ECC REPORT 55

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COMPATIBILITY BETWEEN EXISTING AND PROPOSED SRDS AND OTHER RADIOCOMMUNICATION APPLICATIONS IN THE 169.4-169.8 MHZ FREQUENCY BAND

Stockholm, October 2004

EXECUTIVE SUMMARY

This report presents results of a theoretical study, based on minimum coupling loss method. Three scenarios were studied:

- S1 Compatibility between social alarms and high power applications (channels 8b and 9);
- S2 Sharing between SRDs and asset tracking/tracing applications, with the aim of determining the maximum power of the latter to ensure sharing between these systems;
- S3 Sharing between SRDs and hearing aids, knowing that SRDs are considered to be the main application in the shared part of the band.

Scenario 1: The upper social alarm channel is only separated by 6.25 kHz from the high power allocations, therefore the transmitter noise of the high power transmitter is still significantly high. In the Urban case the calculated required separation distance is about 2400 m when the frequency separation is 25 kHz or less. For a frequency separation of 100 kHz or more the required separation distance is about 150 m. It is not considered necessary to move the upper social alarm channel as there is an alternative second social alarm channel in cases where the upper channel can not be used. However, the social alarm receiver immunity performance has to be improved by 10 to 20 dB above the characteristics given in EN 300220 for operation in the 169MHz band.

Scenario 2: The proposed short range device applications refer to specific use of meter reading and tracking/tracing and not to non-specific generic applications. Therefore only the proposed applications were considered. Two applications are co-channel therefore they are required to share the band. Both systems are low duty cycle and should be able to share the available spectrum, provided they are used only for the intended purpose. Suitable coding and protocol should be used, not necessarily the same one. Listen-before-talk technique could also benefit the systems, especially the automatic meter reading systems, although missing one or two daily reading would not be a problem.

For the purpose of the study 10 mW erp was assumed for the low power tracking system. Although increasing the radiated power would benefit the tracking system, it would have an adverse affect for the meter reading system. Since both systems are co-channel and have to share spectrum, and both are low duty cycle systems it was felt that if a higher radiated power than 10 mW were permitted, then a listen-before-talk protocol should be used.

Scenario 3: As the hearing aids for both public and private are analogue systems, they will receive disturbances from the SRD data systems in the shared band. However, since two alternative channels have been proposed for the hearing aid systems then the potential of interference is reduced.

Again the SRD data systems are low duty cycle, therefore disturbances should be relatively few.

The referenced ETSI standards define blocking response at a frequency offset of at least 1 MHz. Since the frequency range of this study is only 400 kHz, the blocking response of the victim has been calculated at as close as 100 kHz separation.

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1 INTRODUCTION

The ERMES paging system had been allocated to the frequency band 169.4 – 169.8 MHz in accordance with ERC Decision(94)02 and EU Council Directive 90/544/EEC. However, a survey conducted by ERO, which was presented to the FM Working Group in January 2002 showed that in most European countries the paging systems have not reached the expected market penetration. Therefore FM Working Group decided to review the potential re-use of the frequency band. As there was an EU Directive for the ERMES Service, the European Commission also issued a mandate to CEPT for this work, in the light of Community policy.

The project team proposed the following applications for the band that was endorsed by FM Working Group:

- Meter reading systems;
- Tracing and asset tracking systems;
- Social alarms;
- Aids for hearing-impaired persons;
- Applications for temporary use or PMR;
- Paging systems.

A proposed frequency plan for the band 169.4 – 169.8 MHz and the corresponding channelling arrangement are given in Annexes A.1 and A.2 respectively.

The following sharing studies to investigate the compatibility and co-existence between the proposed applications were identified:

- S1 Compatibility between social alarms and high power applications (channels 8b and 9);
- S2 Sharing between SRDs and asset tracking/tracing applications, with the aim of determining the maximum power of the latter to ensure sharing between these systems;
- S3 Sharing between SRDs and hearing aid applications, knowing that SRDs are considered to be the main application in the shared part of the band.

Note: For the purpose of this report SRD only refers to specific applications, namely meter reading and low power tracking devices. The band is not intended for non-specific short range devices.

For expediency, only minimum coupling loss (MCL) methodology was considered for the study and full details are given in Annex B.

2 GENERAL ASSUMPTIONS

2.1 Scenarios

For the purpose of this study the following combinations of interferers and victims have been defined as scenarios to be studied.

Victim / Interferer	Social Alarm	Personal Hearing aids	Hearing aids (public)	Tracking System (low power)	Meter Systems 1)
High power (Channel 9) (e.g. tracking)	S1				
Paging System 7)	S1	5)	5)	6)	5)
Meter Systems	S3	S3	S3	S2	S3
Tracking System (Low power)	4)	4) S3	4) S3	4)	4) S2
Social Alarm	2)	2)	2)	2)	2)
Personal Hearing aids	8)	3)	3)	3)	3)
Hearing aids (public)	8)	8)	8)	S3	S3

Table 2.1: Scenarios for study

The notes explain why the other combinations have or have not been selected:

1) Due to the nature of operation, low duty cycle of the meter reading system, the receiver on the indoor meter has not been considered as a victim.

2) The Social Alarm transmitter has not been considered as an interferer because of the very low radiated power (less than –15 dBm e.r.p), they are mostly used indoors, the very low duty cycle of the Social Alarm systems and their low unit density (units/km^2).

3) Public hearing aids may use up to 27 dBm e.r.p. Therefore, the probability of interference caused by these systems may be greater than personal hearing aid systems, which use output levels of up to 10 dBm e.r.p.

4) The transmitter of the low power tracking system is an active tag with a very low radiated power transmitted and for a limited time, therefore it is not considered as an interferer.

5) It was not considered necessary to study co-existence of paging systems, as an interferer, with hearing aids and meter systems, as victims, therefore these combinations are not made parts of the study.

6) The low power tracking system is considered the most sensitive application within the sub-band, it was therefore agreed to include this combination to the scenarios to be studied.

7) Paging Systems, using up to 400 W e.r.p. output power, represent the highest potential of interference, compared to other PMR systems, therefore only Paging systems were considered as an interferer from the high power frequency range (see Annex A.1).

8) Although not part of the basic scenarios, calculations have also been done for these scenarios. Results are given in annex B.

2.2 Technical parameters

2.2.1 Interferer

Application	e.r.p. dBm	Bandwidth kHz	Duty cycle %	Unit density Units/km^2
Paging	56	25	>95	2 x 10^{-04}
Personal Hearing aid	10	12.5-50	100	< 200
Hearing aid (public)	27	12.5-50	100	<10
Meter systems indoor	27	12.5	<0.1	<1000
Meter systems outdoor	27	12.5	<10	<30
Tracking	44	25	< 1%	10

Table 2.2.1: Transmitter parameters

2.2.2 Adjacent channel power (interferer)

Application	Standard	Limit
Paging	ETS 300 133-6[1]	-70 dBc, but not less than –37 dBm
Personal hearing aid	EN 300 422 [2]	- 60 dBc
Hearing aid public	EN 300 422 [2]	- 60 dBc
Meter systems	EN 300 220 [3][4]	- 20 dBm

Table 2.2.2: Transmitter adjacent channel power limits

Note:
In absence of a specific product standard the requirements of the EN 300 220-1 [3] are used.

2.2.3 High power transmitter spectrum mask

The high power transmitters are operating in the upper sub-band. To determine the interference from these transmitters it is necessary to analyse:

- Transmitter adjacent channel noise interference to receivers in the low power band,
- Blocking to the receivers in the low power band.

The used spectrum mask is shown in Figure 2.2.3 below:

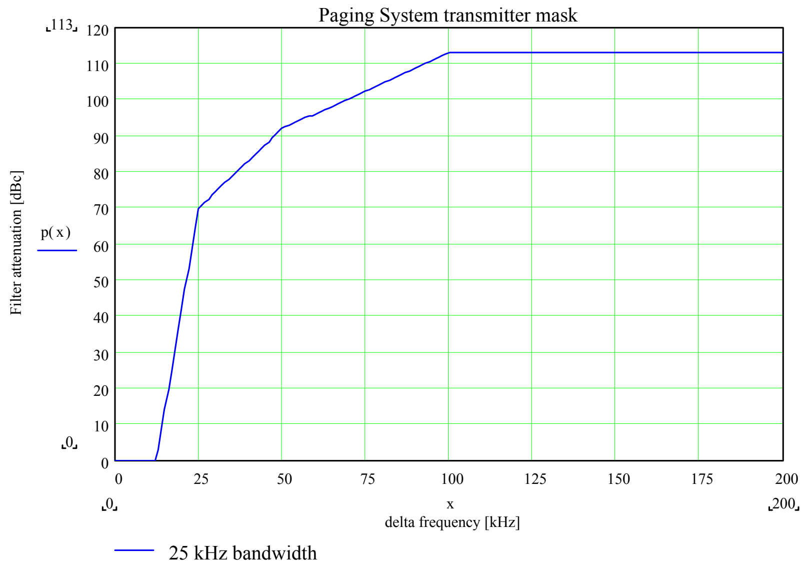

Figure 2.2.3: Transmitter mask for high power systems

2.2.4 Victim

Table 2.2.4: Receiver parameters

Application	**Bandwidth kHz**	**Sensitivity dBm**	**C/(N+I) dB**
Social alarm	12.5	-108	8
Hearing aid private	12.5	-108	8
Hearing aid (public)	12.5-50	-108 to -102	8
Meter systems	12.5	-108	8
Tracking system	0.016	-142	8

2.2.5 Blocking response (victim)

The referenced ETSI standards define blocking response at a frequency offset of at least 1 MHz. Since the frequency range of this study is only 400 kHz, the blocking response of the victim has been calculated at as close as 100 kHz separation.

2.2.6 Antenna characteristics

For the purpose of this study omni-directional vertical polarized antenna with an antenna gain of 0 dB e.r.p without an elevation angle has been used.

The only exception being the antenna of the paging system's base station, which was antenna with 4 dBd gain in the vertical plane. Its radiation pattern is shown below (based on Kathrein K 55 16 23 1, a typical end feed antenna) in Fig. 2.2.6 a-b.

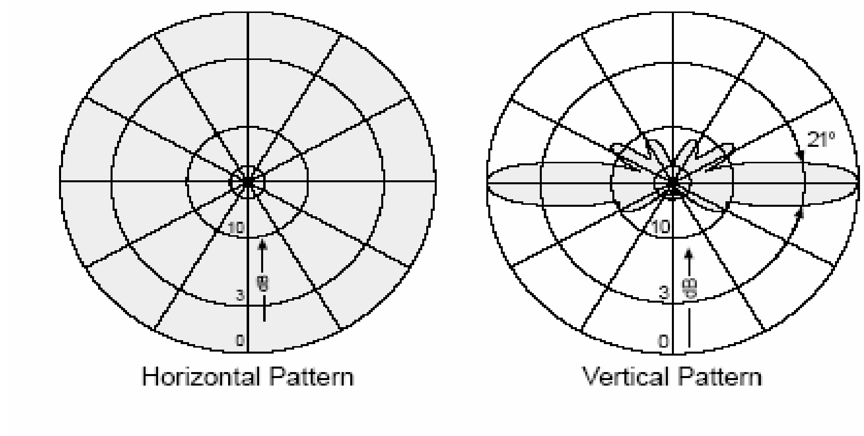

Figure 2.2.6.a: Antenna characteristics of the antenna Kathrein K 55 16 23 1

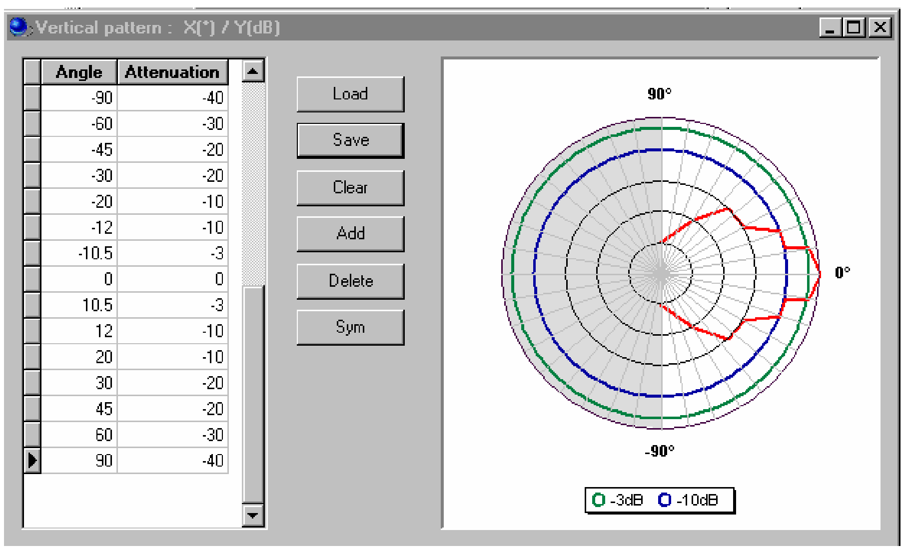

Figure 2.2.6.b: Vertical antenna pattern

An alternative type of antenna (Kathrein 711 530) is shown below in Fig. 2.2.6c.

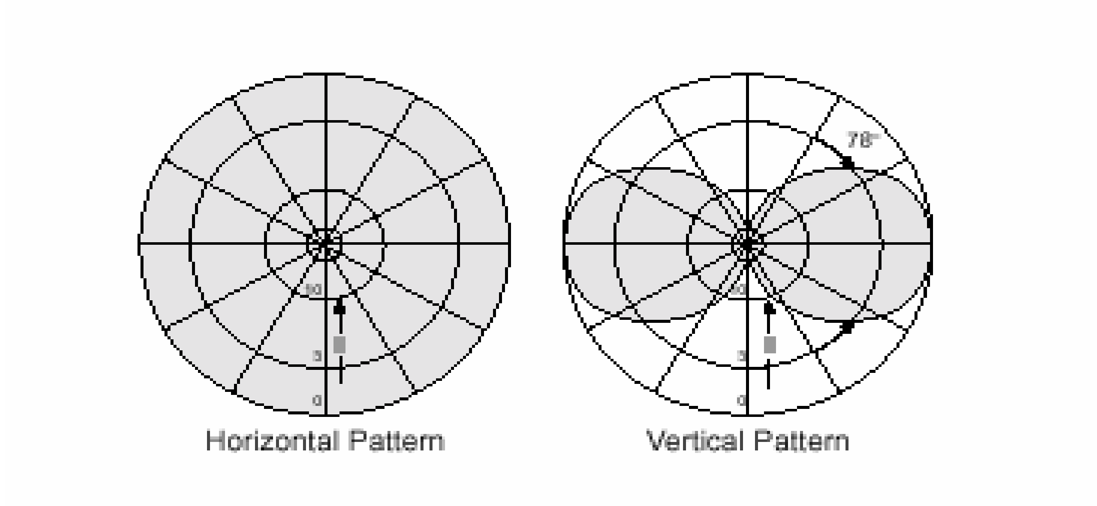

Figure 2.2.6.c: Antenna characteristics of the antenna Kathrein 711 530

The vertical radiation pattern of the latter antenna is shown in Figure 2.2.6d.

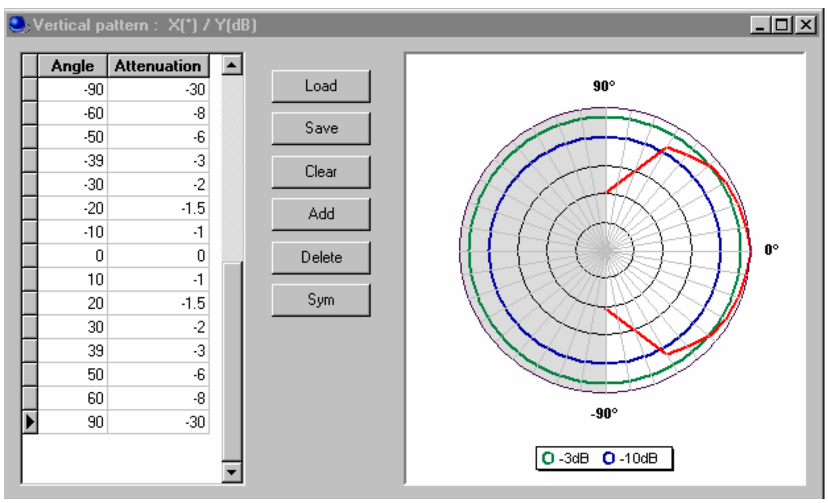

Figure 2.2.6.d: Vertical antenna pattern

2.2.7 Centre frequencies used for the purpose of this study

For the purpose of this study the centre frequencies of the proposed band plan has been used (see Annex A.1).

To avoid conflicts with National allocations the following channel scheme was used:

a) For the frequency range proposed for low power applications (channels 1a to 8b) the channelling scheme according to the ERC/REC T/R 25-08 [5] (12.5 kHz channel spacing) has been used;

b) For the frequency range proposed for high power applications (channels 9a to 16b) the channelling scheme according to ERMES-plan (25 kHz channel spacing) has been used.

2.2.8 Conversion dB(µV/m) to dBm

Sensitivity for hearing aids systems is given in dBµV/m. For the purpose of this study the following formula has been used for the conversion from dB(µV/m) to dBm (see ERC/REP 021 [6])

$$E = ERP + 20\log(F) + 79.36$$

where:

E is the field strength in dB(μV/m)

ERP is the effective radiated power in dBm

F is the frequency in MHz.

Thus, with F = 169.6 MHz the ERP is calculated by:

$$ERP = E - 124 \text{ [dBm]}$$

3 RESULTS

3.1 Minimum protection distances

Victim / Interferer	Social Alarm	Hearing aids (personal)	Hearing aid (public)	Tracking System (low power)
High power (Channel 9)	154 – 538			
Paging System				
25 kHz offset	832 - 2419			
50 kHz offset	173 – 574			
75 kHz offset	55 – 299			
100 kHz offset	17-177			
Meter Systems	23 -191	co-chan: 2762-5310 off-chan: 25 - 65	co-chan: 3411-6388 off-chan: 21-67	103 - 227
Tracking System (Low power)	69 – 280	20 - 139	17 - 167	-
Personal Hearing aids	6 – 32			23 - 48
Hearing aids (public)	12 - 62			52 - 94

Table 3.1: Calculated protection distances in metres

The above protection distances were calculated using the MCL method. A full description is given in Annex B and a separate work sheet is provided for each victim. The tables B.3.4.1 and B 3.4.2 cover the three requested scenarios.

3.2 Analysis of the results

3.2.1 Scenario 1: social alarms and high power transmitters

From the table 3.1 it can be seen that high power systems are likely to be the most potential source of interference, with a required separation distance of approximately 468 m for the rural, in-door/outdoor situation. For the urban case the distance is approximately 538 m.

Similarly for high power paging system, the frequency separation of 25 kHz between the social alarm and the paging channel is not sufficient. The minimum separation is approximately 50 kHz, which is equivalent to 2 paging channels. For a rural situation the worse case would require a 496 m separation and for an urban situation approximately 574 m. Where the channel separation is greater than 4 x 25 kHz then the protection distance is less than 155 m. The same would apply for frequency separation between the high power tracking base station and the social alarm system.

3.2.2 Scenario 2: sharing between meter reading and tracking systems (low power)

It is assumed that the low power tracking /tracing systems would only be activated once an item is stolen, therefore the case of the tracking/tracing system as interferer and meter reading system as victim has not been considered.

For the case of the meter reading system as interferer and the tracking system as victim, the calculated protection distance ranges from approximately 198 m for urban in-door/outdoor case to 227 m for rural outdoor/outdoor case.

3.2.3 Scenario 3: sharing between SRDs and hearing aids

Again, tracking/tracing systems were not considered as an interferer due to the assumed low duty cycle and usage scenario.

For the case of meter reading systems as an interferer and private hearing aid systems as a victim, then the calculated protection distances vary between approximately 31 and 67 m for the off-channel interference. For co-channel usage the protection distances are up to approximately 6.4 km.

4 CONCLUSIONS

Considering the social alarms, the high power systems are the worst potential source of interference. However, as the frequency separation is increased to 100 kHz or more, this provides additional protection and the required distance is substantially reduced.

Consideration may be given to move the upper social alarm channel to another part of the band, however, it is felt that this is unnecessary, provided care is taken in the design of the receiver for the social alarm and suitable protocols are employed. If the upper social alarm channel is moved then the two alarm channels should be kept separate to offer some frequency diversity performance.

Due to the request of co-location of social alarm systems and hearing aids, there is a risk of blocking if the existing ETSI standard is used. The referenced ETSI standards define blocking response at a frequency offset of at least 1 MHz. Since the frequency range of this study is only 400 kHz then the blocking response of the victim has been calculated at as close as 100 kHz separation. The social alarm receiver immunity performance has to be improved by 10 to 20 dB above the characteristics given in EN 300220 for operation in the 169MHz band.

In the 400 MHz Band – sufficiently separated in frequency from SRD Bands and their specific interference problems.
The SRD data systems generally have a low duty cycle therefore different systems should be able to co-exist. In addition, the tracking/tracing systems are likely to be mobile, therefore, the risk of interference to metering receivers is likely to be low.

For automatic metering systems, there is a potential of co-channel interference with the tracking/tracing systems, however, if suitable coding is used then the risk of interference is reduced further.

In the non-exclusive band hearing aids may be subject to co-channel interference from other SRDs. If the devices are analogue, then the hearing aid systems will hear the data burst, however, the SRD applications are low duty cycle systems. In a manual meter reading system, the meters tend to be read every 3 to 6 months. For automatic meter reading systems, these will tend to be read several times per day, typically 4 to 6 times.

This was a theoretical study, there may be other mitigation factors, which have not been considered, but may actually reduce the calculated protection distances. Such factors include additional building loss, especially in built-up areas, also antenna off-beam loss for directional antennas. Also usage patterns and duty cycle has not been taken into consideration.

5 REFERENCES

[1] ETSI ETS 300 133-6

Electromagnetic Compatibility and Radio Spectrum Matters (ERM);Enhanced Radio MEssage System (ERMES);Part 6: Base station conformance specification

[2] EN 300 422

Electromagnetic compatibility and Radio spectrum Matters (ERM); Technical characteristics and test methods for wireless microphones in the 25 MHz to 3 GHz frequency range

[3] EN 300 220-1

Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD);Radio equipment to be used in the 25 MHz to 1000 MHz frequency range with power levels ranging up to 500 mW; Part 1: Technical characteristics and test methods

[4] EN 300 220-2

Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Radio equipment to be used in the 25 MHz to 1 000 MHz frequency range with power levels ranging up to 500 mW; Part 2: Supplementary parameters not intended for conformity purposes

[5] Recommendation T/R 25-08 (Lecce 1989, revised in Vienna 1999)

Planning criteria and coordination of frequencies in the land mobile service in the range 29.7-960 MHz

[6] ERC/REP 021

Compatibility between ERMES and PMR systems

6 ABBREVIATIONS

CEPT	Conférence Européenne des Postes et Télécommunications
EC	European Commission (Commission of European Communities)
ERMES	European Radio Messaging System
e.r.p.	Effective radiated power [dBm]
MCL	Minimum coupling loss method

Annex A

A.1 Frequency plan and channelling arrangement

Frequency plan for the 169.4 - 169.8125 MHz band

<table>
<tr><td colspan="10">Low power applications</td><td rowspan="5">“Guard band”</td><td colspan="16">High power applications</td></tr>
<tr><td colspan="6">Specific low power applications</td><td>So. al.</td><td colspan="2">Hearing aids</td><td>So. al.</td><td colspan="2">Trac.</td><td colspan="2">Paging</td><td colspan="2">Paging</td><td colspan="2">Paging</td><td colspan="2">Trac.</td><td colspan="2">Trac.</td><td colspan="2">Paging</td><td colspan="2">Trac.</td></tr>
<tr><td colspan="6">Hearing aids</td><td colspan="4">Exclusive use</td><td colspan="16">These channels could be used on a national basis for high power application such as paging, tracing, temporary use or PMR.</td></tr>
<tr><td colspan="6">12.5</td><td>12.5</td><td colspan="2">50</td><td>12.5</td><td colspan="16">12.5 (1)</td></tr>
<tr><td>1a</td><td>1b</td><td>2a</td><td>2b</td><td>3a</td><td>3b</td><td>4a</td><td>4b+5+6a</td><td>6b+7+8a</td><td>8b</td><td>9a</td><td>9b</td><td>10a</td><td>10b</td><td>11a</td><td>11b</td><td>12a</td><td>12b</td><td>13a</td><td>13b</td><td>14a</td><td>14b</td><td>15a</td><td>15b</td><td>16a</td><td>16b</td></tr>
</table>

Legend:

- 1st row: category application, i.e. low power applications or high power applications;
- 2nd row: preferred applications:
  Specific low power applications see *decides* 3c and 3d
  So. al. means social alarm systems see *decides* 3b
  Hearing aids see *decides* 3a
  Trac. means tracking and tracing system (high power part) see *decides* 4a
  Paging see *decides* 4b
- 3rd row: alternative applications, see *decides* 5 and 6;
- 4th and 5th rows: channel raster (in kHz) and channel number.

(1): Due to the possibility of using any high power channel for the temporary use application. However, to facilitate border coordination, systems using 25 kHz channels should respect the channel raster starting from the lower edge of the channel 9.

A.2 Proposed centre frequencies for channel plan

12.5 kHz bandwidth		25 kHz bandwidth		50 kHz bandwidth	
Ch. no	Centre freq.	Ch. no	Centre freq.	Ch. no	Centre freq.
1a	169.406250	1	169,412500		
1b	169.418750			"0"	169.437500
2a	169.431250	2	169.437500		
2b	169.443750				
3a	169.456250	3	169.462500		
3b	169.468750				
4a	169.481250	4	169.487500		
4b	169.493750			"1"	169.512500
5a	169.506250	5	169.512500		
5b	169.518750				
6a	169.531250	6	169.537500		
6b	169.543750			"2"	169.562500
7a	169.556250	7	169.562500		
7b	169.568750				
8a	169.581250	8	169.587500		
8b	169.593750				
12.5 kHz gap					
9a	169.618750	9	169.62500		
9b	169.631250				
10a	169.643750	10	169.65000		
10b	169.656750				
11a	169.668750	11	169.67500		
11b	169.681250				
12a	169.693750	12	169.70000		
12b	169.706250				
13a	169.718750	13	169.72500		
13b	169.731250				
14a	169.743750	14	169.75000		
14b	169.756250				
15a	169.768750	15	169.77500		
15b	169.781259				
16a	169.793750	16	169.80000		
16b	169.806250				

Table A2: Channelling arrangement for the band 169.4 – 169.8 MHz

Annex B MCL Interference Calculations for 169.4 – 169.8 MHz

B.1 General introduction for MCL calculations

B.1.1 Used method

Protection distances are calculated for both co-channel interference and blocking from which the cumulative probability of interference is derived.

B.1.2 Interference criteria

B.1.2.1 Co-channel interference

I/N is used as the interference criteria for MCL. Co-channel interference is calculated with I/N = 3 dB level. The interference criteria of I/N = 3 dB equals to receiver's sensitivity with 3 dB margin.

B.1.2.2 Blocking

Protection distances are calculated for blocking level of –20 dBm level at above +/-100 kHz.
The reference BER is 1%.

B.1.3 Characteristics of existing and proposed systems

The proposed devices for operation in the 169.4 – 169.8 MHz band have different characteristics and will have different responses to potential interferers.

B.1.3.1. Summary victim receiver characteristics

Victim characteristics are derived from section 2.2 of this Report. The relevant characteristics are shown in table B.1.3.1 below:

Application	**Bandwidth kHz**	**Sensitivity dBm**	**C/(N+I) dB**
Social alarm	12.5	-108	8
Hearing aid private	12.5	-108	8
Hearing aid (public)	12.5-50	-108 to -102	8
Meter systems	12.5	-108	8
Tracking system	0.016	-142	8

Table B.1.3.1. Characteristics of victim receivers

B.1.3.2 Summary of interfering transmitter characteristics

The values in Table B.1.3.2 below are basis for the values used in the Excel spread sheets.

Application	**e.r.p dBm**	**Bandwidth kHz**	**Duty cycle %**	**Unit density Units/km^2**
Paging	56	25	>95	2 x 10^{-04}
Personal Hearing aid	10	12.5-50	100	< 200
Hearing aid (public)	27	12.5-50	100	<10
Meter systems indoor	27	12.5	<0.1	<1000
Meter systems outdoor	27	12.5	<10	<30
Tracking	44	25	< 1%	10

Table B.1.3.2. Characteristics of Systems for Interference Analysis

B.2 Calculation models

This section describes the principles for using the deterministic model of interference.

B.2.1. Deterministic model

B.2.1.1. General

The deterministic model focuses on one interferer and is relevant for the MCL method.

To achieve a goal at low cost, several compromises are made particularly on fundamental receiver parameters, which normally are considered vital for an operation in the shared band 169.0 - 169.4 MHz. Due to the diversity of different services in this band some performance degradations are to be expected.

ANNEX B.3.0 shows calculations for SRD blocking by the MCL method.

The cumulative probability of co-channel interference effects are not considered under the MCL method as most interference cases are OOB interference.

B.2.1.2. Nominal receiver signal

The MCL study employs all interference scenarios at MUS +3 dB and at MUS + 13 dB. The minimum receive signal, P_{RX_MIN} is:

$$P_{RX\_MIN} = MUS + 3\ dB$$

where:

MUS = Maximum Usable Sensitivity

For the purpose of this study the MCL calculations use an interference criteria of MUS +6dB which is equal to I/N = 3dB

For telemetry and data systems MUS is approximately equal to the receiver noise + 14 dB.

B.2.1.3. Indoor propagation model used for deterministic method

The discussion of this section only applies to calculations performed using the deterministic method.

Propagation models are discussed in clause B.3.2.2.

At 169 MHz, Path Loss, PL is:

a) for distances below 10 m, free-space propagation applies:

$$PL = 17.0 + 20 \log d \quad \text{(dB)} \qquad \text{(B.2.1.3.a)}$$

b) for distances above 10 m:

$$PL = 37.0 + 35 \log \frac{d}{10} \quad \text{(dB)} \qquad \text{(B.2.1.3.b)}$$

where d is the distance in metres.

B.3. Minimum Coupling Loss and protection distance

The protection distance, d_P , for any interference is determined by means of the MCL method.

$$MCL = P_{RAD} - P_{RX} + C / I \qquad \text{(B.3)}$$

where:

MCL = Minimum Coupling Loss in dB;
P_{RAD} = Radiated power (e.r.p.) for interfering transmitter in dBm;
P_{RX} = Victim received power in dBm;
C/I = Carrier to interference ratio specified for the Victim receiver in dB;

The calculated MCL can be considered as path loss, *PL*, over a certain protection distance, d_P. The latter can be then derived from an appropriate propagation model:

$$d = 10^{(PL - 17.0)/20} \qquad \text{for } PL < 37 \text{ dB, and}$$

$$d = 10 * \left(10^{(PL - 37.0)/35}\right) \qquad \text{for } PL \geq 37.0 \text{ dB}$$

B.3.1. Blocking

The following specification is used for the calculation:

- Blocking level criteria: -20 dBm

B.3.2. The method

Interference analysis is a two-step process, leading to an interference assessment for different scenarios.

Those steps are:

Step 1.

- Determine the "Minimum Coupling Loss (MCL)" between the interferer and the victim. The equation for this calculation is given in section B.3.2.1.

Step 2.

- Convert the MCL result from step 1 into a minimum protection distance for a single interferer by means of an appropriate propagation model. These propagation models are described in section B.3.2.2.

B.3.2.1 Minimum coupling loss

The Minimum Coupling Loss between the interfering transmitter and victim receiver determines the minimum protection distance. The cell size (radius) R_{INT} is identical to the calculated protection distance, it has to be calculated by means of an applicable propagation model (see section B.3.2.2).

The Minimum Coupling Loss (MCL) is the minimum path loss required to avoid interference, which is given by:

$$MCL = P_{srd} + G_t - L_b - Lf_t + G_r - Lf_r + 10 \log(B_r \cap B_t / B_t) - I \qquad \text{(B.3.2.1)}$$

where:

I : maximum permissible interference level at victim receiver
P_{srd} : interfering transmitter conducted power

G_t : interfering transmitter antenna gain

G_r : victim receiver antenna gain

Lf_t : interfering transmitter feeder loss

Lf_r : victim receiver feeder loss

B_t : interfering transmitter 3 dB bandwidth

B_r : victim receiver 3 dB bandwidth

L_b : building loss as appropriate

$B_r \cap B_t$: overlapping part of the transmitter and receiver frequency band.

B.3.2.2. Propagation models

For MCL calculations different propagation formulas are used for each combination of the following environments: indoor, urban, and rural. For systems operating indoors, an additional 10 dB building attenuation, M_{WALL}, is assumed per ITU-R P.1238-2. All of the propagation formulas below predict the median value of path loss.

B.3.2.2.1 In- door propagation model
The indoor model uses free space propagation formula which applies for distances, d, of less than 10 m (a path loss exponent of 2). Beyond 10 m, the exponent is 3.5. The following indoor model is assumed valid from 10 m to 500 m:

$$Pl(r)(dB) = 37.0 + 35\log\left(\frac{d}{10}\right) + M_{WALL} \qquad \text{(B.3.2.2)}$$

Beyond 500 m, this model is not applicable since most indoor building areas are smaller than 500 m. The indoor propagation model is supported by numerous measurements found in literature, e.g. "Wireless Communications" by T. S. Rappaport, ISBN 0-13-375536-3, chapter 3.

B.3.2.2.2. Urban model
For the purposes of this study the CEPT SE21 urban model is used. This model is described in ERC Report 68 and is valid for frequencies between 150 MHz and 1500 MHz.

L_{CEPT}(urban, dB) $= 69.6 + 26.2 \log f - 13.82 \log h_{tx} - a(h_{rx}) - a(h_{tx}) + (44.9 - 6.55 \log h_{tx}) \log d$

where $a(h_{tx}) = \text{Min}\,[0, 20 \log (h_{tx}/30)]$

and $a(h_{rx}) = (1.1 \log f - 0.7)\, \text{Min}(10, h_{rx}) - (1.56 \log f - 0.8) + \text{Max}\,[0, 20 \log (h_{rx}/10)]$

are "antenna height gain factors" for the transmitter and receiver antennas, respectively.

The equations given above predict large negative values (*e.g.,* negative 18 dB) for the transmitter's antenna height gain for low antennas. This arises because the CEPT/SE21 model assumes that the transmitter antenna is mounted high (above 30 m) and in the clear. But in the situations of interest in this report, typically both transmit and receiver antennas are below 10 m, so that nearby ground clutter and reflections are no longer negligible.

For the purposes of this study the MCL calculations, the SE21 propagation model is modified by using the "height gain" equation:

$$a(h_{tx}) = (1.1 \log f - 0.7)\, \text{Min}(10, h_{tx}) - (1.56 \log f - 0.8) \text{ dB} + \text{Max}\,[0, 20 \log (ht_{rx}/10)]$$

when both antenna heights are less than 10 m.

B.3.2.2.3 Rural model

The rural propagation model used within the radio line-of-sight in this report is the CEPT SE21 rural model, also referred to as the modified free space loss model. The rural model assumes free space propagation until a certain break point distance, r_{BREAK} depending on the antenna heights for the interferer and victim:

$$Pl(r)(dB) = 20 \log(4\pi r/\lambda) + M_{WALL} \qquad \text{for } r < r_{BREAK} = 4\pi.ht.hr/\lambda$$

$$Pl(r)(dB) = 20 \log(r^2/(ht.hr)) + M_{WALL} \qquad \text{for } r > r_{BREAK} = 4\pi.ht.hr/\lambda$$

It shall be noted that to determine the very long operating range of the tracking systems using a bandwidth of 16 Hz , it is necessary to use the propagation curves from ITU-R P 1540.

B.3.2.3. Loss resulting from out-of-beam for antennas

For the calculation of protection distances a general out-of-beam attenuation of 3 dB is used for all high power transmitters as the antennas of these are mounted at high positions.
For calculation of the protection distances for blocking an attenuation of 6 dB is used as the victims in this case are more out-of-beam. It shall be noted that certain gain antennas have more than 6 dB attenuation in the vertical plane for the given scenarios, but this is not considered in this report.

B.4 Presentation of calculated results

B.4.1 Protection distances for blocking

The calculated protection ranges for blocking are given in table B.4.1 below:

	Power, dBm							
	56	**54**	**52**	**47**	**27**	**44**	**36**	**10**
Urban, m	86	75	66	48	19	39	23	4
Rural, m	483	392	318	188	43	137	60	7

Table B.4.1: Protection distances based on Blocking, m

Note: No receiver pre-selectivity filtering is used.

It is necessary to take special precautions to minimize blocking of receivers when operating close to ERMES transmitters above 100 W e.r.p.

B.4.2 Protection distances for co-channel interference

The calculated protection distances are given in table B.4.2 below:

Table B.4.2: Protection distances based on co-channel calculation

	A	B	C	D	E	F	G	H	I	J	K	L	M
2		**Paging channel separation**				**Meter systems**		**Tracking systems**			**Hearing aid**		**Social**
3	**Interfering transmitters =>**	**1st adj ch**	**2nd adj ch**	**3rd adj ch**	**4th adj ch**			**Fixed**	**Mobile**	**portable**	**Private**	**Public**	**alarm**
4	**Bandwidth =>**	f_0 -25 kHz	f_0 -50 kHz	f_0 -75 kHz	f_0 -100 kHz	12.5 kHz	12.5 kHz	12,5 kHz	16 Hz	20 Hz	35 kHz	50 kHz	12.5 kHz
5	**Radiated power e.r.p. =>**	400W	400W	400W	400W	500mW	500mW	25W	4W	10mW	10 mW	100 mW	10 mW
6	**Victims below:**												**Alarm**
7													**system**
8	**Victim: Social Alarm receiver 12.5 kHz**												**range**
9	Indoor model, in-door to in-door, (km), *(partly not applica*					0.023	0.023				0.006	0.012	0.362
10	Urban model, in-door to out-door, (km)	1.034	0.246	0.128	0.066	0.070	0.070				0.015	0.031	0.883
11	Urban model, out-door to out-door, (km)	2.419	0.574	0.299	0.155	0.163	0.163	0.538	0.457	0.280	0.028	0.060	1.698
12	Rural, in-door to out-door, (km)	0.832	0.173	0.055	0.017	0.090	0.090	0.154	0.115	0.069	0.018	0.035	0.661
13	Rural, out-door to out-door, (km)	1.759	0.496	0.244	0.077	0.191	0.191	0.468	0.405	0.218	0.032	0.062	1.175
14											**Hearing aid**		
15	**Victim: Hearing aid, private**					**co-chan**	**off-chan**				**system range**		
16	Indoor model, in-door to in-door, (km), *(partly not applica*					0.500	0.007				0.233	0.500	0.006
17	Urban model, in-door to out-door, (km)	0.577	0.149	0.077	0.040	2.762	0.025	0.139	0.118	0.072	0.570	1.566	0.015
18	Urban model, out-door to out-door, (km)	1.204	0.286	0.149	0.077	5.310	0.048	0.268	0.227	0.139	1.097	3.011	0.028
19	Rural, in-door to out-door, (km)	0.535	0.071	0.023	0.007	2.313	0.025	0.064	0.048	0.020	0.450	1.094	0.018
20	Rural, out-door to out-door, (km)	0.951	0.226	0.071	0.023	4.114	0.065	0.201	0.151	0.064	0.800	1.946	0.032
21													
22	**Victim: Hearing aid, Public**					**co-chan**	**off-chan**						
23	Indoor model, in-door to in-door, (km), *(partly not applica*					0.500	0.006				0.211	0.500	0.005
24	Urban model, in-door to out-door, (km)	0.773	0.184	0.095	0.050	3.411	0.031	0.172	0.146	0.089	0.704	2.140	0.018
25	Urban model, out-door to out-door, (km)	1.448	0.344	0.179	0.093	6.388	0.058	0.322	0.273	0.167	1.319	4.009	0.034
26	Rural, in-door to out-door, (km)	0.752	0.060	0.019	0.006	3.456	0.021	0.053	0.040	0.017	0.672	1.787	0.017
27	Rural, out-door to out-door, (km)	1.421	0.189	0.060	0.019	6.145	0.067	0.168	0.126	0.053	1.194	3.177	0.048
28													
29	**Victim: Tracking, 12,5 kHz with 16 Hz detection bandwidth**							**Tracking system range**					
30	Indoor model, in-door to in-door, (km), *(not applicable)*								P.1546				
31	Urban model, in-door to out-door, (km), *(not applicable)*					0.103	0.103				0.023	0.049	0.036
32	Urban model, out-door to out-door, (km)	2.419	0.574	0.299	0.155	0.198	0.198	27.548	28.220	10.606	0.045	0.094	0.069
33	Rural, in-door to out-door, (km), *(not applicable)*					0.128	0.128				0.027	0.052	0.039
34	Rural, out-door to out-door, (km)	1.759	0.496	0.244	0.077	0.227	0.227	24.552	63.176	18.860	0.048	0.092	0.070
35													
36	**Victim:Tracking 12.5 kHz with 7.5 kHz detection bandwidth**												
37	Indoor model, in-door to in-door, (km), *(not applicable)*									Report 68			
38	Urban model, in-door to out-door, (km), *(not applicable)*					0.103	0.103				0.023	0.049	0.036
39	Urban model, out-door to out-door, (km)	2.419	0.574	0.299	0.155	0.198	0.198	38.912	7.330	8.383	0.045	0.094	0.069
40	Rural, in-door to out-door, (km), *(not applicable)*					0.128	0.128				0.027	0.052	0.039
41	Rural, out-door to out-door, (km)	1.759	0.496	0.244	0.077	0.227	0.227	21.882	10.353	5.255	0.048	0.092	0.070
42													
43	*Notes:*												
44	*1) Open cells are not applicable for the application*												
45	*2) Most SRD victims need to be at least 3-4 channels away from a high power paging transmitter frequency*												
46	*3) Outdoor co-channel range for tracking systems with 16 Hz detection bandwidth is calculated by using ITU-R P 1546 propagation curves*												

B.4.3 Comments on calculations of protection distances

Calculations are given in the Excel worksheets, as presented in Tables B.4.1 and B.4.2.

Multiple columns per worksheet are related to various existing and proposed systems individually either as an interferer. Interference to different victims is covered in separate worksheets.

Simultaneous interference caused by co-located systems of different categories is not analysed by MCL.

The formulas used in each worksheet are presented in previous sections of this Annex B and are consistent across the worksheets. Input data is entered on a separate input sheet. Each worksheet is organised in a similar manner, resulting in a set of sheets that is easy to compare, modify or expand by adding new sheets for other systems operating in the 169 MHz band.

B.5 Excel spread sheets for interference calculations

The actual files with used Excel spreadsheets are available for download from the server, placed next to the report downloadable files.