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COMPATIBILITY BETWEEN MOBILE RADIO SYSTEMS OPERATING IN THE RANGE 450-470MHz AND DIGITAL VIDEO BROADCASTING - TERRESTRIAL (DVB-T) SYSTEM OPERATING IN UHF TV CHANNEL 21 (470-478MHz)

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EXECUTIVE SUMMARY

This report provides results of compatibility studies between Private Mobile Radio (PMR) / Public Access Mobile Radio (PAMR) systems operating in the 450-470MHz and Digital Video Broadcasting – Terrestrial (DVB-T) system operating in the band 470 - 862MHz.

In particular, the report focuses on the impact of the DVB-T system using UHF Channel 21, 470 – 478 MHz on PMR/PAMR systems operating below 470 MHz, and on the impact of PMR/PAMR operating on the channels just below 470 MHz into DVB-T fixed reception operating on channel 21.

The Minimum Coupling Loss (MCL) and the Monte Carlo (using SEAMCAT) methods have been applied in the studies.

The main results of this report can be summarized as follows:

An adjacent band compatibility study has been carried out between PMR/PAMR systems operating at the top end of the 450 – 470 MHz band and DVB-T operating on channel 21. The study indicates a significant probability of interference in both directions:

- PMR/PAMR Mobile Stations (MS) interfered with by DVB-T: the probability of interference is significant when the PMR/PAMR MS are located in the vicinity (around 1 km) of a high-power DVB-T transmitter even if the DVB-T mask for sensitive cases is used. The problem increases when victim MS is at the edge of the PMR/PAMR base stations (BS) service area.
- For DVB-T receiving stations interfered with by PMR/PAMR BS: The probability of interference is significant when the DVB-T receivers are close to the PMR/PAMR BS and it becomes worse if the victim DVB-T receiver is close to the edge of the DVB-T coverage area.

In order to improve compatibility, the following mitigation measures should be considered:

- DVB-T masks;
- Co-siting of the DVB-T transmitter and PMR/PAMR BS;
- Guard band;
- Directivity discrimination combined with sectorized PMR/PAMR BS;
- Cross-polarization discrimination;
- Application of a robust DVB-T system variant.

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Compatibility between mobile radio systems operating in the range 450-470 MHz and Digital Video Broadcasting – Terrestrial (DVB-T) system operating in UHF TV channel 21 (470-478MHz)

1 INTRODUCTION

This report deals with the compatibility studies between Private Mobile Radio (PMR)/Public Access Mobile Radio (PAMR), including TETRA Enhanced Data Systems (TEDS), systems operating in the 450-470 MHz versus Digital Video Broadcasting – Terrestrial (DVB-T) systems operating in the band 470 – 478 MHz.

In particular, the current document considers:

- The impact of the DVB-T system using UHF Channel 21, 470 – 478 MHz on PMR/PAMR systems operating below 470 MHz, i.e. PMR/PAMR MS receiving in the frequency range 460 - 470 MHz and PMR/PAMR BS receiving in the frequency range 450 – 460 MHz (see ECC/DEC/(04)06 [1] and ECC REPORT 25 [2] for recommended use).
- The impact of PMR/PAMR operating on the channels just below 470 MHz into DVB-T fixed reception operating on channel 21.

The report investigates the possibility of interference into mobile PMR/PAMR equipment operating within the coverage area of DVB-T transmitters, and the possibility of interference into DVB-T fixed receptions operating within the coverage area of PMR/PAMR BS, and uses both SEAMCAT simulations and the MCL method for the compatibility studies.

GE-06 agreement contains the digital frequency plan for T-DAB and DVB-T in the frequency range 174-230 MHz and for DVB-T in the frequency range 470-862 MHz which includes channel 21. The planning process took into account only digital terrestrial television and other primary services within the planned bands, but not other primary services in the adjacent bands. The map of the digital plan entries for channel 21 are provided in Annex 7. In some areas covered by this Plan the frequency range below 470 MHz is extensively used by PMR/PAMR.

The MCL approach is relatively straight forward, modelling only a single interferer-victim pair. It provides a static result which guards against the worst case scenario.

The Monte Carlo (implemented in SEAMCAT) approach is a statistical technique which models a victim receiver's probability of interference when situated amongst a randomly generated population of interferers. It is capable of modelling highly complex systems including CDMA (see www.ero.dk/seamcat and www.seamcat.org).

The following scenarios were considered:

- DVB-T interfering into a PMR/PAMR BS (using MCL);
- DVB-T interfering into a PMR/PAMR Mobile Receiver (SEAMCAT);
- PMR/PAMR BS interfering into a DVB-T receiver (SEAMCAT);
- PMR/PAMR MS interfering into a DVB-T receivers (no simulations deemed necessary).

2 SYSTEM PARAMETERS

2.1 Television characteristics

2.1.1 Analogue TV

Generally across Europe, analogue television is being phased out, therefore this report limits its scope to the impact of DVB-T as an interferer or as a victim.

2.1.2 Digital TV

In the following sections, the technical and operational characteristics are provided for DVB-T transmitters and receivers.

2.1.2.1 Characteristics of DVB-T as a victim

Antenna height: 10 m (rooftop)

Antenna pattern: Recommendation ITU-R BT.419 [3]

2.1.2.1.1 Values for DVB-T field strengths to be protected

Minimum field strength values for DVB-T fixed reception to be calculated from Recommendation ITU-R BT.1368-6 [4].

Applying the method in Appendix 1 to Annex 2 of Recommendation ITU-R BT.1368-6, the minimum field strengths to be protected for fixed reception of DVB-T at 474 MHz (centre of channel 21) are as follows:

TABLE 1

Minimum Field Strengths to be Protected for fixed reception of DVB-T at 474 MHz

	8 MHz DVB-T Modulation scheme – Code Rate		
	QPSK - 2/3	16QAM - 2/3	64QAM - 2/3
Minimum FS value dBμV/m	30.5	36.3	41.3

The modulation 64QAM, code rate 2/3 has been used for the simulations since it was used to determine the protection ratios given in Table 2 and Table 3.

2.1.2.1.2 Protection Ratios (PR) for DVB-T

Protection Ratios for DVB-T are defined in Recommendation ITU-R BT.1368-6. The following PR table applies for DVB-T interfered with by a narrow band FM carrier.

TABLE 2

Protection ratios (dB) for a DVB-T 8 MHz 64-QAM code rate 2/3 signal interfered with by a CW or a FM carrier (non-controlled frequency offset)

Δf (MHz)	–12	–4.5	–3.9	0	3.9	4.5	12
PR (dB)	–38	–33	–3	–3	–3	–33	–38
Δf is the difference between the centre frequencies.							

In addition, the following table provides protection ratios for DVB-T 8 MHz, 64-QAM code rate 2/3 signal interfered with by emissions of CDMA-1X.

TABLE 3

Protection ratios (dB) for DVB-T 8 MHz 64-QAM code rate 2/3 signal interfered with by emissions of CDMA-1X

Δf (MHz)	–12	–4.5	–3.75	0	3.75	4.5	12
PR (dB)	–38	–20	–3	10	–3	–20	–38
Δf is the difference between the centre frequencies.							

The difference in PR at 4.5 MHz between the Tables 2 and 3 is due to the difference of bandwidth between the narrowband and wideband systems. Although for the co-channel case (Δf =0) there is also a difference, this is not a consideration within this study as it is not dealing with co-channel operation.

2.1.2.2 DVB-T transmitter parameters

The following spectrum masks are used within CEPT for DVB-T in bands shared with other services (see section 3.6.2 of Chapter 3 to annex 2) of GE-06 agreement [5]).

The out-of-band radiated signal in any 4 kHz band shall be constrained by one of the two symmetrical spectrum masks given in Figure 1 and Table 4:

- Case 1: the mask having a shoulder attenuation of 40 dB is intended for non-critical cases
- Case 2: the mask with a shoulder attenuation of 50 dB is intended for sensitive cases.

The mask for non-critical cases should also be used for measurements of protection ratios for analogue television interfered with by DVB-T [5].

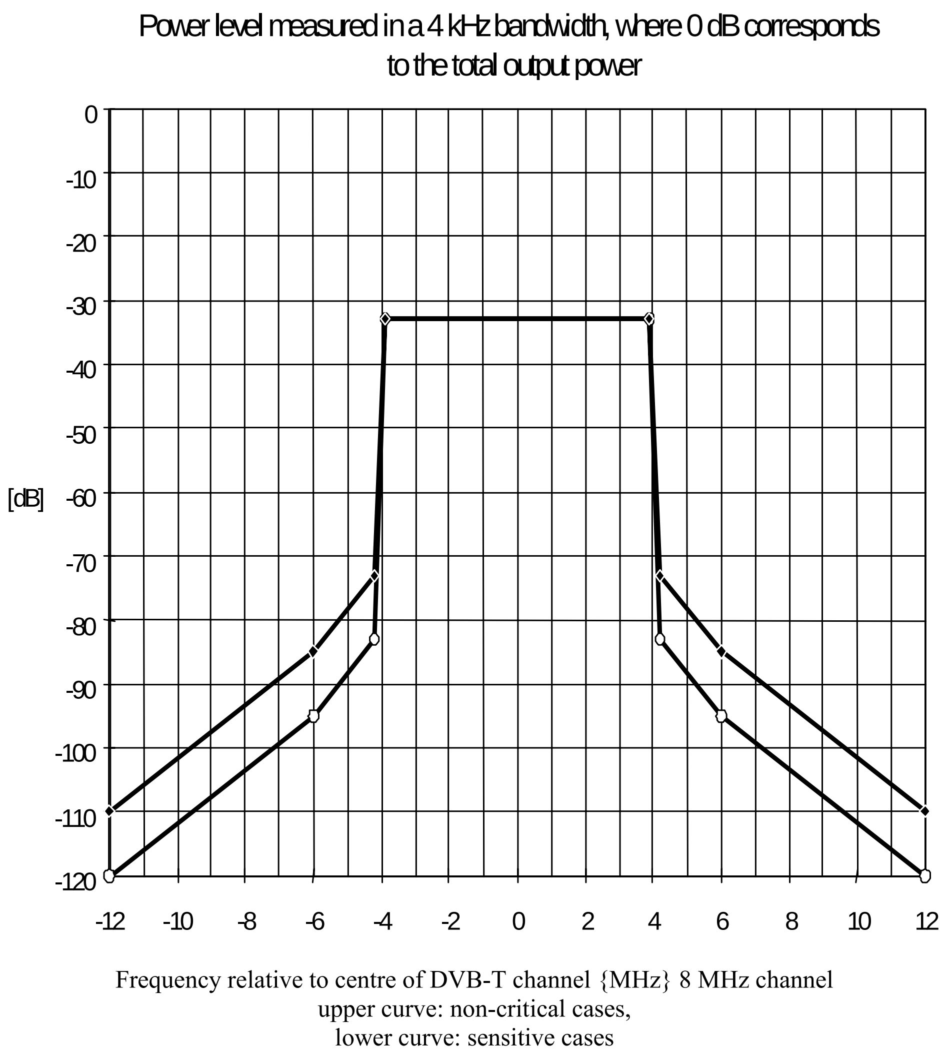


Figure 1: Symmetrical DVB-T spectrum masks for non-critical and for sensitive cases

TABLE 4

Breakpoints for DVB-T masks in Figure 1

Breakpoints		
8 MHz channels		
	Non-critical cases	Sensitive cases
Relative Frequency MHz	Relative Level dB	Relative Level dB
-12.0	-110.0	-120.0
-6.0	-85.0	-95.0
-4.2	-73.0	-83.0
-3.9	-32.8	-32.8
+3.9	-32.8	-32.8
+4.2	-73.0	-83.0
+6.0	-85.0	-95.0
+12.0	-110.0	-120.0

The following assumptions are used in the following sections dealing with DVB-T interfering PMR/PAMR MS:

- Operating frequency: 474 MHz
- 8 MHz channel
- e.i.r.p: 20 kW (73dBm)
- Omni directional antenna
- Tx Antenna height : 100m
- Tx Antenna gain: 0dBi

2.1.3 Antenna amplifiers

Mast head amplifiers may be used in some TV receiving antenna systems. Amplifiers are not standardised, and therefore outside the scope of this study. Some general information about this can be found in Annex 6.

2.2 PMR/PAMR characteristics

Typical analogue PMR/PAMR systems in the 450-470MHz band have equipment conforming to EN 300 113 [6] or EN 300 086 [7] and have an e.r.p. of 10W but can be up to 25W.

Digital PMR/PAMR systems in this band exhibit similar characteristics, however digital PAMR systems for wide area coverage would typically be cellular in nature with an e.r.p. in the region of 250W.

TETRA receiver parameters are available in EN 300 392-2 [8].

2.2.1 Characteristics for PMR/PAMR – 12.5 kHz

TETRAPOL characteristics may be derived using those given in EN 300 113 [6] - the same as for analogue 12.5kHz PMR/PAMR systems.

Report 104 [9] provides the following set of parameters for PMR/PAMR using 12.5 kHz channels.

TABLE 5

Parameters Assumed for 12.5 kHz FM PMR/PAMR Systems

Parameter	Mobile Station	Base Station
Channel Spacing	12.5 kHz	12.5 kHz
Transmit Power	37 dBm	44 dBm
Receiver Bandwidth	8 kHz	8 kHz
Antenna Height	1.5 m	30 m
Cable loss	n.a.	2 dB
Antenna Gain (1)	0 dBi	9 dBi
Receiver Sensitivity	- 107 dBm	- 110 dBm
C/I	21 dB	21 dB
Power Control Characteristic	not used	not used

(1) the antenna is assumed to be omni directional

TABLE 6

Unwanted Emissions for 12.5 kHz FM PMR/PAMR Systems (measurement bandwidth of 8 kHz)

Frequency Offset	Mobile Station	Base Station
12.5 kHz	- 23 dBm	- 16 dBm
100 - 250 kHz	- 43 dBm	- 36 dBm
250 - 500 kHz	- 60 dBm	- 53 dBm
500 kHz - 1 MHz	- 64 dBm	- 57 dBm
1 MHz - 10 MHz	- 69 dBm	- 62 dBm
> 10 MHz	- 71 dBm	- 64 dBm
Linear interpolation (in dB) is used between 12.5 kHz and 100 kHz		

TABLE 7

Receiver Blocking for 12.5 kHz FM PMR/PAMR Systems

Mobile Station	Base Station
- 23 dBm	- 23 dBm

2.2.2 Characteristics for TEDS

2.2.2.1 Mobile stations

Two cases are considered for TEDS MS: 25 kHz and 150 kHz receiver bandwidth. The following characteristics were used in the simulations (see ETSI TR 102 491 [10]).

25 kHz receiver case

- Omni directional antenna
- 0dBi
- 25 kHz reception bandwidth
- Centre frequency: 469.9875 MHz
- Antenna height : 1.5 m
- Sensitivity: -114dBm / -108 dBm / -102 dBm
- C/I is taken equal to 19dB
- C/I is taken equal to -40dB for the first adjacent channel (i.e. in section 3.1.3.2.1)
- Blocking -40 dBm (worst case assumption) (see section 3.1.3.2.2)

150 kHz receiver case

- Omni directional antenna
- 0dBi
- 150 kHz reception bandwidth
- Centre frequency: 469.925 MHz
- Antenna height : 1.5 m
- Sensitivity :-106dBm (a value of -102 dBm was also considered for some simulations – see section 3.1.3.1.2.1)
- C/I is taken equal to 19dB
- C/I is taken equal to -40dB for the first adjacent channel (i.e. in section 3.1.3.2.1)
- Blocking -40 dBm (worst case assumption) (i.e. in section 3.1.3.2.2)

2.2.2.2 Base stations

The following PMR/PAMR BS characteristics are provided in ETSI TR 102 491 [10].

25 kHz transmitter case
Centre frequency 469.9875 MHz (highest channel)
Channel spacing 25 kHz
Power = 46 dBm (power class 1) without power control
Antenna height = 30 m
Antenna peak gain = 7 dB
Unwanted emissions close and far from the carrier from EN 300 392-2 [8] are provided in the following tables:

TABLE 8

Maximum adjacent power levels for frequencies below 700 MHz

Frequency offset	Maximum level for MS power classes 4 and 4L	Maximum level for other power classes
25 kHz	-55 dBc	-60 dBc
50 kHz	-70 dBc	-70 dBc
75 kHz	-70 dBc	-70 dBc

TABLE 9

Wideband noise limits for frequencies below 700 MHz

Frequency offset	Maximum wideband noise level (Note 2)		
	MS nominal power level ≤ 1 W (class 4)	MS nominal power level = 1,8 W or 3 W (class 3L or 3)	MS nominal power level ≥ 5,6 W (class 2L) BS all classes
100 kHz to 250 kHz	-75 dBc	-78 dBc	-80 dBc
250 kHz to 500 kHz	-80 dBc	-83 dBc	-85 dBc
500 kHz to f_{rb} (Note 1)	-80 dBc	-85 dBc	-90 dBc
> f_{rb} (Note 1)	-100 dBc	-100 dBc	-100 dBc
Note 1: f_{rb} denotes the frequency offset corresponding to the near edge of the receive band or 5 MHz (10 MHz for frequencies above 520 MHz) whichever is greater. Note 2: 18 kHz bandwidth is used as a reference bandwidth.			

150 kHz transmitter case
Centre frequency 469.925 MHz (highest channel)
Channel spacing 150 kHz
Power = 46 dBm (power class 1) without power control
Antenna height = 30 m
Antenna peak gain = 7 dB
Unwanted emission mask = Unwanted emissions close and far from the carrier from ETSI TR 102 491

TABLE 10

Maximum adjacent power levels for 150 kHz QAM

Frequency offset	Maximum level for MS and BS
87.5 kHz	-55 dBc
112.5 kHz	-60 dBc
137.5 kHz	-60 dBc

TABLE 11

Wideband noise limits 150 kHz QAM

Frequency offset	Maximum wideband noise level for MS and BS (Note 2)	
	MS nominal power level ≤ 3 W (class 3)	MS nominal power level ≥ 5,6 W (class 2L) BS all classes
162.5 kHz to 312.5 kHz	-60 dBc	-60 dBc
312.5 kHz to 562.5 kHz	-63 dBc	-70 dBc
562.5 kHz - 1 500 kHz	-70 dBc	-75 dBc
1 500 kHz – f_{rb} (Note 1)	-70 dBc	-80 dBc
> f_{rb} (Note 1)	-95 dBc	-95 dBc
Note 1: f_{rb} denotes the frequency offset corresponding to the near edge of the receive band or 5 MHz (10 MHz for frequencies above 520 MHz) whichever is greater. Note 2: 18kHz bandwidth is used as a reference bandwidth.		

2.2.3 Characteristics for CDMA-1X

Some countries are deploying CDMA-based systems to replace analogue cellular systems and provide PAMR service. The System Reference Document ETSI TR 102 260 [11] is available describing such systems.

2.2.3.1 Mobile station

For the CDMA-MS as a victim:

- An Rx filter with a response of – 72 dB at 900 kHz from the centre of the CDMA-PAMR carrier
- Mobile receiver sensitivity tests use a -119.5 dBm signal at the UE input to meet the FER requirements
- Omni directional antenna
- Antenna gain 0dBi
- antenna height 1.5 m

2.2.3.2 Base station

Centre frequency 469.975 MHz (Channel 400 - highest channel)
Channel spacing : channels 1 to 400, frequency = 0.025 (N-1) + 460.000 MHz)
Note that CDMA-1X channel bandwidth is 1.25 MHz
Power = 44 dBm
Antenna height = 30 m
Antenna peak gain = 7 dBi (9 dBi – 2 dB cable loss)
Unwanted emission mask = from ETSI TR 102 260 [11]

TABLE 12

Unwanted emission mask for CDMA-1X PMR/PAMR BS

Separation from centre frequency	Emission limit	Note
750 kHz	-45 dBc / 30kHz	
885 kHz	-60 dBc / 30kHz	
1.125 to 1.98 MHz	-65 dBc / 30kHz	
1.98 to 4.00 MHz	-75 dBc / 30kHz	
4.00 to 6.00 MHz	-36 dBm / 100 kHz	(-80 dBc / 100 kHz)
> 6.00 MHz	-45 dBm / 100 kHz	(-89 dBc / 100 kHz)

For the BS, an Rx filter response is -71 dB at 900 kHz from the centre of the CDMA-PAMR carrier.
Tests described in the standards for the receiver sensitivity performance state that the signal strength at the BS input should be equal to or less than -117 dBm to achieve the FER requirements.

2.2.4 Protection Ratios (PR) for PMR/PAMR

The following protection ratio table for 20/25 kHz analogue FM signals is provided in the table A.4.2-13 in Chapter 4 to Annex 2, in the GE-06 agreement [5]:

TABLE 13

Protection Ratio for 20/25 kHz Analogue FM signals

Wanted:	Analogue FM signal		Default field strength to be protected (dBµV/m)			31	Default Receiving antenna height (m)			1.5
			at Frequency (MHz)			650				
Unwanted	DVB-T/8 MHz									
Δf (MHz)	-12.0	-10.0	-8.0	-6.0	-4.2	-3.8	-3.6	0.0	3.6	3.8
PR (dB)	-97.0	-92.0	-85.0	-80.0	-70.0	-20.0	-14.0	-14.0	-14.0	-20.0
Δf (MHz)	4.2	6.0	8.0	10.0	12.0					
PR (dB)	-70.0	-80.0	-85.0	-92.0	-97.0					

These protection ratios above come from measurements using the GE06 mask for DVB-T, using the less critical mask for smaller frequency offsets and the critical mask at high offsets.
The values in following table come from measurements (see Annex 5), only the worst case value from the measurement are retained).

TABLE 14

PMR/PAMR Protection Ratios for 12.5 kHz analogue FM signals in the Presence of an Offset DVB-T for a Wanted Level of –107.0 dBm

Unwanted Signal	*DVB-T 16 & 64 QAM*							
Wanted Signal	*FM, 1kHz tone, 1.5kHz Deviation, at -107.0 dBm*							
Centre Frequency	*169.0125 MHz*							
For a SINAD of	*14.0 dB*							
Δf (MHz)	**0**	**+4.0**	**+5.0**	**+6.0**	**+7.0**	**+8.0**	**+9.0**	**+10.0**
PR (dB)	**-23**	**-71.5**	**-71.8**	**-74.0**	**-76.0**	**-77.8**	**-79.7**	**-81.8**

Note: The test was conducted at 169.0125MHz but the results are taken to be valid for UHF PMR/PAMR equipment.

3 SCENARIOS, MODELS, CALCULATIONS AND SIMULATION

3.1 DVB-T Transmitter as a source of interference

- Scenario MCL-1: DVB-T transmitter interfering into a 20-25 kHz PMR/PAMR BS receiving in the frequency range 450 - 460 MHz using free space model;
- Scenario SEAMCAT-1: DVB-T transmitter interfering into a 12.5 kHz PMR/PAMR MS in 460 – 470 MHz using SEAMCAT;
- Scenario SEAMCAT-2: DVB-T transmitter interfering into a TEDS MS in 460 – 470 MHz using SEAMCAT;
- Scenario SEAMCAT-3: DVB-T transmitter interfering into a CDMA MS in 460 – 470 MHz using SEAMCAT.

3.1.1 Scenario MCL-1: DVB-T transmitter interfering 20-25 kHz PMR/PAMR BS using free space model

Considering:

- the sensitivity as given in table 5 of - 110dBm;
- the protection ratio of -97 given in table 13 for a 12 MHz offset
- and an antenna gain of 9dBi for 20-25 kHz PMR/PAMR BS

the power at the victim should not exceed:
-110 dBm - 9 + 97 = - 22 dBm = -52 dBW

This is equivalent to a field strength of (see Recommendation ITU-R P.525 [12]):

$E = P_r + 20 \log f + 167.2$ = 108 dB(μV/m))

Where :

P_r: isotropically received power (dB(W))
E: electric field strength (dB(μV/m))
f: frequency (GHz)

Using the equations given in Recommendation ITU-R P.525 [12], it is found that:

$E = P_t - 20 \log d + 74.8$

Where:

d: distance (km).
P_t: isotropically transmitted power (dB(W))
E: electric field strength (dB(μV/m))

For DVB-T with 20 kW power this gives: - 20 log d = 108 – 74.8 – 43 = -10 dB and d equals 3.2 km

The value of 108 dBμV/m results for a DVB-T TX of e.i.r.p of 20 kW at 3.2 km.

3.1.2 Scenario SEAMCAT-1: DVB-T transmitter interfering 12.5 kHz PMR/PAMR MS in 460 – 470 MHz

The simulations in the following sections have been divided into two (0 – 1 km and 1 – x km) because of the difference in propagation models used above and below 1 km, see Annex 1

When the symbol df is used in this section, it is defined as **df (MHz) = Δf – 6.25 kHz.**

3.1.2.1 Victim: 12.5 kHz PMR/PAMR systems – Protection ratio

The methodology to implement the protection ratio in SEAMCAT is described in Annex 2.

The Victim PMR/PAMR system is assumed to operate at 469.99375 MHz (i.e. 470 MHz – Channel Spacing / 2) with a dRSS of -107 dBm. For these simulation the PR from Table 14 for an offset of 4 MHz was used (-71.5 dB).

TABLE 15

Interference Probability for 12.5 kHz PMR/PAMR Victim Receiver– Protection ratio

		Rural	**Suburban**	**Urban**
DVB-T: 20 kW (e.i.r.p.) – 100 m - 50 km simulation radius	**0-1 km**	100 %	100 %	69.7 %
	1-50 km	0.035 %	0.02 %	0 %
	Total	0.0004 x 1+0.9996 x 0.00035 =0.00075 0.075 %	0.0004 x 1+ 0.9996 x 0.0002 =0.0006 0.06 %	0.0004 x 0.697 =0.0002788 0.028 %
DVB-T: 20 kW (e.i.r.p.)– 100 m - simulation radius depending on the environment (see Annex 1)	**0-1 km**	100 %	100 %	69.7 %
	1-Radius km	0.2 %	2.2 %	0.6 %
	Total	0.003 x 1+0.997 x 0.002 =0.0045 **0.45 %**	0.02 x 1+0.022 x 0.98=0.0418 **4.2 %**	0.0816 x 0.69.7 +0.9184 x 0.006 =0.0624 **6.2 %**

Note: Rural environment Radius = 20 km, Suburban environment Radius = 7 km, Urban environment Radius = 3.5 km.

In addition to DVB-T parameters of 20 kW – 100m antenna height a.g.l, simulations were also conducted for a DVB-T system operating at 100 W -20 m, urban case, 3.5 km, (worst case in table 10). The following interference was found, 0.0816 x 0.105 + 0.9184 x 0 =0.0086 corresponding to less than 1% probability of interference therefore no additional simulations based on protection ratio were performed for this system.

3.1.2.2 Victim: 12.5 kHz PMR/PAMR systems – Unwanted emissions

In this section both the non-sensitive case and the sensitive cases were considered (see Figure 1 and Table 4).

Calculations of the probability may be obtained using the C/I criterion and unwanted emissions as interfering signal type. The 12.5kHz Victim receiver is operating at 469.99375 MHz and the DVB-T interfering system is assumed to operate at a frequency of 474 MHz or higher.

3.1.2.2.1 Setting the Desired Received Signal Strength (dRSS) constant, equal to the sensitivity level

Results are provided for sensitive mask and for the non-critical mask.

The following table provides the results of simulations for a dRSS equal to -107 dBm (see Table 5).

3.1.2.2.1.1 Simulations radius of 50 km

For this case, simulations are also conducted with a DVB-T station operating 100 W and 20 m for the purpose of comparison.

TABLE 16

Interference Probability for a dRSS constant and equal to -107 dBm – 12.5 kHz PMR/PAMR Victim Receiver – 50 km simulation radius

		Rural	Suburban	Urban
DVB-T: 20 kW (ei.r.p.) – 100 m Non-Critical case	**0-1 km**	100 %	100 %	100 %
	1-50 km	35 %	35%	19 %
	Total	**35 %**	**35 %**	**19 %**
DVB-T: 20 kW (e.i.r.p.) – 100 m Sensitive case	**0-1 km**	100 %	100 %	100 %
	1-50 km	26 %	26 %	13 %
	Total	**26 %**	**26 %**	**13 %**
DVB-T: 100W (e.i.r.p.) – 20 m Non-Critical case	**0-1 km**	100 %	100 %	100 %
	1-50 km	0.5 %	0.5 %	0.25 %
	Total	**0.55 %**	**0.55 %**	**0.3 %**
DVB-T: 100W (e.i.r.p.) – 20 m Sensitive case	**0-1 km**	100 %	100 %	100 %
	1-50 km	0.4 %	0.4 %	0.1%
	Total	**0.45 %**	**0.45 %**	**0.14 %**

This set of results shows that the worst case to be considered correspond to 20 kW – 100 m. The case 100W – 20 m will no longer be considered in the following simulations.

3.1.2.2.1.2 Calculations for Additional Simulations radius

Calculations were conducted using additional simulation radius depending on the PMR/PAMR environment (see Annex 1):

TABLE 17

Interference Probability for a dRSS constant and equal to -107 dBm – PMR/PAMR Victim Receiver – simulation radius depending on the environment

			Rural	Suburban	Urban
Victim Receiver 12.5 kHz PMR/PAMR DVB-T: 20 kW (ei.r.p.)– 100 m	**Non-Critical case**	0-1 km	100 %	100 %	100 %
		1-Radius km	93%	100 %	100 %
		Total	**93%**	**100 %**	**100 %**
	Sensitive case	0-1 km	100 %	100 %	100 %
		1-Radius km	86%	99.9 %	100 %
		Total	**86 %**	**100 %**	**100 %**
Victim Receiver 8 kHz PMR DVB-T: 20 kW (e.i.r.p.)– 100 m	**Non-Critical case**	0-1 km	100 %	100 %	100 %
		1-Radius km	89.5%	100 %	100 %
		Total	**89.5 %**	**100 %**	**100 %**
	Sensitive case	0-1 km	100 %	100 %	100 %
		1-Radius km	81%	99.7 %	100 %
		Total	**81 %**	**99.7 %**	**100 %**

From the results given in Tables 15 and 16, it can be seen that

- the worst case occurs for Urban, 3.5 km simulation radius;
- the best case occurs for Urban, 50 km simulation radius;

These two cases will be further considered in the following sections. The following table provides results of simulations for different frequency offsets.

TABLE 18

Interference Probability for a dRSS constant and equal to -107 dBm – Urban – 12.5 kHz PMR/PAMR Victim Receiver

		df (MHz)								
		4	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
DVB-T 20 kW (e.i.r.p) 100 m - 3.5 km radius Non-Critical case	**0-1 km**	100.0%	100.0%	100.0%	100.0%	88.0%	68.6%	52.0%	39.1%	28.6%
	1-3.5 km	100.0%	100.0%	51.6%	19.8%	7.7%	2.0%	0.5%	0%	0%
	Total	**100.0%**	**100.0%**	**55.6%**	**26.3%**	**14.3%**	**7.4%**	**4.7%**	**3.2%**	**2.3%**
DVB-T 20 kW (e.i.r.p) 100 m - 3.5 km radius Sensitive case	**0-1 km**	100.0%	100.0%	79.5%	62.0%	47.2%	34.0%	24.3%	17.0%	11.2%
	1-3.5 km	100.0%	51.1%	19.0%	7.3%	2.4%	0.6%	0%	0%	0%
	Total	**100.0%**	**55.1%**	**23.9%**	**11.8%**	**6.1%**	**3.3%**	**2.0%**	**1.4%**	**0.9%**
DVB-T 20 kW (e.i.r.p) 100 m - 50 km radius Non-Critical case	**0-1 km**	100.0%	100.0%	100.0%	100.0%	88.0%	68.6%	52.0%	39.1%	28.6%
	1-50 km	19.0%	0.4%	0.0%	0%	0%	0.0%	0%	0%	0%
	Total	**19.0%**	**0.4%**	**0%**	**0%**	**0%**	**0.0%**	**0.0%**	**0.0%**	**0%**
DVB-T 20 kW (e.i.r.p) 100 m - 50 km radius Sensitive case	**0-1 km**	100.0%	100.0%	79.5%	62.0%	47.2%	34.0%	24.3%	17.0%	11.2%
	1-50 km	13.0%	0%	0%	0%	0%	0%	0.0%	0%	0%
	Total	**13.0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**

3.1.2.2.2 Setting dRSS above the sensitivity level

In this set of simulations instead of using a constant dRSS, a distribution of dRSS is used (Gaussian distribution - dRSS Mean value – 85dBm, Standard Deviation 7dB).

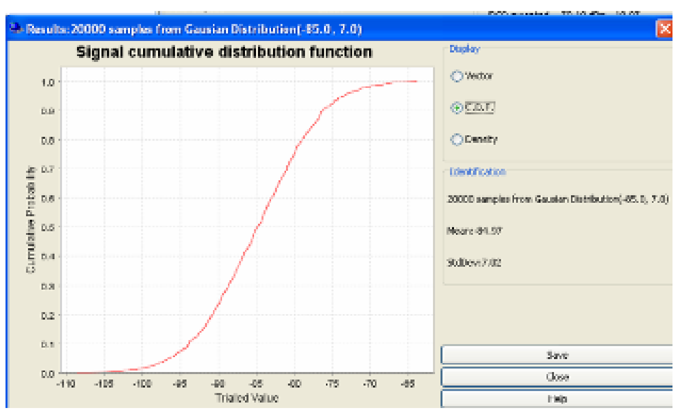


Figure 2: dRSS distribution – Sensitivity of -107 dBm – Urban environment – 12.5 kHz PMR/PAMR receiver

The following table provides results of simulations for variable dRSS and for different frequency offset.

TABLE 19

Interference probability for a dRSS distribution – Urban – 12.5 kHz PMR/PAMR Victim Receiver

		df (MHz)								
		4	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
DVB-T 20 kW (e.i.r.p) 100 m - 3.5 km radius Non-Critical case	**0-1 km**	100.0%	60.0%	39.3%	29.0%	20.0%	14.0%	9.3%	5.4%	3.3%
	1-3.5 km	84.0%	1.5%	0.3%	0%	0%	0%	0%	0%	0%
	Total	**85.3%**	**6.3%**	**3.4%**	**2.4%**	**1.6%**	**1.1%**	**0.8%**	**0.4%**	**0.3%**
DVB-T 20 kW (e.i.r.p) 100 m - 3.5 km radius Sensitive case	**0-1 km**	100.0%	31.0%	18.0%	12.0%	7.3%	4.6%	2.8%	1.5%	1.0%
	1-3.5 km	73.5%	0%	0%	0%	0%	0%	0%	0%	0%
	Total	**75.7%**	**2.5%**	**1.5%**	**1.0%**	**0.6%**	**0.4%**	**0.2%**	**0.1%**	**0.1%**
DVB-T 20 kW (e.i.r.p) 100 m - 50 km radius Non-Critical case	**0-1 km**	100.0%	60.0%	39.3%	29.0%	20.0%	14.0%	9.3%	5.4%	3.3%
	1-50 km	2.0%	0%	0%	0%	0%	0%	0%	0%	0%
	Total	**2.0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
DVB-T 20 kW (e.i.r.p) 100 m - 50 km radius Sensitive case	**0-1 km**	100.0%	31.0%	18.0%	12.0%	7.3%	4.6%	2.8%	1.5%	1.0%
	1-50 km	1.0%	0%	0%	0%	0%	0%	0%	0%	0%
	Total	**1.0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**

3.1.2.3 3.1.2.3Preliminary Conclusions for the case of 12.5 kHz PMR/PAMR MS

Section 3.1.2 considered a combination of both unwanted and blocking mechanisms based on measured protection ratios. It is therefore not expected to find higher probabilities of interference when considering only the impact of unwanted emissions. It has to be noted that the above simulations are based on unwanted emissions masks that have to be met by the DVB-T signal. Therefore, the real signal will be “below” the “envelope” of these masks and the real level of interference will be lower. Other parameters such as “real” receiver bandwidths will also contribute to reduction of the probabilities of interference.

In addition, it should be noted that the probability of interference is significant when the PMR/PAMR receivers are located in the vicinity (1 km) of the DVB-T station. 1 MHz guard band is needed to protect PMR/PAMR from interference from high power DVB-T stations.

3.1.3 Scenario SEAMCAT-2: DVB-T transmitter interfering TEDS PMR/PAMR MS in 460 – 470 MHz

3.1.3.1 Victim TEDS: impact of unwanted emissions falling within the Victim Receiver Bandwidth

In this section, only the impact of unwanted emissions (non-sensitive and sensitive cases) falling into the receiver bandwidth is considered.

The DVB-T transmitter is assumed to operate at 474 MHz or higher frequency. The symbol df is used in this section and defined as follows:

- For TEDS with 25 kHz channels it is defined as **df (MHz) = Δf – 12.5 kHz;**
- For TEDS with 150 kHz channels it is defined as **df (MHz) = Δf – 75 kHz.**

In this set of simulations mainly two cases are considered based on the results given in section 3.1.3.2.1 for the first adjacent channel case:

- Victim Receiver: TEDS – 50 km simulation radius – Urban (best case);
- Victim Receiver: TEDS – 3.5 km simulation radius – Urban (worst case).

3.1.3.1.1 25 kHz TEDS receiver

Two set of results are presented in this section:

- For simulations assuming a constant dRSS taken equal to the sensitivity level;
- For simulations assuming a variable dRSS above the sensitivity level.

3.1.3.1.1.1 Setting dRSS constant, equal to the sensitivity

Results are provided for sensitive mask and for the non-sensitive mask. The following table provides the results of simulations for a dRSS set equal to -114 dBm.

TABLE 20

Interference Probability for a dRSS constant and equal to -114 dBm –TEDS 25 kHz Victim Receiver

		df (MHz)								
		4	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Non-Critical Case 25 kHz - 50 km	**0-1km**	100 %	100 %	100 %	100 %	100 %	100 %	86 %	67 %	51 %
	1-50 km	36.5 %	1 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %
	Total	**36.5 %**	**1.0 %**	**0.4 %**	**0 %**	**0 %**	**0 %**	**0 %**	**0 %**	**0 %**
Non-Critical Case 25 kHz - 3.5 km	**0-1km**	100 %	100 %	100 %	100 %	100%	100 %	86.0 %	67 %	51 %
	1-3.5 km	100 %	89 %	59 %	36 %	18 %	7.0 %	2.0 %	1.0 %	0 %
	Total	**100 %**	**89.0 %**	**62.3 %**	**41.2 %**	**24.7 %**	**14.6 %**	**8.9 %**	**6 %**	**4 %**
Sensitive case 25 kHz - 50 km	**0-1km**	100 %	100 %	100 %	99 %	78 %	60 %	45 %	33 %	24%
	1-50 km	26 %	0.2 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %
	Total	**26.0 %**	**0.2 %**	**0 %**	**0 %**	**0 %**	**0 %**	**0 %**	**0 %**	**0 %**
Sensitive case 25 kHz - 3.5 km	**0-1km**	100 %	100 %	100 %	99 %	78. %	60. %	45. %	33. %	24 %
	1-3.5 km	100 %	40 %	13 %	4 %	0 %	0 %	0 %	0 %	0 %
	Total	**100 %**	**45.0 %**	**19.6 %**	**11.8 %**	**6.4 %**	**4.9 %**	**3.7 %**	**2.7 %**	**2 %**

The following table provides the results of simulations for df = 4 MHz and dRSS set equal to -114 dBm / -108 dBm / -102 dBm.

TABLE 21

Interference Probability for dRSS of -114 dBm / -108 dBm / -102 dBm and df = 4 MHz – TEDS 25 kHz Victim Receiver

		dRSS (dBm)		
		-114	**-108**	**-102**
Non-Critical Case 25 kHz - 50 km	**0-1km**	100 %	100 %	100 %
	1-50 km	36.5 %	21 %	11.5 %
	Total	**36.5%**	**21.0%**	**11.5%**
Non-Critical Case 25 kHz - 3.5 km	**0-1km**	100 %	100 %	100 %
	1-3.5 km	100 %	89 %	59 %
	Total	**100%**	**100%**	**100%**
Sensitive Case 25 kHz - 50 km	**0-1km**	100 %	100 %	100 %
	1-50 km	26 %	15 %	8 %
	Total	**26.0%**	**15.0%**	**8.0%**
Sensitive Case 25 kHz - 3.5 km	**0-1km**	100 %	100 %	100 %
	1-3.5 km	100 %	100 %	100 %
	Total	**100%**	**100%**	**100%**

3.1.3.1.1.2 Setting dRSS above the sensitivity level

In this set of simulations instead of using a constant dRSS, a distribution of dRSS is used as shown below.

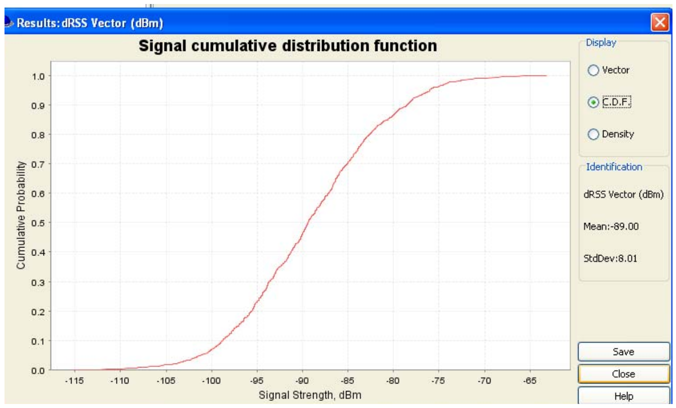


Figure 3: dRSS distribution – Sensitivity of -114 dBm – Urban environment – 25 kHz TEDS receiver[2]

The following table provides the results of simulations for a variable dRSS and for different frequency offset between the Victim Receiver and the interfering transmitter (Wanted Transmitter).

TABLE 22

Interference Probability for a variable dRSS – TEDS 25 kHz Victim Receiver

		df (MHz)							
		4	**5**	**6**	**7**	**8**	**9**	**10**	**11**
25 kHz Non-Critical Case - 50 km	**0-1km**	100 %	75 %	55 %	43 %	32 %	23 %	16 %	10 %
	1-50 km	4 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %
	Total	**4.0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
25 kHz Non-Critical Case - 3.5 km	**0-1km**	100 %	75 %	55 %	43 %	32 %	23 %	16 %	10 %
	1-3.5 km	91 %	6 %	2 %	1 %	0 %	0 %	0 %	0 %
	Total	**91.7%**	**11.6%**	**5.9%**	**4.1%**	**2.6%**	**1.9%**	**1.3%**	**0.8%**
25 kHz Sensitive Case - 50 km	**0-1km**	100 %	44 %	28 %	20 %	14 %	9 %	6 %	3 %
	1-50 km	3 %	0 %	0 %	0 %	0 %	0 %	0 %	0 %
	Total	**2.5%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
25 kHz Sensitive Case - 3.5 km	**0-1km**	100 %	44 %	28 %	20 %	14 %	9 %	6 %	3 %
	1-3.5 km	83 %	0.8 %	0 %	0 %	0 %	0 %	0 %	0 %
	Total	**84.4%**	**4.3%**	**2.3%**	**1.6%**	**1.1%**	**0.7%**	**0.4%**	**0.2%**

Additional simulations were conducted to assess the impact of the sensitivity. This was implemented within SEAMCAT by increasing and translating the dRSS distribution of 6dB and 12 dB to achieve a sensitivity of -108 dBm and -102 dBm respectively (see Annex 4).

[2] Note: It should be verified that the received power is effectively above the sensitivity since for the events where the dRSS is below the sensitivity, SEAMCAT will not include these cases in the calculation of interference.

TABLE 23

Interference Probability for a variable dRSS – different sensitivities - TEDS 25 kHz Victim Receiver

		df (MHz)										
		4	**4.1**	**4.2**	**4.3**	**4.4**	**4.5**	**4.6**	**4.7**	**4.8**	**4.9**	**5**
25 kHz Non Critical Case - 3.5 km - Sensitivity=-114dBm	**0-1km**	100%	99%	88%	87%	85%	84%	83%	82%	78%	77%	75%
	1-3.5 km	91%	52%	15%	13%	12%	11%	10%	9%	8%	7%	6%
	Total	**91.0%**	**55.8%**	**20.9%**	**19.0%**	**17.9%**	**17.0%**	**16.0%**	**15.0%**	**13.7%**	**12.7%**	**11.6%**
25 kHz Sensitive Case - 3.5 km - Sensitivity=-114dBm	**0-1km**	100%	95%	61%	59%	56%	55%	52%	51%	48%	46%	44%
	1-3.5 km	83%	28%	2.4%	2%	2%	2%	1%	1%	1%	1%	0.8%
	Total	**84.4%**	**33.5%**	**7.2%**	**6.6%**	**6.2%**	**6.1%**	**5.5%**	**5.1%**	**4.8%**	**4.5%**	**4.3%**
25 kHz Non Critical Case - 3.5 km - Sensitivity=-102dBm	**0-1km**	100%	88%	55%	50%	49%	48%	46%	45%	43%	40%	39%
	1-3.5 km	57%	15%	2%	1%	1%	1%	0.9%	0.8%	0.6%	0.5%	0.0%
	Total	**60.5%**	**20.5%**	**5.9%**	**5.0%**	**4.9%**	**4.8%**	**4.6%**	**4.4%**	**4.0%**	**3.7%**	**0.0%**
25 kHz Sensitive Case - 3.5 km - Sensitivity=-102dBm	**0-1km**	98%	69%	28%	27%	25%	24%	23%	21%	20%	18%	18%
	1-3.5 km	44%	5%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Total	**48.4%**	**9.8%**	**2.4%**	**2.2%**	**2.0%**	**2.0%**	**1.9%**	**1.7%**	**1.6%**	**1.5%**	**1.4%**

3.1.3.1.2 150 kHz TEDS receiver

Two set of results are presented in this section:

- For simulations assuming a constant dRSS, set equal to the sensitivity level;
- For simulations assuming a variable dRSS above the sensitivity level.

3.1.3.1.2.1 Setting dRSS constant, equal to the sensitivity level

Results are provided for sensitive mask and for the non-sensitive mask.

The following table provides the results of simulations for a dRSS set equal to -106 dBm.

TABLE 24

Interference Probability for a dRSS constant and equal to -106 dBm –TEDS 150 kHz Victim Receiver

		df (MHz)							
		4	**5**	**6**	**7**	**8**	**9**	**10**	**11**
150 kHz Non-Critical Case - 50 km	**0-1km**	100%	100%	100%	100%	100%	100%	84%	65%
	1-50 km	22.0%	1%	0%	0%	0%	0%	0%	0%
	Total	**22.0%**	**1.0%**	**0.3%**	**0.0%**	**0.2%**	**0.0%**	**0.0%**	**0.0%**
150 kHz Non-Critical Case - 3.5 km	**0-1km**	100%	100%	100%	100%	100%	100%	84%	65%
	1-3.5 km	100%	87%	57%	33%	16%	6%	2%	0%
	Total	**100.0%**	**87.6%**	**60.2%**	**38.7%**	**22.8%**	**13.9%**	**8.5%**	**5.3%**
150 kHz Sensitive Case - 50 km	**0-1km**	100%	100%	100%	96%	76%	59%	44%	32%
	1-50 km	14.5%	0.2%	0%	0%	0%	0%	0%	0%
	Total	**14.5%**	**0.2%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**
150 kHz Sensitive Case - 3.5 km	**0-1km**	100%	100%	100%	96%	76%	59%	44%	32%
	1-3.5 km	100%	38%	11%	4%	1%	1%	0%	0%
	Total	**100.0%**	**42.7%**	**18.7%**	**11.3%**	**7.0%**	**5.7%**	**3.6%**	**2.6%**

3.1.3.1.2.2 Variable dRSS above the sensitivity level

In this set of simulations, the same approach as in section 3.1.3.1.1.2 is used. Instead of using a constant dRSS, a distribution of dRSS is used (Gaussian, mean value of -84 dBm, StdDev 7.5dB). Table 2 in Annex 4 provides results of simulations for frequency offset up to 11 MHz for the best case (Urban – 50 km radius) and for the worst case (Urban – 3.5 km radius).

Additional simulations were conducted in order to further investigate the probability of interference for df from 4 to 5 MHz in the worst case situations. In addition, simulations were conducted using a sensitivity of -102 dBm for the non-sensitive case.

TABLE 25

Interference Probability for a variable dRSS – TEDS 150 kHz Victim Receiver

		df (MHz)										
		4	**4.1**	**4.2**	**4.3**	**4.4**	**4.5**	**4.6**	**4.7**	**4.8**	**4.9**	**5**
150 kHz Non-Critical Case (Gaussian - Mean: -84dBm - StdDev 7.5dB)	**0-1km**	100%	99%	92%	92%	91%	89%	88%	87%	85%	84%	82%
	1-3.5 km	88%	44%	19%	18%	16%	15%	13%	12%	11%	9%	9%
	Total	**89.0%**	**48.2%**	**25.4%**	**23.7%**	**21.9%**	**21.0%**	**19.0%**	**17.9%**	**17.0%**	**15.6%**	**14.5%**
150 kHz Sensitive Case (Gaussian - Mean: -84dBm - StdDev 7.5dB)	**0-1km**	100%	92%	68%	66%	64%	62%	60%	57%	56%	53%	51%
	1-3.5 km	77%	18%	3%	3%	2%	2%	2%	1%	1%	1%	1%
	Total	**78.9%**	**23.7%**	**8.3%**	**7.7%**	**7.1%**	**6.9%**	**6.3%**	**5.9%**	**5.5%**	**5.3%**	**5.1%**
150 kHz Non-Critical Case (Gaussian - Mean: -80dBm - StdDev 7dB)	**0-1km**	100%	96%	85%	84%	82%	80%	79%	77%	74%	73%	70%
	1-3.5 km	78%	29%	11%	9%	9%	8%	7%	6%	5%	5%	4%
	Total	**79.4%**	**34.9%**	**16.6%**	**15.5%**	**14.6%**	**13.8%**	**12.6%**	**11.5%**	**10.6%**	**10.5%**	**9.4%**

3.1.3.2 Victim TEDS: first adjacent channel and blocking of the victim TEDS (25 kHz and 150 kHz)

This section provides results of simulations to assess the impact of DVB-T system on TEDS MSs. Two phenomena are considered:

- impact of the DVB-T power falling into the first adjacent channel;
- impact of blocking (i.e. when the DVB-T signal is not “falling within the first adjacent channel”).

Annex 3 provides additional guidance on the way to implement the first adjacent case and the blocking case using SEAMCAT.

TABLE 26

Results for the first adjacent channel

		Rural	Suburban	Urban
25 kHz (dRSS=-114dBm - radius 50 km)	**0-1km**	100%	100%	79%
	1-50 km	0%	0%	0%
	Total	**0%**	**0%**	**0%**
150 kHz (dRSS=-106dBm - radius 50 km)	**0-1km**	100%	100%	100%
	1-50 km	0.25%	0.2%	0%
	Total	**0.3%**	**0.3%**	**0%**
25 kHz (dRSS=-114dBm - radius depending on the environment)	**0-1km**	100%	100%	79%
	1-Radius km	14%	3%	1%
	Total	**14%**	**5.3%**	**7.6%**
150 (dRSS=-106dBm - radius depending on the environment)	**0-1km**	100%	100%	100%
	1-Radius km	46%	16%	14%
	Total	**46%**	**17.3%**	**20.8%**

TABLE 27

Results for the blocking

		Rural	Suburban	Urban
25 kHz Non Critical Case (dRSS=-114dBm - radius 50 km)	**0-1km**	100%	100%	90%
	1-50 km	0%	0%	0%
	Total	**0%**	**0%**	**0%**
25 kHz Non Critical Case (dRSS=-114dBm - radius depending on the environment)	**0-1km**	100%	100%	90%
	1-Radius km	0.6%	5%	3%
	Total	**0.8%**	**7.1%**	**10.2%**

Note: there was no need to conduct the calculations for the other dRSS settings since the results are the same (SEAMCAT checks that the interfering level is above or below -40dBm whatever is the receiving power)

3.1.3.3 Preliminary conclusions for the case of interference to TEDS PMR/PAMR MS

The probability of interference is significant when the TEDS PMR/PAMR MS receivers are located in the vicinity (1 km) of the DVB-T station:

- The unwanted mechanism is causing more difficulties than the adjacent channel rejection/blocking;
- If the sensitive case of DVB-T mask is used, the problem is less significant, see e.g. Table 25.
- A guard band of around 1 MHz and the DVB-T mask for sensitive cases would be needed for a high power DVB-T station.

3.1.4 Scenario SEAMCAT-3: DVB-T transmitter interfering CDMA PAMR MS in 460 – 470 MHz

The methodology to implement the protection ratio in SEAMCAT is described in Annex 2.

The Victim CDMA PAMR system is assumed to operate at 469.375 MHz (i. e. 470 – Receiver Bandwidth / 2). The symbol df is used in this section, for CDMA-1X it is defined as **df (MHz) = Δf – 750 kHz.**

The results given in Table 28 were achieved assuming a PR of -72 dB.

TABLE 28

Interference Probability for CDMA PAMR MS Victim Receiver depending on the simulation radius – Protection Ratio

		Rural	Suburban	Urban
dRSS=-119.5dBm - radius 50 km	**0-1km**	100%	100%	100%
	1-50 km	0%	0%	0%
	Total	**0.4%**	**0.3%**	**0.0%**
dRSS=-119.5dBm – radius depending on the environment	**0-1km**	100%	100%	100%
	1-Radius km	2%	19%	18%
	Total	**2.6%**	**20.4%**	**24.6%**

The results given in Tables 30 and 31 were achieved considering unwanted emissions and the assumptions given in Table 29.

TABLE 29

Additional Assumptions for the unwanted emissions study

K	**1.38 x 10^-23 (J/K)**	**-229 dBJ/K**
T	**300 K**	**25 dBK**
B	**1.5 MHz**	**62 dBHz**
F		**8dB**
N (dBm)		**-104 dBm**
I/N		**-6 dB**

TABLE 30

Results of simulations for the unwanted emissions case

		Rural	Suburban	Urban
Non-Critical Case (dRSS=-119.5dBm - 3.5 km – Urban case)	**0-1km**	100%	100%	100%
	1-50 km	10.0%	10.0%	5.0%
	Total	**10.0%**	**10.0%**	**5.0%**
Non-Critical Case (dRSS=-119.5dBm - radius depending on the environment)	**0-1km**	100%	100%	100%
	1-Radius km	55%	97%	100.0%
	Total	**54.9%**	**97.4%**	**100.0%**
Sensitive Case (dRSS=-119.5dBm - radius 50 km)	**0-1km**	100%	100%	100%
	1-50 km	6%	6.0%	4.5%
	Total	**6.0%**	**6.0%**	**4.5%**
Sensitive Case (dRSS=-119.5dBm - radius depending on the environment)	**0-1km**	100%	100%	100%
	1-Radius km	39.13	92%	98%
	Total	**6.2%**	**91.9%**	**98.2%**

TABLE 31

Results of simulations for the unwanted emissions case for different frequency offsets

		df (MHz)						
		4	**5**	**6**	**7**	**8**	**9**	**10**
Non-Critical Case (dRSS=-119.5dBm - radius depending on the environment)	**0-1km**	100%	100%	100%	100%	88%	69%	53%
	1-3.5 km	98.0%	45.0%	1.4%	0.4%	0%	0%	0%
	Total	**98.2%**	**49.5%**	**9.4%**	**8.5%**	**7.2%**	**5.7%**	**4.3%**
Non-Critical (dRSS=-119.5dBm - radius 50 km)	**0-1km**	100%	100%	100%	100%	88%	69%	53%
	1-50 km	5.0%	0.6%	0%	0%	0%	0%	0%
	Total	**5.0%**	**0.6%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**
Sensitive Case (dRSS=-119.5dBm - radius 50 km)	**0-1km**	100%	100%	81%	62%	47%	35%	24%
	1-50 km	4.5%	0.2%	0%	0%	0%	0%	0%
	Total	**4.5%**	**0.2%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**

Comparison between the effect of the unwanted emissions for 12.5 kHz PMR/PAMR and CDMA PAMR (non-critical case):

1) For PMR/PAMR

In case of 12.5 kHz PMR/PAMR (see section 3.1.2.2) system, we have C=-107 dBm, C/I of 19 dB, this give I=-126 dBm
Interfering power=73dBm
Att at 1 km (Urban)= 115dB
Bandwidth conversion= 33 dB for Bw_{ref_PMR}=4 kHz and 28.24 dB for Bw_{ref_PMR}=12 kHz.

73-115-33 = -75 dBm in 4 kHz or -70 dBm in 12 kHz, i.e., about 55 dB of additional attenuation are needed, which is achieved for an offset of 5-6 MHz, according to the DVB-T masks (section 2.1.22)

2) For CDMA PAMR

C=-104 dBm, I/N of -6 dB, this give I=-110 dBm
Interfering power=73dBm
Att at 1 km (Urban)= 115dB

73-115-33 = -75 dBm in 4 kHz or -54dBm in 1.5 MHz, i.e., about 55 dB of additional attenuation are needed, which is achieved again for an offset of 5-6 MHz , according to the DVB-T masks (section 2.1.2.2)

This means that since the "gap" is the same, then the results in term of interference probability are identical (see Table 18 and Table 31). Then conclusions from 12.5 kHz PMR/PAMR should be also applicable to the case of CDMA PAMR.

3.2 PMR/PAMR as a source of interference

The PMR/PAMR frequency utilization in the 450-470 MHz band is the following:
- 450 to 460 MHz: MS transmit band;
- 460 to 470 MHz: BS transmit band.

A 10 MHz guard band exists between MS transmit band and DVB-T channel 21. Only PMR/PAMR BS will be therefore considered as a source of interference in the following study.

In the following studies, the terminology “frequency separation” is used to define the separation in frequency between the band edges of the PMR/PAMR and the DVB-T systems.

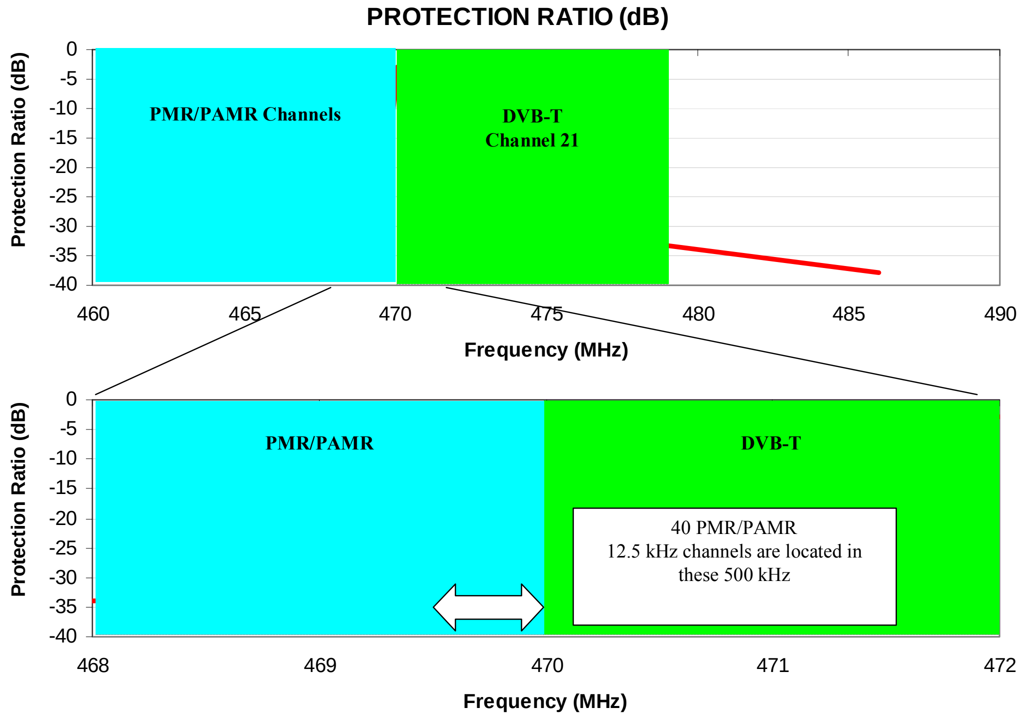


Figure 4: DVB-T receiver selectivity versus PMR/PAMR channels

The figure 4 shows the limited protection provided by selectivity function of a DVB-T channel 21 receiver against the analogue channels of the PMR/PAMR BS transmitters in this frequency range immediately below 470 MHz.

Studies conducted are worst case : a PMR/PAMR BS at the highest channel interfering with DVB-T, both using the same antenna polarization.

3.2.1 Technical approaches

Two different technical approaches are used as SEAMCAT scenarios :

A - single case simulation : one PMR/PAMR BS randomly located within the coverage of a DVB-T transmitter
B - statistical simulation : a density of PMR/PAMR BSs inside the coverage area of a DVB-T transmitter

Simulation scenario A
One DVB-T receiver is positioned at several fixed distances in the coverage area of a DVB-T transmitter. PMR/PAMR BS is randomly placed inside a circle around the receiver to estimate the probability of interference.
Calculation radius is chosen equal to PMR/PAMR cell radius.

Several propagation conditions are tested: Urban, Suburban and Rural.
The DVB-T transmitter power is 73 dBm (20 kW) e.i.r.p.

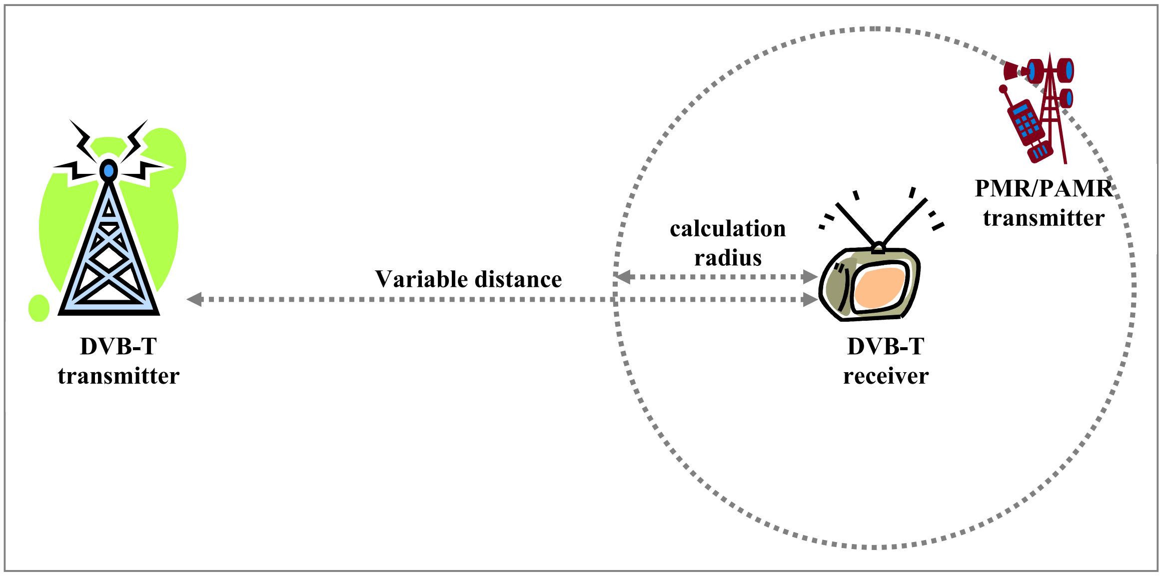


Figure 5: Scenario A

Simulation scenario B

One DVB-T transmitter is transmitting at 73 dBm (20 kW) e.i.r.p. in channel 21. Multiple PMR/PAMR BSs are deployed within the whole DVB-T covered area, using the 5 highest channels, which are the closest to DVB-T channel 21.

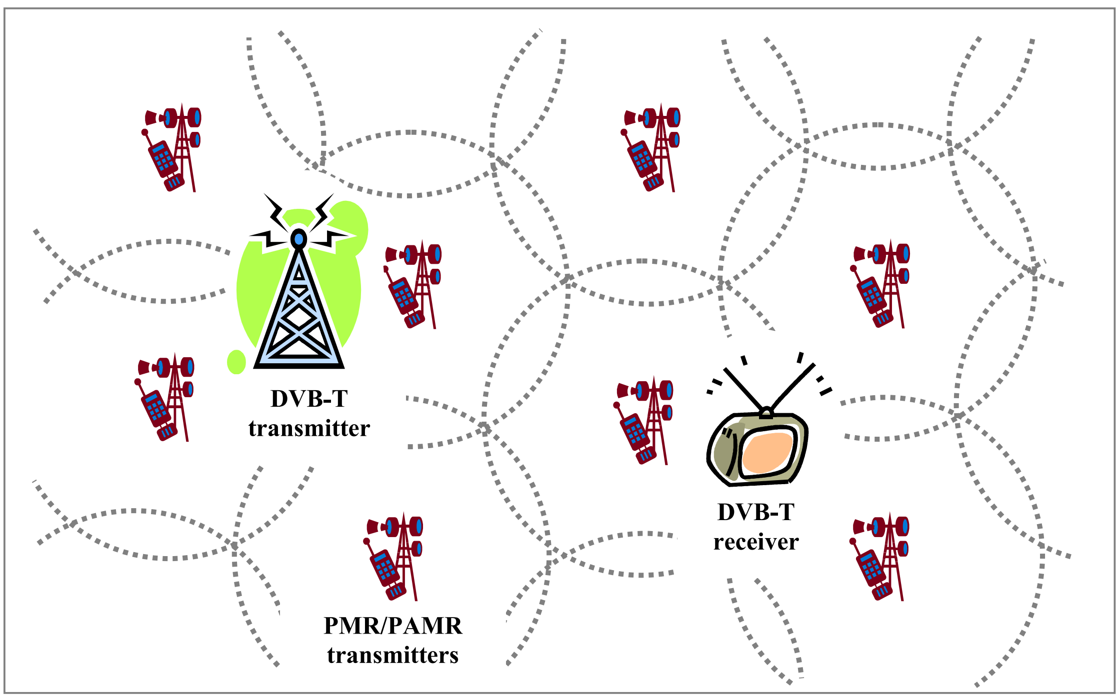


Figure 6: Scenario B

The cell radius are provided in the following table.

TABLE 32

PMR/PARM Cell radius

Area type	Radius (km)
Urban	3.5
Suburban	7
Rural	20

3.2.2 Analogue narrowband FM PMR/PAMR

The following parameters were used in SEAMCAT version 3.1.36.2.
Interference is estimated using Unwanted and Blocking signal type in SEAMCAT.
Variations between scenario A and scenario B are noted.

Victim link (DVB-T)
Frequency = 474 MHz (UHF Channel 21)
Victim Receiver
Reception bandwidth = 7610 kHz
Sensitivity = -79 dBm
C/I = 0 dB (SEAMCAT threshold value)
C/(I+N) = -3 dB

Blocking response is defined as the opposite of protection ratio table provided in Table 2 (co-channel protection ratio DVB-T 8MHz 64QAM 2/3 interfered with by CW or FM).

TABLE 33

Blocking Response – 12.5 kHz case

Δfreq (MHz)	-12	-4.5	-3.9	0	3.9	4.5	12
Blocking (dB)	38	33	3	3	3	33	38

Antenna height = 10 m
Antenna directivity = horizontal pattern given by Recommendation ITU-R BT. 419 [3]
Antenna peak gain = 9.1 dBi (10 dBd + 2.15 isotropic conversion – 2.8 dB cable loss + 10 log(474/500) freq correction)
Relative location for scenario A = fixed, correlated to wanted transmitter, X= variable, Y=0
Relative location for scenario B = Uniform density from 1 to 50 km from transmitter, simulated by the following density in SEAMCAT:

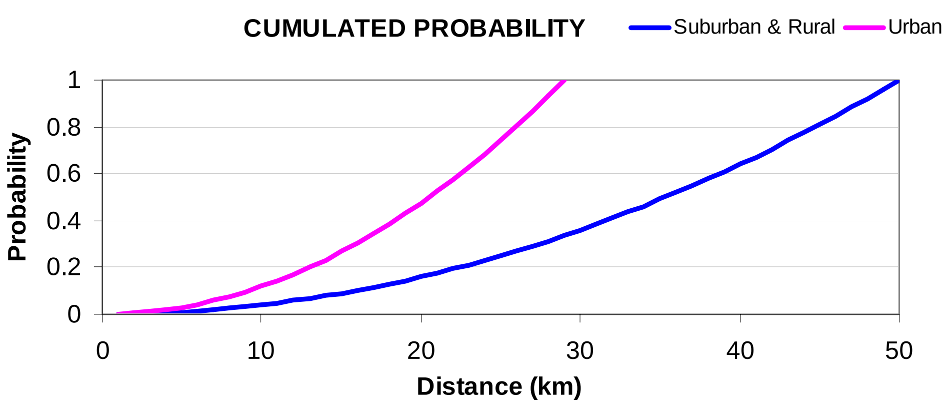


Figure 7: Cumulated density of receivers as a function of distance

Wanted transmitter
Power = 73 dBm
Antenna height = 100 m
Antenna peak gain = 0 dB
Propagation model = Recommendation ITU-R P.1546 [13], Urban, Suburban and Rural

The minimum field strength for fixed reception and 64 QAM 2/3, is around 41.3 dB(µV/m), see section 2.1.2.1.1.
P received (dBm) = Emin (dBµV/m) – 20 x log (f) + Antenna Gain – Cable Loss -77.2= 41.3 – 130.7 + 9.1 = -80.3 dBm

The simulations have been prepared for a sensitivity of – 79 dBm. Using a sensitivity of -80.3 dBm increases only slightly the interference probability at low dRSS.

Interfering link (PMR/PAMR)
Interfering transmitter
Frequency for scenario A = 469.99375 MHz (highest 12.5 kHz channel)
Frequencies for scenario B = 469.99375 MHz, 469.98125 MHz, 469.96875 MHz, 469.95625 MHz, 469.94375 MHz (5 highest 12.5 kHz channels)
Power = 44 dBm
Antenna height = 30 m
Antenna peak gain = 7 dBi (9 dBi – 2 dB cable loss)
Unwanted emission mask = from chapter 2 (Table 6)
Coverage radius = cell radius (Table 32)
Propagation model = Extended Hata, outdoor mode, Urban, Suburban and Rural environments
Relative location for scenario A = uniform distribution around victim receiver. Calculation area size is the same as the PMR/PAMR cell radius.
Relative location for scenario B = Density of transmitters

TABLE 34

Assumptions for the simulations

	Urban	Suburban	Rural	Notes
Cell radius	**3.5 km**	**7 km**	**20 km**	
Density of transmitters	0.026 / km^2	0.0065 / km^2	0.0008 / km^2	1 transmitter per cell
Coverage radius	28.5 km	50 km	50 km	DVB-T transmitter
Number of transmitters	66	51	6	Number of PMR/PAMR cells inside DVB-T coverage

Wanted receiver
Default SEAMCAT scenario values.

Interference calculation is made using Unwanted + Blocking signal type.
Interference criterion is C/I.

Simulation results

Scenario A : probability of interference as a function of DVB-T transmitter-receiver distance, when the receiver is inside a PMR/PAMR cell.

TABLE 35

Results of simulations – Scenario A – 12.5 kHz

	PMR/PAMR cell type and radius					
	Urban - 3.5 km		**Suburban - 7 km**		**Rural 20 km**	
DVB-T Tx/Rx Distance (km)	Mean dRSS (dBm)	Interference probability (%)	Mean dRSS (dBm)	Interference probability (%)	Mean dRSS (dBm)	Interference probability (%)
10	-58.8	16.6	-41.4	1.8	-41.2	1.5
15	-65.8	29.6	-48.4	4.2	-48.4	4.3
20	-71.3	42.0	-54.1	8.1	-54.1	8.8
25	-76.1	50.7	-58.7	13.3	-58.8	15.7
30	-80.2 (*)	55.5	-62.8	19.5	-62.8	22.4
35			-66.6	26.0	-66.6	29.7
40			-69.8	32.6	-69.9	36.9
45			-72.9	37.5	-73.0	43.5
50			-75.8	43.2	-75.8	47.9
55			-78.4 (*)	46.9	-78.4 (*)	51.8

(*) Sensitivity limit

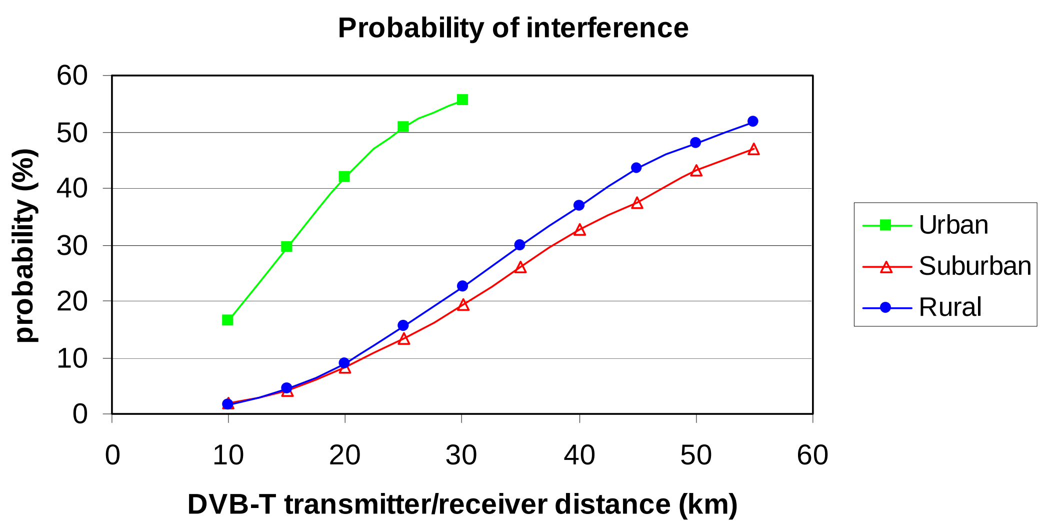


Figure 8: DVB-T receiver interfered by analogue narrowband FM PMR/PAMR BS

Scenario B : Overall probability of interference when the 5 highest PMR/PAMR channels are used in the whole DVB-T coverage area.

TABLE 36

Probability of interference (%) – Scenario B – 12.5 kHz

	PMR/PAMR cell type and radius		
Frequency separation (kHz)	**Urban - 3.5 km**	**Suburban - 7 km**	**Rural - 20 km**
0	73.0	60.2	64.1
100	58.9	43.3	51.2
200	39.6	28.9	35.9
300	21.2	14.7	21.1
400	7.9	5.9	10.7
500	3.0	3.0	6.1

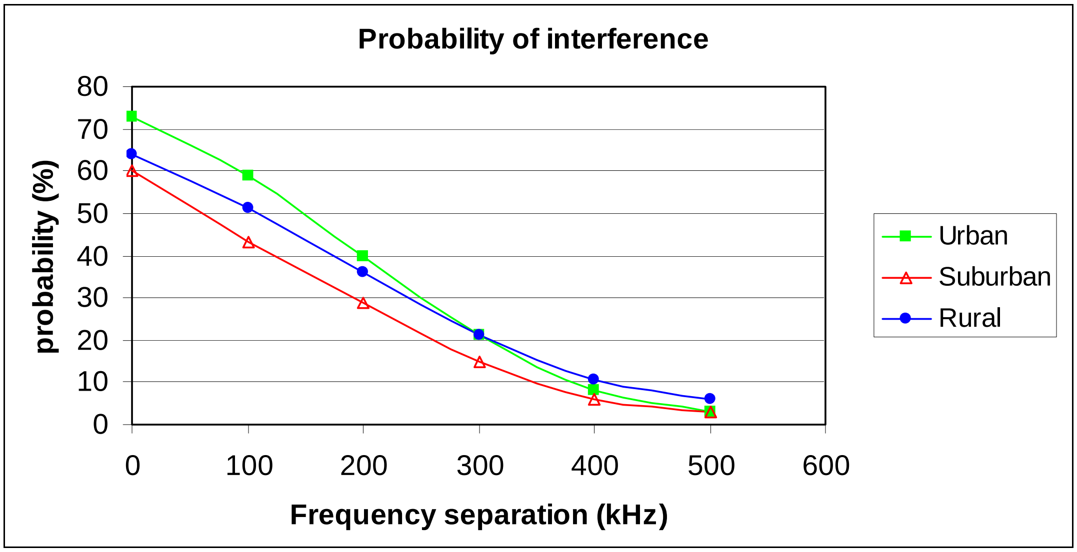


Figure 9: DVB-T receiver interfered by analogue narrowband FM PMR/PAMR BS

3.2.3 TEDS 25 kHz

This simulation considers TEDS (TETRA) transmitter as a continuous CW or FM modulated, instead of real DQPSK or QAM/TDMA transmission.

Victim link
The same assumptions as in section 3.2.2 are used.

Interfering link
Interfering transmitter
Frequency for scenario A = 469.9875 MHz (highest 25 kHz channel)
Frequencies for scenario B = 469.9875 MHz, 469.9625 MHz, 469.9375 MHz, 469.9125 MHz, 469.8875 MHz (5 highest 25 kHz channels)
Power = 46 dBm (power class 1) without power control
Antenna height = 30 m
Antenna peak gain = 7 dB
Unwanted emission mask = from chapter 2 (Tables 8 and 9)
Coverage radius = cell radius
Propagation model = Extended Hata, outdoor mode, Urban, Suburban and Rural environments
Relative location for scenario A = uniform distribution around victim receiver. Calculation area size is the same as the PMR/PAMR cell radius.
Relative location for scenario B = Density of transmitters

The same assumptions as in section 3.2.2 are used for the repartition of interfering transmitters (see Table 34).

Wanted receiver
Default SEAMCAT scenario values.

Simulation results
Scenario A : probability of interference as a function of DVB-T transmitter-receiver distance, when the receiver is inside a PMR/PAMR cell.

TABLE 37

Results of simulations – Scenario A – 25 kHz

	PMR/PAMR cell type and radius					
	Urban - 3.5 km		**Suburban - 7 km**		**Rural - 20 km**	
DVB-T Tx/Rx Distance (km)	Mean dRSS (dBm)	Interference probability (%)	Mean dRSS (dBm)	Interference probability (%)	Mean dRSS (dBm)	Interference probability (%)
10	-58.8	19.3	-41.4	2.0	-41.3	2.1
15	-65.7	33.5	-48.3	4.9	-48.4	5.5
20	-71.4	47.0	-54	9.6	-54.0	10.8
25	-76.1	54.6	-58.8	15.8	-58.7	17.9
30	-80.1 (*)	61.1	-62.9	22.7	-62.9	26.2
35			-66.6	30.2	-66.6	34.5
40			-69.9	38.0	-69.9	41.9
45			-72.9	43.5	-72.9	48.9
50			-75.8	48.5	-75.8	53.4
55			-78.4 (*)	50.6	-78.4 (*)	57.1

(*) Sensitivity limit

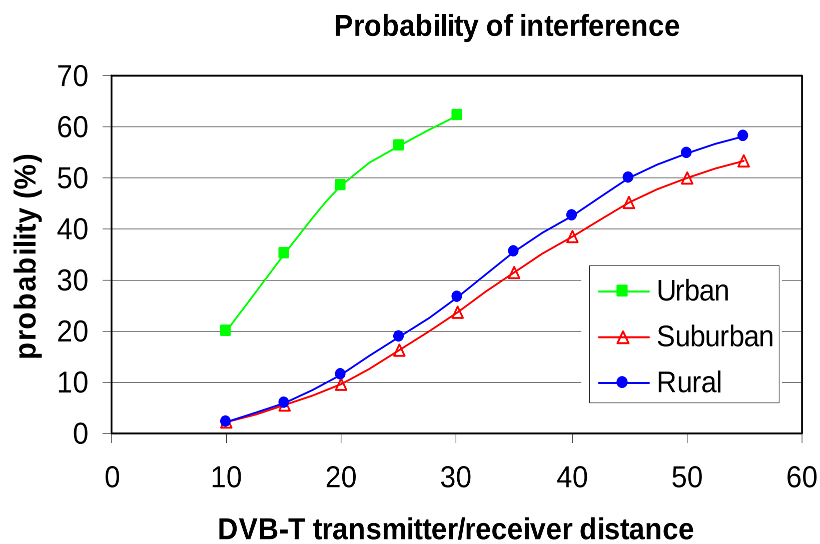


Figure 10: DVB-T receiver interfered by TEDS 25 kHz BS

Scenario B : Overall probability of interference when the 5 highest PMR/PAMR channels are used in the whole DVB-T coverage area.

TABLE 38

Probability of interference (%) – Scenario B – 25 kHz

	PMR/PAMR cell type and radius		
Frequency separation (kHz)	**Urban - 3.5 km**	**Suburban - 7 km**	**Rural - 20 km**
0	81.7	68.1	72.0
100	69.0	52.5	58.5
200	51.2	34.8	41.9
300	27.5	17.2	25.7
400	10.7	7.6	13.3
500	6.8	4.6	9.5

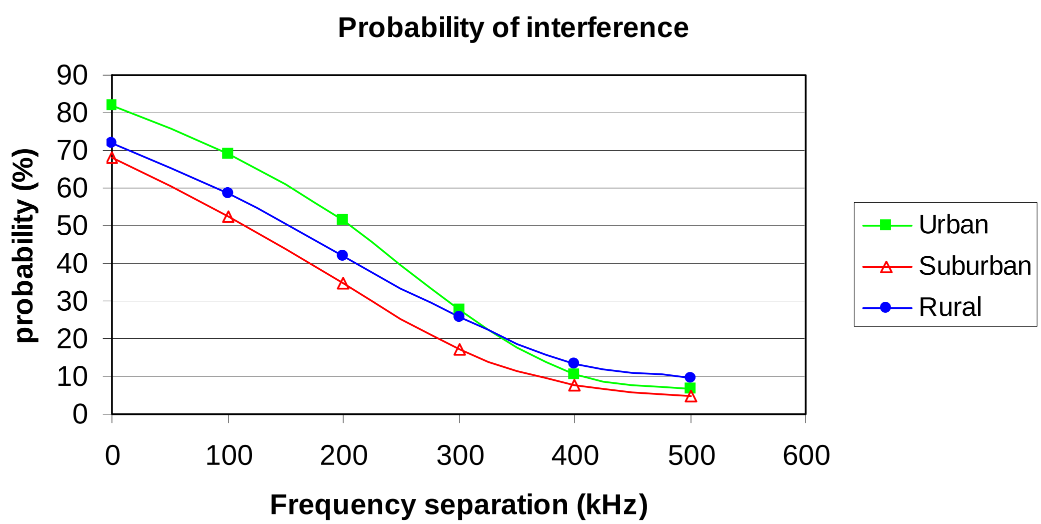


Figure 11: DVB-T receiver interfered by TEDS 25 kHz BS

3.2.4 TEDS 150 kHz

Victim link
The same assumptions as in section 3.2.2 are used.

Interfering link
<u>Interferibng transmitter</u>
Frequency for scenario A = 469.925 MHz (highest 150 kHz channel)
Frequencies for scenario B = 469.925 MHz, 469.775, 469.625, 469.475, 469.325 MHz (5 highest 150 kHz channels)
Power = 46 dBm (power class 1) without power control
Antenna height = 30 m
Antenna peak gain = 7 dB
Unwanted emission mask = from chapter 2 (Tables 10 and 11)

Coverage radius = cell radius
Propagation model = Extended Hata, outdoor mode, Urban, Suburban and Rural environments.
Relative location for scenario A = uniform distribution around victim receiver. Calculation area size is the same as the PMR/PAMR cell radius.
Relative location for scenario B = Density of transmitters.

The same assumptions as in section 3.2.2 are used for the repartition of interfering transmitters (see Table 34).

The same assumptions as in section 3.2.2 are used for the repartition of interfering transmitters.

Wanted receiver
Default SEAMCAT scenario values.

Simulation results

Scenario A : probability of interference as a function of DVB-T transmitter-receiver distance, when the receiver is inside a PMR/PAMR cell.

TABLE 39

Results of the simulations – Scenario A – 150 kHz

	PMR/PAMR cell type and radius					
	Urban - 3.5 km		**Suburban - 7 km**		**Rural - 20 km**	
DVB-T Tx/Rx Distance (km)	Mean dRSS (dBm)	Interference probability (%)	Mean dRSS (dBm)	Interference probability (%)	Mean dRSS (dBm)	Interference probability (%)
10	-58.8	13.9	-41.4	1.3	-41.3	1.3
15	-65.7	26.5	-48.3	3.6	-48.4	3.7
20	-71.4	38.5	-54	7.0	-54.1	7.1
25	-76.1	45.5	-58.8	11.4	-58.8	12.5
30	-80.1(*)	50.9	-62.9	17.2	-62.9	19.0
35			-66.6	23.7	-66.6	26.1
40			-69.9	30.0	-69.9	34.0
45			-72.9	35.4	-72.9	39.8
50			-75.8	39.3	-75.8	43.6
55			-78.4 (*)	42.3	-78.5 (*)	46.4

(*) Sensitivity limit

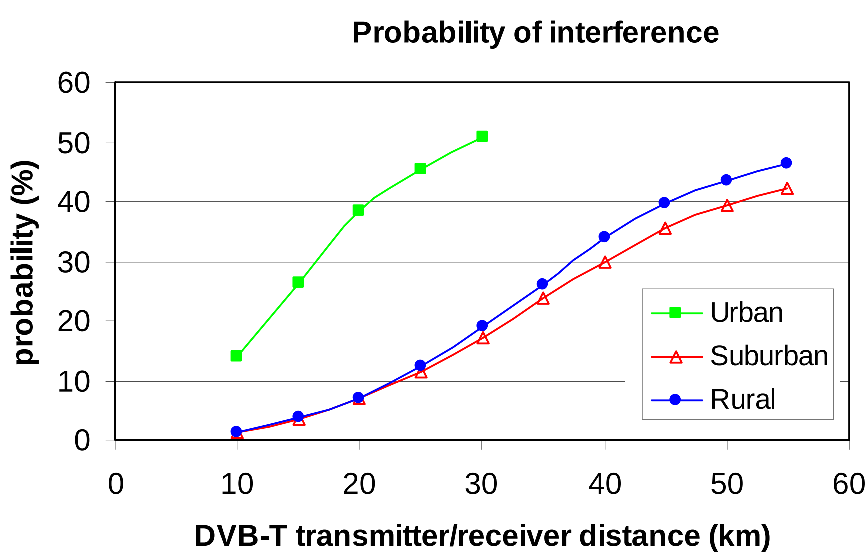


Figure 12: DVB-T receiver interfered by TEDS 150 kHz BS

Scenario B : Overall probability of interference when the 5 highest PMR/PAMR channels are used in the whole DVB-T coverage area.

TABLE 40

Probability of interference (%) – Scenario B – 150 kHz

	PMR/PAMR cell type and radius		
Frequency separation (kHz)	**Urban - 3.5 km**	**Suburban - 7 km**	**Rural - 20 km**
0	55.3	37.4	42.1
100	34.6	21.5	28.2
200	17.8	12.1	18.6
300	9.9	7.4	12.2
400	6.6	5.1	10.1
500	6.7	4.6	9.8

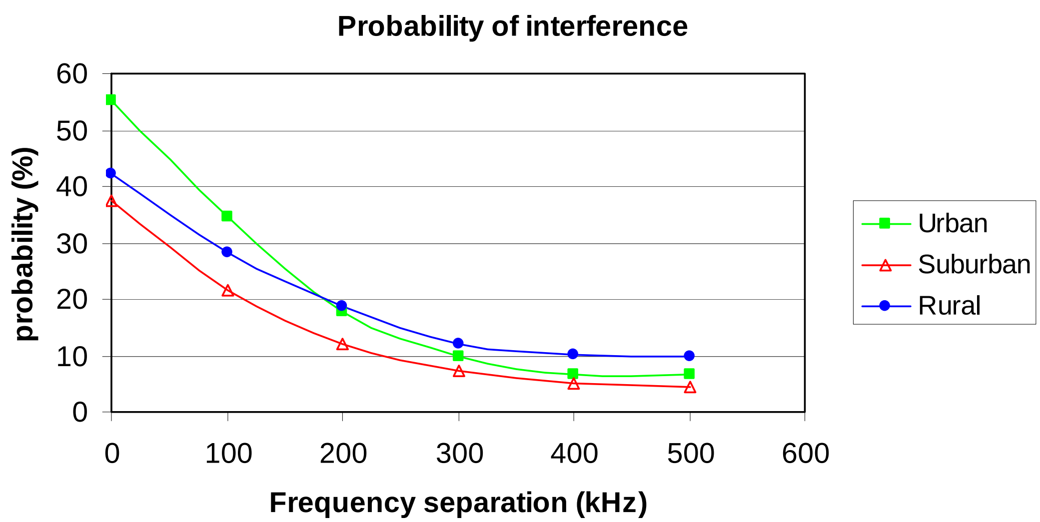


Figure 13: DVB-T receiver interfered by TEDS 150 kHz BS

3.2.5 CDMA-1X PAMR BS transmitter interfering DVB-T

The following parameters were used in SEAMCAT version 3.1.36
Interference is estimated using Unwanted and Blocking signal type in SEAMCAT.

Victim link (DVB-T)
The same assumptions as in section 3.2.2 are used.

Blocking response is defined as the opposite of the protection ratio table provided in Table 3 (Protection ratios for DVB-T 8 MHz 64-QAM code rate 2/3 signal interfered with by emissions of CDMA-1X)

TABLE 41

Blocking Response

Δfreq (MHz)	–12	–4.5	–3.75	0	3.75	4.5	12
Blocking (dB)	38	20	3	-10	3	20	38

Antenna height = 10 m
Antenna directivity = horizontal pattern given by Recommendation ITU-R BT.419.
Antenna peak gain = 9.1 dBi (10 dBd + 2.15 isotropic conversion – 2.8 dB cable loss + 10 log(474/500) freq correction).

Relative location for scenario A = fixed, correlated to wanted transmitter, X= variable, Y=0.
Relative location for scenario B = Uniform density from 1 to 50 km from transmitter.

Interfering link (PMR/PAMR)
Interfering transmitter
Frequency for scenario A = 469.375 MHz (Channel 400 - highest channel centre frequency)
Frequencies for scenario B = 469.375 MHz,
MHz, 468.125 MHz, 466.875 MHz, 465.625 MHz, 464.375 MHz (5 highest 1.25 MHz channels)
Note that CDMA-1X channel bandwidth is 1.25 MHz
Power = 44 dBm
Antenna height = 30 m
Antenna peak gain = 7 dBi (9 dBi – 2 dB cable loss)
Unwanted emission mask = from chapter 2 (Table 12)
Coverage radius = typical cell radius
Propagation model = Extended Hata, outdoor mode, Urban, Suburban and Rural environments.
Scenario A : Relative location = uniform distribution around victim receiver. Calculation area size is the same as the PMR/PAMR cell radius.
Scenario B : Relative location = Density of transmitters

The same assumptions as in section 3.2.2 are used for the repartition of interfering transmitters.

Wanted receiver
Default SEAMCAT scenario values.

Interference calculation is made using Unwanted + Blocking signal type.
Interference criterion is C/I.

Simulation results
Scenario A : probability of interference as a function of DVB-T transmitter-receiver distance, when the receiver is inside a PMR/PAMR cell.

TABLE 42

Results of the simulations – Scenario A – CDMA-1X

	PMR/PAMR cell type and radius					
	Urban - 3.5 km		Suburban - 7 km		**Rural - 20 km**	
DVB-T Tx/Rx Distance (km)	Mean dRSS (dBm)	Interference probability (%)	Mean dRSS (dBm)	Interference probability (%)	Mean dRSS (dBm)	Interference probability (%)
10	-58.8	20.4	-41.4	2.6	-41.3	2.3
15	-65.7	36.0	-48.4	5.5	-48.4	6.0
20	-71.3	49.3	-54.1	10.8	-54.1	11.7
25	-76.1	57.9	-58.7	16.8	-58.8	18.9
30	-80.2 (*)	63.4	-62.9	24.6	-62.8	27.4
35			-66.6	32.7	-66.6	35.8
40			-69.9	40.0	-69.9	43.7
45			-72.9	45.8	-73.0	50.6
50			-75.8	50.9	-75.8	55.9
55			-78.4 (*)	54.4	-78.4 (*)	59.4

(*) Sensitivity limit

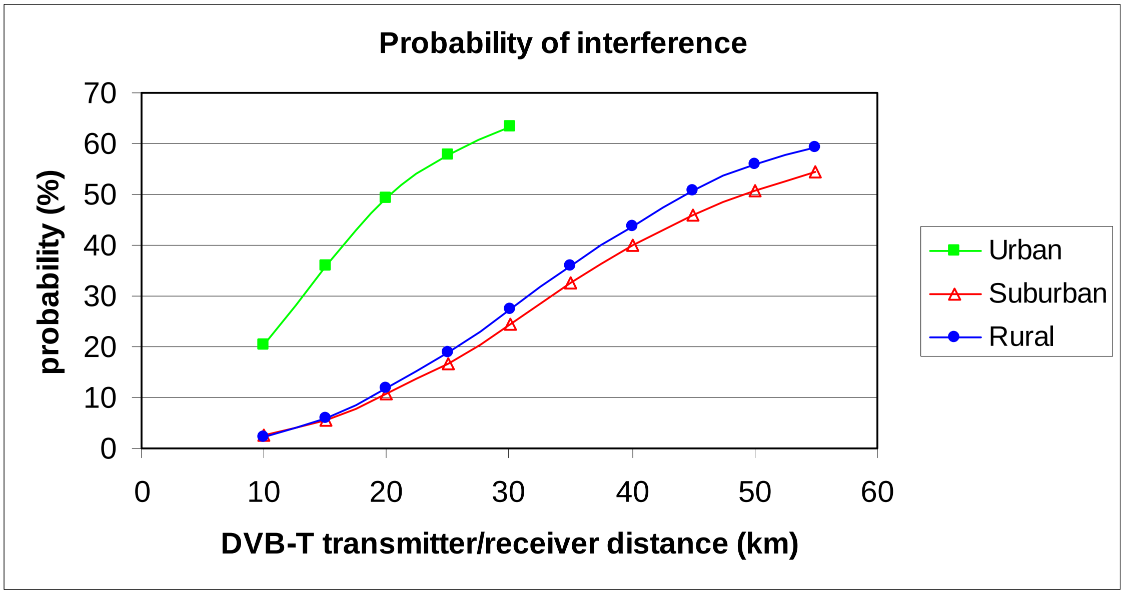


Figure 14: DVB-T receiver interfered by CDMA-1X BS

Scenario B : Overall probability of interference when the 5 highest PMR/PAMR channels are used in the whole DVB-T coverage area.

TABLE 43

Probability of interference (%) – Scenario B – CDMA-1X

	CDMA PAMR cell type and radius		
Frequency separation (kHz)	**Urban - 3.5 km**	**Suburban - 7 km**	**Rural - 20 km**
0	23.3	14.3	21.7
1000	14.7	9.7	16.4
2000	8.5	6.3	11.5
3000	5.5	4.1	8.0
4000	3.1	2.7	5.5
5000	1.8	1.8	4.1

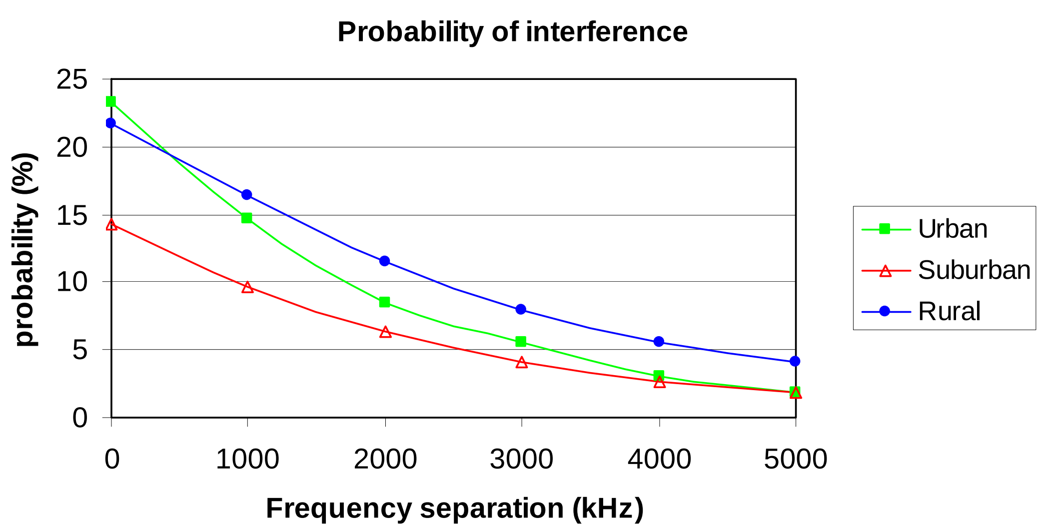


Figure 15: DVB-T receiver interfered by CDMA-1X BS

4 PRACTICAL MEASUREMENTS

Two actual measurements have been undertaken. Details of field measurements to assess the impact of DVB-T transmissions on PMR/PAMR are provided in this section. Measurements to determine the protection ratios required by an analogue PMR/PAMR receiver operating in VHF Band III in the presence of an unwanted DVB-T signal and vice versa are described in Annex 6.

4.1 Introduction

PMR/PAMR BS use transmitting frequencies up to 469.975 MHz, and one administration investigated to what extent receivers in the corresponding portable units could be affected, depending on both the geographical distance and frequency separation to the DVB-T transmitter.

It should be emphasized that this was a field test, with less control of all input signals and a bit more uncertainty than measurements made in a laboratory. The quality of the receiver may introduce some further uncertainty to the results.

4.2 Test Method

A common problem with a narrowband receiver exposed to a wideband signal is a reduction in receiver sensitivity. The reduction is dependent of the signal strength of the unwanted signal, and the frequency separation between the centre frequencies of the wanted and the unwanted signals, Δf.

Instead of doing this in a laboratory, it was decided to do a field test of how a DVB-T signal would influence a narrowband PMR/PAMR receiver. The main principle of the test was to find out how much the wanted signal had to be increased to overcome the reduction in sensitivity.

A local DVB-T transmitter was used as the unwanted signal source, and the wanted signal was generated with an HP signal generator. The test equipment was installed in a mobile test van, with a roof mounted antenna for reception of the DVB-T signal. The signal from the antenna passed through a tuneable band-pass filter before being combined with the wanted signal from the generator. The combiner represents a loss of 6 dB.

The DVB-T signal was measured with a spectrum analyser, to ensure that it was in accordance with the spectrum mask in ITU-R SM.1541 [14]. For the high power DVB-T transmitters, this mask is more relaxed than the Chester masks.

At the time of the test, channels 33 and 49 were in operation at the test location, and they were used as the unwanted signal source.

The receiver used in the test was an ICOM IC-R3, tuneable over a wider range than usual for PMR/PAMR equipment. This receiver was chosen because no commercial PMR/PAMR equipment was available at the test frequencies.

The squelch was adjusted to -113 dBm, a typical value for PMR. Because of the loss in the combiner, the receiver would open at an output level of -107 dBm from the signal generator.

Without any interference, the receiver would open at an input of -113 dBm (-107 dBm). The signal generator, the band-pass filter and the receiver were tuned simultaneously over a range of frequencies close to the frequency of the unwanted signal, while recording the input level from the signal generator. Getting closer to the unwanted signal, the input level of the wanted signal had to be increased. Several measurements were made, with a Δf ranging from 2.6 to 15.5 MHz relative to the DVB-T centre frequency. The measurements set-up is shown in Figure 16 and measurements results are listed in Table 44.

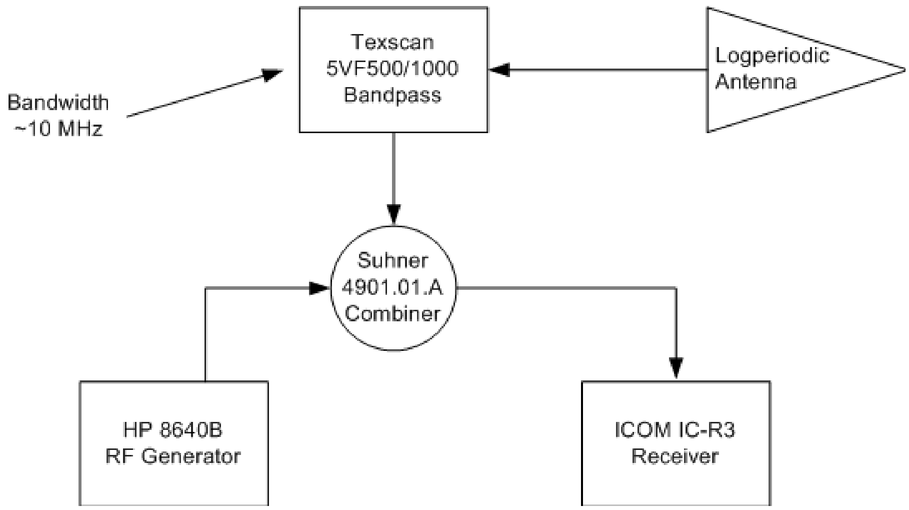


Figure 16: Measurement setup

4.3 Test Points

The two test points were chosen with different distances to the transmitters, at 4 km and 8 km. For practical reasons, the test points were in different directions from the transmitter. Both were in line-of-sight to the DVB-T transmitter.

4.4 Analysis of results

If the interfering signal from the DVB-T at the PMR/PAMR receiver exceeds – 40 dBm (89 dBµV/meter) it will cause problems for PMR/PAMR users in the band 469 – 470 MHz.

If the interfering DVB-T signal exceeds – 32 dBm (97 dBµV/meter), there would be problems in almost the entire band from 460 – 470 MHz.

At the test points, the following values were recorded for the DVB-T signal:

Test point 1:	Horizontal antenna:	Channel 33	-21 dBm (108 dBµV/m)
		Channel 49	-20 dBm (109 dBµV/m)
	Vertical antenna:	Channel 33	-37 dBm (92 dBµV/m)
		Channel 49	-35 dBm (94 dBµV/m)
Test point 2:	Horizontal antenna:	Channel 33	-26 dBm (103 dBµV/m)
		Channel 49	-33 dBm (96 dBµV/m)
	Vertical antenna:	Channel 33	-42 dBm (87 dBµV/m)
		Channel 49	-43 dBm (86 dBµV/m)

Please note that the values are the actual input level at the receiver. In the test configuration, the signal level would drop 6 dB because of the loss in the combiner. The level was measured at the centre frequency of each channel.

For reference and use in later calculations, the field strength at the test points was calculated on the basis of the specifications of the antenna, cables and levels measured. Level measurements were made with an HP 8593A Spectrum analyser. Settings: 5 MHz res BW and max hold.

TABLE 44

Results of Measurements

Channel 33	Required increase of input signal of analogue PMR/PAMR signal			
Δf MHz	DVB-T= -27 dBm	DVB-T= -32 dBm	DVB-T= -43 dBm	/DVB-T= -48 dBm
15.5		1		
15		1		
14.5		3		
14		4		
13.5		5		
13		5		
12.5		5		
12		6		
11.5		6		
11		7		
10.5		7		
10	21	8		
9.5	21	11		
9	20	13		
8.5	22	15		
8	22	17		
7.5	24	19	1	
7	25	19	1	
6.5	28	21	1	
6	28	22	1	
5.5	28	21	1	
5	29	22	1	
4.8	31	23	1	1
4.6	32	22	1	1
4.4	31	23	1	1
4.2	32	24	1	1
4	33	23	0	1
3.9	31	23	2	2
3.8	46	41	35	26
3.7	46	41	35	27
3.5	46	43	36	27
3.3	46	43	36	27
3.1	46	43	36	27
2.8	46	43	36	27
2.6	46	43	36	27

Channel 49	Required increase of input signal of analogue PMR/PAMR signal			
Δf MHz	DVB-T= -26 dBm	DVB-T= -39 dBm	DVB-T= -41 dBm	DVB-T= -49 dBm
13	14			
12.5	15			
12	15			
11.5	15			
11	15			
10.5	15			
10	16			
9.5	16			
9	16		1	
8.5	19		0	
8	21	0	1	1
7.5	22	0	1	1
7	24	0	1	1
6.5	25	0	1	0
6	24	0	0	0
5.5	27	0	0	0
5	28	3	0	0
4.5	29	3	2	0
4	32	6	3	0
3.9	32	6	4	0
3.8	45	34	32	29
3.7	42	34	31	32
3.6	44	36	33	32
3.4	44	36	33	32
3.2	44	36	33	32
3	44	36	33	32
2.8	44	36	33	32
2.6	44	36	33	32

Table 44 provides Recorded values for how much the input signal of the analogue PMR/PAMR had to be increased at various input levels of the DVB-T signal. Values in red are inside the DVB-T channel.

4.5 Conclusions on the measurements results

The measurements showed that analogue PMR/PAMR equipment just below 470 MHz could be heavily influenced by DVB-T transmitters in channel 21. This is because the analogue receiver interprets the digital signal as white noise, which in the next step influences the squelch detector.

To what extent this is a problem, depends on both the field strength and the Δf to the DVB-T transmitter:

- For signal levels from the DVB-T below -50dBm (79 dBμV/meter), it will be possible to use channel 21 and PMR/PAMR frequencies up to 470 MHz;
- At approximately -40 dBm (89 dBμV/meter), the frequency range 469 – 470 MHz will be affected if channel 21 is used;
- At approximately -32 dBm (97 dBμV/meter), the whole frequency range 460 – 470 MHz will be affected if channel 21 is used and effectively sterilising the 450 to 470 band for PMR/PAMR;

For further studies, it may be desirable to calculate the geographical area affected by a DVB-T transmitter. However, the recorded values (-26 to -43 dBm) at test point 2, which was 8 km from the DVB-T transmitter, show that this may be a problem in quite large areas. It should also be noted that the users of the PMR/PAMR equipment have no indication of the reduced sensitivity, hence they might be not aware of the presence of interference.

5 COMPARISON OF PRACTICAL MEASUREMENTS WITH THE RESULTS OF CALCULATIONS AND SIMULATIONS

It can be seen from the results of the field measurements, that at a field strength lower than 89 dBµV/meter, the frequency range 469 - 470 will not be affected, see section 4.5. This field strength corresponds to a distance of around 28 km using free space path loss for a 20 kW transmitter. Converting this to the case of a 100 W transmitter, this corresponds to a distance of around 2 km.

A comparison with Table 16 shows that the measurement results agree quite well with the results of simulations:

- In the case of 20 kW non-critical case the interference distance is in the order of 28 km, corresponding to 31 % of 50 km radius.
- In the case of 100 W non-critical case the interference distance is in the order of 2 km, corresponding to 2 % of 50 km radius.

A further comparison can be done with the results produced by MCL method, as described below.

Considering:

- the sensitivity of - 113dBm;
- the protection ratio of -72.4 dB given in table A5.4 (see Annex 5) for a 4 MHz offset;
- and an antenna gain of 0 dBi for a handheld receiver,

the power at the victim should not exceed:
-113 dBm + 0 + 72.4 = - 40.6 dBm = -70.6 dBW

This is equivalent to a field strength of (see Recommendation ITU-R P.525 [12]):

$E = P_r + 20 \log f_{\text{GHz}} + 167.2$ = -70.2 dBW + 20 log f_{GHz} + 167.2 = 90 dB(µV/m)),
where :

P_r: isotropically received power (dB(W))
E: electric field strength (dB(µV/m))
f: frequency (GHz)

Using the equations given in Recommendation ITU-R P.525, it is found that:

$E = P_t - 20 \log d + 74.8$
where:

d: distance (km).
P_t: isotropically transmitted power (dB(W))
E: electric field strength (dB(µV/m))

For DVB-T at 20 kW, this gives: - 20 log d = 90 – 74.8 – 43 = -28 dB and d equals 25 km.

Accordingly, the value of 90 dBµV/m results for a DVB-T TX of e.i.r.p. of 20 kW at 25 km.

The protection ratio from Table A5.4 is for a sensitivity of – 107 dBm. The protection ratio for a sensitivity of – 113 dBm would be larger, and resulting in a shorter distance (10 – 15 km).

From Table 48, it can be seen that for a Δf of 4 MHz (i.e. f=470 MHz), the interference starts to appear at around 40…– 45 dBm (column 3 for both channels 33 and 49). This was measured at the test points with a distance of 4 and 8 km from a 50 kW (erp) transmitter. These levels were measured after the combiner, which have an attenuation of 6 dB. The calculations elsewhere in this report used a 20 kW transmitter, a difference of 4 dB. As the MCL method is a Worst Case approach, compared with the measurements and all the uncertainties of a filed test, the distance where we can expect interference for a mobile PMR/PAMR transceiver at 470 MHz, is around 5 – 10 km from a 20 kW transmitter.

6 CONCLUSIONS

An adjacent band compatibility study has been carried out between PMR/PAMR systems operating at the top end of the 450 – 470 MHz band and DVB-T operating on channel 21. The study indicates a significant probability of interference in both directions:

- PMR/PAMR MS interfered with by DVB-T: the probability of interference is significant when the PMR/PAMR MS are located in the vicinity (around 1 km) of a high-power DVB-T transmitter even if the DVB-T mask for sensitive cases is used. The problem increases when victim MS is at the edge of the PMR/PAMR BS service area.
- For DVB-T receiving stations interfered with by PMR/PAMR BS: The probability of interference is significant when the DVB-T receivers are close to the PMR/PAMR BS and it becomes worse if the victim DVB-T receiver is close to the edge of the DVB-T coverage area.

Possible mitigation measures

In order to improve compatibility, the following mitigation measures should be considered:

- DVB-T masks
To minimize the impact of DVB-T transmissions on PMR/PAMR receivers in the adjacent band, the DVB-T masks have to be chosen carefully. In GE06 two DVB-T masks are provided, one for sensitive cases and one for non-critical cases. Therefore, the best option to improve compatibility with services in the adjacent band is for DVB-T to use the sensitive case mask.

- Co-Siting of the DVB-T transmitter and PMR/PAMR BS
The alignment of the attenuations between the two signals allows for minimal interference. However it is highly recommended to consider applying this measure on a case-by-case basis.

- Guard band
A guard band of around 1 MHz would be needed to protect PMR/PAMR receivers from a high power DVB-T transmitters, assuming that the DVB-T mask for sensitive cases is used.
For the protection of DVB-T receivers from narrowband FM/TEDS PMR/PAMR transmissions a guard band of around 1 MHz would be needed. For the protection of DVB-T from CDMA-1X PAMR transmissions a guard band of at least 2 MHz would be needed.

- Directivity discrimination combined with sectorized PMR/PAMR BSs
Directivity discrimination can be used together with sectorized PMR/PAMR BS to reduce the interference potential of PMR/PAMR BS on DVB-T fixed reception. Further study on the effect of this is required.

- Cross-polarization discrimination
If possible, polarization discrimination can be used to reduce the impact of PMR/PAMR transmissions on DVB-T fixed reception.

- Configuration of DVB-T network
If possible, in order to protect the DVB-T fixed reception, either the use of a more robust DVB-T system variant (e.g. lower order modulation type) while assuming the same DVB-T transmitted power and accepting a lower data capacity, or increasing the power of the DVB-T transmitter (to increase the wanted field strength) within the GE06 constrains, could minimize the effects of the interferences.

ANNEX 1: PROPAGATION MODEL FOR SEAMCAT SIMULATIONS ON THE IMPACT OF DVB-T ON PMR/PAMR AT 470 MHZ

A1.1 Introduction

In order to assess the impact of DVB-T on PMR/PAMR systems, it is proposed to use a propagation model based on Recommendation ITU-R P.1546 [13], as implemented within SEAMCAT version 3.

It has to be noted that the propagation model defined in Recommendation ITU-R P.1546 is not defined for distances lower than 1 km; therefore there is a need to develop a "complementary" model that will provide attenuation for distances lower than 1 km.

A1.2 Complementary models for distances lower than 1km

A simple model may also be defined by considering the values obtained using Recommendation ITU-R P.1546 as implemented within SEAMCAT version 3 at 1 km for a transmitter antenna height of 100 m.

Table A1.1: Attenuation at 1 km

Environment	Receiver Antenna height = 1.5 m
Urban	115 dB
Suburban	107.5 dB
Rural	107 dB

The respective attenuation using the free space model is about 86 dB.

Table A1.2: Gap between the free space model and the P.1546 at 1 km

Environment	Receiver Antenna height = 1.5 m
Urban	29 dB
Suburban	21.5 dB
Rural	21 dB

The attenuation may then be defined as:

L_{bf} = 32.4 + 20 log f + 20 log d + d x values from Table A1.2
where:

- f : frequency (MHz)
- d : distance, 0-1 (km).

Close to 0 km, the model will give results equivalent from those resulting from the free space. At larger distance, approaching 1 km, the results will approach those obtained using P.1546 as implemented within SEAMCAT.

A1.3 Derivation of the Probability of Interference

The total probability of interference may be estimated by appropriate summation of the probability of interference resulting from samples falling at distances larger than 1 km and the probability of interference resulting from the samples falling at a distance less then 1 km. This should take into account the simulation radii considered for the simulations.

A simulation radius of 50 km was initially considered and in addition, for PMR/PAMR systems, simulation radii corresponding to the cell radius of PMR/PAMR systems depending on the environment were also considered.

Table A1.3: Radius Depending on the Environment

Cell Radius – Urban	km	3.5
– Suburban	km	7
– Rural	km	20

So, if simulations are run using the P.1546 model, the overall probability of interference will have to take into account the percentage of samples falling into the 1 km area.

Table A1.4: ratio between the simulation radius area and the 1 km area

Simulation Radius (km)	3.5	7	20	50
Area defined by 1 km radius as a percentage of entire simulated area	8.2 %	2 %	0.3 %	0.04 %

As a consequence, the 1 km area will have a significant impact only for simulations using a 3.5 km or 7 km radius (Urban or Suburban cells). The total probability of interference for these cases may be estimated by using the following formula:

$$P_{tot} = P_{P.1546}(1 - p) + P_{1km} \times p$$

where:

$P_{P.1546}$ is the probability of interference for the area outside 1 km radius, obtained using the P.1546 model;

P_{1km} is the probability of interference within 1 km defined area, obtained using the model described in section A1.2;

p is the probability of having 1 transmitter located in the 1 km area (i.e. the percentages given in table A1.4).

A1.4 Implementation within SEAMCAT

P_{1km} may be determined using SEAMCAT by employing the model described in section A1.2 and, for example, by setting a "Simulation radius" of 1 km for the simulations.

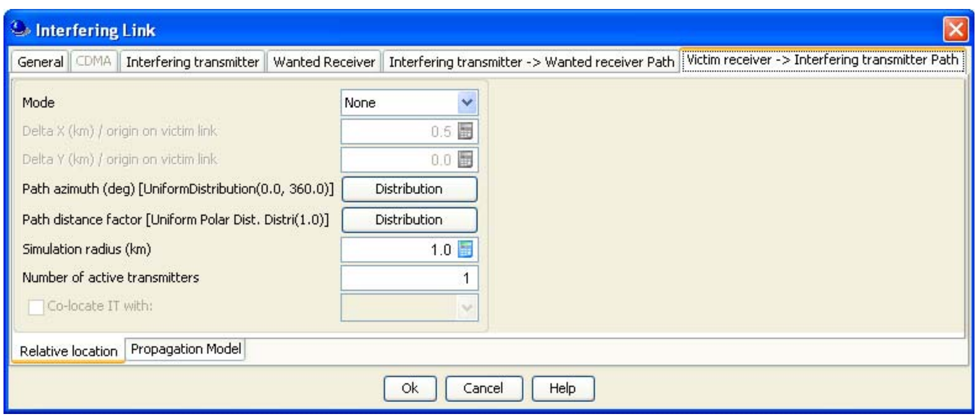


Figure A1.1: Determination of P_{1km}

$P_{P.1546}$ may be determined using SEAMCAT and employing the option "uniform density" for the location of interfering transmitter relative to the victim receiver. A protection distance of 1 km has to be set up in order to avoid generating transmitters at distances lower than 1 km for which P.1546 is not valid.

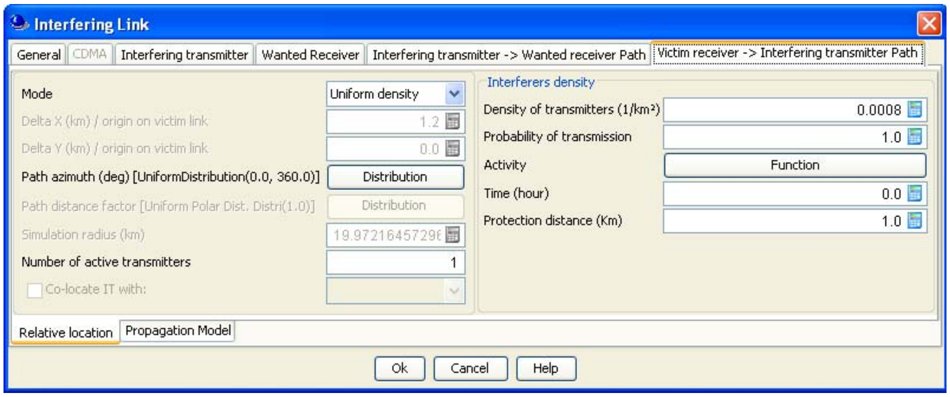


Figure A1.2: Determination of $P_{P.1546}$

The density of transmitters is depending on the considered Radius and is given by:

Surface x density = 1 active transmitter

Where surface = π x (Radius x Radius -1)

This gives a density of active transmitters, for a radius of:

50 km: $1.27 * 10^{-4}$

20 km: $8 * 10^{-4}$ (Rural environment)

7 km: $6.6 * 10^{-3}$ (Suburban environment)

3.5 km: $2.8 * 10^{-2}$ (Suburban environment)

ANNEX 2: IMPLEMENTATION OF PROTECTION RATIO WITHIN SEAMCAT

When the dRSS (i.e. wanted signal, or carrier - C) is defined as a constant and the Noise Floor is taken equal to the dRSS (C), then, the Protection Ratio (PR = Wanted Signal / Unwanted Signal) may also be defined relative to the Noise Floor. The PR may then be modeled through the blocking mask of the victim receiver and SEAMCAT feature using the protection ratio mode, since it represents the attenuation from the Interfering Power to the Noise Floor (here equal to the dRSS). We have:

Interfering Power – Attenuation (Protection Ratio as defined within SEAMCAT) = Noise Floor, or dRSS

In this case the blocking mask has to be defined as the opposite of Protection Ratio (PR) of the system.

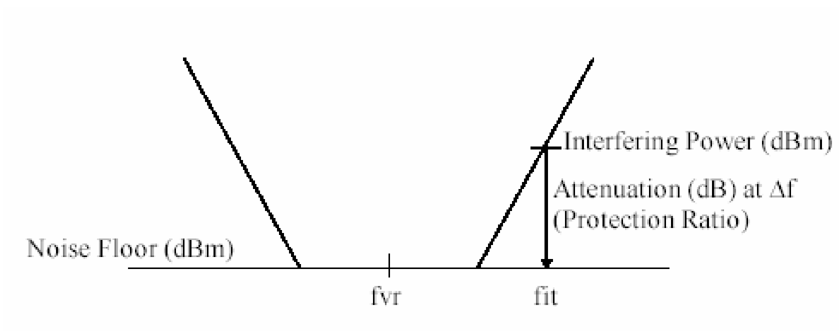


Figure A2.1: Protection Ratio as defined within SEAMCAT

Reading the SEAMCAT User Documentation, it is found that the C/(I+N) criterion has to be provided when using the protection ratio made within SEAMCAT.

If N is taken as equal to C, then the acceptable level of interference at the receiver, is calculated in SEAMCAT as:

I threshold at the receiver – blocking level as defined in the mask = N = C
= I threshold at the receiver + PR

Then, the C/(I+N) criterion has to be defined as:

C/(I+N)= C/(C+C) = -3dB

In addition, when calculating the probability of interference, the C/I criterion may be used as a threshold if defined equal to 0dB.

In conclusion:

- the blocking mask should be defined using the values given in Tables 13 or 14 (with opposite sign);
- protection ratio mode for the definition of blocking mask should be activated;
- C/(I+N) taken equal to -3dB;
- Noise Floor has to be defined equal to the dRSS (i.e. -107dBm in case of PMR/PAMR 12.5 kHz MS);
- C/I taken equal to 0dB;
- Probability of interference may be then determined by using the blocking mode and C/(I+N) or C/I criterion.

ANNEX 3: IMPLEMENTATION OF BLOCKING AND FIRST ADJACENT CRITERION WITHIN SEAMCAT WHEN MODELING TEDS

A3.1 First Adjacent Channel

These simulations are conducted by calculated the amount of power falling into the adjacent channel, i.e. in SEAMCAT this will be provided as the operating frequency of the victim.

In the 25 kHz case, the first adjacent channel is assumed to be above 470 MHz i.e. extending from 470 MHz till 470.025 MHz. The corresponding TEDS system will operate at a frequency of 469.9875 MHz. The interference probability is calculated by using a victim receiver operating at 470.0125 MHz, having a receiving bandwidth of 25 kHz and a C/I of -40dB.

In the 150 kHz case, the first adjacent channel is assumed to be above 470 MHz i.e. extending from 470 MHz over 150 kHz. The corresponding TEDS system will operate at a frequency of 469.925 MHz. The interference probability is calculated by using a victim receiver operating at 470.075 MHz, having a receiving bandwidth of 150 kHz and a C/I of -40dB.

The probability of interference is calculated by using the “Unwanted” signal type and the “C/I” criterion.

A3.2 Blocking

The blocking value may be provided within SEAMCAT by using the “Sensitivity” mode (i.e. the mode where the blocking is provided in absolute value). In this case the user has to define the sensitivity taking into account the following equation:

Interfering signal (as defined by the user – in dBm) = Blocking (dB) + Sensitivity (dBm) + 3dB

SEAMCAT checks whether the dRSS (C) is below or above the Sensitivity level (if the dRSS is found to be lower than the Sensitivity, then the wanted link is deemed to be in outage and therefore discounted from interference statistics). Therefore the sensitivity should be defined with a value lower than C.

The sensitivity may be taken equal to -117dBm for 25 kHz system and -109 for 150 kHz systems (i.e. 3dB below the dRSS) so that the blocking (dB) also refers to the dRSS (C).

The probability of interference is calculated by using the “Blocking” signal type and the “C/I” criterion.

25 kHz case

- C= -114dBm
- Blocking= -40 dBm
- Sensitivity= -117 dBm

The C/I must then be taken equal to C/I= -114 dBm – 40dBm = -74 dB

According to the SEAMCAT User Documentation, when using the “Sensitivity” mode, the user must define the C/(N+I). Assuming that N is taken equal to the maximum allowed level of interference (-40dBm), the C/(N+I) is equal to -77dB.

150 kHz case

- C= -106dBm
- Blocking= -40 dBm
- Sensitivity= -109 dBm
- C/I= -106 dBm – 40dBm = -66 dB
- C/(N+I)=-69
- N=-40dBm

A3.3 Validation and Implementation of the blocking within SEAMCAT - 25 kHz TEDS case

Using the following set of assumptions:

- C= -114dBm
- Blocking -40 dBm (Sensitivity mode)
- Sensitivity= -117 dBm
- N=-40dBm
- C/I= -74 dB
- C/(N+I)= -77dB.

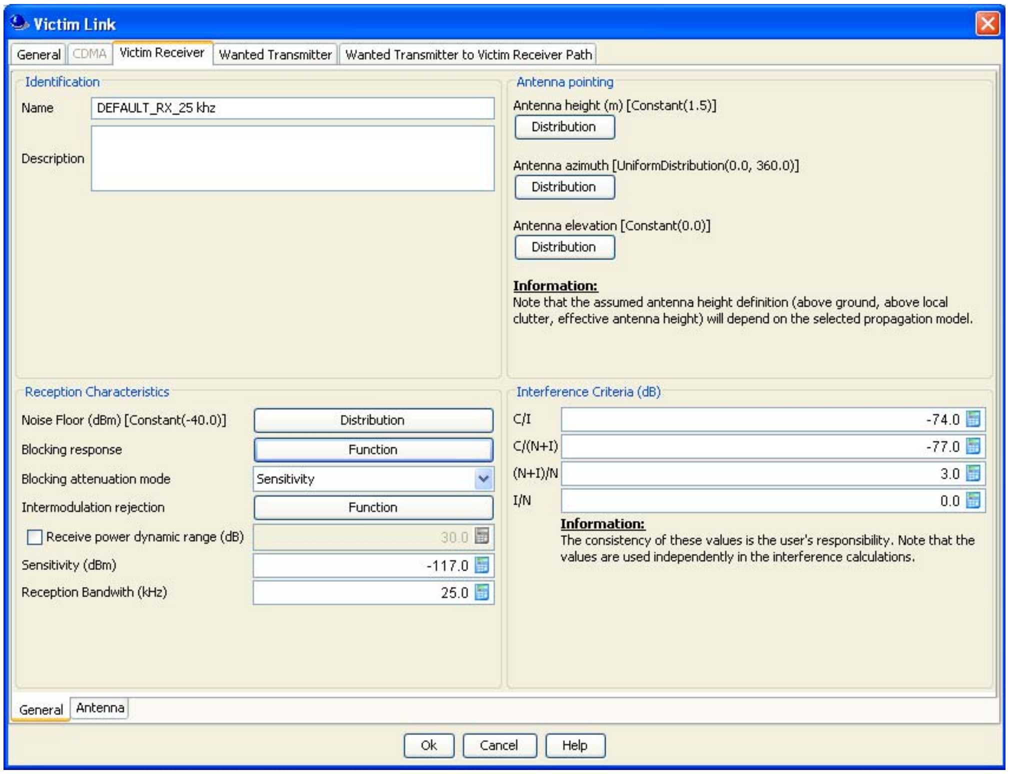


Figure A3.1: Implementation of blocking

The attenuation to be applied on the interfering signal is calculated using the following equation (see the SEAMCAT User Documentation available at www.ero.dk/seamcat):

Attenuation (dB) = Interfering Signal Level (dBm) – Sensitivity (dBm) + C/(N+I)

For 25 kHz system, this gives:

Attenuation (dB) = - 40 dBm +117 – 77 dB = 0dB

Using a simplified propagation as follows:

L=0;
eval L;

If the Interfering Power is -41dBm then the received interfering power is also -41dBm - i.e. no attenuation from propagation model and no attenuation from blocking- and there is no interference.

ANNEX 4: ADDITIONAL RESULTS OF SIMULATIONS

The following table provides additional results of simulations defined in section 3.1.3.1.1.2. For these simulations, the dRSS distribution was modified to reflect higher sensitivity level.

TABLE A4.1

Interference Probability for variable dRSS – TEDS 25 kHz Victim Receiver

		Sensitivity, dBm		
		-114	**-108**	**-102**
Non-Critical Case – 50 km	0-1km	100%	100%	100%
	1-50 km	4%	2%	0.7%
	Total	**4.0%**	**2.0%**	**0.7%**
Non-Critical Case - 3.5 km	0-1km	100%	100%	100%
	1-3.5 km	91%	77%	60.5%
	Total	**91.7%**	**78.9%**	**60.5%**
Sensitive Case - 50 km	0-1km	100%	100%	100%
	1-50 km	3%	1%	0%
	Total	**2.5%**	**1.0%**	**0.0%**
Sensitive Case - 3.5 km	0-1km	100%	100%	98%
	1-3.5 km	83%	66%	44%
	Total	**84.4%**	**68.8%**	**48.4%**

Additional simulations were conducted in order to further investigate the probability of interference for df from 4 to 5 MHz for two different sensitivities for TEDS 150 kHz systems.

TABLE A4.2

Interference Probability for a variable dRSS – TEDS 150 kHz Victim Receiver with variable dRSS (Gaussian - Mean: -84dBm - StdDev 7.5dB)

		df (MHz)							
		4	**5**	**6**	**7**	**8**	**9**	**10**	**11**
150 kHz Non-CriticalCase - 50 km	0-1km	100%	82%	62%	50%	37%	28%	19%	13%
	1-50 km	3%	0%	0%	0%	0%	0%	0%	0%
	Total	**2.7%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**
150 kHz Non-CriticalCase - 3.5 km	0-1km	100%	82%	62%	50%	37%	28%	19%	13%
	1-3.5 km	88%	9%	2%	1%	0%	0%	0%	0%
	Total	**89.0%**	**14.5%**	**7.2%**	**4.8%**	**3.3%**	**2.3%**	**1.6%**	**1.1%**
150 kHz Sensitive Case - 50 km	0-1km	100%	51%	33%	24%	16%	11%	7%	4%
	1-50 km	1.5%	0%	0%	0%	0%	0%	0%	0%
	Total	**1.5%**	**0.2%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**
150 kHz Sensitive Case - 3.5 km	0-1km	100%	51%	33%	24%	16%	11%	7%	4%
	1-3.5 km	77%	1%	0%	0%	0%	0%	0%	0%
	Total	**78.9%**	**5.1%**	**2.7%**	**1.9%**	**1.3%**	**0.9%**	**0.5%**	**0.4%**

ANNEX 5: MEASUREMENTS AT 170 MHZ

A5.1 Introduction

The following laboratory tests were undertaken with the purpose of determining the protection ratios required by an Analogue PMR/PAMR receiver operating in VHF Band III in the presence of an unwanted DVB-T signal and vice versa.

A5.2 Test Method: Co-Channel Rejection Ratio (Relative)

The tests carried out were performed in order to determine the PMR/PAMR protection ratios when in the presence of a DVB-T transmission and were carried out for wanted signal levels (at the Device Under Test - DUT) of -107.0 and -87.0 dBm. Tests were undertaken with a co-channel unwanted signal as well as with an off-set unwanted signal. Figures are quoted for the DVB-T generator operating with 16 QAM modulation. Confidence checks were carried out to confirm that there was no significant difference in these figures when 64 QAM modulation was used.

The tests to determine DVB-T protection ratios in the presence of PMR/PAMR transmissions were carried with a wanted signal level of -59.0 dBm (at the DUT) and employed a subjective assessment of the picture quality.

NOTE: All signal levels recorded were taken by reading values from the signal generator front panels. The results in Section A5.3 are all adjusted to give the level at the DUT by subtracting the 6 dB loss introduced by the combiner.

A5.2.1 PMR/PAMR Protection Ratios (DVB-T Unwanted emissions)

A5.2.1.1 Test Configuration

. The configuration for this part of the test is shown in Figure A5.1 below.

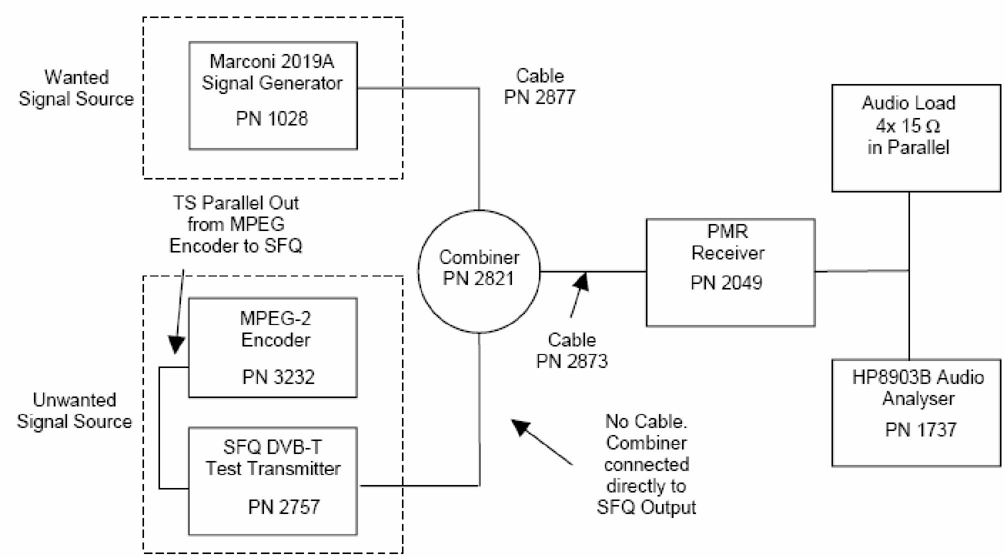


Figure A5.1 Test configuration for determining PMR/PAMR Protection Ratios

DVB-T system

This test used a DVB-T generator and the Table A5.1 below provides some information regarding the configuration of the DVB-T generator used during testing. The parameters identified were set under the I/Q Coder Configuration Menu of the SFQ T.V. Test Transmitter.

TABLE A5.1

I/Q Coder Configuration

Parameter	16 QAM	64 QAM
I/P Data Rate	18.096257 MBit/s	24.128343 MBit/s
Mode	DATA	
Code Rate	3/4	2/3
Used B/W	7.607143 MHz	
FFT Mode	2k	
Guard Interval	1/32	

The configuration of both the wanted and unwanted signals is given in Table A5.2 below.

TABLE A5.2

Test Signal Configuration

Wanted Signal		
Modulation Type	FM	
Centre Frequency	169.0125	MHz
Deviation	1.5	kHz
Audio Tone	1.0	kHz
R.F. Level at DUT Input	-107.0 (≡+6.0dBµV EMF) -87.0	dBm
Unwanted Signal		
Modulation Type[3]	DVB-T COFDM with 16/64 QAM	
Centre Frequency	169.0125	MHz
R.F. Level at DUT Input	As required	

A5.2.1.2 Test Procedure

The following steps were used to obtain the protection ratio for an Analogue PMR/PAMR in the presence of a DVB-T signal:

i. Using test configuration shown in Figure A5.1 a wanted signal as described in Table A5.2 was applied to the PMR/PAMR receiver with an EMF of +6 dBµV (≡ -107.0 dBm). To do this an output level of -101.0 dBm was set on the wanted signal source, which results in an adjusted level of -107.0 dBm at the DUT.
ii. The volume control on the DUT was set to give an output level of ~ 50%.
iii. The unwanted signal was produced by DVB-T signal generator configured as described in Table A5.1 with the modulation set to 16 QAM.
iv. The unwanted signal level was increased until a weighted[4] SINAD ratio of 14.0 dB was observed on the audio analyser. The unwanted signal level was then recorded.
v. The unwanted signal was offset from the centre frequency by -1.0 MHz. The unwanted signal level was then altered until the weighted SINAD ratio returned to 14.0dB. The unwanted signal level was then recorded.
vi. Step v was repeated for each of the offset frequencies specified in the result tables in Section 3.1.
vii. Steps iii through to vi were repeated with the wanted signal set to -87.0 dBm at the DUT.

Confidence checks were carried out to determine the effect of changing the unwanted signal from 16 QAM to 64 QAM. No significant difference to the results was observed by making this change.

NOTE: The Combiner results in a 6 dB Loss in signal level. Therefore all settings on signal sources were adjusted by 6 dB to give the correct value at the DUT.

A5.2.2 DVB-T Protection Ratio (PMR/PAMR Unwanted emissions)

[3] See Annex 6.1 for further details of the unwanted signal configuration.
[4] During the test the CCITT psophometric weighted filter was selected on the audio analyser.

A5.2.2.1 Test Configuration

This test uses a DVB-T generator, and a subjective assessment of the degradation. The configuration for this part of the test is shown in Figure A5.2 below.

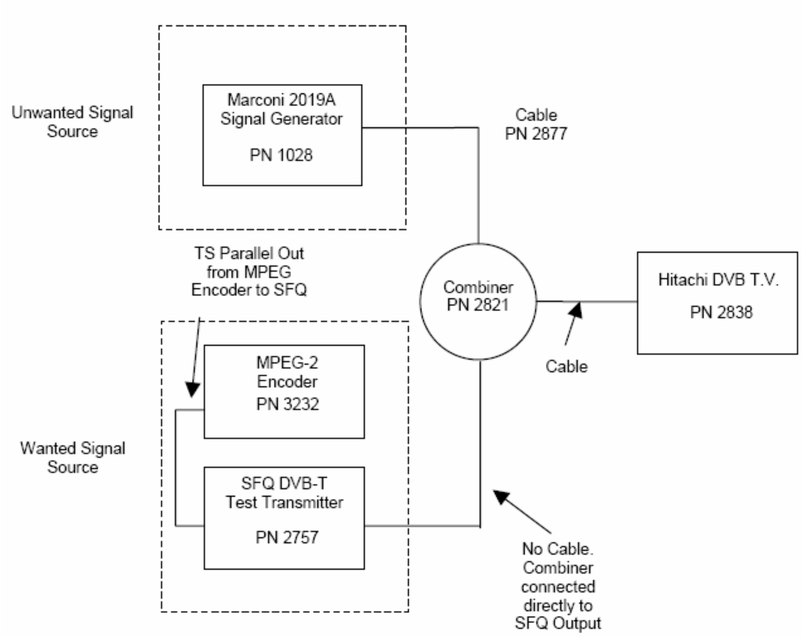


Figure A5.2: Test configuration for determining DVB-T Protection Ratio

The configuration of both the wanted and unwanted signals is given in Table A5.3 below.

TABLE A5.3

Test Signal Configuration

Wanted Signal		
Modulation Type[1]	DVB-T COFDM with 16/64 QAM	
Centre Frequency	818.0	MHz
R.F. Level at DUT Input	-59.0	dBm
Unwanted Signal		
Modulation Type	FM	
Centre Frequency	818.0	MHz
Deviation	1.5	kHz
Audio Tone	1.0	kHz
R.F. Level at DUT Input	As required	

A5.2.2.2 Test Procedure

The following steps were followed to obtain the protection ratio for DVB-T in the presence of PMR:

i. Using the test configuration shown in Figure A5.2 a wanted signal as described in Table A5.3 was applied to the DVB TV receiver at a level of -59.0 dBm. To do this an output level of -53.0 dBm was set on the Wanted Signal Source, which results in an adjusted level of -59.0 dBm at the DUT.
ii. The Wanted Signal was configured as described in Table A5.3 with the Modulation set to 16 QAM.
iii. The unwanted signal was configured as described in Table A5.3.
iv. The unwanted signal level was increased until a noticeable degradation in the quality of the picture on the T.V. screen could be observed. The unwanted signal level was recorded.
v. Step iv was repeated with the unwanted signal generator configured to produce 64 QAM modulation.

NOTE: The combiner results in a 6 dB loss in signal level. Therefore all settings on signal sources were adjusted by 6 dB to give the correct value at the DUT.

A5.2.3 Measurement of DVB-T Peak to Average Power

The results in Section A5.3 quote protection ratios with reference to average power (Pav) from the DVB-T Signal Generator. For information a test was carried out to determine the ratio of Pav to the Peak Power (Ppk) of the DVB-T signal.

Using the test configuration in Figure A5.3 the output level of the DVB-T generator was set to -30dBm at a frequency of 818.0 MHz. The average and peak power were then measured using a Boonton power meter. The results are shown in Section A5.3.3.

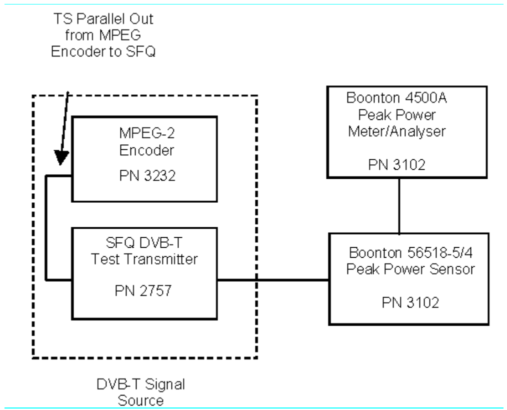


Figure A5.3: Test Configuration for DVB-T Average and Peak Power Measurement

The results show that the RF Level set on the DVB-T Generator is equivalent to the average RMS power at the generator output.

A5.2.4 Calculation of Protection Ratios

The protection ratios quoted in this report were calculated using the following relationship:

Protection Ratio (dB) = Wanted Signal Level (dBm) – Unwanted Signal Level (dBm)

A5.2.5 Estimate of Measurement Uncertainty

A5.2.5.1 PMR/PAMR Protection Ratios (DVB-T Unwanted emissions)

The FM source used during the test was maintained to Cal Class 1, as were the combiner and audio analyser. The DVB-T generator was maintained to Cal Class 2 but with the levels measured using a Cal Class 1 power meter. It is assumed that the R.F. power level from the DVB-T generator is accurate over the range of operation used for these tests.

Therefore measurement uncertainty was estimated to be in the order of:

Measurement uncertainty = ±3.0 dB which is based upon a standard uncertainty multiplied by a coverage factor k = 2 providing a level of confidence of approximately 95%.

A5.2.5.2 DVB-T Protection Ratio (PMR/PAMR Unwanted emissions)

However as the magnitude of the degradation to a digital system changes rapidly around the onset point, the additional uncertainty is considered to be relatively small.

A5.3 Test Results

A5.3.1 PMR/PAMR Protection Ratios (DVB-T Unwanted emissions)

The results of testing carried out as described in Section A5.2.1.2 are presented in Tables A5.4 and A5.5 below. The results are referenced to the average power of the unwanted (DVB-T) signal level. Section A5.3.3 explains the conversion factor needed to change average DVB-T signal power to peak power, as well as how to determine the power falling in a 12.5 kHz bandwidth.

TABLE A5.4

PMR/PAMR Protection Ratios in the Presence of an Offset DVB-T signal for a Wanted Level of -107.0 dBm

Unwanted Signal				DVB-T 16 & 64 QAM									
Wanted Signal				FM, 1kHz tone, 1.5kHz Deviation, at -107.0 dBm									
Centre Frequency				169.0125 MHz									
For a SINAD of				14.0 dB									
Δf (MHz)	-10.0	-9.0	-8.0	-7.0	-6.0	-5.0	-4.0	-3.9	-3.8	-3.7	-3.0	-1.0	0.0
PR (dB)	-83.9	-83.9	-82.3	-79.8	-76.5	-73.1	-72.4	-52.6	-24.1	-23.0	-23.0	-23.0	-23.0
Δf (MHz)	+1.0	+3.0	+3.7	+3.8	+3.9	+4.0	+5.0	+6.0	+7.0	+8.0	+9.0	+10.0	
PR (dB)	-23.0	-23.0	-23.0	-24.1	-53.1	-71.5	-71.8	-74.0	-76.0	-77.8	-79.7	-81.8	

TABLE A5.5

PMR/PAMR Protection Ratios in the Presence of an Offset DVB-T signal for a Wanted Level of –87.0 dBm

Unwanted Signal				DVB-T 16 & 64 QAM									
Wanted Signal				FM, 1kHz tone, 1.5kHz Deviation, at -87.0 dBm									
Centre Frequency				169.0125 MHz									
For a SINAD of				14.0 dB									
Δf (MHz)	-10.0	-9.0	-8.0	-7.0	-6.0	-5.0	-4.0	-3.9	-3.8	-3.7	-3.0	-1.0	0.0
PR (dB)	-78.5	-75.8	-73.0	-70.2	-67.5	-65.0	-63.1	-52.3	-24.3	-23.2	-23.2	-23.2	-23.2
Δf (MHz)	+1.0	+3.0	+3.7	+3.8	+3.9	+4.0	+5.0	+6.0	+7.0	+8.0	+9.0	+10.0	
PR (dB)	-23.2	-23.2	-23.2	-24.0	-53.1	-61.2	-61.8	-63.0	-64.3	-65.8	-67.9	-70.5	

Note: The protection ratio, measured at a large Δf, might be limited by the phase noise performance of the DVB-T test transmitter rather than the unwanted signal rejection performance of the PMR/PAMR receiver. It is not known how the phase noise performance of the test transmitter compares with that of a broadcast DVB-T signal.

Figure A5.4 below shows the data from Tables A5.4 and A5.5. The chart shows a clear difference in the protection ratios required for different wanted levels when offsets greater than approximately ±4.0 MHz are used.

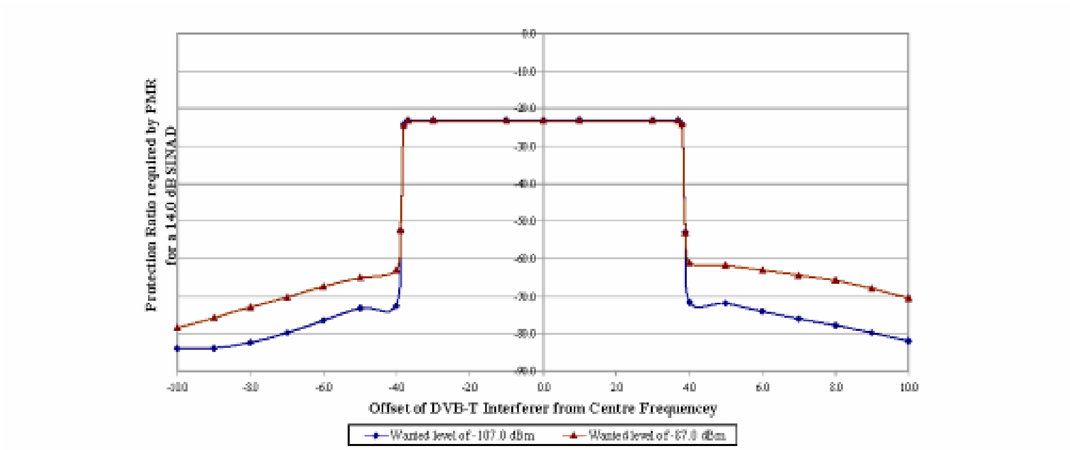


Figure A5.4: PMR/PAMR Protection Ratios in the Presence of DVB-T interfering signal

According to the results, the protection ratio is reduced by approximately 10 dB for offsets between ±4.0 MHz to ±10.0 MHz.

This is due to the unwanted signal acting as a 'blocker' at these higher offset frequencies when the wanted signal level is -87.0 dBm. Therefore although the wanted signal level has increased by 20 dB, the unwanted has only increased by 10dB.

This implies that at higher offsets the performance of the receiver is, as expected, limited by its blocking performance. i.e. it's unwanted signal rejection performance cannot be accurately conveyed by a protection ratio at large frequency offsets.

A5.3.2 DVB-T Co-Channel Protection Ratio (PMR/PAMR Unwanted emissions)

The results of testing carried out as described in Section A5.2.2.2 are presented in Tables A5.6 and A5.7 below. The results are referenced to the average power of the wanted (DVB-T) signal level. Section A5.3.3 explains the conversion factor needed to change average DVB-T signal power to peak power.

TABLE A5.6

DVB-T (16 QAM) Protection Ratios in the Presence of PMR/PAMR interfering signal

Wanted Signal	DVB-T 16 QAM, at -59 dBm
Unwanted Signal	FM, 1kHz tone, 1.5kHz Deviation
Centre Frequency	169.0125 MHz
Impairment Criteria	Initial Degradation of Picture (Subjective Assessment)
Δf (MHz)	0
PR (dB)	-0.5

TABLE A5.7

DVB-T (64 QAM) Protection Ratios in the Presence of PMR/PAMR interfering signal

Wanted Signal	DVB-T 64 QAM, at -59 dBm
Unwanted Signal	FM, 1kHz tone, 1.5kHz Deviation
Centre Frequency	169.0125 MHz
Impairment Criteria	Initial Degradation of Picture (Subjective Assessment)
Δf (MHz)	0
PR (dB)	+0.5

A5.3.3 DVB-T Power Level conversions

Tables A5.8 shows the relationship between peak and average power measured from the DVB-T test transmitter for an output level setting of -30.0 dBm.

TABLE A5.8

Measurement of Average and Peak DVB-T Powers

Modulation Scheme	Signal Level Set (dBm)	Power Measured		
		Pav (dBm)	Ppk (dBm)	Ratio Peak to Average (dB)
16 QAM	-30.0	-29.5	-20.3	9.2
64 QAM	-30.0	-29.8	-20.3	9.5

Table A5.9 shows the conversion factor required to determine the DVB-T power falling within a 12.5 kHz Bandwidth.

TABLE A5.9

Calculation of DVB-T Power falling in 12.5 kHz Bandwidth

DVB-T Bandwidth	PMR/PAMR Channel Bandwidth	Conversion Factor
7.6 MHz	12.5 kHz	10 log BW1/BW2 = -27.8 dB

i.e. a 7.6 MHz wide DVB-T signal of -20 dBm (average) would, assuming noise like characteristics, produce a power of -47.8 dBm (average) in a 12.5 kHz bandwidth.

A5.4 Conclusions

A5.4.1 PMR/PAMR in the Presence of DVB-T interfering signal

The results in Section A5.3.1 show that for an analogue PMR/PAMR receiver working in the presence of a co-channel DVB-T signal, a protection ratio of the order of -23.0 dB is required to achieve a SINAD of 14.0 dB. This corresponds to a protection ratio of +4.8 dB relative to the DVB-T signal power falling within a 12.5 kHz bandwidth. The result was found to be relatively independent of the unwanted DVB-T signals modulation.

It is noted that for offsets of the unwanted signal of less than ±3.7 MHz the protection ratio does not change. There is then a marked transition in the protection ratio measured for offsets between ±3.7 to ±3.9 MHz. This coincides with the band edges of the DVB-T signal and is as expected by inspection of the DVB-T spectrum on the spectrum analyser.

At large frequency offsets the measured protection ratio depends on the wanted signal level i.e. receiver blocking occurs.

A5.4.2 DVB-T in the presence of PMR/PAMR interfering signal

The results in Section A5.3.2 indicate that for a DVB-T receiver working in the presence of an Analogue PMR/PAMR signal, a protection ratios of the order of -0.5 dB for 16 QAM and +0.5 dB for 64 QAM are required.

Protection ratios of -1.0 and +2.0 dB are required for DVB-T, 16 QAM and 64 QAM respectively, when operating in the presence of a PMR/PAMR signal.

ANNEX 6: MAST HEAD AMPLIFIERS

In the television broadcast Bands IV and V, mast head signal amplifiers are sometimes used in domestic television receiving applications, and amplifiers are common in both professional and domestic television distribution systems.

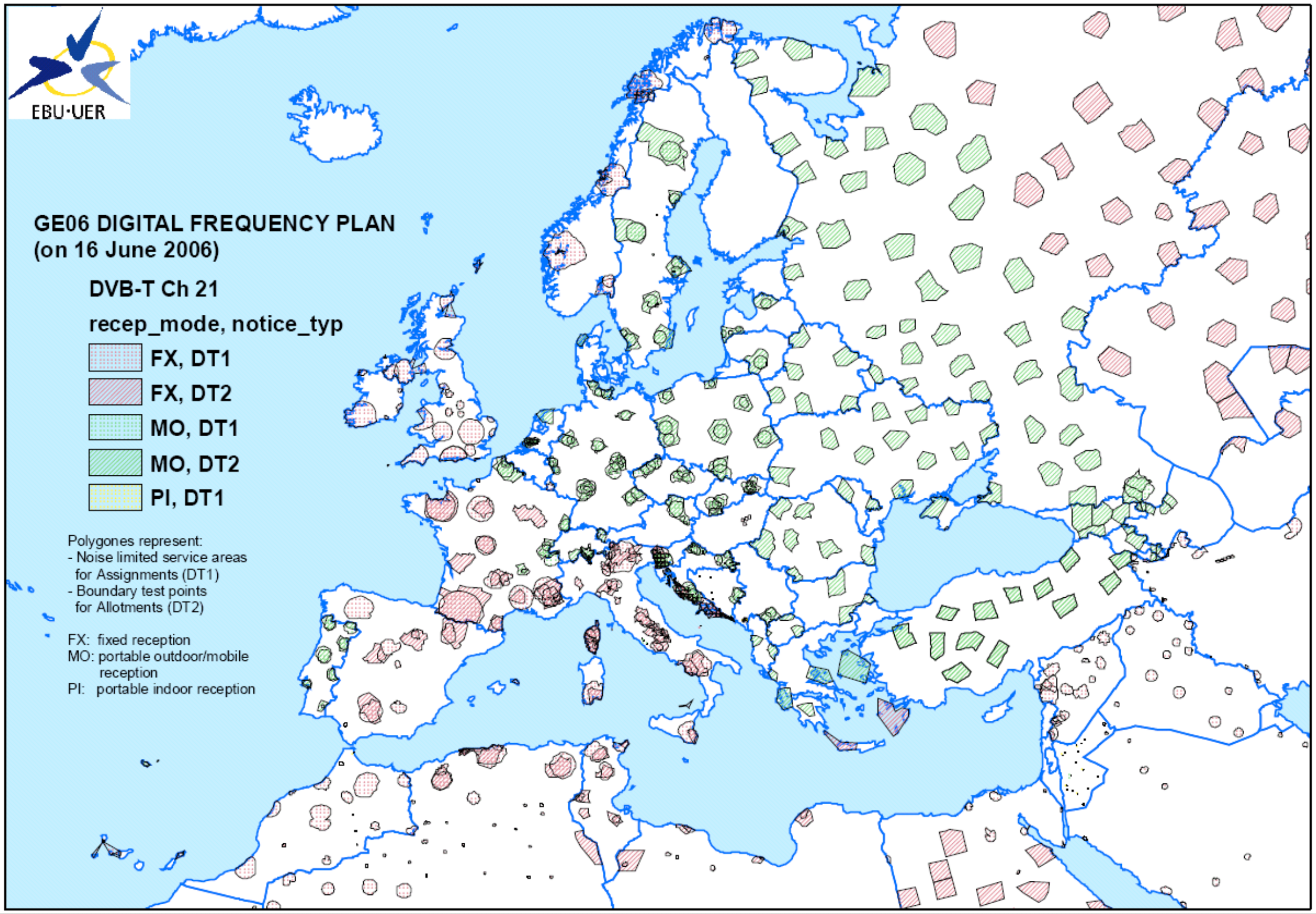
Previously, there have been no agreed technical standards available for such amplifiers and therefore we must resort to practical experience in assessing their performance. However, ETSI has started work on Product Standards covering active antennas (ES 202 056 [15] amplifiers and/or pre-amplifiers (ES 202 127 [16]),) used for broadcast TV and sound reception from 47 MHz to 860MHz.

It has been suggested that a certain amount of frequency selectivity may be assumed if such amplifiers are employed and that this could improve the isolation between PMR/PAMR in the 450 – 470 MHz band and television in UHF Channel 21, 470 – 478 MHz. There is evidence that the majority of signal amplifiers currently on the market have little or no intentional attenuation outside the television broadcasting bands. Though the introduction of general out of band attenuation in TV signal amplifiers could have a major impact on the reduction of interference in many cases, for the interference scenario of TV reception in channel 21 and land mobile transmission at 469MHz, introducing such general attenuation outside the broadcasting band will have little or no effect.

The amplifiers currently commercially available are usually designed to be wide-band, to cover, with a single device, either the whole of the UHF band or the whole of Band IV (470 - 582 MHz). This means that without the use of relatively complex filters, not usually incorporated in such equipment, the frequency response extends well below 470 MHz. Consequently, for the purposes of this study, the response should be assumed to remain flat throughout the PMR/PAMR band and the television channels in question. Practical experience also shows that frequency selectivity is very poor. Amplifiers supposedly dedicated to Channel 26, would work just as well in Channel 23 and 32. In one of the CEPT administrations, expensive custom-built filters had to be installed to protect UHF signal amplifiers from interference from NMT-450 BS operating in 463 – 467.5 MHz.

It is also worth pointing out that when a number of radio signals of widely varying levels and possibly modulation schemes are present, the indiscriminate use of UHF amplifiers can be counter productive. In these cases interference effects such as blocking and inter-modulation may be the limiting performance of the receiving installation.

ANNEX 7: MAP OF THE DIGITAL PLAN GE-06 FOR DVB-T IN CHANNEL 21



ANNEX 8: BIBLIOGRAPHY

[1] ECC/DEC/(04)06: ECC Decision of 19 March 2004 on the availability of frequency bands for the introduction of Wide Band Digital Land Mobile PMR/PAMR in the 400 MHz and 800/900 MHz bands

[2] ECC Report 25: "Strategies For The European User Of Frequency Spectrum For PMR/PAMR Applications "

[3] Recommendation ITU-R BT.419: "Directivity and polarization discrimination of antennas in the reception of television broadcasting"

[4] Recommendation ITU-R. BT.1368-6: "Planning criteria for digital terrestrial television services in the VHF/UHF bands"

[5] Final Acts of the Regional Radiocommunication Conference for planning of the digital terrestrial broadcasting service in parts of Regions 1 and 3, in the frequency bands 174-230 MHz and 470-862 MHz (RRC-06)

[6] EN 300 113: "Radio Equipment and Systems (RES); Land mobile service; Technical characteristics and test conditions for radio equipment intended for the transmission of data (and speech) and having an antenna connector"

[7] EN 300 086: "Land Mobile Service; Radio equipment with an internal or external RF connector intended primarily for analogue speech"

[8] EN 300 392-2 : "Terrestrial Trunked Radio (TETRA)"

[9] ERC Report 104: "Adajacent Band Compatibility of 400 MHz TETRA AND Analogue FM PMR/PAMR - "An Analysis Completed Using a Monte Carlo Based Simulation Tool"

[10] ETSI TR 102 491: "TETRA Enhanced Data Service (TEDS) System Reference Document"

[11] ETSI TR 102 260: "Code Division Multiple Access Public Access Mobile Radio (CDMA-PAMR)"

[12] Recommendation ITU-R P.525: "Calculation of free-space attenuation"

[13] Recommendation ITU-R P.1546: "Method for point-to-area predictions for terrestrial services in the frequency range 30 MHz to 3 000 MHz"

[14] Recommendation ITU-R SM.1541: "Unwanted emissions in the out-of-band domain"

[15] ES 202 056: "Active Antennas used for Broadcast TV and Sound Reception from 47 MHz to 860 MHz"

[16] ES 202 127: "Radio Frequency Amplifiers and Pre-Amplifiers used for Broadcast TV and Sound Reception from 47 MHz to 860 MHz"

ANNEX 9: LIST OF ABBREVIATIONS

BS	Base Station
CDMA	Code Division Multiple Access
CEPT	European Conference of Posts and Telecommunications Administrations
CW	Continuous Wave
DQPSK	Differential Quadrature Phase Shift Keying
DVB-T	Digital Video Broadcasting - Terrestrial
dRSS	desired Received Signal Strength
ERC	European Radio Commission
e.i.r.p.	Equivalent Isotropically Radiated Power
e.r.p.	Effective Radiated Power
ETSI	European Telecommunications Standards Institute
FER	Frame Error Rate
FM	Frequency Modulation
MCL	Minimum Coupling Loss
MS	Mobile Station
PAMR	Public Access Mobile Radio
PMR	Private (or Professional) Mobile Radio
PR	Protection Ratios
PT	Project Team
QAM	Quadrature Amplitude Modulation
RES	Radio Equipment and Systems
SE	Spectrum Engineering
SEAMCAT	Spectrum Engineering Advanced Monte Carlo Analysis Tool
TDM	Time Division Multiplexing
TDMA	Time Division Multiple Access
TEDS	TETRA Enhanced Data Service
TETRA	Terrestrial Enhanced Trunked Radio
UE	User Equipment
UHF	Ultra High Frequency