Electronic Communications Committee (ECC)
within the European Conference of Postal and Telecommunications Administrations (CEPT)

THE TECHNICAL IMPACT OF INTRODUCING TAPS ON 12.5 / 25 kHz PMR/PAMR TECHNOLOGIES IN THE 380-400, 410-430 and 450-470 MHz BANDS

Cavtat, May 2003

EXECUTIVE SUMMARY

This report considers the technical impact of introducing TETRA Release 2 TAPS on the existing PMR/PAMR radio systems / services in the bands 380-400[1], 410-430 and 450-470 MHz. In this report, PMR/PAMR radio systems / services refers to 12.5 kHz and 25 kHz analogue systems, and other systems compliant to ES 300 086, ES 300 113, including Mobitex and Tetrapol, and EN 300 392 (TETRA). The report establishes the level of interference that can be expected to affect analogue PMR/PAMR, TETRA, Mobitex or Tetrapol systems in the harmonised CEPT bands between 380-400, 410-430 and 450-470 MHz when TAPS is deployed adjacent to them.

Monte Carlo simulations have been performed using the CEPT's SEAMCAT modelling tool in order to establish the level of interference from TAPS to PMR/PAMR systems. The simulations have considered four scenarios, namely:

- Scenario 1, TAPS MS into PMR/PAMR MS (at frequencies around the duplex transition frequency)
- Scenario 2, TAPS MS into PMR/PAMR BS (at frequencies in the uplink band)
- Scenario 3, TAPS BS into PMR/PAMR MS (at frequencies in the downlink band)
- Scenario 4, TAPS BS into PMR/PAMR BS (at frequencies around the duplex transition frequency).

Monte Carlo modelling has established that, provided that a guard band[2] of 100 kHz is left in the uplink band and downlink band, and a guard band of 300 kHz is left around the duplex transition frequency, then the level of interference from TAPS into PMR/PAMR will be low.

In the last of these four scenarios, the use of SEAMCAT alone to calculate the level of interference is not sufficient to establish compatibility between TAPS base station transmitters and PMR/PAMR base station receivers when they are operating at frequencies close to each other (e.g. close to the duplex transition frequencies at 390, 420 or 460 MHz). For such cases, MCL modelling has been performed in order to establish the conditions under which the two systems can co-exist, and the mitigation measures that may be necessary in order to ensure that interference is avoided. The report establishes that co-ordination between TAPS and incumbent PMR/PAMR services may be required in some circumstances in order to avoid interference to PMR/PAMR base station receivers from TAPS base station transmitters. The report further establishes the separation distances and/or other mitigation measures necessary to avoid interference. (See Figures 2,3 and 4).

The report concludes that the CEPT PMR/PAMR bands between 380-400, 410-430 and 450-470 MHz can be utilised for TAPS with negligible risk of interference to PMR/PAMR including TETRA, Mobitex and Tetrapol systems provided a guard band of 100 kHz in the normal uplink to uplink, downlink to downlink cases and also at the uplink to downlink interference case (scenario 1, 2 & 3). For the particular case where downlink interferes with uplink (scenario 4) around the transition frequencies i.e. at 390, 420 and 460 MHz, although the probabilities of interference are reasonably low for the suburban and rural cases, the results for the urban case suggest that coordination is required. From the urban results it can be seen that with a 300 kHz guard band between 7% and 21% of the base stations will require some sort of mitigation.

It should be noted that the report does not consider the interference from existing PMR/PAMR Radio systems into TAPS deployed in adjacent bands, since the effect from the new systems on the incumbent ones is the most important part to deal with. Since this direction of interference will address interference from narrow band 12.5/25 kHz to wider band systems, it has been considered that under the conditions presented above TAPS systems would not be interfered with and both systems would then be compatible.

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[1] In a number of European countries only the band segments 380-385/390-395 MHz have been allocated to Digital PMR Emergency Services. The remainder of 380-400 MHz band is used in accordance with the footnote EU27 of the European Common Allocation Table (ERC Report 025, Dublin 2003). In these countries the duplex transition frequency of 390 MHz does not exist.

[2] In this report the term guard band is considered to be the minimum frequency separation between the channel edges of the two systems.

Index Table

THE TECHNICAL IMPACT OF INTRODUCING TAPS ON 12.5 / 25 kHz PMR/PAMR TECHNOLOGIES IN THE 380-400[3], 410-430 and 450-470 MHz BANDS

1 INTRODUCTION

This report considers the technical impact of introducing TETRA Release 2 TAPS on the existing PMR/PAMR radio systems / services in the bands 380-400, 410-430 and 450-470 MHz. In this report, PMR/PAMR radio systems / services refers to 12.5kHz and 25kHz FM PMR/PAMR systems, and other systems compliant to ES 300 086, ES 300 113 and EN 300 392 (TETRA), including Mobitex and Tetrapol.

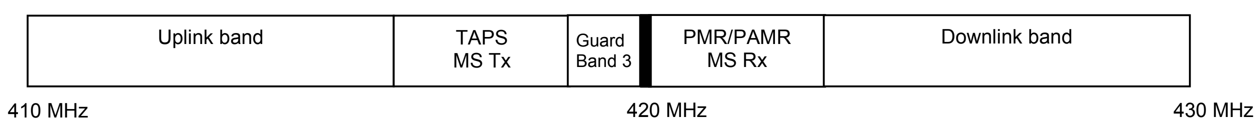
Part of the calculations in this report have been performed using the specification ES 300 113. This is because this specification is representative for a large number of systems and by applying the specification for 12.5 kHz this will also cover 25 kHz. Again, the reason is that the blocking figures remain the same for 12.5 and 25 kHz and that whilst the receiver bandwidth is slightly wider than double for 25 kHz, this is countered by a 4 dB reduction in co-channel rejection ratio. It is therefore considered that using the 12.5 kHz requirements is representative for the purpose of this study.

The report also contains calculations according to EN 300 392 to cover the interference from TETRA Release 2 TAPS to TETRA V+D.

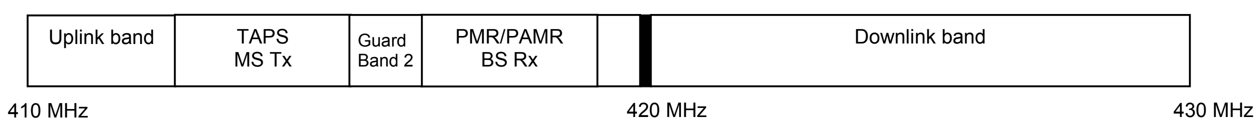
The report considers in particular the interference from TAPS into existing PMR/PAMR systems including TETRA in the 400 MHz bands. Monte Carlo modelling has been performed using SEAMCAT in order to investigate the interference to a PMR/PAMR system caused by the introduction of a TAPS network in adjacent spectrum with a guard band between them. The simulations focus on a 2.8 MHz band for TAPS. 2.8 MHz will result in a total of 14 frequency channels being available with the normal quantity of transmitters per base station being limited to 1. This is considered the minimum spectrum which would be required for a TAPS network. The modelling has investigated the effects of interference from both TAPS base stations and mobiles to both PMR/PAMR base stations and mobiles.

Figure 1: Examples of the different scenarios of PMR/PAMR and TAPS systems in the 410-430 MHz bands, similar figures apply to the 380-400 and the 450-470 MHz bands

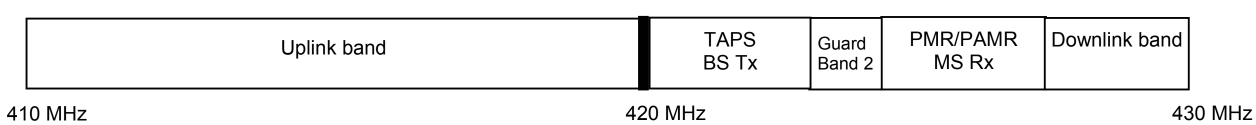
Scenario 1 example MS to MS



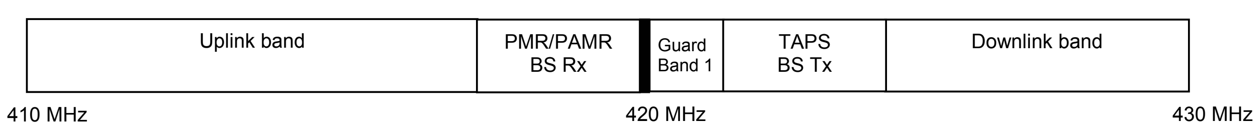
Scenario 2 example MS to BS



Scenario 3 example BS to MS



Scenario 4 example BS to BS



In addition to the Monte Carlo modelling, the report also focuses in more detail on adjacent band compatibility at the duplex frequency boundaries (see fig.1), in particular interference from TAPS BS transmissions into PMR/PAMR BS receivers. The report specifically studies the different scenarios of PMR/PAMR and TAPS systems in the 410-430 MHz bands. However, similar figures apply to the 380-400 and the 450-470 MHz bands.

It should be noted that the report does not consider the interference from existing PMR/PAMR radio systems into TAPS deployed in adjacent bands, since the effect from the new systems on the incumbent ones is the most important part to deal with.

2 METHODOLOGY

2.1 Monte Carlo

Monte Carlo modelling using SEAMCAT® (Spectrum Engineering Advanced Monte Carlo Analysis Tool) was undertaken in the following scenarios.

- Scenario 1, TAPS MS into PMR/PAMR MS (at frequencies around the duplex transition frequency)
- Scenario 2, TAPS MS into PMR/PAMR BS (at frequencies in the uplink band)
- Scenario 3, TAPS BS into PMR/PAMR MS (at frequencies in the downlink band)
- Scenario 4, TAPS BS into PMR/PAMR BS (at frequencies around the duplex transition frequency).

The scenarios were modelled for a block of 2.8 MHz (14 x 200 kHz channels) interfering with a block of 2 MHz of PMR/PAMR (160 x 12.5 kHz channels) where the geographical position of the systems and the frequencies of both TAPS and PMR/PAMR systems are randomised. In addition a scenario was modelled where the PMR/PAMR system is operating on a single adjacent channel to provide more precise information about the impact of the guard band (all other parameters as above).

In the scenarios where mobile stations are involved the SEAMCAT® tool is used exclusively. This is because of the statistical distribution of the mobile stations for which reason MCL was deemed inappropriate.

In the special case of the TAPS BS to PMR/PAMR BS scenario the SEAMCAT® tool was used to determine the actual size of the problem of interference between two base stations randomly positioned within a given area and with random selected frequency from within their respective sub bands.

2.2 MCL

Minimum Coupling Loss (MCL) is a method which involves calculating a static link budget. It is used in addition to the MC SEAMCAT tool for the base station to base station scenarios (see fig.4) where TAPS is the interferer and PMR/PAMR is the victim. This approach is used because both the interferer and victim are fixed both in frequency and geographical position (static interference scenario). MCL is a means to address the worst case scenario that can determine how much additional attenuation is required for interference free operation.

MCL is used in the frequency range where uplink meets downlink (e.g. around 419-421 MHz), for the case

TAPS (downlink) > PMR/PAMR (uplink). It uses a single channel for both the PMR/PAMR system and TAPS.

3 INTERFERENCE MODELLING

This section presents results from the interference modelling undertaken, firstly using SEAMCAT and then using MCL for the BS to BS case.

The following study investigates the interference that occurs from a TAPS transmitter into a PMR/PAMR receiver.

Two mechanisms have been identified that need to be considered when introducing TAPS services in the band.

Blocking will occur where the incoming power from the TAPS transmitters is above the specified PMR/PAMR blocking level; this will desensitise the PMR/PAMR receiver such that the reference sensitivity performance may not be maintained.

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[3] Not in all European countries, see footnote 1 in the Executive Summary of this report.

The Unwanted Emission (Spurious Emission and Wide Band Noise) from the TAPS transmitters that is above the receiver noise floor will desensitise the PMR/PAMR receiver such that low level signals may not be received.

All specifications used in the calculations have been derived using standard ETSI specification values as these represent the worst case values even though it is recognised that in practice real equipment performance may be better. With respect to the parameters required for the MCL and MC methods used in this report it was decided to use the requirements of ES 300 113 and EN 300 092.

3.1 Propagation models and AIDs

The propagation models were selected so as to be appropriate for the task.

3.1.1 Monte Carlo models:

All Monte Carlo models were undertaken using the Extended Hata propagation model as defined by WGPT SE21.

3.1.2 Minimum Coupling Loss:

ITU recommends that for distances up to 1 kilometre ITU Rec. P1411 is appropriate. However, for this distance and for antenna heights above 9 metres, P 1411 and the Free Space propagation model deliver the same mean value. In the MCL scenario (TAPS BS TX into PMR/PAMR BS RX) the Free Space propagation model has been used to calculate the path loss.

3.1.3 Active Interferer Densities:

The active interferer densities (AID) were calculated on the basis that a limited amount of spectrum would be available. This report focuses on a 2.8 MHz band for TAPS. 2.8 MHz will result in a total of 14 frequency channels being available with the normal quantity of transmitters per base station being limited to 1. This is the minimum spectrum which would be required for a TAPS network.

TAPS employs GPRS technology. It is assumed that the typical number of users of a single frequency carrier at any one time will be unlikely to be more than 3. Based on this user density and the calculated cell radii the AIDs would appear as follows:

Environment	Cell Radius (km)	Cell Area (km^2)	AID (max) ($1/km^2$)	Number of Users at 0.015 Erlangs	AID (typical) ($1/km^2$)	Number of Users at 0.015 Erlangs
Urban	2	12.6	0.5	420	0.1	84
Suburban	7	154	0.1	1027	0.02	205
Rural	15	707	0.02	943	0.004	189

Table 1: Description of Cell Radii and Active Interferer Density

Maximum modelled AID figures are higher than would normally be experienced in a PAMR network and very considerably higher than would be found in a PMR network. The Urban maximum AID of 420 users and a total traffic of 6.3 Erlangs would be found in perhaps the most densely used cell in a national network. 1,000 users occupying a suburban cell is also very unlikely, it is equivalent to UHF system with 19 channels on each base station.

The typical AIDs use figures are more representative of the user volumes found in a PAMR network. 84 users in 12 square kilometres would be representative of the total number of users in taxi and field service organisations in a large town. Similarly 205 users in a suburban cell or 1.3 users per square kilometre would describe a UHF system with only six channels. 190 users in a rural cell represent one user for each 5 square kilometres and is slightly higher than would normally be expected in a rural environment.

3.2 Monte Carlo modelling results

Monte Carlo simulations were performed using the CEPT's SEAMCAT modelling tool in order to establish the level of interference from TAPS into PMR/PAMR 12.5kHz systems. The simulations considered four scenarios, namely:

- Scenario 1, TAPS MS into PMR/PAMR MS (at frequencies around the duplex transition frequency)
- Scenario 2, TAPS MS into PMR/PAMR BS (at frequencies in the uplink band)
- Scenario 3, TAPS BS into PMR/PAMR MS (at frequencies in the downlink band)
- Scenario 4, TAPS BS into PMR/PAMR BS (at frequencies around the duplex transition frequency).

The effect of a TAPS 2.8 MHz band into PMR/PAMR was the main case considered. The effect of a TAPS 4.4 MHz band was also studied.

In each results table the typical values of interference are highlighted. Please also see section 4.1 on variation of results.

3.2.1 Scenario 1 Results, MS to MS

The following tables 2.1-2.5 contain results of SEAMCAT modelling of the probability of interference from TAPS MS into PMR/PAMR MS for a variety of different guard bands.

		Urban		Suburban		Rural	
Guard Band⇩	AID ⇨	0.5	0.1	0.1	0.02	0.02	0.004
100 kHz		0.14%	0.03%	0.03%	0.01%	0.02%	0.00%
150 kHz		0.12%	0.03%	0.03%	0.00%	0.01%	0.00%
300 kHz		0.12%	0.02%	0.03%	0.01%	0.01%	0.00%
500 kHz		0.11%	0.02%	0.03%	0.01%	0.01%	0.00%
1700 kHz		0.11%	0.02%	0.02%	0.00%	0.01%	0.00%

Table 2.1: TAPS MS 2.8 MHz band into PMR/PAMR MS 2 MHz band

		Urban		Suburban		Rural	
Guard Band⇩	AID ⇨	0.5	0.1	0.1	0.02	0.02	0.004
100 kHz		0.14%	0.02%	0.03%	0.00%	0.01%	0.00%
150 kHz		0.11%	0.02%	0.03%	0.01%	0.01%	0.00%
300 kHz		0.10%	0.03%	0.03%	0.00%	0.01%	0.00%
500 kHz		0.12%	0.02%	0.02%	0.01%	0.01%	0.00%
1700 kHz		0.09%	0.02%	0.02%	0.01%	0.01%	0.00%

Table 2.2: TAPS MS 4.4 MHz band into PMR/PAMR MS 2 MHz band

		Urban		Suburban		Rural	
Guard Band⇩	AID ⇨	0.5	0.1	0.1	0.02	0.02	0.004
100 kHz		0.22%	0.04%	0.06%	0.01%	0.03%	0.00%
150 kHz		0.18%	0.05%	0.06%	0.01%	0.03%	0.01%
300 kHz		0.19%	0.04%	0.07%	0.01%	0.02%	0.01%
500 kHz		0.18%	0.04%	0.06%	0.01%	0.02%	0.01%
1700 kHz		0.17%	0.04%	0.05%	0.01%	0.02%	0.00%

Table 2.3: TAPS MS 2.8 MHz band into TETRA MS 2 MHz band

		Urban		Suburban		Rural	
Guard Band⇩	AID ⇨	0.5	0.1	0.1	0.02	0.02	0.004
100 kHz		0.23%	0.05%	0.05%	0.01%	0.02%	0.01%
150 kHz		0.19%	0.04%	0.05%	0.01%	0.02%	0.00%
300 kHz		0.17%	0.04%	0.04%	0.01%	0.02%	0.01%
500 kHz		0.17%	0.02%	0.04%	0.01%	0.01%	0.00%
1700 kHz		0.11%	0.02%	0.03%	0.00%	0.01%	0.00%

Table 2.4: TAPS MS 2.8 MHz band into PMR/PAMR MS single adjacent channel

Guard Band⇩	AID ⇨	Urban		Suburban		Rural	
		0.5	0.1	0.1	0.02	0.02	0.004
100 kHz		0.28%	0.05%	0.10%	0.03%	0.01%	0.01%
150 kHz		0.27%	0.05%	0.08%	0.02%	0.05%	0.01%
300 kHz		0.24%	0.05%	0.07%	0.01%	0.03%	0.00%
500 kHz		0.20%	0.04%	0.06%	0.01%	0.03%	0.01%
1700 kHz		0.19%	0.04%	0.06%	0.01%	0.03%	0.00%

Table 2.5: TAPS MS 2.8 MHz band into TETRA MS single adjacent channel

The results indicate that, even for AID values that are very high, the probability of interference is very low.

3.2.2 Scenario 2 Results, MS to BS

The following tables 3.1-3.5 contain results of SEAMCAT modelling of probability of interference from TAPS MS into PMR/PAMR BS for a variety of different guard bands.

Guard Band⇩	AID ⇨	Urban		Suburban		Rural	
		0.5	0.1	0.1	0.02	0.02	0.004
100 kHz		0.71%	0.14%	0.38%	0.06%	0.51%	0.08%
150 kHz		0.70%	0.13%	0.37%	0.05%	0.41%	0.09%
300 kHz		0.68%	0.12%	0.32%	0.05%	0.41%	0.08%
500 kHz		0.62%	0.13%	0.29%	0.05%	0.33%	0.06%
1700 kHz		0.53%	0.10%	0.23%	0.03%	0.29%	0.05%

Table 3.1: TAPS MS 2.8 MHz band into PMR/PAMR BS 2 MHz band

Guard Band⇩	AID ⇨	Urban		Suburban		Rural	
		0.5	0.1	0.1	0.02	0.02	0.004
100 kHz		0.69%	0.12%	0.28%	0.06%	0.37%	0.06%
150 kHz		0.60%	0.12%	0.31%	0.06%	0.37%	0.07%
300 kHz		0.61%	0.11%	0.27%	0.06%	0.36%	0.07%
500 kHz		0.58%	0.12%	0.29%	0.05%	0.30%	0.06%
1700 kHz		0.49%	0.09%	0.19%	0.04%	0.26%	0.04%

Table 3.2: TAPS MS 4.4 MHz band into PMR/PAMR BS 2 MHz band

		Urban		Suburban		Rural	
Guard Band⇩	AID ⇨	0.5	0.1	0.1	0.02	0.02	0.004
100 kHz		2.62%	0.54%	1.90%	0.36%	2.47%	0.52%
150 kHz		2.54%	0.54%	1.82%	0.39%	2.31%	0.52%
300 kHz		2.44%	0.47%	1.74%	0.37%	2.18%	0.44%
500 kHz		2.35%	0.49%	1.63%	0.34%	2.08%	0.42%
1700 kHz		2.10%	0.44%	1.51%	0.29%	1.83%	0.39%

Table 3.3: TAPS MS 2.8 MHz band into TETRA BS 2 MHz band

		Urban		Suburban		Rural	
Guard Band⇩	AID ⇨	0.5	0.1	0.1	0.02	0.02	0.004
100 kHz		1.81%	0.42%	0.94%	0.21%	1.33%	0.30%
150 kHz		1.45%	0.33%	0.76%	0.14%	1.06%	0.21%
300 kHz		1.04%	0.19%	0.50%	0.09%	0.67%	0.13%
500 kHz		0.94%	0.17%	0.46%	0.09%	0.56%	0.11%
1700 kHz		0.49%	0.08%	0.22%	0.04%	0.30%	0.06%

Table 3.4: TAPS MS 2.8 MHz band into PMR/PAMR BS single adjacent channel

		Urban		Suburban		Rural	
Guard Band⇩	AID ⇨	0.5	0.1	0.1	0.02	0.02	0.004
100 kHz		4.96%	1.29%	3.98%	1.08%	5.05%	1.37%
150 kHz		4.22%	0.97%	3.31%	0.76%	4.23%	1.05%
300 kHz		3.31%	0.67%	2.46%	0.52%	3.13%	0.67%
500 kHz		3.00%	0.60%	2.18%	0.47%	2.84%	0.65%
1700 kHz		2.51%	0.53%	1.79%	0.37%	2.23%	0.45%

Table 3.5: TAPS MS 2.8 MHz band into TETRA BS single adjacent channel

3.2.3 Scenario 3 Results, BS to MS

The following tables 4.1-4.5 results of SEAMCAT modelling of probability of TAPS BS into PMR/PAMR MS for a variety of different guard bands.

		Urban	Suburban	Rural
Guard Band⇩	AID ⇨	0.0796	0.0065	0.0014
100 kHz		0.15%	0.03%	0.03%
150 kHz		0.17%	0.03%	0.03%
300 kHz		0.14%	0.03%	0.04%
500 kHz		0.14%	0.02%	0.02%
1100 kHz		0.12%	0.03%	0.03%
1700 kHz		0.12%	0.03%	0.02%

Table 4.1: TAPS BS 2.8 MHz band into PMR/PAMR MS 2 MHz band

The results indicate that the probability of interference is extremely low.

		Urban	Suburban	Rural
Guard Band⇩	AID ⇨	0.0796	0.0065	0.0014
100 kHz		0.16%	0.03%	0.03%
150 kHz		0.15%	0.03%	0.03%
300 kHz		0.14%	0.02%	0.02%
500 kHz		0.14%	0.02%	0.03%
1100 kHz		0.12%	0.01%	0.02%
1700 kHz		0.11%	0.02%	0.02%

Table 4.2: TAPS BS 4.4 MHz band into PMR/PAMR MS 2 MHz band

		Urban	Suburban	Rural
Guard Band⇩	AID ⇨	0.0796	0.0065	0.0014
100 kHz		0.33%	0.08%	0.12%
150 kHz		0.31%	0.10%	0.10%
300 kHz		0.31%	0.08%	0.09%
500 kHz		0.30%	0.09%	0.09%
1100 kHz		0.29%	0.09%	0.09%
1700 kHz		0.27%	0.08%	0.08%

Table 4.3: TAPS BS 2.8 MHz band into TETRA MS 2 MHz band

		Urban	Suburban	Rural
Guard Band⇩	AID ⇨	0.0796	0.0065	0.0014
100 kHz		0.58%	0.11%	0.19%
150 kHz		0.43%	0.10%	0.10%
300 kHz		0.26%	0.05%	0.06%
500 kHz		0.21%	0.04%	0.04%
1100 kHz		0.15%	0.02%	0.02%
1700 kHz		0.13%	0.02%	0.02%

Table 4.4: TAPS BS 2.8 MHz band into PMR/PAMR MS single adjacent channel

		Urban	Suburban	Rural
Guard Band⇩	AID ⇨	0.0796	0.0065	0.0014
100 kHz		0.86%	0.33%	0.38%
150 kHz		0.63%	0.20%	0.24%
300 kHz		0.37%	0.11%	0.11%
500 kHz		0.34%	0.09%	0.10%
1100 kHz		0.28%	0.09%	0.09%
1700 kHz		0.29%	0.08%	0.10%

Table 4.5: TAPS BS 2.8 MHz band into TETRA MS single adjacent channel

3.2.4 Scenario 4 Results, BS to BS

The following tables 5.1-5.5 contain results of SEAMCAT modelling of probability interference from TAPS BS into PMR/PAMR BS for a variety of different guard bands.

		Urban	Suburban	Rural
Guard Band⇩	AID ⇨	0.0796	0.0065	0.0014
100 kHz		7.63%	1.94%	0.68%
150 kHz		7.38%	1.91%	0.69%
300 kHz		6.93%	1.81%	0.54%
500 kHz		6.58%	1.61%	0.52%
1100 kHz		6.41%	1.51%	0.46%
1700 kHz		6.29%	1.51%	0.44%

Table 5.1: TAPS BS 2.8 MHz band into PMR/PAMR BS 2 MHz band

		Urban	Suburban	Rural
Guard Band⇩	AID ⇨	0.0796	0.0065	0.0014
100 kHz		7.27%	1.95%	0.66%
150 kHz		7.33%	1.84%	0.61%
300 kHz		6.96%	1.70%	0.55%
500 kHz		6.53%	1.62%	0.49%
1100 kHz		6.36%	1.46%	0.42%
1700 kHz		6.00%	1.43%	0.41%

Table 5.2: TAPS BS 4.4 MHz band into PMR/PAMR BS 2 MHz band

Guard Band⇩	AID ⇨	Urban	Suburban	Rural
		0.0796	0.0065	0.0014
100 kHz		21.87%	11.31%	5.34%
150 kHz		21.70%	11.42%	5.25%
300 kHz		21.12%	10.91%	4.86%
500 kHz		21.02%	10.65%	4.76%
1100 kHz		20.13%	10.19%	4.60%
1700 kHz		19.92%	10.14%	4.34%

Table 5.3: TAPS BS 2.8 MHz band into TETRA BS 2 MHz band

Guard Band⇩	AID ⇨	Urban	Suburban	Rural
		0.0796	0.0065	0.0014
100 kHz		14.68%	6.01%	3.36%
150 kHz		13.52%	5.15%	2.63%
300 kHz		11.32%	3.56%	1.49%
500 kHz		9.60%	2.78%	1.05%
1100 kHz		6.94%	1.65%	0.50%
1700 kHz		6.33%	1.47%	0.42%

Table 5.4: TAPS BS 2.8 MHz band into PMR/PAMR BS single adjacent channel

Guard Band⇩	AID ⇨	Urban	Suburban	Rural
		0.0796	0.0065	0.0014
100 kHz		29.29%	17.97%	10.55%
150 kHz		28.03%	16.84%	9.13%
300 kHz		24.97%	13.71%	6.88%
500 kHz		23.36%	12.39%	5.76%
1100 kHz		21.25%	10.88%	4.94%
1700 kHz		19.91%	10.00%	4.41%

Table 5.5: TAPS BS 2.8 MHz band into TETRA BS single adjacent channel

For the special case where downlink interferes with uplink around the transition frequencies i.e. 390, 420 and 460 MHz, although the probabilities of interference are reasonably low for the suburban and rural cases, the results for the urban case suggest that coordination is required. From the urban results it can be seen that with a 300 kHz guard band.

- In the case of interference of TAPS BS into PMR/PAMR BS approximately 7% of the cases will require mitigation,
- In the case of interference of TAPS BS into TETRA BS approximately 21% of cases will require some sort of mitigation.

3.3 *MCL modelling for the BS to BS case (Scenario 4)*

The scenario used for the BS to BS interference includes the urban and suburban case where antennas of base stations are mounted on rooftops. This will lead to a worst case situation where the antennas of the TAPS and PMR/PAMR base stations are facing each other and have a direct line of sight. For this scenario a separation distance of 20 metres was selected to form the basis for the calculations.

Another scenario for BS to BS is where the antennas are co-sited, for this a coupling loss of 30 dB between the antennas has been introduced because this is a recognised standard value. An alternative coupling loss of 40 dB has been considered recognising that site engineering is able to provide additional coupling loss.

In the following figures 2-4, the attenuation required to avoid interference as a function of separation distance is depicted. The MCL method is used to calculate the interference that may occur. The figures make use of the worst case scenario from the calculations of interference and add a free space propagation to extrapolate the required attenuation as a function of the physical separation distance.

The calculations were made for 20 m separation distance for the rooftop-to-rooftop scenario. For the close proximity of antennas scenario there are calculations for 30 dB and 40 dB isolation between the antennas.

A graphic representation is provided for blocking of the PMR/PAMR base station receiver by a TAPS transmitter as a function of separation distance for different power levels (figure 2). Also the influence of the spurious emission from TAPS is provided as a function of separation distance (figure 3). Further the influence of the wide band noise from TAPS is provided as a function of separation distance for different frequency separations (figure 4).

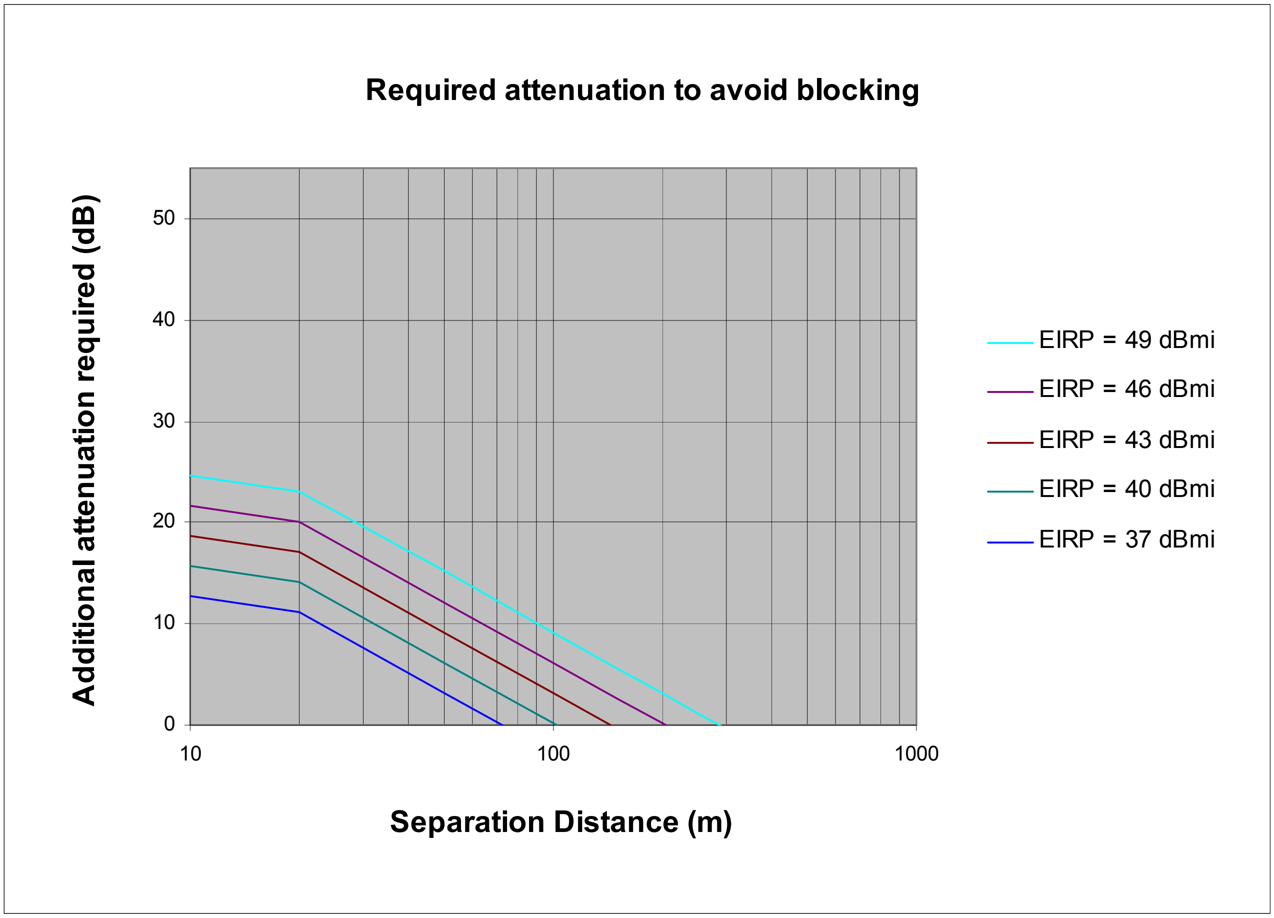

Figure 2: Required attenuation to avoid blocking

Note:
Reference is made to table 7 (Annex1) for antennas facing each other on adjacent buildings (20 m) scenario at an EIRP of 49 dBmi. The additional output power ranges and separation distances have been derived by extrapolation.

It should be noted that the impact of blocking is only transmitter output power dependent. The required filter must be located at the PMR/PAMR base station receiver input terminal.

Required attenuation for two carriers = 10*LOG10(10^(attenuation 1st carrier/10)+10^(attenuation 2nd carrier /10)).
Deduct 2 dB if adjacent service is a TETRA system because TETRA has a 2 dB better protection to blocking.

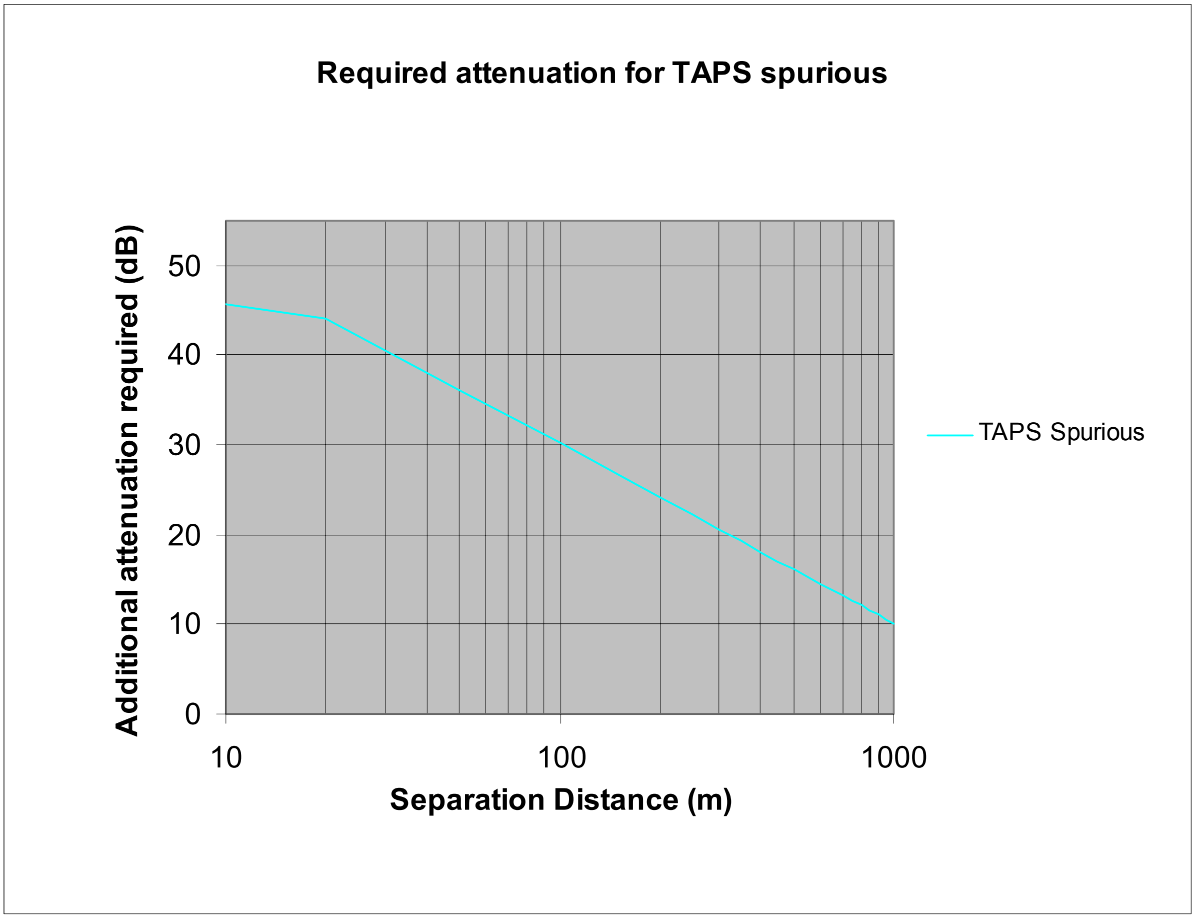

Figure 3: Required attenuation for TAPS spurious

Note 1:
Reference is made to table 8 (Annex 1) for the case of antennas facing each other on adjacent buildings (20 m). The additional separation distances have been derived by extrapolation.

Required attenuation for two carriers = 10*LOG10(10^(attenuation 1st carrier/10)+10^(attenuation 2nd carrier /10)).

Any filter required must be located at the transmitter's output terminal of the TAPS base station.

Note 2:
Because of the low probability that a spurious will occur at its limit and at the frequency of the adjacent PMR/PAMR base station receiver this should be considered a special case. The attenuation required for suppression of wide band noise will, with a high probability, also remove any spurious products. In the unlikely event where spurious emission proves to be the predominant source of interference additional attenuation must be provided according to the values above.

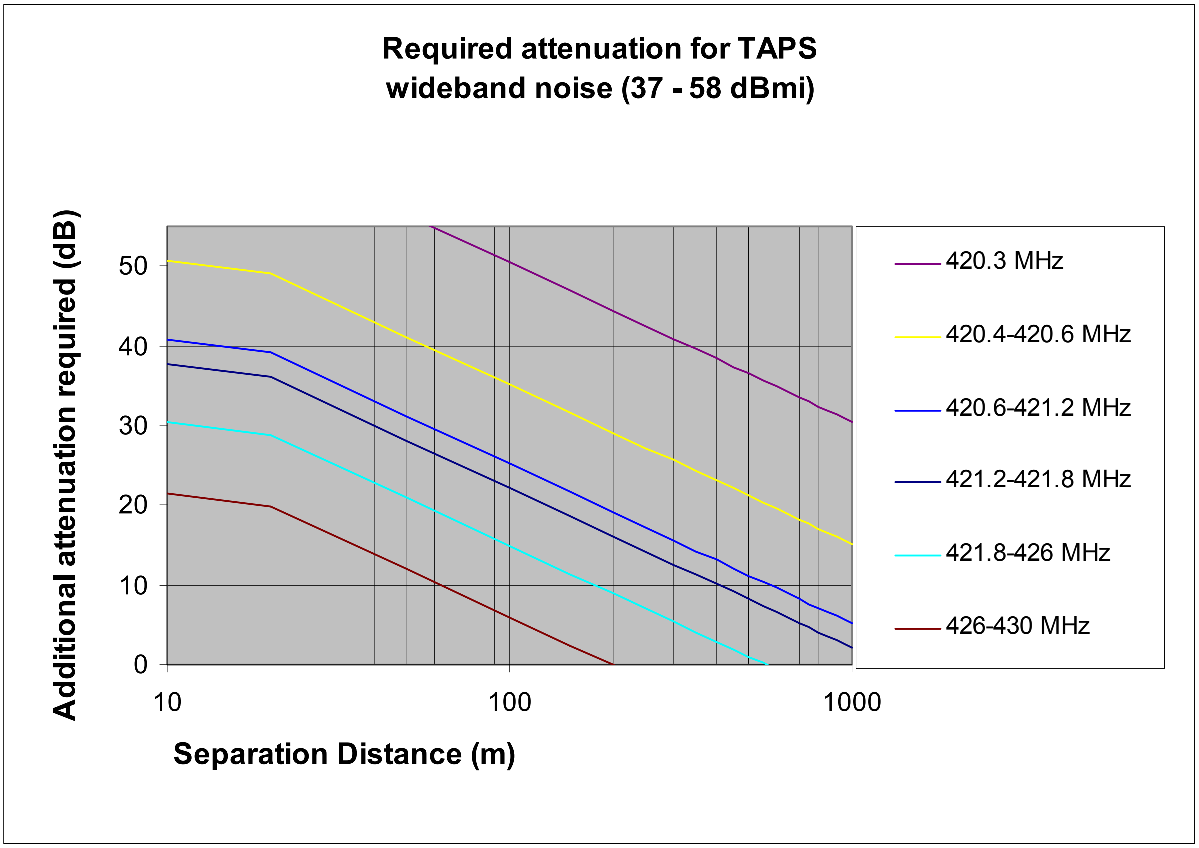

Figure 4: Required attenuation for TAPS wideband noise (37 - 58 dBmi)

Note:
Reference is made to table 9 (Annex 1) for the case of antennas facing each other on adjacent buildings (20 m) scenario covering the frequency range 420.3 to 430 MHz. The additional separation distances have been derived by extrapolation.

The victim is located at the channel immediately below 420 MHz.

It should be noted that for TAPS the impact of wideband noise is frequency dependent but is independent of the TAPS transmitter output power.

Any filter required must be located at the transmitter output terminal of a TAPS base station.

Required attenuation for two carriers = 10*LOG10(10^(attenuation 1st carrier/10)+10^(attenuation 2nd carrier /10)).

Add 3 dB if adjacent system is TETRA because the bandwidth is double of the 12.5 kHz calculated in the figure.

4 OBSERVATIONS

From the results of the calculations it is clear that a very low level of interference may be expected in the scenarios where mobile stations are involved. However, for the BS to BS scenario it is also clear from the probability of interference and the level of the attenuation required to avoid interference that co-ordination between TAPS and PMR/PAMR systems is required. This is true for the frequency region around the transition from uplink to downlink. If an uncoordinated approach were taken this would most likely result in interference to some PMR/PAMR base station receivers in the vicinity of a TAPS base station transmitter.

The results also show that to avoid blocking of PMR/PAMR BS receivers additional filtering at the PMR/PAMR BS receiver may be required when a PMR/PAMR BS receiver is located within a certain distance of a TAPS BS transmitter and both operate at frequencies around the transition between uplink and downlink. The amount of filtering required is dependent on the actual frequency, the number of carriers, the separation distance, the type of antennas deployed and the transmitter power of the TAPS BS.

In the case of wide band noise the results again show that filtering is required at the TAPS BS transmitter when located within a certain distance of a PMR/PAMR BS receiver. The amount of filtering required is dependent on the actual frequency, the number of carriers, the type of antennas deployed and the separation distance.

The interference reduced when a larger band (4.4 MHz) was employed for TAPS, therefore for the purpose of this study it can be assumed that the 2.8 MHz TAPS band is the worst case.

4.1 Variation of Results

All statistical models, which yield a percentage, are subject to errors resulting from the limits of the sample size. These errors are equivalent to the errors encountered in statistical sampling. In this study SEAMCAT® was run for 100,000 iterations. This was considered to be the best compromise between simulation run time and achievable accuracy. Using 100,000 iterations the potential for error is defined as a percentage error within which the real figure will occur for 95% of the time.

Table 3 shows the percentage variation with a 95% probability against the percentages determined by the model run 100,000 times.

Probability of Interference	± Error at 95%
30%	0.284%
10%	0.186%
3%	0.106%
1%	0.0617%
0.3%	0.034%
0.1%	0.0196%

Table 6: Percentage variation with a 95% probability

This probability of error is the percentage difference between the calculated figure and the true figure which will not be exceeded 95% of the time if the sample size i.e. number of iterations is 100,000. This means that 5% of the readings will vary from the true figure by greater than the figure shown. But of course we don't know whether it is by plus or minus. Normally the variation would be 2.5% plus and 2.5% minus.

5 MITIGATION FACTORS (BS to BS only)

As can be seen from the results in section 3, TAPS will be able to operate in the 400 MHz bands without causing harmful interference to adjacent PMR/PAMR services, provided that the geographic and/or frequency separation between TAPS and PMR/PAMR base stations is sufficiently large. A number of possible mitigation measures are available that can be used to avoid the possibility of harmful interference even when this is not the case.

In this section, different techniques are discussed that will enable TAPS base stations to operate without producing harmful interference into the PMR/PAMR base station receivers. The different techniques required to ensure the PMR/PAMR base station receiver can operate as intended are: frequency separation, physical separation distance, improved performance (filters) and any combination of these.

From the Monte Carlo modeling it is seen that between 7% and 21% of base stations at the transition band edge will require mitigation. The mitigation will in most cases only require additional filtering in the TAPS base station.

5.1 Frequency planning and co-ordination

It is necessary that the use of the frequencies around the transition between uplink and downlink at 390, 420 and 460 MHz is co-ordinated between the existing systems and the new TAPS system.

5.2 Separation distance

The use of physical separation is expected to be the normal way of achieving the majority of the necessary attenuation. It is the most cost effective way of establishing the required coupling loss between the TAPS base station transmitter and the PMR/PAMR base station receiver.

Physical separation is feasible in rural and suburban areas. It is also possible to use physical separation in urban areas either alone or as a partial solution. Because the PMR/PAMR systems are well established the task of finding suitable locations, meeting the physical separation criteria, will be on the new TAPS system.

5.3 Frequency separation

Use of frequency separation as a single solution to achieve the necessary attenuation of both the power and wideband noise from TAPS may be difficult. This is because of the availability of the amount of contiguous spectrum. This combined with the difficulties in network planning and especially re-planning for optimisation of the network makes frequency separation unattractive as a stand alone solution.

5.4 Filters

The performance of both the TAPS transmitter and the PMR/PAMR receiver can be improved using filters. To allow the filters to operate a guard band is considered necessary. The requirements of the filter needed for improving the PMR/PAMR receiver blocking performance are relatively low and do not require any power handling capability.

The filters necessary to improve the TAPS transmitter wideband noise attenuation in the PMR/PAMR receiver frequency range are more demanding. The filters will also need to be able to dissipate the power.

5.5 Separation distance and filters

Where it is impossible to establish sufficient physical separation to eliminate blocking and desensitisation by wideband noise of the PMR/PAMR base station receiver additional filters could be used. The filters are selected to produce the desired attenuation, taking into account the physical separation distance loss at the particular frequency separation, for the PMR/PAMR base station receiver to operate as intended.

6 CONCLUSIONS

From the above SEAMCAT calculations it can be seen that, provided a guard band of 100 kHz is used, the risk of harmful interference from TAPS interfering with PMR/PAMR 12.5 and 25 kHz systems in the 400MHz bands is very low for the MS to MS, MS to BS ad BS to MS cases.

It is however clear for the BS to BS case, that the utilisation of TAPS requires co-ordination between the existing PMR/PAMR systems and the new TAPS system at the frequencies around the transition between uplink and downlink at 390, 420 and 460 MHz. Mitigation in the form of filters will be required in some cases. To allow the filters to operate, a guard band of 300 kHz is considered to be necessary at the duplex transition frequency between base stations.

Concerning the protection of the existing PMR/PAMR base station receivers against interference from TAPS base station transmissions, the technical requirements for the utilisation of the 380-400, 410-430 and 450-470MHz bands have been found.

It should be noted that the report does not consider the interference from existing PMR/PAMR radio systems into TAPS deployed in adjacent bands, since the effect from the new systems on the incumbent ones is the most important part to deal with. Since this direction of interference will address interference from narrow band 12.5/25 kHz to wider band systems, it has been considered that under the conditions presented above TAPS systems would not be interfered with and both systems would then be compatible.

ANNEX 1: MCL CALCULATIONS OF THE TAPS BS INTO PMR/PAMR BS SCENARIO (SCENARIO 4).

By considerations of blocking, TAPS	TAPS Tx power Watts	losses dB	Tx Ant Gain dBi	TAPS Tx EIRP - dBm dBmi	No of Tx	Distance m	Free space propagation dB	FM RX antenna gain dB	feeders etc dB	Interference power dBm	specified blocking (EN 300 113 (5.2.8)) dBm	**Required attenuation for blocking** dB
Shared site antennas facing or antennas on adjacent buildings	7.9	1.0	11.0	49.0	1.0	20.0	50.9	3.0	1.0	0.1	-23.0	23.1
Antennas in close proximity	7.9	1.0	0.0	N/A	1.0	N/A	30.0	0.0	1.0	7.0	-23.0	30.0
Antennas in close proximity	7.9	1.0	0.0	N/A	1.0	N/A	40.0	0.0	1.0	-3.0	-23.0	20.0

Table 7: Calculation of the required attenuation to avoid blocking of a PMR/PAMR Base Station Receiver from TAPS Base Station Transmitter

I) Propagation model used is free space loss for antenna distances of 20m and over.
II) The antenna gain of the victim (PMR/PAMR) and interferer (TAPS) base station is assumed to be 3 dBi and 11 dBi respectively.
III) It has been agreed that a figure of 30 dB is used between two antennas in close proximity because it is considered a standard value. 40 dB is also included because improved attenuation can be achieved with high gain antennas by site engineering.

By consideration of TAPS spurious	Conducted spurious: TAPS dBm	losses dB	Tx side ant gain dB	Radiated spurious dBmi dBmi	no of spurious	Distance m	Free space propagation dB	FM RX antenna gain dB	feeders etc dB	Interference power dBm	Protected sensitivity; C/I (12 dB) below neg 107 dBm dBm	**Required attenuation for spurious emission** dB
Shared site antennas facing or antennas on adjacent buildings	-36.0	1.0	11.0	-26.0	1.0	20.0	50.9	3.0	1.0	-74.9	-119.0	44.1
Antennas in close proximity	-36.0	1.0	0.0	-37.0	1.0	N/A	30.0	0.0	1.0	-68.0	-119.0	51.0
Antennas in close proximity	-36.0	1.0	0.0	-37.0	1.0	N/A	40.0	0.0	1.0	-78.0	-119.0	41.0

Table 8: Calculation of the required attenuation to avoid desensitisation of a PMR/PAMR Base Station Receiver from TAPS Base Station Transmitter spurious emission

I) Propagation model used is free space loss for antenna distances of 20m and over.
II) For antenna separation distances below 20m a fixed coupling of 30 and 40 dB has been used.
III) The antenna gain of the victim (PMR/PAMR) and interferer (TAPS) base station is assumed to be 3 dBi and 11 dBi respectively.
IV) The value of -113 dBm for protection of PMR/PAMR is from EN 300 113.

Note: Because of the low probability that a spurious will occur at its limit and at the frequency of the adjacent PMR/PAMR base station receiver this should be considered a special case. The attenuation required for suppression of wide band noise will, with a high probability, also remove any spurious products. In the unlikely event where spurious emission proves to be the predominant source of interference additional attenuation must be provided.

By consideration of wide band noise TAPS at 420.3 MHz	TAPS Tx power Watts	losses dB	Tx Ant Gain dBi	TAPS WBN interpolated dBc	Bandwidth gain (ref. 200 kHz. Victim bw. 8 kHz) dB	Radiated noise dBmi in 8 kHz dBmi	No	Distance m	Free space propagation dB	FM RX antenna gain dB	feeders etc dB	Interference power dBm	Protected sensitivity; C/I (12 dB) below neg 107 dBm dBm	**Required attenuation for wide band noise** dB
Shared site antennas facing or antennas on adjacent buildings	7.9	1.0	11.0	-40.7	-14.0	-5.7	1.0	20.0	50.9	3.0	1.0	-54.6	-119.0	64.4
Antennas in close proximity	7.9	1.0	0.0	-40.7	-14.0	-16.7	1.0	N/A	30.0	0.0	1.0	-47.7	-119.0	71.3
Antennas in close proximity	7.9	1.0	0.0	-40.7	-14.0	-16.7	1.0	N/A	40.0	0.0	1.0	-57.7	-119.0	61.3

By consideration of wide band noise TAPS at 420.4 - 420.6 MHz	TAPS Tx power Watts	losses dB	Tx Ant Gain dBi	TAPS WBN dBc	Bandwidth gain (ref. 200 kHz. Victim bw. 8 kHz) dB	Radiated noise dBmi in 8 kHz dBmi	No	Distance m	Free space propagation dB	FM RX antenna gain dB	feeders etc dB	Interference power dBm	Protected sensitivity; C/I (12 dB) below neg 107 dBm dBm	**Required attenuation for wide band noise** dB
Shared site antennas facing or antennas on adjacent buildings	7.9	1.0	11.0	-56.0	-14.0	-21.0	1.0	20.0	50.9	3.0	1.0	-69.9	-119.0	49.1
Antennas in close proximity	7.9	1.0	0.0	-56.0	-14.0	-32.0	1.0	N/A	30.0	0.0	1.0	-63.0	-119.0	56.0
Antennas in close proximity	7.9	1.0	0.0	-56.0	-14.0	-32.0	1.0	N/A	40.0	0.0	1.0	-73.0	-119.0	46.0

By consideration of wide band noise TAPS at 420.6 - 421.2 MHz	TAPS Tx power Watts	losses dB	Tx Ant Gain dBi	TAPS WBN dBc	Bandwidth gain (ref. 200 kHz. Victim bw. 8 kHz) dB	Radiated noise dBmi in 8 kHz dBmi	No	Distance m	Free space propagation dB	FM RX antenna gain dB	feeders etc dB	Interference power dBm	Protected sensitivity; C/I (12 dB) below neg 107 dBm dBm	**Required attenuation for wide band noise** dB
Shared site antennas facing or antennas on adjacent buildings	7.9	1.0	11.0	-66.0	-14.0	-31.0	1.0	20.0	50.9	3.0	1.0	-79.9	-119.0	39.1
Antennas in close proximity	7.9	1.0	0.0	-66.0	-14.0	-42.0	1.0	N/A	30.0	0.0	1.0	-73.0	-119.0	46.0
Antennas in close proximity	7.9	1.0	0.0	-66.0	-14.0	-42.0	1.0	N/A	40.0	0.0	1.0	-83.0	-119.0	36.0

By consideration of wide band noise TAPS at 421.2 - 421.8 MHz	TAPS Tx power Watts	losses dB	Tx Ant Gain dBi	TAPS WBN dBc	Bandwidth gain (ref. 200 kHz. Victim bw. 8 kHz) dB	Radiated noise dBmi in 8 kHz dBmi	No	Distance m	Free space propagation dB	FM RX antenna gain dB	feeders etc dB	Interference power dBm	Protected sensitivity; C/I (12 dB) below neg 107 dBm dBm	**Required attenuation for wide band noise** dB
Shared site antennas facing or antennas on adjacent buildings	7.9	1.0	11.0	-69.0	-14.0	-34.0	1.0	20.0	50.9	3.0	1.0	-82.9	-119.0	36.1
Antennas in close proximity	7.9	1.0	0.0	-69.0	-14.0	-45.0	1.0	N/A	30.0	0.0	1.0	-76.0	-119.0	43.0
Antennas in close proximity	7.9	1.0	0.0	-69.0	-14.0	-45.0	1.0	N/A	40.0	0.0	1.0	-86.0	-119.0	33.0

By consideration of wide band noise TAPS at 421.8 - 426 MHz	TAPS Tx power Watts	losses dB	Tx Ant Gain dBi	TAPS WBN dBc	Bandwidth gain (ref. 666 kHz. Victim bw. 8 kHz) dB	Radiated noise dBmi in 8 kHz dBmi	No	Distance m	Free space propagation dB	FM RX antenna gain dB	feeders etc dB	Interference power dBm	Protected sensitivity; C/I (12 dB) below neg 107 dBm dBm	**Required attenuation for wide band noise** dB
Shared site antennas facing or antennas on adjacent buildings	7.9	1.0	11.0	-71.0	-19.2	-41.2	1.0	20.0	50.9	3.0	1.0	-90.1	-119.0	28.9
Antennas in close proximity	7.9	1.0	0.0	-71.0	-19.2	-52.2	1.0	N/A	30.0	0.0	1.0	-83.2	-119.0	35.8
Antennas in close proximity	7.9	1.0	0.0	-71.0	-19.2	-52.2	1.0	N/A	40.0	0.0	1.0	-93.2	-119.0	25.8

By consideration of wide band noise TAPS at 426 - 430 MHz	TAPS Tx power Watts	losses dB	Tx Ant Gain dBi	TAPS WBN dBc	Bandwidth gain (ref. 666 kHz. Victim bw. 8 kHz) dB	Radiated noise dBmi in 8 kHz dBmi	No	Distance m	Free space propagation dB	FM RX antenna gain dB	feeders etc dB	Interference power dBm	Protected sensitivity; C/I (12 dB) below neg 107 dBm dBm	**Required attenuation for wide band noise** dB
Shared site antennas facing or antennas on adjacent buildings	7.9	1.0	11.0	-80.0	-19.2	-50.2	1.0	20.0	50.9	3.0	1.0	-99.1	-119.0	19.9
Antennas in close proximity	7.9	1.0	0.0	-80.0	-19.2	-61.2	1.0	N/A	30.0	0.0	1.0	-92.2	-119.0	26.8
Antennas in close proximity	7.9	1.0	0.0	-80.0	-19.2	-61.2	1.0	N/A	40.0	0.0	1.0	-102.2	-119.0	16.8

Table 9 a - f. Calculation of the required attenuation to avoid desensitisation of a PMR/PAMR Base Station Receiver from TAPS Base Station Transmitter wide band noise

These results are based on the following assumptions:

I) Propagation model used is free space loss for antenna distances of 20m and over.
II) For antenna separation distances below 20m a fixed coupling of 30 and 40 dB has been used.
III) The antenna gain of the victim (PMR/PAMR) and interferer (TAPS) base station is assumed to be 3 dBi and 11 dBi respectively.
IV) Bandwidth adjustment is required because TAPS is a 200 kHz carrier and PMR/PAMR 8 kHz carrier.
V) For frequency separation above 1.8 MHz TAPS effective measuring bandwidth is increased to 666 kHz resulting in a further 5.2 dB compensation for bandwidth.
VI) The value of -113 dBm for protection of PMR/PAMR is from EN 300 113

ANNEX 2: TECHNICAL PARAMETERS FOR SEAMCAT® MONTE CARLO MODELLING

Parameter			TAPS		FM		TETRA	
			MS	BS	MS	BS	MS	BS
Channel Spacing		kHz	200	200	12.5	12.5	25	25
Cell Radius – Urban (Note 1)		km	2		5		3.5	
– Suburban		km	7		7		6	
– Rural		km	15		20		16	
Transmit Power		dBm	33	35	37	41	30	34
Receiver Bandwidth		kHz	200	200	8	8	18	18
Antenna Height		m	1.5	30	1.5	30	1.5	30
Antenna Gain		dBi	-2 (0 - Rural)	10	0	3	0	10
Receiver Sensitivity		dBm	-104	-104	-106	-109	-103	-106
Receiver Protection Ratio		dB	9	9	12	12	19	19
Power Control Characteristics	Step	dBm	2	2	N/A	N/A	N/A	N/A
	Minimum	dBm	5	5	N/A	N/A	N/A	N/A
	Threshold	dBm	-85	-85	N/A	N/A	N/A	N/A

Note 1 : This coverage is limited by capacity. Without this limitation, this cell size would in practice be significantly exceeded in the 400 MHz band

Unwanted Emissions

Frequency Offset			TAPS	
			MS	BS
0	MHz	dBc	0.5	0.5
0.025	MHz	dBc	0.5	0.5
0.05	MHz	dBc	0.5	0.5
0.075	MHz	dBc	0.5	0.5
0.1	MHz	dBc	0.5	0.5
0.2	MHz	dBc	-30	-30
0.25	MHz	dBc	-33	-33
0.3	MHz	dBc	-40	-40
0.4	MHz	dBc	-54	-54
0.5	MHz	dBc	-57	-57
0.6	MHz	dBc	-60	-66
1.1	MHz	dBc	-60	-66
1.2	MHz	dBc	-60	-69
1.7	MHz	dBc	-60	-69
1.8	MHz	dBc	-68.2	-76.2
2.9	MHz	dBc	-68.2	-76.2
3	MHz	dBc	-70.2	-76.2
5.9	MHz	dBc	-70.2	-76.2
6	MHz	dBc	-76.2	-85.2
20	MHz	dBc	-76.2	-85.2

Receiver Blocking Characteristics

Frequency Offset		FM	
		MS	BS
4 kHz	dBc	0	0
6.25 kHz	dBc	60	60
18.75 kHz	dBc	60	60
18.76 kHz	dBc	70	70
1000 kHz	dBc	70	70
1000.01 kHz	dBc	84	84
20000 kHz	dBc	84	84

Frequency Offset		TETRA	
		MS	BS
100 kHz	dBc	0	0
600 kHz	dBc	67	84
799.99 kHz	dBc	67	84
800 kHz	dBc	67	94
1599.99 kHz	dBc	67	94
1600 kHz	dBc	77	94
2999.99 kHz	dBc	77	94
3000 kHz	dBc	87	97
20000 kHz	dBc	87	97

Active Interferer Densities

Environment	TAPS	
	MS	BS (1/Cell)
Urban	0.5, 0.1	0.0796
Suburban	0.1, 0.02	0.0065
Rural	0.02, 0.004	0.0014