INTERNATIONAL STANDARD

IEC 62002-1

First edition
2005-10

Mobile and portable DVB-T/H radio access –

**Part 1:
Interface specification**

Reference number
IEC 62002-1:2005(E)

Publication numbering

As from 1 January 1997 all IEC publications are issued with a designation in the 60000 series. For example, IEC 34-1 is now referred to as IEC 60034-1.

Consolidated editions

The IEC is now publishing consolidated versions of its publications. For example, edition numbers 1.0, 1.1 and 1.2 refer, respectively, to the base publication, the base publication incorporating amendment 1 and the base publication incorporating amendments 1 and 2.

Further information on IEC publications

The technical content of IEC publications is kept under constant review by the IEC, thus ensuring that the content reflects current technology. Information relating to this publication, including its validity, is available in the IEC Catalogue of publications (see below) in addition to new editions, amendments and corrigenda. Information on the subjects under consideration and work in progress undertaken by the technical committee which has prepared this publication, as well as the list of publications issued, is also available from the following:

- **IEC Web Site (www.iec.ch)**

- **Catalogue of IEC publications**

  The on-line catalogue on the IEC web site (www.iec.ch/searchpub) enables you to search by a variety of criteria including text searches, technical committees and date of publication. On-line information is also available on recently issued publications, withdrawn and replaced publications, as well as corrigenda.

- **IEC Just Published**

  This summary of recently issued publications (www.iec.ch/online_news/ justpub) is also available by email. Please contact the Customer Service Centre (see below) for further information.

- **Customer Service Centre**

  If you have any questions regarding this publication or need further assistance, please contact the Customer Service Centre:

  Email: custserv@iec.ch
  Tel: +41 22 919 02 11
  Fax: +41 22 919 03 00

INTERNATIONAL STANDARD

IEC 62002-1

First edition
2005-10

Mobile and portable DVB-T/H radio access –

Part 1: Interface specification

International Electrotechnical Commission, 3, rue de Varembé, PO Box 131, CH-1211 Geneva 20, Switzerland
Telephone: +41 22 919 02 11 Telefax: +41 22 919 03 00 E-mail: inmail@iec.ch Web: www.iec.ch

Commission Electrotechnique Internationale
International Electrotechnical Commission
Международная Электротехническая Комиссия

PRICE CODE XA

For price, see current catalogue

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

MOBILE AND PORTABLE DVB-T/H RADIO ACCESS –

Part 1: Interface specification

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC provides no marking procedure to indicate its approval and cannot be rendered responsible for any equipment declared to be in conformity with an IEC Publication.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

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

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

CDV	Report on voting
100/920/CDV	100/1012/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.

IEC 62002 consists of the following parts, under the general title *Mobile and portable DVB-T/H Radio access:*

Part 1: Interface specification

Part 2: Interface conformance testing

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.

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 QoS criteria
- Antenna characteristics
- Channel models
- $C/$ -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 300 744:2004, *Digital Video Broadcasting (DVB); Framing structure, Channel coding and modulation for digital terrestrial television, V1.5.1*

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*

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 = 3,0 × 10^8 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 3dB
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
ICI	Intercarrier interference
J	joule
K	Boltzmann's constant k = 1,38 × 10^{-26} J/K
K	kelvin
L1, L2, L3	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
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 compended 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
Px	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
RF	Radiofrequency
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 kelvins
Tc	Corner point
Te	Total duration of the gating pulses
ti	Time of arrival for the *i*-th signal
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 specification three different terminal categories are considered. The requirements cover all categories unless otherwise stated.

The terminal categories are:

a) Integrated car terminals

   This category covers DVB-T 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 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]

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 used in various countries. The centre frequencies f_c of the incoming DVB-T RF signals are as follows.

1) Figures in square brackets refer to the Bibliography.

VHF III

For countries using 8 MHz channel raster

fc = 178 MHz + (N – 6) x 8 MHz +f offset

N = {6, …,12} (VHF channel number)

For countries using 7 MHz channel raster

fc = 177,5 MHz + (N – 5) x 7 MHz +f offset

N = {5, …,12} (VHF channel number)

For countries using 6 MHz channel raster

fc = 177,0 MHz + (N – 7) x 6 MHz +f offset

N = {7, …,13} (VHF channel number)

In some countries offsets may be used

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

UHF IV and V

For countries using 8 MHz channel raster

fc = 474 MHz + (N – 21) x 8 MHz +f offset

n = {21, …,69} (UHF channel number)

For countries using 7 MHz channel raster

fc = 529,5 MHz +(N – 28) x 7 MHz +f offset

n = {28, …,67} (UHF channel number)

For countries using 6 MHz channel raster

fc = 473,0 MHz +(N – 14) x 6 MHz +f offset

n = {14, …,83} (UHF channel number)

In some countries offsets may be used

Preferred offset is ± n x 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 the case where GSM 900 is used in a convergence terminal (category c), the usable frequency range is limited to channel 49 (698 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 49 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. DVB-T modes

7 DVB-T modes

7.1 Supported DVB-T 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). The front end 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 *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 Trade 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 an *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, whilst *MER* is effectively the ratio of carrier power to noise power.) The *MER* is converted into *END* by means of the following formula:

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

where $(C/N)_{\text{ref}}$ 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)*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

$(C/N)_{ref}$ 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 16,5 dB, to which must be added the implementation margin for the channel equalizer 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 $(C/N)_{ref}$ of the receiver is 19 dB. The *END* of the test transmitter is made up of two contributions:

$MER - (C/N)_{ref}$ = 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 × (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 *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 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. In order 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 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 specification.

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 λ/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 λ/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 λ/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 49 [698 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 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 shall be 75 Ω.

The input connector for terminal category b1 can, as an optional feature, provides a supply of DC-power for an active indoor antenna. This supply should have the following characteristics.

- 5V(DC), maximum 30 mA, the centre contact as a positive terminal.
- The supply should be short circuit proof.
- The supply can be switchable by software, default state should be off.

10 Receiver performance

10.1 Reference model

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

Figure 1.

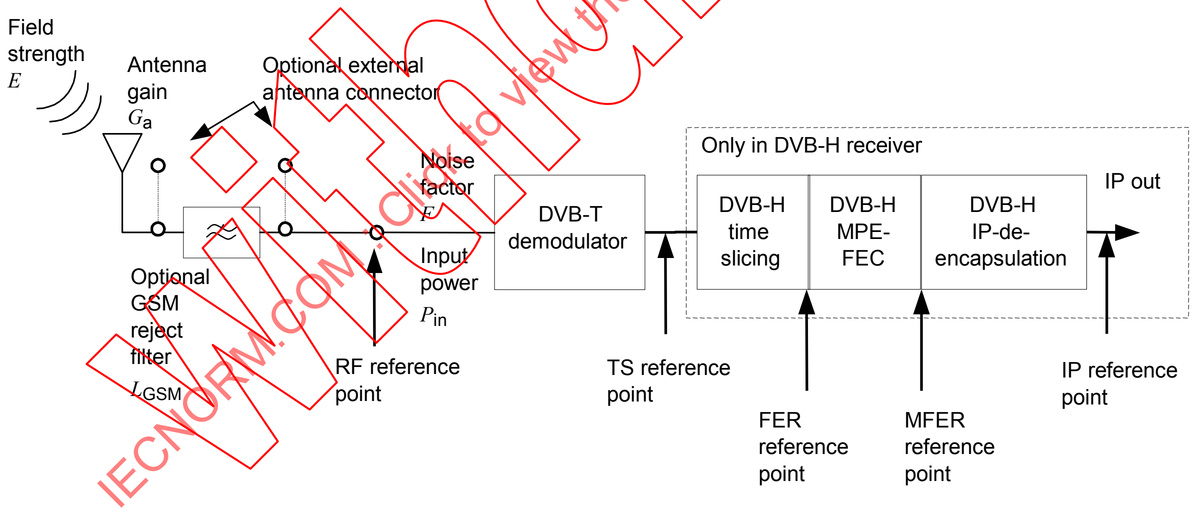


Figure 1 – Reference model

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:

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

where η = 120π Ω. Note that the optional GSM-reject filter is not included in the above formula.

Practical formula in dB:

$$E[dB\mu V/m] = P_{in}[dB(mW)] - G_a[dB] + L_{GSM}[dB] + 77{,}2 + 20\log_{10} f[MHz]$$

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 noise factor F 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 of 2 dB to 3 dB.

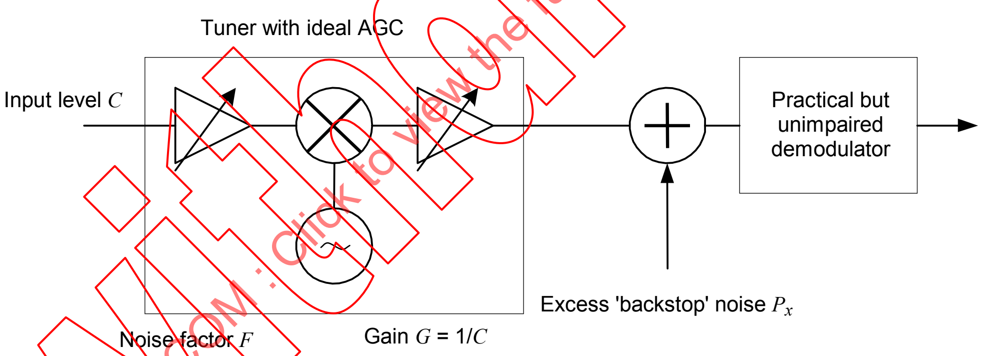


Figure 2 – Noise model

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 / k$TBFG$ at the tuner output. Hence the carrier-to-noise ratio at the input to the "practical" demodulator is given by

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

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

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 1-2 dB carrier power increase will improve the reception quality to QEF-level. Table 4 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 4.

Table 4 – 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 (erroneous second ratio 5 %) criterion, which allows one erroneous second within the 20 s observation period. Thus, the ESR_5 method can be used to measure the SFP. The SFP corresponds also fairly well to a packet error ratio *PER* = 10^{-4} after RS-decoder at the demodulator TS-output. The observation period for the *PER*-measurement should be at least 800k TS-packets, corresponding roughly 2 min with 16QAM *CR*=½ *GI*=1/4mode.

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.

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

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 1dB 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 FER 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 the degradation point is set at 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 to what would be achieved using the 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 a 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 (polarization, radiation pattern, etc);
- by the algorithm used to compute and possibly iteratively adapt the weight factors.

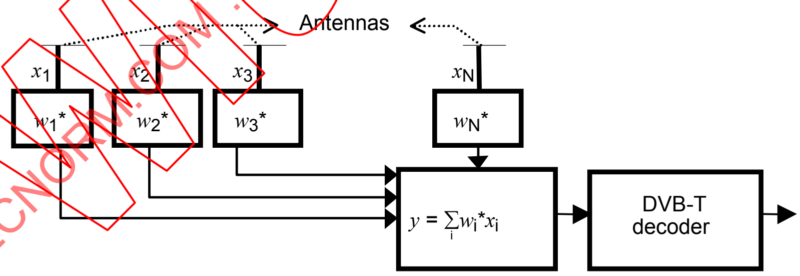


Figure 3 – Antenna diversity receiver

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 maximum speed of the mobile for correct reception to increase by a factor of two.

In portable indoor reception (terminal category b1), the channel conditions change more slowly 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 categories 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 uses the DVB-T transmission system as the physical layer and adds extra error correction and time-slicing mechanisms on the link layer. DVB-H carries 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 and seamless frequency handover.
  - Forward error correction for multi-protocol encapsulated data (MPE-FEC) for an improvement in the *C/N* and Doppler performance in mobile channels, also improving tolerance to impulse interference.
- Physical layer

  DVB-T (ETSI EN 300 744) 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, thus adding flexibility in the network design.
  - In-depth symbol interleaver for the 2k and 4k modes for further improving their robustness in a 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 (see the DVB-T tables provided in 10.7). If MPE-FEC is used with DVB-H, this will improve the *C/N* performance and new *C/N* tables are needed. Preliminary information of the DVB-H *C/N* performance is given in Annex D.

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 Portable indoor or outdoor reception

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

Table 5 – 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 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 nearly 900 MHz. Adaptation of the COST 207 profiles to mobile DVB-T reception was made by the motivate project [5].

10.6.2.1 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 six paths having wide dispersion in delay and relatively strong power. The profile parameters are given in Table 6. This channel profile has been proven to present fairly well the general mobile DVB-T reception by several field tests.

Table 6 – Typical urban profile (TU6) constitution

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

10.6.2.2 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 equalization 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.

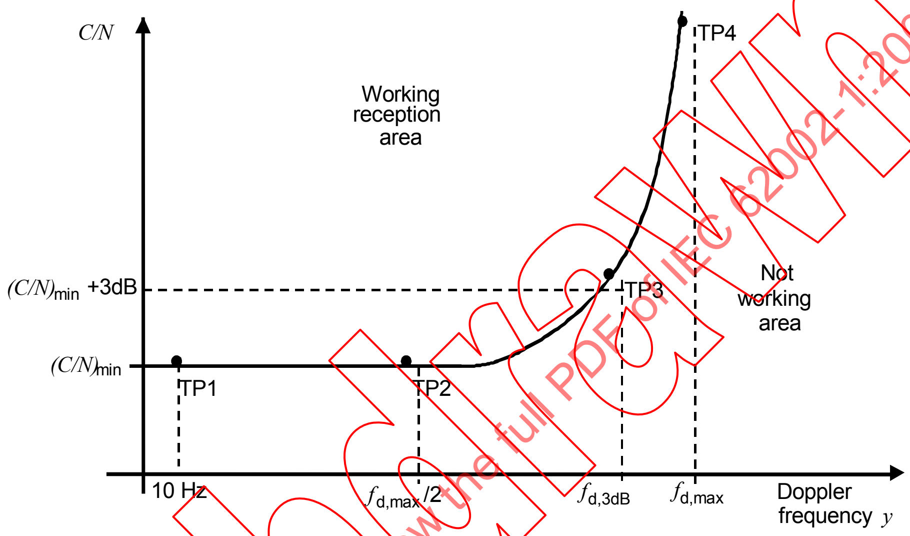


Figure 4 – Receiver behaviour in a mobile channel

This curve is characterized 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 characterize the *C/N* versus Doppler curve in a given DVB-T mode, using a given channel profile, four points are used.

TP1: the maximum Doppler limit which characterizes the “absolute maximum speed”

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

10.7 *C/N* performance

10.7.1 *C/N* performance in Gaussian channel

The receiver should have the performance given in Table 7 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 added by an implementation margin of 2,5 dB 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.

Table 7 – *C/N* (dB) for reference *BER* in Gaussian channel

Modulation	Code rate	Gaussian
QPSK	1/2	5,6
QPSK	2/3	7,4
QPSK	3/4	8,4
16-QAM	1/2	11,3
16-QAM	2/3	13,7
16-QAM	3/4	15,1
64-QAM	1/2	17,0
64-QAM	2/3	19,2
64-QAM	3/4	20,8

NOTE 1 Reference *BER* is defined as *BER* = 2 x 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.

Information of the *C/N* performance of DVB-H receivers with MPE-FEC in Gaussian channel can be found in Annex D.

10.7.2 *C/N* performance in portable channel

The receiver should have the performance given in Table 8 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. The values are calculated using the theoretical *C/N* figures given in ETSI EN 300 744 added by an implementation margin of 2,5 dB 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.

Table 8 – *C/N* (dB) for reference *BER* in portable channel

Modulation	Code rate	Portable
QPSK	1/2	7,9
QPSK	2/3	10,9
QPSK	3/4	13,2
16-QAM	1/2	13,8
16-QAM	2/3	16,8
16-QAM	3/4	19,4
64-QAM	1/2	18,7
64-QAM	2/3	22,1
64-QAM	3/4	24,8

Information on the *C/N* performance of DVB-H receivers with MPE-FEC in portable channel can be found in Annex D.

10.7.3 *C/N* performance in mobile channels

The single antenna receiver should have the performance given in Table 9 when noise (N) and Doppler shift (Fd) is applied together with the wanted carrier (C) in a signal bandwidth of 7,61 MHz. 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 of PER = 10^{-4} is used due to the bursty nature of the error behaviour. This error criteria corresponds rather well to the SFP. The normal reference BER is not applicable. The performance figures are given to the shortest guard interval 1/32, which is the least critical case in terms of Doppler. With 1/4 guard interval about 85 % of this performance is to be expected. The performance figures are based on the motivate reference receiver [5].

Table 9 – C/N (dB) for PER = 10^{-4} in typical urban channel for single antenna receiver

Guard interval = 1/32			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	13,0	318	259	1 398	559	349	13,0	76	65	349	140	87
QPSK	8,04	2/3	16,0	247	224	1 207	483	302	16,0	65	53	286	114	71
16-QAM	12,06	1/2	18,5	224	182	985	394	246	18,5	59	47	254	102	64
16-QAM	16,09	2/3	21,5	176	147	794	318	199	21,5	41	35	191	76	48
64-QAM	18,10	1/2	23,5	141	118	635	254	159	23,5	35	29	159	64	40
64-QAM	24,13	2/3	27,0	82	65	349	140	87	27,0	24	18	95	38	24

The diversity receiver should have the performance given in Table 10. This table is similar to that of Table 9 but takes into account a 6 dB diversity gain factor and a doubling of the maximum Doppler frequency, which should be achieved by the use of diversity techniques.

Table 10 – C/N (dB) for PER = 10^{-4} in typical urban channel for diversity receiver

Guard interval = 1/32			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	7,0	560	518	2 795	1 118	699	7,0	140	129	699	280	175
QPSK	8,04	2/3	10,0	494	447	2 414	966	604	10,0	129	106	572	229	143
16-QAM	12,06	1/2	12,5	447	365	1 969	788	492	12,5	118	94	508	203	127
16-QAM	16,09	2/3	15,5	353	294	1 588	635	397	15,5	82	71	381	152	95
64-QAM	18,10	1/2	17,5	282	235	1 271	508	318	17,5	71	59	318	127	79
64-QAM	24,13	2/3	21,0	165	129	699	280	175	21,0	47	35	191	76	48

Information on the C/N performance of DVB-H receivers with MPE-FEC in mobile channel can be found in Annex D.

10.8 Receiver minimum and maximum signal input levels

10.8.1 Noise floor

At the sensitivity level for each DVB-T mode the receiver shall have a noise figure of 5 dB or less at the RF reference point (see Figure 1). The total noise figure of the receiver shall be 6 dB or less if the GSM reject filter is included.

A noise figure of 5 dB corresponds to the following noise floor power levels (see also A.4).

P_n = -100,2 dB(mW) (for 8 MHz channels, BW = 7,61 MHz)

P_n = -100,7 dB(mW) (for 7 MHz channels, BW = 6,66 MHz)

P_n = -101,4 dB(mW) (for 6 MHz channels, BW = 5,71 MHz)

10.8.2 Minimum input levels

At RF reference point, the receiver should provide better than reference *BER* for the wanted signal levels greater than P_{min} and less than P_{max} (see 10.8.3).

P_{min} = -100,2 dB(mW) +*C/N* (dB) (for 8 MHz)

P_{min} = -100,7 dB(mW) +*C/N* (dB) (for 7 MHz)

P_{min} = -101,4 dB(mW) +*C/N* (dB) (for 6 MHz)

where *C/N* is specified in 10.7 and is dependent on the channel conditions and DVB-T mode.

10.8.3 Total maximum power for wanted and unwanted signals

10.8.3.1 For terminal category a

The maximum total average power from the wanted and unwanted signals shall be less than -15 dB(mW).

10.8.3.2 For terminal category b and c

The maximum total average power from the wanted and unwanted signals shall be less than -25 dB(mW).

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 analogue or digital interfering signals according to patterns S1 ($n \pm 1$), S2 ($n \pm 1$), L1, L2 and L3 is –25 dB(mW). The maximum tolerated level for analogue or digital interfering signals, according to patterns S1 ($n \pm m$, $m \neq 1$) and S2 ($n \pm m$, $m \neq 1$), is –18 dB(mW). All levels are valid for receivers operating on all DVB-T modes. Maximum input levels for terminal category a and b1 are shown in Table 11.

Table 11 – 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	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 for S1-35 for S2	–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 analogue or digital interfering signals according to patterns S1 (n ± 1), S2 (n ± 1), L1, L2 and L3 is –35 dB(mW). The maximum tolerated level for analogue or digital interfering signals according to patterns S1 (n ± m, $m \neq 1$), S2 (n ± m, $m \neq 1$) is –28 dB(mW). All levels are valid for receivers operating on all DVB-T modes. Maximum input levels for terminal category b2 and c are shown in Table 12.

Table 12 – 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	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 pre-selection 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 mainly tests receiver selectivity and includes two classical single interferer patterns. The second one tests 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 B/G/I1

Figure 5 shows the PAL B/G/I1 interfering signals. 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 NICAM is 40 % and PAL I1 NICAM is 100 %.

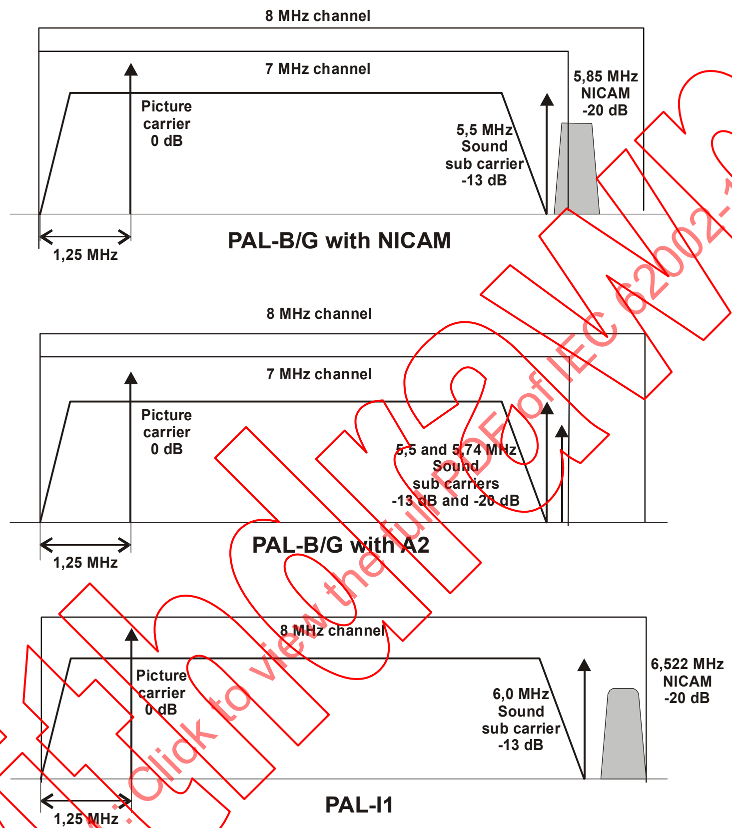


Figure 5 – PAL interfering signals

10.9.2.2 SECAM L

Figure 6 shows the standard SECAM signal with NICAM sound (1,25 MHz vestigial sideband bandwidth).

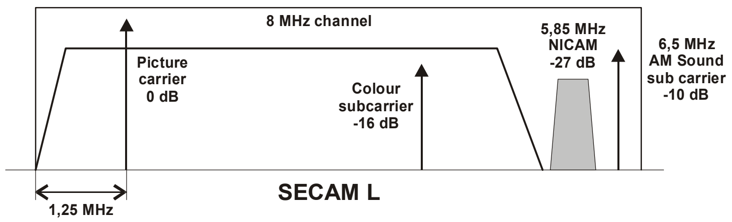


Figure 6 – SECAM L interfering signal

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

10.9.2.3 DVB-T

The DVB-T signal according to ETSI EN 300 744.

10.9.2.4 Number of signals

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

- 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, the 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 7 and Figure 8.

10.9.4 Linearity patterns

The following three patterns are used for receiver linearity testing. Note that similar cases as $N + 2/N + 4$ 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

The patterns are shown in Figure 9, Figure 10 and Figure 11.

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 signal on channel N.

The receiver shall provide the reference BER 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 13. The performance is only provided when the input level restrictions of 10.8.4 apply.

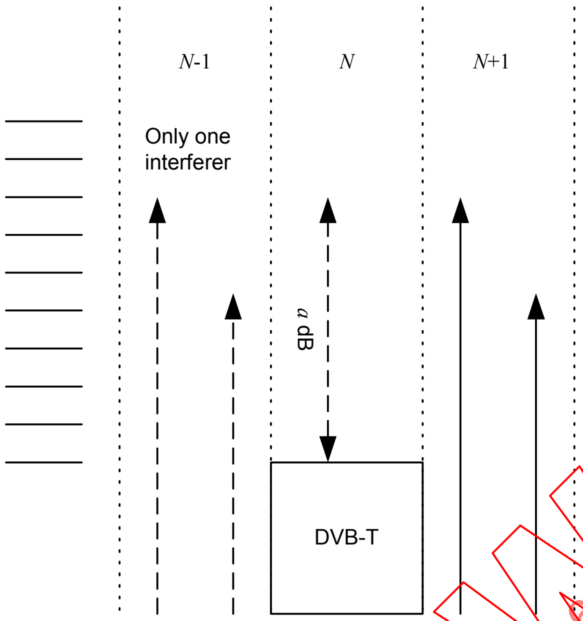


Figure 7 – Pattern S1 in case of *N* + 1 or *N* – 1

Table 13 – Immunity to pattern S1

Mode	*a* [*N* ± 1] PALG or I1	*a* [*N* ± 1] PALB *	*a* [*N* – 1] SECAM L	*a* [*N* + 1] SECAM L	*a* [*N* ± *m*] (*m* ≠ 1) SECAM L	*a* [*N* ± *m*] (*m* ≠ 1) PAL B/G/I1
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	30 dB	33 dB	45 dB	46 dB
2k/8k 64QAM *CR*=3/4, *GI*=All	35 dB	33 dB	30 dB	33 dB	42 dB	43 dB

* 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.

10.9.6 Immunity to pattern S2

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

The receiver shall provide the reference *BER* 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 14. The performance is only provided when the input level restrictions of 10.8.4 apply.

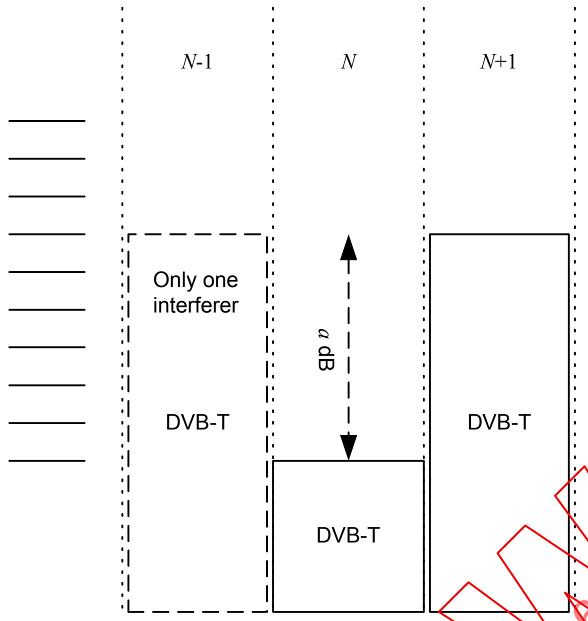


Figure 8 – Pattern S2 in case of *N* + 1 or *N* – 1

Table 14 – Immunity to pattern S2

Mode	***a*** **[*N* ± 1]**	***a*** **[*N* ± *m* (*m* ≠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.			

10.9.7 Immunity to pattern L1

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

The performance given in Table 15 is only provided when the input level restrictions in 10.8.4 apply and the unwanted signal is at the highest allowed level.

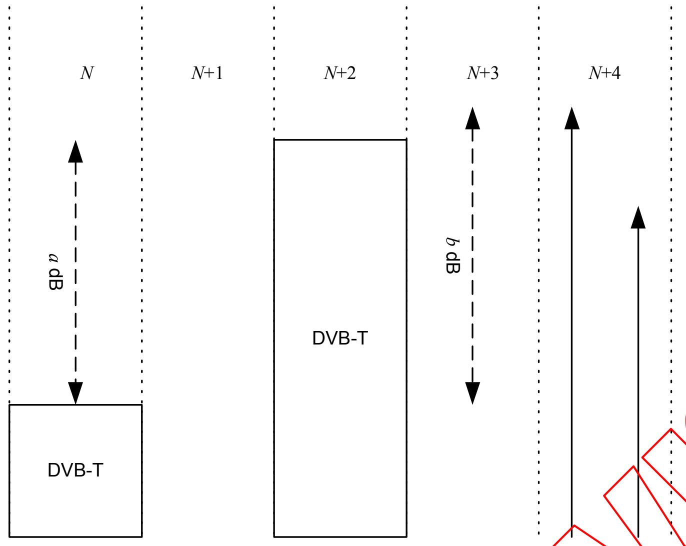


Figure 9 – Pattern L1

Table 15 – Immunity to pattern L1

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

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 signal on channel *N*.

The performance given in Table 16 is only provided when the input level restrictions in 10.8.4 apply and the unwanted signal is at the highest allowed level.

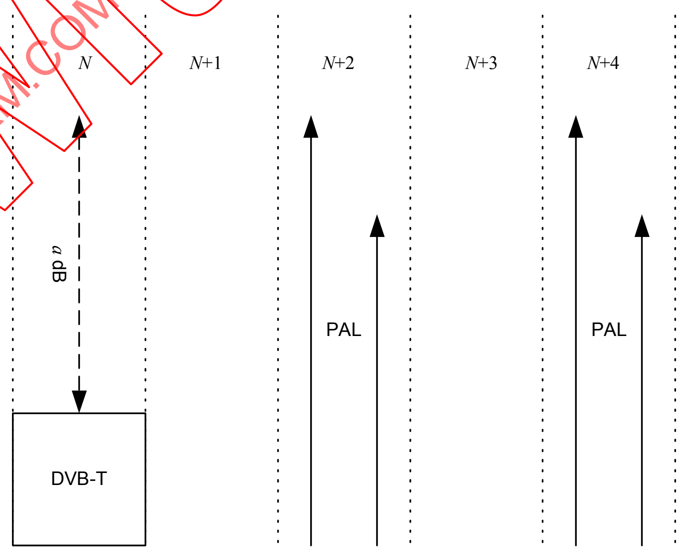


Figure 10 – Pattern L2

Table 16 – Immunity to pattern L2

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

10.9.9 Immunity to pattern L3

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

The performance given in Table 17 is only provided when the input level restrictions in 10.8.4 apply and the unwanted signal is at the highest allowed level.

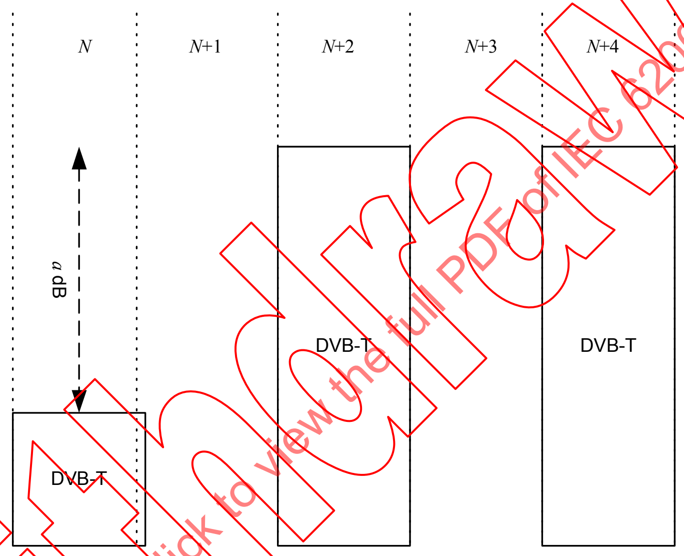


Figure 11 – Pattern L3

Table 17 – Immunity to pattern L3

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

10.10 Immunity to co-channel interference from analogue TV signals

The immunity for interference from analogue TV signal is specified in Table 18 as the minimum carrier to interference ratio, *C/I*, required for reception.

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

Table 18 – Immunity to co-channel interference from analogue signals

Mode	PAL I1	PAL B/G	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

10.11 Guard interval utilization

10.11.1 Performance with echo within guard interval

For the modes,

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

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

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

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

the receiver shall provide the reference *BER* 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 19.

Table 19 – *C/N* for echo within guard interval

Mode	*C/N*[dB
2k/8k, 16-QAM, R =1/2, *GI* = All	16,3
2k/8k, 16-QAM, R =2/3, *GI* = All	20,9
2k/8k, 64-QAM, R =2/3, *GI* = All	26,2
2k/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 receiver shall provide reference *BER* when the level of the echo, compared to the main signal, is lower than the mask shown in Figure 12.

The mask is defined by three points, the starting point at 0,9 × Tg, the inflection point at 1,0 × Tg and the corner point at Tc. Timing of the point Tc depends on the guard interval according to Table 20.

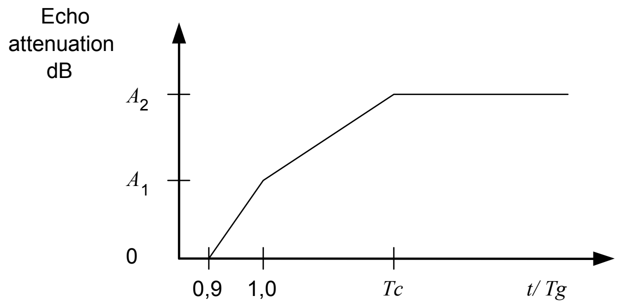


Figure 12 – Echo outside guard interval mask

Table 20 – 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 modulation used and is calculated by adding a value Δ to the C/N requirement of the mode in the Gaussian channel as defined in Table 7. The value Δ is defined in Table 21.

Table 21 – Definition of the value *Δ*

Modulation	Δ dB
QPSK	2
16QAM	3
64QAM	4

A_2 then becomes

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

Echo attenuation A_1 at the inflection point at $t = 1{,}0 \times Tg$ depends on the modulation used and the code rate as defined in Table 22.

Table 22 – 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 13.

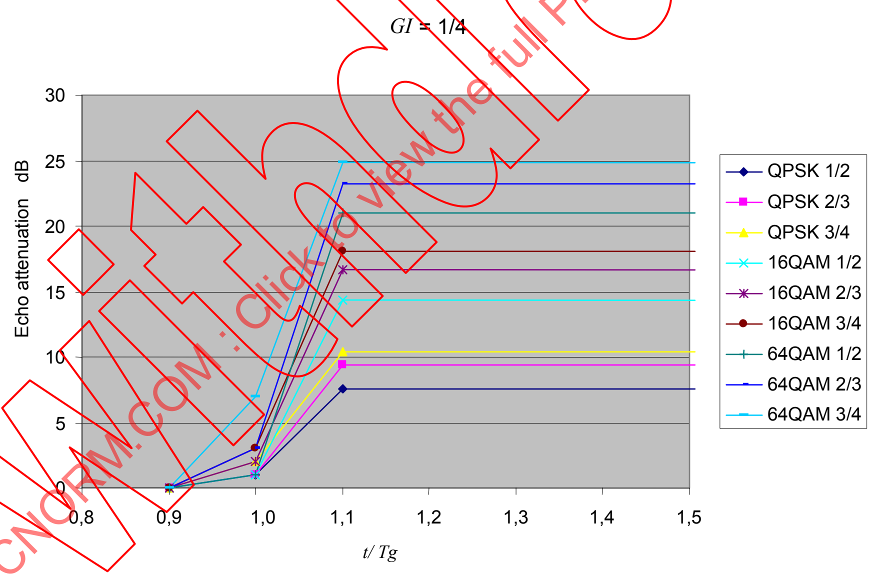


Figure 13 – Mask for echo outside *GI* for *GI* = 1/4

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

10.12 Tolerance to impulse interference

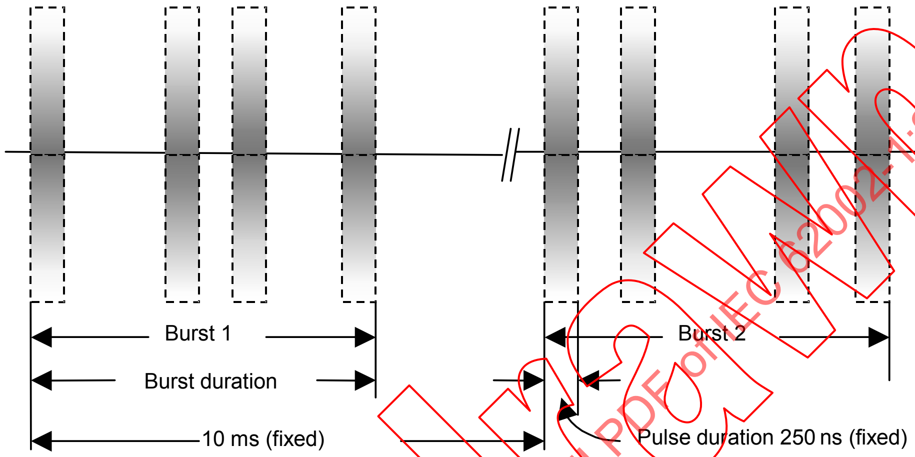
10.12.1 General

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 the 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 14 illustrates the terminology used with the test patterns.



NOTE The number of pulses per burst is defined, but the spacing between pulses is allowed to vary randomly between the given maximum and minimum values.

Figure 14 – 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 the case where 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 23, together with their associated 'tolerance factors'.

Table 23 – Impulse interference test patterns

Test No.	Pulses per burst	Minimum/maximum pulse spacing µs		Burst duration µs	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 counter-measures against impulse interference should have tolerance factors in excess of those given in Table 23 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 in-depth 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 the simultaneous operation of several radios in small-sized hand-held terminals, 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 PA out-of-band signals;

    2) transmitter PA noise.

Undisturbed operation of cellular radio must also be maintained. Possible impairments caused by THE 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 15.

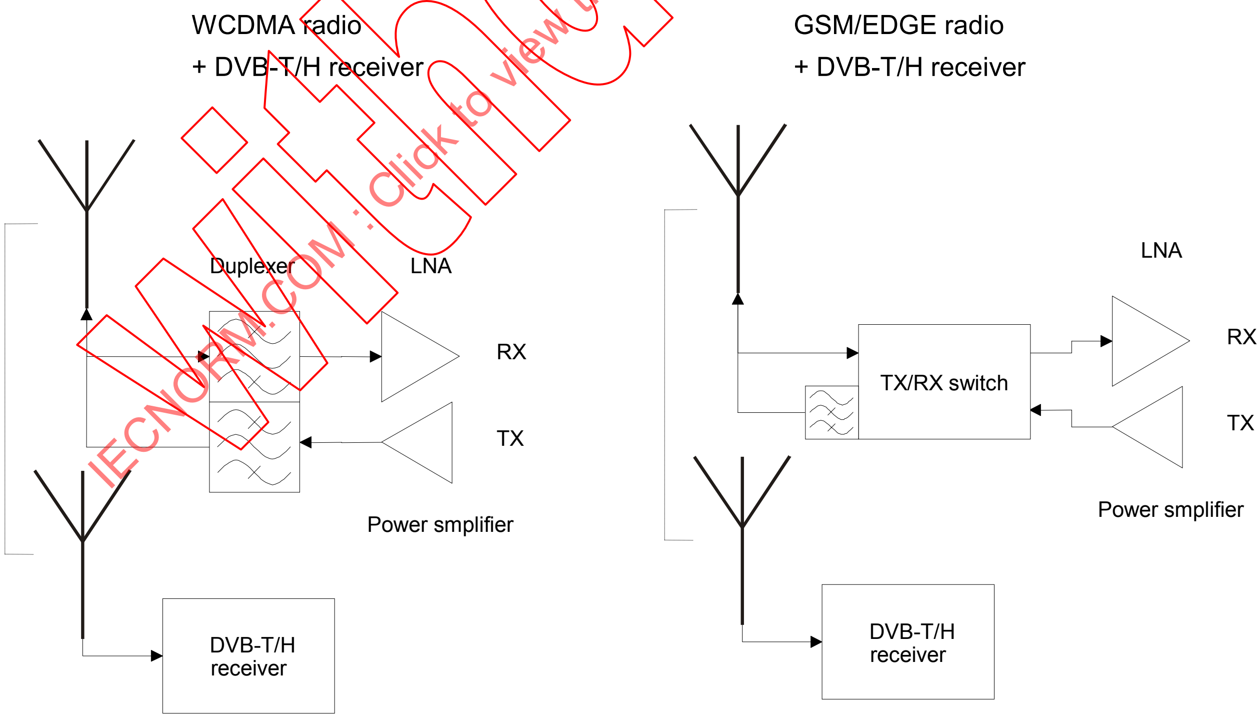


Figure 15 – Terminal architectures

Most probably the DVB-T/H receiver and the 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 the duplex filter, but the majority of modern GSM/EDGE radios use the 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 the WCDMA terminal if a duplexer is used. However, the problem will be severe in the GSM/EDGE terminal with a TX/RF switch.

11.1.1.3 Frequency bands

The frequency bands used by the different radio systems are presented in Figure 16.

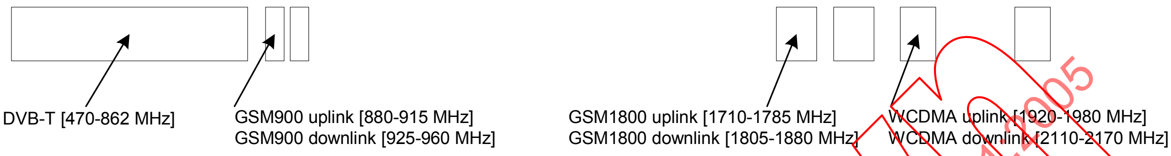


Figure 16 – Frequency bands

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 represented by the high power level. The downlink (receiving/RX) bands of cellular radios are above the corresponding uplink bands.

From Figure 16, it is obvious that the most problematic cellular radio from the interoperability point of view is GSM 900 because of the very narrow guard band between the DVB-T band and the GSM 900 uplink. The guard band is only 18 MHz wide. Therefore, the relative band-with 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. The 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 the 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: de-sensitization and cross-modulation.

11.1.2.2 Interoperability requirements

The practical solution for interoperability in 11.1.2 is to insert the GSM rejection filter in front of the DVB-T/H receiver. The filter has to attenuate the GSM Tx signal to the allowed out-of-band unwanted signal level, which for category c terminal is –28 dB(mW) (see 10.8.4). Stop-band attenuation thus becomes:

$$A_{GSM} = P_{TX} - A_A - P_{\max} = 33\,dB(mW) - A_A - (-28\,dB(mW)) = 61\,dB - A_A$$

where

A_{GSM}	is the	stop band attenuation of the GSM reject filter;
P_{TX}	is the	GSM Tx output power;
A_A	is the	coupling between the antennas at 698 MHz;
P_{max}	is the	maximum allowed power at the DVB-T/H receiver input.

The filter should have this attenuation at the frequencies shown in Table 24.

Table 24 – GSM reject filter attenuation

Frequency MHz	880-915	1 710-1 785	1 920-1 980
Attenuation	A_{GSM}	A_{GSM}	A_{GSM}

The GSM reject filter placement is shown in the reference model in

Figure 1. Typically, the insertion loss of the filter L_{GSM} is in the order of 1dB, raising the overall noise figure to 6 dB.

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 shall take care that the performance degradation is low enough at the relevant frequencies.

11.1.3.2 Transmitter 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 17.

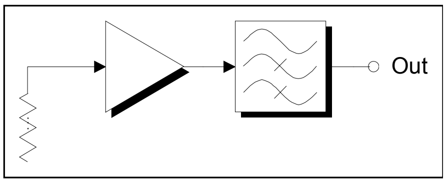


Figure 17 – GSM Tx block diagram

In GSM/EDGE radio where the RX/TX switch (like in Figure 15) is used, the last high pass filter is very relaxed or non-existent. 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 50 Ω.

$$P_{noise} = -174 + 10 \cdot \log(7.61 MHz) + G + NF \text{ [dBm]}$$

where

G	is the	gain of the PA, typically 20 dB;
NF	is the	noise figure of the PA, 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 –105 dB(mW) within one DVB-T channel.

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

Reduction of the noise level becomes possible when the DVB-T operating band for terminal category c is limited to channel 49 (centre frequency 698 MHz). At 698 MHz, matching of the PA already provides considerable filtering, i.e. the gain of the PA at 698 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 18.

The noise level is affected by the gain, noise figure and bandwidth of the PA, 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.

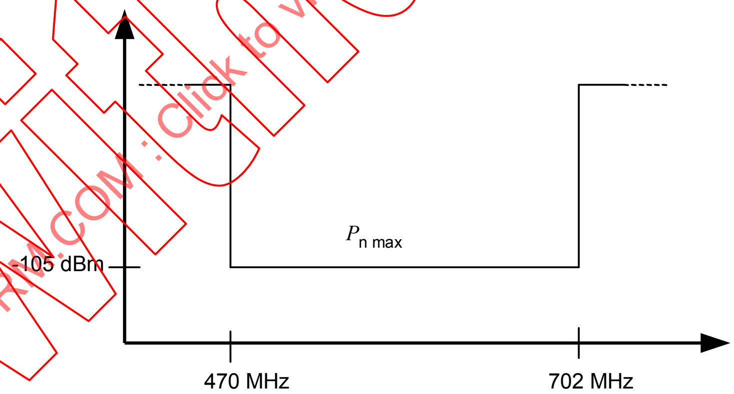


Figure 18 – Tx PA-noise mask in DVB-T/H receiver input

11.2 DVB-RCT

The DVB-RCT specification [14] has been developed for interactive applications in the UHF band. It has been designed for rooftop antenna applications.

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

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