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INTERNATIONAL STANDARD

Mobile and portable DVB-T/H radio access –
Part 1: Interface specification

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MOBILE AND PORTABLE DVB-T/H RADIO ACCESS –

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FOREWORD

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International Standard IEC 62002-1 has been prepared by technical area 1: Terminals for audio, video and data services and content, of IEC technical committee 100: Audio, video and multimedia systems and equipment.

This second edition cancels and replaces the first edition, published in 2005 and constitutes a technical revision.

The main changes with respect to the previous edition are listed below.

- DVB-H has been included as a part of the main specification.
- All the performance figures have bee revised as new simulation results have been made available as well as new reference receivers for DVB-H have been developed.
- DVB-H now includes all the different MPE-FEC code rates.
- New portable indoor and portable outdoor channel models have been included as well as performance figures for those.
- A new 2x TU-6 mobile SFN test channel has been included.

- A new L4 linearity pattern has been added.
- Dedicated performance figures for DVB-H for S1, S2, L1 to L4 interference patterns have been included.
- A new GSM-interference measurement method has been added.

The text of this standard is based on the following documents:

CDV	Report on voting
100/1289/CDV	100/1381/RVC

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts of the IEC 62002 series, under the general title *Mobile and portable DVB-T/H radio access*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed;
- withdrawn;
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

The contents of the corrigendum of July 2008 have been included in this copy.

MOBILE AND PORTABLE DVB-T/H RADIO ACCESS –

Part 1: Interface specification

1 Scope

This part of IEC 62002 is a radio access specification for mobile, portable and hand-held portable devices capable of receiving DVB-T/H services. It includes informative system aspects as well as specifications for minimum RF-performance. It covers terminals in three main classes, namely integrated car terminals, portable digital TV sets and hand-held portable convergence terminals. Interoperability with integrated cellular radios is also considered. The specification covers the following areas.

- Frequency ranges
- Supported modes
- Definition of receiving conditions
- Definition of the receiver RF-reference model
- Definition of degradation criteria
- Antenna characteristics
- Channel models
- C/N-performance with different channels
- Minimum and maximum input levels
- Immunity to interfering signals
- Definition of an ensemble of interference patterns
- Tolerance to impulse interference
- SFN-performance
- Transmitter minimum performance
- Interoperability of cellular radios
- EMC aspects

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

CISPR 13, *Sound and television broadcast receivers and associated equipment – Radio disturbance characteristics – Limits and methods of measurement*

CISPR 20, *Sound and television broadcast receivers and associated equipment – Immunity characteristics – Limits and methods of measurement*

IEC 60169-2, *Radio-frequency connectors – Part 2: Coaxial unmatched connector*

ETSI EN 300 744:2007, *Digital Video Broadcasting (DVB); Framing structure, Channel coding and modulation for digital terrestrial television, V1.5.2*

ETSI ETS 300 342-1, *Radio Equipment and Systems (RES); ElectroMagnetic Compatibility (EMC) for European digital cellular telecommunications system (GSM 900 MHz and DCS 1 800 MHz); Part 1: Mobile and portable radio and ancillary equipment*

ETSI EN 300 607-1, *Digital cellular telecommunications system (Phase 2+) (GSM) – Mobile Station (MS) conformance specification – Part 1: Conformance specification*

ETSI EN 302 304:2004, *Digital Video Broadcasting (DVB); Transmission System for Handheld Terminals (DVB-H), V1.1.1*

ETSI TR 101 190 V1.2.2, *Digital Video Broadcasting (DVB); Implementation guidelines for DVB terrestrial services; Transmission aspects*

ITU-R BT.1701-1, *Characteristics of radiated signals of conventional analogue television systems*

3 Abbreviations

For the purposes of this document, the following abbreviations apply.

λ	Lambda, wavelength (λ = c/f)
A2	German analogue TV-stereo system
A_A	Coupling between antennas
AGC	Automatic gain control
A_{GSM}	Stop band attenuation of the GSM reject filter
B	Bandwidth
BER	Bit error ratio
C	Carrier power [In band carrier power including any echoes]
C	Speed of light c = 3,0x10^8 m/s
Ci	Power contribution from the i-th signal
Ct	Total useful carrier power
C/N	Carrier to noise ratio
C/N_{min}	Minimum C/N
CPE	Common phase error
CR	Code rate
dB	Decibel
dBc	dB compared to carrier power C
dBd	Antenna gain in dB compared to reference dipole (0 dBd = –2,14 dBi)
dBi	Antenna gain in dB compared to isotropic antenna (0 dBi = 2,14 dBd)
dB(mW)	Power in dB compared to 1 mW
DVB, DVB-T	Digital video broadcasting, terrestrial digital video broadcasting
DVB-H	Digital video broadcasting to hand-held terminals
DVB-RCT	DVB terrestrial return channel
E	Field strength V/m
E(dBµV/m)	Field strength in dB compared to 1 µV
EDGE	Enhanced data rates for GSM/Global evolution

EMC	Electromagnetic compatibility
END	Equivalent noise degradation
ENF	Equivalent noise floor
ESR	Erroneous second ratio
F	Frequency in Hz
f (MHz)	Frequency in MHz
Fc	Centre frequency
F	Noise factor
Fd, Fd	Doppler frequency
Fd_{3dB}	Doppler frequency with minimum *C/N* requirement raised by 3 dB
FER	Frame error rate
G	Gain
Ga	Antenna gain
GI	Guard interval
GPRS	General packet radio service
GSM	Global system for mobile communications
I	Interfering power
Im	Implementation margin
ICI	Intercarrier interference
J	joule
k	Boltzmann's constant $k = 1{,}38 \times 10^{-26}$ J/K
K	kelvin
L1, L2, L3, L4	Linearity patterns
L_{GSM}	Insertion loss of the GSM reject filter
LNA	Low noise amplifier
MER	Modulation error ratio
MFER	MPE-FEC frame error rate
MHz	Megahertz
MPE-FEC	Multi Protocol Encapsulation Forward Error Correction
MPEG-2	Motion pictures expert group, video compression standard
N, m, N	Channel indexes
NF	Noise figure in dB
NICAM	Additional sound carrier for analogue TV, modulated with a near instantaneous companded audio multiplex.
PA	Power amplifier
PAL, PAL B, PAL G, PAL I, PAL I1	Phase alternation line, TV-systems using PAL
PER	Packet error ratio
P_{in}	Input power W
P_{in} (dB(mW))	Input power dB compared to 1 mW
P_{max}	Maximum power

P_{min}	Minimum power
ppm	Parts per million
PSI/SI	Program specific information, service information
P_{TX}	Transmission power
P_x	Excess noise power dBc
QAM16, QAM64	Quadrature amplitude modulation, 16-level and 64-level versions
QEF	Quasi error free
QoS	Quality of service
QPSK	Quaternary phase shift keying
R_{DQEF}	Minimum level of performance
RF	Radio frequency
RS	Reed Solomon
Rx	Receiver
S1,S2	Selectivity patterns
SECAM, SECAM L	Sequential à mémoire, TV-system using SECAM
SFN	Single frequency network
SFP	Subjective failure point
T	Temperature in kelvin
Tc	Corner point
Te	Total duration of the gating pulses
Ti	Time of arrival for the i-th signal
TPS	Transmission Parameter Signalling
TS	Transport stream
Tg	Guard interval duration
Tu	Active symbol duration
Tx	Transmitter
UHF	Ultra high frequency
UMTS	Universal mobile telecommunications system
VHF	Very high frequency
W	watt
WCDMA	Wide-band code division multiple access
Wi	Weighting coefficient for the i-th component

4 Terminal categories

In this standard three different terminal categories are considered. The requirements are covering all categories unless otherwise stated.

The terminal categories are:

a) Integrated car terminals

This category covers DVB-T/H terminals installed in a car and where the antenna is integral with the car.

b) Portable digital TV sets

This category covers terminals, which are intended for receiving normal DVB-T MPEG-2 based digital TV services indoors and outdoors with terminal attached antennas. This category is divided into two subcategories.

1) The receiver screen size is typically greater than 25 cm and the receiver may be battery or mains powered. Typically, the terminal is stationary during the reception. An example of the antenna construction may be an adjustable telescope or wide-band design, either active or passive, attached to the receiver.

2) Pocketable digital TV-receiver. The terminal is battery operated and can be moved during use. Usually the antenna is integral with the terminal.

c) Hand-held portable convergence terminals

This category covers small battery powered hand-held convergence terminals with built in cellular radio like GSM, GPRS or UMTS. The terminals have the functionality of a mobile phone and can receive IP-based services using DVB-H over DVB-T physical layer. The DVB-T antenna and the cellular antenna are both integral with the terminal.

5 Definition of receiving conditions

5.1 Portable reception

This is when a portable receiver (terminal category b1) with an attached or integral antenna is used indoors or outdoors at a minimum height of 1,5 m above floor or ground level. It is assumed that the receiving antenna is omni-directional. It is also assumed that the antenna and any nearby large objects are stationary. Extreme cases, such as reception in completely shielded rooms, are disregarded. [1][1)]

As a special case of portable reception a small hand-held portable receiver (terminal category b2 or c) is used indoors or outdoors at a minimum height of 1,0 m above floor or ground level. It is assumed that the receiving antenna is omni-directional. It is also assumed that the channel conditions can change due to slow movements (≤3 km/h) of the antenna and any nearby large objects. Extreme cases, such as reception in completely shielded rooms, are disregarded.

The main difference between portable and hand-held portable reception is the antenna gain of the terminal.

5.2 Mobile reception

This applies to the use of integrated car terminals (terminal category a) with speeds higher than 3 km/h. It is assumed that the receiving antenna is omni directional with a minimum height above ground level of 1,5 m. Other vehicles such as buses or high-speed trains could be considered as special cases.

A small hand-held portable receiver (terminal category b2 or c) used within a car or train could also be considered as a case of mobile reception. [2]

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1) Figures in square brackets refer to the Bibliography.

6 Frequencies and channel bandwidths

6.1 Channel frequencies

The channel frequencies of bands III, IV and V are given below 6 MHz, 7 MHz and 8 MHz channel rasters are used in various countries. The centre frequencies fc of the incoming DVB-T RF-signals are the following.

VHF III

For countries using 8 MHz channel raster

fc = 178 MHz +(N-6) × 8 MHz +f $offset$

N = {6, …,12} (VHF channel number)

For countries using 7 MHz channel raster

fc = 177,5 MHz +(N-5) × 7 MHz +f $offset$

N = {5, …,12} (VHF channel number)

For countries using 6 MHz channel raster

fc = 177,0 MHz + (N-7) × 6 MHz +f $offset$

N = {7, …,13} (VHF channel number)

In some countries offsets may be used:

Preferred offset is ± n × 1/6 MHz. n = { 1, 2,…}

UHF IV and V

For countries using 8 MHz channel raster

fc = 474 MHz + (N-21) × 8 MHz +f $offset$

n = {21, …,69} (UHF channel number)

For countries using 7 MHz channel raster

fc = 529,5 MHz +(N-28) × 7 MHz +f $offset$

n = {28, …,67} (UHF channel number)

For countries using 6 MHz channel raster

fc = 473,0 MHz +(N-14) × 6 MHz +f $offset$

n = {14, …,83} (UHF channel number)

In some countries offsets may be used:

Preferred offset is ± n × 1/6 MHz. n = { 1, 2,…}
In the UK n = 1.

The error in the centre frequency (fc) of the transmitted RF-signal should not exceed 500 Hz in MFN. In SFN the error in the centre frequency (fc) of the transmitted RF-signal should not exceed 1 Hz.

6.2 Supported frequency ranges

The receivers in terminal categories a and b1 shall be able to receive all channels in the VHF band III and UHF bands IV and V. VHF III can be left out in market areas, where it is not used. The receivers in terminal category b2 shall be able to receive all channels in UHF bands IV and V, VHF III is an option depending on the market area needs. The receivers in terminal category c shall be able to receive all channels in UHF band IV and V, provided that the terminal does not support GSM 900.

In case GSM 900 is used in a convergence terminal (category c), the usable frequency range is limited to channel 55 [746 MHz] due to the interoperability considerations. Supported frequency ranges are shown in Table 1.

Table 1 – Supported frequency ranges

Terminal category		VHF III	UHF IV	UHF V
a	Integrated car terminals	Yes, in areas where VHF is in use for DVB-T.	Yes	Yes
b1	Portable digital TV-sets	Yes, in areas where VHF is in use for DVB-T.	Yes	Yes
b2	Pocketable TV-sets	Optional	Yes	Yes
c	Convergence terminals	No	Yes	Yes / up to ch 55 See text above

6.3 Supported bandwidths

The receiver should support the 6 MHz, 7 MHz and 8 MHz bandwidths according to the market area needs. 5 MHz variant of DVB-H exists, but is not covered in this specification.

7 DVB-T/H modes

7.1 Supported DVB-T/H modes

The receiver shall be capable of correctly demodulating all modes specified in ETSI EN 300 744, except the code rates 5/6 and 7/8. The front end shall therefore be able to work with any combination of

- constellation (QPSK, 16-QAM, 64-QAM, hierarchical 16-QAM, hierarchical 64-QAM),
- code rate (1/2, 2/3, 3/4),
- guard interval (1/4, 1/8, 1/16 or 1/32),
- transmission mode (2k or 8k),
- where applicable α (1, 2 or 4).

Receivers in terminal category c should be capable of correctly demodulating the modes specified in EN 300 744, Annex F, additional features for DVB hand-held terminals (DVB-H). Optionally, receivers in other terminal categories can also support DVB-H. The front end in this case should therefore also be able to support

- 4k transmission mode,
- in depth interleavers usable in 2k and 4k modes.

During channel search, the receiver shall automatically detect which mode is being used. The receiver, when fed with one of the hierarchical modes (16-QAM or 64-QAM) specified in ETSI EN 300 744, shall be capable of correctly demodulating whichever of the high or low priority streams is selected by the user.

7.2 Change of modulation parameters

Dynamic change of modulation parameters during the transmission (signalled in the TPS-data) does not have to be supported by the receiver. If this happens, then a new channel search may be required in order to detect which mode is being used.

7.3 Tuning procedure

The receiver shall be able to provide a channel search. It shall also be able to receive information regarding tuning parameters found in PSI/SI.

8 Transmitter performance

8.1 Transmitter noise-like impairments

8.1.1 Noise-like processes

Many of the impairments introduced by transmitters are said to be 'noise-like', because their effect is equivalent to the addition of white Gaussian noise. This equivalence enables the overall 'noise' power to be calculated by summing the 'noise' powers introduced by the individual impairments. It is then approximately true that the total equivalent noise degradation (*END*), as defined in the following paragraph, equals the sum of the contributing *END*s.

The impairments considered to be noise-like are the following.

- Finite precision in the OFDM modulator and other digital processing stages.
- High-frequency phase noise introduced by local oscillators and timing references; that is, those phase noise components occurring at offset frequencies greater than half the OFDM carrier spacing.
- Thermal noise.
- Intermodulation products resulting from non-linearity in the transmitter chain.
- Amplitude errors. (Work carried out by the Digital Television Group (DTG) has confirmed this to be a noise-like impairment.)

Impairments that cannot be considered as being equivalent to the addition of white Gaussian noise are the following.

- Group delay errors.
- Low-frequency phase noise.

These "further transmitter impairments" are considered in 8.2.

A transmission chain should be designed such that its *END* does not exceed 0,5 dB.

A typical signal analyser makes a measurement of the noise remaining in the channel once the OFDM signal has been stripped away. The result is expressed as an *ENF* or a modulation error ratio (*MER*). (When measured in dB, *ENF* and *MER* are numerically identical but of opposite sign: *ENF* equals the ratio of noise power to OFDM carrier power, while *MER* is effectively the ratio of carrier power to noise power.) The *MER* is converted into *END* by means of the following formula:

$$1/END = 1 - \{(C/N)_{\mathrm{ref}} / MER\},$$

where $(C/N)_{\mathrm{ref}}$ is the carrier-to-noise ratio at which the monitoring receiver gives the reference *BER*. The quantities here are all expressed in linear terms. Expressing them in more convenient dB gives Table 2:

Table 2 – Conversion of *MER* to *END*

MER – *(C/N)*$_{\text{ref}}$ dB	*END* dB
12	0,283
13	0,223
14	0,176
15	0,140
16	0,110
17	0,088
18	0,069
19	0,055
20	0,044
23	0,022
26	0,011

$(C/N)_{\text{ref}}$ also has to be determined: it is the carrier-to-noise ratio at which the monitoring receiver gives the reference *BER*. For the 64QAM 2/3 mode, this may be taken as 19 dB: the theoretical figure is 16,7 dB, to which must be added the implementation margin for the channel equaliser within the receiver. Slight errors (within 0,5 dB) are unimportant.

MER measurements do not take into account amplitude response errors: they look for 'real' noise appearing on the OFDM signal, not the 'virtual' noise introduced by response errors. The 'calibrated' test transmitter is likely to be nearly 'perfect' in this respect, but an allowance should be made. Reference [10] provides the following formula for the 64 QAM 2/3 mode:

$$END\ (\text{dB}) = 0{,}021 \times (\text{amplitude response ripple, dB pk-pk})^2$$

As an example, suppose the *MER* of the test transmitter is 39 dB, and it possesses an amplitude response ripple of 0,5 dB peak-to-peak. The $(C/N)_{\text{ref}}$ of the receiver is 19 dB. The *END* of the test transmitter is made up of two contributions:

$MER - (C/N)_{\text{ref}}$ = 39 dB – 19 dB = 20 dB

END_1 = 0,044 dB (from Table 2)

The contribution from the amplitude response ripple is given by:

END_2 = $0{,}021 \times (0{,}5)^{2}$ dB

= 0,005 dB

The total *END* ($END_1 + END_2$) of the test transmitter is therefore 0,049 dB.

8.2 Further transmitter impairments

8.2.1 Group delay errors

At the input to antenna feeder, the delay of any OFDM-carrier relative to that of any other should not exceed 500 ns.

This value may be measured by exciting the first analogue up-converter with a frequency sweep waveform and examining the group delay response into the input to antenna feeder. Note that most of the group delay errors are likely to be introduced by any high-power filters and combiners.

8.2.2 Phase noise in OFDM systems

Phase noise is introduced by local oscillators and timing references within the transmission chain. If a noisy oscillator signal is viewed on a spectrum analyser, the phase noise appears as sidebands symmetrically disposed about the oscillator centre frequency. Away from the centre frequency, the sideband density generally falls off rapidly. Oscillator phase noise degrades the signal because, in the frequency conversion process, the noise is transferred from the oscillator to each of the carriers within the OFDM ensemble.

Phase noise is specified by quoting $L(f)$, the single sideband phase noise power in a 1 Hz bandwidth at a frequency f from the centre frequency. The unit of $L(f)$ is dBc/Hz, the "c" signifying that the reference is the total power of the oscillator. Oscillator manufacturers normally provide plots of $L(f)$ versus f.

At the receiver demodulator, the phase noise has two different effects. Low-frequency noise gives rise to common phase error (*CPE*) – "common" because each of the OFDM carriers suffers the same phase error. In principle, this error can be measured and removed by the demodulator. High-frequency noise introduces intercarrier interference (*ICI*). The noise from one carrier becomes superimposed upon the neighbouring carriers within the ensemble, and cannot be removed by the demodulator. Because *CPE* and *ICI* are different in their effect, they must be specified differently.

ICI may be calculated approximately by integrating $L(f)$ for all values of f above half the OFDM carrier spacing and for all carriers within the ensemble. (An accurate calculation makes use of weighting functions; see, for instance, [11].) The result is a contribution to the system noise floor, or *ENF*, which may be measured in the way described in section 11.7.2 of [6]. As *ICI* is genuinely "noise-like", the *END* may be calculated by reference to Table 2.

An approximate value of *CPE* is given by integrating $L(f)$ for all values of f below half the OFDM carrier spacing and for a single carrier within the ensemble. (Again, an accurate calculation makes use of weighting functions.) The result is expressed in dB relative to 1 radian^2, or dB(rad^2). The actual effect of *CPE* depends strongly on the receiver design. For a transmission to be compliant with all possible receiver designs, it is recommended that the total *CPE* for all values of f greater than 10 Hz should not exceed –40 dB(rad^2).

Where the phase noise spectrum is known, the *ICI* and *CPE* components may be calculated by reference to [12].

8.2.3 OFDM clock frequency

The error in the clock frequency of the transmitted OFDM signal should not exceed 3×10^{-6}.

8.3 Spectrum masks

The spectrum masks specified in this subclause are designed to prevent interference between digital terrestrial TV transmissions, analogue terrestrial TV transmissions and other transmissions. Transmissions conforming to these masks will not necessarily be acceptable in other respects. For example, the amount of transmitter non-linearity implied by subclause 8.3.1 could give rise to an excessive *END*. Receiver manufacturers should note that transmissions outside bands IV and V could cause interference if the receivers are not suitably designed; GSM (900 MHz) and Tetra (380 MHz to 470 MHz) are such transmissions. The masks may be changed in a future edition of this standard.

8.3.1 DVB-T signals (general)

All DVB-T emissions shall at least meet the spectrum mask requirements defined by ETSI EN 300 744 chapter 4.8.2 for system B/G/I/K/L environments.

8.3.2 DVB-T signals (critical cases)

Where the DVB-T transmission is at the edge of the UHF band, or adjacent to sensitive non-broadcast applications, a second spectrum mask with higher out-of-channel attenuation shall be used. The requirements are given in ETSI EN 300 744 chapter 4.8.2.

8.3.3 DVB-T signals (DVB-T in adjacent channel)

At sites where a DVB-T transmission is present in the adjacent channel, additional restrictions on the transmitted sideband energy may be necessary. Work has shown that, if the two transmissions are to be received with a level difference of 25 dB, the total sideband power in the adjacent channel should not exceed –60 dBc. (This interference level corresponds to an *END* of 0,1 dB for the 64QAM 2/3 modulation mode.)

9 Receiver antenna characteristics

9.1 Antennas for terminal category a

The practical standard antenna for car reception is $\lambda/4$ monopole which use the metallic roof as ground plane.

The antenna gain for conventional incident wave angles depends on the position of the antenna on the roof. For passive antenna systems the following values can be expected:

VHF III	–3 dBi
UHF IV	0 dBi
UHF V	1 dBi

The polarisation discrimination is theoretically about 4 dB to 10 dB depending on the roof position of the antenna, centre of roof giving higher figures.

The horizontal polarisation of the transmitted signal will be influenced by the environment in the propagation path. According to these unpredictable effects, the polarisation discrimination will be less than the theoretical values, but reliable statements can not be made.

The philosophy of the car industry is to integrate the antennas into the windows resulting lower antenna gain. However, the use of diversity system combined with active antennas will enhance the performance significantly.

The dimensioning of the diversity system and the amplifiers should compensate the lower gain and the notches in the radiation pattern of the single screen antennas to achieve a similar reception quality compared with the single roof monopoles mentioned above. The diversity system also partially compensates polarisation discrimination effects.

9.2 Antennas for terminal category b1

In Chester 97 [1], it is assumed that the antenna of a portable receiver intended for indoor or outdoor reception is omni-directional and that the gain relative to $\lambda/2$ dipole is 0 dBd for a UHF antenna and –2,1 dBd for a VHF III antenna. To achieve these gains it is probably assumed that the rod type antenna length is adjusted to be optimum for each reception frequency.

However, an individual adjustment of the antenna length to the current frequency is not practicable. As consequence of it, a fixed length must be chosen. An acceptable value could be 100 mm to 150 mm. This corresponds to a $\lambda/4$ rod antenna for UHF IV / V.

For a passive version of an attached antenna the following gain values are typically:

VHF III	–6 dBi
UHF IV	–1 dBi
UHF V	0 dBi

The preferential direction for the best reception differs because of the use for portable reception. In addition to this reason, the position of the antenna at the receiver could be variable.

No polarisation discrimination can be expected in VHF III.

In UHF IV / V a polarisation discrimination up to 6 dB is possible.

9.3 Antennas for terminal category b2 and c

The antenna solution in a small hand-held terminal has to be an integral part of the terminal construction and will therefore be small when compared to the wavelength. If the antenna has to cover the whole wide tuning range, it probably has to be matched with a tunable matching circuit. The resistive part of antenna impedance (radiation resistance), which is to be matched to the receiver input impedance, will be rather small due to the small size of the antenna (< 1/10 λ). This leads to rather high losses and to a low overall efficiency. Moreover, in this type of terminal the ground plane does not function any more, but acts as a radiator. However, even the size of the radiating ground plane is small when compared to the wavelength resulting low radiation efficiency.

Another issue is the influence of the user on the radiation characteristic of the antenna.

Depending on the relative position of the user to the hand-held terminal, the human body could act as an absorber or a reflector.

Current understanding of the design problem indicates that the typical antenna gain at the lowest UHF-band frequencies would be in the order of –10 dBi increasing to –5 dBi at the end of UHF-band. Nominal antenna gain between these frequencies can be obtained by linear interpolation.

In case GSM 900 is used in a convergence terminal (category c), the usable frequency range is limited to channel 55 [746 MHz] due to the interoperability considerations. In case GSM 900 is not used, this limitation does not apply.

Generally, no polarisation discrimination can be expected from this type of portable reception antenna and the radiation pattern in the horizontal plane is omni-directional.

Typical gain of the antenna is presented in Table 3.

Table 3 – Typical antenna gain for terminal category b2 and c

Frequency MHz	**Gain** dBi
474 [channel 21]	–10
698 [channel 49]	–7
858 [channel 69]	–5

9.4 External antennas

9.4.1 General

External active or passive antennas may be used. More information about external active antennas is found in Annex A.

9.4.2 External antennas for terminal category b2 and c

Urban indoor reception is often affected by high levels of building penetration losses. Therefore, in some cases it might be difficult to guarantee the appropriate reception quality using low gain integrated antennas as explained in the subclause 9.3 In these cases, the following solutions could be foreseen.

- Use of an external antenna instead of integrated antenna.
- Use of wired headsets as the external antenna.
- Provision of an antenna connector, to facilitate the use of a user-connected external antenna.
- In case that only integrated antenna is available, the use of indoor / in-vehicle gap fillers.

The achievable antenna gain in case of external antenna depends on the specific implementation. The expected range of values is between –3 dBi and +3 dBi, an improvement of about 7 dB with respect to an integrated antenna.

9.4.3 External antenna connector

External antenna connector may be provided in all terminal categories. For terminal category b1, the connector shall be IEC female in accordance with IEC 60169-2. The input impedance of this shall be 75 Ω.

The input connector for terminal category b1 can, as an optional feature, provide a supply of DC-power. This supply would be used for powering external equipment such as masthead amplifiers, distribution amplifiers and active indoor antennas. It must be switchable, and must be able to recover from the large inrush currents taken by high value capacitors within the external equipment. A specification for such a supply is given in Table 4.

Table 4 – Specification for optional antenna supply

Parameter	Value	See NOTE
Voltage in ON state	+5,0 V	
Voltage tolerance	±0,2 V	1, 2
Maximum load current	30 mA	3
Maximum load capacitance	100 μF	4
Resistance in OFF state	47 kΩ – 1 MΩ	5
Protection: externally applied voltages	±15 V DC	6
Default state (new receiver)	OFF	
State following receiver power-up	Last known	7

NOTE 1 The specified voltage and tolerance apply at the centre pin of the antenna connector (relative to the outer conductor ground) at any load current between zero and the specified maximum.

NOTE 2 The power supply, when enabled by the user, shall remain present when the receiver is in the STANDBY state.

NOTE 3 Continuous short-circuit protection shall be provided. This must operate when a resistance of 10 Ω or below is connected to the antenna socket. Recovery from a short-circuit condition should be automatic, without a user "reset" being required.

NOTE 4 The devices to be powered may incorporate decoupling and filtering capacitors. The supply should be able to start up into any load capacitance up to the specified maximum without tripping any protection circuit. In addition, the supply should handle the connection of the load when the output voltage is already present ("hot-plugging").

NOTE 5 In the OFF state the DC resistance measured at the antenna input shall be in the specified range. The upper limit is intended to prevent the accumulation of atmospheric 'static' charge from an antenna.

NOTE 6 In either the ON or OFF state, the receiver shall be undamaged by connection of an external DC voltage in the specified range.

NOTE 7 When not in use, the receiver shall remember the state of the power supply and restore it promptly after repowering.

10 Receiver performance

10.1 Reference model

The receiver performance is defined according to the reference model shown in Figure 1.

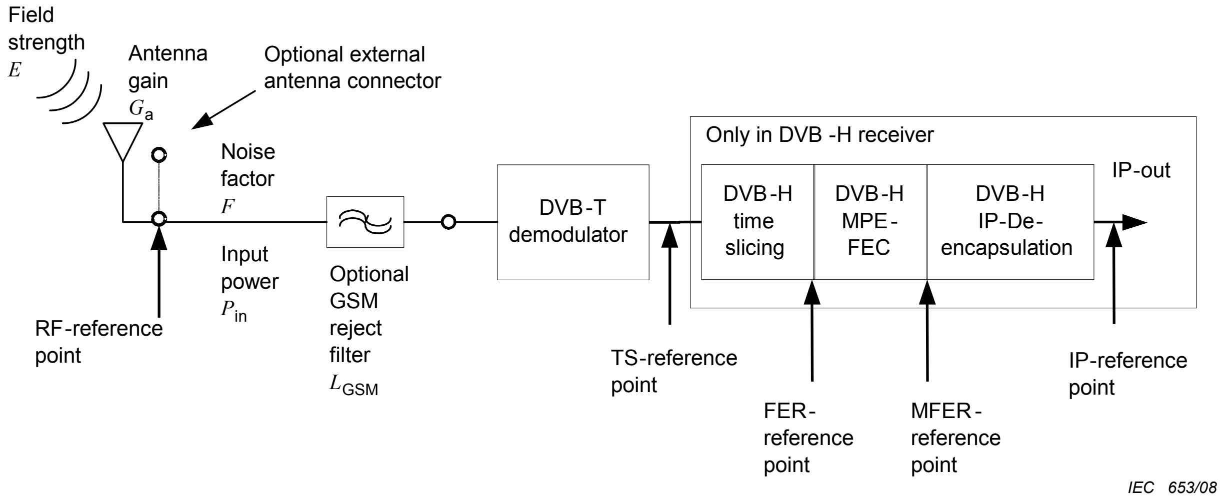


Figure 1 – Reference model

All the receiver performance figures are specified at the reference point, which is the input of the receiver.

Relation between field strength and input power is:

$$E = \frac{f}{c} \cdot \sqrt{4\pi\eta \frac{P_{\text{in}}}{G_{\text{a}}}}$$

where η = 120 π Ω.

Practical formula in dB:

$$E = P_{\text{in}} - G_{\text{a}} + 77{,}2 + 20\log_{10} f$$

where

E is the field strength in dB(μV/m);

P_{in} is the input power in dB(mW);

G_{a} is the antenna gain in dB;

f is the frequency in MHz.

10.2 Noise model

A useful model for calculating noise performance is illustrated in Figure 2 [6]. The terminology used is as follows:

C = Signal input power (W) of the DVB-T ensemble

k = Boltzmann's constant (1,38 × 10^{-23} J/K)

T = Reference temperature (290 K)

B = System noise bandwidth (7,61 MHz, 6,65 MHz or 5,71 MHz)

The model comprises the following representative components.

- A front-end stage with system noise factor F_{sys} and ‘perfect’ automatic gain control (AGC). The action of the AGC is to provide a power gain of $1/C$, and so the tuner output is unity as a consequence.
- An excess noise source of power P_x. Note that, by normalising the carrier power to unity at the tuner output, the relative value P_x can be added directly at this point.
- A practical but unimpaired demodulator; that is, a demodulator with a fast channel equaliser and a consequent implementation margin according Table 5.

Table 5 – Modulation versus implementation margin

Modulation	Im dB
QPSK	1,1
16 QAM	1,3
64 QAM	1,5

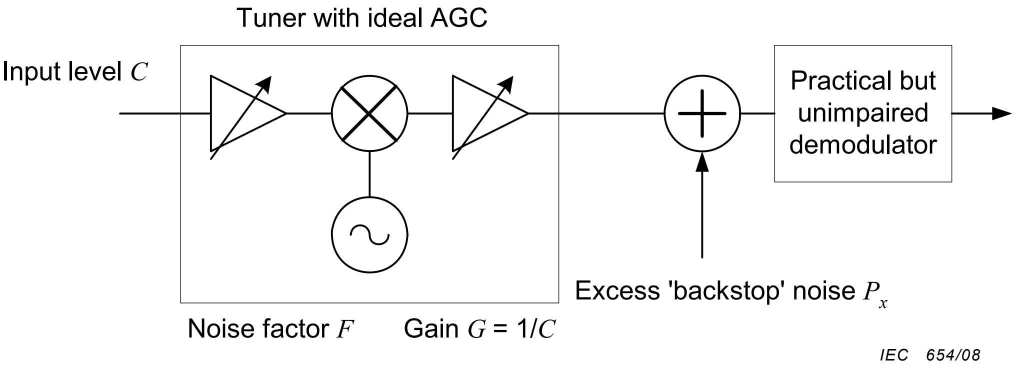


Figure 2 – Noise model

Note that the relative excess noise P_x is the sum of contributions from all stages in the signal chain. Significant contributions could include

- local oscillator phase noise,
- quantisation noise introduced by the demodulator analogue-to-digital converter,
- “backstop” thermal noise introduced after the gain-controlled stages in the receiver,
- transmitter intermodulation products.

The carrier-to-noise ratio is C/kTB at the tuner input, and $CG/kTBFG$ at the tuner output. Hence the carrier-to-noise ratio at the input to the “practical” demodulator is given by

$$C/N = CG / (kTBFG + P_x)$$

$$= C / (kTBF + CP_x)\text{ , since } G = 1/C.$$

The C/N ratio at the demodulator for a minimum level of performance (R_{DQEF} say) will depend upon the theoretical performance for a particular modulation mode and an implementation margin Im as specified above. The value of P_{in} for this level of performance is the sensitivity. Re-arranging the above equation gives this:

$$P_{\mathrm{in}}(sensitivity) = \frac{KT_0 BF_{\mathrm{sys}}}{\left(1/R_{DQEF} - P_x \right)}$$

Note that the C/N ratio at the receiver input (reference point) for this performance level (C_{RQEF}/N say) is then:

$$\frac{P_{\mathrm{in}}(sensitivity)}{KT_0 BF\mathrm{sys}} = \frac{1}{\left(\frac{1}{R_{DQEF}} - Px \right)}$$

All the above parameters are taken to be linear quantities. In practice, it is more usual to express C/N, P_{in}, G, F, P_X, R_{DQEF} and C_{RQEF}/N in dB.

A practical formula for R_{DQEF} in dB is given below:

$$R_{DQEF} = \text{Theoretical } C/N \text{ (dB)} + Im \text{ (dB)}$$

A practical formula for sensitivity in dB is given below:

$$P_{\mathrm{in}}(\text{sensitivity}) \text{ (dB(mW))} = C_{RQEF}/N \text{ (dB)} + Noise\ floor \text{ (dB(mW))}$$

where C_{RQEF}/N is the C/N ratio in dB at the receiver input that provides the minimum performance level. Note this is slightly greater than R_{DQEF}, especially so for high capacity modes.

NOTE All the above parameters are taken to be linear quantities. In practice, it is more usual to express C/N, C, G, F and P_x in dB.

10.3 Degradation criteria

Four different degradation criteria are used. The criteria a) and b) can be used in the non-mobile cases. Criterion c) is for mobile reception and criterion d) is used with IP-streams and DVB-H:

a) Reference BER, defined as BER =2x10^{-4} after Viterbi decoding

   This criterion corresponds to the DVB-T standard defined quasi error free (QEF) criteria, causing ”less than one uncorrected error event per hour”. In the stationary reception cases, QEF is equivalent to the reference BER after Viterbi decoding.

b) Picture failure point

   The picture failure point is defined as the C/N or C/I value where visible picture errors start to appear on the screen. This is more convenient for some of the measurements than the normal reference BER criterion, which might be unreachable. A more objective definition can be made using the ESR_5 (erroneous second ratio 5 %) criterion, which allows one erroneous second within the 20 s observation period in the transport stream. Note that the reception quality is poor at picture failure point as one possible error in each 20 s interval is too much for fixed TV-reception. The criterion is nevertheless suitable measurements, and a 1 dB to 2 dB carrier power increase will improve the reception quality to QEF-level. Table 6 shows the correlation between the picture failure point and the reference BER error criterion for various measurements. The specified performance in the indicated subclauses is given for reference BER error criterion. When the picture failure point is used in the measurement, the measured value can be converted to corresponding reference BER value by using Table 6.

Table 6 – Delta values between picture failure point and reference *BER*

Measurement	Subclause	Delta dB
C/N in Gaussian channel	10.7.1	1,3
Minimum input level	10.8.2	1,3
Immunity to other channels	10.9	2,0
Immunity to co-channel	10.10	2,0
C/N in fixed and portable channels	10.7.1, 10.7.2	1,3

c) Subjective failure point in mobile reception SFP

The reference *BER*, meaning perfect "quality of transmission", is unfortunately not suitable in the mobile environment due to the fast channel variations. In mobile cases, the reference *BER* criterion may give unstable values which could result in an underestimation of DVB-T mobile capabilities. Within the motivate project, a subjective quality has been defined, referred to as the subjective failure point (SFP). SFP corresponds to: "On average, one visible error in the video, during an observation period of 20 s". This corresponds the ESR_5 (5% erroneous second ratio, 5 % *ESR*) criterion, which allows one erroneous second within the 20 s observation period. Thus, the ESR_5 method can be used to measure the SFP.

d) DVB-H criterion

In DVB-H a suitable degradation criterion is the MPE-FEC frame error rate (*MFER*), referring to the error rate of the time sliced burst protected with the MPE-FEC. As an erroneous frame will destroy the service reception for the whole interval between the bursts, it is appropriate to fix the degradation point to the frequency of lost frames. Obviously, the used burst and IP-parameters will affect the final service quality obtained with certain fixed *MFER*, but experience has shown that the behaviour is very steep and a very small change in *C/N* will result a large change in *MFER*. *MFER* is the ratio of the number of erroneous frames (i.e. not recoverable) and total number of received frames. To provide sufficient accuracy, at least 100 frames shall be analysed.

$$MFER = \frac{\text{Number of erroneous frames} \times 100}{\text{Total number of frames}} \text{ in \%}$$

It has been agreed that 5 % *MFER* is used to mark the degradation point of the DVB-H service. Note that the service reception quality at the 5 % *MFER* degradation point may not meet the QoS requirement in all cases. The criterion is nevertheless suitable for measurements, and a small 0,5 dB to 1 dB carrier power increase will improve the reception quality to less than 1 % *MFER*.

It is also possible to estimate the *MFER* with good accuracy without performing the actual MPE-FEC calculation by just observing row by row the number of erroneous bytes and comparing this with the error correction capability of the RS-code used and marking the row erroneous or non-erroneous. If all rows are non-erroneous, the frame is non-erroneous. With this method, it is possible to decode all services (i.e. the whole transport stream) in parallel and shorten the observation time for the 100 frames needed.

In DVB-H receivers with no MPE-FEC the frame error rate criterion can be used in a slightly different way. A frame is marked erroneous if any TS-packet within the frame is erroneous. This criterion is called *FER* and degradation point is set to 5 % value. Note that 5 % *FER* may lead to better actual QoS than 5 % *MFER* as in *FER* it is possible that only a few TS-packets within the frame are erroneous, but in *MFER* a non recoverable frame is probably highly corrupted. The actual performance figures with *FER* 5 % are very similar what would be achieved using ESR_5 criterion to the transport stream directly.

10.4 Diversity receivers

Antenna diversity receivers, like the one in Figure 3, will reduce the effect of the fast fading Rayleigh-channel, which is always present in mobile receiving environment. In an antenna diversity receiver, output signals obtained from several antennas are linearly combined using adjustable complex weight factors before being decoded. Implementations may differ:

- by the antenna system's characteristics: number of antennas, relative positions, orientation and characteristics of each antenna (polarisation, radiation pattern, etc);
- by the algorithm used to compute and eventually iteratively adapt the weight factors.

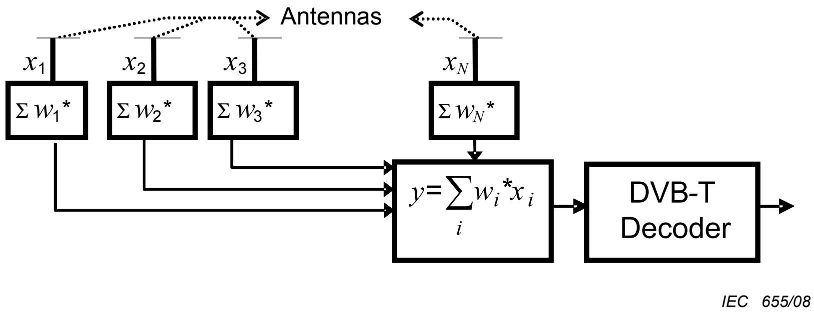


Figure 3 – Antenna diversity receiver

In mobile reception conditions (terminal category a), antenna diversity is expected to offer a gain equivalent to a reduction of the required transmitted power by 6 dB to 8 dB for the same coverage. It should also allow the mobile's maximum speed for correct reception to increase by a factor of two.

In portable indoor reception (terminal category b1), the channel conditions are changing slower than mobile reception.

The benefit of diversity reception is a reduction in the probability of having deep or flat fades on two antennas simultaneously. A single antenna will have a fade level that is both position and channel (i.e. several frequencies) dependent. Therefore, antenna diversity offers improved reception of all available multiplexes.

For small hand-held terminal (terminal category b2 and c), the diversity approach is not practical due to the power consumption and cost limitations and due to the small terminal size, which limits antenna separation in this frequency range.

10.5 DVB-H receivers

DVB-H, as specified in EN 302 304, is a transmission system to provide an efficient way of carrying multimedia services over digital terrestrial broadcasting networks to hand-held terminals. DVB-H is using the DVB-T transmission system as the physical layer and adding extra error correction and time slicing mechanism on the link layer. DVB-H is carrying IP-datagrams encapsulated with multi protocol encapsulation.

A full DVB-H system is defined by combining elements in the physical and link layers as well as service information. DVB-H makes use of the following technology elements for the link layer and the physical layer:

- Link layer:
  - time-slicing in order to reduce the average power consumption of the terminal and enabling smooth & seamless frequency handover;
  - forward error correction for multiprotocol encapsulated data (MPE-FEC) for an improvement in C/N-performance and Doppler performance in mobile channels, also improving tolerance to impulse interference.
- Physical layer:

DVB-T (ETSI EN 300 744 standard) with the following technical elements specifically targeting DVB-H use:

– DVB-H signalling in the TPS-bits to enhance and speed up service discovery. Cell identifier is also carried on TPS-bits to support quicker signal scan and frequency handover on mobile receivers.
– 4k-mode for trading off mobility and SFN cell size, allowing single antenna reception in medium SFNs at very high speed, adding thus flexibility in the network design.
– In-depth symbol interleaver for the 2k and 4k-modes for further improving their robustness in mobile environment and impulse noise conditions.

It should be mentioned that both time-slicing and MPE-FEC technology elements, as they are implemented on the link layer, do not impact the DVB-T physical layer in any way.

A DVB-H receiver will in general have the same RF-performance as a DVB-T receiver when a similar testing environment and degradation criterion is used. If MPE-FEC is used with DVB-H, this will improve the C/N-performance and new separate C/N-tables are needed.

Receivers in terminal category c will be DVB-H receivers. Optionally, receivers in other terminal categories can also support DVB-H.

10.6 Channel models

10.6.1 DVB-T Rayleigh channel (P_1)

The Rayleigh fading channel (P_1) defined in the DVB-T specification ETSI EN 300 744 is used to describe the portable indoor or outdoor reception conditions. The channel does not include any Doppler and should therefore be considered as a snapshot of a real time variant Rayleigh channel. The model has 20-taps, and is therefore difficult to use in any practical work.

In,Table 7 one possible 6-tap approximation is given [15]. The channel response of this approximation is a good match to that of P1 and the signal power has been made the same. Note that the signal power is 4,24 dB greater than that of a single 0 dB path (Gaussian channel) due to the vector addition of the six paths.

Delays have been defined at accuracy of 0,05 ms and starting point is zero. Amplitudes have been defined in dB at accuracy of 0,1 dB. The absolute values are exact transformations of those. The phases have been defined in degrees at 1° accuracy.

Table 7 – Approximation of the DVB-T specified Rayleigh channel

Tap number	Delay τ µs	Amplitude r	Level dB	Phase θ °
1	0,00	0,358 921 93	–8,9	–165
2	0,45	1	0,0	0
3	0,55	0,785 235 63	–2,1	125
4	1,85	0,588 843 66	–4,6	–26
5	2,70	0,484 172 37	–6,3	–150
6	3,15	0,451 855 94	–6,9	164

10.6.2 Portable indoor (PI) and outdoor (PO) channels

The portable indoor (PI) and portable outdoor channel models have been developed by the Wing-TV project [17] for describing the slowly moving hand-held reception indoors and outdoors. The channel models are based on measurements in DVB-H Single Frequency

Networks and have paths from two different transmitter locations. Definitions of the taps for the channels are given in Table 9 and Table 10. The indicated Doppler frequency of 1,5 Hz is corresponding 3 km/h velocity at mid UHF. The Doppler spectra of various taps are defined in Table 8.

Table 8 – Doppler spectrum definitions for PI and PO channels

Spectrum for the 1st tap	Spectrum for taps 2-12
$0{,}1\ G(f;0{,}08 f_D) + \delta(f - 0{,}5 f_D)$	$G(f;0{,}08 f_D)$

where $$G(f;\sigma) = \exp\left(\frac{-f^2}{2\sigma^2}\right).$$

Table 9 – Definition of PI channel

Path	Delay µs	Power dB	Doppler spectrum	f_D (Hz)	STD Norm.
1	0,0	0,0	See Table 8	1,5	0,08
2	0,1	–6,4	Gauss	1,5	0,08
3	0,2	–10,4	Gauss	1,5	0,08
4	0,4	–13,0	Gauss	1,5	0,08
5	0,6	–13,3	Gauss	1,5	0,08
6	0,8	–13,7	Gauss	1,5	0,08
7	1,0	–16,2	Gauss	1,5	0,08
8	1,6	–15,2	Gauss	1,5	0,08
9	8,1	–14,9	Gauss	1,5	0,08
10	8,8	–16,2	Gauss	1,5	0,08
11	9,0	–11,1	Gauss	1,5	0,08
12	9,2	–11,2	Gauss	1,5	0,08

Table 10 – Definition of PO channel

Path	Delay µs	Power dB	Doppler spectrum	f_D Hz	STD Norm.
1	0,0	0,0	See Table 8	1,5	0,08
2	0,2	–1,5	Gauss	1,5	0,08
3	0,6	–3,8	Gauss	1,5	0,08
4	1,0	–7,3	Gauss	1,5	0,08
5	1,4	–9,8	Gauss	1,5	0,08
6	1,8	–13,3	Gauss	1,5	0,08
7	2,3	–15,9	Gauss	1,5	0,08
8	3,4	–20,6	Gauss	1,5	0,08
9	4,5	–19,0	Gauss	1,5	0,08
10	5,0	–17,7	Gauss	1,5	0,08
11	5,3	–18,9	Gauss	1,5	0,08
12	5,7	–19,3	Gauss	1,5	0,08

10.6.3 Mobile reception

The technical specification of COST 207 [4] describes the equipment and techniques used to measure the channel characteristics over typical bandwidths of 10 MHz to 20 MHz at near 900 MHz. Adaptation of the COST 207 profiles to mobile DVB-T reception was done by the Motivate project [5]. This chapter is defining two mobile channels typical urban TU-6 and mobile SFN-channel, which is composed of two TU-6 channels.

10.6.3.1 Typical urban reception (TU6)

This profile reproduces the terrestrial propagation in an urban area. It has been defined by COST 207 as a typical urban (TU6) profile and is made of 6 paths having wide dispersion in delay and relatively strong power. The profile parameters are given in Table 11.This channel profile has been proven to present fairly well the general mobile DVB-T/H reception by several field tests.

Table 11 – Typical urban profile (TU6) constitution

Tap number	**Delay** us	**Power** dB	**Doppler spectrum**
1	0,0	–3	Rayleigh
2	0,2	0	Rayleigh
3	0,5	–2	Rayleigh
4	1,6	–6	Rayleigh
5	2,3	–8	Rayleigh
6	5,0	–10	Rayleigh

10.6.3.2 DVB-T receiver performance in the presence of Doppler shift

Until a given Doppler limit (or inter-carrier interference level), the receivers are able to perform sufficient channel equalisation to demodulate the DVB-T signal. Then, when the Doppler (i.e. the speed of the mobile) further increases, the recovery performance decreases drastically until a point where no demodulation remains possible [5].

In general, the required C/N over a mobile channel is defined as the average C/N over a sufficiently long time as to obtain a stable value, and a sufficiently short time as to avoid any influence of shadow fading. For a given DVB-T mode and a given channel profile, the required C/N for a certain quality level is therefore a function of Doppler frequency only, and a graph like the one presented in Figure 4 can be drawn.

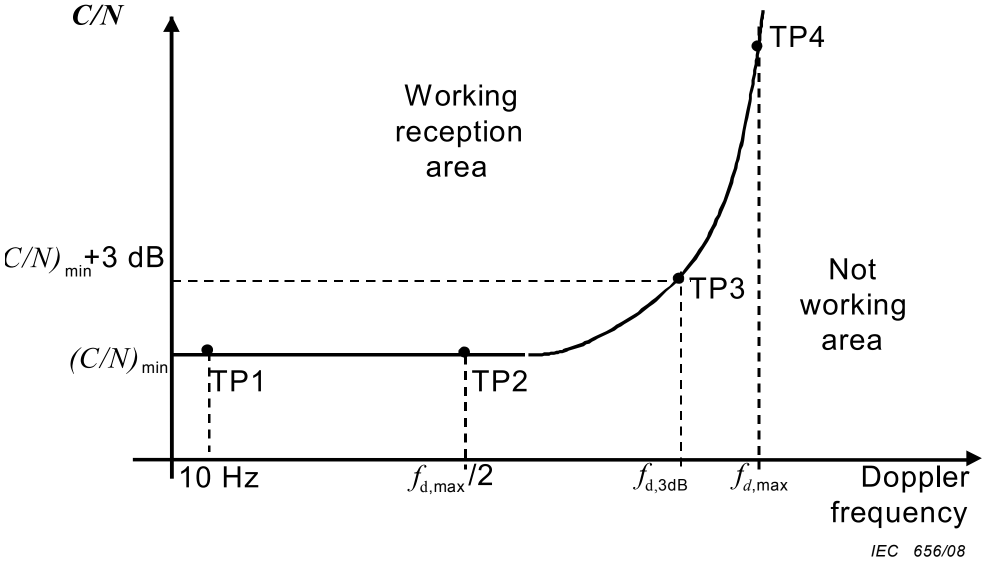


Figure 4 – Receiver behaviour in a mobile channel

This curve is characterised by a C/N floor, C/N_{min}, which gives information about the minimum signal requirement for good reception when in motion. For low speeds, the required C/N value is relatively independent of the specific Doppler frequency. For higher speeds (or Doppler frequencies), the required C/N value increases gradually until a maximum acceptable Doppler frequency is reached.

To characterise the C/N versus Doppler curve in a given DVB-T mode, using a given channel profile, four points are used.

TP1: the C/N_{min} at low Doppler (10 Hz)

TP2: the C/N at half of maximum speed

TP3: the C/N_{min} + 3 dB which gives indication on the speed limit

TP4: the maximum Doppler limit which characterises the “absolute maximum speed”

10.6.3.3 DVB-H receiver performance in the presence of Doppler shift

The used reference receiver model describes the DVB-H receiver performance in an idealised way using two figures, C/N_{min} and Fd_{3dB}. C/N_{min} gives the minimum required C/N for $MFER$ 5 %. The C/N-curve is flat up to high Doppler frequencies, but is not applicable to very low Doppler frequencies Fd<1/burst duration. Fd_{3dB} gives the Doppler frequency, where the C/N requirement has raised 3 dB from the C/N_{min} value. Note that Fd_{3dB} is almost equal the Fd_{max}. The behaviour of the reference receiver is shown in Figure 5.

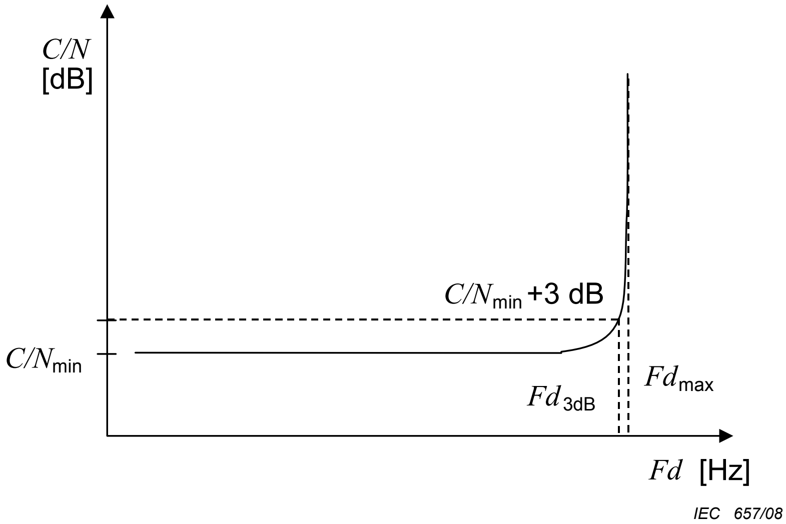


Figure 5 – DVB-H reference receiver C/N behaviour in mobile channel

10.6.3.4 Mobile SFN synchronisation test channel

This profile consists of two independent TU-6 profiles next to each other (short echo) or separated in time by 80 % of the longest used guard interval (1/4) (long echo). The purpose of this channel profile is mainly to test receiver synchronisation performance in a large SFN in mobile conditions. The two groups of paths are simulating signals from two distant transmitters. The amplitudes of the groups can be varied so that both strong and weak echo cases are covered. The profile parameters are given in Table 12, Table 13 and Table 14 and the profiles are depicted in Figure 6, Figure 7, Figure 8 . The $C/Nmode$ value in Table 12 is depending on the mode and is listed in Table 15.

Table 12 – Mobile SFN synchronisation test channel for weak long echo

Tap number	Delay µs	Power dB	Doppler spectrum
1	0,0	–3	Rayleigh
2	0,2	0	Rayleigh
3	0,5	–2	Rayleigh
4	1,6	–6	Rayleigh
5	2,3	–8	Rayleigh
6	5,0	–10	Rayleigh
7	0,8×GI(1/4)+0,0	–3 – $C/Nmode$	Rayleigh
8	0,8×GI(1/4)+0,2	0 – $C/Nmode$	Rayleigh
9	0,8×GI(1/4)+0,5	–2 – $C/Nmode$	Rayleigh
10	0,8×GI(1/4)+1,6	–6 – $C/Nmode$	Rayleigh
11	0,8×GI(1/4)+2,3	–8 – $C/Nmode$	Rayleigh
12	0,8×GI(1/4)+5,0	–10 – $C/Nmode$	Rayleigh

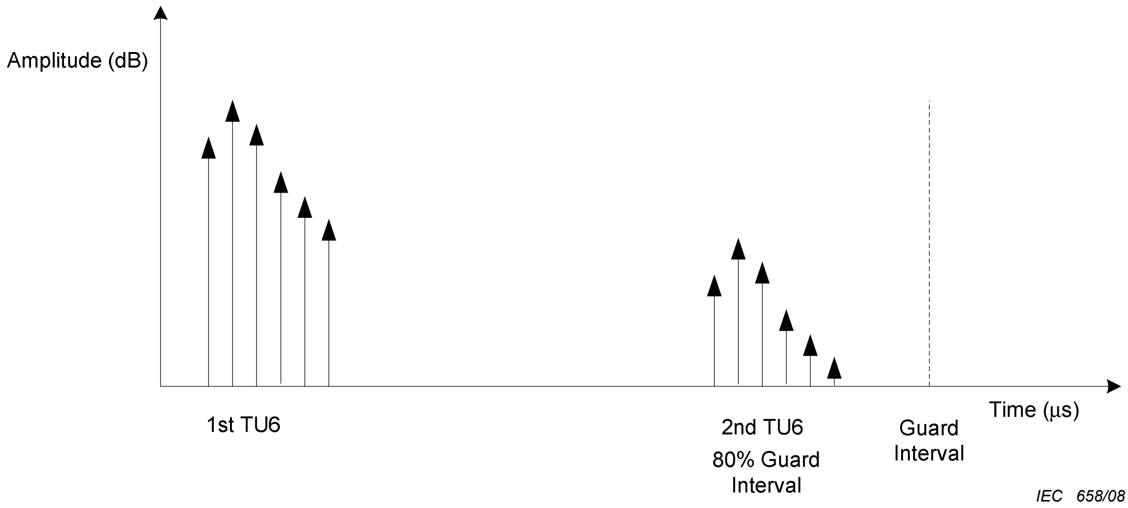


Figure 6 – Mobile SFN synchronisation test channel for weak long echo

Table 13 – Mobile SFN synchronisation test channel for strong long echo

Tap number	**Delay** µs	**Power** dB	**Doppler spectrum**
1	0,0	–3	Rayleigh
2	0,2	0	Rayleigh
3	0,5	–2	Rayleigh
4	1,6	–6	Rayleigh
5	2,3	–8	Rayleigh
6	5,0	–10	Rayleigh
7	0,8×GI(1/4)+0,0	–3	Rayleigh
8	0,8×GI(1/4)+0,2	0	Rayleigh
9	0,8×GI(1/4)+0,5	–2	Rayleigh
10	0,8×GI(1/4)+1,6	–6	Rayleigh
11	0,8×GI(1/4)+2,3	–8	Rayleigh
12	0,8×GI(1/4)+5,0	–10	Rayleigh

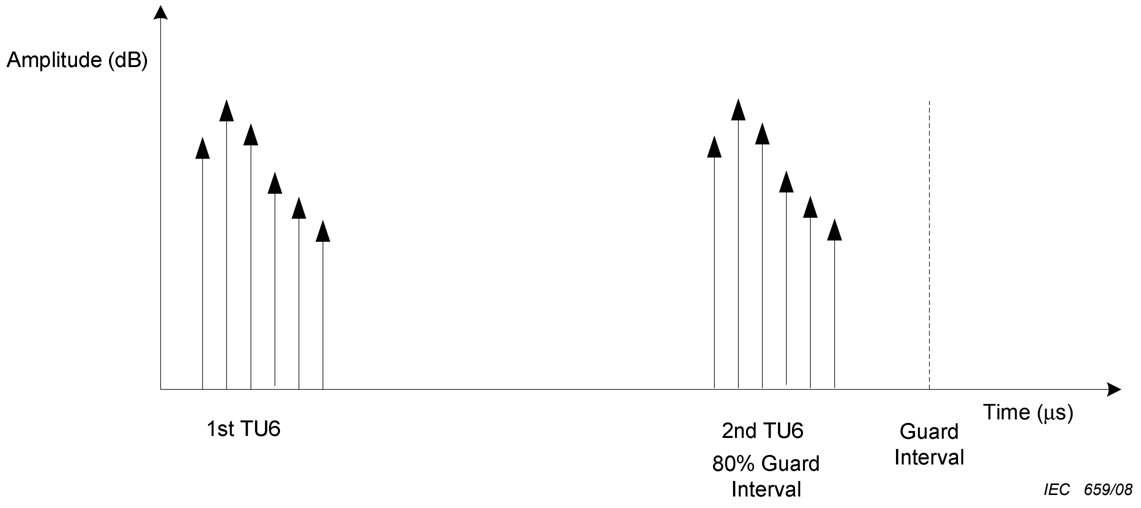


Figure 7 – Mobile SFN synchronisation test channel for strong long echo

Table 14 – Mobile SFN synchronisation test channel for strong short echo

Tap number	Delay µs	Power dB	Doppler spectrum
1	0,0	–3	Rayleigh
2	0,2	0	Rayleigh
3	0,5	–2	Rayleigh
4	1,6	–6	Rayleigh
5	2,3	–8	Rayleigh
6	5,0	–10	Rayleigh
7	6,0	–3	Rayleigh
8	6,2	0	Rayleigh
9	6,5	–2	Rayleigh
10	7,6	–6	Rayleigh
11	8,3	–8	Rayleigh
12	11,0	–10	Rayleigh

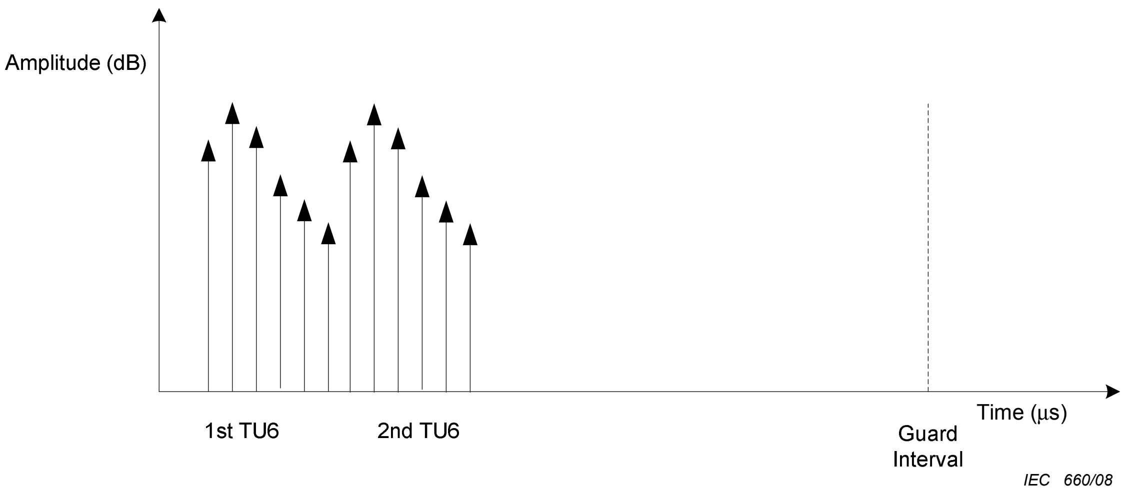


Figure 8 – Mobile SFN synchronisation test channel for strong short echo

10.7 *C/N* performance

10.7.1 *C/N* performance in Gaussian channel

The DVB-T receiver shall have the performance given in Table 15 and DVB-H receiver shall have the performance given in Table 16, when noise (*N*) is applied together with the wanted carrier (*C*) in a signal bandwidth of 7,61 MHz. The values are calculated using the theoretical *C/N* figures given in ETSI EN 300 744 V1.5.2 added by an implementation margin of 1,1 dB for QPSK, 1,3 dB for 16QAM and 1,5 dB for 64QAM modes and using the noise model given in 10.2 with a receiver excess noise source value P_x of –33 dBc. An ideal transmitter is assumed. An example of the effects in transmitter degradation on the *C/N*-values is given in Annex B. The DVB-H figures are valid for all MPE-FEC code rates. Figures for DVB-T are given for degradation criteria a and figures for DVB-H for degradation criteria d.

Table 15 – DVB-T *C/N* (dB) for reference *BER* in Gaussian channel

Modulation	Code rate	Gaussian
QPSK	1/2	4,6
QPSK	2/3	6,4
QPSK	3/4	7,4
16-QAM	1/2	10,6
16-QAM	2/3	12,7
16-QAM	3/4	14,0
64-QAM	1/2	15,4
64-QAM	2/3	18,3
64-QAM	3/4	19,9

Table 16 – DVB-H *C/N* (dB) for 5% *MFER* in Gaussian channel

Modulation	Code rate	Gaussian
QPSK	1/2	3,6
QPSK	2/3	5,4
16-QAM	1/2	9,6
16-QAM	2/3	11,7
64-QAM	1/2	14,4
64-QAM	2/3	17,3

NOTE 1 Reference *BER* is defined as *BER* $=2 \times 10^{-4}$ after Viterbi decoding.

NOTE 2 The figures in ETSI EN 300 744 V1.5.2 are the results of new simulations and differ from earlier versions.

10.7.2 *C/N* performance in DVB-T Rayleigh channel (P_1)

The DVB-T receiver shall have the performance given in Table 17 and DVB-H receiver shall have the performance given in Table 18 when noise (*N*) is applied together with the wanted carrier (*C*) in a signal bandwidth of 7,61 MHz. Degradation point criteria a or b should be used for DVB-T and degradation criteria d for DVB-H. The values are calculated using the theoretical *C/N* figures given in ETSI TR 101 190 V1.2.2 added by an implementation margin of 1,6 dB for QPSK, 1,8 dB for 16QAM and 2,0 dB for 64QAM modes and using the noise model given in subclause 10.2 with a receiver excess noise source value P_x of –33 dBc. An ideal transmitter is assumed. An example of the effects in transmitter degradation on the *C/N*-values is given in Annex B. The DVB-H figures are valid for all MPE-FEC code rates.

Table 17 – *C/N* (dB) for reference *BER* in DVB-T Rayleigh channel (P_1)

Modulation	Code rate	Portable
QPSK	1/2	7,5
QPSK	2/3	11,5
QPSK	3/4	15,3
16-QAM	1/2	13,8
16-QAM	2/3	17,7
16-QAM	3/4	21,5
64-QAM	1/2	18,9
64-QAM	2/3	23,4
64-QAM	3/4	27,5

Table 18 – *C/N* (dB) for 5 % *MFER* in portable channel

Modulation	Code rate	Rayleigh (P_1)
QPSK	1/2	6,5
QPSK	2/3	10,5
16-QAM	1/2	12,8
16-QAM	2/3	16,7
64-QAM	1/2	17,9
64-QAM	2/3	22,4

10.7.3 *C/N* Performance in portable indoor (PI) and portable outdoor (PO) channels

The DVB-T receiver shall have the performance given in Table 19 and DVB-H receiver shall have the performance given in Table 20 when noise (*N*) is applied together with the wanted carrier (*C*) in a signal bandwidth of 7,61 MHz. Degradation point criteria a) or b) should be used for DVB-T and degradation criteria d) for DVB-H. The *C/N* performance figures are based on the state of the art receivers on the market added with a 2 dB margin.

Table 19 – *C/N* (dB) for 5 % *ESR* in PI and PO channel

Modulation	Code rate	PI	PO
QPSK	1/2	9,0	10,5
QPSK	2/3	12,0	13,5
QPSK	3/4	13,9	15,4
16-QAM	1/2	15,0	16,5
16-QAM	2/3	18,0	19,5
16-QAM	3/4	20,5	22,0
64-QAM	1/2	19,7	21,2
64-QAM	2/3	22.8	24.3
64-QAM	3/4	25,3	27,5

Table 20 – *C/N* (dB) for 5 % *MFER* in PI and PO channel

Modulation	Code rate	MPE-FEC code rate	PI	PO
QPSK	1/2	1/2	6,6	7,6
QPSK	1/2	2/3	6,8	7,8
QPSK	1/2	3/4	7,0	8,0
QPSK	1/2	5/6	7,2	8,2
QPSK	1/2	7/8	7,4	8,4
QPSK	2/3	2/3	9,8	10,8
QPSK	2/3	3/4	10,0	11,0
QPSK	2/3	5/6	10,2	11,2
QPSK	2/3	7/8	10,4	11,4
16-QAM	1/2	2/3	12,8	13,8
16-QAM	1/2	3/4	13,0	14,0
16-QAM	1/2	5/6	13,2	14,2
16-QAM	1/2	7/8	13,4	14,4
16-QAM	2/3	2/3	15,8	16,8
16-QAM	2/3	3/4	16,0	17,0
16-QAM	2/3	5/6	16,2	17,2
16-QAM	2/3	7/8	16,4	17,4
64-QAM	1/2	5/6	17,7	18,7
64-QAM	1/2	7/8	17,9	18,9
64-QAM	2/3	2/3	20,6	21,6
64-QAM	2/3	3/4	20,8	21,8
64-QAM	2/3	5/6	21,0	22,0

10.7.4 DVB-T *C/N* performance in mobile channels for terminal class a

The single antenna receiver shall have the performance given in Table 21 when noise (N) and Doppler shift (Fd) is applied together with the wanted carrier (C) in a signal bandwidth of 7,61 MHz in mobile channels defined in 10.6.3. C/N_{min} gives the required C/N performance at Doppler frequency of 10 Hz. Fd_{max} is the maximum achievable Doppler frequency when no noise is applied. Fd_{3dB} gives the achievable Doppler frequency at a point where additional 3 dB noise is applied over the C/N_{min} value. Degradation criteria c) (5 % *ESR*) is used due to the bursty nature of the error behaviour. The performance figures are given to the longest guard interval 1/4, which is the most critical case in terms of Doppler. With 1/32 guard interval about 120 % of this performance is to be expected. The C/N performance figures are based on the state of the art receivers on the market added with a 2 dB margin. The Doppler performance figures are based on a use case analysis where the target speed with 8k mode at high UHF channels is 130 km/h. For modes where this cannot be met with the state of the art receivers a smaller practical figure is given. Roughly 10 Hz margin is used in these cases.

Table 21 – C/N (dB) for 5 % ESR in mobile channels for single antenna receiver

Guard interval =1/4			**2k**			**Speed at Fd_{3dB}** km/h			**8k**			**Speed at Fd_{3dB}** km/h		
Modulation	**Bit rate** Mbit/s	**Code rate**	C/N_{min} dB	Fd_{max} Hz	Fd_{3dB}	**200** MHz	**500** MHz	**800** MHz	C/N_{min} dB	Fd_{max} Hz	Fd_{3dB}	**200** MHz	**500** MHz	**800** MHz
QPSK	6,03	1/2	16,0	400	400	2 160	864	540	16,0	100	100	540	216	135
QPSK	8,04	2/3	19,0	400	320	1 728	691	432	19,0	100	80	432	173	108
16-QAM	12,06	1/2	21,0	400	300	1 620	648	405	21,0	100	75	405	162	101
16-QAM	16,09	2/3	24.0	240	200	1 080	432	270	24,0	60	50	270	108	68
64-QAM	18,10	1/2	26.0	220	180	972	389	243	26,0	55	45	243	97	61
64-QAM	24,13	2/3	30,0	120	100	540	216	135	30,0	30	25	135	54	34

The diversity receiver should have the performance given in Table 22. This table is similar to that of Table 21, but takes into account an 8 dB diversity gain factor in C/N. The Doppler performance figures are based on a use cases analysis where the target speed with 8k mode at high UHF channels is 180 km/h. For modes where this cannot be met with the state of the art receivers a smaller practical figure is given.

Table 22 – C/N (dB) for ESR 5 % in mobile channels for diversity receiver

Guard interval = 1/4			**2k**			**Speed at Fd_{3dB}** km/h			**8k**			**Speed at Fd_{3dB}** km/h		
Modulation	**Bit rate** Mbit/s	**Code rate**	C/N_{min} dB	Fd_{max} Hz	Fd_{3dB}	**200** MHz	**500** MHz	**800** MHz	C/N_{min} dB	Fd_{max} Hz	Fd_{3dB}	**200** MHz	**500** MHz	**800** MHz
QPSK	6,03	1/2	8	560	560	3 024	1 210	756	8	140	140	756	302	189
QPSK	8,04	2/3	11	520	500	2 700	1 080	675	11	130	125	675	270	169
16-QAM	12,06	1/2	13	520	500	2 700	1 080	675	13	130	125	675	270	169
16-QAM	16,09	2/3	16	460	440	2 376	950	594	16	115	110	594	238	149
64-QAM	18,10	1/2	20	420	400	2 160	864	540	20	105	100	540	216	135
64-QAM	24,13	2/3	22	400	380	2 052	821	513	22	100	95	513	205	128

10.7.5 DVB-H C/N performance in mobile channels

The DVB-H receiver shall have the performance given in Table 23 when noise (N) and Doppler shift (Fd) is applied together with the wanted carrier (C) in mobile channels defined in 10.6.3. The figures are given for guard interval 1/4. The C/N performance is based on the state of the art DVB-H receivers with added 2 dB margin. The Doppler performance is derived from a use case analysis where the target speed with 8k mode at 750 MHz is 130 km/h. This corresponds a Doppler frequency of 100 Hz. The 4k and 2k Doppler performance is obtained by multiplying the 8k performance by 2 and 4.

Table 23 – DVB-H C/N (dB) in mobile channel for 5 % $MFER$

Guard interval = 1/4			2k Speed at Fd_{3dB} km/h				4k Speed at Fd_{3dB} km/h				8k Speed at Fd_{3dB} km/h			
Modulation	**Code rate**	**MPE-FEC CR**	C/N_{min} dB	Fd_{3dB} Hz	**474** MHz	**746** MHz	C/N_{min} dB	Fd_{3dB} Hz	**474** MHz	**746** MHz	C/N_{min} dB	Fd_{3dB} Hz	**474** MHz	**746** MHz
QPSK	1/2	1/2	8,5	400	911	579	8,5	200	456	290	8,5	100	228	145
		2/3	9,0	400	911	579	9,0	200	456	290	9,0	100	228	145
		3/4	9,5	400	911	579	9,5	200	456	290	9,5	100	228	145
		5/6	10,0	400	911	579	10,0	200	456	290	10,0	100	228	145
		7/8	10,5	400	911	579	10,5	200	456	290	10,5	100	228	145
QPSK	2/3	2/3	12,0	400	911	579	12,0	200	456	290	12,0	100	228	145
		3/4	12,5	400	911	579	12,5	200	456	290	12,5	100	228	145
		5/6	13,5	400	911	579	13,5	200	456	290	13,5	100	228	145
		7/8	14,5	400	911	579	14,5	200	456	290	14,5	100	228	145
16-QAM	1/2	2/3	15,0	400	911	579	15,0	200	456	290	15,0	100	228	145
		3/4	15,5	400	911	579	15,5	200	456	290	15,5	100	228	145
		5/6	16,5	400	911	579	16,5	200	456	290	16,5	100	228	145
		7/8	17,5	400	911	579	17,5	200	456	290	17,5	100	228	145
16-QAM	2/3	2/3	18,0	380	866	550	18,0	190	433	275	18,0	95	216	138
		3/4	18,5	380	866	550	18,5	190	433	275	18,5	95	216	138
		5/6	19,5	380	866	550	19,5	190	433	275	19,5	95	216	138
		7/8	20,5	380	866	550	20,5	190	433	275	20,5	95	216	138
64-QAM	1/2	5/6	21,5	200	456	290	21,5	100	228	145	21,5	50	114	73
		7/8	22,5	200	456	290	22,5	100	228	145	22,5	50	114	73
64-QAM	2/3	2/3	25,0	120	273	174	25,0	60	137	87	25,0	30	68	43
		3/4	25,5	120	273	174	25,5	60	137	87	25,5	30	68	43
		5/6	27,0	120	273	174	27,0	60	137	87	27,0	30	68	43

10.8 Receiver minimum and maximum signal input levels

10.8.1 Noise floor

At the sensitivity level for each DVB-T/H mode receivers in terminal classes a) and b1) should have a system noise figure of 6 dB or less at the RF-reference point. Receivers in terminal class b2) and c) without the GSM-reject filter (see Figure 1) should have a system noise figure of 4 dB or less at the RF-reference point. Receivers in terminal class c) with the GSM-reject filter should have a system noise figure of 6dB or less at the RF-reference point.

A system noise figure of 4 dB corresponds to the following noise floor power levels (see also A.4):

P_n = –101,2 dB(mW), [for 8 MHz channels, BW= 7,61 MHz]

P_n = –101,7 dB(mW), [for 7 MHz channels, BW= 6,66 MHz]

P_n = –102,4 dB(mW), [for 6 MHz channels, BW= 5,71 MHz]

A system noise figure of 6 dB corresponds to the following noise floor power levels:

P_n = –99,2 dB(mW), [for 8 MHz channels, BW= 7,61 MHz]

P_n = –99,7 dB(mW), [for 7 MHz channels, BW= 6,66 MHz]

P_n = –100,4 dB(mW), [for 6 MHz channels, BW= 5,71 MHz]

10.8.2 Minimum input levels (sensitivity)

At RF-reference point, the receiver shall fulfil degradation point criteria a for DVB-T and degradation criteria d for DVB-H for the wanted signal levels greater than P_{min} and less than P_{max} (see 10.8.3).

For terminals in terminal classes b2) and c) without GSM-reject filter:

P_{min} = –101,2 dB(mW) +C/N [dB], [for 8 MHz]

P_{min} = –101,7 dB(mW) +C/N [dB], [for 7 MHz]

P_{min} = –102,4 dB(mW) +C/N [dB], [for 6 MHz]

For terminals in terminal classes a), b1) and c) with GSM-reject filter:

P_{min} = –99,2 dB(mW) +C/N [dB], [for 8 MHz]

P_{min} = –99,7 dB(mW) +C/N [dB], [for 7 MHz]

P_{min} = –100,4 dB(mW) +C/N [dB], [for 6 MHz]

where C/N is specified in 10.7.1 and is dependent on the DVB-T/H mode. Different tables should be used for DVB-T and DVB-H.

10.8.3 Total maximum power for wanted and unwanted signals

10.8.3.1 For terminal category a

The receiver design shall be able to handle at least –15 dB(mW) maximum total average power from the wanted and unwanted signals at the receiver reference point within the entire reception frequency range.

10.8.3.2 For terminal category b and c

The receiver design shall be able to handle at least –25 dB(mW) maximum total average power from the wanted and unwanted signals at the receiver reference point within the entire reception frequency range.

10.8.4 Maximum input levels for wanted and unwanted signals

The allowed maximum input level on the RF-reference point will depend on the antenna characteristics and linearity requirements restricted by power consumption and is therefore different for different terminal categories.

In this subclause and in 10.9 the analogue interferer level is defined as the peak sync power level.

10.8.4.1 For terminal category a and b1

The receiver shall be able to handle wanted DVB-T signals up to a level of –18 dB(mW) while providing the specified performance, when no other interfering signals are present at the input. Maximum tolerated level for each analogue or digital interfering signal according to patterns

S1 ($n \pm 1$), S2 ($n \pm 1$), L1, L2, L3 and L4 is –25 dB(mW). Maximum tolerated level for each analogue or digital interfering signal according to patterns S1 ($n \pm m$, $m \neq 1$), S2 ($n \pm m$, $m \neq 1$) is –18 dB(mW). All levels are valid for receivers operating on all DVB-T/H modes. Maximum input levels for terminal category a and b1 are shown in Table 24.

Table 24 – Maximum input levels for terminal category a and b1

Wanted signal P_{max} dB(mW)	**Interferer signal patterns** P_{max} **dB**(mW) **for highest interferer**		
N	**S1 ($n \pm 1$), S2 ($n \pm 1$)**	**L1, L2, L3, L4**	**S1 ($n \pm m$, $m \neq 1$), S2 ($n \pm m$, $m \neq 1$)**
–18	No signal	No signal	No signal
See 10.8.3.1 and 10.8.3.2	–25	–25	–18

10.8.4.2 For terminal category b2 and c

The receiver shall be able to handle wanted DVB-T signals up to a level of –28 dB(mW) while providing the specified performance, when no other interfering signals are present at the input. Maximum tolerated level for each analogue or digital interfering signal according to patterns S1 ($n \pm 1$), S2 ($n \pm 1$), L1, L2, L3 and L4 is –35 dB(mW). Maximum tolerated level for each analogue or digital interfering signal according to patterns S1 ($n \pm m$, $m \neq 1$), S2 ($n \pm m$, $m \neq 1$) is –28 dB(mW). All levels are valid for receivers operating on all DVB-T/H modes. Maximum input levels for terminal category b2 and c are shown in Table 25.

Table 25 – Maximum input levels for terminal category b2 and c

Wanted signal P_{max} dB(mW)	**Interferer signal patterns** P_{max} **dB**(mW) **for highest interferer**		
N	**S1 ($n \pm 1$), S2 ($n \pm 1$)**	**L1, L2, L3, L4**	**S1 ($n \pm m$, $m \neq 1$), S2 ($n \pm m$, $m \neq 1$)**
–28	No signal	No signal	No signal
See 10.8.3.2	–35	–35	–28

10.9 Immunity to analogue and/or digital signals in other channels

10.9.1 General

Traditionally immunity to analogue and digital signals has been defined with simple single interferer patterns. Either one digital or one analogue interfering adjacent signal has been introduced and protection ratio to the wanted digital signal has then been defined. This assumes that the receiver would have some degree of preselection to remove other interfering signals that are also present. From a linearity point of view, the single interferer scenario is most probably not challenging enough for some types of circuit topology. Therefore, in addition to the single interferer approach, a more complete ensemble of interfering patterns is proposed for the testing.

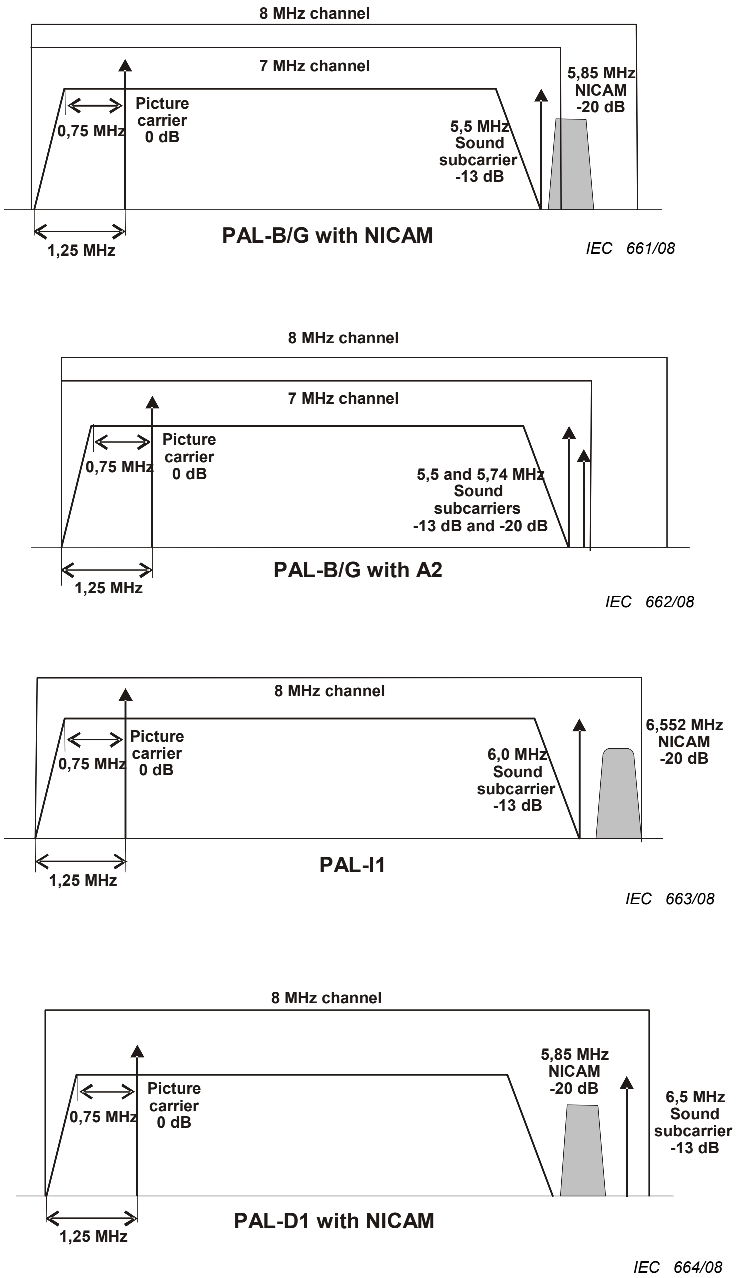
Two different interference pattern sets have been defined. The first one is testing mainly receiver selectivity and includes two classical single interferer patterns. The second one is testing receiver linearity with two interferers.

No additional noise is added and the channel profile is Gaussian.

10.9.2 Interfering signal definitions

10.9.2.1 PAL

Figure 9 represents the PAL B/G/I1/D1 interfering signals, which are defined in ITU-R BT.1701. Modulating signals are: 75 % colour bars for the vision carrier, 1 kHz FM sound with ±50 kHz deviation and any modulation for NICAM. The level of the FM sound carrier relative to the vision carrier is –13 dB. The level of the NICAM signal relative to the vision carrier is -20 dB. Note that the filter roll-off factor for PAL B/G/D1 NICAM is 40 % and PAL I1 NICAM is 100 %. PAL D/K without the NICAM is expected to have similar performance than D1 in this specification.



Note: PAL D/K is very similar but without NICAM

Figure 9 – PAL interfering signals

10.9.2.2 SECAM L

Figure 10 represents the SECAM L interfering signal which is defined in ITU-R BT.1701.

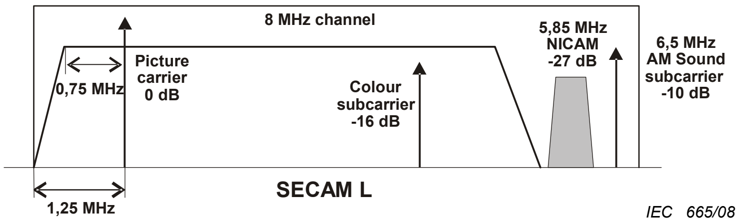


Figure 10 – SECAM L interfering signal

Modulating signals are: 75 % colour bars for the vision carrier, 1 kHz with 54 % AM for the AM sound carrier and any modulation for NICAM. The level of the AM sound sub carrier relative to the vision carrier is –10 dB . The level of the NICAM signal relative to the vision carrier is -27 dB. Note that the filter roll-off factor for SECAM L NICAM is 40 %.

10.9.2.3 DVB-T/H

The DVB-T/H signal according to the ETSI EN 300 744, Digital Video Broadcasting (DVB); Framing structure, Channel coding and modulation for digital terrestrial television.

10.9.2.4 Number of signals

For practical reasons, the number of interfering signals has been limited to two. Also other limitations apply:

- two analogue channels cannot be adjacent to each other;
- the level difference between adjacent analogue and digital channel can be minimum 15 dB (digital at lower level). If the difference is smaller, analogue picture will be disturbed.

10.9.3 Selectivity patterns

The following two patterns are used for receiver selectivity testing.

- Pattern S1, one adjacent analogue signal on $N \pm 1$ or $N \pm m$ or image
- Pattern S2, one adjacent digital DVB-T signal on $N \pm 1$ or $N \pm m$ or image

The patterns are shown in Figure 11 and Figure 12.

10.9.4 Linearity patterns

The following four patterns are used for receiver linearity testing. Note that similar cases as the described L1 − L3 $N + 2/N + 4$ are any $N + n/N + 2*n$, where n {1,2,…,24}.

- Pattern L1, $N + 2$ DVB-T and $N + 4$ analogue
- Pattern L2, $N + 2$ and $N + 4$ analogue
- Pattern L3, $N + 2$ and $N + 4$ digital
- Pattern L4, analogue in VHF III and digital in UHF

The patterns are shown in Figure 13, Figure 14 and Figure 15.

10.9.5 Immunity to pattern S1

This pattern has one analogue signal on $N \pm 1$ or $N \pm m$ channel in addition to the wanted DVB-T/H signal on channel N.

The DVB-T receiver shall provide the reference *BER* and the DVB-H receiver 5 % *MFER* when the unwanted signal is at the highest allowed level and the wanted signal is at (*a*) dB lower level, where the value for (*a*) is given in Table 26 and Table 27. The performance is only provided when the input level restrictions of 10.8.4 apply. The DVB-H figures apply for all MPE-FEC code rates.

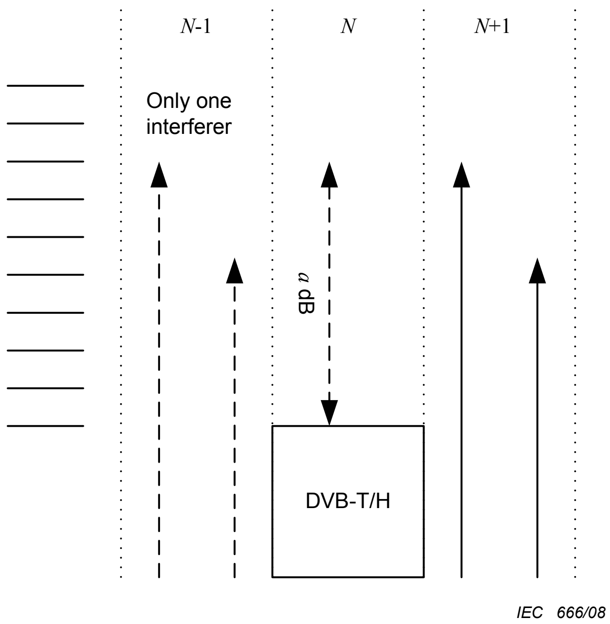


Figure 11 – Pattern S1 in case of N+1 or N-1

Table 26 – Immunity to pattern S1 for DVB-T

Mode	a [$N \pm 1$] PALG or I1	a [$N \pm 1$] PALB [a]	a [$N - 1$] SECAM L PAL D1 [b]	a [$N + 1$] SECAM L PAL D1 [b]	a [$N \pm m$] ($m \neq 1$) SECAM L	a [$N \pm m$] ($m \neq 1$) PAL B/G/I1/D1 [b]
2k/8k 16QAM *CR*=1/2, *GI*=All	38 dB	36 dB	30 dB	36 dB	48 dB	48 dB
2k/8k 16QAM *CR*=2/3, *GI*=All	38 dB	36 dB	30 dB	36 dB	48 dB	48 dB
2k/8k 16QAM *CR*=3/4, *GI*=All	37 dB	35 dB	29 dB	35 dB	48 dB	48 dB
2k/8k 64QAM *CR*=2/3, *GI*=All	35 dB	33 dB	27 dB	33 dB	45 dB	46 dB
2k/8k 64QAM *CR*=3/4, *GI*=All	35 dB	33 dB	27 dB	33 dB	42 dB	43 dB

[a] Note that if PAL B N-1 is with NICAM sound, the digital channel on N can not be used without offset, because of the overlapping spectrums.

[b] Note that the figures for PAL D1 are provisional. Performance for PAL D/K is similar than D1. Other analogue interfering signals may be considered in the future.

Table 27 – Immunity to pattern S1 for DVB-H

Mode	a [$N \pm 1$] PALG or I1	a [$N \pm 1$] PALB [a]	a [$N - 1$] SECAM L PAL D1 [b]	a [$N + 1$] SECAM L PAL D1 [b]	a [$N \pm m$] ($m \neq 1$) SECAM L	a [$N \pm m$] ($m \neq 1$) PAL B/G/I1/D1 [b]
2k/4k/8k QPSK *CR*=1/2, *GI*=All	40 dB	38 dB	32 dB	38 dB	50 dB	50 dB
2k/4k/8k QPSK *CR*=2/3, *GI*=All	40 dB	38 dB	32 dB	38 dB	50 dB	50 dB

2k/4k/8k 16QAM *CR*=1/2, *GI*=All	40 dB	38 dB	32 dB	38 dB	50 dB	50 dB
2k/4k/8k 16QAM *CR*=2/3, *GI*=All	40 dB	38 dB	32 dB	38 dB	50 dB	50 dB
2k/4k/8k 16QAM *CR*=3/4, *GI*=All	39 dB	37 dB	31 dB	37 dB	50 dB	50 dB
2k/4k/8k 64QAM *CR*=1/2, *GI*=All	37 dB	35 dB	29 dB	35 dB	47 dB	48 dB
2k/4k/8k 64QAM *CR*=2/3, *GI*=All	37 dB	35 dB	29 dB	35 dB	44 dB	45 dB

[a] Note that if PAL B $N - 1$ is with NICAM sound, the digital channel on N can not be used without offset, because of the overlapping spectrums.

[b] Note that the figures for PAL D1 are provisional. Performance for PAL D/K is similar than D1. Other analogue interfering signals may be considered in the future.

10.9.6 Immunity to pattern S2

This pattern has one digital DVB-T/H signal on $N \pm 1$ or $N \pm m$ channel in addition to the wanted DVB-T/H signal on channel N. Image channel is a special case where m is +9.

The DVB-T receiver shall provide the reference *BER* and the DVB-H receiver 5 % *MFER* when the unwanted signal is at the highest allowed level and the wanted signal is at (*a*) dB lower level, where the value for (*a*) is given in Table 28 and Table 29. The performance is only provided when the input level restrictions of 10.8.4 apply. The DVB-H figures apply for all MPE-FEC code rates.

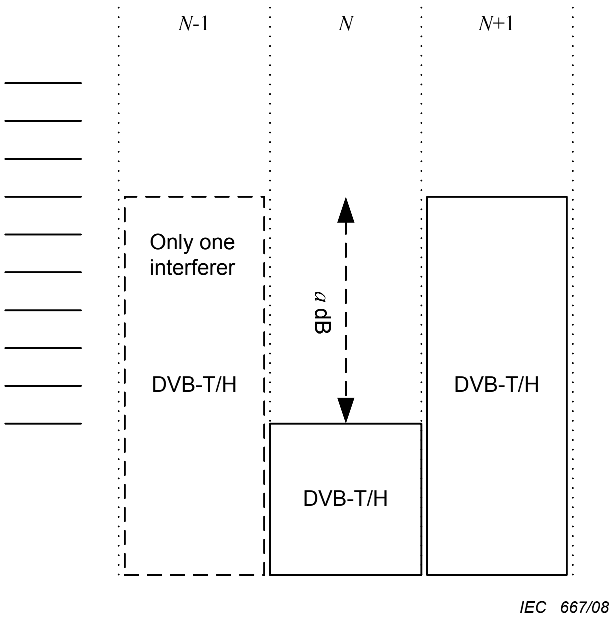


Figure 12 – Pattern S2 in case of $N + 1$ or $N - 1$

Table 28 – Immunity to pattern S2 for DVB-T

Mode	*a* [$N \pm 1$]	*a* [$N \pm m$ ($m \neq 1$) except $m = +9$	*a* $N + 9$
2k/8k 16QAM *CR*=1/2, *GI*=All	29 dB	40 dB	39 dB
2k/8k 16QAM *CR*=2/3, *GI*=All	29 dB	40 dB	36 dB
2k/8k 16QAM *CR*=3/4, *GI*=All	29 dB	40 dB	35 dB
2k/8k 64QAM *CR*=2/3, *GI*=All	27 dB	40 dB	31 dB
2k/8k 64QAM *CR*=3/4, *GI*=All	27 dB	40 dB	29 dB
NOTE $N + 9$ is a common image frequency.			

Table 29 – Immunity to pattern S2 for DVB-H

Mode	*a* [*N* ± 1]	*a* [*N* ± *m* (*m* ≠ 1) except *m* = +9	*a* *N* + 9
2k/4k/8k 16QAM *CR*=1/2, *GI*=All	31 dB	42 dB	41 dB
2k/4k/8k 16QAM *CR*=2/3, *GI*=All	31 dB	42 dB	38 dB
2k/4k/8k 16QAM *CR*=3/4, *GI*=All	31 dB	42 dB	37 dB
2k/4k/8k 64QAM *CR*=1/2, *GI*=All	29 dB	42 dB	33 dB
2k/4k/8k 64QAM *CR*=2/3, *GI*=All	29 dB	42 dB	31 dB
NOTE *N* + 9 is a common image frequency.			

10.9.7 Immunity to pattern L1

This pattern has one analogue signal on *N* + 4 channel and one digital DVB-T/H signal on *N* + 2 channel in addition to the wanted DVB-T/H signal on channel *N*.

The DVB-T receiver shall provide the reference *BER* and the DVB-H receiver 5 % *MFER* when the unwanted signals are at the highest allowed level and the wanted signal is at (*a*) dB lower level, where the value for (*a*) is given in Table 30 and Table 31.

The performance is only provided when the input level restrictions in subclause10.8.4 apply.

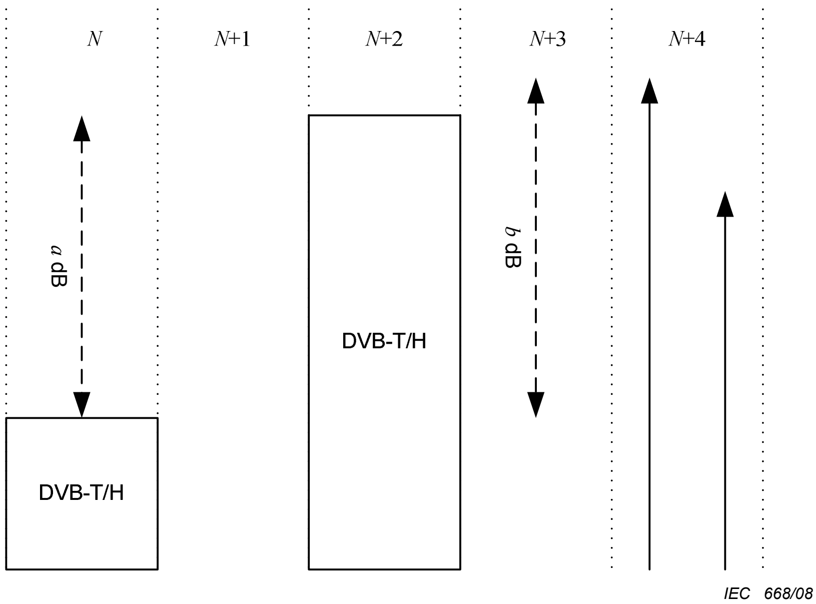


Figure 13 – Pattern L1

Table 30 – Immunity to pattern L1 for DVB-T

Mode	*a* [*N* + 2]	*b* [*N* + 4]
2k/8k 16QAM *CR*=1/2, *GI*=All	40 dB	45 dB
2k/8k 16QAM *CR*=2/3, *GI*=All	40 dB	45 dB
2k/8k 16QAM *CR*=3/4, *GI*=All	36 dB	41 dB
2k/8k 64QAM *CR*=2/3, *GI*=All	32 dB	37 dB

Table 31 – Immunity to pattern L1 for DVB-H

Mode	*a* [*N* + 2]	*b* [*N* + 4]
2k/4k/8k QPSK *CR*=1/2, *GI*=All	42 dB	47 dB
2k/4k/8k QPSK *CR*=2/3, *GI*=All	42 dB	47 dB
2k/4k/8k 16QAM *CR*=1/2, *GI*=All	42 dB	47 dB
2k/4k/8k 16QAM *CR*=2/3, *GI*=All	42 dB	47 dB

10.9.8 Immunity to pattern L2

This pattern has one analogue signal on *N* + 4 channel and another analogue signal on *N* + 2 channel in addition to the wanted DVB-T/H signal on channel *N*.

The DVB-T receiver shall provide the reference *BER* and the DVB-H receiver 5 % *MFER* when the unwanted signals are at the highest allowed level and the wanted signal is at (*a*) dB lower level, where the value for (*a*) is given in Table 32 and Table 33.

The performance given is only provided when the input level restrictions in 10.8.4 apply.

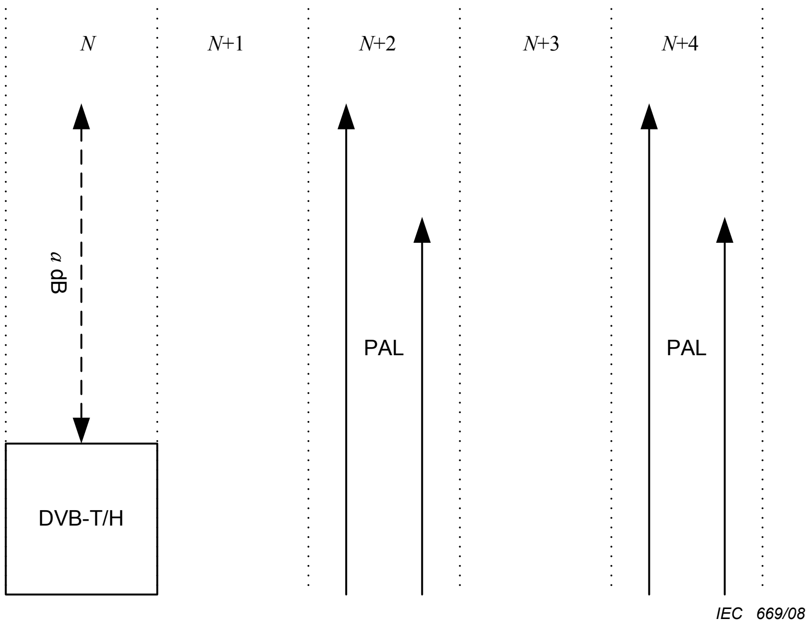


Figure 14 – Pattern L2

Table 32 – Immunity to pattern L2 for DVB-T

Mode	*a* [*N*+2 and *N*+4]
2k/8k 16QAM *CR*=1/2, *GI*=All	45 dB
2k/8k 16QAM *CR*=2/3, *GI*=All	45 dB
2k/8k 16QAM *CR*=3/4, *GI*=All	41 dB
2k/8k 64QAM *CR*=2/3, *GI*=All	37 dB

Table 33 – Immunity to pattern L2 for DVB-H

Mode	*a* [*N* + 2 and *N* + 4]
2k/4k/8k QPSK *CR*=1/2, *GI*=All	47 dB
2k/4k/8k QPSK *CR*=2/3, *GI*=All	47 dB
2k/4k/8k 16QAM *CR*=1/2, *GI*=All	47 dB
2k/4k/8k 16QAM *CR*=2/3, *GI*=All	47 dB

10.9.9 Immunity to pattern L3

This pattern has one digital DVB-T/H signal on *N* + 4 channel and another digital DVB-T/H signal on *N* + 2 channel in addition to the wanted DVB-T signal on channel *N*.

The DVB-T receiver shall provide the reference *BER* and the DVB-H receiver 5 % *MFER* when the unwanted signals are at the highest allowed level and the wanted signal is at (*a*) dB lower level, where the value for (*a*) is given in Table 34 and Table 35.

The performance given is only provided when the input level restrictions in 10.8.4 apply.

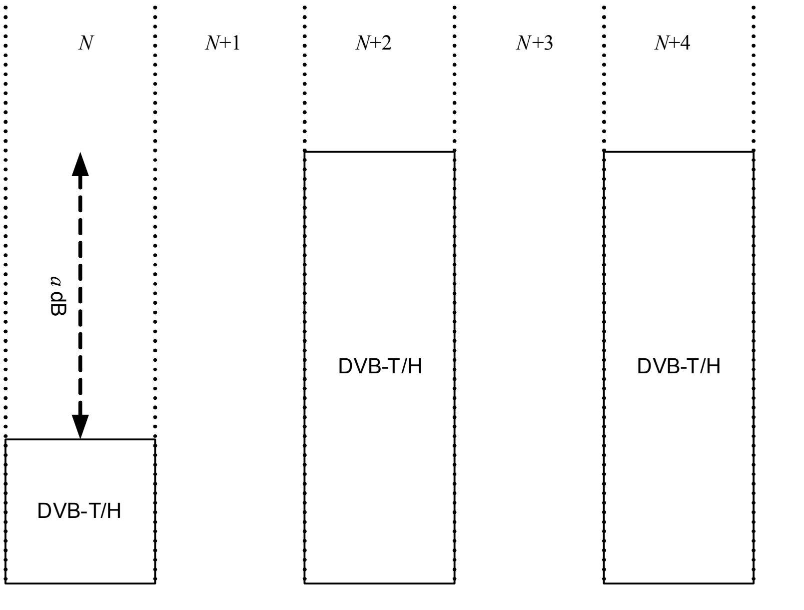


Figure 15 – Pattern L3

Table 34 – Immunity to pattern L3 for DVB-T

Mode	*a* [*N* + 2 and *N* + 4]
2k/8k 16QAM *CR*=1/2, *GI*=All	40 dB
2k/8k 16QAM *CR*=2/3, *GI*=All	40 dB
2k/8k 16QAM *CR*=3/4, *GI*=All	36 dB
2k/8k 64QAM *CR*=2/3, *GI*=All	32 dB

Table 35 – Immunity to pattern L3 for DVB-H

Mode	*a* [*N* + 2 and *N* + 4]
2k/4k/8k QPSK *CR*=1/2, *GI*=All	42 dB
2k/4k/8k QPSK *CR*=2/3, *GI*=All	42 dB
2k/4k(8k 16QAM *CR*=1/2, *GI*=All	42 dB
2k/4k/8k 16QAM *CR*=2/3, *GI*=All	42 dB

10.9.10 Immunity to pattern L4

This pattern has one interfering analogue signal on VHF channel L and one digital interfering DVB-T/H signal on UHF channel M so that the sum or difference of the frequencies of the interfering signals will overlap the wanted DVB-T signal on channel *N*.

$$f(N = f(M) \pm f(L)$$

The DVB-T receiver shall provide the reference *BER* and the DVB-H receiver 5 % *MFER* when the unwanted signals are at the highest allowed level and the wanted signal is at (*a*) dB lower level, where the value for (*a*) is given in Table 36 for DVB-T and Table 37 for DVB-H.

The performance given is only provided when the input level restrictions in 10.8.4 apply.

Table 36 – Immunity to pattern L4 for DVB-T

Mode	*a*
2k/8k QPSK *CR*=1/2, *GI*=All	45 dB
2k/8k QPSK *CR*=2/3, *GI*=All	45 dB
2k/8k 16QAM *CR*=1/2, *GI*=All	45 dB
2k/8k 16QAM *CR*=2/3, *GI*=All	45 dB

Table 37 – Immunity to pattern L4 for DVB-H

Mode	*a*
2k/4k/8k QPSK *CR*=1/2, *GI*=All	47 dB
2k/4k/8k QPSK *CR*=2/3, *GI*=All	47 dB
2k/4k/8k 16QAM *CR*=1/2, *GI*=All	47 dB
2k/4k/8k 16QAM *CR*=2/3, *GI*=All	47 dB

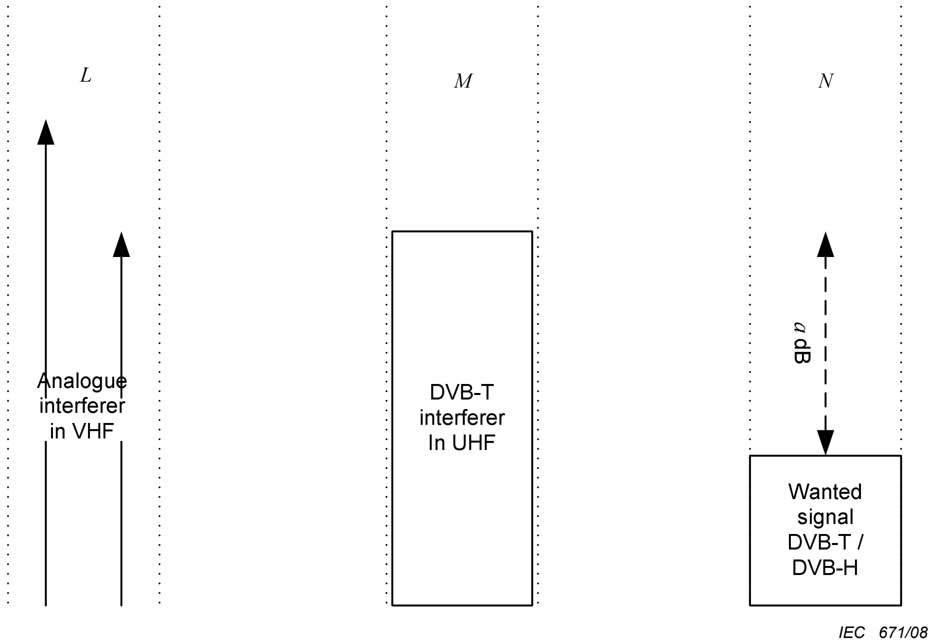


Figure 16 – Pattern L4

10.10 Immunity to co-channel interference from analogue TV signals

The immunity for interference from analogue TV-signal is specified for DVB-T in Table 38 and for DVB-H in Table 39 as the minimum interference to carrier ratio, *I/C*, required for reference *BER* for DVB-T and 5 % *MFER* for the DVB-H.

The interfering analogue signal is defined in 10.9.1. The digital signal level should be -50 dB(mW).

Table 38 – Immunity to co-channel interference from analogue signals for DVB-T

Mode	PAL I1	PAL B/G/D1 [a]*	SECAM
2k/8k 16QAM *CR*=1/2 *GI*=All	6 dB	6 dB	5 dB
2k/8k 16QAM *CR*=2/3 *GI*=All	1 dB	–1 dB	0 dB
2k/8k 16QAM *CR*=3/4 *GI*=All	0 dB	–2 dB	–3 dB
2k/8k 64QAM *CR*=2/3 *GI*=All	–4 dB	–4 dB	–5 dB
2k/8k 64QAM *CR*=3/4 *GI*=All	–7 dB	–7 dB	–8 dB

[a] Note that the figures for Pal D1 are provisional. Performance for PAL D/K is similar than D. Other analogue interfering signals may be considered in the future.

Table 39 – Immunity to co-channel interference from analogue signals for DVB-H

Mode	All analogue interferers
All QPSK and 16 QAM modes, *CR*=1/2 and 2/3	–4 dB

10.11 Guard interval utilization

10.11.1 Performance with echo within guard interval

For the modes:

{2k/4k/8k, 16-QAM, R =1/2, *GI* = All},

{2k/4k/8k, 16-QAM, R =2/3, *GI* = All},

{2k/4k/8k, 64-QAM, R =2/3, *GI* = All},

{2k/4k/8k, 64-QAM, R =3/4, *GI* = All},

the DVB-T receiver shall provide the reference *BER* and the DVB-H receiver shall provide 5 % *FER* when the channel contains two static paths with relative delay from 0,2 µs up to 0,9 times the guard interval length independently of the relative amplitudes and phases of the two paths. Noise is added according to Table 40.

Table 40 – *C/N* for echo within guard interval

Mode	*C/N* dB
2k/4k/8k, 16-QAM, R =1/2, *GI* = All	16,3
2k/4k/8k, 16-QAM, R =2/3, *GI* = All	20,9
2k/4k/8k, 64-QAM, R =2/3, *GI* = All	26,2
2k/4k/8k, 64-QAM, R =3/4, *GI* = All	30,6

10.11.2 Performance with echo outside guard interval

When receiving a signal, which consists of the main path and one echo with a delay longer than 0,9 times the guard interval, the DVB-T receiver shall provide reference *BER* and the DVB-H receiver shall provide 5 % *FER* when the level of the echo, compared to the main signal, is lower than the mask shown in Figure 17.

The mask is defined by three points, the starting point at $0{,}9 \times Tg$, the inflection point at $1{,}0 \times Tg$ and the corner point at Tc. Timing of the point Tc depends on the guard interval according the Table 41.

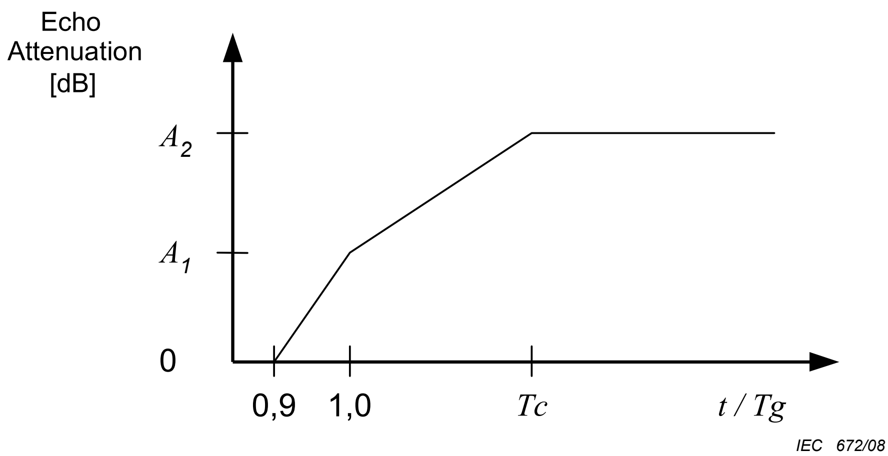


Figure 17 – Echo outside guard interval mask

Table 41 – Timing of the corner point Tc

Guard interval	Tc relative to Tg
1/4	1,1
1/8	1,3
1/16	2,0
1/32	3,1

Echo attenuation A_2 at the corner point Tc is dependent on the used modulation and is calculated by adding a value Δ to the C/N requirement of the mode in the Gaussian channel, as defined in the Table 15. The value Δ is defined in the Table 42.

Table 42 – Definition of the value Δ

Modulation	Δ dB
QPSK	2
16QAM	3
64QAM	4

A_2 then becomes:

$$A_2 = C / N_{\text{Mode}} + \Delta$$

Echo attenuation A_1 at the inflection point at t = 1,0 × Tg depends on the used modulation and code rate, as defined in Table 43.

Table 43 – Definition of the inflection point

Modulation	Code rate	A_1 at t = 1,0 × Tg dB
QPSK	1/2	1
QPSK	2/3	1
QPSK	3/4	2
16-QAM	1/2	1
16-QAM	2/3	2
16-QAM	3/4	3
64-QAM	1/2	1
64-QAM	2/3	3
64-QAM	3/4	7

At the starting point t = 0,9 × Tg, the echo attenuation is always 0 dB.

The definition of the mask results in a series of curves for each guard interval. They are valid for all FFT-sizes. As an example, masks for GI = 1/4 are shown in Figure 18.

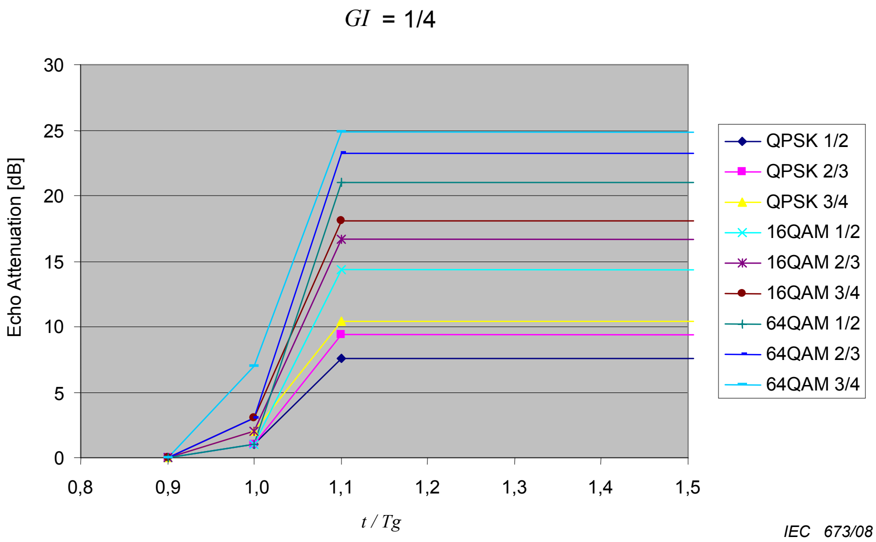


Figure 18 – Mask for echo outside *GI* for *GI* = 1/4

Useful theoretical background and a simple model is given in Annex C.

10.12 Tolerance to impulse interference

10.12.1 General

Impulse interference is different from other forms of interference, in that it is generated in short bursts. Sources include car ignition systems and domestic appliances such as switches and electric motors. In portable and mobile environment, the impulse interference will reach the receiver directly through the antenna. The damage is potentially serious because a single impulse burst can destroy a complete symbol's worth of data. Research work on the impulse interference has been mainly carried out in the UK digital television group. The specifications presented here are results of that work.

10.12.2 Test patterns

Various test signals comprising gated bursts of Gaussian noise are defined. The theoretical tolerance of the standard receiver for these can be calculated as follows. The interference power is integrated over a symbol period; then the energy of the wanted signal within that symbol period is divided by this figure. Should the result fall below the minimum *C/N* requirement for the particular modulation mode, the system will fail.

Six different test patterns have been defined. Figure 19 illustrates the terminology used with the test patterns.

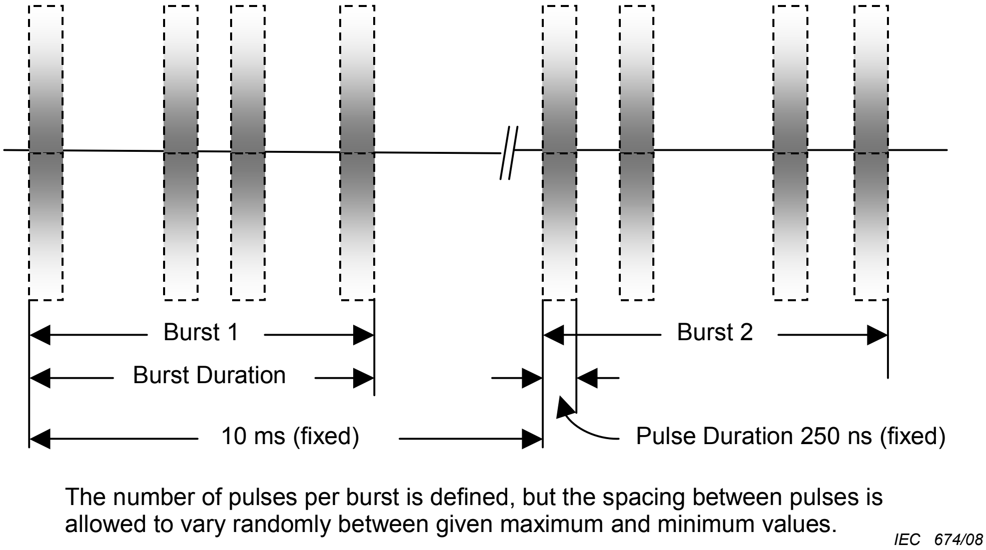


Figure 19 – Definition of the impulse interference test pattern

Each burst is relatively short compared with the symbol period, so that most bursts only affect a single symbol. The separation between bursts is sufficiently great for them to behave as isolated events: any errors resulting from the first burst will have been flushed from the system by the time the second burst is received.

All pulses are generated by gating a Gaussian noise source of power P. Hence the noise energy in a burst is the product of P and the total duration of the gating pulses, Te, within the burst. Since the total signal energy is the product of the carrier power, C, and the active symbol duration, Tu, the ratio of wanted signal energy to interference energy is

$$(C \times Tu) / (P \times Te)$$

The theoretical failure point corresponds to this quantity equalling the minimum carrier-to-noise requirement, $(C/N)ref$, for the system. In other words, the tolerance of the receiver to the test signal should exceed its tolerance to ungated Gaussian noise by a factor (Tu/Te). This so-called 'tolerance factor' is generally expressed in dB. Note that it is independent of modulation mode, receiver implementation margin and degradation criterion, but that the FFT-size affects it via the Tu duration, giving 6 dB higher figures for 8k than for 2k and 3 dB higher figures for 4k than 2k. In case the in-depth interleaver is used with 2k or 4k mode, the 8k tolerance factor should be used.

The tests so far defined are detailed in the Table 44, together with their associated 'tolerance factors'.

Table 44 – Impulse interference test patterns

Test No.	Pulses per burst	Minimum/maximum pulse spacing µs		Burst duration ms	Tolerance factor 2k dB	Tolerance factor 4k dB	Tolerance factor 8k dB
1	1	N/A	N/A	0,25	29,5	32,5	35,5
2	2	1,5	45	45,25	26,5	29,5	32,5
3	4	15,0	35	105,25	23,5	26,5	29,5
4	12	10,0	15	165,25	18,7	21,7	24,7
5	20	1,0	2	38,25	16,5	19,5	22,5
6	40	0,5	1	39,25	13,5	16,5	19,5

As an example, suppose that a receiver reaches 'picture failure' when C/N = 18 dB with a 2k mode. The expected picture failure point for test 2 then corresponds to a pulse power of -18 dBc + 26,5 dB or +8,5 dBc. A convenient way of measuring the pulse power is to switch off the gating, so that the noise is present continuously.

A receiver which employs countermeasures against impulse interference should have tolerance factors in excess of those given in Table 44 for one or more tests. The higher the test number, the greater the difficulty in designing effective countermeasures.

DVB-H receivers with MPE-FEC or receivers using the indepth interleavers with 4k or 2k are expected to have an improved performance against impulse interference over the DVB-T receivers.

10.13 EMC characteristics

10.13.1 Terminal category c

If the DVB-T receiver function is implemented as an accessory to the phone terminal the accessory shall comply with the ETS 300 342-1.

In case of full integration of the DVB-T part, the terminal shall comply with ETS 300 607-1, chapter 12 transceiver (pages 132-139), reference test methods (page 1552).

Note that the emission limits set by the EMC standards are far higher than should be expected from a convergence terminal intended to work with full DVB-T receiver sensitivity.

10.13.2 Terminal category a and b

Terminal categories a and b shall comply with CISPR 13 and CISPR 20.

11 Interoperability with other radio systems

11.1 Cellular radios

11.1.1 General

Most of the services presented for convergence terminals (terminal category c) require the co-existence and partly simultaneous operation of DVB-T/H receiver and cellular radios. The cellular radio could be in Europe GSM/EDGE 900, GSM/EDGE 1800, WCDMA or a combination of these.

The co-existence and especially simultaneous operation of several radios in small sized hand-held terminal causes several challenges for the design.

11.1.1.1 Issues

The system level interoperability issues for DVB-T/H reception coming from the co-existence and operation of DVB-T/H receiver and cellular radio transmitter can be divided into two main categories:

a) cellular radio uplink wanted signal interference to DVB-T/H receiver;
b) cellular radio uplink unwanted signal interference to DVB-T/H receiver,
   1) transmitter power amplifier out of band signals,
   2) transmitter power amplifier (PA) noise.

Undisturbed operation of cellular radio must also be maintained. Possible impairments caused by DVB-T/H receiver could be

- out-of-band unwanted signals in cellular downlink (RX) band,
- affects to the cellular antenna pattern.

These problems are pure implementation issues and can be solved by proper terminal design.

11.1.1.2 Terminal architectures

The terminal architecture (relevant parts) of a typical modern GSM/EDGE or WCDMA + DVB-T convergence terminal is presented in Figure 20.

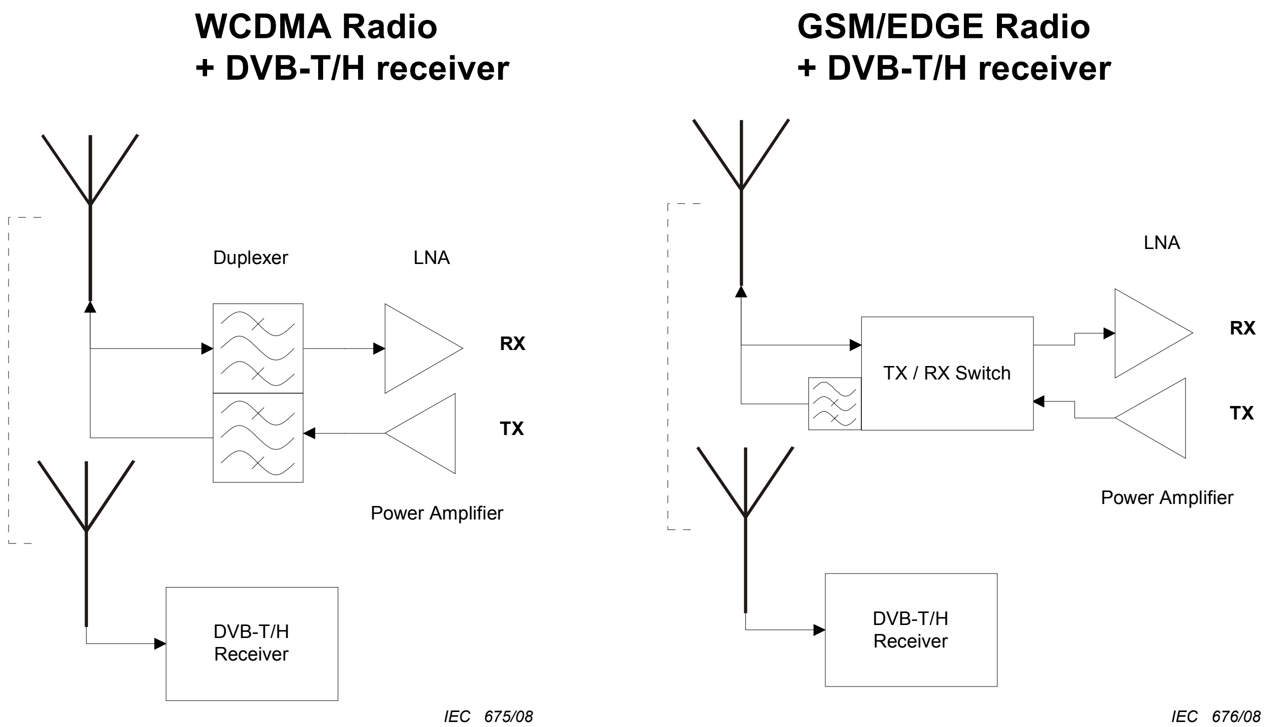


Figure 20 – Terminal architectures

Most probably DVB-T/H receiver and cellular radio will have two physically separate antennas, which will have frequency dependent antenna isolation between them.

An important difference between WCDMA and GSM/EDGE radios is the duplex filter. WCDMA will use duplex filter, but majority of modern GSM/EDGE radios use TX/RX switch. This has a major implication on the interoperability, and it is obvious that the cellular radio uplink unwanted signal interference to DVB-T/H receiver will not be a problem in WCDMA terminal if a duplexer is used. However, the problem will be severe in GSM/EDGE terminal with TX/RF switch.

11.1.1.3 Frequency bands

The frequency bands used by the different radio systems are presented in Figure 21.

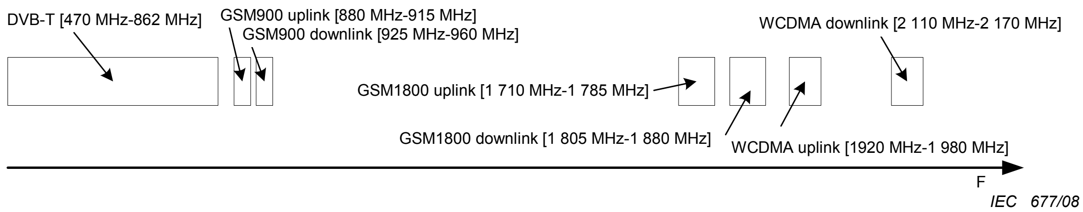


Figure 21 – Frequency bands

The full UHF DVB-T band is from 470 MHz to 862 MHz and the uplink bands of cellular radios are marked with arrows in the figure. This means transmitted signal (TX) in the mobile terminal end and therefore represent by the high power level. The downlink (receiving / RX) bands of cellular radios are above the corresponding uplink bands.

From the Figure 21 it is obvious that the most problematic cellular radio from interoperability point of view is the GSM 900 because of the very narrow guard band between DVB-T band and GSM 900 uplink. The guard band is only 18 MHz wide. Therefore, the relative bandwidth of the guard band is very small. The problems are much less severe with GSM 1800 and even easier with WCDMA because of the bigger guard band between RX and TX-bands.

11.1.2 Cellular radio uplink wanted signal interference to DVB-T/H receiver

11.1.2.1 Problem area

The transmitted cellular signal is very high power compared to the received DVB-T/H signals. GSM 900 TX signal is the strongest one and therefore it will be considered here as a worst-case situation. Also the guard band is smallest between GSM 900 TX and DVB-T/H RX bands.

GSM 900 transmitted power is +33 dB(mW) (2W). Part of this is coupled from cellular transmitter antenna to the DVB-T/H receiver antenna. Optimistic assumption for the coupling loss between antennas is 10 dB. Therefore without any filtering the cellular TX signal present in the DVB-T/H receiver, input would be +23 dB(mW).

This very high interference signal level would cause severe blocking effects by two mechanisms: desensitisation and cross-modulation.

11.1.2.2 Interoperability requirements

The practical solution for interoperability in 11.1.2 is to insert GSM-rejection filter in front of the DVB-T/H receiver. The filter has to attenuate the cellular Tx-signal to a level where the receiver sensitivity will drop a maximum of 1,5 dB from the specified sensitivity (see 10.8.2). It is assumed that the antenna isolation between the cellular transmitter antenna and DVB-H reception antenna is at least 15 dB. When the cellular Tx signal maximum level is 33 dB(mW), this means a level of +18 dB(mW) at the reference point in front of the GSM-reject filter.

This requirement has to be met when the cellular interferer frequency is in the frequency ranges given in Table 45.

Table 45 – Cellular interferer frequency ranges

Cellular system	Frequency MHz
GSM 900	880 - 915
GSM 1800	1 710 - 1 785
WCDMA	1 920 - 1 980

11.1.3 Cellular radio uplink unwanted signal interference to DVB-T/H receiver

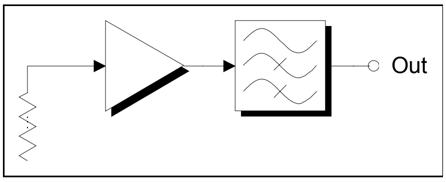
11.1.3.1 Transmitter power amplifier carrier like unwanted signals

The GSM specification (GSM 05.05) defines that within 100 kHz measurement bandwidth, the power shall not be greater than –36 dB(mW) within frequency band 9 kHz … 1 GHz.

In practice, the spectrum of the carrier like unwanted signals is very sparse, and DVB-T itself is very tolerant to this kind of interference. However, the implementation of the terminal has to take care that the performance degradation is low enough at the relevant frequencies.

11.1.3.2 Transmitter power amplifier (PA) noise

The cellular radio transmitter emits in addition to the wanted cellular TX signal and carrier like unwanted signals also wideband noise. The circuit model of the GSM transmitter TX branch is presented in Figure 22.



IEC 678/08

Figure 22 – GSM Tx block diagram

In GSM/EDGE radio where RX/TX switch (like in Figure 20) is used, the last high pass filter is very relaxed or nonexistent. If we assume that the filter is not implemented at all and no natural roll off zero is present, the noise power within one DVB-T channel in the power amplifier output can be calculated from the following equation. The power amplifier input is assumed to be matched to 50Ω.

$$P_{\text{noise}} = -174 + 10 \cdot \log_{10}(7{,}61 \cdot 10^{6}) + G + NF$$

where

P_{noise} is the noise power in dB(mW);

G is the gain of the PA in dB, typically 20 dB;

NF is the noise figure of the PA in dB, typically at least 15 dB

With these figures and assuming a 10 dB coupling loss between GSM and DVB-T/H antennas, the interference power entering DVB-T/H receiver would be –80 dB(mW). As the sensitivity of the DVB-T/H receiver, for example with 16QAM CR = 1/2 mode, is –88,9 dB(mW), it is obvious that the transmitter output noise reduces the DVB-T/H receiver sensitivity considerably.

In order to degrade the DVB-T/H receiver sensitivity "only" by 3 dB, the transmitter output noise would need to be –99,2 dB(mW) within one DVB-T channel and with 6 dB noise figure.

In practice, the problem is most severe with GSM 900 band. With GSM 1800 band natural roll-off and possible TX high pass filter and bandwidth limitation of the power amplifier provides adequate attenuation for the DVB-T band. In WCDMA radio, the problem does not exist because of the used duplex filter.

Reduction of the noise level becomes possible when the DVB-T operating band for terminal category c is limited to channel 55 (centre frequency 746 MHz). At 746 MHz, matching of the power amplifier already provides considerable filtering, i.e. the gain of the PA at 746 MHz is much reduced when compared to the gain at 880 MHz. Also possible extra filters become much easier to realize. All this gives a good possibility to drop the PA noise contribution to a negligible level in band IV.

11.1.3.3 Interoperability requirements

To guarantee interoperability between the radio systems, the noise power at the DVB-T/H receiver input must fulfil the mask shown in Figure 23.

The noise level is affected by the gain, noise figure and band width of the power amplifier, by antenna coupling between the two antennas at the DVB-T reception band and by the attenuation of the possible high pass filter at the output of the PA.

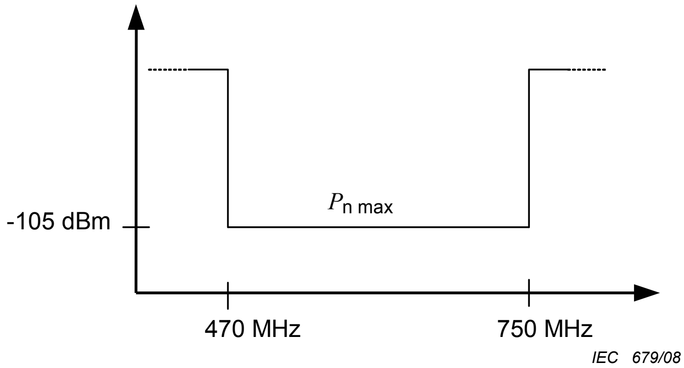


Figure 23 – Tx PA-noise mask in DVB-T/H receiver input

11.2 DVB-RCT

The DVB-RCT specification (ETSI EN 301 958 [14]) has been developed for interactive applications in the UHF band. It has been designed for rooftop antenna applications.

Although the specification has been completed in 2001, no frequency band has been allocated to this application so far. Moreover, commercial rollout of RCT is now becoming doubtful.

In view of this situation, no recommendation can be done regarding interoperability of portable and mobile DVB-T with DVB-RCT applications.

Annex A
(informative)

Active external antennas and system noise floor

A.1 Active antennas

An active antenna consists of a passive antenna followed by and combined with a low noise pre-amplifier. The combination can be considered as a single entity with a total gain G_t. Alternatively, it may be expressed as an equivalent passive antenna with a gain G_{eq} which results in the same overall system noise performance.

A.2 Antenna noise temperature

The noise temperature of a passive UHF antenna is generally taken to be equal to the reference temperature T_o = 290 K.

Therefore, the noise temperature of an active UHF antenna is:

$$T_o F_\mathrm{p} G_\mathrm{amp}$$

where

F_p is the noise factor (linear ratio) of the active antenna pre-amplifier;

G_amp is the gain (linear ratio) of the active antenna pre-amplifier.

A.3 '*G/T*' figure of merit (*m*)

One method of specifying overall performance is the 'gain over temperature ratio' or '*G/T*'

$$m \text{ (dBi / K)} = 10 \lg (G/T) = G \text{ (dBi)} - 10 \lg (T_\mathrm{sys})$$

where

m is the figure of merit in dBi/K;

G is the antenna gain in dBi;

T_sys is the noise temperature of the total system in kelvin (K).

The noise temperature of the total system is the noise temperature of the antenna plus the equivalent noise temperature of the receiver. If the receiver noise factor is F (linear ratio), then the equivalent noise temperature of the receiver is: $(F - 1)T_\mathrm{o}$.

Example:

An active antenna has the following parameters:

Omni directional antenna gain	= 0 dBi	
Pre-amplifier noise figure	= 3,0 dB	(F_p = 2)
Pre-amplifier gain	= 14,9 dB	(G_amp = 30,9)
Total gain	= 14,9 dBi	(G_t = 30,9)

The antenna noise temperature is:

$$T_0 F_p G_{amp} = 17\ 881\ \text{K}$$

If the receiver noise figure is 8 dB (F = 6,3), then the equivalent noise temperature of the receiver is:

$$(F - 1)T_0 = 1\ 540\ \text{K}$$

The noise temperature of the total system

$$T_{sys} = 19\ 421\ \text{K}$$

$$10\ \lg\ (T_{sys}) = 42{,}9\ \text{dB}$$

So the figure of merit (m) is

$$m = -28{,}0\ \text{dBi/K}$$

Engineers familiar with terrestrial systems may prefer the concept of an active antenna being specified in terms of an equivalent passive antenna. This is now calculated:

The noise temperature of a UHF passive antenna	= 290 K
The equivalent noise temperature of the receiver (as above)	= 1 540 K
The noise temperature of an equivalent 'passive' system T_{sys}	= 1 830 K
And 10 log (T_{sys})	= 32,6 dB
Therefore, for the same (as above) figure of merit (m)	= –28,0 dBi / K

The gain of an equivalent passive antenna is

$$G_{eq} = 4{,}6\ \text{dBi}$$

A.4 System noise floor

The system noise floor at the reference point can be calculated from:

$$\text{Noise floor} = kT_0 B F_{sys}$$

where: k = Boltzmann's constant (1,38 × 10^{-23} J/K)

T_0 = Reference temperature (290 K)

B = System noise bandwidth (7,61 MHz, 6,65 MHz or 5,71 MHz)

F_{sys} = System noise factor

The system noise factor F_{sys} should include all noise sources both internal and external [ref ITU_R P.372].

$$F_{sys} = F_a - 1 + F_r$$

$$= F_a - 1 + F_{tuner} \cdot F_{gsm}$$

where: F_a = External noise factor (man-made noise).

F_r = noise factor of the receiver.

F_{gsm} = noise factor of the GSM filter (can be taken to equal its loss).

F_{tuner} = noise factor of the tuner.

Note the above noise factors are linear ratios. The value of F_a and hence F_{sys} will depend upon the electromagnetic (EM) environment. Even with no antenna connected, there may be ingress of man-made noise from digital circuitry within the receiver.

All the receiver performance figures are specified at the reference point, which is the input of the receiver. A practical formula for Noise floor in dB(mW) is given below:

Noise floor (dB(mW)) = F_{sys} (dB) –105,2 (dB(mW)) (8 MHz channels)

Noise floor (dB(mW)) = F_{sys} (dB) –105,7 (dB(mW)) (7 MHz channels)

Noise floor (dB(mW)) = F_{sys} (dB) –106,4 (dB(mW)) (6 MHz channels)

For conformance testing the values are given in Table A.1.

Table A.1 – Noise floor values

Terminal category	F_{sys} dB	**Noise floor** dB(mW)		
		7,61 MHz	**6,66** MHz	**5,71** MHz
a	6	–99,2	–99,7	–100,4
b1	6	–99,2	–99,7	–100,4
b2	4	–101,2	–101,7	–102,4
c (no GSM filter)	4	–101,2	–101,7	–102,4
c (with GSM filter)	6	–99,2	–99,7	–100,4

Note that the system noise floor F_{sys} will be dependent upon both F_a and F_r. Studies of radio noise indicate that F_a is likely to be greater than unity (0 dB) due to increased man-made noise pollution. This could mean that the receiver noise floor is greater than expected. Also, there would not be a dB for dB relationship between receiver noise figure and noise floor. This is illustrated in Figure A.1.

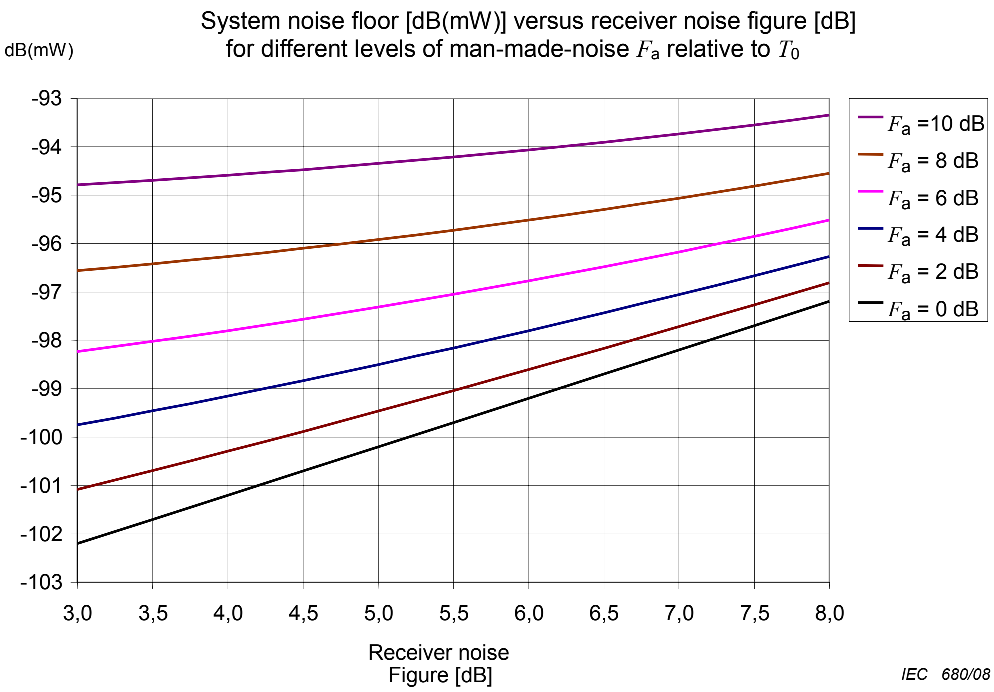


Figure A.1 – System noise floor versus receiver noise figure for different levels of man-made-noise F_a relative to T_0

Annex B
(informative)

An example of *C/N*-performance with a practical transmitter

C/N values for *IL* specified in 10.7.1 and 10.7.2, receiver P_x =–33 dBc and transmitter *ENF* =–34 dBc are given in Table B.1.

Table B.1 – *C/N* (dB) for reference *BER*

Modulation	Code rate	Gaussian	Portable P_1
QPSK	1/2	4,6	7,4
QPSK	2/3	6,4	11,5
QPSK	3/4	7,4	15,2
16-QAM	1/2	10,6	13,6
16-QAM	2/3	12,8	17,6
16-QAM	3/4	14,0	21,5
64-QAM	1/2	15,4	18,7
64-QAM	2/3	18,5	23,4
64-QAM	3/4	20,1	28,1

NOTE 1 Reference *BER* is defined as $BER = 2 \times 10^{-4}$ after Viterbi decoding.

NOTE 2 The figures in ETSI EN 300 744 are all the result of early simulation work, and could change as a result of improved simulations.

Annex C
(informative)

Multipath reception in a DVB-T system

C.1 General

The issue of multipath and resulting inter-symbol interference (ISI) in an OFDM system is well understood and documented [13]. Figure C.1 provides a pictorial explanation. It is possible to quantify the resulting ISI in terms of carrier-to-interference power ratios (C/I) based on theoretical analysis. These could then be used to extract the theoretical echo profiles of a DVB-T system.

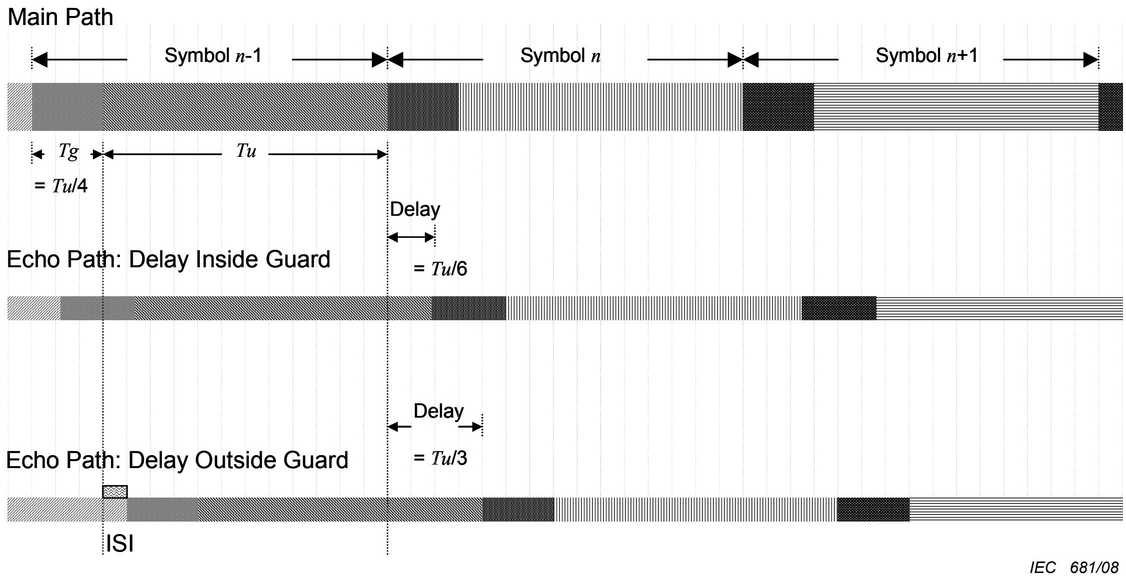


Figure C.1 – Theoretical limits of out of guard delay

C.2 Theoretical quantification of ISI in a DVB-T system

In a DVB-T system, the insertion of the guard interval allows for the constructive combination of multipath signals contributing towards useful component. This, however, depends on the time of arrival of the signals. As the time of arrival (echo delay) exceeds the guard interval, the useful contribution decreases sharply while ISI increases as the power in the echo turns into an interfering component. In the case of DVB-T, due to the pilot carriers that are needed for coherent demodulation, the total loss of constructive signal components occurs after a delay of $Tp = Tu/3$. Thus, it would make it impossible to adequately equalise the received signal.

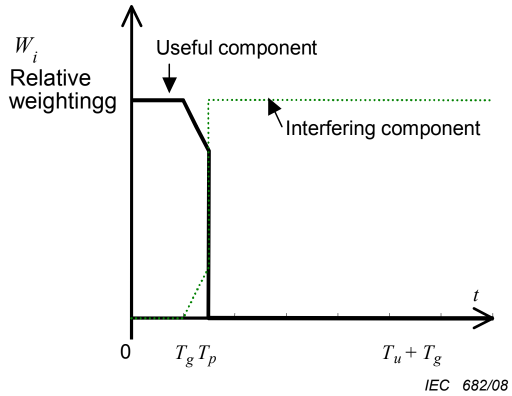


Figure C.2 – DVB-T model – Splitting of the signal power into contributing and interfering components

The signal power of the contributing and interfering components can be mathematically expressed as given be Equation C.1.

$$C = \sum_i W_i . C_i$$
$$I = \sum_i (1 - W_i) . C_i$$
$$W_i = \begin{cases} 1 & \text{if} \quad 0 \le |\, t_i \,| \le T_g \\ \left(\dfrac{(T_u + T_g) - |\, t_i \,|}{T_u} \right)^2 & \text{if} \quad T_g < |\, t_i \,| \le T_p \\ 0 & \text{if} \quad |\, t_i \,| > T_p \end{cases} \tag{C.1}$$
$$T_p = \frac{T_u}{3}$$

where

- C is the total power of the effective useful signal;
- I is the total effective interfering power;
- C_i is the power contribution from i-th signal at the receiver input;
- W_i is the weighting coefficient for the i-th component;
- t_i is the time of arrival of i-th component (t_i = 0, for main path).

This expression assumes symmetrical performance, i.e. the same behaviour for both pre- and post-cursive echoes.

C.3 Theoretical echo power profiles

For a single echo channel (i.e. I = 0 for main path and I = 1 for echo signal), the total power of the effective useful signal, C_t, can be defined as:

$$C_t = C_0 + W_1 \cdot I$$

where 'C_0' is the power of the main path signal and 'I' is the echo power. The total effective interfering power, I_t, can also be defined as:

$$I_t = (1 - W_1) \cdot I$$

If $(C/N)_{\text{Mode}}$ represented the Gaussian performance (minimum C/N to obtain QEF condition) of different transmission modes, we could then try to find the maximum echo power that would satisfy the following condition:

$$C_t / I_t = C / N_{\text{Mode}} \Rightarrow \frac{C_0 + W_1 \cdot I}{(1 - W_1) \cdot I} = C / N_{\text{Mode}}$$

for a range of 't_i', echo delays.

This procedure would generate the theoretical echo power profile. It is important to note that in this analysis an ideal receiver (perfect synchronisation) is assumed and thus the echo power masks obtained in this way should only be used as guidelines. This is the ultimate performance and it might not be possible to achieve this with a 'real' system.

A typical theoretical echo profile is shown in Figure C.3. This corresponds to 8k, 64QAM, 2/3 where $(C/N)_{\mathrm{Mode}}$ = 19,2 dB.

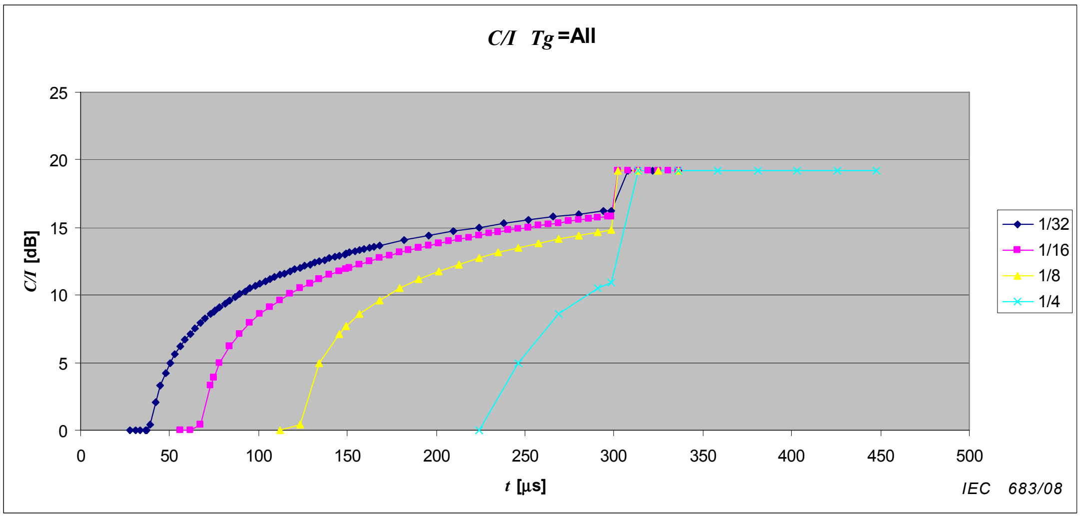


Figure C.3 – Theoretical echo power profile for 8k, 64QAM, 2/3

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