WP4 / D4.1 deliverable

Front-end and Antennas External Specification

Based on

Mobile and Portable DVB-T Radio Access Interface Specification
EICTA / TAC / MBRAI-02-16 [Version 1.0 (1.1.2004)]

Contents

Contents (continued)

1 SCOPE

This document is the radio access external specification of the integrated DVB-T /DVB-H front-end to be developed within Workpackage 4 of the INSTINCT project.
It is supposed to equip mobile, portable and hand-held portable devices capable of receiving DVB-T/DVB-H services. It includes informative system aspects as well as specifications for minimum RF-performance. It covers terminals in three main classes, namely PC Terminals, Portable Digital TV Sets and Hand-Held portable convergence terminals. Interoperability with integrated cellular radios is also considered. The specification based mainly on Mobile and Portable DVB-T Radio Access Interface Specification *EICTA / TAC / MBRAI-02-16* [Version 1.0 (1.1.2004)] 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/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
- EMC aspects
- Hardware interfaces

In WP4, two Front-ends are developed in parallel:

Task 4.2.1 : Integrated DVB-T front-end designed by Philips [see chapter 1.2]
Task 4.2.2 : Integrated DVB-T / DVB-H front-end designed by DiBcom (Base Band IC) and Motorola (Silicon Tuner) [see chapter 1.3]

1.1 Front-end description for Task 4.1

For the first phase of INSTINCT, the antenna of the Task 2.1 will be developed for the category 2a terminal (see chapter 2) and will have the following characteristics:
- *output impedance*: 50 Ω
- *output connector*: Female SMA connector
- *Return losses:* RL < -8 dB all over the UHF bandwidth in the worst case. However, the objective design is a return loss of –10 dB.
- *Gain*. compliant with the figures given in §7.2 (VHF III - 6dBi, UHF IV -1 dBi, UHF V 0 dBi),
- *Dimensions*

Diameter of the antenna to be integrated in the category terminal 2a (Laptop PC for example) will be less than 150 mm. This dimension is due to the antenna and not to the ground plane, which must be present for a good radiation. The ground plane would be mounted on the terminal structure i.e. on the folded cover of a laptop PC

1.2 Front-end description for Task 4.2.1

Within the Task 4.2.1: Philips plans to deliver an Integrated DVB-T front-end module that focuses mainly on *low power consumption* and *small form factor***.** The schematic block is as follows:

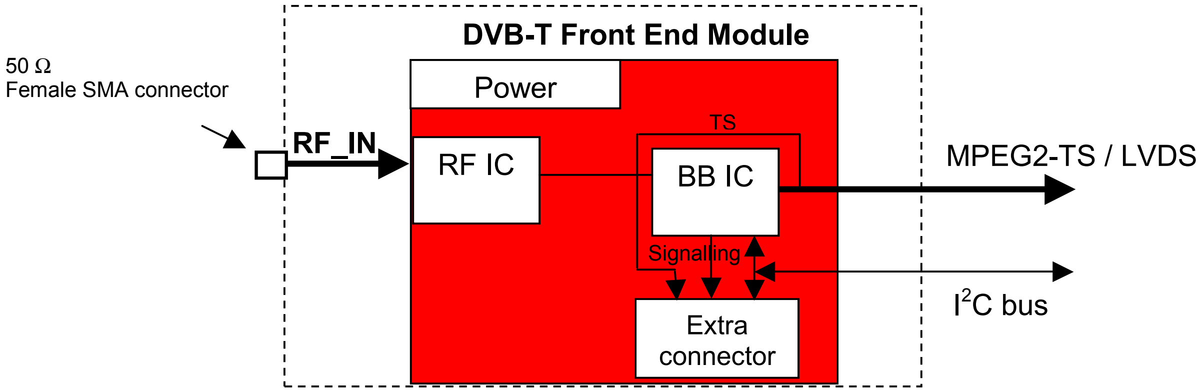

FIG1-1: DVB-T integrated front-end to be delivered by Philips (Task 4.2.1)

The main applications will be handheld devices, for instance PDAs and mobile phones.

Within the first phase of INSTINCT (the first two years), a full DVB-H capability will not be integrated into the “Front End Module”. However, an extra board will be added to demonstrate some DVB-H functionalities such as, for instance, the “Time-Slicing” and the “MPE-FEC”

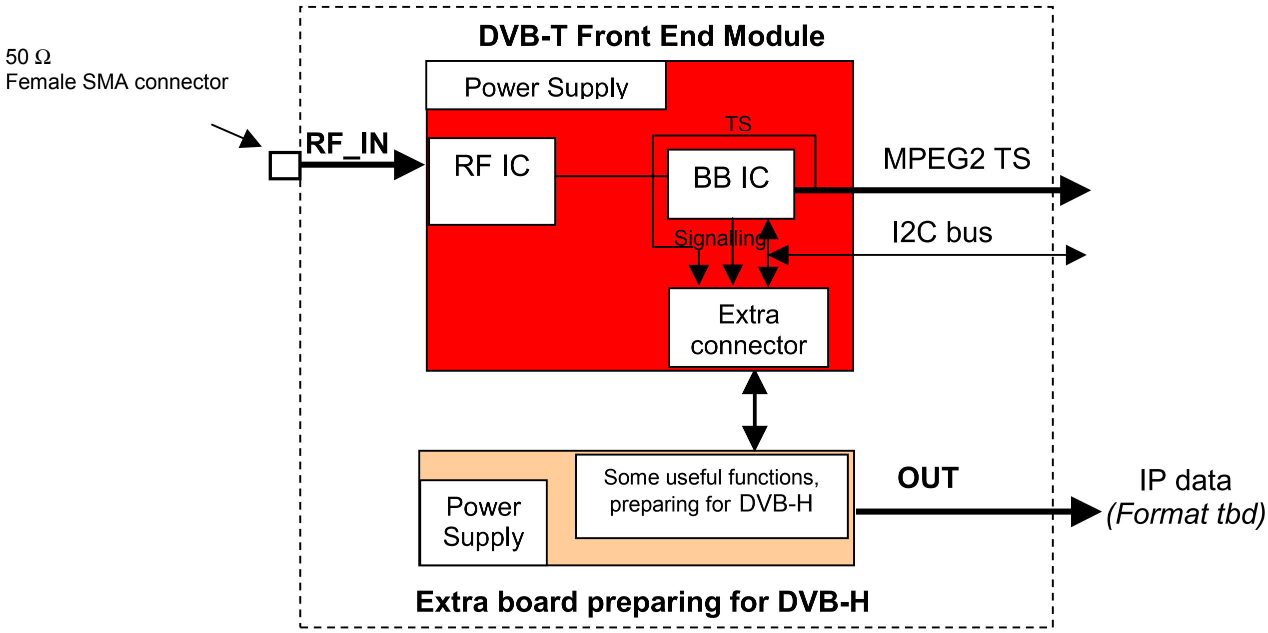

FIG1-2: DVB-T integrated front-end + DVB-H extra board to be delivered by Philips (Task 4.2.1)

The performance of the above module is based on the Mobile and Portable DVB-T radio Access Interface Specification whose relevant chapter is included in this document.
However, for the first phase of INSTINCT the compliance list will be limited to:

- Terminal category (see chapter 2):
  - Category 2b for pocketable digital TV (PDA for example)
  - Category 3 for handheld convergence terminals

- Receiving conditions and DVB-T modes:
  - Slow movement (≤ 3km/h)
  - Static reception (see chapter 8.6.1)
  - Portable reception (see chapter 3)
  - Channel bandwidth: UHF / 8 MHz

- Test pattern:
  The following parameters:
  - C/N performance for Gaussian channel
  - C/N performance for Portable channel
  - Sensitivity (one signal)
  - Maximum input level (one signal)
  - Selectivity, Linearity, Co-Channel

  will be tested for:
    - QPSK ½
    - 16QAM ½
    - 16QAM 2/3
    - 8 MHz channel Bandwidth
    - 8k mode
    - 3 channels inside UHF IV (low, mid, high)
    - 3 channels inside UHF V (low, mid, high)

  - Guard interval: 1/32
  - Tolerance to impulse interference: tbd.

1.3 Front-end description for Task 4.2.2

Within the Task 4.2.2: Motorola and DiBcom plan to deliver an Integrated DVB-T / DVB-H front-end module. Motorola is in charge of the RFIC / Tuner module and DiBcom of the Base Band demodulator IC. The schematic block is as follows:

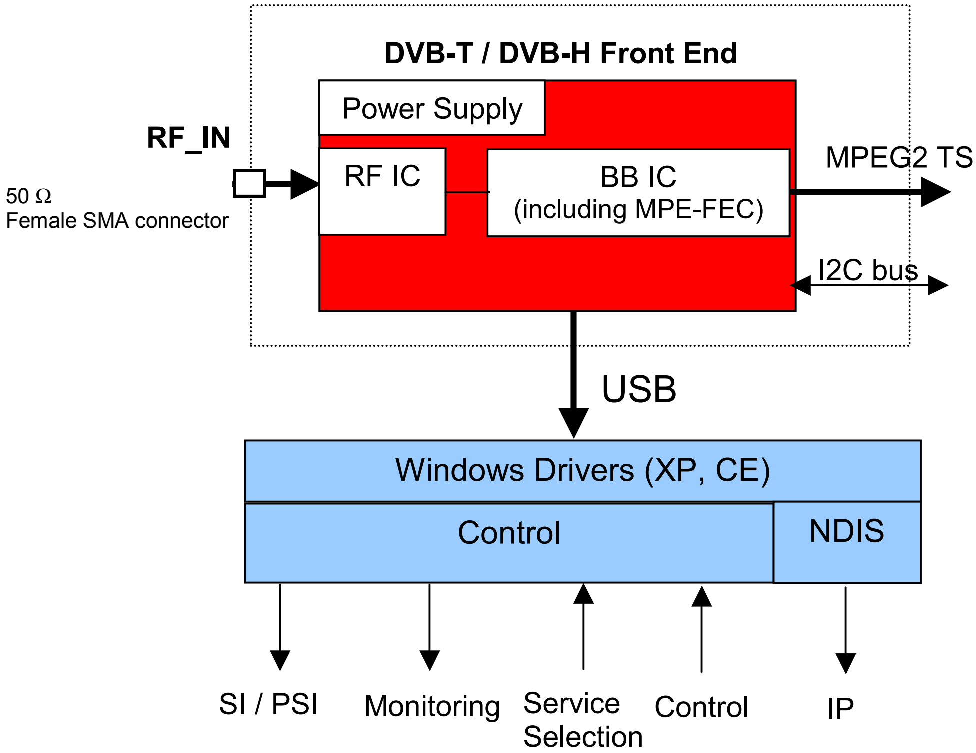

FIG1-3: DVB-T / DVB-H integrated front-end to be delivered by DiBcom / MSPS (Task 4.2.2)

The DVB-T / DVB-H module includes the "Time-Slicing" and the "MPE-FEC" functionalities.
The MPEG2-TS output (LVDS) is made available for DVB-T test purposes.

The IP data recovered from the DVB-H signal are transported over USB. The necessary drivers for IP and SI/PSI tables extraction, monitoring and control are delivered for installation in a Laptop PC for Windows OS (in a first step).
In a second step, the main applications will be handheld devices, for instance PDAs and mobile phones.

The performance of the above module is based on the Mobile and Portable DVB-T radio Access Interface Specification whose relevant chapter is included in this document.
However, for the first phase of INSTINCT the compliance list will be limited to:

- Terminal category (see chapter 2):
  - Category 2a for Laptop PC or Tablet PC

- Receiving conditions and DVB-T modes:
  - Mobile performance (see chapter 8.6.3)
  - Static reception (see chapter 8.6.1)
  - Portable reception (see chapter 3)
  - Channel bandwidth: UHF / 8 MHz and 6MHz (for the Brazilian application)

- Test pattern:
  The following parameters:
  - C/N performance for Gaussian channel
  - C/N performance for Portable channel
  - Sensitivity (one signal)
  - Maximum input level (one signal)
  - Selectivity, Linearity, Co-Channel

  will be tested on the following modes:
    - QPSK 1/2 and 2/3
    - 16QAM 1/2 and 2/3
    - 64QAM 1/2 and 2/3
    - 8 MHz and 6MHz channel Bandwidth
    - 8k mode
    - 3 channels inside UHF IV (low, mid, high)
    - 3 channels inside UHF V (low, mid, high)

  - Guard interval: 1/32
  - Tolerance to impulse interference: (see Chapter 8.11.2)

2 Terminal Categories

In this specification three different terminal categories are considered. Nevertheless, during the first phase of INSTINCT we will focus on the terminal category 2a for Laptop PC. The terminal categories are:

1. Integrated car terminals

2. Portable Digital TV Sets or Laptop PC modules

   This category covers terminals that are intended for receiving normal MPEG-2 based digital TV services indoors and outdoors with terminal attached antennas. This category is divided to two sub-categories:

   2a) The receiver screen size is typically greater than 25 cm and the receiver may be either a TV Set or **Laptop PC or tablet PC (platform with CPU and display and RAM)**, battery or mains powered (power coming from the PC via USB). Typically, the terminal is stationary during the reception. An example of the antenna construction will be developed for a Laptop PC.

   2b) Pocketable digital TV-receiver. The terminal is battery operated and can be moved during use. Usually the antenna is integral within the terminal. This receiver is intended to be developed in a later phase of INSTINCT.

3. 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 over DVB-T or DVB-H. The DVB-T/DVB-H antenna and the cellular antenna are both integral with the terminal. (This category is to be developed in a later phase of INSTINCT).

3 Definition of Receiving Conditions

3.1 Portable Reception

This is when a portable receiver (Terminal Category 2a) 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.

As a special case of portable reception a small hand-held portable receiver (Terminal Category 2b or 3) 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 quite 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.

3.2 Mobile Reception

This applies to the use of Integrated Car Terminals (Terminal Category 1) 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 1.5m. Other vehicles such as buses or high-speed trains could be considered as special cases.

A small hand-held portable receiver (Terminal Category 2b or 3) used within a car or train could also be considered as a case of mobile reception.

4 Frequencies and Channel Bandwidths

4.1 Channel Frequencies

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

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 6 MHz channel raster (such as Brazil)

  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.

4.2 Supported Frequency Ranges

The integrated front-end in Terminal Categories 2a, to be delivered at the end of the first phase of INSTINCT (D4.3) shall be able to receive all channels in the UHF bands IV and V.

For the second phase of INSTINCT:

In case GSM 900 is used in a convergence terminal (category 3) the usable frequency range is limited to channel 49 [698 MHz] due to the interoperability considerations.
The terminal will be able to operate in presence of GSM900 signals.

4.3 Supported Bandwidths

The receiver should support the 6, 7 and 8 MHz bandwidths according to the market area needs.
But for the first phase:
- only the 8MHz band will be tested for Task 4.2.1.
- only the 8MHZ and 6MHz (for Brazil) bands will be tested for Task 4.2.2

5 DVB-T Modes

5.1 Supported DVB-T Modes

In the final product the receiver shall be capable of correctly demodulating all modes specified in EN 300 744. 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 (1/2,2/3,3/4,5/6, 7/8),
- Guard interval (1/4,1/8,1/16 or 1/32),
- Transmission mode (2K or 8K),
- Where applicable α (1, 2 or 4).

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 EN 300 744, shall be capable of correctly demodulating the high priority stream.

In the first step, the tested modes will be limited to those listed in the chapter 1.2 and 1.3

5.2 Change of Modulation Parameters

Dynamic change of modulation parameters during the transmission signalled in the TPS-data is not supported by the receiver. In case this happens, the receiver should recover from this by doing a new channel search.

5.3 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.

6 DVB-H Modes

The performance difference between DVB-H and DVB-T systems depends on the MPE-FEC coding rate and on the FFT mode used with the different interleaver options.

6.1 DVB-H performance in "DVB-T like" mode

The system in this mode can be qualified in the same way as DVB-T (TS level and same criteria) with the following parameters:

- 2K mode with 8K Interleaver
- 4K mode with 8K interleaver
- 4K mode with the 4K interleaver

In this case the different measurements done for DVB-T can be performed again here.

6.2 DVB-H IP criteria

For DVB-H performance measurements it is necessary to define a criteria that reflects the quality of service at an IP level. This performance depends on the IP packets size distribution and on the MEP-FEC coding rate. We can define here different testing scenarios:

a. Without MPE-FEC
b. With MPE-FEC coding rate 3/4
c. With MPE-FEC coding rate 1/2

6.3 DVB-H reception testing

Two types of performance can be measured here:

6.3.1 MPE Reception performance

We assume here that the receiver has already locked the information (SI/PSI) not protected by the MPE-FEC and we measure the performance that was listed for DVB-T for the different scenarios and the criteria (TBD) listed above.

6.3.2 Service acquisition

We measure here the ability of the receiver to acquire the non-protected data (SI/PSI) that will enable the receiver to tune the desired service. This test is independent from the MPE-FEC and from the IP packet size distribution. The performance may only depend on the repetition rate of the broadcasted tables. A testing scenario as well as measurement criteria must be defined here.

6.3.3 Cell handover (not for the first phase of INSTINCT)

In a later phase of INSTINCT, in order to ensure cell handover in places where MFN is used instead of SFN, it will be necessary, for example, to study how to carry the cell id to manage the frequency changes.

7 Receiver Antenna Characteristics

7.1 Antennas for Terminal Category 1 (not applicable for the first phase of INSTINCT)

The practical standard antenna for car reception is λ/4 monopole which use the metallic roof as the ground plane. However, planar structures (travelling wave antennas or log-periodic) may be also used.

Antenna pattern is strongly dependent of the position of the antenna on the vehicle, so gain will depend on it. Gain definition follows standard IEEE 147-1973. 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 (defined as the axial ratio at any direction in the case of linear polarisation and difference between the left and right hand polarisation in case of circular polarisation) is usually at least 4 dB depending on the position on the vehicle. However, there are a few directions with worse polarization discrimination.

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

The dimensioning of the diversity system and the amplifiers should compensate for 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.

7.2 Antennas for Terminal Category 2a

In Chester 97 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 dB for a UHF antenna and -2.1 dB for a VHF III antenna.

However, an individual adjustment of the antenna length to the current frequency is not practicable. As consequence of this, a fixed length must be chosen. An acceptable value could be 100 to 150 mm.
Besides the antenna pattern is quasi omni-directional in the horizontal plane, with uncontrolled nulls due to terminal shape and environment interaction.

Gain is mainly limited by the low efficiency of small radiant structures. Its definition follows standard IEEE 147-1973. For a passive version of an attached antenna, the following gain values are typical:

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, the position of the antenna at the receiver could be variable.

In UHF IV / V a polarisation discrimination, (defined as the axial ratio at any direction in the case of linear polarisation and difference between left and right hand polarisation in the case of circular polarisation), up to 6 dB is possible. However, a few directions may have worse polarization discrimination.

7.3 Antennas for Terminal Category 2b and 3

Small antenna (compared with wavelength) forming part of the terminal. Although antenna design should be initially done to perform impedance matching along the whole tuning range, a tuneable circuit with resistive elements may be included. As the radiation resistance of the antenna is small, due to the small size of the antenna, a lower efficiency is expected. Moreover, the terminal will behave as a small radiating ground plane, modifying the antenna pattern. Humans could also absorb or reflect radiation modifying the radiation pattern.

The antenna pattern is quasi omni-directional in the horizontal plane, with uncontrolled nulls due to terminal shape and environment interaction. Antenna pattern measurement must be performed both placed on an anechoic chamber and forming part of a terminal.

The typical gain of the antenna is presented in the following table and may be considered to be the minimum specified value. Nominal gain between table frequencies can be obtained by linear interpolation.

474 [channel 21]	-10 dBi
698 [channel 49]	-7 dBi
858 [channel 69]	-5 dBi

Gain definition follows standard IEEE 147-1973, so the gain is obtained as the maximum obtained in the power gain pattern. Gain measurements must be performed placed on an anechoic chamber and forming part of a terminal.

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.

In case GSM 900 is used in a convergence terminal (category 3) 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.

7.4 External Antennas

7.4.1 General

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

7.4.2 External Antenna Connector

An external antenna connector may be provided in all terminal categories. For terminal category 2a the connector shall be male SMA. The input impedance shall be 50 Ω.

The input connector for terminal category 2a can, as an optional feature, provide DC-power supply for an active indoor antenna. This output should have the following characteristics:

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

8 Receiver Performance

8.1 Reference Model

The receiver performance is defined according to the reference model shown in Figure 8-1.

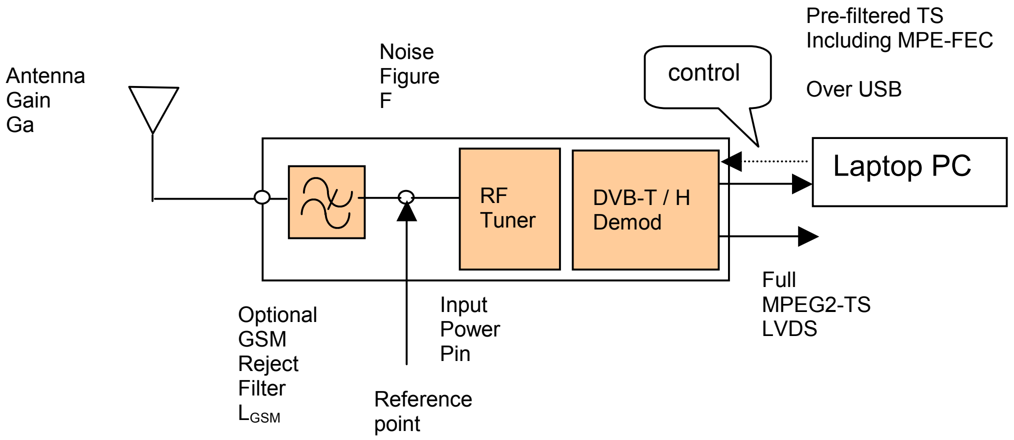

Figure 8-1 Reference Model

8.2 Noise Model

A useful model for calculating noise performance is illustrated in **Figure 8-2**.
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 figure F and 'perfect' automatic gain control (AGC). The action of the AGC is to provide a power gain of 1/C; the tuner output is unity as a consequence.
- An excess noise source of power P_x at the tuner output. Note that by normalising the carrier power at this point P_x becomes a relative value.
- A practical but unimpaired demodulator; that is, a demodulator with a fast channel equaliser and a consequent implementation margin of 2 to 3 dB.

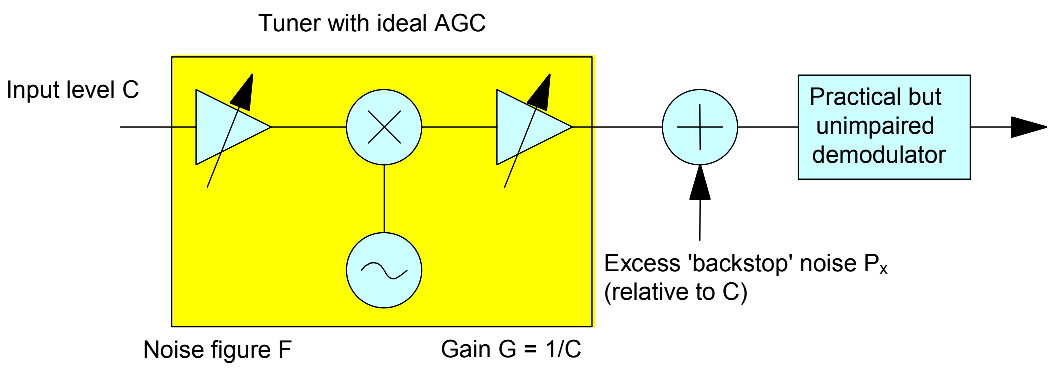

Figure 8-2 Noise Model

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

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

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.

8.3 Failure Point Criteria

Four different failure point criteria are used. The criteria 1 and 2 can be used in the non-mobile cases. Criteria 3 is for mobile reception and criteria 4 is used with IP-streams and DVB-H:

1) Reference BER, defined as BER $=2\times10^{-4}$ after Viterbi decoding.
This criteria 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.

2) Picture failure point.
Picture failure point defined as the minimum C/N or C/I value for more than 1 TS-packet error in 10 seconds. This is more convenient for some of the measurements than the normal Reference BER criterion that might be unreachable. Table 8-1 shows the correlation between the picture failure point and the Reference BER error criteria.

Measurement	Chapter	Delta [dB]
C/N in Gaussian channel	8.6.1	1.3
Minimum input level	8.7.2	1.3
Immunity to other channels	8.8	2.0
Immunity to co-channel	8.9	2.0
C/N in Fixed and Portable channels	8.6.1, 8.6.2	1.3

Table 8-1 Delta values between picture failure point and reference BER

3) Subjective failure point in mobile reception SFP, defined as PER = 1×10^{-4} at the RS-output.
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 criteria may give unstable values that could result in an underestimation of DVB-T’s 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 seconds”. The SFP corresponds fairly well to a Packet Error Ratio PER = 10^{-4} after the RS-decoder at the demodulator TS-output. The observation period for the PER-measurement should be at least 800k TS-packets, corresponding roughly to 2 minutes with 16QAM CR=½ GI=1/4mode.

4) IP Criteria
This criteria will be used with the IP-streams carried with DVB-H. The criteria is still to be defined.

8.4 Diversity Receivers

(Not applicable for the INSTINCT project)

8.5 Channel Models

8.5.1 Portable Indoor or Outdoor Reception

The Rayleigh fading channel (P_1) defined in the DVB-T specification 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 8-2 one possible 6-tap approximation is given. The result has been derived based on low-pass filtering and selecting dominant taps. The approximation gives fairly good correspondence at low levels, which should be desirable. The fitting has been made in such a way that the signal powers after the channels are the same both for the standard model and the 6-tap approximation.

Tap number	Delay τ (μs)	Amplitude r	Level (dB)	Phase θ (rad)
1	0.050	0.36	-8.87	-2.875
2	0.479	1	0	0
3	0.621	0.787	-2.09	2.182
4	1.907	0.587	-4.63	-0.460
5	2.764	0.482	-6.34	-2.616
6	3.193	0.451	-6.92	2.863

Table 8-2 Approximation of the DVB-T specified Rayleigh channel

8.5.2 Mobile Reception

The technical specification of COST 207 describes the equipment and techniques used to measure the channel characteristics over typical bandwidths of 10 to 20 MHz at near 900MHz. Adaptation of the COST 207 profiles to mobile DVB-T reception was done by the Motivate project.

Typical Urban Reception (TU6)

This profile reproduces the terrestrial propagation in an urban area. It has been defined by COST207 as a Typical Urban (TU6) profile and is made of 6 paths having wide dispersion in delay and relatively strong power. This channel profile has been proven to present fairly well the general mobile DVB-T reception by several field tests.

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

Table 8-3 Typical Urban profile (TU6) constitution

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
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 8-4 can be drawn.

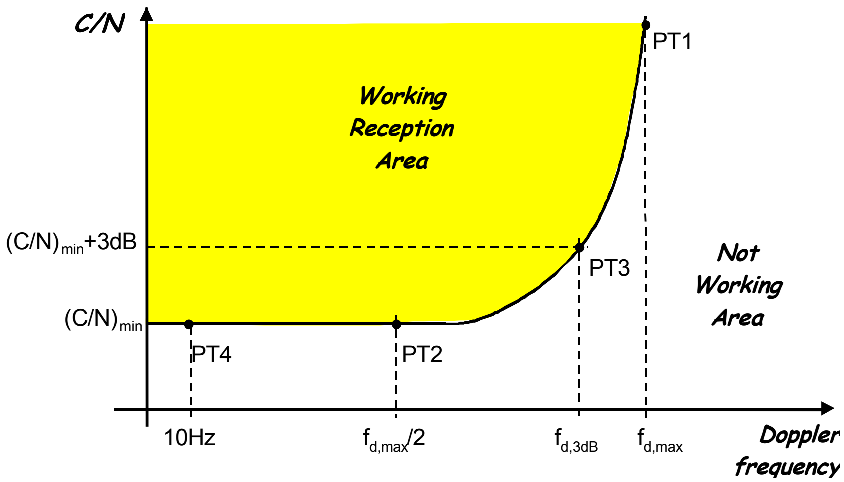

Figure 8-4 Receiver behaviour in a mobile channel

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:
PT1 : the maximum Doppler limit which characterises the “absolute maximum speed”
PT2 : the C/N at half of maximum speed
PT3 : the C/N_{min} + 3 dB which gives an indication of the speed limit
PT4 : the C/N_{min} at low Doppler (10 Hz)

8.6 C/N Performance

8.6.1 C/N Performance in Gaussian Channel

The receiver should have the performance given in Table 8-4 C/N (dB) for Reference BER 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 EN 300 744 added to an implementation margin of 2.5 dB and using the noise model given in chapter 8.2 with a receiver excess noise source value P x of -33 dBc. An ideal transmitter is assumed. An example of the effects of transmitter degradation on the C/N-values is given in “AnnexB“.

Modulation	Code rate	Gaussian
QPSK	½	5.6
QPSK	2/3	7.4
QPSK	¾	8.4
16-QAM	½	11.3
16-QAM	2/3	13.7
16-QAM	¾	15.1
64-QAM	½	17.0
64-QAM	2/3	19.2
64-QAM	3/4	20.8

Table 8-4 C/N (dB) for Reference BER in Gaussian channel

Note 1: Reference BER is defined as BER =$2x10^{-4}$ after Viterbi decoding.

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

8.6.2 C/N Performance in Portable Channel

The receiver should have the performance given in Table 8-5 when noise (N) is applied together with the wanted carrier (C) in a signal bandwidth of 7.61 MHz. Failure point criteria 1 or 2 should be used. The values are calculated using the theoretical C/N figures given in EN 300 744 added to an implementation margin of 2.5 dB and using the noise model given in chapter 8.2 with a receiver excess noise source value P x of -33 dBc. An ideal transmitter is assumed.

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

Table 8-5 C/N (dB) for Reference BER in Portable Channel

8.6.3 C/N performance in Mobile Channels

The single antenna receiver should have the performance given in Table 8-6 C/N (dB) for PER=10-4 in Typical Urban Channel when noise (N) and Doppler shift (Fd) are 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 a Doppler frequency of 10 Hz. Fd_{max} is the maximum achievable Doppler frequency when no noise is applied. Fd @ C/N_{min} + 3dB gives the achievable Doppler frequency at a point where an additional 3 dB noise is applied over the C/N_{min} value. An error criteria of PER = 10^{-4} is used due to the bursty nature of the error behaviour. This error criteria corresponds rather well to the subjective failure point (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.

GI=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]	Fdmax [Hz]	Fd @ C/N min+3dB	200 MHz	500 MHz	800 MHz	C/N min [dB]	Fdmax [Hz]	Fd @ C/N min+3dB	200 MHz	500 MHz	800 MHz
QPSK	6.03	1/2	13.0	318	259	1398	559	349	13.0	76	65	349	140	87
QPSK	8.04	2/3	16.0	247	224	1207	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

Table 8-6 C/N (dB) for PER=10^{-4} in Typical Urban Channel for single antenna receiver (MOTIVATE RESULTS)

More recent results (early 2003) coming from CONFLUENT measurements are shown in the following table:

SINGLE GI=1/32			Gaussian (Fixe)	TU6 / Mobile										
					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]	$(C/N)_{min}$ [dB]	Fd_{max} [Hz]	Fd_{3dB} [Hz]	200 MHz	500 MHz	800 MHz	Fd_{max} [Hz]	Fd_{3dB} [Hz]	200 MHz	500 MHz	800 MHz
QPSK	6,03	1/2	3,6	**13,0**	340	**314**	1697	679	424	85	**79**	424	170	106
QPSK	8,04	2/3	5,5	**16,0**	320	**297**	1602	641	401	80	**74**	401	160	100
16-QAM	12,06	1/2	9,6	**18,0**	297	**271**	1461	584	365	74	**68**	365	146	91
16-QAM	16,09	2/3	11,8	**22,0**	284	**183**	990	396	247	71	**46**	247	99	62
64-QAM	18,10	1/2	15,0	**23,5**	240	**153**	825	330	206	60	**38**	206	82	52
64-QAM	24,13	2/3	17,2	**27,5**	218	**122**	660	264	165	55	**31**	165	66	41

Table 8-7 C/N (dB) for PER=10^{-4} in Typical Urban Channel for single antenna receiver (CONFLUENT RESULTS)

8.7 Minimum and maximum Receiver Signal Input Levels

8.7.1 Noise Floor

The receiver shall have a noise figure better than 5 dB at the reference point at the sensitivity level of each DVB-T mode.

This corresponds the following noise floor power levels:

P_n = -100.2 dBm, [for 8 MHz channels, BW= 7.61 MHz]

P_n = -100.7 dBm, [for 7 MHz channels, BW= 6.66 MHz]

P_n = -101.4 dBm, [for 6 MHz channels, BW= 5.71 MHz]

8.7.2 Minimum Input Levels

The receiver should provide reference BER for the minimum signal levels (P_{min}) stated below and higher.

P_{min} = -100.2 dBm +C/N [dB], [for 8 MHz]

P_{min} = -100.7 dBm +C/N [dB], [for 7 MHz]

P_{min} = -101.4 dBm +C/N [dB], [for 6 MHz]

where C/N is specified in chapter 8.6 “C/N Performance” and is depending on the channel conditions and DVB-T mode.

8.7.3 Total Maximum Power for Wanted and Unwanted Signals

For this sub-section 8.7.3 the power from the analogue interferer should be considered as the average power.

For terminal category 2 and 3

The maximum total power from the wanted and unwanted signals shall be less than -25 dBm.

8.7.4 Maximum Input Levels for Wanted and Unwanted Signals

The allowed maximum input level on the 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 sub-section 8.7.4 and in section 8.8 the analogue interferer level is defined as the peak sync power level.

For terminal category 2 and 3

The receiver shall be able to handle wanted DVB-T signals up to a level of -28 dBm while providing the specified performance when no other interfering signals are present at the input. The maximum tolerated level for analogue or digital interfering signals according to patterns S1 (n±1), S2 (n±1), L1, L2 and L3 is -35 dBm. The maximum tolerated level for analogue or digital interfering signals according to patterns S1 (n±m, m≠1), S2 (n±m, m≠1) is –28 dBm. All levels are valid for receivers operating on all DVB-T modes.

Wanted Signal Pmax [dBm]	Interferer Signal Patterns Pmax [dBm] for highest interferer		
N	S1 (n±1), S2 (n±1)	L1, L2, L3	S1 (n±m, m≠1), S2 (n±m, m≠1)
-28	No signal	No signal	No signal
See 8.8	-35	-35	-28

Table 8-9 Maximum input levels for terminal category 2 and 3

8.8 Immunity to Analogue and/or Digital Signals in Other Channels

8.8.1 General

Traditionally immunity to analogue and digital signals has been defined with simple single interferer patterns. Either one digital or one analogue interfering signal has been introduced and the protection ratio to the wanted digital signal has then been defined. This does not represent very accurately normal field operation conditions where several interfering signals are present. Also, from a linearity point of view the single interferer scenario is most probably not challenging enough. 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.

8.8.2 Interfering Signal Definitions

PAL B/G/I1

Figure 8-5 shows the PAL B/G/I1 interfering signals. The level of the FM sound relative to the vision carrier is -13 dB. The level of the NICAM signal relative to the analogue vision carrier is -20 dB. Modulating signals are 75% colour bars, and 1 kHz FM sound with ±50 kHz deviation.

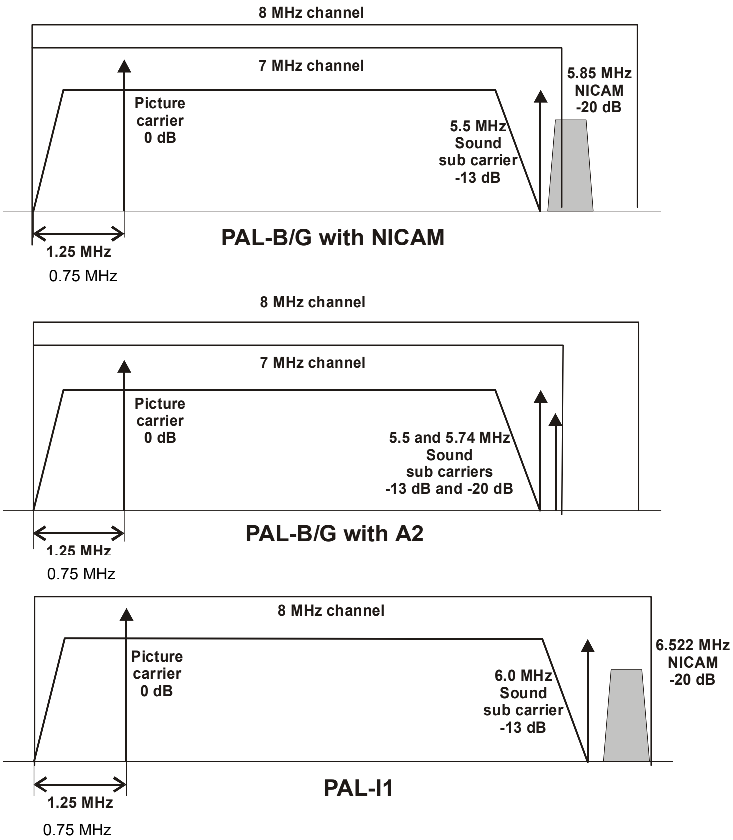

Figure 8-5 PAL interfering signals

SECAM L

Figure 8-6 shows the standard SECAM signal with NICAM sound (1.25MHz vestigal sideband bandwidth).

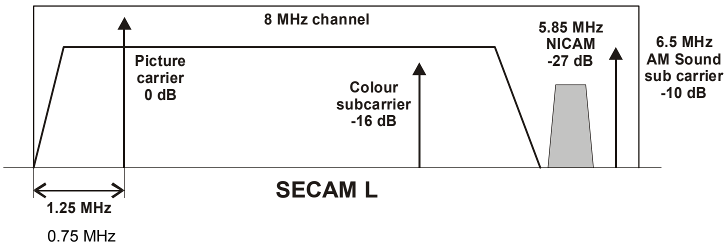

Figure 8-6 SECAM L interfering signal

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. Modulating signals are 75% colour bars for the picture carrier and 1 kHz with 54% AM for the AM sound carrier.

DVB-T

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 channels can be a minimum of 15 dB (digital at lower level). If the difference is smaller, the analogue picture will be disturbed.

8.8.3 Selectivity Patterns

The following two patterns are used for receiver selectivity testing:

- Pattern S1, One adjacent analogue signal on N±1 or N±m or image
- Pattern S2, One adjacent digital DVB-T signal on N±1 or N±m or image

The patterns are shown in Figure 8-7 and Figure 8-8.

8.8.4 Linearity Patterns

The following three patterns are used for receiver linearity testing. Note that similar cases to the described N+2/N+4 are any N+n/N+2*n, where n $\in$ {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 8-9, Figure 8-10, and Figure 8-11.

8.8.5 Immunity to Pattern S1

This pattern has one analogue signal on N±1 or N±m channel in addition to the wanted DVB-T signal on channel N. The 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 level a dB lower, where the value for a is given in Table 8-10.The performance given is only provided when the input level restrictions of 8.7.4 apply.

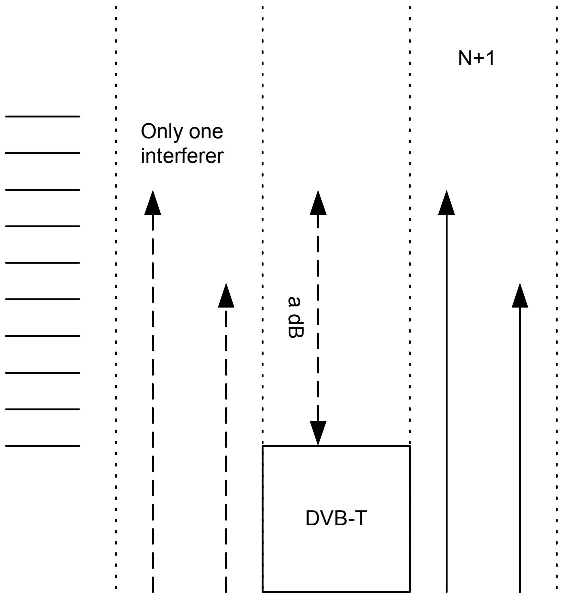

Figure 8-7 Pattern S1 in the case of N+1 or N-1

Mode	a [N±1] PALG or I1	a [N±1] PALB *	a [N-1] SECAM L	a [N+1] SECAM L	a [Image] SECAM L	a [N±m] (m≠1) and Image for PAL B/G/I1
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
2k/8k 16QAM CR=1/2 GI=All	38 dB	36 dB	30 dB	36 dB	55 dB	56 dB
2k/8k 16QAM CR=2/3 GI=All	38 dB	36 dB	30 dB	36 dB	50 dB	51 dB
2k/8k 16QAM CR=3/4 GI=All	37 dB	35 dB	29 dB	35 dB	49 dB	50 dB

Table 8-10 Immunity to pattern S1

*, 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.

8.8.6 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. The 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 level of a dB lower, where the value for a is given in Table 8-.The performance given is only provided when the input level restrictions of 8.7.4 apply.

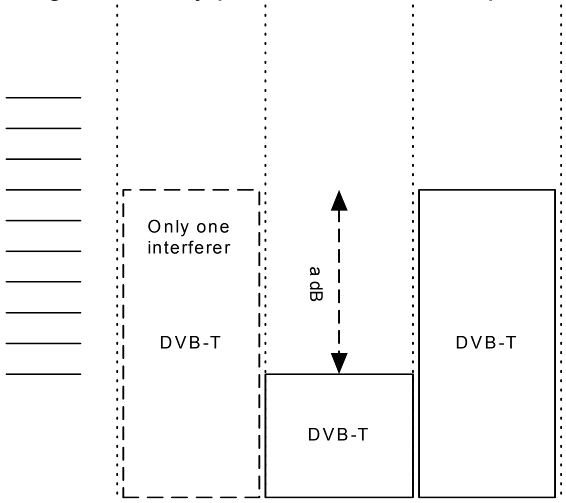

Figure 8-8 Pattern S2 in case of N+1 or N-1

Mode	a [N±1]	a [N±m (m≠1) except Image]	a [Image]
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
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

Table 8-11 Immunity to Pattern S2

8.8.7 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 following performance is only provided when the input level restrictions in 8.7.4 apply and the unwanted signal is at the highest allowed level.

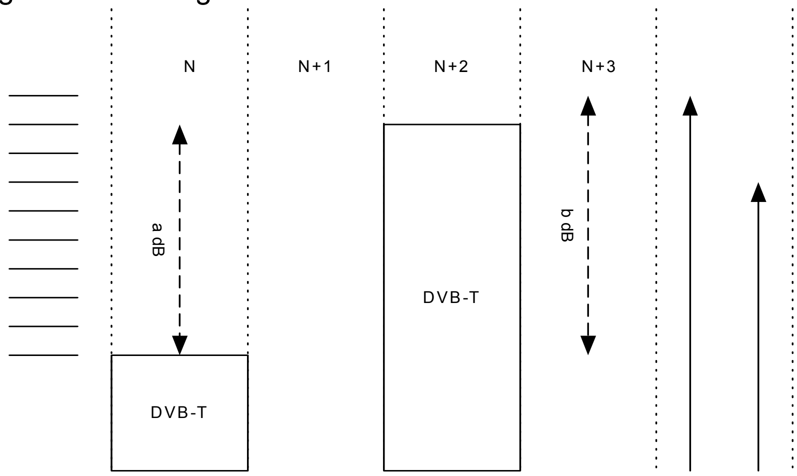

Figure 8-9 Pattern L1

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

Table 8-12 Immunity to Pattern L1

8.8.8 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 following performance is only provided when the input level restrictions in 8.7.4 apply and the unwanted signal is at the highest allowed level.

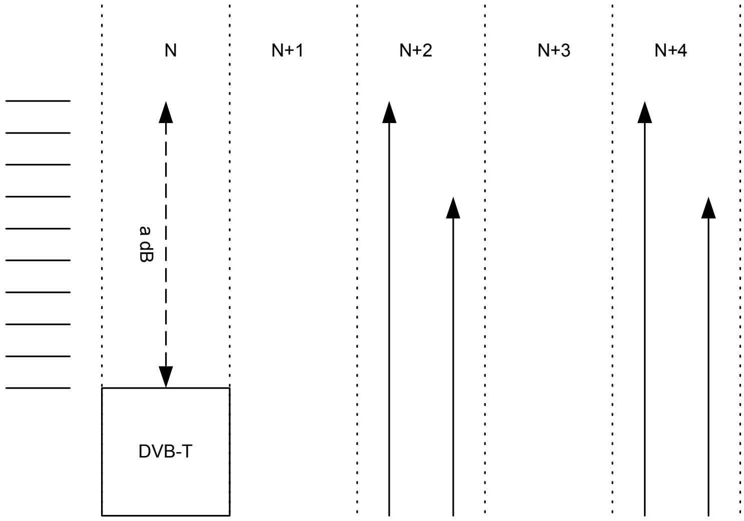

Figure 8-10 Pattern L2

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

Table 8-13 Immunity to Pattern L2

8.8.9 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 following performance is only provided when the input level restrictions in 8.7.4 apply and the unwanted signal is at the highest allowed level.

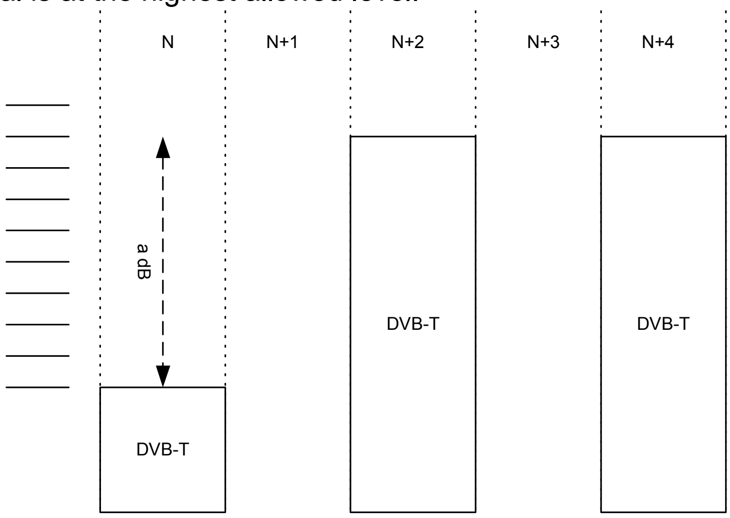

Figure 8-11 Pattern L3

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

Table 8-14 Immunity to Pattern L3

8.9 Immunity to Co-channel Interference from Analogue TV Signals

The immunity to interference from an analogue TV-signal is specified as the minimum carrier to interference ratio, C/I, required for reception.

The interfering analogue signal is defined in 8.8.1. The digital signal level should be -50 dBm.

Mode	PAL B/G/I1	SECAM
2k/8k 64QAM CR=2/3 GI=All	4 dB	5 dB
2k/8k 64QAM CR=3/4 GI=All	7 dB	8 dB
2k/8k 16QAM CR=1/2 GI=All	-6 dB	-5 dB
2k/8k 16QAM CR=2/3 GI=All	-1 dB	0 dB
2k/8k 16QAM CR=3/4 GI=All	0 dB	1 dB

Table 8-15 Immunity to co-channel interference from analogue signals

8.10 Guard Interval Utilization in Single Frequency Networks

8.10.1 Performance with Echoes within Guard Interval

For the modes:

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

{8K, 64-QAM, R =3/4, GI = All},
{8K, 16-QAM, R =1/2, GI = All},
{8K, 16-QAM, R =2/3, 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 the Table 8-16

Mode	C/N [dB]
8K, 64-QAM, R =2/3, GI = All	26.2
8K, 64-QAM, R =3/4, GI = All	30.6
8K, 16-QAM, R =1/2, GI = All	16.3
8K, 16-QAM, R =2/3, GI = All	20.9

Table 8-16 Added noise

8.10.2 Performance with Echoes outside Guard Interval

When the receiver receives 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 when compared to the main signal is lower than the mask shown in Figure 8-12

The mask is defined by three points, the starting point at 0.9 x Tg, the inflection point at 1.0 x Tg and the corner point at Tc. The timing of the point Tc depends on the guard interval according Table 8-17.

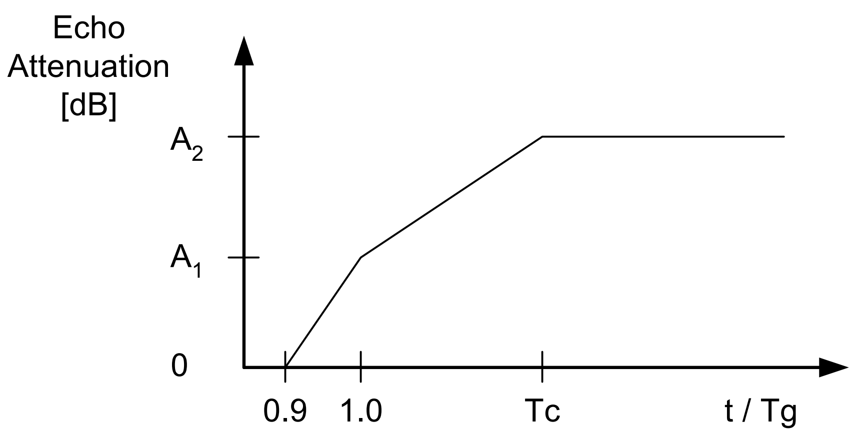

Figure 8-12 Echoes Outside Guard Interval Mask

Guard Interval	Tc relative to Tg
1/4	1.1
1/8	1.3
1/16	2.0
1/32	3.1

Table 8-17 Timing of the Corner Point Tc

Echo attenuation A_2 at the corner point Tc depends 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 the Table 8-4 C/N (dB) for Reference BER in Gaussian channel. The value Δ is defined in the Table 8-18

Modulation	Δ [dB]
QPSK	2
16QAM	3
64QAM	4

Table 8-18 Definition of the Value Δ

A_2 then becomes:

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

Echo attenuation A_1 at the inflection point at t=1.0xTg depends on the modulation used and the code rate as defined in Table 8-19.

Modulation	Code rate	A_2 at t=1.0 x Tg [dB]
QPSK	½½	1
QPSK	2/3	1
QPSK	¾¾	2
16-QAM	½½	1
16-QAM	2/3	2
16-QAM	¾¾	3
64-QAM	½½	1
64-QAM	2/3	3
64-QAM	¾¾	7

Table 8-19 Definition of the Infection Point

At the starting point t = 0.9 x Tg the echo attenuation is always 0dB.

The definition of the mask will result 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 8-13.

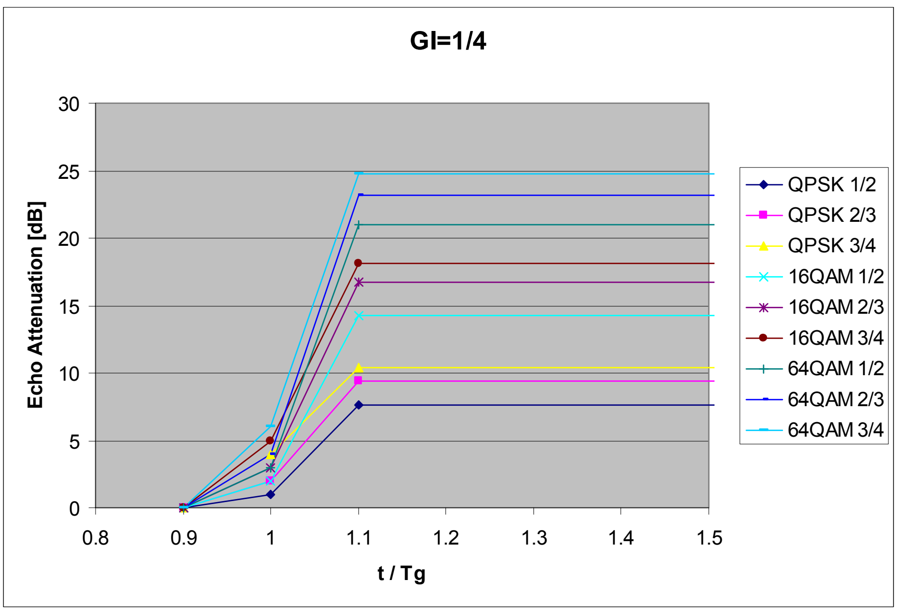

Figure 8-13 Mask for Echo Outside GI for GI=1/4

8.11 Tolerance to Impulse Interference

8.11.1 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 environments 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 impulse interference has been mainly carried out in the UK Digital Television Group. The specifications presented here are results of that work. *(It noted that new impulse noise models are under development for the mobile environment)*

8.11.2 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 8-14 illustrates the terminology used with the test patterns.

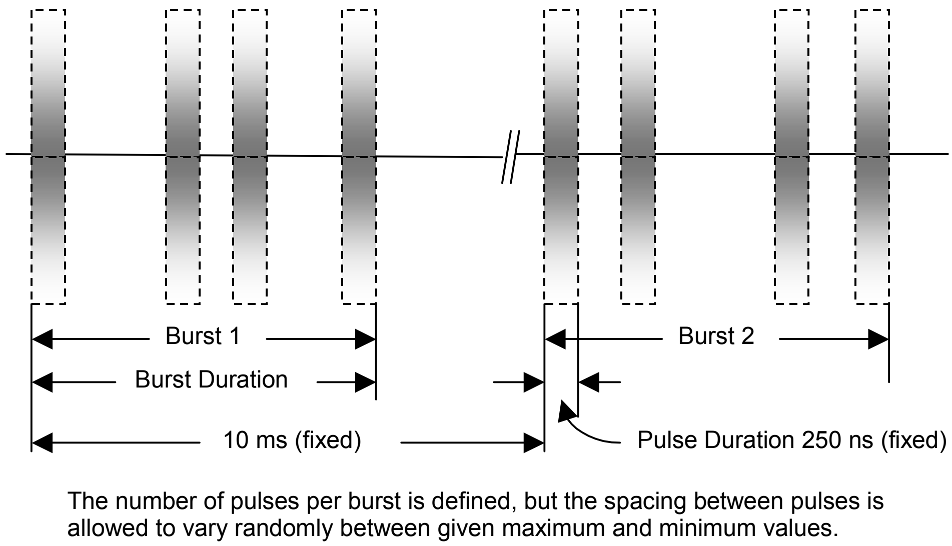

Figure 8-14 Definition of the impulse interference test pattern

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 given by:

$$(C \times T_u) / (P \times T_e) .$$

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 of 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.

The tests so far defined are detailed in the table below, together with their associated ‘tolerance factors’.

Test No.	Pulses per Burst	Minimum/Maximum Pulse Spacing (us)		Burst Duration (us)	Tolerance Factor 2k (dB)	Tolerance Factor 8k (dB)
1	1	N/A	N/A	0.25	29.5	35.5
2	2	1.5	45	45.25	26.5	32.5
3	4	15.0	35	105.25	23.5	29.5
4	12	10.0	15	165.25	18.7	24.7
5	20	1.0	2	38.25	16.5	22.5
6	40	0.5	1	39.25	13.5	19.5

Table 8-20 Impulse Interference Test Patterns

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 8-20 for one or more tests. The higher the Test Number, the greater the difficulty in designing effective countermeasures.

Annex A Active External Antennas

Active Antennas

An active antenna consists of a passive antenna followed by and combined with a low noise pre-amplifier. This 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.

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:

$$T_o F_p G_{amp}$$

Where: F_p is the noise figure (linear ratio) of the active antenna pre-amplifier.
G_{amp} is the gain (linear ratio) of the active antenna pre-amplifier.

'G/T' Figure of merit (m)

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

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

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 figure is F (linear ratio), then the equivalent noise temperature of the receiver is: $(F – 1)T_o$.

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	Gt = 30.9

The antenna noise temperature is:

$$T_o F_p G_{amp} = 17922 \text{ K}$$

If the receiver noise figure is 8 dB (F = 6.3), then the equivalent noise temperature of the receiver is:

$$(F - 1)T_o = 1537 \text{ K}$$

The noise temperature of the total system is:

$$T_{sys} = 19459 \text{ K}$$
$$10 \log (T_{sys}) = 42.9 \text{ dB}$$

So the figure of merit (m) is

m = -28.0 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 as:

The noise temperature of a UHF passive antenna is	= 290 K
The equivalent noise temperature of the receiver (as above) is	= 1537 K
The noise temperature of an equivalent 'passive' system T_{sys}	= 1827 K
And 10 log (Tsys)	= 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 dBi