 5 (MFN rooftop, using SFN fill in) |
|---|---|---|---|---|---|
| **Modulation** | 256-QAM | 256-QAM | 256-QAM | 16-QAM | 256-QAM |
| **FFT size** | 32k | 32k | 32k | 16k | 32k |
| **Code rate** | 2/3 | 3/4 | 3/5 | 1/2 | 3/5 |
| **Pilot Pattern** | PP4 | PP2 | PP4 | PP3 | PP7 |
| **Guard interval fraction** | 1/16 | 1/8 | 19/256 | 1/8 | 1/128 |
| **$T_g$ (µs)** | 224 | 448 | 266 | 224 | 28 |
| **$T_u$ (µs)** | 3584 | 3584 | 3584 | 1792 | 3584 |
| **Nyquist limit as fraction of $T_u$** | 1/12 | 1/6 | 1/12 | 1/6 | 1/96 |
| **Nyquist limit (µs)** | 299 | 597 | 299 | 299 | 37 |
| **Equalisation factor** | 57/64 | 57/64 | 57/64 | 57/64 | 57/64 |
| **$T_p$ time (µs)** | **266** | **532** | **266** | **266** | **33** |

It can be seen from the above that $T_p$ is the same as, or slightly larger than the guard interval length $T_g$. This means that the degradation beyond the guard interval will be graceful from the end of the guard interval up the end of the interval EI. This also applies for pre-echoes as long as the pre-echo lies within the interval EI.

For planning purposes it is recommended to assume the use of combined time and frequency interpolation as this is the predominant mode of operation. If, however, the pilot pattern is matched to the echo lengths that are expected in the network, i.e. a high density pilot pattern used in a network primarily designed as an MFN or with only limited area SFNs, frequency-only interpolation could also be possible. Frequency-only interpolation could be of interest for portable and mobile reception where Doppler performance is more critical.

## 4.3 MISO (Multiple Input Single Output)

### 4.3.1 General considerations

The DVB-T2 standard introduces the ability to implement Multiple Input Single Output, or MISO networks, a network configuration not available in DVB-T. A general MISO network configuration is shown in **Figure 4.6**. Referring to the diagram it can be seen that one of the main points of difference between a MISO and a standard broadcasting network is that the MISO network transmits two slightly different versions of the wanted signal from a number of different transmitters at the same time. Usually, though not necessarily, the transmitters are geographically separated from each other as this is generally the most beneficial configuration. By transmitting multiple wanted signals, the network is able to incorporate the advantages of transmit diversity in order to improve the system's SNR and subsequently the network's coverage or data rate.

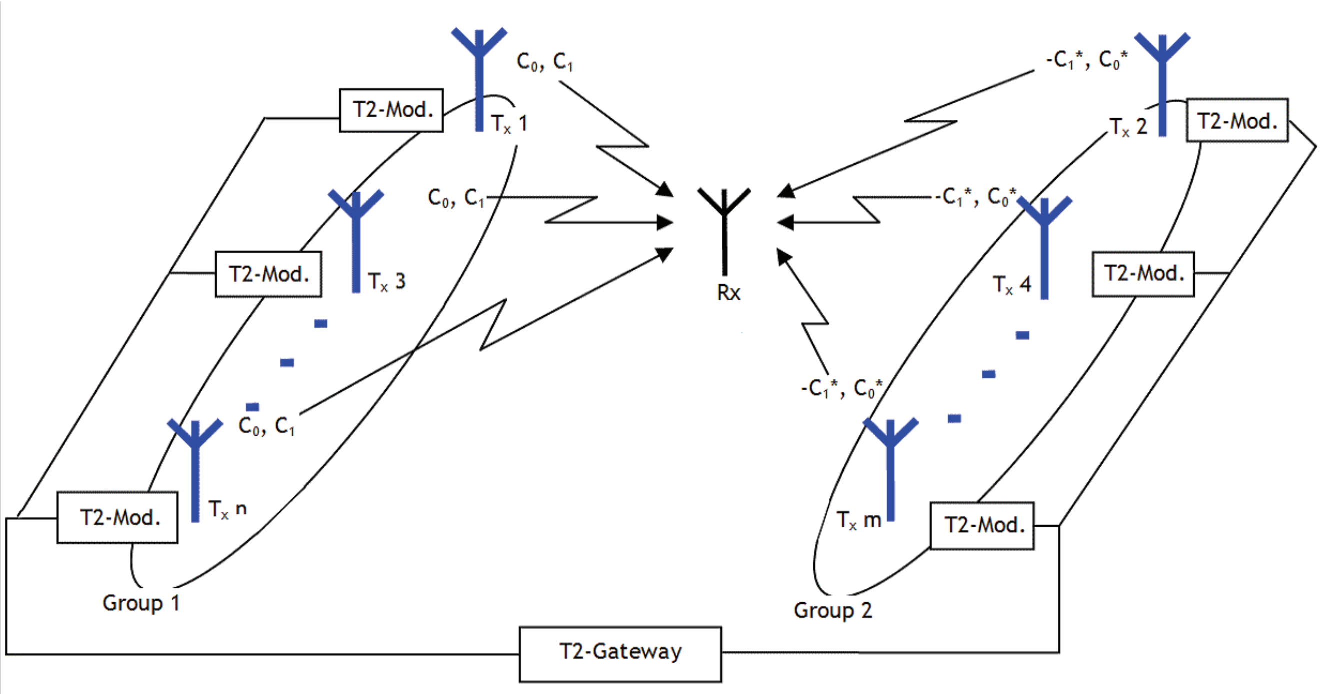



**Figure 4.6: A general DVB-T2 MISO network**

A DVB-T2 MISO network should be viewed as a particular form of an SFN, as the multiple transmissions require synchronization and timing in much the same way as a 'standard' SFN.

The DVB-T2 standard is based on a modified form of Alamouti's scheme, one of a number of different possibilities. One of the main benefits of this particular scheme is that it can be implemented in a relatively straightforward manner that requires little additional complexity at both the transmit and receive sides of the network. Using only a *single* receive antenna the Alamouti scheme allows improvements in the received SNR equivalent to that obtained from a receive diversity system incorporating *two* receive antennas and a maximal ratio combining scheme It also ensures that the ripples and notches that can form in a standard, two station, SFN channel, which subsequently degrade the system's SNR, do not occur in a MISO network as the two transmitted signals are no longer identical so destructive signal combination is essentially avoided. In a Gaussian channel, a 3 dB improvement in SNR could be achieved compared with the same network utilizing a 'standard' SFN. Slightly greater gains are possible in locations of similar receive levels. Although it is not without its tradeoffs, Alamouti coding can improve coverage, allow a greater data rate or more efficient spectrum usage, or a combination of these outcomes.

The basic operation of the Alamouti based MISO network can be understood by referring to **Figure 4.6**. Each of the network's multiple transmitters is assigned to one of two groups where each transmitter can be thought to transmit payload cells in pairs. Transmitters in group 1 transmit an un-modified version of every constellation, just as they would in a 'standard' SFN - neither buffering nor negation or complex conjugation is applied. The first pair of cells is shown as $C_0$ and $C_1$ in the diagram. Transmitters in group 2 however, transmit a slightly modified version of each constellation pair, and in reverse frequency order[1]. Group 2 transmits $-C_1^*$ and $C_0^*$ where $^*$ denotes the complex conjugation operation.

The receiver then recovers the components from the combined signals in a relatively straightforward manner that requires little additional complexity compared with a standard, non-MISO receiver.

The diagram also shows two pieces of equipment that are required in order for the network to operate correctly: the T2-Gateway and the DVB-T2 modulator. The T2-Gateway produces a T2-MI (T2-Modulator Interface) stream that contains all the information required to describe both the content and emission timing of T2-frames. The T2-MI stream is fed to the T2 modulators which apply the desired delays and the Alamouti coding.

As the diagram shows, all transmitters in the MISO network are locked to the same clock reference so the signals can be appropriately synchronized and delayed in a manner similar to a 'standard' SFN. Usually a GPS is used for this purpose.

It is also worth noting that the diagram shows an unlimited number of transmitters per group. Although that is possible, it is not likely to occur in practice where two or three transmitters per group would be more common.

## 4.3.2 Transmission Parameter Considerations

It should be noted that the DVB-T2 specification limits the maximum guard interval fraction (GIF) to 1/8. Subsequently, geographical SFN sizes could be limited. Furthermore, the scattered-pilot pattern chosen for a given FFT size and guard interval generally needs to be twice as dense because only half of the pilots are used for each of the sum and difference channel estimates – a factor that reduces capacity.

Both of the above factors should be considered when determining the suitability of a MISO network to a particular application.

## 4.3.3 Planning Applications and Considerations

In general, MISO should be considered for networks designed with a GIF up to 1/8 where capacity is not the limiting factor. In situations such as these where a 'standard' SFN might have been previously utilised, a MISO network may be more beneficial.

Moreover, the Alamouti coding is most beneficial when signals of equal magnitude from the two different transmitter groups are combined. Consideration should therefore be given to maximising signal overlaps between the two groups as that would yield the largest gains. Conversely the scheme would be of limited benefit in networks with little overlap, particularly given the increased overhead.

Portable and mobile networks would typically be most likely to benefit from the scheme as they

[1] For example, if $C_0$ is transmitted on carrier n for transmitters in group one, then $C_1$ would be transmitted on carrier n+1. Simultaneously, the transmitters in group two would transmit $-C_1^*$ on carrier n and $C_0^*$ on carrier n+1. The Alamouti coding is carried out in the frequency direction rather than the time direction.

generally contain more omnidirectional reception antennas, which would increase the likelihood of similar strength signals overlapping. Furthermore, for these types of network and for mobile networks in particular, their transmitter network tend to be denser and the transmitters often have lower powers, which would likely increase overlaps further.

Perhaps the situation that a MISO network would most suit is one in which an area such as a large town is broadly served by two main transmitters which have overlapping signals. In this case one transmitter could be assigned to each transmitter group. The maximum potential of MISO might then be realized.

Fixed reception networks with relatively highly directional antennas may not be well suited to a MISO network unless the transmit antennas were located relatively close together so they fell roughly within the beam-width of a majority of the receive antennas. On the other hand, it may be possible to provide improvement to localised areas in such networks, particularly if the transmitters fell within the beam-width of the receive antennas.

Since there are only two possible “variants” of the transmitted signal when MISO is applied, it may in practice be difficult to arrange the transmitter in two groups in order to maximize the MISO gain in large area SFNs. However for example in a network with one central main transmitter surrounded by several small SFN-fill-in transmitters, it may be possible to take advantage of the MISO gain more efficiently. The overlap between the fill-in sites would then be small and coverage overlap would exist between the main transmitter and the fill-in sites. The main transmitter would then be assigned to one transmitter group and the fill-in sites to the other transmitter group.

Moreover, there is a restriction with regard to the choice of the guard interval. **Table 4.4** shows the possible combinations of guard interval and scattered pilot pattern in MISO mode.

**Table 4.4: Possible combinations of guard interval and scattered pilot pattern**

| FFT size | Guard interval | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1/128 | 1/32 | 1/16 | 19/256 | 1/8 | 19/128 | 1/4 |
| 32k | PP8<br>PP4<br>PP6 | PP8<br>PP4 | PP2<br>PP8 | PP2<br>PP8 | NA | NA | NA |
| 16k | PP8<br>PP4<br>PP5 | PP8<br>PP4<br>PP5 | PP3<br>PP8 | PP3<br>PP8 | PP1<br>PP8 | PP1<br>PP8 | NA |
| 8k | PP8<br>PP4<br>PP5 | PP8<br>PP4<br>PP5 | PP3<br>PP8 | PP3<br>PP8 | PP1<br>PP8 | PP1<br>PP8 | NA |
| 4k, 2k | NA | PP4<br>PP5 | PP3 | NA | PP1 | NA | NA |
| 1k | NA | NA | PP3 | NA | PP1 | NA | NA |

In MISO mode, guard interval 1/4 is not possible. Therefore, in large SFNs, MISO seems to be feasible only if FFT modes higher than 8k are applied.

### 4.3.4 Qualitative description of the MISO gain

As shown in the section above the MISO gain depends on the level difference. **Figure 4.7** shows the qualitative effect of the level difference.

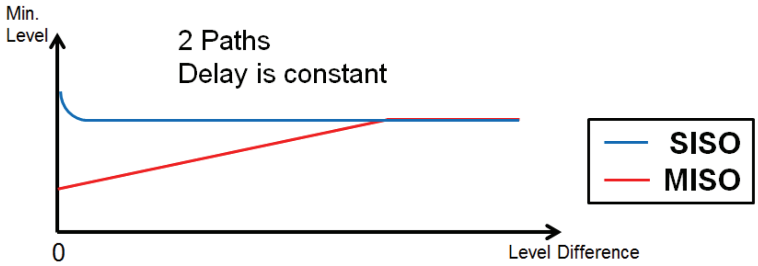



**Figure 4.7: MISO gain as a function of level difference (MISO gain = difference of min. required levels)**

Furthermore, the performance of MISO is also a function of the delay time. The channel estimation and/or correction is performed on pairs of cells, basically two adjacent sub-carriers. This means that MISO will work best if these adjacent sub-carriers are faded very similarly. This is the case for short delays. Long delays fade adjacent sub-carriers differently. Therefore an error is introduced that decreases the MISO effect. It might even occur at very large echoes that the MISO effect becomes a negative gain. The exact function needs to be verified by measurements. **Figure 4.8** illustrates the qualitative effect of increasing delay.

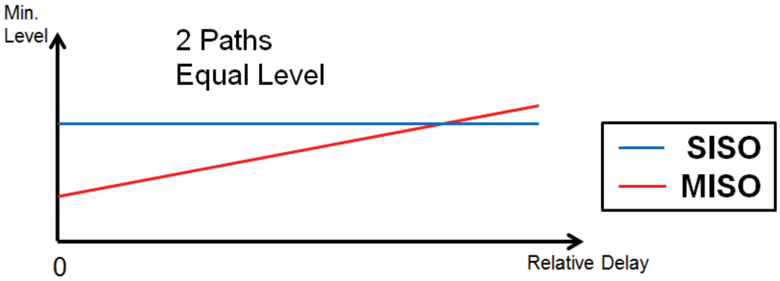



**Figure 4.8: MISO gain as a function of relative delay (MISO gain = difference of min. required levels)**

Unfortunately, the implementation guideline [TS 102 831] does not yet give results of MISO simulations; but at least test scenarios are formulated, so that more reliable results can be expected soon.

### 4.3.5 Example of MISO coverage gain

In this example a coverage scenario with two transmitters is chosen [Ro2009]. The DVB-T2 parameters are 64-QAM, 8k, LDPC-code rate 3/4. **Figure 4.9** shows the predicted coverage gain for distributed MISO, expressed in terms of gain of aggregated wanted field strength.

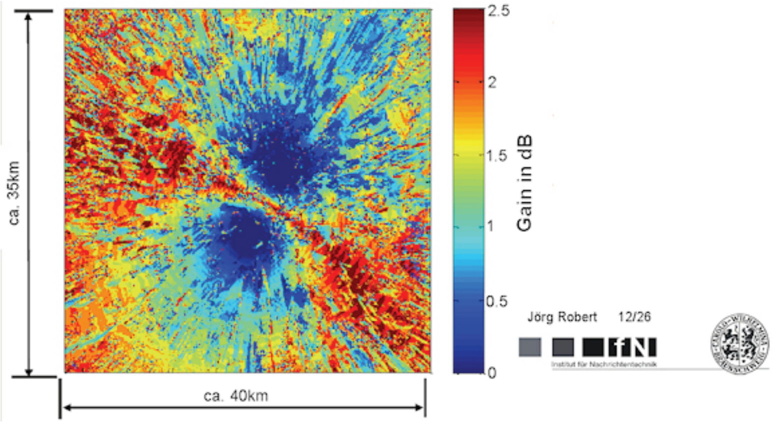



**Figure 4.9: Predicted coverage gain with MISO**

**from [Ro2009])**

Additional gain is achieved outside the core coverage areas of the two transmitters. With regard to acceptable indoor reception the coverage gain amounts to 30% in this simulation.

The above simulation is based on the assumption that MISO gain applies equally to all delay times between the signals from the two transmitters and that the only difference in MISO gain arises from the difference of the signal strengths. However, this assumption is still to be verified since considerations on multipath statistics also suggest that the effect may be restricted to linear dimensions of c/B, where c is the speed of light and B the bandwidth under consideration, which for a bandwidth of 8 MHz would result to several hundred meters and would thus reduce the relevant area of MISO gain remarkably – at least as far as the improvement with regard to flat fading is concerned.

## 4.4 Time-Frequency Slicing (TFS)

### 4.4.1 TFS in the DVB-T2 standard

Time-frequency slicing (TFS) is fully specified in the DVB-T2 standard, but has a less formal status. It is not a part of the "single profile" but is referred to as "for future implementations" in an informative annex. Full support for TFS could also be found in "surrounding" specifications such as "T2 delivery system descriptor" (Service Information) and the "T2 Modulator Interface specification (T2-MI)".

### 4.4.2 The TFS concept

With TFS many statistically multiplexed services are transmitted over more than one RF channel; up to six may be used. Each service "jumps around" among the available frequencies.

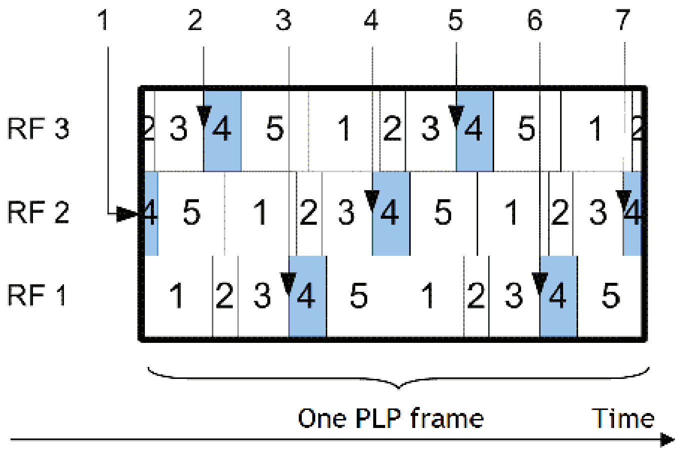



**Figure 4.10: Example, TFS over three frequencies**

In Figure **4.10** each Physical Layer Pipe (PLP) is spread out over all (here 3) RF channels and over time. Each PLP is interleaved within the Physical Layer (PL) frame resulting in much improved time and frequency diversity.

With TFS it is possible to statistically multiplex over a significantly larger statistical multiplex pool than for a single multiplex. For example, in the case of six RF channels operating at 33 Mbit/s, 198 Mbit/s would be available compared with 33 Mbit/s available in a single RF channel. Statistical multiplexing with a pool of this size is almost ideal.

### 4.4.3 TFS gains

TFS allows for two independent gains

*Statistical multiplexing gain*

Large TS bit rate allows statmuxing of “many” services

Allows more services to be transmitted

Allows more stable video quality

*Network planning gain*

Improved frequency diversity when each service is spread over several RF channels

Improved link budget for “reception of all services”

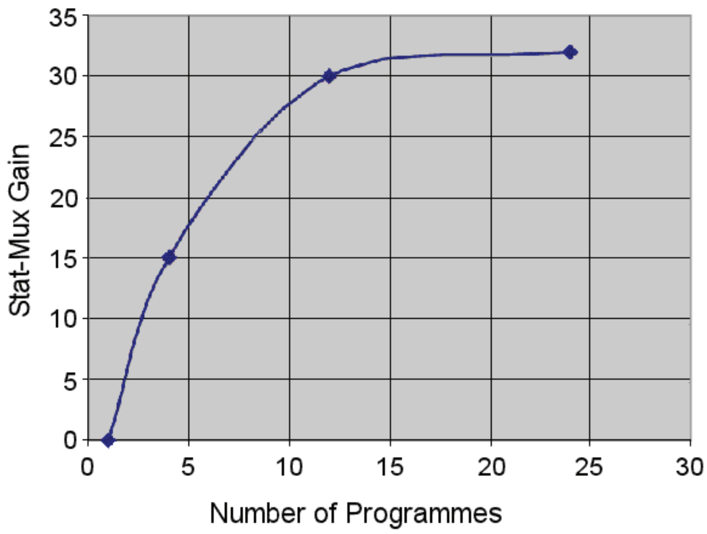
The improved link budget could allow for lower network costs and/or increased data rate

A coherent reception of all services (PLPs with identical parameters)

Improved robustness against time-varying channels and interference

#### *Statistical multiplexing gain*

It is a bit difficult to precisely estimate statmux gain. However, the gain can be presented as percentage reduction of required bit rate or percentage increase in number of services. But one has to be careful in how the gain Figure is defined; a 50% reduction in required bit rate implies a 100% gain in number of services, see **Figure 4.11**.




- 0% for 1 HD programme
- 15% for 3-4 HD programmes
- 30% for 9-12 HD programmes
- 32% for 18-24 HD programmes

Source: Thomson

**Figure 4.11: Statistical multiplex gain with MPEG-4 AVC**

The stat-mux gain could also be expressed as a virtual increase of bit rate and compared with statistical multiplexing within one RF channel (non-TFS):

3 RF channels: Virtual increase of bit rate = 21%

6 RF channels: Virtual increase of bit rate = 25%

Another feature is a more equal picture quality and the possibility of fine-tuning the bit rate per service.

#### *Network planning gain*

Without TFS the coverage of a set of multiplexes at a given location is limited by the multiplex with the lowest signal strength. With TFS the reception at a particular location is more likely to be determined by the average signal strength of the RF channels involved in TFS.

There are several components of the TFS network planning gain:

- TFS coverage gain
- TFS interference gain
- Improved robustness

### 4.4.4 TFS coverage gain

For a given equal ERP on multiple RF frequencies the received signal level, especially for fixed reception, varies significantly due to:

- Frequency-dependent transmitter antenna diagram
- Frequency-dependent terrain shielding (systematic)
- Frequency dependent local variation (random)
- Frequency-dependent receiving antenna efficiency and gain (systematic and implementation dependent)

For each location the TFS coverage gain could be expressed as the difference between the average signal strength and the minimum signal strength calculated over all RF frequencies at that particular location.

*TFS coverage gain = P(average) – P(minimum) [dB]*

### 4.4.5 TFS interference gain

TFS improves the robustness against static and time varying interference from other transmitters, since interference level varies with frequency. For example, one frequency could be completely lost due to temporary interference.

### 4.4.6 Improved robustness

TFS improves the robustness against channel time variations (similar to $R_X$ diversity), especially important for portable/mobile reception.

### 4.4.7 Calculation of potential TFS coverage gain - example

The potential TFS coverage gain could be calculated based on field strength measurements for a certain transmitter which transmits on more than one RF channel (multiplex).

In this example the field measurements were performed for:

- Six transmitter sites (non SFN) with four multiplexes (frequencies) per site
- Equal ERP on all four frequencies
- About 40000 measurements at a height of 3 m per measuring site
- Constant $R_X$ antenna gain

The measured TFS gain distribution is based on the received signal strength on each frequency. In **Figure 4.12** the measured distribution of TFS gain for six stations A - F is shown.

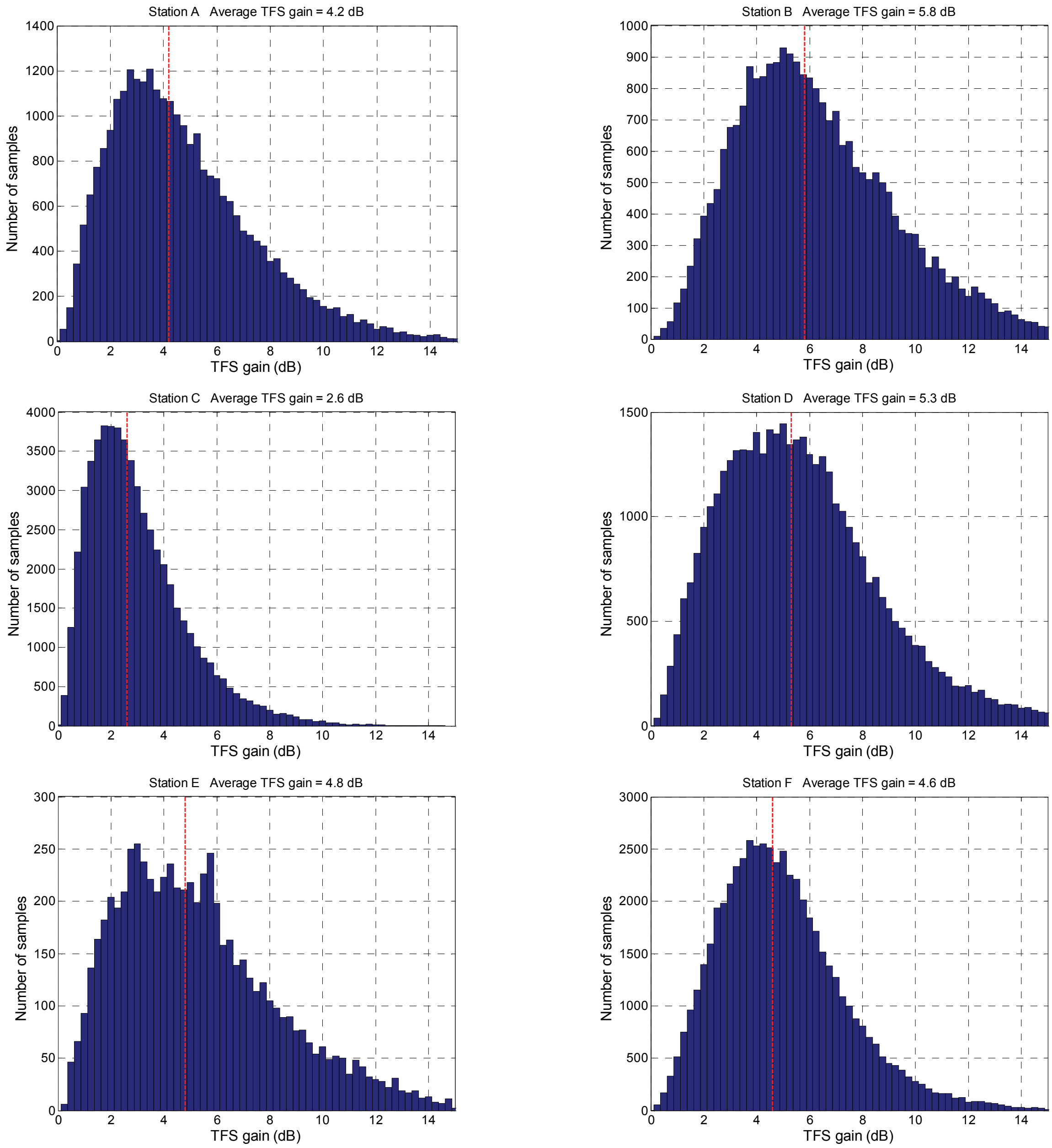



**Figure 4.12: Measured distribution of TFS gain**

The measurements are performed at 3 m with an omnidirectional antenna. A summary is given in **Table 4.5**.

**Table 4.5: Summary of measurement results at 3 m**

| Station | Average TFS signal gain | Number of measurements samples | Number of multiplexes | Channel number difference |
|---|---|---|---|---|
| A | 4.2 | 27,000 | 4 | 16 |
| B | 5.8 | 30,000 | 4 | 34 |
| C | 2.6 | 58,000 | 4 | 15 |
| D | 5.3 | 41,000 | 4 | 32 |
| E | 4.8 | 6,000 | 4 | 24 |
| F | 4.6 | 56,000 | 4 | 26 |

The average TFS gain over all six areas is 4.5 dB.

### 4.4.8 Coherent Coverage Effects

For the case that each PLP has the same parameters the coverage of all PLPs will be very similar if not identical.

A further aspect is the "common coverage shrinking". TFS uses several RF channels at a time. If one RF channel fails (transmitter failure) the coverage will then shrink but not completely vanish. Only the outer part of the coverage is affected in that case. The more RF channels that are combined, the less is the loss of coverage when one channel fails.

## *4.5 Time Slicing*

The DVB-T2 specification allows for time slicing, which is a well-known DVB-H feature. Time slicing reduces the energy consumption of the receiving device. This is achieved by transmitting the services of a multiplex in time blocks which allows the receiver to demodulate the signal only for a certain fraction of time in order to receive a particular service. For the rest of the time the receiver may remain idle, it may use the remaining time for the check of other frequency blocks or channels.

## *4.6 Physical Layer Pipes*

### 4.6.1 Input streams and Physical Layer Pipes

The commercial requirement for service-specific robustness together with the need for different stream types is met by the concept of fully transparent **Physical Layer Pipes (PLPs)**. Both the allocated capacity and the robustness can be adjusted to the content/service providers' particular needs, depending on the type of receiver and the receiving conditions to be addressed.

The DVB-T2 specification allows a constellation, code rate and time-interleaving depth to be assigned individually to each single PLP. A high level T2 block diagram is shown in **Figure 4.13**.

Input streams are MPEG-2 Transport Streams (TS) or so called Generic Streams which could carry MPEG-2 or MPEG-4 video content. Each input stream is carried by a corresponding PLP in DVB-T2. A maximum of 255 input streams/PLPs could be transmitted with, typically, one service per TS/PLP.

A given MPEG-2 TS operates at constant bit rate (CBR) but it can contain payload with a variable bit rate (VBR) and "null packets" to make up the difference. TS packets which are null packets are, however, never transmitted. They are extracted before transmission and reinserted in the right places into the TS in the receiver; hence there is no null packet overhead in the transmission (transparent TS through the DVB-T2 system).

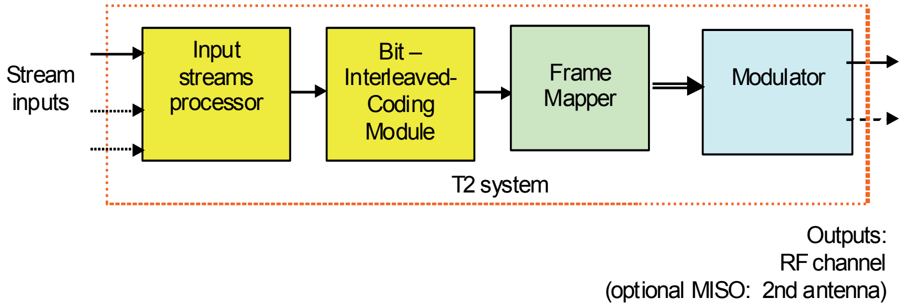



**Figure 4.13: High level T2 block diagram**

### 4.6.2 Single and multiple PLPs

There are two general input modes defined. Input mode A uses a single PLP, whilst input mode B uses multiple PLPs.

#### *Input Mode A*

This most simple mode can be viewed as a straightforward extension of DVB-T. Here the DVB-T2 signal uses only one single PLP transmitted over one frequency containing one MPEG-2 TS. Consequently the same robustness is applicable to all content, as in DVB-T.

#### *Input Mode B*

This more advanced mode of operation applies the concept of multiple PLPs (**Figure 4.14**). In Mode B, one service is typically transmitted per PLP but a group of services (each with low bit rate) could also share one PLP.

Advantages with multiple PLPs

- Service-specific robustness (combination of modulation & code rate)
- Longer time-interleaving depth
- Allows for power saving in the receiver via time slicing as in DVB-H
- Allows for frequency diversity via Time-Frequency Slicing (TFS)

Therefore even in the case of identical physical parameter settings, it might be useful to apply this mode, especially if portable and/or mobile devices are to be targeted.

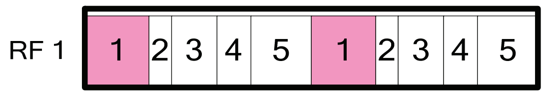



**Figure 4.14**: T2 frame for single RF channel, multiple PLP mode (here, 5 PLPs)

Typically a group of services will share common elements such as PSI/SI tables, like EPG information, or CA information. To avoid the need to duplicate this information for each PLP, Mode B offers the concept of common PLPs, shared by a group of PLPs. Hence, receivers need to decode up to two PLPs at the same time when receiving a single service: the data PLP and the common PLP.

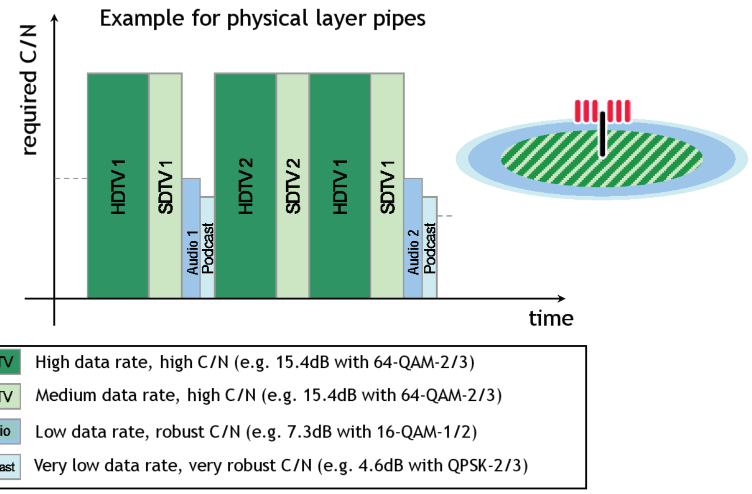



**Figure 4.15:**

**Example of a DVB-T2 multiplex using PLP and carrying services with different data rates and different coverage radii**

An example is given in **Figure 4.15** where four different classes of services (HDTV, SDTV, Audio Broadcasting and Data Broadcasting) are carried in one multiplex. Each of the services has a different data rate and a different coverage radius indicated in the Figure on the right hand side.

Additional advantages with multiple PLPs are:

- Different types of receivers and different reception cases could be addressed by the same signal, for example HDTV to fixed rooftop aerials and mobile receivers simultaneously, with a certain capacity and robustness for each category.
- One could prioritize the robustness for one or many services in one multiplex ➔ prioritized services “last longer”.
- When one service in a multiplex does not need to have the same coverage as the other, that service could be transmitted with lower robustness saving transmission capacity.
- Simplifies the change to local/regional content (with constant bit rate) in a multiplex in which the rest of the content is centrally statistically multiplexed. The use of one dedicated PLP for local/regional content could result in an easier/cheaper implementation.
- When one wish to further increase the capacity and coverage by using the Time-Frequency Slicing (TFS) concept.

One limitation with the use of PLPs is that it is not possible to have PLPs with different FFT sizes in the same multiplex. This could for example be a limitation when there is the need to provide rooftop reception for HD services and a mobile service in the same multiplex, using a large area SFN.

In order not to lose capacity there may then be a need to use the 32k FFT mode for the HD services. With the long symbol time it is possible to use a lower guard interval fraction, thus maximizing capacity. However if the 32k mode is used it will mean that the frequency distance between the OFDM carriers is short, which will make the mobile service sensitive to Doppler shift at higher speeds.

This limitation might be overcome by using the future extension frame (FEF), see **section 4.8**.

## *4.7 Peak-to-Average Power Ratio (PAPR) reduction techniques*

OFDM systems set high requirements on the linearity of the transmitter amplifiers. This fact reduces the power efficiency of OFDM systems remarkably. DVB-T2 offers two techniques for the reduction of the peak-to-average power ratio (PAPR), thus increasing the RF power-amplifier efficiency. These techniques are Active Constellation Extension (ACE) and Tone Reservation (TR).

The following short description of these two techniques is taken from the Implementation Guideline [TR 102 831]. A more detailed description can be found in § 9.3.8 of the Implementation Guideline.

The Active Constellation Extension (ACE) algorithm searches for the peaks in the OFDM signal and analyses the constellations to find out which data cells already contribute negatively to that peak. To intensify the effect of these cells their amplitude is increased, which is done by shifting the constellation points further out.

The basic idea of Tone Reservation is that some carriers are reserved to reduce PAPR. These reserved carriers do not carry any data information and are instead filled with a peak-reduction signal. Because data and reserved carriers are allocated in disjointed subsets of subcarriers, Tone Reservation needs no side information at the receiver other than an indication that the technique is in use, carried in the L1-pre signalling field "PAPR".

It is possible to use both ACE and TR simultaneously; however, depending on the constellation, picking the better technique based on the constellation will provide most of the benefit. Both techniques come at a cost: ACE increases the noise level that the receiver sees while TR decreases throughput.

It should be noted that ACE cannot be applied when the rotated constellation mode (see **§ 2.6**) is chosen.

## *4.8 Future Extension Frames (FEF)*

DVB-T2 allows for the introduction of additional, as yet undefined or specified features by means of so-called Future Extension Frames (FEF). The Implementation Guideline [TR 102 831] describes this feature as follows:

Future Extension Frame (FEF) insertion enables carriage of frames defined in a future extension of the DVB-T2 standard in the same multiplex as regular T2-frames. The use of future extension frames is optional. A future extension frame may carry data in a way unknown to a DVB-T2 receiver addressing the current standard version. A receiver addressing the current standard version is not expected to decode future extension frames. All receivers are expected to detect FEF parts but ignore them for demodulation.

The only currently defined attributes of FEF parts, which are inserted between T2-frames (see **Figure 4.16**), are that they begin with a P1 symbol and their positions in the superframe and duration in time are signalled in the L1 signalling in the T2-frames. This enables early receivers to ignore the FEFs whilst still receiving the T2 signal, as desired.

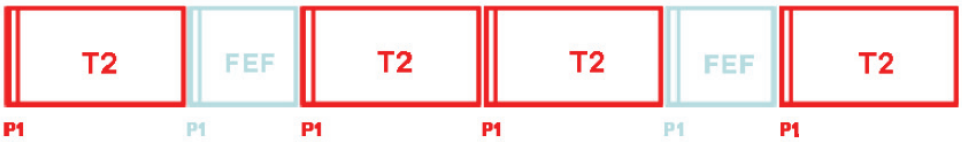



**Figure 4.16: Co-existence of T2 Frames and Future Extension Frames (from [TR 102 831])**

Future Extension Frames can be used for Transmitter Signatures [A150]. They allow measurements to identify which echo (path) in the channel impulse response originates from which transmitter of the SFN. It is also possible to display the parts of the channel impulse response originating from individual transmitters of the SFN.

Future Extension Frames could also be used, for example, for:

- Handheld services with MIMO support
- Upstream for a DVB-T2 return channel
- Data transport of mobile service providers which use the same spectrum but have a different network structure

More details on FEF can be found in [TR 102 831, § 8.4].

# 5. Implementation Scenarios

## *5.1 Introduction*

DVB-T2 offers a significantly wider choice of parameters (which is described in **§ 2)** than did DVB-T. The choice is so large that it is not possible to consider all of their possible combinations. This section considers a number of common applications of DVB-T2 and discusses some possible parameter sets which may be suitable for each of the scenarios.

Firstly, a number of scenarios appropriate to fixed roof-level reception are described. They comprise an MFN as well as an SFN approach and also reflect the need for a transition from DVB-T to DVB-T2, which is likely to be a common requirement.

Secondly, five scenarios particularly suited to portable and mobile DTT reception are described. All five scenarios are based on an SFN approach and include relatively large guard intervals to minimise intra-SFN interference and to allow greater transmitter separation. The 32k FFT mode is not applied for the same reason, since it is expected that this mode is particularly vulnerable to Doppler degradation and may be unsuitable for mobile and portable networks.

Parameters, C/N Figures and data rates for DVB-T2 are based on the information given in the ETSI specification and Implementation Guideline [TS 102 831, EN 302 755]. In **§ 2.5** the inclusion of implementation margins in the C/N values is described.

In scenarios 1 and 4 the parameters of a corresponding DVB-T mode are also given for comparison. The C/N values are taken from the respective ETSI specification [EN 300 744], including an implementation margin of 3 dB.

## *5.2 Scenario 1: MFN rooftop reception and a transition case*

A number of countries will wish to move from an established DVB-T network to one using DVB-T2. This scenario provides an example of how that transition might take place while incorporating some common practical considerations.

Although DVB-T2 may make it possible to improve or optimize the coverage of an existing network, in many cases the existing network's coverage would be considered sufficient and it would therefore be desirable to keep the coverage constant while increasing its capacity as that would allow new services can be introduced. In such situations it would be desirable to re-use existing infrastructure such as the transmission stations, transmitters, combiners and antenna systems. The example below would allow this type of transition with a minimum of changes - essentially the only requirement being the upgrade of modulators. The transmission side of the network, otherwise unchanged, would maintain essentially constant coverage.[2]

For comparison, two sets of parameters are provided, one for the DVB-T network and another for the DVB-T2. Importantly, both sets of parameters result in a similar C/N, meaning that if the transmit antennas and powers of the DVB-T network are maintained for DVB-T2, the network's coverage would essentially remain unchanged. Both sets of parameters also exhibit the same guard interval duration despite the guard interval fraction being substantially reduced for the DVB-T2 case. Again, if the transmit antennas and radiated powers remained constant in both networks, the SFN timings of the DVB-T network would translate directly to the DVB-T2 network with little change in coverage.

[2] Changes to the distribution network and other similar details have not been considered.

| DVB-T Parameters | | DVB-T2 Parameters | |
|---|---|---|---|
| Bandwidth: | 8 MHz | Bandwidth: | 8 MHz |
| FFT size: | 2k | FFT size: | 32k |
| Carrier mode: | N/A | Carrier mode: | extended |
| Scattered Pilot Pattern: | N/A | Scattered Pilot Pattern: | PP7 |
| Guard interval: | 1/32 (7 µs) | Guard interval: | 1/128 (28 µs) |
| Modulation: | 64-QAM | Modulation: | 256-QAM |
| Code rate: | 2/3 | Code rate: | 2/3 |
| C/N (Rice): | 20.1 dB | C/N (Rice): | 18.9 dB |
| **Resulting data rate:** | **~ 24.1 Mbit/s** | **Resulting data rate:** | **~ 40.2 Mbit/s** |

## *5.3 Scenario 2: SFN rooftop reception, maximum coverage*

This scenario is intended to maximize coverage in an SFN while providing rooftop reception. In this case it is necessary to use a relatively robust DVB-T2 mode. Several possible lengths of the guard interval may be possible depending on the network structure to be used; transmitter distance, radiated powers and terrain. Because of the relatively high robustness of the mode, it may be possible to reduce the guard interval to 1/16 (224 µs) for very large SFNs – a change that would increase capacity.

| | |
|---|---|
| Bandwidth: | 8 MHz |
| FFT size: | 32k |
| Carrier mode: | extended |
| Scattered Pilot Pattern: | PP4 |
| Guard interval: | 1/8 (448 µs) |
| Modulation: | 16-QAM |
| Code rate: | 2/3 |
| C/N (Rice): | 10.6 dB |
| **Resulting data rate:** | **~ 18.3 Mbit/s** |

## *5.4 Scenario 3: SFN rooftop reception, moderate coverage*

Generally two different choices of DVB-T2 parameter sets can be identified:

- Where DVB-T2 is to replace an existing DVB-T SFN serving a moderately sized area, say up to a diameter of 100 km. This also seems to be a typically sized allotment area in the GE06 plan.
- Where there is a need to create a large area DVB-T2 SFN of “unlimited” size. In this case it would have been difficult to use DVB-T because of SFN self-interference.

Due to limited results from DVB-T2 field trials it may be too early to make a clear choice of code rate for the SFN case. There are two main candidates; code rates 3/5 and 2/3. The scenarios presented here are based upon the use of the 2/3 code rate, which gives higher capacity.

In these scenarios it is suggested that the 32k FFT size be used. It should be pointed out that 32k is mainly aimed at fixed rooftop reception due to its sensitivity to Doppler. It remains to be confirmed that the 32k modes are also suitable for portable indoor reception. This means that in cases where it is necessary to provide both rooftop *and* indoor reception the16k modes may be more appropriate. This would result in the use of a higher GI fraction, and hence reduced capacity, to achieve the required guard interval duration.

### 5.4.1 Scenario 3a: Rooftop reception for limited area SFN

The selection of the guard interval in this scenario would be the same as the longest existing DVB-T mode (224 µs), using 8k FFT. However in this case DVB-T2 will allow use of a lower GI fraction (1/16) in order to maximize the capacity, due to the availability of 32k FFT. The use of the "new" GI fraction 19/256 (266 µs) could also be an option in some cases in order to improve the situation where there is SFN self-interference when using 1/16.

It should be pointed out that for the rooftop reception case, SFN self-interference effects may not be as large as in the mobile or portable cases where omnidirectional receiving antennas are used. This can possibly allow for a further reduction of the GI-fraction to, for example, 1/32 (112 µs) in some cases.

For large area SFNs it is in principle also possible to use the 19/128 (532 µs) GI-fraction but preliminary results show that a GI of 448 µs is sufficient in order to avoid self-interference in "infinitely" large SFNs.

| | |
|---|---|
| Bandwidth: | 8 MHz |
| FFT size: | 32k |
| Carrier mode: | extended |
| Scattered Pilot Pattern: | PP4 |
| Guard interval: | 1/16 (224 µs) |
| Modulation: | 256-QAM |
| Code rate: | 2/3 |
| C/N (Rice): | 19.6 dB |
| **Resulting data rate:** | **~ 37 Mbit/s** |

### 5.4.2 Scenario 3b: Rooftop reception for large area SFNs

This parameter set would be used in cases where it is possible to create a large area SFN, for "nationwide coverage". The GI fraction needs to be higher compared to the previous case in order to avoid SFN self interference.

| | |
|---|---|
| Bandwidth: | 8 MHz |
| FFT size: | 32k |
| Carrier mode: | extended |
| Scattered Pilot Pattern: | PP2 |
| Guard interval: | 1/8 (448 µs) |
| Modulation: | 256-QAM |
| Code rate: | 2/3 |
| C/N (Rice): | 20.0 dB |
| **Resulting data rate:** | **~ 35 Mbit/s** |

## *5.5 Scenario 4: Portable reception (maximum data rate)*

Scenario 4 describes a parameter set for portable reception. The parameters are adapted to the present DTT implementations based on DVB-T in Germany. They are designed for portable reception and are based on an SFN approach. The 16k mode is chosen with a guard interval length of 224 µs. This allows for SFNs with a diameter of up to about 150 km.

| DVB-T Parameters | | DVB-T2 Parameters | |
|---|---|---|---|
| Bandwidth: | 8 MHz | Bandwidth: | 8 MHz |
| FFT mode: | 8k | FFT mode: | 16k |
| Carrier mode: | N/A | Carrier mode: | extended |
| Scattered Pilot Pattern: | N/A | Scattered Pilot Pattern: | PP3 |
| Guard interval: | 1/4 (224 µs) | Guard interval: | 1/8 (224 µs) |
| Modulation: | 16-QAM | Modulation: | 64-QAM |
| Code rate: | 2/3 | Code rate: | 2/3 |
| C/N (Rayleigh): | 17.2 dB | C/N (Rayleigh): | 17.1 dB |
| **Resulting data rate:** | **~ 13.3 Mbit/s** | **Resulting data rate:** | **~ 26.2 Mbit/s** |

Since the corresponding DVB-T implementation (8k, 16-QAM-2/3, GI 1/4) allows for a data rate of 13.3 Mbit/s this DVB-T2 scenario roughly provides twice the data rate.

If it turns out that even the 32k mode were appropriate for portable reception, the following parameter set would be possible:

| | |
|---|---|
| Bandwidth: | 8 MHz |
| FFT mode: | 32k |
| Carrier mode: | extended |
| Scattered Pilot Pattern: | PP3 |
| Guard interval: | 1/16 (224 µs) |
| Modulation: | 64-QAM |
| Code rate: | 2/3 |
| C/N (Rayleigh): | 17.1 dB |
| **Resulting data rate:** | **~ 27.7 Mbit/s** |

However, the viability of the 32k mode for portable reception is still to be proven in field trials.

## *5.6 Scenario 5: Portable reception (maximum coverage area extension)*

On the other hand, DVB-T2 may be used to extend an existing (DVB-T) coverage while keeping the (DVB-T) data rate. This can be achieved by applying a more rugged DVB-T2 system variant. An example scenario may be:

| | |
|---|---|
| Bandwidth: | 8 MHz |
| FFT mode: | 16k |
| Carrier mode: | extended |
| Scattered Pilot Pattern: | PP3 |
| Guard interval: | 1/8 (224 µs) |
| Modulation: | 16-QAM |
| Code rate: | 1/2 |
| C/N (rRayleigh): | 9.0 dB |
| **Resulting data rate:** | **~ 13.1 Mbit/s** |

As compared to the corresponding DVB-T implementation, a gain of about 7 – 8 dB is achieved. This may suffice to supply large parts of an area with portable reception where previously only fixed reception was possible, or to supply portable indoor reception where previously only portable outdoor reception was possible.

## 5.7 Scenario 6: Portable reception (optimal spectrum usage)

This scenario aims at an optimal spectrum usage in the sense that DTT service areas with the same MUX content are covered by one (possibly very large) SFN. For this purpose a very large guard interval has to be chosen. This approach is best suited for national service areas; however, it has to be kept in mind that the present GE06 plan does not provide such large allotment areas. Thus, additional coordination is necessary to realise this scenario.

| | |
|---|---|
| Bandwidth: | 8 MHz |
| FFT mode: | 16k |
| Carrier mode: | extended |
| Scattered Pilot Pattern: | PP3 |
| Guard interval: | 1/4 (448 µs) |
| Modulation: | 64-QAM |
| Code rate: | 2/3 |
| C/N (Rayleigh): | 17.1 dB |
| **Resulting data rate:** | **~ 23.6 Mbit/s** |

As compared to scenario 4 the higher expected spectrum efficiency is paid for by a smaller data rate of about 2.6 Mbit/s.

## 5.8 Scenario 7: Mobile reception (1.7 MHz bandwidth in Band III)

DVB-T2 additionally provides an operation mode with 1.7 MHz bandwidth. This allows for an implementation compliant with the DAB frequency block structure of the GE06 Plan. In this way also audio and mobile TV (with low bit rate) services may be supported.

In the presented scenario a 4k mode is chosen which allows for a relatively high data rate. But as already encountered in a previous scenario the viability of an FFT mode with such a small carrier separation is still to be proven in field trials.

| | |
|---|---|
| Bandwidth: | 1.7 MHz |
| FFT mode: | 4k |
| Carrier mode: | normal |
| Scattered Pilot Pattern: | PP2 |
| Guard interval: | 1/8 (278 µs) |
| Modulation: | 16-QAM |
| Code rate: | 1/2 |
| C/N (Rayleigh): | 9.4 dB |
| **Resulting data rate:** | **~ 2.5 Mbit/s** |

A similar guard interval length to that of T-DAB is chosen in this scenario. Nonetheless it can be expected that the SFN performance is worse for DVB-T2 since the degradation characteristics of DVB-T2 are more critical than those of T-DAB. Therefore, it might be necessary to choose a larger guard interval for the DVB-T2 scenario in order to allow for large SFN areas. A possible scenario for this could be:

| | |
|---|---|
| Bandwidth: | 1.7 MHz |
| FFT mode: | 4k |
| Carrier mode: | normal |
| Scattered Pilot Pattern: | PP2 |
| Guard interval: | 1/4 (555 μs) |
| Modulation: | 16-QAM |
| Code rate: | 1/2 |
| C/N (Rayleigh): | 9.4 dB |
| **Resulting data rate:** | **~ 2.2 Mbit/s** |

In the end, simulations and field trials are required to assess the appropriate guard interval for this scenario.

## *5.9 Scenario 8: Portable and mobile reception (common MUX usage by different services) – Multiple PLP*

This scenario describes a joint usage of a DVB-T2 multiplex by different services (high/low data rate, rugged/less rugged, etc.). A typical example could be audio/mobile TV on one hand and SD/HD TV on the other hand. This is possible in DVB-T2 because of its high flexibility with regard to the separate choice of modulation, code rate or time interleaving for each service. Restrictions have to be observed regarding the choice of the FFT mode and the Scattered Pilot Pattern. These are common to all services and have therefore to be chosen appropriately.

| | |
|---|---|
| Bandwidth: | 8 MHz |
| FFT mode: | 8k |
| Carrier mode: | Extended |
| Scattered Pilot Pattern: | PP2 |
| Guard interval: | 1/4 (224 μs) |

High data rate service (TV)

| | |
|---|---|
| Modulation: | 64-QAM |
| Code rate: | 2/3 |
| C/N (Rayleigh): | 17.5 dB |
| **maximum data rate:** | **~22.4 Mbit/s** (100% high data rate, 0% low data rate service) |

Low data rate service (Audio / Mobile TV)

| | |
|---|---|
| Modulation: | 16-QAM |
| Code rate: | 1/2 |
| C/N (Rayleigh): | 9.4 dB |
| **maximum data rate:** | **~11.2 Mbit/s** (0% high data rate, 100% low data rate service) |

A possible partitioning of the MUX could be:

**1.5 Mbit/s** for the low data rate service (13% of the MUX capacity)

**19.4 Mbit/s** for the high data rate service (87% of the MUX capacity)

## *5.10 Overview of scenarios*

**Tables 5.1** and **5.2** give an overview of the scenarios.

**Table 5.1: Overview of the Rooftop Implementation Scenarios**

| **Implementation**<br>Scenario | **Fixed rooftop reception MFN (UK mode)**<br>1 | **Fixed rooftop reception (maximum coverage area extension)**<br>2 | **Fixed rooftop reception Limited area SFN (GE06 Allotment)**<br>3a | **Fixed rooftop reception Large area SFN**<br>3b |
|---|---|---|---|---|
| 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 | PP4 | PP4 | PP2 |
| Guard interval | 1/128 (28 µs) | 1/8 (448 µs) | 1/16 (224 µs) | 1/8 (448 µs) |
| Modulation | 256-QAM | 16-QAM | 256-QAM | 256-QAM |
| Code rate | 2/3 | 2/3 | 2/3 | 2/3 |
| C/N | 18.9 dB | 10.6 dB | 19.6 dB | 20.0 dB |
| Data rate | 40.2 Mbit/s | 18.3 Mbit/s | 37 Mbit/s | 35.5 Mbit/s |

**Table 5.2: Overview of the Portable and Mobile Implementation Scenarios**

| **Implemen-tation**<br><br>**Scenario** | **portable reception (maximum date rate)**<br><br>4a | **portable reception (maximum date rate, alternative)**<br><br>4b | **portable reception (maximum coverage area extension)**<br><br>5 | **portable reception (optimum spectrum usage)**<br><br>6 | **mobile reception Band III**<br><br>7a | **mobile reception Band III (alternative)**<br><br>7b | **portable and mobile reception (common usage of MUX by different services)**<br><br>8 | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | high data rate | low data rate |
| **Bandwidth** | 8 MHz | 8 MHz | 8 MHz | 8 MHz | 1.7 MHz | 1.7 MHz | 8 MHz | |
| **FFT mode** | 16k | 32k | 16k | 16k | 4k | 4k | 8k | |
| **Carrier mode** | Extended | Extended | Extended | Extended | Normal | Normal | Extended | |
| **Scattered Pilot Pattern** | PP3 | PP3 | PP3 | PP3 | PP2 | PP2 | PP2 | |
| **Guard interval** | 1/8 (224 µs) | 1/16 (224 µs) | 1/8 (224 µs) | 1/4 (448 µs) | 1/8 (278 µs) | 1/4 (555 µs) | 1/4 (224 µs) | |
| **Modulation** | 64-QAM | 64-QAM | 16-QAM | 64-QAM | 16-QAM | 16-QAM | 64-QAM | 16-QAM |
| **Code rate** | 2/3 | 2/3 | 1/2 | 2/3 | 1/2 | 1/2 | 2/3 | 1/2 |
| **C/N** | 17.1 dB | 17.1 dB | 9.0 dB | 17.1 dB | 9.4 dB | 9.4 dB | 17.5 dB | 9.4 dB |
| **Data rate** | 26.2 Mbit/s | 27.7 Mbit/s | 13.1 Mbit/s | 23.6 Mbit/s | 2.5 Mbit/s | 2.2 Mbit/s | 22.4 Mbit/s (max) | 11.2 Mbit/s (max) |

# 6. Transition to DVB-T2

## *6.1 DVB-T2 in GE06*

### 6.1.1 Implementing alternative broadcasting transmission systems under the GE06 Agreement

The RRC-06 adopted DVB-T and T-DAB as the two transmission systems for which the GE06 Plan was developed. Contracting Members of the GE06 Agreement adopted these two transmission systems as the only transmission systems for modifying the Plan and their Plan entries. Furthermore, the Plan modification procedures of Article 4 have been developed specifically in terms of these two transmission systems. The result is that only these two transmission systems can be used when submitting modifications to the Plan. This implies that if a Contracting Member of the GE06 Agreement wants to implement assignments using DVB-T2 or another transmission system, then such assignments must first be submitted as Plan modifications using suitable technical characteristics and either indicating T-DAB or DVB-T as the transmission system.

When the Plan entry is brought into operation the administration can notify the actual transmission system (e.g. DVB-T2, DVB-H or any other suitable system) under the Article 5 provision 5.1.3 of the agreement. Under this provision such an implementation is restricted not to cause more interference or require a higher level of protection than the original Plan entry. Additionally, the peak power density over any 4 kHz of such an implementation should not exceed the peak power density in the same 4 kHz of the corresponding digital broadcasting Plan entry.

### 6.1.2 Requirements for the development of the DVB-T2 specification

It was felt essential that DVB-T2 implementations should be able to use DVB-T assignments and allotments of the GE06 Plan in order to avoid re-planning activities and therefore adding complexity to the introduction of DVB-T2. The commercial requirements for the development of the DVB-T2 specification therefore include the following: *"Transmissions using the DVB-T2 specification shall meet the interference levels and spectrum mask requirements as defined by GE06 and not cause more interference than DVB-T would do."*

With respect to DVB-T as planned in the GE06 Plan, DVB-T2:

- offers the same or better protection ratios and comparable minimum median field strength values for suitable equivalent variants;
- can use the same linear (single or mixed) polarisation of the digital broadcasting Plan entry;
- can realise the same service areas using the same or lower radiated power levels;
- maintains the same or lower peak power densities for variants operating in the same bandwidth and having the same or higher number of OFDM carriers (FFT size) for the same levels of radiated power.

### 6.1.3 Implementation of DVB-T2 in the GE06 Plan

DVB-T2 offers sufficient flexibility in terms of the number of suitable equivalent variants that would maintain the same service area and would permit the operation of an assignment(s) within the limitations of Provision 5.1.3 of the GE06 Agreement and a corresponding digital broadcasting Plan entry. Additionally, in order to ensure that a DVB-T2 implementation respects the radiated power limitations outside the operating bandwidth, the DVB-T2 implementation will have to conform with the spectrum mask of the corresponding GE06 Plan entry as given in the GE06 Agreement in Figure 3-2 and Table 3-10 (of the Agreement text) for T-DAB Plan entries and

Figure 3-3 and Table 3-11 for DVB-T Plan entries. Furthermore, the technical characteristics of the DVB-T2 implementation should be such, that it would receive a favourable finding when examining it under Section II of Annex 4 to the GE06 Agreement, along with Rule of Procedure Part A10/GE06 5.1.3, decisions 1 to 3 for conformity with respect to the corresponding Plan entry. DVB-T2 implementations that are in conformity with the relevant digital Plan entry and that have received a favourable finding will be recorded in the MIFR.

There remains a certain ambiguity with respect to the implementation of certain DVB-T2 variants and/or modes, for example, extended carrier mode and additional bandwidths. ITU-R Rec. BT.1877 [BT1877] indicates that the 7 MHz and 8 MHz channel variants of DVB-T2 are compatible with the GE06 Plan for digital television broadcasting and the 1.7 MHz channel variant is compatible with T-DAB frequency planning. However, the DVB-T2 7 MHz extended carrier modes are not compatible with a DVB-T 7 MHz Plan entry if the required occupied bandwidth is compared with the GE06 DVB-T spectrum mask for 7 MHz. Similarly, the variants with a 1k FFT for 7 and 8 MHz channels would be affected in a similar manner if the relevant filter GE06 DVB-T mask is applied. DVB-T2 variants for 5 and 6 MHz channel arrangements may also be considered for the implementation of a GE06 Plan entry if suitable filtering is applied, however variants for these channel arrangements do not yet have defined spectrum shaping limits in the ETSI specification [EN 302 755] or in ITU-R Rec. BT.1877 [BT1877].

Based on these considerations, DVB-T2 variants which are directly compatible with GE06 are listed in **Tables 6.1** to **6.3** (noting that the other abovementioned restrictions would need to be observed as well):

**Table 6.1: DVB-T2 variants directly compatible with 7 MHz channel arrangements**

| Modulation | FFT size | Code rate* | Guard interval |
|---|---|---|---|
| QPSK or 16-QAM or 64-QAM or 256-QAM | 2k | 1/2, 3/5, 2/3, 3/4, 4/5, 5/6 | 1/32, 1/16, 1/8, 1/4 |
| | 4k | 1/2, 3/5, 2/3, 3/4, 4/5, 5/6 | 1/32, 1/16, 1/8, 1/4 |
| | 8k | 1/2, 3/5, 2/3, 3/4, 4/5, 5/6 | 1/128, 1/32, 1/16, 19/256, 1/8, 19/128, 1/4 |
| | 16k | 1/2, 3/5, 2/3, 3/4, 4/5, 5/6 | 1/128, 1/32, 1/16, 19/256, 1/8, 19/128, 1/4 |
| | 32k | 1/2, 3/5, 2/3, 3/4, 4/5, 5/6 | 1/128, 1/32, 1/16, 19/256, 1/8, 19/128 |
| * For block sizes of 16,200 and 64,800 bits | | | |

**Table 6.2: DVB-T2 variants directly compatible with 8 MHz channel arrangements**

| Modulation | FFT size | Code rate* | Guard interval |
|---|---|---|---|
| QPSK or 16-QAM or 64-QAM or 256-QAM | 2k | 1/2, 3/5, 2/3, 3/4, 4/5, 5/6 | 1/32, 1/16, 1/8, 1/4 |
| | 4k | 1/2, 3/5, 2/3, 3/4, 4/5, 5/6 | 1/32, 1/16, 1/8, 1/4 |
| | 8k | 1/2, 3/5, 2/3, 3/4, 4/5, 5/6 | 1/128, 1/32, 1/16, 19/256, 1/8, 19/128, 1/4 |
| | 16k | 1/2, 3/5, 2/3, 3/4, 4/5, 5/6 | 1/128, 1/32, 1/16, 19/256, 1/8, 19/128, 1/4 |
| | 32k | 1/2, 3/5, 2/3, 3/4, 4/5, 5/6 | 1/128, 1/32, 1/16, 19/256, 1/8, 19/128 |
| | 8k extended | 1/2, 3/5, 2/3, 3/4, 4/5, 5/6 | 1/128, 1/32, 1/16, 19/256, 1/8, 19/128, 1/4 |
| | 16k extended | 1/2, 3/5, 2/3, 3/4, 4/5, 5/6 | 1/128, 1/32, 1/16, 19/256, 1/8, 19/128, 1/4 |
| | 32k extended | 1/2, 3/5, 2/3, 3/4, 4/5, 5/6 | 1/128, 1/32, 1/16, 19/256, 1/8, 19/128 |
| * For block sizes of 16,200 and 64,800 bits | | | |

**Table 6.3: DVB-T2 variants directly compatible with 1.7 MHz channel arrangements**

| Modulation | FFT size | Code rate* | Guard interval |
|---|---|---|---|
| QPSK or 16-QAM or 64-QAM or 256-QAM | 1k | 1/2, 3/5, 2/3, 3/4, 4/5, 5/6 | 1/16, 1/8, 1/4 |
| | 2k | 1/2, 3/5, 2/3, 3/4, 4/5, 5/6 | 1/32, 1/16, 1/8, 1/4 |
| | 4k | 1/2, 3/5, 2/3, 3/4, 4/5, 5/6 | 1/32, 1/16, 1/8, 1/4 |
| | 8k | 1/2, 3/5, 2/3, 3/4, 4/5, 5/6 | 1/128, 1/32, 1/16, 19/256, 1/8, 19/128, 1/4 |
| * For block sizes of 16,200 and 64,800 bits | | | |

It is however important to note that if suitable filtering is applied, all DVB-T2 variant RF signals can be made compatible with the corresponding spectrum mask of the GE06 Agreement. In a similar manner filtering is also applied on a baseband and/or RF level in the case of DVB-T transmissions. No spectrum mask has been defined for DVB-T2 (in contrast to DVB-T) in ITU-R Rec. BT.1877 [BT1877] or in the ETSI specification [EN 302 755], since, as stated in **§ 6.1.2**, it is assumed that DVB-T2 transmissions will need to fulfil the same spectrum mask as has been defined for DVB-T. The spectral characteristics of the transmitted signal are a function of the natural OFDM signal, additional digital filtering, transmitter non-linearity and analogue RF-filtering. It is therefore possible to use a DVB-T2 mode which has a natural spectrum that is “incompatible” with the GE06 spectrum mask as long as the additional steps of the processing chain before emission ensure that the transmitted spectrum does indeed fulfil the GE06 spectrum mask.

Thus, in terms of their interference potential, all DVB-T2 1.7 MHz, 7 MHz and 8 MHz system variants (including all FFT sizes as well as normal or extended bandwidth, where applicable) could be used as long as the GE06 spectrum masks and other GE06 constraints are fulfilled for the transmitted signal. It should be noted that there may exist unconventional but commercially relevant cases where, for example, an 8 MHz signal could be transmitted in a 7 MHz Plan entry, but with additional filtering to ensure that the transmitted signal conforms to the GE06 spectrum mask.

These operational aspects are not however part of a formal Plan modification or notification procedure in the GE06 Agreement and such filtering will result in changing the technical characteristics of the DVB-T2 implementation (e.g. C/N ratios, protection ratios and required minimum median field strength values) from that of the standard specific DVB-T2 variant that has been filtered only to its necessary occupied bandwidth. This renders such implementations difficult to apply by administrations when they are recorded in the MIFR and their required level of protection is to be established in the case that harmful interference could occur to these implementations, where these assignments can only claim protection to the level afforded by the corresponding Plan entry.

## *6.2 Transition scenarios*

### 6.2.1 Introduction

When moving from analogue to digital transmissions broadcasters have gained experience with the transition from one system to another. Some of the lessons learned were:

- the higher the percentage of viewers that depend on the terrestrial platform as compared to other platforms, the more difficult and lengthy is the transition period;
- for a certain period, a parallel operation of the old and the new technique is required;
- a certain amount of additional spectrum is needed for this, to accomplish the transition to new and more efficient techniques;
- an incentive in terms of additional programmes, higher service quality, etc. is required for viewers to accept the transition to new techniques because it may imply an upgrade of the user equipment, which they will have to pay for.

Some of these aspects are addressed further in this section as far as general considerations on the transition to DVB-T2 are concerned. Aspects particular to individual countries are described in **Annex 4**.

### 6.2.2 Infrastructure

For DVB-T2 the existing infrastructure (from analogue TV or DVB-T) which is related to antennas, masts, amplifiers, repeaters (although not re-transmitters which re-generate the signal), etc. at the transmitting side can be used. On the receiver side existing antenna infrastructure can be re-used. This is valid if no change in the channel arrangement is made.

Since DVB-T2 is not downward compatible with DVB-T new tuners, i.e., new TV sets or at least additional set-top boxes are required at the receiving side. Accordingly, modulators, gateways in the case of SFNs, upgrade of the contribution network, monitoring equipment and possibly filters are required at the transmitting side. In addition, the operation modus of relays which are fed off-air may have to be changed with the migration to DVB-T2.

Most probably, also MPEG-4 source coding will then be used, although this aspect does not affect the RF transmission/reception side.

### 6.2.3 Frequency planning issues

The commercial requirements for DVB-T2 foresee compatibility with the GE06 Plan as a matter of principle. Therefore it is possible to use the existing GE06 Plan assignments and/or allotments for the implementation of DVB-T2. The preceding **§ 6.1** showed that there certain constraints have to be taken into account.

From a frequency planning point of view, for the transition to DVB-T2, it is therefore the easiest way to use the existing GE06 Plan structure. No additional frequency re-planning is required in this case, neither on national nor on international level. It implies that the same characteristics with regard to transmitter power, antenna position and diagram, etc. are used. A gain in data capacity and/or coverage quality is achieved. Similarly, for an allotment implementation the characteristics of the allotment plan entry regarding its interference potential should be kept while achieving a gain in data capacity and/or coverage quality.

But DVB-T2 would, in principle, also allow for a more radical approach with regard to frequency and network planning resulting in even higher spectrum efficiency. For DVB-T it is well known that the size of SFN is restricted because of self-interference effects. This restriction is reduced with DVB-T2 because of the larger guard intervals coming along with higher FFT modes. In a similar manner, existing coverage concepts (with regard to data capacity and reception mode) could be realised with less transmitter sites and/or frequency assignments.

But such approaches would imply a major re-arrangement of the existing frequency plan which is best achieved by a new planning conference. At present, such a general re-design of the existing frequency plan is not regarded as feasible. However, some improvements may be achieved by national or bilateral re-arrangements. An example for the latter is the aggregation of several national co-channel allotments to one large allotment in order to increase the coverage area which becomes technically possible with the new DVB-T2 variants; although then some multiplex capacity is lost.

### 6.2.4 Transition from Analogue TV to DVB-T2

For countries that have not yet started their transition to DTT, it seems logical that they should immediately introduce DVB-T2. Since DVB-T2 has already started as a regular service in some countries it can be expected that DVB-T2 equipment will soon be available on a mass market.

It is expected that a simulcast period similar to that required for the transition from analogue TV to DVB-T will be needed for this transition. The length of the simulcast period will largely depend on the relevance of the terrestrial platform as compared to other platforms. The higher the terrestrial penetration the more care that needs to be taken with the transition, and in general, the more time it will take.

For the simulcast period, additional spectrum is required for the parallel transmission of TV services. The required amount of spectrum will heavily depend on the introduction strategy adopted for DVB-T2. For example in Spain, with a high percentage of the population using the terrestrial platform as their main means of reception, additional available spectrum was used for the simulcast period.

A short simulcast period will reduce additional costs, where possible a region-wise transition may avoid too abrupt changes across the whole country. This approach was taken by Germany with the introduction of DTT, based on the fact that the percentage of the terrestrial platform was relatively small.

The simulcast situation is eased with a transition from analogue to DVB-T2 as this technology can accommodate more individual programmes in a multiplex and so a smaller number of multiplexes is required. This will alleviate the cost of the simulcast period and the difficulty of finding spectrum for the simulcast.

### 6.2.5 Transition from DVB-T to DVB-T2

Many European countries have already introduced DVB-T and have, or are about to cease analogue transmissions. For them a migration to DVB-T2 is a possible next step in the development and implementation of broadcast delivery technologies.

DVB-T2 is not backwards compatible with DVB-T, so an abrupt migration from DVB-T to DVB-T2 is not possible. More sophisticated migration strategies are required. It is a commonly held view that this migration should be based on there being additional offers to the consumer in order to be successful. These offers may consist of additional programmes or may consist of different service types, such as HDTV.

In general therefore, for the migration period, unused and/or additional spectrum is required. This may be found in temporarily unused spectrum, available perhaps in countries where DVB-H is regarded as not being successful. Other countries may use available VHF spectrum for this purpose. A further possibility may be the more compact aggregation of DVB-T programmes in existing multiplexes (with a possible slight loss of quality) in order to free spectrum for an additional DVB-T2 multiplex. In exceptional cases the switch-off of DVB-T programmes may also be considered in order to free up spectrum for a DVB-T2 multiplex.

Some broadcasters may choose the enlarged possibilities of DVB-T2 to change or extend their coverage and/or service concept. For example, a change from a coverage which up to now mainly provides fixed reception to portable outdoor/mobile reception is possible. Also the provision of a better video quality is possible.

For countries that have already switched to DTT the issue of consumer reinvestment becomes an issue. The introduction of DVB-T, perhaps within the last ten years, was accompanied by the need for consumers to invest in new receiving equipment. Now, with the migration to DVB-T2, a new investment in receiving equipment is required by the consumers. This is a difficult situation since consumers have been used to longer renewal cycles of TV receiving equipment. The introductory strategy for DVB-T2 has to be chosen carefully in order not to lose customers to other platforms, as happened in some countries with the transition from analogue TV to DVB-T.

A special situation arises in countries that have started but not completed the process of digital switch-over from analogue TV to DVB-T and that also start to introduce DVB-T2. This situation is not that uncommon. Countries where the terrestrial platform is used by a large percentage of the population as the primary means of reception will necessarily have a long transition period and they are now faced with the challenge of an additional migration. Special considerations have then to be applied. A particular case is described in detail in **Annex 4** for the UK.

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# Annex 1: Planning methods, criteria and parameter

## A1.1 Reception modes

### A1.1.1 Fixed antenna reception

Fixed antenna reception is defined as:

Reception where a directional receiving antenna mounted at roof-level is used. In calculating the equivalent field strength required for fixed antenna reception, a receiving antenna height of 10 m above ground level is considered to be representative.

### A1.1.2 Portable antenna reception

In the context of this document, portable reception is defined as the reception at rest (stationary reception) or at very low speed (walking speed). Portable reception will, in practice, take place under a great variety of conditions (outdoor, indoor, ground floor and upper floors). In this document, portable reception is comprised of two classes:

- **Class A: portable outdoor reception**
  - with external (for example telescopic or wired headsets) or integrated antenna
  - at no less than 1.5 m above ground level, at very low speed or at rest
- **Class B: portable indoor reception**
  - with external (for example telescopic or wired headsets) or integrated antenna
  - at no less than 1.5 m above ground level, at very low speed or at rest
  - on the ground floor in a room with a window in an external wall.

It is assumed that the portable receiver is not moved during reception and that large objects near the receiver are also not moved. This does not mean that the transmission channel is static; rather, a slowly time-varying channel is assumed. It is also understood that extreme cases, such as reception in completely shielded rooms, be disregarded.

### A1.1.3 Mobile reception

Mobile reception is defined as the reception of a DVB-T2 signal by a receiver in motion with an antenna situated at no less than 1.5 m above ground level. The term motion covers speeds from a walking person to a car driven on a motorway. High-speed trains, buses and other vehicles could be considered in some countries.

### A1.1.4 Handheld reception

#### A1.1.4.1 Handheld portable reception

In the context of this document, handheld portable reception is defined as the reception at rest (stationary reception) or at very low speed (walking speed). Handheld portable reception will, in practice, take place under a great variety of conditions (outdoor, indoor, ground floor and upper floors). In addition, the hand held receiver will probably be moved (at walking speed) while being viewed.

The difference between portable reception and handheld portable reception lies in the different antenna gains which are assumed for the two reception modes.

In this document, handheld portable reception is comprised of two classes:

- **Class H-A: hand held portable outdoor reception**
  - with external (for example telescopic or wired headsets) or integrated antenna
  - at no less than 1.5 m above ground level, at very low speed or at rest

- **Class H-B: hand held portable indoor reception**
  - with external (for example telescopic or wired headsets) or integrated antenna
  - at no less than 1.5 m above ground level, at very low speed or at rest
  - on the ground floor in a room with a window in an external wall.

It is assumed that the handheld portable receiver is not moved during reception and that large objects near the receiver are also not moved. This does not mean that the transmission channel is static; rather, a slowly time-varying channel is assumed. It is also understood that extreme cases, such as reception in completely shielded rooms, be disregarded.

For the handheld reception mode, it is often possible to improve reception by moving the receiver position and/or by using an antenna with higher efficiency.

It is to be expected that there will be significant variation of reception conditions for indoor portable reception, also depending on the floor-level at which reception is required. There will also be considerable variation of building penetration loss from one building to another and considerable variation from one part of a room to another. Also, handheld receivers could suffer from body-absorption/reflection loss in certain circumstances, e.g. file-downloading applications when the receiver is in a pocket. It is to be expected that "portable coverage" will be mainly aimed at urban and suburban areas.

### A1.1.4.2 Handheld mobile reception

In the context of this document, handheld mobile reception is comprised of two classes:

- **Class H-C: hand held reception inside a moving vehicle (car, bus etc.)**
  - with the receiver connected to the external antenna of the vehicle.
  - at no less than 1.5 m above ground level, at higher speed.

- **Class H-D: hand held reception inside a moving vehicle (e.g. car, bus, etc.)**
  - without connexion of the receiver to the external antenna of the vehicle.
  - with external (for example telescopic or wired headsets) or integrated antenna.
  - at no less than 1.5 m above ground level, at higher speed.

It should be noted that body-absorption/reflection losses could also be of importance in Class H-D under certain circumstances, for example when the terminal is in a pocket and file downloading is underway. However, the present document does not consider this situation.

It is to be expected that there will be significant variation of reception conditions for handheld mobile reception, depending on the environment of the receiver. There might also be considerable variation of entry loss caused by the varying construction of cars and vehicles.

In both cases, it is assumed that the handheld mobile receiver and/or large objects near the receiver may move during the reception. It is also understood that extreme cases, such as reception in completely shielded vehicles, be disregarded.

Again, the difference between mobile reception and handheld mobile reception, Class H-C, lies in the different antenna gains which are assumed for the two reception modes.

## A1.2 Coverage definitions

It is necessary to have definitions for the coverage of a terrestrial television transmitting station or a group of such stations. Digital television service coverage is characterized by a very rapid transition from near perfect reception to no reception at all and it thus becomes critical to be able to define which areas are going to be covered and which are not. However, because of the very rapid transition described above, there is a cost penalty if the coverage target within a small area (say, 100 m x 100 m) is set too high. This occurs because it is necessary either to increase the transmitter powers or to provide a larger number of transmitters in order to guarantee coverage to the last few percent of the worst-served small areas.

For this reason, the coverage definition of “good” has been selected as the case where 95% of the locations within a small area are covered. Similarly, “acceptable” has been defined to be the case where 70% of the locations within a small area are covered.

The definitions do not aim to describe the area where coverage is achieved under worst case conditions. They provide a description of the area where "good" or "acceptable" coverage should be achieved under representative practical conditions. They may be regarded as describing the “quality” of the coverage achieved.

In defining the coverage area for each reception condition, a three-level approach is taken:

### *Receiving location*

The smallest unit is a receiving location with dimensions of about 0.5 m × 0.5 m. In the case of portable antenna reception, it is assumed that optimal receiving conditions will be found by moving the antenna or by moving the handheld terminal up to 0.5 m in any direction.

Such a location is regarded as covered if the required carrier-to-noise and carrier-to-interference values are achieved for 99% of the time.

### *Small area coverage*

The second level is a "small area" (typically 100 m × 100 m). In this small area the percentage of covered location is indicated.

The coverage of a small area is classified as:

- ‘Good’, if at least 95% of receiving locations within the area are covered for portable reception and 99% of receiving locations within it are covered for mobile reception.
- ‘Acceptable’, if at least 70% of receiving locations within the area are covered for portable reception and 90% of receiving locations within it are covered for mobile reception.

### *Coverage area*

The third level is the coverage area.

The coverage area of a transmitter, or a group of transmitters, is made up of the sum of the individual small areas in which a given class of coverage is achieved.

## A1.3 Calculation of signal levels

To calculate the minimum median power flux density or equivalent field strength needed to ensure that the minimum values of signal level can be achieved at the required percentage of locations, the following formulas are used:

| | | |
|---|---|---|
| $\phi_{min}$ | $= P_{s\ min} - A_a + L_f$ | |
| $E_{min}$ | $= \phi_{min} + 120 + 10\log_{10}(120\pi) = \phi_{min} + 145.8$ | |
| $\phi_{med}$ | $= \phi_{min} + P_{mmn} + C_l$ | (for fixed reception) |
| $\phi_{med}$ | $= \phi_{min} + P_{mmn} + C_l + L_h$ | (for portable outdoor reception, Class A, mobile reception and, handheld portable outdoor reception, Class H-A, and handheld mobile vehicular reception, Class H-C) |
| $\phi_{med}$ | $= \phi_{min} + P_{mmn} + C_l + L_h + L_b$ | (for portable indoor reception, Class B, and handheld portable indoor reception, Class H-B) |
| $\phi_{med}$ | $= \phi_{min} + P_{mmn} + C_l + L_h + L_v$ | (for handheld mobile reception, Class H-D) |
| $E_{med}$ | $= \phi_{med} + 120 + 10\log_{10}(120\pi) = \phi_{med} + 145.8$ | |

where:

| | |
|---|---|
| C/N | : RF signal to noise ratio required by the system [dB] |
| $\phi_{min}$ | : Minimum power flux density at receiving place [dBW/m$^2$] |
| $E_{min}$ | : Equivalent minimum field strength at receiving place [dBμV/m] |
| $L_f$ | : Feeder loss [dB] |
| $L_h$ | : Height loss (10 m a.g.l. to 1.5 m a.g.l.) [dB] |
| $L_b$ | : Building penetration loss [dB] |
| $L_v$ | : Vehicle entry loss [dB] |
| $P_{mmn}$ | : Allowance for man-made noise [dB] |
| $C_l$ | : Location correction factor [dB] |
| $\phi_{med}$ | : Minimum median power flux density, planning value [dBW/m$^2$] |
| $E_{med}$ | : Minimum median equivalent field strength, planning value [dBμV/m] |
| $A_a$ | : Effective antenna aperture [dBm$^2$] [$A_a = G_{iso} + 10\log_{10}(\lambda^2/4\pi)$]. $G_{iso}$ is the antenna gain relative to an isotropic antenna. |
| $P_{s\ min}$ | : Minimum receiver input power [dBW] |

For calculating the location correction factor $C_l$ a log-normal distribution of the received signal is assumed.

$C_l = \mu * \sigma$

where:

| | |
|---|---|
| $\mu$ | : distribution factor, being 0.52 for 70%, 1.28 for 90%, 1.64 for 95% and 2.33 for 99%; |
| $\sigma$ | : standard deviation taken as 5.5 dB for outdoor reception. See § A1.3.7 for $\sigma$ values appropriate for indoor reception. |

While the matters dealt with in this section are generally applicable, additional special considerations are needed in the case of SFNs where there is more than one wanted signal contribution.

### A1.3.1 Antenna gain

The antenna gains used in the derivation of the minimum median wanted signal levels in **§ 3** are given in **Table A1.1**.

For portable and mobile reception, an omnidirectional antenna is applied.

Within any frequency band, the variation of antenna gain with frequency may be taken into account by the addition of a correction term:

$$\text{Corr} = 10 \log_{10}(F_A/F_R),$$

where

$F_A$ is the actual frequency being considered;

$F_R$ is the relevant reference frequency quoted in **§ 3**.

For further detailed information concerning the antenna gain values of handheld receivers, see § 1.3.3.2 of [Tech3317].

**Table A1.1: Antenna gain in dBd for the different bands and for the different reception modes**

| | Gain (dBd) | | Reception Mode |
|---|---|---|---|
| | **Band III** | **Bands IV/V** | |
| Rooftop antenna | 7 | 11 | Fixed rooftop |
| Adapted antenna | -2.2 | 0 | Portable Class A and B<br>Mobile<br>Handheld mobile vehicular Class H-C |
| External antenna* | -13 | -5.5 | Handheld portable outdoor Cass H-A<br>Handheld portable indoor Cass H-B<br>Handheld mobile reception H-D |
| Integrated antenna | -17 | -9.5 | Handheld portable outdoor Cass H-A<br>Handheld portable indoor Cass H-B<br>Handheld mobile reception H-D |

* Telescopic or wired headsets

### A1.3.2 Feeder loss

The feeder losses used in the derivation of the minimum median wanted signal levels in **section 3** are given in **Table A1.2**:

**Table A1.2: Feeder loss in dB for the different bands.**

| | Feeder loss (dB) | | |
|---|---|---|---|
| | **Band III** | **Bands IV/V** | **Reception Mode** |
| Rooftop antenna | 2 | 4 | Fixed rooftop |

Portable, mobile and handheld receivers can be assumed to have a low feeder loss in all bands. For planning purposes, no feeder losses are to be considered for portable, mobile and handheld reception.

### A1.3.3 Man-Made Noise (MMN)

IRT measurements of man-made noise in Band III [BCP078] have shown much higher values than those assessed in the RRC-06 Report [RRC06] (8 dB instead of 2 dB in urban areas), affecting mobile reception using an adapted antenna (mobile reception and handheld mobile vehicular Class H-C). On the other hand the effect of man-made noise in the receiving environment is affected by the negative antenna gains. The full man-made noise values are only valid for antennas with a gain greater than 0 dBi (2.2 dBd). For antennas with a gain less than 0 dBi it is important to distinguish between the pure antenna gain and the efficiency of the antenna. The efficiency of the antenna reduces all received signals equally, also the man-made noise. Due to this, the relevant value for calculation purposes is reduced. In [BCP078] the treatment of man-made noise for negative isotropic antenna gains is further described.

The allowance for man-made noise for Bands IV and V is usually taken to be negligible. However, according to measurements [TR 102 377], an allowance of 1 dB is specified for Bands IV and V in urban areas for adapted antennas.

For planning purposes, the figures in **Tables A1.3** and **A1.4** are used.

In the ITU-R Recommendation P.372-10 [P372], the difference between the man-made noise values for residential and rural areas is 2 – 3 dB. It seems reasonable to apply this difference also to the new man-made noise values here. Therefore the rural MMN value for adapted antennas in Band III is assumed to be 5 dB, in Bands IV/V 0 dB. The corresponding relevant values for external and integrated antennas are 0 dB in all bands.

It may be noted that there are also lower MMN values quoted for rural areas in accordance with [NTIA02-390] and [CPRT008].

**Table A1.3: Allowance for man-made noise used in the calculation for urban areas**

| Urban | Band III | Bands IV/ V | Reception Mode |
|---|---|---|---|
| **Allowance for man-made noise** | | | |
| Relevant value for integrated antenna | 0 | 0 | Handheld portable outdoor Cass H-A<br>Handheld portable indoor Cass H-B<br>Handheld mobile reception H-D |
| Relevant value for external antenna* | 1 | 0 | Handheld portable outdoor Cass H-A<br>Handheld portable indoor Cass H-B<br>Handheld mobile reception H-D |
| Relevant value for rooftop antenna | 2 dB | 0 dB | Fixed rooftop |
| Relevant value for adapted antenna | 8 dB | 1 dB | Portable Class A and B,<br>Mobile<br>Handheld mobile vehicular Class H-C |

*Telescopic or wired handsets

**Table A1.4: Allowance for man-made noise used in the calculation for rural areas**

| Rural | Band III | Bands IV/ V | Reception Mode |
|---|---|---|---|
| **Allowance for man-made noise** | | | |
| Relevant value for integrated antenna | 0 | 0 | Handheld portable outdoor Cass H-A<br>Handheld portable indoor Cass H-B<br>Handheld mobile reception H-D |
| Relevant value for external antenna* | 0 | 0 | Handheld portable outdoor Cass H-A<br>Handheld portable indoor Cass H-B<br>Handheld mobile reception H-D |
| Relevant value for rooftop antenna | 2 dB | 0 dB | Fixed rooftop |
| Relevant value for adapted antenna | 5 dB | 0 dB | Portable Class A and B<br>Mobile<br>Handheld mobile vehicular Class H-C |

### A1.3.4 Height Loss

For portable (Classes A, B, H-A and H-B) and mobile reception (Classes H-C and H-D), the antenna height of 10 m above ground level, generally used for planning purposes, is not representative and a correction factor needs to be introduced based on a receiving antenna near ground floor level. For this reason a receiving antenna height of 1.5 m above ground level (outdoor) or above floor level (indoor) has been assumed.

The propagation prediction method of ITU-R Recommendation P.1546 [P1546] uses a receiving height that corresponds to the height of the surrounding clutter (buildings etc.). To correct the predicted values for a receiving height of 1.5 m above ground level a factor called "height loss" has been introduced.

However, the height loss can also be specified for different types of receiving environments. CEPT ECC Report 49 [ECC049] provides the height loss values for some type of environments.

For planning purposes the values in **Table A1.5** could be used for the different bands and environment classes.

**Table A1.5: Height loss for the different bands and environment classes**

| | Receiving antenna height loss (dB) | |
|---|---|---|
| | **Band III** | **Bands IV/V** |
| Urban | 19 | 23.5 |
| Suburban | 12 | 17 |
| Rural | 12 | 16.5 |

The height loss values are based on the ITU R Rec. P.1546 [P1546].

The height loss may also depend on the distance between the transmitter and the receiver, which makes it variable with the size of the coverage area. Therefore, in this document the Figures of minimum median equivalent field strength for portable (Classes A, B, H-A and H-B) and mobile reception (Classes H-C and H-D) are calculated at 1.5 m a.g.l. The values of height loss given in this section could be used to derive the minimum median equivalent field strength corresponding to the height of the surrounding clutter (buildings etc.). Further investigations about the height loss are, however, needed.

For fixed reception the Figures of minimum median equivalent field strength are calculated at 10 m a.g.l.

### A1.3.5 Building penetration Loss

Portable reception will take place at outdoor and indoor locations. The field strength at indoor locations will be significantly attenuated by an amount depending on the materials of, and the construction of the building. A large spread of building penetration losses and entry losses for moving objects is to be expected.

For planning purposes, the present document assumes the values shown in **Table A1.6** for Class B (portable indoor) and Class H-B (handheld portable indoor).

**Table A1.6: Building penetration loss**

| Band | Class B / Portable indoor reception<br>Class H-B / Handheld portable indoor reception | |
|---|---|---|
| | **Median value** | **Standard deviation** |
| Band III | 9 dB | 3 dB |
| Bands IV/V | 11 dB | 6 dB |

For Band III, the values are taken from the GE06 Final Acts [RRC06].

For Bands IV and V, the values are taken from the ETSI DVB-H implementation guidelines [TR 102 377] where further information on building penetration loss can be found.

### A1.3.6 Vehicle (car) entry loss

For Class H-D (mobile inside), the values shown in **Table A1.7** are used in the calculations:

**Table A1.7: Vehicle (car) entry loss**

| Band | Class H-D | |
|---|---|---|
| | **Median value** | **Standard deviation** |
| Band III | 8 dB | 2 dB |
| Bands IV/V | 8 dB | 2 dB |

These values come from a study presented in [KHM98] which shows in-car penetration losses of 8 dB with an associated standard deviation of 2 – 3 dB, based on measurements at 800 MHz.

Furthermore, it is expected that the value of 8 dB will not be sufficient for estimating penetration loss into trains.

Due to the lack of investigations concerning the car entry loss and its variation with the frequency, the same value is taken for all Bands III and IV/V. Further studies are needed on this subject.

### A1.3.7 Location percentage

#### A1.3.7.1 Signal level variations

Field strength variations can be divided into macro-scale and micro-scale variations. The macro-scale variations relate to areas with linear dimensions of 10 m to 100 m or more and are mainly caused by shadowing, reflection and scattering. The micro-scale variations relate to areas with dimensions in the order of a wavelength and are mainly caused by multi-path reflections from nearby objects. The effect of micro-scale fading is normally taken into account by an appropriate C/N value for the transmission channel under consideration. Moreover, as it may be assumed that for portable reception the position of the antenna can be optimized within the order of a wavelength, micro-scale variations will not be too significant for planning purposes.

Macro-scale variations of the field strength are very important for coverage assessment. In general, a high target percentage for coverage would be required to compensate for the rapid failure rate of digital TV signals. Therefore an extra correction is required to the value derived from a field strength prediction that applies to 50% of locations.

### A1.3.7.2 Location percentage requirements at outdoor locations (Portable Class A and H-A)

ITU-R Recommendation P.1546 [P1546] gives a standard deviation for wideband signals of 5.5 dB. This value is used here for determining the location correction factor for outdoor locations for all Bands III and IV/V.

**Table A1.8: Macro-scale variation for portable outdoor reception: Coverage targets and location correction factors**

| Classes A and H-A, all bands | |
|---|---|
| Coverage target | Location correction factor (dB) |
| **>70%** | **3** |
| **>95%** | **9** |

### A1.3.7.3 Location percentage requirements at indoor locations (Classes B and H-B)

The location correction factor at indoor locations is the combined result of the outdoor variation and the variation factor due to building attenuation. These distributions are expected to be uncorrelated. The standard deviation of the indoor field strength distribution can therefore be calculated by taking the root of the sum of the squares of the individual standard deviations. As a consequence, the location variation of the field strength is increased for indoor reception.

In Band III, where the macro-scale standard deviations are 5.5 dB and 3 dB (**§ A1.3.5**), respectively, the combined value is 6.3 dB.

In Bands IV/V, where the macro-scale standard deviations are 5.5 dB and 6 dB (**§ A1.3.5**), respectively, the combined value is 8.1 dB.

**Table A1.9: Macro-scale variation for portable indoor reception: Coverage targets and location correction factors**

| | **Classes B and H-B** | |
|---|---|---|
| | **Location correction factor (dB)** | |
| **Coverage target** | **Band III** | **Bands IV/V** |
| >70% | 3 | 4 |
| >95% | 10 | 13 |

The resultant location correction factors at indoor locations for the different bands are given in **Table A1.9**.

### A1.3.7.4 Location percentage requirements for mobile and handheld mobile vehicular reception, Class H-C

The value of standard deviation given in **§ A1.3.7.2** is used here for determining the location variation at outdoor locations for mobile and handheld mobile vehicular reception. To cope with a mobile environment, larger values of location correction factors than for portable reception are used.

These location correction factors are given in **Table A1.10**.

**Table A1.10: Macro-scale variation for mobile reception: Coverage targets and location correction factors**

| Mobile reception, all bands | |
|---|---|
| **Coverage target** | **Location correction factor** |
| >90% | 7 dB |
| >99% | 13 dB |

### A1.3.7.5 Location percentage requirements for handheld reception in a moving vehicle (Class H-D)

The location correction factor for handheld reception in a moving vehicle is the combined result of the outdoor variation and the variation factor due to vehicle penetration loss. These distributions are expected to be uncorrelated. The standard deviation of the field strength distribution for handheld reception in a moving vehicle can therefore be calculated by taking the root of the sum of the squares of the individual standard deviations.

In all bands, the macro-scale standard deviations are 5.5 dB and 2 dB (**§ A1.3.6**), respectively; the combined value is 5.9 dB.

The resultant location correction factors for handheld reception in a moving vehicle (Class D) are given in **Table A1.11**.

**Table A1.11: Macro-scale variation for handheld reception in moving vehicle (Class H-D): Coverage targets and location correction factors**

| Class H-D, all bands | |
|---|---|
| **Coverage target** | **Location correction factor** |
| >90% | 7.6 dB |
| >99% | 13.7 dB |

## A1.3.8 Frequency interpolation in the UHF band (Bands IV and V)

The minimum median field strength $Fs_1$ for a frequency $f_1$ using the value of the field strength Fs for the frequency f given in the examples, for Bands IV/V, may be calculated from [RRC06]:

for fixed reception: $Fs_1 = Fs + 20 \log_{10}(f_1/f)$, and

for portable and mobile reception: $Fs_1 = Fs + 30 \log_{10}(f_1/f)$

The difference between the two cases is due to the fact that the height loss scales with an additional factor of $10 \log_{10}(f_1/f)$.

# Annex 2: Estimation of the net data capacity of a DVB-T2 multiplex

The exact data capacity of a DVB-T2 configuration depends on a large variety of parameters. Possible combinations of FFT and guard interval fraction for different bandwidths are given in **Tables 2.1, 2.2** and **2.3** in **§ 2.1**.

This annex gives an overview of the net data capacity of a DVB-T2 multiplex. It is based on the data rates given in [A133] for the 32k mode taking into account scattered pilot pattern, bandwidth-extension, guard interval fraction and symbol length.

The error associated with this estimation should be less than 0.5% for an 8 MHz channel and less than 3.5% for a 1.7 MHz channel. The information is taken from [AFM10].

In general, the data rate is independent of the FFT mode as long as other parameters such as GIF or code rate are kept unchanged. However, the bandwidth extension depends on the FFT mode. The net data capacities for different DVB-T2 configurations in an 8 MHz and a 1.7 MHz channel are given in **Tables A2.1** to **A2.4**.

### Table A2.1: Capacity in a 8 MHz channel, normal carrier mode, FFT modes: 1k to 32k

| | | Scattered Pilot Pattern 1 & 2 | | | | | | | Scattered Pilot Pattern 3 & 4 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | GIF | | | | | | | GIF | | | | | | |
| Modulation | Code rate | 1/128 [Mbit/s] | 1/32 [Mbit/s] | 1/16 [Mbit/s] | 19/256 [Mbit/s] | 1/8 [Mbit/s] | 19/128 [Mbit/s] | 1/4 [Mbit/s] | 1/128 [Mbit/s] | 1/32 [Mbit/s] | 1/16 [Mbit/s] | 19/256 [Mbit/s] | 1/8 [Mbit/s] | 19/128 [Mbit/s] | 1/4 [Mbit/s] |
| QPSK | 1/2 | 6.8 | 6.6 | 6.5 | 6.4 | 6.1 | 6.0 | 5.5 | 7.1 | 6.9 | 6.7 | 6.7 | 6.4 | 6.2 | 5.7 |
| | 3/5 | 8.2 | 8.0 | 7.8 | 7.7 | 7.3 | 7.2 | 6.6 | 8.5 | 8.3 | 8.1 | 8.0 | 7.7 | 7.5 | 6.9 |
| | 2/3 | 9.1 | 8.9 | 8.6 | 8.5 | 8.2 | 8.0 | 7.3 | 9.5 | 9.3 | 9.0 | 8.9 | 8.5 | 8.3 | 7.7 |
| | 3/4 | 10.2 | 10.0 | 9.7 | 9.6 | 9.2 | 9.0 | 8.3 | 10.7 | 10.4 | 10.1 | 10.0 | 9.6 | 9.4 | 8.6 |
| | 4/5 | 10.9 | 10.7 | 10.4 | 10.2 | 9.8 | 9.6 | 8.8 | 11.4 | 11.1 | 10.8 | 10.7 | 10.2 | 10.0 | 9.2 |
| | 5/6 | 11.4 | 11.1 | 10.8 | 10.7 | 10.2 | 10.0 | 9.2 | 11.9 | 11.6 | 11.3 | 11.2 | 10.7 | 10.4 | 9.6 |
| 16-QAM | 1/2 | 13.6 | 13.3 | 12.9 | 12.8 | 12.2 | 12.0 | 11.0 | 14.3 | 13.9 | 13.5 | 13.4 | 12.8 | 12.5 | 11.5 |
| | 3/5 | 16.4 | 16.0 | 15.6 | 15.4 | 14.7 | 14.4 | 13.2 | 17.1 | 16.7 | 16.3 | 16.1 | 15.4 | 15.1 | 13.8 |
| | 2/3 | 18.2 | 17.8 | 17.3 | 17.1 | 16.4 | 16.0 | 14.7 | 19.1 | 18.6 | 18.1 | 17.9 | 17.1 | 16.7 | 15.4 |
| | 3/4 | 20.5 | 20.1 | 19.5 | 19.3 | 18.4 | 18.0 | 16.6 | 21.4 | 21.0 | 20.4 | 20.1 | 19.2 | 18.8 | 17.3 |
| | 4/5 | 21.9 | 21.4 | 20.8 | 20.6 | 19.6 | 19.2 | 17.7 | 22.9 | 22.4 | 21.7 | 21.5 | 20.5 | 20.1 | 18.5 |
| | 5/6 | 22.8 | 22.3 | 21.7 | 21.4 | 20.5 | 20.1 | 18.4 | 23.9 | 23.3 | 22.6 | 22.4 | 21.4 | 21.0 | 19.3 |
| 64-QAM | 1/2 | 20.4 | 20.0 | 19.4 | 19.2 | 18.3 | 18.0 | 16.5 | 21.4 | 20.9 | 20.3 | 20.0 | 19.1 | 18.8 | 17.2 |
| | 3/5 | 24.6 | 24.0 | 23.3 | 23.1 | 22.0 | 21.6 | 19.8 | 25.7 | 25.1 | 24.4 | 24.1 | 23.0 | 22.5 | 20.7 |
| | 2/3 | 27.3 | 26.7 | 25.9 | 25.7 | 24.5 | 24.0 | 22.1 | 28.6 | 27.9 | 27.1 | 26.8 | 25.6 | 25.1 | 23.1 |
| | 3/4 | 30.7 | 30.0 | 29.2 | 28.9 | 27.6 | 27.0 | 24.8 | 32.1 | 31.4 | 30.5 | 30.2 | 28.8 | 28.2 | 25.9 |
| | 4/5 | 32.8 | 32.1 | 31.1 | 30.8 | 29.4 | 28.8 | 26.5 | 34.3 | 33.5 | 32.5 | 32.2 | 30.7 | 30.1 | 27.7 |
| | 5/6 | 34.2 | 33.4 | 32.5 | 32.1 | 30.7 | 30.0 | 27.6 | 35.7 | 34.9 | 33.9 | 33.5 | 32.0 | 31.4 | 28.9 |
| 256-QAM | 1/2 | 27.3 | 26.7 | 25.9 | 25.6 | 24.5 | 24.0 | 22.1 | 28.5 | 27.9 | 27.1 | 26.8 | 25.6 | 25.1 | 23.0 |
| | 3/5 | 32.8 | 32.1 | 31.1 | 30.8 | 29.4 | 28.8 | 26.5 | 34.3 | 33.5 | 32.5 | 32.2 | 30.7 | 30.1 | 27.7 |
| | 2/3 | 36.5 | 35.7 | 34.6 | 34.3 | 32.7 | 32.1 | 29.5 | 38.1 | 37.3 | 36.2 | 35.8 | 34.2 | 33.5 | 30.8 |
| | 3/4 | 41.1 | 40.1 | 39.0 | 38.6 | 36.8 | 36.1 | 33.2 | 42.9 | 41.9 | 40.7 | 40.3 | 38.5 | 37.7 | 34.7 |
| | 4/5 | 43.8 | 42.8 | 41.6 | 41.1 | 39.3 | 38.5 | 35.4 | 45.8 | 44.8 | 43.5 | 43.0 | 41.1 | 40.2 | 37.0 |
| | 5/6 | 45.7 | 44.7 | 43.4 | 42.9 | 41.0 | 40.1 | 36.9 | 47.7 | 46.7 | 45.3 | 44.8 | 42.8 | 41.9 | 38.6 |

| Modulation | Code rate | Scattered Pilot Pattern 5 & 6 GIF | | | | | | | Scattered Pilot Pattern 7 & 8 GIF | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1/128 [Mbit/s] | 1/32 [Mbit/s] | 1/16 [Mbit/s] | 19/256 [Mbit/s] | 1/8 [Mbit/s] | 19/128 [Mbit/s] | 1/4 [Mbit/s] | 1/128 [Mbit/s] | 1/32 [Mbit/s] | 1/16 [Mbit/s] | 19/256 [Mbit/s] | 1/8 [Mbit/s] | 19/128 [Mbit/s] | 1/4 [Mbit/s] |
| QPSK | 1/2 | 7.3 | 7.1 | 6.9 | 6.8 | 6.5 | 6.4 | 5.9 | 7.3 | 7.2 | 7.0 | 6.9 | 6.6 | 6.4 | 5.9 |
| | 3/5 | 8.7 | 8.5 | 8.3 | 8.2 | 7.8 | 7.7 | 7.0 | 8.8 | 8.6 | 8.4 | 8.3 | 7.9 | 7.7 | 7.1 |
| | 2/3 | 9.7 | 9.5 | 9.2 | 9.1 | 8.7 | 8.5 | 7.8 | 9.8 | 9.6 | 9.3 | 9.2 | 8.8 | 8.6 | 7.9 |
| | 3/4 | 10.9 | 10.7 | 10.4 | 10.2 | 9.8 | 9.6 | 8.8 | 11.0 | 10.8 | 10.5 | 10.4 | 9.9 | 9.7 | 8.9 |
| | 4/5 | 11.6 | 11.4 | 11.1 | 10.9 | 10.4 | 10.2 | 9.4 | 11.8 | 11.5 | 11.2 | 11.0 | 10.6 | 10.3 | 9.5 |
| | 5/6 | 12.1 | 11.9 | 11.5 | 11.4 | 10.9 | 10.7 | 9.8 | 12.3 | 12.0 | 11.6 | 11.5 | 11.0 | 10.8 | 9.9 |
| 16-QAM | 1/2 | 14.6 | 14.2 | 13.8 | 13.7 | 13.1 | 12.8 | 11.8 | 14.7 | 14.4 | 14.0 | 13.8 | 13.2 | 12.9 | 11.9 |
| | 3/5 | 17.5 | 17.1 | 16.6 | 16.4 | 15.7 | 15.4 | 14.1 | 17.7 | 17.3 | 16.8 | 16.6 | 15.9 | 15.5 | 14.3 |
| | 2/3 | 19.5 | 19.0 | 18.5 | 18.3 | 17.5 | 17.1 | 15.7 | 19.7 | 19.2 | 18.7 | 18.5 | 17.6 | 17.3 | 15.9 |
| | 3/4 | 21.9 | 21.4 | 20.8 | 20.6 | 19.6 | 19.2 | 17.7 | 22.1 | 21.6 | 21.0 | 20.8 | 19.9 | 19.5 | 17.9 |
| | 4/5 | 23.4 | 22.9 | 22.2 | 21.9 | 21.0 | 20.5 | 18.9 | 23.6 | 23.1 | 22.4 | 22.2 | 21.2 | 20.8 | 19.1 |
| | 5/6 | 24.4 | 23.8 | 23.1 | 22.9 | 21.9 | 21.4 | 19.7 | 24.6 | 24.1 | 23.4 | 23.1 | 22.1 | 21.6 | 19.9 |
| 64-QAM | 1/2 | 21.8 | 21.3 | 20.7 | 20.5 | 19.6 | 19.2 | 17.6 | 22.0 | 21.5 | 20.9 | 20.7 | 19.8 | 19.4 | 17.8 |
| | 3/5 | 26.2 | 25.6 | 24.9 | 24.6 | 23.5 | 23.0 | 21.2 | 26.5 | 25.9 | 25.1 | 24.9 | 23.8 | 23.3 | 21.4 |
| | 2/3 | 29.2 | 28.5 | 27.7 | 27.4 | 26.2 | 25.6 | 23.6 | 29.5 | 28.8 | 28.0 | 27.7 | 26.4 | 25.9 | 23.8 |
| | 3/4 | 32.8 | 32.1 | 31.1 | 30.8 | 29.4 | 28.8 | 26.5 | 33.2 | 32.4 | 31.5 | 31.1 | 29.7 | 29.1 | 26.8 |
| | 4/5 | 35.0 | 34.2 | 33.2 | 32.9 | 31.4 | 30.8 | 28.3 | 35.4 | 34.6 | 33.6 | 33.2 | 31.7 | 31.1 | 28.6 |
| | 5/6 | 36.5 | 35.7 | 34.6 | 34.3 | 32.7 | 32.1 | 29.5 | 36.9 | 36.1 | 35.0 | 34.6 | 33.1 | 32.4 | 29.8 |
| 256-QAM | 1/2 | 29.1 | 28.5 | 27.7 | 27.4 | 26.1 | 25.6 | 23.5 | 29.5 | 28.8 | 27.9 | 27.6 | 26.4 | 25.9 | 23.8 |
| | 3/5 | 35.0 | 34.2 | 33.2 | 32.9 | 31.4 | 30.8 | 28.3 | 35.4 | 34.6 | 33.6 | 33.2 | 31.7 | 31.1 | 28.6 |
| | 2/3 | 39.0 | 38.1 | 37.0 | 36.6 | 34.9 | 34.2 | 31.5 | 39.4 | 38.5 | 37.4 | 37.0 | 35.3 | 34.6 | 31.8 |
| | 3/4 | 43.8 | 42.9 | 41.6 | 41.2 | 39.3 | 38.5 | 35.4 | 44.3 | 43.3 | 42.0 | 41.6 | 39.7 | 38.9 | 35.8 |
| | 4/5 | 46.8 | 45.7 | 44.4 | 43.9 | 41.9 | 41.1 | 37.8 | 47.3 | 46.2 | 44.9 | 44.4 | 42.4 | 41.5 | 38.2 |
| | 5/6 | 48.8 | 47.7 | 46.3 | 45.8 | 43.7 | 42.8 | 39.4 | 49.3 | 48.2 | 46.8 | 46.3 | 44.2 | 43.3 | 39.8 |

### Table A2.2: Capacity in a 8 MHz channel, extended carrier mode, FFT mode: 8k

| Modulation | Code rate | Scattered Pilot Pattern 1 & 2 GIF 1/128 [Mbit/s] | 1/32 [Mbit/s] | 1/16 [Mbit/s] | 19/256 [Mbit/s] | 1/8 [Mbit/s] | 19/128 [Mbit/s] | 1/4 [Mbit/s] | Scattered Pilot Pattern 3 & 4 GIF 1/128 [Mbit/s] | 1/32 [Mbit/s] | 1/16 [Mbit/s] | 19/256 [Mbit/s] | 1/8 [Mbit/s] | 19/128 [Mbit/s] | 1/4 [Mbit/s] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| QPSK | 1/2 | 6.9 | 6.7 | 6.5 | 6.5 | 6.2 | 6.1 | 5.6 | 7.2 | 7.0 | 6.8 | 6.8 | 6.5 | 6.3 | 5.8 |
| | 3/5 | 8.3 | 8.1 | 7.9 | 7.8 | 7.4 | 7.3 | 6.7 | 8.7 | 8.5 | 8.2 | 8.1 | 7.8 | 7.6 | 7.0 |
| | 2/3 | 9.2 | 9.0 | 8.8 | 8.7 | 8.3 | 8.1 | 7.4 | 9.6 | 9.4 | 9.1 | 9.0 | 8.6 | 8.5 | 7.8 |
| | 3/4 | 10.4 | 10.1 | 9.8 | 9.7 | 9.3 | 9.1 | 8.4 | 10.8 | 10.6 | 10.3 | 10.2 | 9.7 | 9.5 | 8.8 |
| | 4/5 | 11.1 | 10.8 | 10.5 | 10.4 | 9.9 | 9.7 | 8.9 | 11.6 | 11.3 | 11.0 | 10.9 | 10.4 | 10.2 | 9.3 |
| | 5/6 | 11.5 | 11.3 | 11.0 | 10.8 | 10.3 | 10.1 | 9.3 | 12.1 | 11.8 | 11.4 | 11.3 | 10.8 | 10.6 | 9.7 |
| 16-QAM | 1/2 | 13.8 | 13.5 | 13.1 | 13.0 | 12.4 | 12.2 | 11.2 | 14.5 | 14.1 | 13.7 | 13.6 | 13.0 | 12.7 | 11.7 |
| | 3/5 | 16.6 | 16.3 | 15.8 | 15.6 | 14.9 | 14.6 | 13.4 | 17.4 | 17.0 | 16.5 | 16.3 | 15.6 | 15.3 | 14.0 |
| | 2/3 | 18.5 | 18.1 | 17.6 | 17.4 | 16.6 | 16.3 | 15.0 | 19.3 | 18.9 | 18.4 | 18.2 | 17.3 | 17.0 | 15.6 |
| | 3/4 | 20.8 | 20.4 | 19.8 | 19.5 | 18.7 | 18.3 | 16.8 | 21.8 | 21.3 | 20.6 | 20.4 | 19.5 | 19.1 | 17.6 |
| | 4/5 | 22.2 | 21.7 | 21.1 | 20.9 | 19.9 | 19.5 | 17.9 | 23.2 | 22.7 | 22.0 | 21.8 | 20.8 | 20.4 | 18.8 |
| | 5/6 | 23.2 | 22.6 | 22.0 | 21.7 | 20.8 | 20.3 | 18.7 | 24.2 | 23.7 | 23.0 | 22.7 | 21.7 | 21.3 | 19.6 |
| 64-QAM | 1/2 | 20.7 | 20.3 | 19.7 | 19.5 | 18.6 | 18.2 | 16.7 | 21.7 | 21.2 | 20.6 | 20.3 | 19.4 | 19.0 | 17.5 |
| | 3/5 | 24.9 | 24.4 | 23.6 | 23.4 | 22.3 | 21.9 | 20.1 | 26.0 | 25.4 | 24.7 | 24.4 | 23.3 | 22.9 | 21.0 |
| | 2/3 | 27.7 | 27.1 | 26.3 | 26.0 | 24.9 | 24.4 | 22.4 | 29.0 | 28.3 | 27.5 | 27.2 | 26.0 | 25.4 | 23.4 |
| | 3/4 | 31.2 | 30.5 | 29.6 | 29.3 | 28.0 | 27.4 | 25.2 | 32.6 | 31.8 | 30.9 | 30.6 | 29.2 | 28.6 | 26.3 |
| | 4/5 | 33.3 | 32.5 | 31.6 | 31.2 | 29.8 | 29.2 | 26.9 | 34.8 | 34.0 | 33.0 | 32.6 | 31.2 | 30.5 | 28.1 |
| | 5/6 | 34.7 | 33.9 | 32.9 | 32.6 | 31.1 | 30.5 | 28.0 | 36.2 | 35.4 | 34.4 | 34.0 | 32.5 | 31.8 | 29.3 |
| 256-QAM | 1/2 | 27.7 | 27.1 | 26.3 | 26.0 | 24.8 | 24.3 | 22.4 | 28.9 | 28.3 | 27.5 | 27.2 | 25.9 | 25.4 | 23.4 |
| | 3/5 | 33.3 | 32.5 | 31.6 | 31.2 | 29.8 | 29.2 | 26.9 | 34.8 | 34.0 | 33.0 | 32.6 | 31.2 | 30.6 | 28.1 |
| | 2/3 | 37.0 | 36.2 | 35.1 | 34.8 | 33.2 | 32.5 | 29.9 | 38.7 | 37.8 | 36.7 | 36.3 | 34.7 | 34.0 | 31.3 |
| | 3/4 | 41.7 | 40.7 | 39.5 | 39.1 | 37.4 | 36.6 | 33.7 | 43.5 | 42.6 | 41.3 | 40.9 | 39.0 | 38.2 | 35.2 |
| | 4/5 | 44.5 | 43.5 | 42.2 | 41.7 | 39.9 | 39.1 | 35.9 | 46.5 | 45.4 | 44.1 | 43.6 | 41.7 | 40.8 | 37.5 |
| | 5/6 | 46.3 | 45.3 | 44.0 | 43.5 | 41.6 | 40.7 | 37.4 | 48.4 | 47.3 | 46.0 | 45.5 | 43.4 | 42.5 | 39.1 |

| Modulation | Code rate | Scattered Pilot Pattern 5 & 6 GIF 1/128 [Mbit/s] | 1/32 [Mbit/s] | 1/16 [Mbit/s] | 19/256 [Mbit/s] | 1/8 [Mbit/s] | 19/128 [Mbit/s] | 1/4 [Mbit/s] | Scattered Pilot Pattern 7 & 8 GIF 1/128 [Mbit/s] | 1/32 [Mbit/s] | 1/16 [Mbit/s] | 19/256 [Mbit/s] | 1/8 [Mbit/s] | 19/128 [Mbit/s] | 1/4 [Mbit/s] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| QPSK | 1/2 | 7.4 | 7.2 | 7.0 | 6.9 | 6.6 | 6.5 | 5.9 | 7.4 | 7.3 | 7.1 | 7.0 | 6.7 | 6.5 | 6.0 |
| | 3/5 | 8.8 | 8.6 | 8.4 | 8.3 | 7.9 | 7.8 | 7.1 | 8.9 | 8.7 | 8.5 | 8.4 | 8.0 | 7.9 | 7.2 |
| | 2/3 | 9.8 | 9.6 | 9.3 | 9.2 | 8.8 | 8.6 | 8.0 | 9.9 | 9.7 | 9.4 | 9.3 | 8.9 | 8.7 | 8.0 |
| | 3/4 | 11.1 | 10.8 | 10.5 | 10.4 | 9.9 | 9.7 | 8.9 | 11.2 | 10.9 | 10.6 | 10.5 | 10.0 | 9.8 | 9.0 |
| | 4/5 | 11.8 | 11.6 | 11.2 | 11.1 | 10.6 | 10.4 | 9.5 | 11.9 | 11.7 | 11.3 | 11.2 | 10.7 | 10.5 | 9.6 |
| | 5/6 | 12.3 | 12.0 | 11.7 | 11.6 | 11.0 | 10.8 | 10.0 | 12.4 | 12.2 | 11.8 | 11.7 | 11.2 | 10.9 | 10.1 |
| 16-QAM | 1/2 | 14.8 | 14.4 | 14.0 | 13.9 | 13.2 | 13.0 | 11.9 | 14.9 | 14.6 | 14.2 | 14.0 | 13.4 | 13.1 | 12.1 |
| | 3/5 | 17.8 | 17.4 | 16.8 | 16.7 | 15.9 | 15.6 | 14.3 | 17.9 | 17.5 | 17.0 | 16.8 | 16.1 | 15.8 | 14.5 |
| | 2/3 | 19.8 | 19.3 | 18.7 | 18.5 | 17.7 | 17.4 | 16.0 | 20.0 | 19.5 | 18.9 | 18.7 | 17.9 | 17.5 | 16.1 |
| | 3/4 | 22.2 | 21.7 | 21.1 | 20.9 | 19.9 | 19.5 | 18.0 | 22.5 | 22.0 | 21.3 | 21.1 | 20.1 | 19.7 | 18.1 |
| | 4/5 | 23.7 | 23.2 | 22.5 | 22.3 | 21.3 | 20.8 | 19.2 | 24.0 | 23.4 | 22.7 | 22.5 | 21.5 | 21.1 | 19.4 |
| | 5/6 | 24.7 | 24.2 | 23.5 | 23.2 | 22.2 | 21.7 | 20.0 | 25.0 | 24.4 | 23.7 | 23.5 | 22.4 | 21.9 | 20.2 |
| 64-QAM | 1/2 | 22.1 | 21.6 | 21.0 | 20.8 | 19.8 | 19.4 | 17.9 | 22.4 | 21.9 | 21.2 | 21.0 | 20.1 | 19.6 | 18.1 |
| | 3/5 | 26.6 | 26.0 | 25.2 | 25.0 | 23.8 | 23.4 | 21.5 | 26.9 | 26.3 | 25.5 | 25.2 | 24.1 | 23.6 | 21.7 |
| | 2/3 | 29.6 | 28.9 | 28.1 | 27.8 | 26.5 | 26.0 | 23.9 | 29.9 | 29.2 | 28.4 | 28.1 | 26.8 | 26.3 | 24.2 |
| | 3/4 | 33.3 | 32.5 | 31.6 | 31.2 | 29.8 | 29.2 | 26.9 | 33.6 | 32.9 | 31.9 | 31.6 | 30.2 | 29.5 | 27.2 |
| | 4/5 | 35.5 | 34.7 | 33.7 | 33.3 | 31.8 | 31.2 | 28.7 | 35.9 | 35.1 | 34.1 | 33.7 | 32.2 | 31.5 | 29.0 |
| | 5/6 | 37.0 | 36.2 | 35.1 | 34.8 | 33.2 | 32.5 | 29.9 | 37.4 | 36.6 | 35.5 | 35.1 | 33.5 | 32.9 | 30.2 |
| 256-QAM | 1/2 | 29.6 | 28.9 | 28.1 | 27.8 | 26.5 | 26.0 | 23.9 | 29.9 | 29.2 | 28.3 | 28.0 | 26.8 | 26.2 | 24.1 |
| | 3/5 | 35.5 | 34.7 | 33.7 | 33.3 | 31.9 | 31.2 | 28.7 | 35.9 | 35.1 | 34.1 | 33.7 | 32.2 | 31.5 | 29.0 |
| | 2/3 | 39.5 | 38.6 | 37.5 | 37.1 | 35.4 | 34.7 | 31.9 | 39.9 | 39.0 | 37.9 | 37.5 | 35.8 | 35.1 | 32.3 |
| | 3/4 | 44.5 | 43.5 | 42.2 | 41.7 | 39.9 | 39.1 | 35.9 | 44.9 | 43.9 | 42.6 | 42.2 | 40.3 | 39.5 | 36.3 |
| | 4/5 | 47.5 | 46.4 | 45.0 | 44.5 | 42.5 | 41.7 | 38.3 | 48.0 | 46.9 | 45.5 | 45.0 | 43.0 | 42.1 | 38.7 |
| | 5/6 | 49.5 | 48.4 | 46.9 | 46.4 | 44.4 | 43.5 | 40.0 | 50.0 | 48.9 | 47.4 | 46.9 | 44.8 | 43.9 | 40.4 |

### Table A2.3: Capacity in a 8 MHz channel, extended carrier mode, FFT modes: 16k and 32k

| | | Scattered Pilot Pattern 1 & 2 | | | | | | | Scattered Pilot Pattern 3 & 4 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | GIF | | | | | | | GIF | | | | | | |
| Modulation | Code rate | 1/128 [Mbit/s] | 1/32 [Mbit/s] | 1/16 [Mbit/s] | 19/256 [Mbit/s] | 1/8 [Mbit/s] | 19/128 [Mbit/s] | 1/4 [Mbit/s] | 1/128 [Mbit/s] | 1/32 [Mbit/s] | 1/16 [Mbit/s] | 19/256 [Mbit/s] | 1/8 [Mbit/s] | 19/128 [Mbit/s] | 1/4 [Mbit/s] |
| QPSK | 1/2 | 6.9 | 6.8 | 6.6 | 6.5 | 6.2 | 6.1 | 5.6 | 7.3 | 7.1 | 6.9 | 6.8 | 6.5 | 6.4 | 5.9 |
| | 3/5 | 8.3 | 8.2 | 7.9 | 7.8 | 7.5 | 7.3 | 6.7 | 8.7 | 8.5 | 8.3 | 8.2 | 7.8 | 7.7 | 7.0 |
| | 2/3 | 9.3 | 9.1 | 8.8 | 8.7 | 8.3 | 8.2 | 7.5 | 9.7 | 9.5 | 9.2 | 9.1 | 8.7 | 8.5 | 7.8 |
| | 3/4 | 10.4 | 10.2 | 9.9 | 9.8 | 9.4 | 9.2 | 8.4 | 10.9 | 10.7 | 10.4 | 10.2 | 9.8 | 9.6 | 8.8 |
| | 4/5 | 11.1 | 10.9 | 10.6 | 10.5 | 10.0 | 9.8 | 9.0 | 11.6 | 11.4 | 11.1 | 10.9 | 10.4 | 10.2 | 9.4 |
| | 5/6 | 11.6 | 11.4 | 11.0 | 10.9 | 10.4 | 10.2 | 9.4 | 12.1 | 11.9 | 11.5 | 11.4 | 10.9 | 10.7 | 9.8 |
| 16-QAM | 1/2 | 13.9 | 13.6 | 13.2 | 13.1 | 12.5 | 12.2 | 11.3 | 14.6 | 14.2 | 13.8 | 13.7 | 13.1 | 12.8 | 11.8 |
| | 3/5 | 16.8 | 16.4 | 15.9 | 15.7 | 15.0 | 14.7 | 13.5 | 17.5 | 17.1 | 16.6 | 16.4 | 15.7 | 15.4 | 14.1 |
| | 2/3 | 18.6 | 18.2 | 17.7 | 17.5 | 16.7 | 16.4 | 15.1 | 19.5 | 19.0 | 18.5 | 18.3 | 17.5 | 17.1 | 15.7 |
| | 3/4 | 21.0 | 20.5 | 19.9 | 19.7 | 18.8 | 18.4 | 16.9 | 21.9 | 21.4 | 20.8 | 20.6 | 19.6 | 19.2 | 17.7 |
| | 4/5 | 22.4 | 21.9 | 21.2 | 21.0 | 20.1 | 19.7 | 18.1 | 23.4 | 22.9 | 22.2 | 21.9 | 21.0 | 20.5 | 18.9 |
| | 5/6 | 23.3 | 22.8 | 22.1 | 21.9 | 20.9 | 20.5 | 18.8 | 24.4 | 23.8 | 23.1 | 22.9 | 21.9 | 21.4 | 19.7 |
| 64-QAM | 1/2 | 20.9 | 20.4 | 19.8 | 19.6 | 18.7 | 18.3 | 16.9 | 21.8 | 21.3 | 20.7 | 20.5 | 19.6 | 19.2 | 17.6 |
| | 3/5 | 25.1 | 24.5 | 23.8 | 23.6 | 22.5 | 22.0 | 20.3 | 26.2 | 25.6 | 24.9 | 24.6 | 23.5 | 23.0 | 21.2 |
| | 2/3 | 27.9 | 27.3 | 26.5 | 26.2 | 25.0 | 24.5 | 22.6 | 29.2 | 28.5 | 27.7 | 27.4 | 26.2 | 25.6 | 23.6 |
| | 3/4 | 31.4 | 30.7 | 29.8 | 29.5 | 28.2 | 27.6 | 25.4 | 32.8 | 32.1 | 31.1 | 30.8 | 29.4 | 28.8 | 26.5 |
| | 4/5 | 33.5 | 32.8 | 31.8 | 31.5 | 30.0 | 29.4 | 27.1 | 35.0 | 34.2 | 33.2 | 32.9 | 31.4 | 30.8 | 28.3 |
| | 5/6 | 34.9 | 34.1 | 33.2 | 32.8 | 31.3 | 30.7 | 28.2 | 36.5 | 35.7 | 34.6 | 34.3 | 32.7 | 32.1 | 29.5 |
| 256-QAM | 1/2 | 27.9 | 27.3 | 26.5 | 26.2 | 25.0 | 24.5 | 22.5 | 29.1 | 28.5 | 27.7 | 27.4 | 26.1 | 25.6 | 23.5 |
| | 3/5 | 33.5 | 32.8 | 31.8 | 31.5 | 30.1 | 29.4 | 27.1 | 35.0 | 34.2 | 33.2 | 32.9 | 31.4 | 30.8 | 28.3 |
| | 2/3 | 37.3 | 36.5 | 35.4 | 35.0 | 33.4 | 32.8 | 30.1 | 39.0 | 38.1 | 37.0 | 36.6 | 34.9 | 34.2 | 31.5 |
| | 3/4 | 42.0 | 41.0 | 39.8 | 39.4 | 37.6 | 36.9 | 33.9 | 43.8 | 42.9 | 41.6 | 41.2 | 39.3 | 38.5 | 35.4 |
| | 4/5 | 44.8 | 43.8 | 42.5 | 42.0 | 40.1 | 39.3 | 36.2 | 46.8 | 45.7 | 44.4 | 43.9 | 41.9 | 41.1 | 37.8 |
| | 5/6 | 46.7 | 45.6 | 44.3 | 43.8 | 41.9 | 41.0 | 37.7 | 48.8 | 47.7 | 46.3 | 45.8 | 43.7 | 42.8 | 39.4 |

| | | Scattered Pilot Pattern 5 & 6 GIF | | | | | | | Scattered Pilot Pattern 7 & 8 GIF | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Modulation | Code rate | 1/128 [Mbit/s] | 1/32 [Mbit/s] | 1/16 [Mbit/s] | 19/256 [Mbit/s] | 1/8 [Mbit/s] | 19/128 [Mbit/s] | 1/4 [Mbit/s] | 1/128 [Mbit/s] | 1/32 [Mbit/s] | 1/16 [Mbit/s] | 19/256 [Mbit/s] | 1/8 [Mbit/s] | 19/128 [Mbit/s] | 1/4 [Mbit/s] |
| QPSK | 1/2 | 7.4 | 7.2 | 7.0 | 7.0 | 6.6 | 6.5 | 6.0 | 7.5 | 7.3 | 7.1 | 7.0 | 6.7 | 6.6 | 6.1 |
| | 3/5 | 8.9 | 8.7 | 8.5 | 8.4 | 8.0 | 7.8 | 7.2 | 9.0 | 8.8 | 8.5 | 8.5 | 8.1 | 7.9 | 7.3 |
| | 2/3 | 9.9 | 9.7 | 9.4 | 9.3 | 8.9 | 8.7 | 8.0 | 10.0 | 9.8 | 9.5 | 9.4 | 9.0 | 8.8 | 8.1 |
| | 3/4 | 11.2 | 10.9 | 10.6 | 10.5 | 10.0 | 9.8 | 9.0 | 11.3 | 11.0 | 10.7 | 10.6 | 10.1 | 9.9 | 9.1 |
| | 4/5 | 11.9 | 11.6 | 11.3 | 11.2 | 10.7 | 10.5 | 9.6 | 12.0 | 11.8 | 11.4 | 11.3 | 10.8 | 10.6 | 9.7 |
| | 5/6 | 12.4 | 12.1 | 11.8 | 11.6 | 11.1 | 10.9 | 10.0 | 12.5 | 12.3 | 11.9 | 11.8 | 11.2 | 11.0 | 10.1 |
| 16-QAM | 1/2 | 14.9 | 14.5 | 14.1 | 14.0 | 13.3 | 13.1 | 12.0 | 15.0 | 14.7 | 14.3 | 14.1 | 13.5 | 13.2 | 12.1 |
| | 3/5 | 17.9 | 17.5 | 17.0 | 16.8 | 16.0 | 15.7 | 14.4 | 18.1 | 17.7 | 17.1 | 17.0 | 16.2 | 15.9 | 14.6 |
| | 2/3 | 19.9 | 19.4 | 18.9 | 18.7 | 17.8 | 17.5 | 16.1 | 20.1 | 19.7 | 19.1 | 18.9 | 18.0 | 17.7 | 16.2 |
| | 3/4 | 22.4 | 21.9 | 21.2 | 21.0 | 20.1 | 19.7 | 18.1 | 22.6 | 22.1 | 21.5 | 21.2 | 20.3 | 19.9 | 18.3 |
| | 4/5 | 23.9 | 23.3 | 22.7 | 22.4 | 21.4 | 21.0 | 19.3 | 24.1 | 23.6 | 22.9 | 22.7 | 21.6 | 21.2 | 19.5 |
| | 5/6 | 24.9 | 24.3 | 23.6 | 23.4 | 22.3 | 21.9 | 20.1 | 25.2 | 24.6 | 23.9 | 23.6 | 22.6 | 22.1 | 20.3 |
| 64-QAM | 1/2 | 22.3 | 21.8 | 21.1 | 20.9 | 20.0 | 19.6 | 18.0 | 22.5 | 22.0 | 21.4 | 21.1 | 20.2 | 19.8 | 18.2 |
| | 3/5 | 26.8 | 26.2 | 25.4 | 25.1 | 24.0 | 23.5 | 21.6 | 27.1 | 26.5 | 25.7 | 25.4 | 24.3 | 23.8 | 21.9 |
| | 2/3 | 29.8 | 29.1 | 28.3 | 28.0 | 26.7 | 26.2 | 24.1 | 30.1 | 29.4 | 28.6 | 28.3 | 27.0 | 26.5 | 24.3 |
| | 3/4 | 33.5 | 32.8 | 31.8 | 31.5 | 30.1 | 29.4 | 27.1 | 33.9 | 33.1 | 32.1 | 31.8 | 30.4 | 29.8 | 27.4 |
| | 4/5 | 35.8 | 35.0 | 33.9 | 33.6 | 32.1 | 31.4 | 28.9 | 36.1 | 35.3 | 34.3 | 33.9 | 32.4 | 31.8 | 29.2 |
| | 5/6 | 37.3 | 36.4 | 35.4 | 35.0 | 33.4 | 32.8 | 30.1 | 37.7 | 36.8 | 35.8 | 35.4 | 33.8 | 33.1 | 30.4 |
| 256-QAM | 1/2 | 29.8 | 29.1 | 28.3 | 27.9 | 26.7 | 26.2 | 24.1 | 30.1 | 29.4 | 28.6 | 28.2 | 27.0 | 26.4 | 24.3 |
| | 3/5 | 35.8 | 35.0 | 34.0 | 33.6 | 32.1 | 31.4 | 28.9 | 36.2 | 35.3 | 34.3 | 33.9 | 32.4 | 31.8 | 29.2 |
| | 2/3 | 39.8 | 38.9 | 37.8 | 37.4 | 35.7 | 35.0 | 32.2 | 40.2 | 39.3 | 38.2 | 37.8 | 36.1 | 35.3 | 32.5 |
| | 3/4 | 44.8 | 43.8 | 42.5 | 42.0 | 40.2 | 39.3 | 36.2 | 45.3 | 44.2 | 42.9 | 42.5 | 40.6 | 39.8 | 36.6 |
| | 4/5 | 47.8 | 46.7 | 45.3 | 44.9 | 42.9 | 42.0 | 38.6 | 48.3 | 47.2 | 45.8 | 45.3 | 43.3 | 42.4 | 39.0 |
| | 5/6 | 49.8 | 48.7 | 47.3 | 46.8 | 44.7 | 43.8 | 40.2 | 50.3 | 49.2 | 47.8 | 47.3 | 45.1 | 44.2 | 40.7 |

## Table A2.4: Capacity in a 1.7 MHz channel, normal carrier mode, FFT modes: 1k to 32k

| | | Scattered Pilot Pattern 1 & 2 | | | | | | | Scattered Pilot Pattern 3 & 4 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | GIF | | | | | | | GIF | | | | | | |
| Modulation | Code rate | 1/128 [Mbit/s] | 1/32 [Mbit/s] | 1/16 [Mbit/s] | 19/256 [Mbit/s] | 1/8 [Mbit/s] | 19/128 [Mbit/s] | 1/4 [Mbit/s] | 1/128 [Mbit/s] | 1/32 [Mbit/s] | 1/16 [Mbit/s] | 19/256 [Mbit/s] | 1/8 [Mbit/s] | 19/128 [Mbit/s] | 1/4 [Mbit/s] |
| QPSK | 1/2 | 1.4 | 1.3 | 1.3 | 1.3 | 1.2 | 1.2 | 1.1 | 1.4 | 1.4 | 1.4 | 1.3 | 1.3 | 1.3 | 1.2 |
| | 3/5 | 1.6 | 1.6 | 1.6 | 1.5 | 1.5 | 1.4 | 1.3 | 1.7 | 1.7 | 1.6 | 1.6 | 1.5 | 1.5 | 1.4 |
| | 2/3 | 1.8 | 1.8 | 1.7 | 1.7 | 1.6 | 1.6 | 1.5 | 1.9 | 1.9 | 1.8 | 1.8 | 1.7 | 1.7 | 1.5 |
| | 3/4 | 2.1 | 2.0 | 2.0 | 1.9 | 1.9 | 1.8 | 1.7 | 2.2 | 2.1 | 2.0 | 2.0 | 1.9 | 1.9 | 1.7 |
| | 4/5 | 2.2 | 2.2 | 2.1 | 2.1 | 2.0 | 1.9 | 1.8 | 2.3 | 2.2 | 2.2 | 2.2 | 2.1 | 2.0 | 1.9 |
| | 5/6 | 2.3 | 2.2 | 2.2 | 2.2 | 2.1 | 2.0 | 1.9 | 2.4 | 2.3 | 2.3 | 2.3 | 2.2 | 2.1 | 1.9 |
| 16-QAM | 1/2 | 2.8 | 2.7 | 2.6 | 2.6 | 2.5 | 2.4 | 2.2 | 2.9 | 2.8 | 2.7 | 2.7 | 2.6 | 2.5 | 2.3 |
| | 3/5 | 3.3 | 3.2 | 3.1 | 3.1 | 3.0 | 2.9 | 2.7 | 3.5 | 3.4 | 3.3 | 3.2 | 3.1 | 3.0 | 2.8 |
| | 2/3 | 3.7 | 3.6 | 3.5 | 3.5 | 3.3 | 3.2 | 3.0 | 3.8 | 3.8 | 3.7 | 3.6 | 3.5 | 3.4 | 3.1 |
| | 3/4 | 4.1 | 4.0 | 3.9 | 3.9 | 3.7 | 3.6 | 3.3 | 4.3 | 4.2 | 4.1 | 4.1 | 3.9 | 3.8 | 3.5 |
| | 4/5 | 4.4 | 4.3 | 4.2 | 4.1 | 4.0 | 3.9 | 3.6 | 4.6 | 4.5 | 4.4 | 4.3 | 4.1 | 4.1 | 3.7 |
| | 5/6 | 4.6 | 4.5 | 4.4 | 4.3 | 4.1 | 4.0 | 3.7 | 4.8 | 4.7 | 4.6 | 4.5 | 4.3 | 4.2 | 3.9 |
| 64-QAM | 1/2 | 4.1 | 4.0 | 3.9 | 3.9 | 3.7 | 3.6 | 3.3 | 4.3 | 4.2 | 4.1 | 4.0 | 3.9 | 3.8 | 3.5 |
| | 3/5 | 5.0 | 4.8 | 4.7 | 4.7 | 4.4 | 4.4 | 4.0 | 5.2 | 5.1 | 4.9 | 4.9 | 4.6 | 4.5 | 4.2 |
| | 2/3 | 5.5 | 5.4 | 5.2 | 5.2 | 4.9 | 4.8 | 4.5 | 5.8 | 5.6 | 5.5 | 5.4 | 5.2 | 5.1 | 4.7 |
| | 3/4 | 6.2 | 6.1 | 5.9 | 5.8 | 5.6 | 5.5 | 5.0 | 6.5 | 6.3 | 6.2 | 6.1 | 5.8 | 5.7 | 5.2 |
| | 4/5 | 6.6 | 6.5 | 6.3 | 6.2 | 5.9 | 5.8 | 5.3 | 6.9 | 6.8 | 6.6 | 6.5 | 6.2 | 6.1 | 5.6 |
| | 5/6 | 6.9 | 6.7 | 6.5 | 6.5 | 6.2 | 6.1 | 5.6 | 7.2 | 7.0 | 6.8 | 6.8 | 6.5 | 6.3 | 5.8 |
| 256-QAM | 1/2 | 5.5 | 5.4 | 5.2 | 5.2 | 4.9 | 4.8 | 4.5 | 5.8 | 5.6 | 5.5 | 5.4 | 5.2 | 5.1 | 4.7 |
| | 3/5 | 6.6 | 6.5 | 6.3 | 6.2 | 5.9 | 5.8 | 5.3 | 6.9 | 6.8 | 6.6 | 6.5 | 6.2 | 6.1 | 5.6 |
| | 2/3 | 7.4 | 7.2 | 7.0 | 6.9 | 6.6 | 6.5 | 6.0 | 7.7 | 7.5 | 7.3 | 7.2 | 6.9 | 6.8 | 6.2 |
| | 3/4 | 8.3 | 8.1 | 7.9 | 7.8 | 7.4 | 7.3 | 6.7 | 8.7 | 8.5 | 8.2 | 8.1 | 7.8 | 7.6 | 7.0 |
| | 4/5 | 8.8 | 8.6 | 8.4 | 8.3 | 7.9 | 7.8 | 7.1 | 9.2 | 9.0 | 8.8 | 8.7 | 8.3 | 8.1 | 7.5 |
| | 5/6 | 9.2 | 9.0 | 8.7 | 8.7 | 8.3 | 8.1 | 7.4 | 9.6 | 9.4 | 9.1 | 9.0 | 8.6 | 8.5 | 7.8 |

| Modulation | Code rate | Scattered Pilot Pattern 5 & 6 GIF 1/128 [Mbit/s] | 1/32 [Mbit/s] | 1/16 [Mbit/s] | 19/256 [Mbit/s] | 1/8 [Mbit/s] | 19/128 [Mbit/s] | 1/4 [Mbit/s] | Scattered Pilot Pattern 7 & 8 GIF 1/128 [Mbit/s] | 1/32 [Mbit/s] | 1/16 [Mbit/s] | 19/256 [Mbit/s] | 1/8 [Mbit/s] | 19/128 [Mbit/s] | 1/4 [Mbit/s] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| QPSK | 1/2 | 1.5 | 1.4 | 1.4 | 1.4 | 1.3 | 1.3 | 1.2 | 1.5 | 1.4 | 1.4 | 1.4 | 1.3 | 1.3 | 1.2 |
| | 3/5 | 1.8 | 1.7 | 1.7 | 1.7 | 1.6 | 1.5 | 1.4 | 1.8 | 1.7 | 1.7 | 1.7 | 1.6 | 1.6 | 1.4 |
| | 2/3 | 2.0 | 1.9 | 1.9 | 1.8 | 1.8 | 1.7 | 1.6 | 2.0 | 1.9 | 1.9 | 1.9 | 1.8 | 1.7 | 1.6 |
| | 3/4 | 2.2 | 2.2 | 2.1 | 2.1 | 2.0 | 1.9 | 1.8 | 2.2 | 2.2 | 2.1 | 2.1 | 2.0 | 2.0 | 1.8 |
| | 4/5 | 2.4 | 2.3 | 2.2 | 2.2 | 2.1 | 2.1 | 1.9 | 2.4 | 2.3 | 2.3 | 2.2 | 2.1 | 2.1 | 1.9 |
| | 5/6 | 2.5 | 2.4 | 2.3 | 2.3 | 2.2 | 2.2 | 2.0 | 2.5 | 2.4 | 2.4 | 2.3 | 2.2 | 2.2 | 2.0 |
| 16-QAM | 1/2 | 2.9 | 2.9 | 2.8 | 2.8 | 2.6 | 2.6 | 2.4 | 3.0 | 2.9 | 2.8 | 2.8 | 2.7 | 2.6 | 2.4 |
| | 3/5 | 3.5 | 3.5 | 3.4 | 3.3 | 3.2 | 3.1 | 2.9 | 3.6 | 3.5 | 3.4 | 3.4 | 3.2 | 3.1 | 2.9 |
| | 2/3 | 3.9 | 3.8 | 3.7 | 3.7 | 3.5 | 3.5 | 3.2 | 4.0 | 3.9 | 3.8 | 3.7 | 3.6 | 3.5 | 3.2 |
| | 3/4 | 4.4 | 4.3 | 4.2 | 4.2 | 4.0 | 3.9 | 3.6 | 4.5 | 4.4 | 4.2 | 4.2 | 4.0 | 3.9 | 3.6 |
| | 4/5 | 4.7 | 4.6 | 4.5 | 4.4 | 4.2 | 4.1 | 3.8 | 4.8 | 4.7 | 4.5 | 4.5 | 4.3 | 4.2 | 3.9 |
| | 5/6 | 4.9 | 4.8 | 4.7 | 4.6 | 4.4 | 4.3 | 4.0 | 5.0 | 4.9 | 4.7 | 4.7 | 4.5 | 4.4 | 4.0 |
| 64-QAM | 1/2 | 4.4 | 4.3 | 4.2 | 4.1 | 3.9 | 3.9 | 3.6 | 4.4 | 4.3 | 4.2 | 4.2 | 4.0 | 3.9 | 3.6 |
| | 3/5 | 5.3 | 5.2 | 5.0 | 5.0 | 4.7 | 4.6 | 4.3 | 5.3 | 5.2 | 5.1 | 5.0 | 4.8 | 4.7 | 4.3 |
| | 2/3 | 5.9 | 5.8 | 5.6 | 5.5 | 5.3 | 5.2 | 4.8 | 5.9 | 5.8 | 5.6 | 5.6 | 5.3 | 5.2 | 4.8 |
| | 3/4 | 6.6 | 6.5 | 6.3 | 6.2 | 5.9 | 5.8 | 5.3 | 6.7 | 6.5 | 6.4 | 6.3 | 6.0 | 5.9 | 5.4 |
| | 4/5 | 7.1 | 6.9 | 6.7 | 6.6 | 6.3 | 6.2 | 5.7 | 7.1 | 7.0 | 6.8 | 6.7 | 6.4 | 6.3 | 5.8 |
| | 5/6 | 7.4 | 7.2 | 7.0 | 6.9 | 6.6 | 6.5 | 6.0 | 7.4 | 7.3 | 7.1 | 7.0 | 6.7 | 6.5 | 6.0 |
| 256-QAM | 1/2 | 5.9 | 5.7 | 5.6 | 5.5 | 5.3 | 5.2 | 4.8 | 5.9 | 5.8 | 5.6 | 5.6 | 5.3 | 5.2 | 4.8 |
| | 3/5 | 7.1 | 6.9 | 6.7 | 6.6 | 6.3 | 6.2 | 5.7 | 7.1 | 7.0 | 6.8 | 6.7 | 6.4 | 6.3 | 5.8 |
| | 2/3 | 7.9 | 7.7 | 7.5 | 7.4 | 7.1 | 6.9 | 6.4 | 7.9 | 7.8 | 7.5 | 7.5 | 7.1 | 7.0 | 6.4 |
| | 3/4 | 8.8 | 8.6 | 8.4 | 8.3 | 7.9 | 7.8 | 7.1 | 8.9 | 8.7 | 8.5 | 8.4 | 8.0 | 7.9 | 7.2 |
| | 4/5 | 9.4 | 9.2 | 9.0 | 8.9 | 8.5 | 8.3 | 7.6 | 9.5 | 9.3 | 9.1 | 9.0 | 8.6 | 8.4 | 7.7 |
| | 5/6 | 9.8 | 9.6 | 9.3 | 9.2 | 8.8 | 8.6 | 7.9 | 9.9 | 9.7 | 9.4 | 9.3 | 8.9 | 8.7 | 8.0 |

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## Annex 3: Nyquist time for frequency & time interpolation vs. guard interval

The theoretical time delay which a signal path may have with regard to the first signal path arriving at the receiver in order to still contribute constructively is the Nyquist time (labelled $T_n$ or $T_p$). For DVB-T this time is $T_u/3$, where $T_u$ designates the useful symbol length. For DVB-T2 this theoretical limit depends on the chosen scattered pilot pattern. In **§ 4.2.2** the theoretical background was explained and the theoretical limits for selected implementation scenarios were given.

In **Table A3.1** a comprehensive overview of the Nyquist time for the available combinations of guard interval and scattered pilot pattern in SISO mode is given.

**Table A3.1: Nyquist time for frequency and time interpolation vs. guard interval (SISO mode, 8 MHz bandwidth, elementary period T = 0.1094 µs, $T_u$: useful symbol length, struck-through text = not available)**

| | GIF | 1/128 | 1/32 | 1/16 | 19/256 | 1/8 | 19/128 | 1/4 |
|---|---|---|---|---|---|---|---|---|
| 32k | GI | 28.0 µs | 112.0 µs | 224.0 µs | 266.0 µs | 448.0 µs | 532.0 µs | ~~896.0 µs~~ |
| ($T_u$ = 3.584 µs) | $T_n$ (PP1) | ~~1194.7 µs~~ | ~~1194.7 µs~~ | ~~1194.7 µs~~ | ~~1194.7 µs~~ | ~~1194.7 µs~~ | ~~1194.7 µs~~ | ~~1194.7 µs~~ |
| | $T_n$ (PP2,3,8) | ~~597.3 µs~~ | ~~597.3 µs~~ | 597.3 µs | 597.3 µs | 597.3 µs | 597.3 µs | ~~597.3 µs~~ |
| | $T_n$ (PP4,5) | ~~298.7 µs~~ | 298.7 µs | 298.7 µs | 298.7 µs | ~~298.7 µs~~ | ~~298.7 µs~~ | ~~298.7 µs~~ |
| | $T_n$ (PP6,7) | 149.3 µs | 149.3 µs | ~~149.3 µs~~ | ~~149.3 µs~~ | ~~149.3 µs~~ | ~~149.3 µs~~ | ~~149.3 µs~~ |
| 16k | GI | 14.0 µs | 56.0 µs | 112.0 µs | 133.0 µs | 224.0 µs | 266.0 µs | 448.0 µs |
| ($T_u$ = 1.792 µs) | $T_n$ (PP1) | ~~597.3 µs~~ | ~~597.3 µs~~ | ~~597.3 µs~~ | ~~597.3 µs~~ | ~~597.3 µs~~ | ~~597.3 µs~~ | 597.3 µs |
| | $T_n$ (PP2,3,8) | ~~298.7 µs~~ | ~~298.7 µs~~ | 298.7 µs | 298.7 µs | 298.7 µs | 298.7 µs | 298.7 µs |
| | $T_n$ (PP4,5) | ~~149.3 µs~~ | 149.3 µs | 149.3 µs | 149.3 µs | ~~149.3 µs~~ | ~~149.3 µs~~ | ~~149.3 µs~~ |
| | $T_n$ (PP6,7) | 74.7 µs | 74.7 µs | ~~74.7 µs~~ | ~~74.7 µs~~ | ~~74.7 µs~~ | ~~74.7 µs~~ | ~~74.7 µs~~ |
| 8k | GI | 7.0 µs | 28.0 µs | 56.0 µs | 66.5 µs | 112.0 µs | 133.0 µs | 224.0 µs |
| ($T_u$ = 896 µs) | $T_n$ (PP1) | ~~298.7 µs~~ | ~~298.7 µs~~ | ~~298.7 µs~~ | ~~298.7 µs~~ | ~~298.7 µs~~ | ~~298.7 µs~~ | 298.7 µs |
| | $T_n$ (PP2,3,8) | ~~149.3 µs~~ | ~~149.3 µs~~ | 149.3 µs | 149.3 µs | 149.3 µs | 149.3 µs | 149.3 µs |
| | $T_n$ (PP4,5) | ~~74.7 µs~~ | 74.7 µs | 74.7 µs | ~~74.7 µs~~ | ~~74.7 µs~~ | ~~74.7 µs~~ | ~~74.7 µs~~ |
| | $T_n$ (PP6,7) | 37.3 µs | 37.3 µs | ~~37.3 µs~~ | ~~37.3 µs~~ | ~~37.3 µs~~ | ~~37.3 µs~~ | ~~37.3 µs~~ |
| 4k | GI | ~~3.5 µs~~ | 14.0 µs | 28.0 µs | ~~33.3 µs~~ | 56.0 µs | ~~66.5 µs~~ | 112.0 µs |
| ($T_u$ = 448 µs) | $T_n$ (PP1) | ~~149.3 µs~~ | ~~149.3 µs~~ | 149.3 µs | ~~149.3 µs~~ | 149.3 µs | ~~149.3 µs~~ | 149.3 µs |
| | $T_n$ (PP2,3,8) | ~~74.7 µs~~ | ~~74.7 µs~~ | 74.7 µs | ~~74.7 µs~~ | 74.7 µs | ~~74.7 µs~~ | 74.7 µs |
| | $T_n$ (PP4,5) | ~~37.3 µs~~ | 37.3 µs | 37.3 µs | ~~37.3 µs~~ | 37.3 µs | ~~37.3 µs~~ | 37.3 µs |
| | $T_n$ (PP6,7) | ~~18.7 µs~~ | 18.7 µs | 18.7 µs | ~~18.7 µs~~ | 18.7 µs | ~~18.7 µs~~ | 18.7 µs |
| 2k | GI | ~~1.8 µs~~ | 7.0 µs | 14.0 µs | ~~16.6 µs~~ | 28.0 µs | ~~33.3 µs~~ | 56.0 µs |
| ($T_u$ = 224 µs) | $T_n$ (PP1) | ~~74.7 µs~~ | ~~74.7 µs~~ | ~~74.7 µs~~ | ~~74.7 µs~~ | ~~74.7 µs~~ | ~~74.7 µs~~ | 74.7 µs |
| | $T_n$ (PP2,3,8) | ~~37.3 µs~~ | ~~37.3 µs~~ | ~~37.3 µs~~ | ~~37.3 µs~~ | 37.3 µs | ~~37.3 µs~~ | ~~37.3 µs~~ |
| | $T_n$ (PP4,5) | ~~18.7 µs~~ | 18.7 µs | 18.7 µs | ~~18.7 µs~~ | ~~18.7 µs~~ | ~~18.7 µs~~ | ~~18.7 µs~~ |
| | $T_n$ (PP6,7) | ~~9.3 µs~~ | 9.3 µs | ~~9.3 µs~~ | ~~9.3 µs~~ | ~~9.3 µs~~ | ~~9.3 µs~~ | ~~9.3 µs~~ |
| 1k | GI | ~~0.9 µs~~ | ~~3.5 µs~~ | 7.0 µs | ~~8.3 µs~~ | 14.0 µs | ~~16.6 µs~~ | 28.0 µs |
| ($T_u$ = 112 µs) | $T_n$ (PP1) | ~~37.3 µs~~ | ~~37.3 µs~~ | ~~37.3 µs~~ | ~~37.3 µs~~ | 37.3 µs | ~~37.3 µs~~ | 37.3 µs |
| | $T_n$ (PP2,3,8) | ~~18.7 µs~~ | ~~18.7 µs~~ | ~~18.7 µs~~ | ~~18.7 µs~~ | 18.7 µs | ~~18.7 µs~~ | ~~18.7 µs~~ |
| | $T_n$ (PP4,5) | ~~9.3 µs~~ | ~~9.3 µs~~ | 9.3 µs | ~~9.3 µs~~ | ~~9.3 µs~~ | ~~9.3 µs~~ | ~~9.3 µs~~ |
| | $T_n$ (PP6,7) | ~~4.7 µs~~ | ~~4.7 µs~~ | ~~4.7 µs~~ | ~~4.7 µs~~ | ~~4.7 µs~~ | ~~4.7 µs~~ | ~~4.7 µs~~ |

From the table it can be seen that in SISO mode (not in MISO mode) combinations of guard interval and scattered pilot pattern are available for which the Nyquist time is smaller than the guard interval (marked in red). It is questionable whether these combinations are feasible.

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## Annex 4: Specific Implementation Scenarios / Country situation

This annex gives an overview of the current status (Spring 2011) of DVB-T2 implementation in selected countries in Europe.

### *A4.1 Introduction of DVB-T2 in the UK*

The UK committed to adopting DVB-T2 in the spring/summer of 2008, primarily to facilitate delivery of HD services via the terrestrial network by the most efficient means possible. The aim was to introduce DVB-T2 as soon as possible so that viewers would have the opportunity to upgrade their receivers directly to DVB-T2 as they prepared for switchover, bypassing DVB-T.

At that time the T2 specification was not complete and no DVB-T2 transmission equipment was available on the market, nor were there any receivers. Furthermore, the UK was part-way through a detailed and complex digital switchover (DSO) programme involving some 3,100 stations. The DSO programme, scheduled for completion in late 2012, follows a regional basis as shown in **Figure A4.1**.

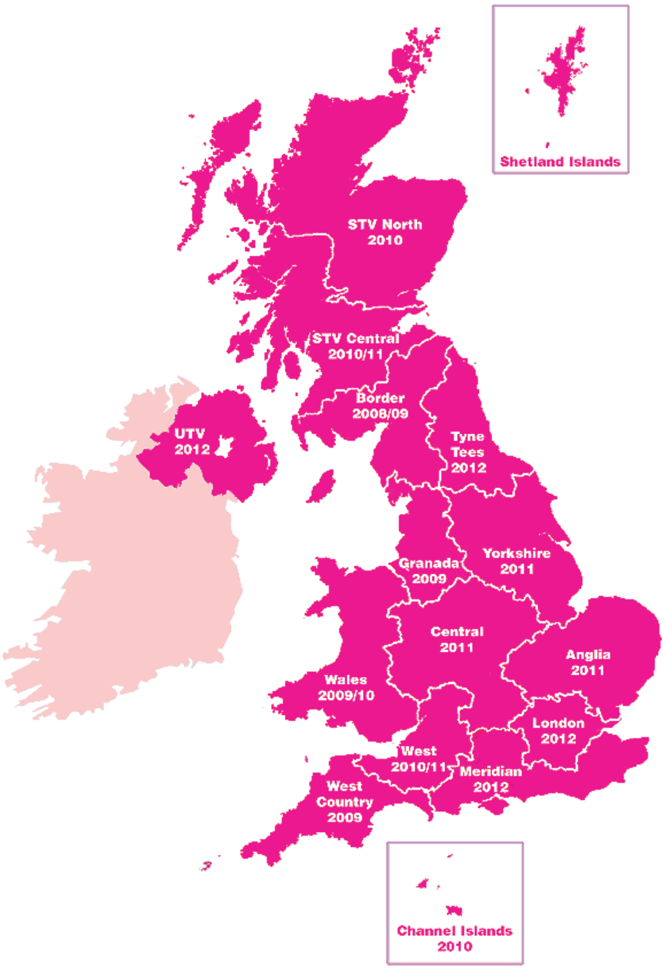


**Figure A4.1: UK DSO Regions and Timescales**

In order to successfully adopt T2 in a relatively aggressive timetable was set with a launch date planned for December 2009. The following section outlines the main steps in the launch plan and provides some detail for the main considerations in the project. A substantial amount of work was required by the many stakeholders in the project including: the regulator, broadcasters, infrastructure providers and equipment manufacturers as well as content providers.

### A4.1.1 UK T2 Rollout Process

#### A4.1.1.1 Timeline

The UK DVB-T2 programme broadly followed the high level timeline shown in **Figure A4.2**. Each of the major work streams shown is described briefly below.

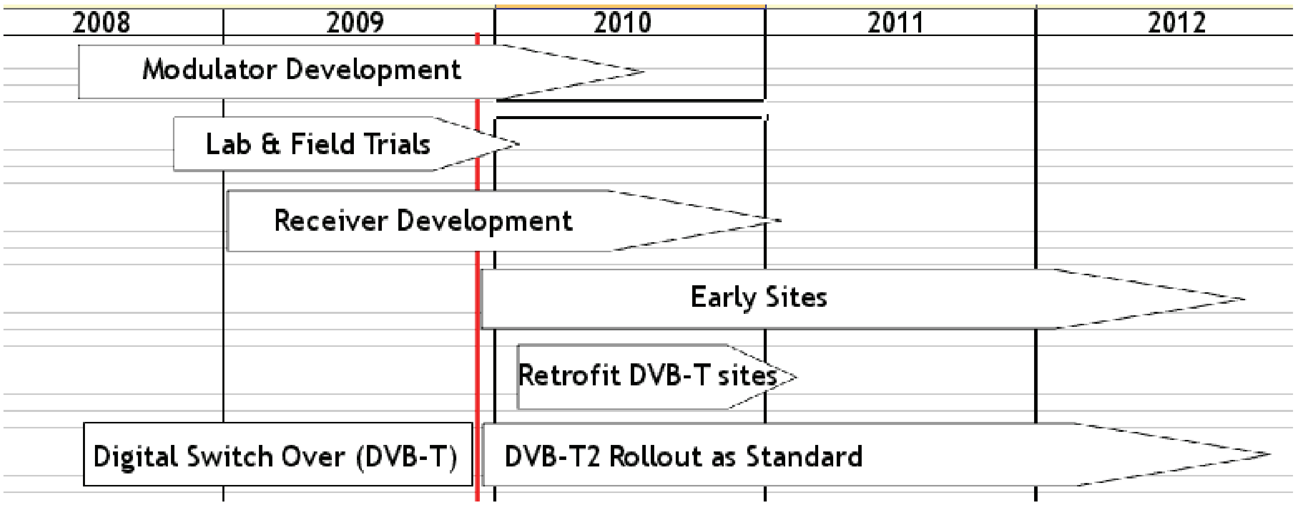


**Figure A4.2: High Level Timeline of UK T2 Rollout Programme. Red line shows T2 launch date**

#### A4.1.1.2 Modulator Development

The BBC began the world's first DVB-T2 compliant test transmissions on June 27 2008 from Guildford. Following this a number of manufacturers developed products which first came to market in 2009, ready for the UK T2 launch.

#### A4.1.1.3 Lab and Field Trials

The UK regulator Ofcom and the BBC ran field trials in conjunction with manufacturers to fulfil the following aims:

- Test and validate the DVB-T2 standard
- Determine the UK transmission mode
- Aid manufacturers' receiver development

Not all the possible modes in the DVB-T2 specification were tested as explained in the following section.

#### A4.1.1.4 Determination of Transmission Mode

Three main factors determined the UK mode for T2:

- PSB coverage requirement of 98.5% of the UK population.
- Re-use of existing broadcast infrastructure for practicality and to reduce implementation costs (a commercial requirement of the T2 specification). This implies the same ERP and antenna patterns as proposed for the DVB-T multiplex that was upgraded.
- Maximum capacity

The first two points above largely dictate a C/N for the T2 system within a dB or so of the post DSO DVB-T network.

Potential optimisation of the network based on other modes was not considered.

#### A4.1.1.5 Receivers

The UK stakeholders developed a minimum receiver specification for:

- Set top Boxes
- Integrated Digital TVs
- Digital Television Recorders

The DTG HD D-Book version 6 (March 2009) initially specified the technical system for use within the UK. Subsequent versions have since been released.

The UK broadcasters worked closely with a number of manufacturers to develop DVB-T2 products for launch in late 2009.

#### A4.1.1.6 Early Sites

It is apparent from **Figure A4.1** that that some key population areas would not receive the HD services until late in the DSO programme, with London planned to switch in 2012.

To increase the consumer market for receivers and to aid a successful launch, five 'early' T2 services were launched in the following key cities covering approximately seven million households.

- London
- Glasgow and Edinburgh
- Leeds/York
- Birmingham
- Newcastle, Sunderland, Middlesbrough

Furthermore, the following significant sporting events occur before HD services would be available in some of the above regions if no 'early' sites were introduced. Providing large cities with HD for these events is likely to increase T2 uptake.

- Football World Cup (June/July 2010)
- Rugby World Cup (September/October 2011)
- London Olympics (July 2012)

#### A4.1.1.7 Integration of T2 into the DSO Programme and Retrofit

The T2 launch began part-way through the pre-determined DVB-T rollout, meaning that some areas in the UK were entirely switched over to DVB-T by the time DVB-T2 launched, while others had a mixture of the pre-switchover analogue and low power DVB-T networks.

Beginning with the Granada region in late 2009, DVB- T2 was incorporated into the DSO programme and one PSB mux has been 'rolled out' with T2 as standard. Managing to do this at such an early stage in the DSO programme significantly simplified the consumer message and rapidly began growing the consumer market.

It was also necessary undertake a retro-fit programme to upgrade to T2 the areas of the UK such as the West Country that had already switched over and were operating as DVB-T only.

At that date, T2 will be rolled out as standard for one PSB service. Therefore it is also planned to introduce a programme to retrospectively fit (retro-fit) T2 in the stations already switched over to DVB-T.

To achieve these goals in a short time frame, a substantial amount of work has been undertaken by the many stakeholders in the project including the regulator, broadcasters, infrastructure providers and equipment manufacturers.

#### A4.1.1.8 Re-transmitters and Transposers

The regenerative relays in the DVB-T network require replacement or upgrade to make them suitable for DVB-T2. It is anticipated that a substantial portion of the DVB-T transposer network will continue to operate correctly with a DVB-T2 signal without modification, although some changes will be necessary to maintain the monitoring/alarm systems.

#### A4.1.1.9 SFNs

The UK network makes use of medium power SFNs in a small number of cases. One T2 Gateway is needed for each SFN to create the Management Interface (T2-MI) stream that enables the SFNs to work correctly. These devices were not required for DVB-T.

## *A4.2 Introduction of DVB-T2 in Finland*

In VHF there are two national multiplexes, HD1 and HD2, dedicated to DVB-T2 broadcasting. The coverage must be 60 per cent of the population in Finland by the end of 2011 according to the network licences. Both network licenses were granted to the network operator DNA in June 2009. In April 2011 two DVB-T2 HDTV multiplexes cover about 55% of the population. DNA is building the networks mainly on telecom sites with lower power transmitters.

In UHF dedicated to DVB-T2 broadcasting there are one national multiplex (mux-F) and one regional multiplex (HD3) covering Helsinki Metropolitan Area. Both network licences were granted to the network operator Anvia in April 2010 and the transmissions were started in February 2011. In April 2011 the national DVB-T2 HDTV multiplex covered about 60% of the population. Anvia is using the tall masts of Digita with high power transmitters.

Digita already operates 4 national DVB-T muxtiplexes plus one DVB-H multiplex; migration from DVB-T to DVB-T2 will take place in the future step by step.

Furthermore, in VHF there will be one regional DVB-T2 multiplex to cover about 90% of the population maximum. The network license will be granted in the near future.

## *A4.3 Introduction of DVB-T2 in Sweden*

HDTV was launched in the terrestrial network in Sweden on 1st of November 2010. Nine HDTV programmes have been awarded licenses, offering a mixture of existing programmes (simulcast SD & HD) and new programmes (HD exclusively). The public service broadcaster “Sveriges Television” has been awarded a license for two of its programmes (simulcast with SD).

The programmes are transmitted in two multiplexes, Multiplex 6 and 7, both using DVB-T2 MPEG-4. Multiplex 6 uses UHF frequencies only and will carry five programmes, while Multiplex 7 uses both UHF and VHF frequencies. For the UHF transmissions the extended bandwidth mode is used. For VHF this feature is not possible without exceeding the spectrum mask. Therefore the normal bandwidth mode is used for the VHF transmissions. Because of the slightly lower data rate possible for a 7 MHz channel and the normal bandwidth mode, the seventh multiplex carries one programme less, i.e. four programmes. The reason for using frequencies in the VHF band is the loss of the seventh UHF layer in certain areas as a consequence of the decision by the Government to use the frequency band 790 – 862 MHz for mobile services.

For Multiplex 7 about half of the transmitters will use VHF frequencies and the other half UHF frequencies. This is also reflecting the population coverage, where approximately half of the population will be reached by the VHF transmissions and the other half by the UHF transmissions. It is very important to inform the viewers about the fact that they might need a new VHF antenna to receive all the new services, especially in areas where frequencies in VHF Band III were not used for the analogue TV network.

In the network planning for the VHF transmissions a slightly lower antenna gain has been assumed, compared to what is common in previous planning documents for terrestrial television and in the GE06 Agreement, taking into account that the viewers might not be very keen on buying new big VHF antennas. The higher man-made noise level in VHF is also taken into account using a planning margin.

In March 2011 the two HDTV multiplexes covered just above 80% of the population. Nationwide coverage is expected to be reached