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

COMPATIBILITY BETWEEN TETRA RELEASE 2 TAPS AND TACTICAL RADIO RELAYS IN THE 870-876 AND 915-921 MHz BANDS

Stockholm, October 2004

EXECUTIVE SUMMARY

This report considers sharing between TETRA Release 2 TAPS and Tactical Radio Relay links (TRR) in the 870-876 / 915-921 MHz band.

Specifically this report sets out:

1. To define the necessary geographical separation if systems operate within distinctly separate geographical areas;
2. To define the necessary frequency separation if systems operate in the same area.

Studies related to the effect of TRR sharing with narrowband PMR systems have previously been considered within ECC Report 34 [1].

The two methods used in this study are complementary to each other:

- The SEAMCAT® method calculates the probability of interference, which gives the extent of the problem.
- The MCL method provides the necessary attenuation required between the systems to enable interference-free operation under specified conditions.

The MCL method indicates that for the scenarios investigated the potential of interference exists at very large distances when the frequency used is shared and no mitigation techniques are applied.

It can be seen that frequency separation alone requires very large guard bands to avoid interference. In a rural environment operation of TRR and TAPS is feasible provided a guard band is established of 750 kHz in the case of Eurocom and 1500 kHz for STANAG 4212. In suburban and urban environments for both TRR types there will be a risk of interference.

The use of geographical separation alone requires large separation distances. Operation of TRR and TAPS is feasible provided a separation 70km for Eurocom and 80 km for STANAG 4212 is maintained.

It can also be deduced from the progression of the results for both frequency and physical separation distance that a combination of these may be used to optimise the co-existence between actual deployments of TAPS and TRRs. This will allow operation at smaller distances with a minimum guard band. The use of co-ordination and mitigation techniques as described in section 5 would further reduce the required minimum gap between the separated geographical service areas and /or the required frequency separation.

Where sharing is wanted there are several mitigation techniques that can be applied, some of which require some degree of co-ordination and others that are mainly good engineering practices. These techniques are mainly applicable where there is a geographical separation between TAPS and the Tactical Radio Relay systems and are:

- Use of directional antennas for TAPS base stations pointing away from known military exercise areas.
- Optimise, when practical, the alignment of the TRR antennas to minimise interference, but at the same time maintain the wanted link. However, this may imply reduction of the TRR operational capabilities.
- Mitigation can be brought by careful selection of frequency used by TRR, for example where a TRR is pointing towards a known TAPS system it should preferably use TAPS downlink frequencies. In such a case the TAPS uplink frequencies could be used by the coupled TRR which is pointing away from the TAPS base station.
- Using the power setting of the TRR to increase the wanted link signal level in case of interference from TAPS. The same limitations as above apply. However, it will also increase the interference from TRR to TAPS.
- The use of direct contact to the TAPS operator for reducing the power of a particular base station (this implies regulatory measures such as license requirements).

It should also be noted that the band 870-871 paired with 915-916 MHz is foreseen as a guard band between TAPS and GSM (ref ECC Report 005 [5]). Therefore this band will not be used by TAPS and the effect of interference between TRR and TAPS is minimised where TRR uses these frequencies. Combined with a degree of co-ordination between the operators, solutions could be found for cases where the two systems are not overlapping geographically, such as specific military exercise areas, if directional antennas are used for nearby TAPS coverage.

This study only considered situations where both systems operate continuously within the defined areas (i.e. no activity factor has been taken into account for the TRR).

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Compatibility between TETRA release 2 taps and Tactical Radio Relays in the 870-876 and 915-921 MHz bands

1 INTRODUCTION

This report is concerned with the joint use of TETRA Release 2 TAPS (wideband PMR) and conventional Military Tactical Radio Relay links (TRR) equipment in the same band. Therefore, it is necessary to study the possibilities for sharing between TAPS and Military TRR in the 870-876 MHz and 915-921 MHz bands before taking a final decision on the strategic plan for the 900 MHz band. Studies related to the effect of TRR sharing with narrowband PMR systems have already been considered within ECC Report 34 [1].

This report focuses on the technical impact of introducing TAPS on the existing tactical radio relay links (TRR) in the bands 870-876 and 915-921 MHz.

The purpose of this Report is:

1. To define the figure of necessary geographical separation if systems would operate within distinctly separate geographical areas;
2. To define the figure of necessary frequency separation[1] if systems would operate co-located in the same area.

The two methods used in this study are complementary to each other:

- The SEAMCAT® method. For the purposes of these calculations the TRR is deemed to be mobile, but will be static for a period of time. In the modelling of TAPS mobile and TRR the probability of interference is calculated. For the TAPS base station and TRR it models the probability of interference at each location.
- The MCL method, used to analyse the interference between base stations, provides the necessary attenuation required between the systems to enable interference-free operation under specified conditions.

The report uses technical parameters available from the relevant standards combined with realistic deployment scenarios. Two TRR equipment types have been considered in this report.

- STANAG 4212, NATO standard [2].
- Eurocom, STANAG 4212 enhanced with Unwanted Emissions and Blocking characteristics of AN/GRC-245, Eurocom radio equipment.

The Eurocom deployment has been considered as it is more spectrally efficient than the STANAG 4212 deployment.

Parameters used for TAPS were taken from previous studies for ECC Report 22 [3].

The report considers two operational cases, co-channel and adjacent channel operation (illustrated in Figures 1 & 2). Each case considers the four scenarios listed below to assess the impact on each system of introducing TAPS into the band.

- TAPS-MS into TRR.
- TRR into TAPS-BS.
- TAPS-BS into TRR.
- TRR into TAPS-MS.

[1] The terms Frequency Separation or Guard Band are used in this report to describe the minimum separation (kHz) required between the channel edges of two adjacent band systems for them to co-exist.

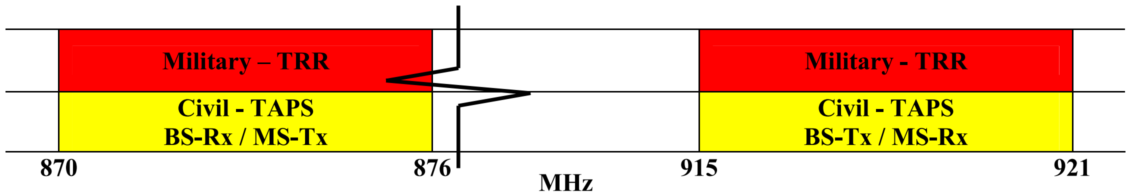

Figure 1: Co-channel Configuration

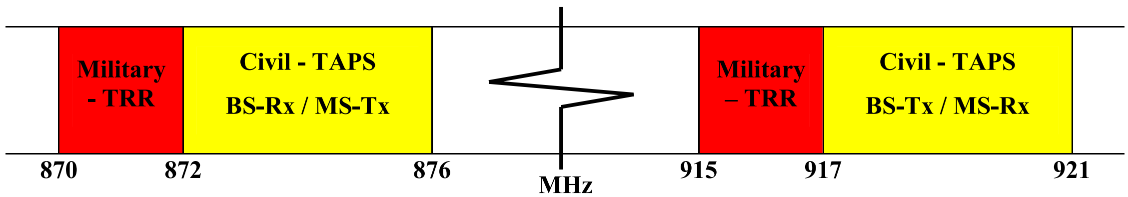

Figure 2: Adjacent Channel Configuration

2 METHODOLOGY

2.1 Co-channel Operation

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

- C-1) TAPS-MS into TRR between 870-876 MHz
- C-2) TRR into TAPS-BS between 870-876 MHz
- C-3) TAPS-BS into TRR between 915-921 MHz
- C-4) TRR into TAPS-MS between 915-921 MHz

In all scenarios the TAPS system was deployed in an urban environment while the environment of the TRR system was varied.

Mitigation techniques were used to determine a geographical separation that is necessary to allow the two systems to co-exist. Using the facility within SEAMCAT® it is possible to enter a distribution to represent the effect of the two systems existing in two discrete areas illustrated in Figure 3. In this study the term "Gap" refers to the distance between the two discrete areas of operation, i.e. where Gap = 0 the operational areas touch but do not overlap.

Where this mitigation technique has been examined a single TAPS cell has been considered moving away from a 55 km radius TRR operating area.

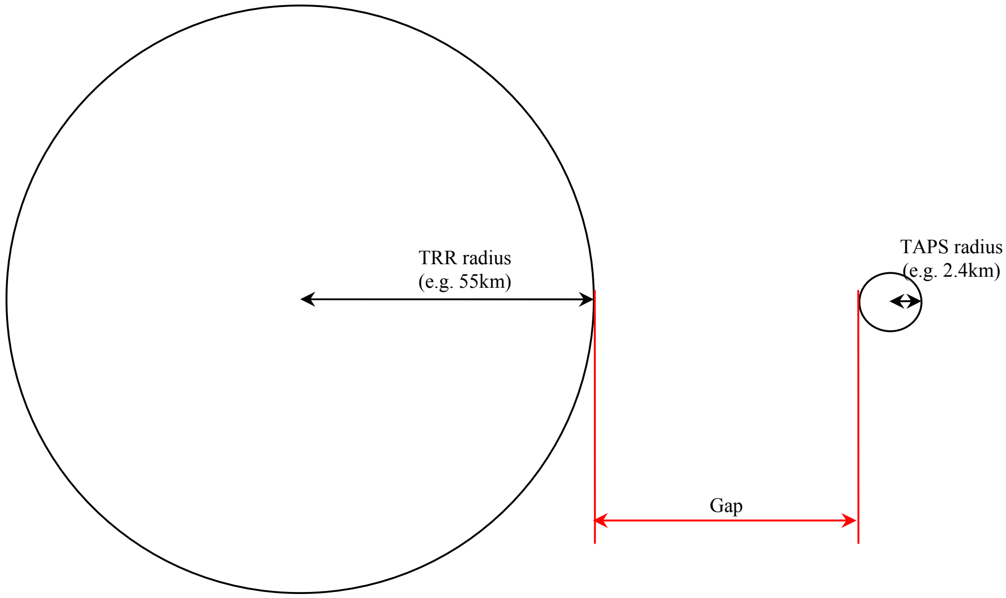

Figure 3: Geographical Separation of Systems

2.2 Adjacent Channel Operation

For adjacent channel operation Monte Carlo modelling using SEAMCAT® was undertaken in the following scenarios.

A-1) TAPS-MS into TRR around 872 MHz

A-2) TRR into TAPS-BS around 872 MHz

A-3) TAPS-BS into TRR around 917 MHz

A-4) TRR into TAPS-MS around 917 MHz

In all scenarios the TAPS system was deployed in an urban environment while the environment of the TRR system was varied.

The above scenarios were analysed to assess the guard band necessary to facilitate co-existence, an illustration of the frequency separation is shown for the TAPS uplink band in Figure 4, this is mirrored in the TAPS downlink band.

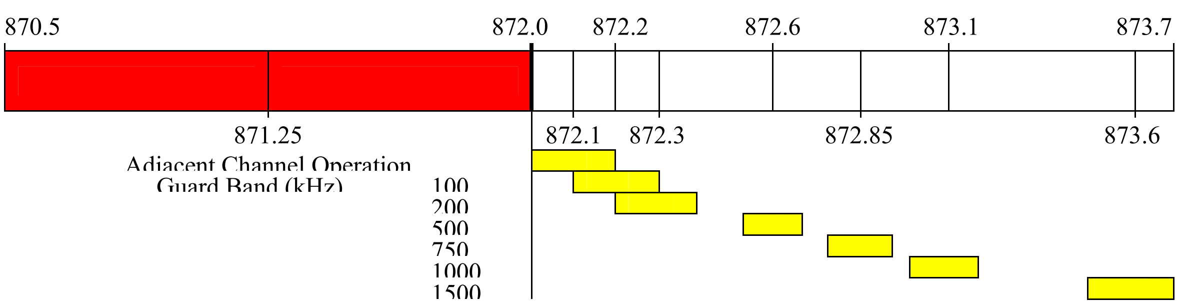

Figure 4: Frequency Separation of Systems

2.3 Base to Base MCL Modelling

Minimum Coupling Loss (MCL) is a method which involves calculating a static link budget. It is used in addition to the Monte Carlo modelling for the base station to base station scenarios. 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.

3 INTERFERENCE MODELLING

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

3.1 Propagation Models and Active Interferer Densities

3.1.1 Propagation models

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

All Monte Carlo and MCL calculations models were undertaken using the Extended Hata propagation model as defined by WGPT SE21 [4] in order to be able to make a good comparison of the results.

3.1.2 Active Interferer Densities (AID)

3.1.2.1 TRR

Two values of AID have been considered for TRR, one based on military requirements, referred to as “maximum”, the second on TRR link budgets, referred to as “typical”.

Maximum AID Value used

75 links per 10,000 km^2 gave a figure of 0.0075 for AID. This value was provided by Military authorities and was also used in ECC Report 34.

Calculation of Typical AID Values

The typical AID for a TRR was calculated as follows:

Using MCL and the protected sensitivity of the TAPS system, an average path loss in order to cause interference was calculated. This path loss was applied to the antenna profile to generate a protection distance for each angle of the transmitting antenna. This is the distance at which there would be a 50% probability that a receiving antenna would receive the maximum permissible interference.

Converting these radii to sectors and totalling them yielded an area of 912 km^2. Therefore, for each transmitting antenna 912 km^2 is made unusable. The TRR operating area considered had a radius of 55 km with an area of 9503 km^2. This gives a limit to the number of times a single frequency can be repeated of 10.4. In reality this figure would be lower due to operational reasons concerning the siting of radio equipment.

Given the 6 MHz band available, allowing for filter roll-off, this enables 3 channels to be used for the STANAG 4212 equipment and 8 for the Eurocom equipment.

Using a frequency reuse of 5 gives:

- 40 links for the Eurocom equipment; and
- 15 links for the STANAG 4212 equipment.

These figures were used during the modelling

3.1.2.2 TAPS

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 ($1/km^2$)	No. Users at 0.015 Erlangs	AID – Typical ($1/km^2$)	No. 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 AID 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 Co-channel Operation Monte Carlo Modelling Results

Note: For urban scenarios, the TRR link will only be achieved for approximately 45% of time using the specified parameters before interference is applied, this can be seen from the desired received signal strength (dRSS) given in the SEAMCAT® report. This rises to approximately 80% for suburban and 100% for rural scenarios.

Values highlighted in bold fall below 2% interference.

3.2.1 Scenario C-1, TAPS-MS into TRR

	TAPS AID ($1/km^2$)	TRR Environment Urban
STANAG 4212	0.5	96.07%
STANAG 4212	0.1	70.56%
EUROCOM	0.5	84.85%
EUROCOM	0.1	45.73%
		TRR Environment Suburban
STANAG 4212	0.5	80.64%
STANAG 4212	0.1	43.98%
EUROCOM	0.5	62.02%
EUROCOM	0.1	24.85%
		TRR Environment Rural
STANAG 4212	0.5	33.19%
STANAG 4212	0.1	9.13%
EUROCOM	0.5	17.04%
EUROCOM	0.1	3.98%

Table 2: Probability of interference from TAPS-MS into TRR between 870-876 MHz
(Co-channel, Co-located)

	Separation Gap (km) ⇨	0	0.25	5
	TAPS AID (1/km^2)	TRR Environment Urban		
STANAG 4212	0.5	2.13%	**1.91%**	**0.74%**
	0.1	**0.49%**	**0.43%**	**0.13%**
EUROCOM	0.5	**1.04%**	**0.86%**	**0.25%**
	0.1	**0.26%**	**0.21%**	**0.07%**
		TRR Environment Suburban		
STANAG 4212	0.5	**0.89%**	**0.75%**	**0.16%**
	0.1	**0.22%**	**0.21%**	**0.03%**
EUROCOM	0.5	**0.47%**	**0.28%**	**0.05%**
	0.1	**0.10%**	**0.06%**	**0.03%**
		TRR Environment Rural		
STANAG 4212	0.5	**0.24%**	**0.14%**	**0.01%**
	0.1	**0.05%**	**0.04%**	**0.00%**
EUROCOM	0.5	**0.10%**	**0.06%**	**0.00%**
	0.1	**0.03%**	**0.02%**	**0.00%**

Table 3: Probability of interference from TAPS-MS into TRR between 870-876 MHz
(Co-channel, Geographically Separated)

3.2.2 Scenario C-2, TRR into TAPS-BS

	TRR AID (1/km^2)	TRR Environment Urban
STANAG 4212	0.0075	81.08%
	0.0015	39.83%
EUROCOM	0.0075	76.50%
	0.0040	60.75%
		TRR Environment Suburban
STANAG 4212	0.0075	80.90%
	0.0015	40.21%
EUROCOM	0.0075	76.13%
	0.0040	60.41%
		TRR Environment Rural
STANAG 4212	0.0075	81.10%
	0.0015	39.62%
EUROCOM	0.0075	76.05%
	0.0040	60.45%

Table 4: Probability of interference from TRR into TAPS-BS between 870-876 MHz
(Co-channel, Co-located)

	Separation Gap (km) ⇨	0	70	80
	TRR AID (1/km^2)	TRR Environment Urban		
STANAG 4212	0.0075	60.07%	2.79%	**1.79%**
	0.0015	20.41%	**0.47%**	**0.37%**
EUROCOM	0.0075	53.78%	2.21%	**1.40%**
	0.0040	36.54%	**1.27%**	**0.39%**
	TRR Environment Suburban			
STANAG 4212	0.0075	59.45%	2.97%	**1.73%**
	0.0015	20.55%	**0.49%**	**0.37%**
EUROCOM	0.0075	53.37%	2.29%	**1.57%**
	0.0040	36.73%	**1.30%**	**0.03%**
	TRR Environment Rural			
STANAG 4212	0.0075	59.92%	2.87%	**1.70%**
	0.0015	20.12%	**0.51%**	**0.36%**
EUROCOM	0.0075	54.01%	2.26%	**1.41%**
	0.0040	36.56%	**1.23%**	**0.76%**

Table 5: Probability of interference from TRR into TAPS-BS between 870-876 MHz
(Co-channel, Geographically Separated)

3.2.3 Scenario C-3, TAPS-BS into TRR

	TRR Environment Urban
STANAG 4212	100.00%
EUROCOM	100.00%
	TRR Environment Suburban
STANAG 4212	99.99%
EUROCOM	99.92%
	TRR Environment Rural
STANAG 4212	100.00%
EUROCOM	93.83%

Table 6: Probability of interference from TAPS-BS into TRR between 915-921 MHz
(Co-channel, Co-located)

Separation Gap (km) ⇨	0	50	60	70
	TRR Environment Urban			
STANAG 4212	14.97%	3.15%	2.28%	**1.50%**
EUROCOM	7.07%	**1.38%**	**0.86%**	**0.66%**
	TRR Environment Suburban			
STANAG 4212	7.65%	**1.05%**	**0.73%**	**0.38%**
EUROCOM	3.61%	**0.33%**	**0.20%**	**0.15%**
	TRR Environment Rural			
STANAG 4212	**1.69%**	**0.06%**	**0.02%**	**0.01%**
EUROCOM	**0.78%**	**0.02%**	**0.01%**	**0.00%**

Table 7: Probability of interference from TAPS-BS into TRR between 915-921 MHz
(Co-channel, Geographically Separated)

3.2.4 Scenario C-4, TRR into TAPS-MS

	TRR AID (1/km²)	TRR Environment Urban
STANAG 4212	0.0075	**1.91%**
	0.0015	**0.33%**
EUROCOM	0.0075	**1.27%**
	0.0040	**0.70%**
		TRR Environment Suburban
STANAG 4212	0.0075	**1.74%**
	0.0015	**0.39%**
EUROCOM	0.0075	**1.34%**
	0.0040	**0.71%**
		TRR Environment Rural
STANAG 4212	0.0075	**1.92%**
	0.0015	**0.38%**
EUROCOM	0.0075	**1.29%**
	0.0040	**0.73%**

Table 8: Probability of interference from TRR into TAPS-MS between 915-921 MHz
(Co-channel, Co-located)

	Separation Gap (km) ⇨	0	0.25	5
	TRR AID (1/km²)	TRR Environment Urban		
STANAG 4212	0.0075	2.74%	**1.68%**	**0.18%**
	0.0015	**0.52%**	**0.31%**	**0.05%**
EUROCOM	0.0075	**1.95%**	**1.16%**	**0.12%**
	0.0040	**0.64%**	**0.05%**	**0.00%**
		TRR Environment Suburban		
STANAG 4212	0.0075	2.42%	**1.67%**	**0.23%**
	0.0015	**0.48%**	**0.32%**	**0.03%**
EUROCOM	0.0075	**1.16%**	**0.11%**	**0.00%**
	0.0040	**0.69%**	**0.09%**	**0.00%**
		TRR Environment Rural		
STANAG 4212	0.0075	2.63%	**1.68%**	**0.23%**
	0.0015	**0.51%**	**0.33%**	**0.05%**
EUROCOM	0.0075	**1.26%**	**0.15%**	**0.00%**
	0.0040	**0.61%**	**0.07%**	**0.00%**

Table 9: Probability of interference from TRR into TAPS-MS between 915-921 MHz
(Co-channel, Geographically Separated)

3.3 Adjacent channel Operation Monte Carlo Modelling Results

Values highlighted in bold fall below 2% interference.

3.3.1 Scenario A-1, TAPS-MS into TRR

	TAPS AID (1/km^2)	TRR Environment Urban
STANAG 4212	0.5	94.19%
	0.1	74.97%
EUROCOM	0.5	22.02%
	0.1	6.40%
		TRR Environment Suburban
STANAG 4212	0.5	80.66%
	0.1	48.29%
EUROCOM	0.5	8.75%
	0.1	**1.98%**
		TRR Environment Rural
STANAG 4212	0.5	33.15%
	0.1	10.73%
EUROCOM	0.5	**1.23%**
	0.1	**0.24%**

Table 10: Probability of interference from TAPS-MS into TRR around 872 MHz
(Adjacent Channel, Co-located)

Guard Band (kHz) ⇨ / TAPS AID (1/km^2) ⇩		100	200	500	750	1000	1500
		TRR Environment Urban					
STANAG 4212	0.5	84.31%	73.77%	33.66%	12.83%	5.09%	2.92%
	0.1	55.04%	40.71%	10.85%	2.97%	**1.08%**	**0.61%**
EUROCOM	0.5	10.55%	7.32%	3.76%	2.87%	2.36%	**1.73%**
	0.1	2.38%	**1.46%**	**0.78%**	**0.58%**	**0.49%**	**0.29%**
		TRR Environment Suburban					
STANAG 4212	0.5	61.31%	46.85%	14.73%	4.64%	**1.80%**	**0.99%**
	0.1	29.33%	18.85%	3.39%	**0.90%**	**0.35%**	**0.20%**
EUROCOM	0.5	3.73%	2.42%	**1.29%**	**0.98%**	**0.78%**	**0.53%**
	0.1	**0.78%**	**0.53%**	**0.21%**	**0.20%**	**0.15%**	**0.11%**
		TRR Environment Rural					
STANAG 4212	0.5	18.50%	10.73%	2.08%	**0.55%**	**0.19%**	**0.08%**
	0.1	4.79%	2.52%	**0.44%**	**0.10%**	**0.02%**	**0.04%**
EUROCOM	0.5	**0.46%**	**0.31%**	**0.16%**	**0.14%**	**0.08%**	**0.05%**
	0.1	**0.08%**	**0.06%**	**0.04%**	**0.03%**	**0.02%**	**0.01%**

Table 11: Probability of interference from TAPS-MS into TRR around 872 MHz
(Frequency Separated, Co-located)

3.3.2 Scenario A-2, TRR into TAPS-BS

	TRR AID (1/km²)	TRR Environment Urban
STANAG 4212	0.0075	33.22%
	0.0015	8.71%
EUROCOM	0.0075	11.32%
	0.0040	6.43%
		TRR Environment Suburban
STANAG 4212	0.0075	32.83%
	0.0015	9.09%
EUROCOM	0.0075	11.52%
	0.0040	6.35%
		TRR Environment Rural
STANAG 4212	0.0075	33.11%
	0.0015	8.95%
EUROCOM	0.0075	11.49%
	0.0040	6.19%

Table 12: Probability of interference from TRR into TAPS-BS around 872 MHz
(Adjacent Channel, Co-located)

Guard Band (kHz) ⇨ / TRR AID (1/km²) ⇩		100	200	500	750	1000	1500
	TRR Environment Urban						
STANAG 4212	0.0075	17.44%	7.83%	**0.55%**	**0.15%**	**0.17%**	**0.14%**
	0.0015	3.82%	**1.75%**	**0.10%**	**0.04%**	**0.03%**	**0.01%**
EUROCOM	0.0075	9.02%	7.88%	**0.86%**	**0.50%**	**0.52%**	**0.46%**
	0.0040	4.80%	4.27%	**0.39%**	**0.27%**	**0.24%**	**0.27%**
	TRR Environment Suburban						
STANAG 4212	0.0075	17.19%	7.77%	**0.50%**	**0.16%**	**0.11%**	**0.12%**
	0.0015	4.03%	**1.56%**	**0.09%**	**0.03%**	**0.01%**	**0.02%**
EUROCOM	0.0075	8.98%	7.83%	**0.87%**	**0.54%**	**0.54%**	**0.46%**
	0.0040	4.70%	4.33%	**0.53%**	**0.33%**	**0.30%**	**0.32%**
	TRR Environment Rural						
STANAG 4212	0.0075	17.48%	7.73%	**0.51%**	**0.11%**	**0.12%**	**0.13%**
	0.0015	4.18%	**1.73%**	**0.08%**	**0.02%**	**0.02%**	**0.02%**
EUROCOM	0.0075	8.66%	7.78%	**0.90%**	**0.46%**	**0.57%**	**0.49%**
	0.0040	4.82%	4.30%	**0.46%**	**0.31%**	**0.21%**	**0.29%**

Table 13: Probability of interference from TRR into TAPS-BS around 872 MHz
(Frequency Separated, Co-located)

Note: For TRR systems in an urban environment at an AID of 0.0075 additional scenarios were run for both TRR systems to establish the 2% interference level, in both cases this was 350 kHz.

3.3.3 Scenario A-3, TAPS-BS into TRR

	TRR Environment Urban
STANAG 4212	99.88%
EUROCOM	77.75%
	TRR Environment Suburban
STANAG 4212	99.00%
EUROCOM	58.88%
	TRR Environment Rural
STANAG 4212	87.89%
EUROCOM	21.96%

Table 14: Probability of interference from TAPS-BS into TRR around 917 MHz
(Adjacent Channel, Co-located)

Guard Band (kHz) ⇨	100	200	500	750	1000	1500
	TRR Environment Urban					
STANAG 4212	99.04%	97.69%	86.19%	65.50%	43.12%	28.46%
EUROCOM	62.52%	54.17%	34.22%	26.54%	23.56%	20.86%
	TRR Environment Suburban					
STANAG 4212	95.80%	91.77%	69.86%	44.00%	23.68%	13.43%
EUROCOM	41.12%	32.45%	16.90%	12.27%	10.34%	8.98%
	TRR Environment Rural					
STANAG 4212	74.67%	63.74%	31.32%	12.61%	4.23%	**1.93%**
EUROCOM	11.18%	7.52%	2.60%	**1.64%**	**1.47%**	**1.12%**

Table 15: Probability of interference from TAPS-BS into TRR around 917 MHz
(Frequency Separated, Co-located)

3.3.4 Scenario A-4, TRR into TAPS-MS

	TRR AID (1/km^2)	TRR Environment Urban
STANAG 4212	0.0075	**0.10%**
	0.0015	**0.02%**
EUROCOM	0.0075	**0.05%**
	0.0040	**0.02%**
	TRR Environment Suburban	
STANAG 4212	0.0075	**0.11%**
	0.0015	**0.02%**
EUROCOM	0.0075	**0.04%**
	0.0040	**0.01%**
	TRR Environment Rural	
STANAG 4212	0.0075	**0.10%**
	0.0015	**0.02%**
EUROCOM	0.0075	**0.02%**
	0.0040	**0.01%**

Table 16: Probability of interference from TRR into TAPS-MS around 917 MHz
(Adjacent Channel, Co-located)

Guard Band (kHz) ⇨ / TRR AID (1/km²) ⇩		100	200	500	750	1000	1500
	TRR Environment Urban						
STANAG 4212	0.0075	**0.06%**	**0.03%**	**0.02%**	**0.00%**	**0.01%**	**0.00%**
	0.0015	**0.01%**	**0.00%**	**0.01%**	**0.00%**	**0.00%**	**0.00%**
EUROCOM	0.0075	**0.03%**	**0.03%**	**0.02%**	**0.01%**	**0.00%**	**0.00%**
	0.0040	**0.00%**	**0.00%**	**0.01%**	**0.03%**	**0.01%**	**0.00%**
	TRR Environment Suburban						
STANAG 4212	0.0075	**0.06%**	**0.03%**	**0.00%**	**0.00%**	**0.00%**	**0.01%**
	0.0015	**0.00%**	**0.01%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
EUROCOM	0.0075	**0.04%**	**0.01%**	**0.01%**	**0.00%**	**0.01%**	**0.00%**
	0.0040	**0.01%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.01%**
	TRR Environment Rural						
STANAG 4212	0.0075	**0.05%**	**0.04%**	**0.01%**	**0.01%**	**0.00%**	**0.00%**
	0.0015	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
EUROCOM	0.0075	**0.03%**	**0.04%**	**0.02%**	**0.00%**	**0.00%**	**0.00%**
	0.0040	**0.04%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**

Table 17: Probability of interference from TRR into TAPS-MS around 917 MHz
(Frequency Separated, Co-located)

3.4 Base to Base MCL Modelling Results

In this section, the results of the calculations using the MCL method are presented.

3.4.1 TAPS-BS into TRR (915-921 MHz)

TAPS-BS Parameters	
Tx Power	35 dBm
Antenna Gain	15 dB *
ERP	50 dBm
Bandwidth	200 kHz

TRR Parameters	
Rx Sensitivity	-93 dBm
Protection Ratio	15 dB
Protected Sensitivity	-108 dBm
Antenna Gain	16 dB *
Bandwidth	1500 kHz

Table 18: MCL parameters for interference from TAPS-BS into TRR

* Only the main lobe is considered

3.4.1.1 Co-channel case

Assumption: For unwanted emissions, as TAPS bandwidth is much less than TRR bandwidth. Bandwidth conversion is 0 dB.

Required Path Loss	=	TAPS-BS ERP	-	TRR Protected Sensitivity	+	TRR Antenna Gain	+	Unwanted Emissions Bandwidth Conversion
	=	50	-	-108	+	16	+	0
	=	174 dB						

	Distance (km)		
Frequency (MHz)	**Urban**	**Suburban**	**Open Area**
915	33.2	42.3	100.9
921	33.1	42.2	100.7

Table 19: Co-channel separation distance: MCL results for TAPS-BS into TRR

3.4.1.2 Adjacent channel case

Assumption: Blocking effects are more significant than unwanted emissions.

Required Path Loss	=	TAPS-BS ERP	-	TRR Protected Sensitivity	+	TRR Antenna Gain	+	TRR Blocking Protection
	=	50	-	-108	+	16	+	Varies with frequency separation

The results are dependant on frequency separation and plotted in Figures 5 and 6.

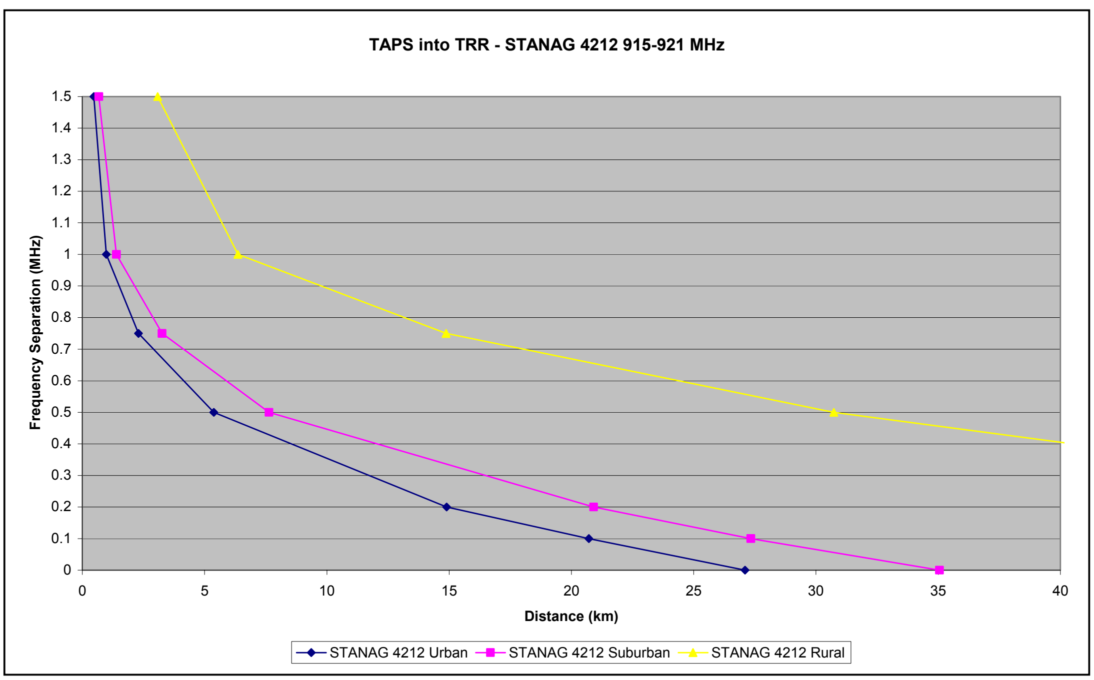

Figure 5: MCL for TAPS-BS into STANAG 4212 TRR dependant on frequency separation

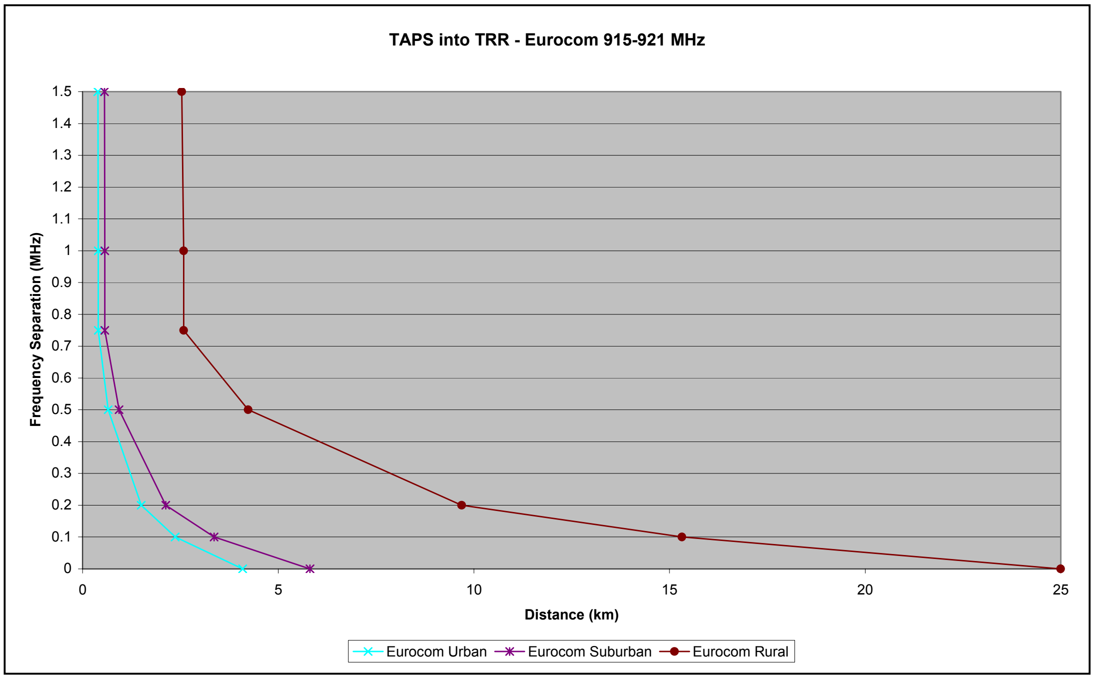

Figure 6: MCL for TAPS-BS into Eurocom TRR dependant on frequency separation

3.4.2 TRR into TAPS-BS (870-876 MHz)

TRR Parameters		
Tx Power		37 dBm
Antenna Gain		16 dB *
ERP		53 dBm
Bandwidth	STANAG 4212	750 kHz
	EUROCOM	496 kHz

TAPS-BS Parameters	
Rx Sensitivity	-104 dBm
Protection Ratio	9 dB
Protected Sensitivity	-113 dBm
Antenna Gain	15 dB *
Bandwidth	200 kHz

Table 20: MCL parameters for interference from TRR into TAPS-BS

* Only the main lobe is considered

3.4.2.1 Co-channel case

	STANAG 4212	EUROCOM
Unwanted Emissions Bandwidth Conversion	**10 Log (200/750) = -5.74**	**10 Log (200/496) = -3.94**

Table 21: Bandwidth conversion factors

Required Path Loss	=	TRR ERP	-	TAPS-BS Protected Sensitivity	+	TAPS-BS Antenna Gain	+	Unwanted Emissions Bandwidth Conversion
				STANAG 4212				
	=	53	-	-113	+	15	+	-5.74
	=	175.26 dB						
				EUROCOM				
	=	53	-	-113	+	15	+	-3.94
	=	177.06 dB						

STANAG

	Distance (km)		
Frequency (MHz)	**Urban**	**Suburban**	**Open Area**
870	36.1	45.8	107.4
876	36.0	45.6	107.1

Table 22: Co-channel MCL results for STANAG 4212 TRR into TAPS-BS

EUROCOM

	Distance (km)		
Frequency (MHz)	**Urban**	**Suburban**	**Open Area**
870	39.2	49.4	113.8
876	39.0	49.2	113.5

Table 23: Co-channel MCL results for EUROCOM TRR into TAPS-BS

3.4.2.2 Adjacent channel case

Assumption: Blocking effects are more significant than unwanted emissions.

Required Path Loss	=	TRR ERP	-	TAPS-BS Protected Sensitivity	+	TAPS-BS Antenna Gain	+	TAPS-BS Blocking Protection
	=	53	-	-113	+	15	+	Varies with frequency separation and TRR emissions bandwidth

The results are a dependant on frequency separation[1] and TRR system, plotted in Figures 7 and 8.

[1] The terms Frequency Separation or Guard Band are used in this report to describe the minimum separation (kHz) required between the channel edges of two adjacent band systems for them to co-exist.

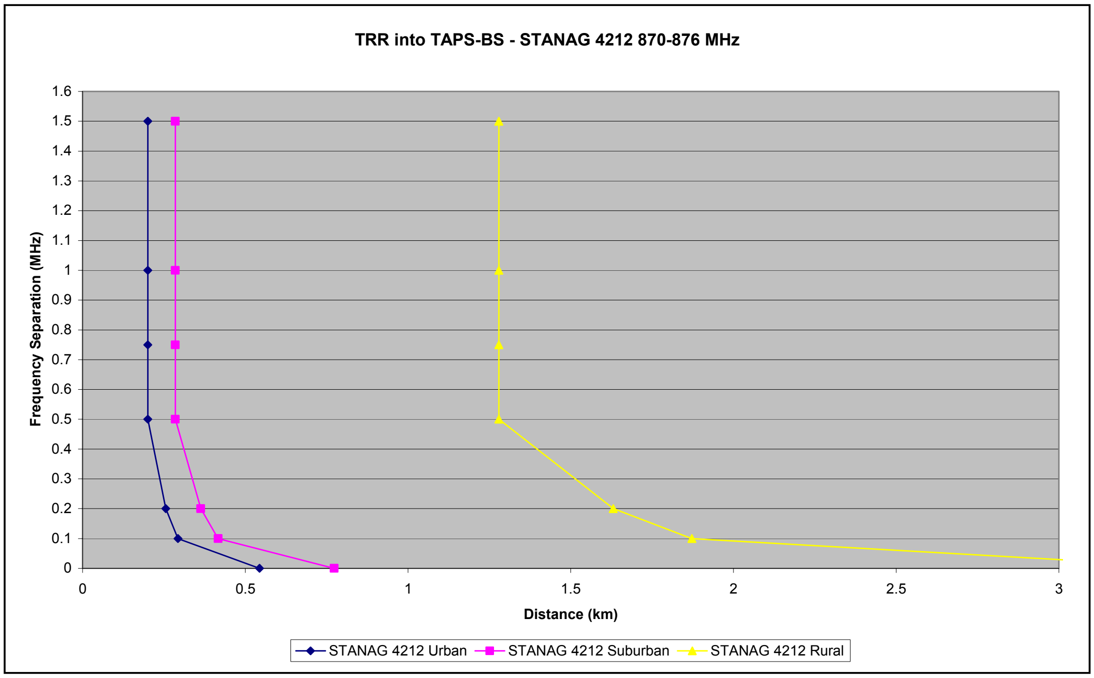

Figure 7: MCL for Eurocom TRR into TAPS-BS dependant on frequency separation

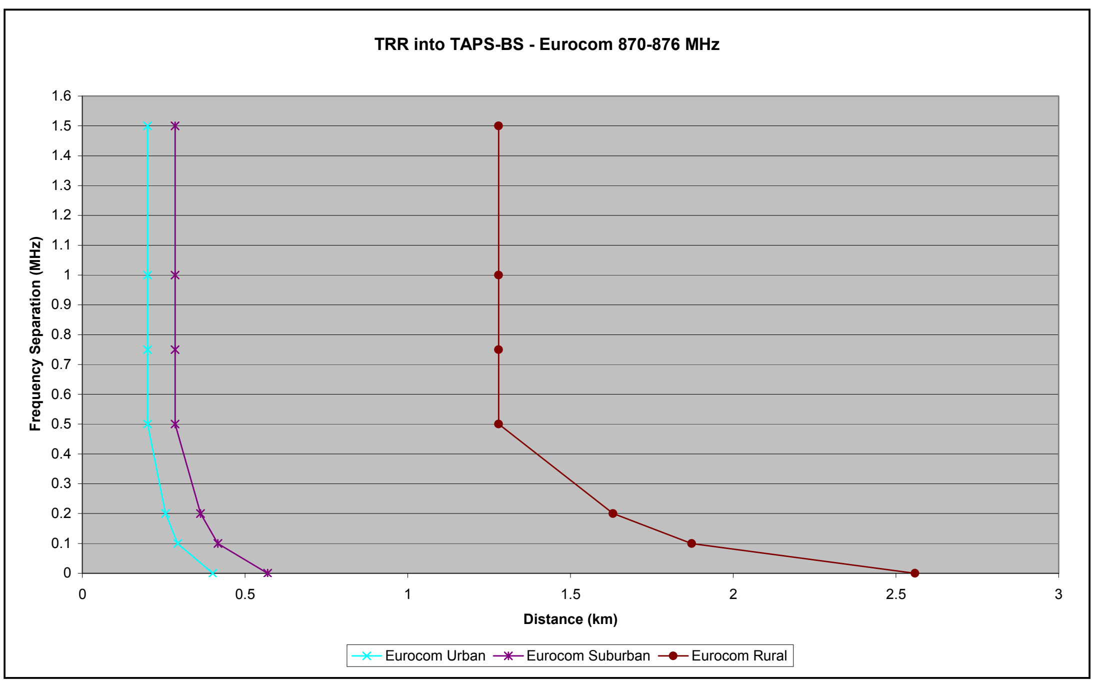

Figure 8: MCL for STANAG 4212 TRR into TAPS-BS dependant on frequency separation

4 OBSERVATIONS

For urban scenarios, the TRR link will only be achieved for approximately 45% of time using these parameters before interference is applied, this can be seen from the dRSS given in the SEAMCAT® report. This rises to approximately 80% and 100% for suburban and rural scenarios respectively.

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 50,000 iterations. This was considered to be the best compromise between simulation run time and achievable accuracy. Using 50,000 iterations the potential for error is defined as a percentage error within which the real figure will occur for 95% of the time.

Table 24 shows the percentage variation with a 95% probability against the percentages determined by the model run 50,000 times.

Probability of Interference	Error at 95%
30%	0.35%
10%	0.23%
3%	0.13%
1%	0.08%
0.3%	0.04%
0.1%	0.02%

Table 24: Interference estimation error 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 50,000. This means that 5% of the readings will vary from the true figure by greater than the figure shown. It is not known whether it is plus or minus.

5 MITIGATION FACTORS

Where sharing is wanted there are several mitigation techniques that can be applied, some of which require some degree of co-ordination and others that are mainly good engineering practices. These techniques are mainly applicable where there is a geographical separation between TAPS and the TRR systems and are:

- Use of directional antennas for TAPS base stations pointing away from known military exercise areas.
- Optimise, when practicable, the alignment of the TRR antennas to minimise interference but at the same time maintain the wanted link. However, this may imply reduction of the TRR operational capabilities.
- Mitigation can be brought by careful selection of frequency used by TRR, for example where a TRR is pointing towards a known TAPS system it should preferably use TAPS downlink frequencies. In such a case the TAPS uplink frequencies could be used by the coupled TRR which is pointing away from the TAPS base station.
- Using the power setting of the TRR to increase the wanted link signal level in case of interference from TAPS. The same limitations as above apply. However, it will also increase the interference from TRR to TAPS.
- The use of direct contact to the TAPS operator for reducing the power of a particular base station (this implies regulatory measures such as license requirements).

It should also be noted that, the band 870-871 paired with 915-916 MHz is foreseen as a guard band between TAPS and GSM (ref ECC Report 005 [5]). Therefore this band will not be used by TAPS and the effect of interference between TRR and TAPS is minimised where TRR uses these frequencies.

If a degree of co-ordination was introduced between the operators, solutions could be found for cases where the two systems are not overlapping geographically, such as specific military exercise areas, if directional antennas are used for nearby TAPS coverage.

6 CONCLUSIONS

The MCL method indicates that for the scenarios investigated the potential of interference exists at very large distances when the frequency used is shared and no mitigation techniques are applied. This sharing analysis also confirms that, when narrower and a wide band systems are deployed, the interference is determined in both directions by the bandwidth of the wider system.

The SEAMCAT® simulations provide the overall probability of interference in an uncoordinated approach. The extent of the problem is summarised in Tables 25 and 26, with the probability of interference criteria of 2%.

	Co-Located			Geographical Separation (gap in km – see Figure 3)
	Co-Channel	Adjacent Channel	Frequency Separation [1](kHz)	
Scenario ⇨	C-2	A-2	A-2	C-2
Table ⇨	4	12	13	5
STANAG 4212	Not possible	Not possible	350	80
Eurocom	Not possible	Not possible	350	70

Table 25: Assessment of co-existence prospects: TRR interference into TAPS base stations

Note: This summary is taken from results for TRR operating in an urban environment with an AID of 0.0075.
Interference from TRR into TAPS mobile stations is negligible, this can be seen in tables 16 and 17.

[1] The term Frequency Separation or Guard Band are used in this report to describe the minimum separation (kHz) required between the channel edges of two adjacent band systems for them to co-exist.

		Co-Located						Geographical Separation (gap in km – see Figure 3)	
		Co-Channel		Adjacent Channel		Frequency Separation [1](kHz)			
		MS	BS	MS	BS	MS	BS	MS	BS
	Scenario ⇨	C-1	C-3	A-1	A-3	A-1	A-3	C-1	C-3
	Table ⇨	2	6	10	14	11	15	3	7
STANAG 4212	Urban	No	No	No	No	**>1500**	No	**0**	**70**
	Suburban	No	No	No	No	**1000**	No	**0**	**50**
	Rural	No	No	No	No	**500**	**1500**	**0**	**0**
Eurocom	Urban	No	No	No	No	**1500**	No	**0**	**50**
	Suburban	No	No	No	No	**500**	No	**0**	**50**
	Rural	No	No	**OK**	No	**0**	**750**	**0**	**0**

Table 26: Assessment of co-existence prospects: TAPS interference into TRR

It can be seen that frequency separation alone requires very large guard bands to avoid interference. In a rural environment operation of TRR and TAPS is feasible provided a guard band of 750 kHz in the case of Eurocom and 1500 kHz for STANAG 4212 is established. In suburban and urban environments for both TRR types there will be a risk of interference.

The use of geographical separation alone requires large separation distances. Operation of TRR and TAPS is feasible provided a separation of 70 km for Eurocom and 80 km for STANAG 4212 is maintained.

It can also be deduced from the extension of the results for both frequency and physical separation distances, that a combination of these may be used to optimise the co-existence between actual deployments of TAPS and TRR systems. This will allow operation at smaller distances with a minimum guard band. The use of co-ordination and mitigation techniques as described in section 5 would further reduce the required minimum gap between the separated geographical service areas and/or the required frequency separation.

This study only considered situations where both systems operate continuously within the defined areas (i.e. no activity factor has been taken into account for the TRR).

7 REFERENCES

[1] ECC Report 34, Compatibility between Narrowband Digital PMR /PAMR and Tactical Radio Relay in the 900 MHz Band

[2] STANAG 4212 (TRR)

[3] ECC Report 22, 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

[4] SEAMCAT® User Documentation, Sep 2000

[5] ECC Report 005, Adjacent band compatibility between GSM and TETRA Mobile Services at 915 MHz.

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[1] Frequency Separation or Guard Band are the terms given in this report to the minimum separation (kHz) required between the channel edges of two adjacent band systems for them to co-exist.

ANNEX 1

TECHNICAL PARAMETERS USED FOR SEAMCAT® MONTE CARLO MODELLING

Parameter			TAPS		TRR
			MS	BS	
Channel Spacing		kHz	200	200	750
Cell Radius – Urban		km	2.4		30-70
Transmit Power		dBm	33	35	37
Receiver Bandwidth		kHz	200	200	1500
Antenna Height		m	1.5	30	25
Antenna Gain		dBi	0	15	16 (boresight)
Receiver Sensitivity		dBm	-104	-104	-93
Receiver Protection Ratio		dB	9	9	15
Power Control Characteristics	Step	dBm	2	N/A	N/A
	Minimum	dBm	5	N/A	N/A
	Dynamic range	dBm	28	N/A	N/A
	Threshold	dBm	-85	N/A	N/A

TRR Antenna Pattern

Angle	dB Gain relative to boresight
0	0
10	-3
18	-10
24	-15
30	-30
36	-12
48	-14
60	-20
84	-24
90	-26
136	-40
168	-32
180	-40
192	-26
224	-24
270	-20
276	-14
300	-12
312	-12
324	-30
336	-15
342	-10
350	-3
360	0

Unwanted Emissions

Frequency Offset		TRR		TAPS	
		STANAG 4212	EUROCOM	MS	BS
0 MHz	dBc	0	0	0.5	0.5
0.025 MHz	dBc			0.5	0.5
0.05 MHz	dBc		-0.8	0.5	0.5
0.075 MHz	dBc			0.5	0.5
0.1 MHz	dBc		-2.5	0.5	0.5
0.15 MHz	dBc		-2.5		
0.2 MHz	dBc		-4.2	-30	-30
0.25 MHz	dBc		-6.7	-33	-33
0.3 MHz	dBc		-10	-40	-40
0.35 MHz	dBc		-16.7		
0.375 MHz	dBc	0			
0.4 MHz	dBc		-25.8	-54	-54
0.45 MHz	dBc		-20.8		
0.5 MHz	dBc		-20	-57	-57
0.55 MHz	dBc		-23.3		
0.6 MHz	dBc		-29.2	-60	-66
0.65 MHz	dBc		-38.3		
0.7 MHz	dBc		-40.8		
0.75 MHz	dBc		-40.8		
0.8 MHz	dBc		-42.9		
0.85 MHz	dBc		-46.7		
0.9 MHz	dBc		-50		
0.95 MHz	dBc		-46.7		
1 MHz	dBc		-45.4		
1.05 MHz	dBc		-47.5		
1.1 MHz	dBc		-54.2	-60	-66
1.15 MHz	dBc		-60		
1.2 MHz	dBc		-61.7	-60	-69
1.25 MHz	dBc		-62.5		
1.3 MHz	dBc		-64.2		
1.35 MHz	dBc		-66.7		
1.4 MHz	dBc		-68.3		
1.425 MHz	dBc		-70		
1.5 MHz	dBc	-80			
1.7 MHz	dBc			-60	-69
1.8 MHz	dBc			-68.2	-76.2
2 MHz	dBc		-70		
2.9 MHz	dBc			-68.2	-76.2
3 MHz	dBc			-70.2	-76.2
4 MHz	dBc		-71.6		
5.9 MHz	dBc			-70.2	-76.2
6 MHz	dBc		-74	-76.2	-85.2
8 MHz	dBc		-77.5		
10 MHz	dBc	-80	-80	-76.2	-85.2

Notes on the calculation of the EUROCOM unwanted emission mask are given in Annex 2.

Receiver Blocking Characteristics

Frequency Offset		TRR		TAPS	
		STANAG 4212	EUROCOM	MS	BS
0.01 MHz	dBc		0		
0.06 MHz	dBc		0.2		
0.1 MHz	dBc			0	0
0.12 MHz	dBc		0.7		
0.18 MHz	dBc		1.6		
0.24 MHz	dBc		2.9		
0.36 MHz	dBc		6.5		
0.48 MHz	dBc		11.7		
0.6 MHz	dBc		18.2	61	78
0.72 MHz	dBc		26.2		
0.75 MHz	dBc	0			
0.799 MHz	dBc			61	78
0.8 MHz	dBc			61	88
0.84 MHz	dBc		35.7		
0.96 MHz	dBc		46.7		
1.28 MHz	dBc		60		
1.5 MHz	dBc		70		
1.599 MHz	dBc			61	88
1.6 MHz	dBc			71	88
2 MHz	dBc	65	70		
2.999 MHz	dBc			71	88
3 MHz	dBc			81	91
4 MHz	dBc		71.6		
5 MHz	dBc	85			
6 MHz	dBc		74		
8 MHz	dBc		77.5		
10 MHz	dBc	110	80	81	91
88 MHz	dBc	110			

Active Interferer Densities

	TRR		TAPS	
	STANAG 4212	EUROCOM	MS	BS
Typical AID	0.0015	0.0040	0.1	0.0553 (1/Cell)
Highest probable AID	0.0075	0.0075	0.5	

ANNEX 2

CALCULATION OF PROFILE FOR TRANSMITTED POWER

The SEAMCAT Monte Carlo modelling tool uses the bandwidth of the radio system in order to calculate the proportion of a wide band interfering signal which affects the victim receiver. For this reason it is necessary to define a bandwidth.

For the Eurocom compatible TRR it was only possible to obtain a power profile. It was therefore necessary to convert this to a Tx Power profile and to calculate the nominal band width.

This procedure was less easy than would normally be the case because the power profile of a signal of this type has a strong central peak.

Methodology

The procedures used involved the calculation of the power spectrum as 50 kHz and 25 kHz increments. The mean power for each of these increments was converted into dBm units. They were summed and the mean power was calculated.

Results

The mean power was 2.6 dB below the peak power.

It was assumed that the nominal bandwidth would be given by the bandwidth measured at a value 3 dB below the mean power i.e. 5.6 dB below the peak power. The bandwidth for this figure is 496 kHz.

In order to confirm that this bandwidth was valid the power was summed and it was found that 90% of the total power was within this bandwidth.

A bandwidth of 496 kHz was therefore used in the SEAMCAT models.