COMPATIBILITY BETWEEN MOBILE EARTH STATION OF THE MOBILE SATELLITE SERVICE BELOW 1 GHz USING NARROW BAND FASHION AND PRIVATE MOBILE RADIO EQUIPMENT CURRENTLY USED IN THE FREQUENCY BAND 148 - 149.9 MHz

1. Introduction

The introduction of non-GSO MSS below 1 GHz, a mobile satellite service for short burst data exchange, is only possible if the radio compatibility with existing and planned terrestrial services is guaranteed. To reduce the interference to the existing services there are several constraints on the mobile satellite service. Among these constraints are the limitation of the data burst lengths, duty cycles for the transmission of an individual mobile earth station (MES), forced frequency changes, even if the frequency is available for an uplink transmission and dynamic channel assignment techniques.

It has been proven by in-orbit demonstration tests, that a current dynamic channel assignment technique used by one of the satellite manufacturers is able to detect signals of a transmission power lower than 0.1 W e.i.r.p.

The dynamic channel assignment techniques of future satellites have been modified in both, the frequency scanning speed and the sensitivity of the scanning receivers performing fast Fourier transform processing in the satellite to simultaneously view the entire uplink band and to identify clear uplink channels for assignment to MSS MES.

2 Description of the Analyses

Because of the channel assignment techniques described above, co-channel interferences are very unlikely in cases of transmitting mobile and fixed stations, therefore these cases are not considered in these analyses. In this study only adjacent channel interferences are considered.

The study comprises the calculation of the required separation distance between MSS MES equipment and PMR equipment based on a worst-case scenario calculation and Monte Carlo simulations to determine the probability of interference to PMR. Furthermore, the analyses take into account PMR equipment with and without selective calling (SELCAL) owing to the different Carrier-to-Carrier and Carrier-to-Interference ratios as seen in the receiver spectrum mask (Annex 5).

There is also taken into account the location percentage in respect of the individual users, the time percentage of transmission of the MSS MES and the LMS and the average number of scanned 20 kHz-channels of the LMS. In the frequency band 148 - 149.9 MHz there are

95 available LMS channels of 20 kHz. In order to speed up the scan of a the frequency band the MSS system might not scan the whole frequency range but build up a history table avoiding channels with high loading factors. Therefore the actually number of scanned channels is smaller the 95 channels. These analyses are carried out assuming a number of 70 scanned channels.

2.1 Description of the Annexes

Annex 1

1.1 Calculation of guard bands (worst-case scenario)

1.1.1 PMR **without** selective calling

1.1.1.1 PMR system receiver sensitivity: -105 dBm
1.1.1.2 PMR system receiver sensitivity: -85 dBm

1.1.2 PMR **with** selective calling

1.1.2.1 PMR system receiver sensitivity: -105 dBm
1.1.2.2 PMR system receiver sensitivity: -85 dBm

Annex 2

1.2 Determination of the probability of interference (Monte Carlo simulation): PMR **without** selective calling

1.2.1 LEO MES cause interference to PMR MS
1.2.2 LEO MES cause interference to PMR BS

Annex 3

1.3 Determination of the probability of interference (Monte Carlo simulation): PMR **with** selective calling

1.3.1 LEO MES cause interference to PMR MS
1.3.2 LEO MES cause interference to PMR BS

Annex 4

1.4 Determination of the probability of interference (Monte Carlo simulation): PMR **without** selective calling in "Peak Traffic Areas"

Annex 5

The technical parameters of the systems are detailed in Annex 5.

The PMR system parameters are derived from ETS 300 086 [1] and results of measurements [2] carried out by the Federal Office for Posts and Telecommunications (BAPT). The MSS MES parameters are derived from ORBCOMM proprietary information [3] and result of measurement of the BAPT [2].

The figures for the time percentage of the PMR systems are derived from traffic occupancy measurements carried out in selected areas in Germany in the frequency band 148 - 149.9 MHz by the monitoring service of the BAPT. The same figures for the Earth-to-space links of the MSS MES are based on information provided by an MSS service provider.

A detailed description of the results of measurements in [1]

3. Potential Interference from non-GSO MSS Earth Stations into PMR Equipment

The Monte Carlo method was used to determine the probability of interference. The simulations were used to examine the effects of interference from 10 MSS MES users per 1 km^2 on PMR MS and PMR BS. All of the simulations assumed that the interfering equipment was located within a radius of 500 m from the victim equipment. Three interferer/victim scenarios were simulated:

A	Urban coverage	PMR coverage radius of 5000 m
B	Suburban coverage	PMR coverage radius of 10000 m
C	Rural coverage	PMR coverage radius of 15000 m

The probability of interference is based on the following formula:

$$p(\%) = LP * TP_{PMR} * TP_{MES} * 1/n * V$$

p(%) Probability of interference (in percent)

LP Location percentage

TP_{PMR} Time percentage of the PMR systems (Channel occupancy of the PMR in percent)

TP_{PMR} Time percentage of the PMR systems (Channel occupancy of the PMR in percent)

n Number of scanned PMR channel

The table below summarises the outcome of the probability calculations carried out in the annexes of this document:

Worst Case Scenario				
Parameter	w/o SELCAL	w/o SELCAL	SELCAL	SELCAL
Rx Signal Power	-105 dBm	- 85 dBm	-105 dBm	- 85 dBm
Guard band	20 kHz	20 kHz	20 kHz	20 kHz
Separation Distance	2200 m	220 m	60 m	7 m

Table 1

Probability of Interference				
Parameter	MES → MS	MES → BS	MES → MS	MES → BS
Coverage Area	w/o SELCAL	w/o SELCAL	SELCAL	SELCAL

5000 m	0.0004	0.001	0.00003	0.0003
10000 m	0.002	0.005	0.0004	0.002
15000 m	0.0012	0.008	0.0001	0.002

Table 2

Probability of Interference (Peak Traffic Area)				
Parameter	MES → MS	MES → BS	MES → MS	MES → BS
Coverage Area	w/o SELCAL	w/o SELCAL	SELCAL	SELCAL
5000 m	0.06	0.18	0.004	0.042

Table 3

Peak Traffic Area i.e. Container Ports of Transhipment, Harbour, Marshalling Yards
SELCAL Selective Calling

4. Conclusion

Table 1 contains the results of the worst case scenario described in Annex 1 and the results of twelve (12) different simulations are contained in Table 2 using the Monte Carlo method to determine the location percentage, as described in the annexes 2 and 3. The results show that the probability of interference is not critical in most cases. This is due to the low figure of time percentage of MSS MES transmissions.

Even with a figure of 70 % for the time percentage of PMR systems the probability of interference is very low. Some receivers of the PMR systems will operate without selective calling, therefore they stay tuned on there assigned frequency all the time. In these cases the figure for the time percentage is 100 %, but the analyses have shown that the probability of interference will raise only 0.2 % in respect to the 70 % figure in the worst case.

Some cases of interference might occur in "Peak Traffic Areas", like container ports etc., and PMR base stations in high elevated areas with gain antennas mounted on tall masts. In the first case there might be a probability of interference of 0.4 to 6 % for mobile stations of the PMR. In the latter case this figure might be up to 18 %. The results are contained in Table 3.

The duration of the interference on a particular frequency will only exist for 500 ms. After this period the interference will occur on a different frequency. Therefore the user of the PMR equipment might only notice a click or pop in his receiver. If data is interfered, the data will be simply retransmitted by the terrestrial system

5 Relevant Documents

[1] ETS 300 086
Radio Equipment and systems; Land mobile service
Technical characteristics and test conditions for radio equipment with an internal or external RF connector intended primarily for analogue speech

[2] ORBCOMM low earth orbiting (LEO) satellite system
Results of the radio compatibility study conducted by the radio monitoring service of the Federal Office for Posts and Telecommunications (BAPT)
CEPT/ERC/CPG/PT3(97)17 or CEPT/ERC/SE/PT28(97)66

[3] ORBCOMM
System Overview
Revision 4.1; Sept. 20,1996

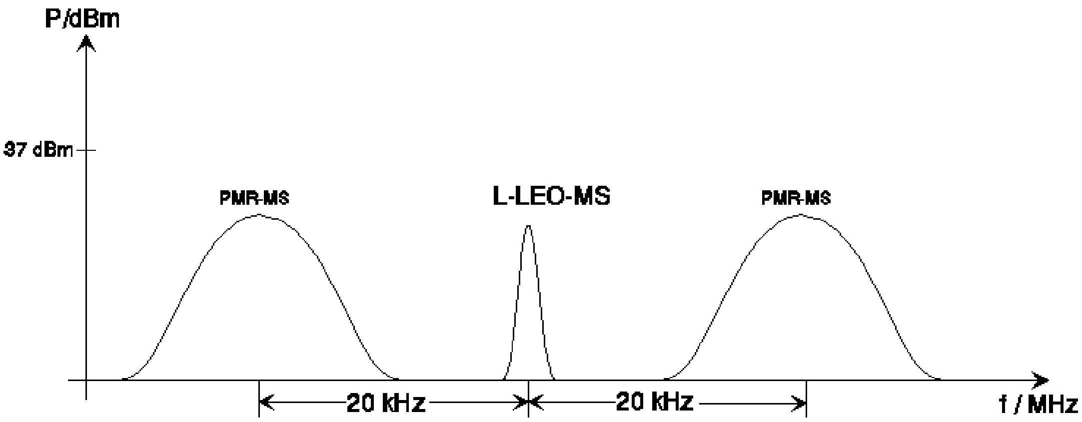
1.1 Guard Band Calculations (Worst-Case)

The guard bands were calculated taking into account two different receiver sensitivities.

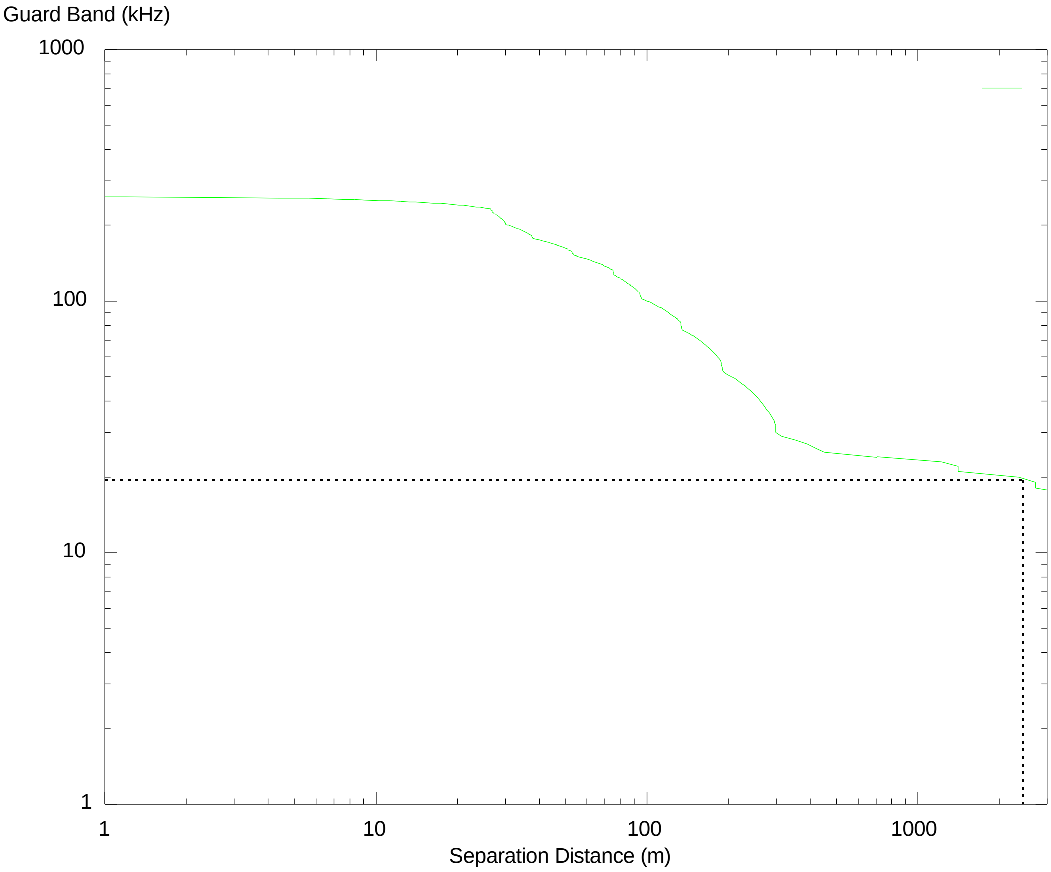
Sections 1.1.1.1 and 1.1.2.1 assume a receiver sensitivity of -105 dBm which is specified in ETS 300 086 and is to be regarded as the minimum receiver sensitivitiy.

Sections 1.1.1.2 und 1.1.2.2 assume a receiver sensitivity of -85 dBm (average receiver input power). This is to be seen more realistic in practice since fading and shadowing may occur without interrupting the connection. The MSS MES and the PMR equipment have different bandwidths (MSS: 5 kHz and PMR: 20 kHz). The MSS-System is designed to set it's MES carrier in Earth-to-space direction on an available channel right in the middle between two busy channels.

Example:

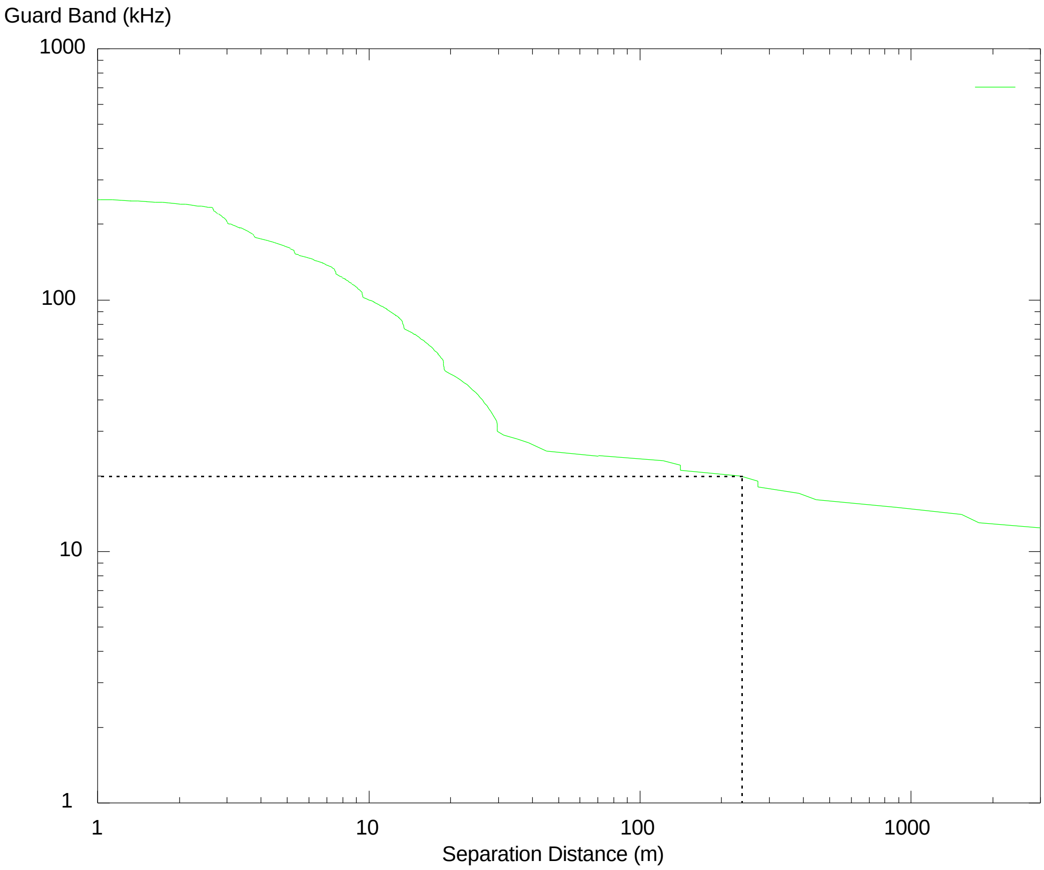


1.1.1.1 PMR system receiver sensitivity: -105 dBm.



The diagram shows that the separation distance required to enable the simultaneous operation of the two systems in adjacent channels is not realistic.

1.1.1.2 PMR system receiver sensitivitiy: -85 dBm.

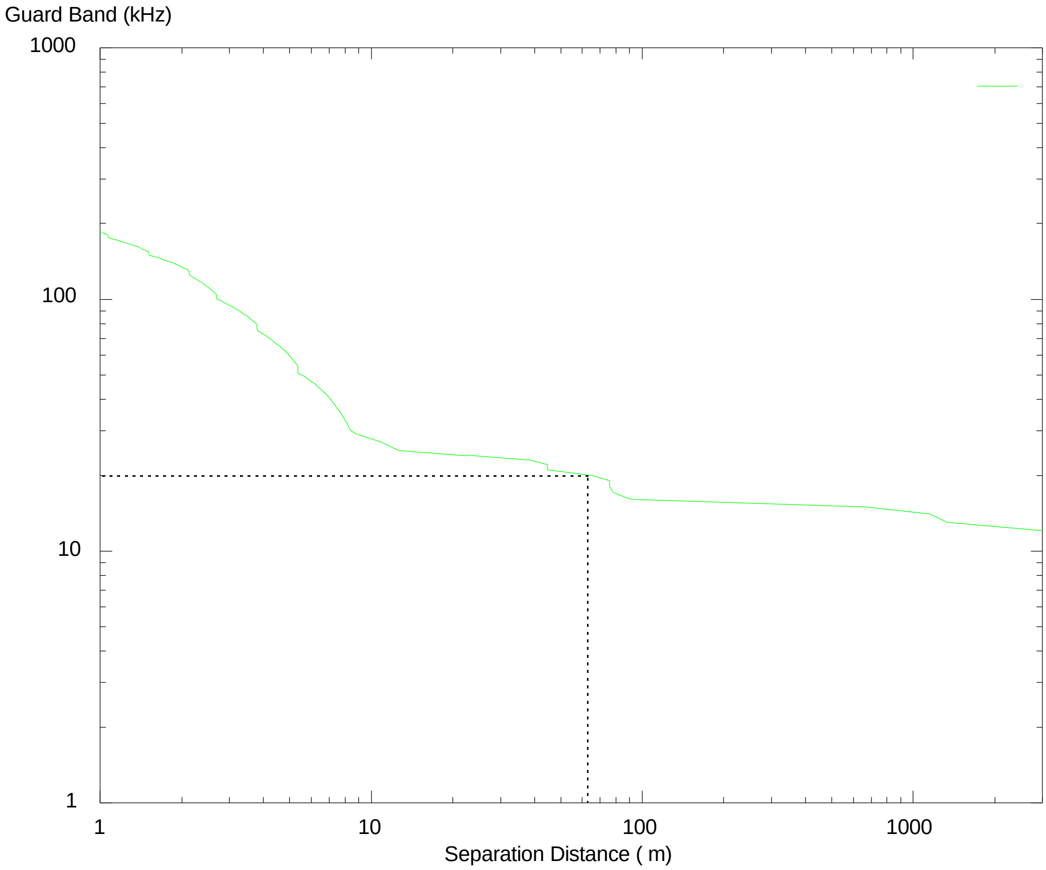


The diagram shows that the seperation distance required to ensure the simultaneous operation of PMR equipment and MSS MES withoutinterference given a guard band of 20 kHz is approximately 220 m.

1.1.2 PMR with selective calling

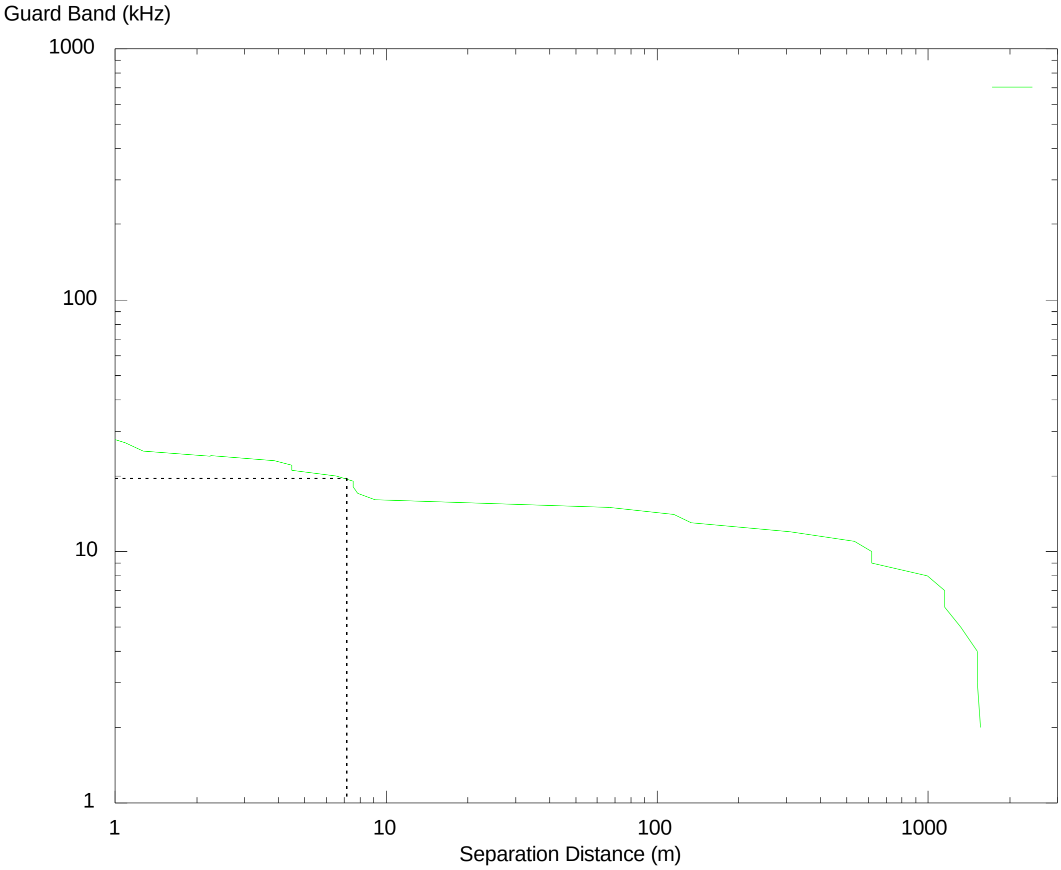
As a rule the separation distances in case of equipment with selective calling are smaller since the carrier-to-carrier ratios required to ensure that the equipment is not subject to interference are lower (see Annex 5).

1.1.2.1 PMR system receiver sensitivity: -105 dBm



The diagram shows a decrease in separation distance to approximately 62m.

1.1.2.2 PMR system receiver sensitivitiy: -85 dBm.



The diagram clearly shows a decrease in the separation distance to a few metres.

1.2 Determination of the probability of interference (Monte Carlo simulation): PMR **without** selective calling

The Monte Carlo method was used to determine the probability of interference in percentage terms.
The simulations were used to examine the effects of interference from 10 LEO MES users per 1 km^2 on PMR MS and PMR BS. All of the simulations assumed that the interfering equipment was located within a radius of 500 m from the victim equipment.
Three interferer/victim scenarios were simulated:

A Urban coverage: PMR coverage radius = 5000 m.
B Suburban coverage: PMR coverage radius = 10000 m.
C Rural coverage: PMR coverage radius = 15000 m.

Explanatory notes to the diagrams:

Horizontal axis: 0 dB corresponds to the receiver spectrum mask in Annex 5;
+5 dB denotes a degradation in the receiver spectrum mask of 5 dB;
-5 dB denotes an improvement in the receiver spectrum mask of 5 dB.

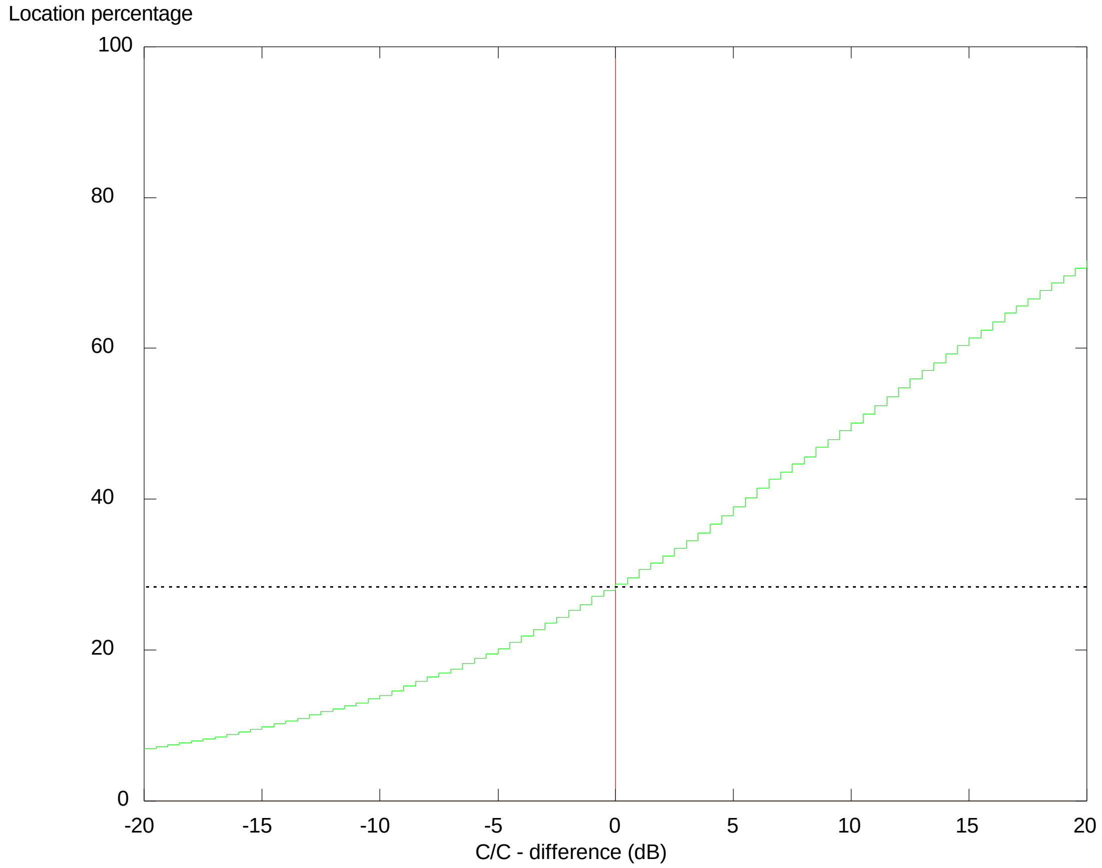
Vertical axis: Location percentage (%).

This will be followed by the incorporation of the time percentage in the analyses. The final outcome of these analyses is a probability of interference based on location and time percentage of both systems.

1.2.1 MSS MES cause interference to PMR MS

The aim of these simulations was to examine how MSS MES affect PMR MS.

Interferer/victim scenario A: urban coverage with PMR coverage radius of 5000 m

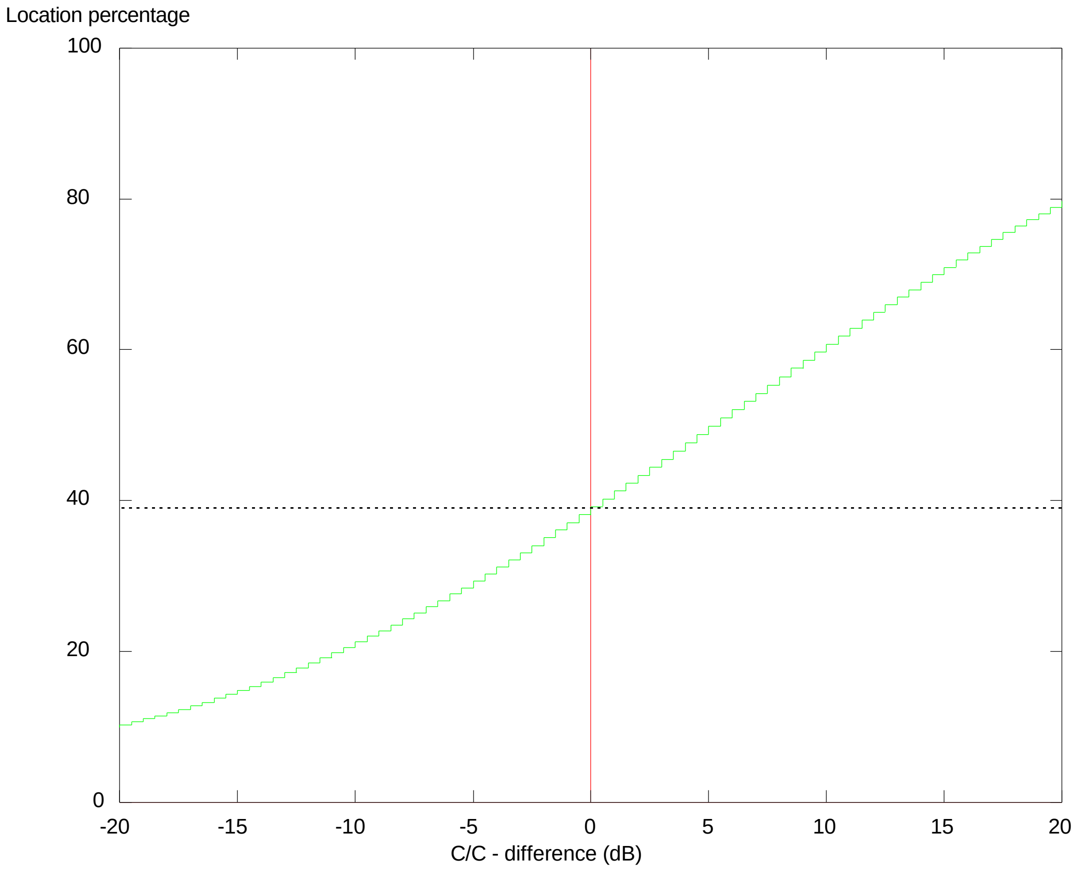


The expected location percentage in this scenario is 30 %.

Therefore the probability of interference is:

p_i(%) = 30 % * 70 % * 0.19 % = 0.04 %

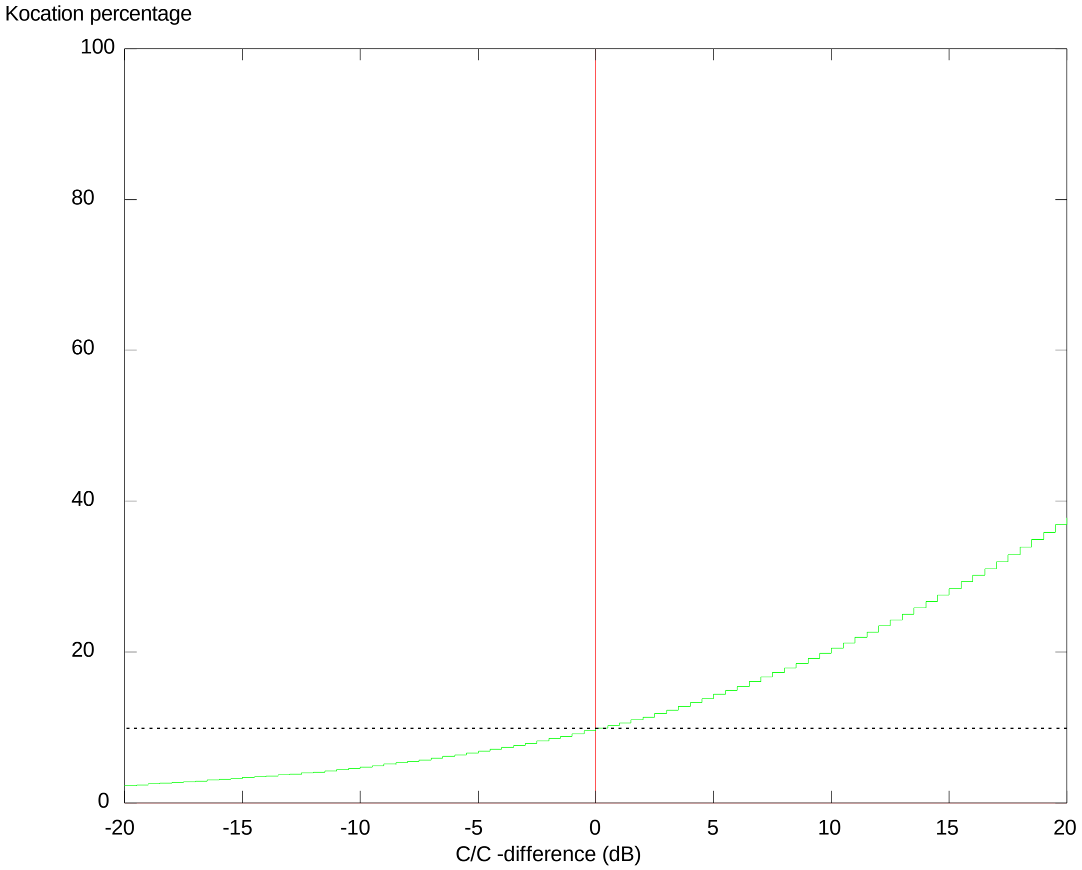
Interferer/Victim scenario B: suburban coverage with a PMR coverage radius of 10000 m



The increase in the coverage radius results in an increase in the locationpercentage to approximately 40 %.

pi(%) = 40 % * 70 % * 0.76 % = 0.2 %

Interferer/victim scenario C: rual coverage with a PMR system radius of 15000 m



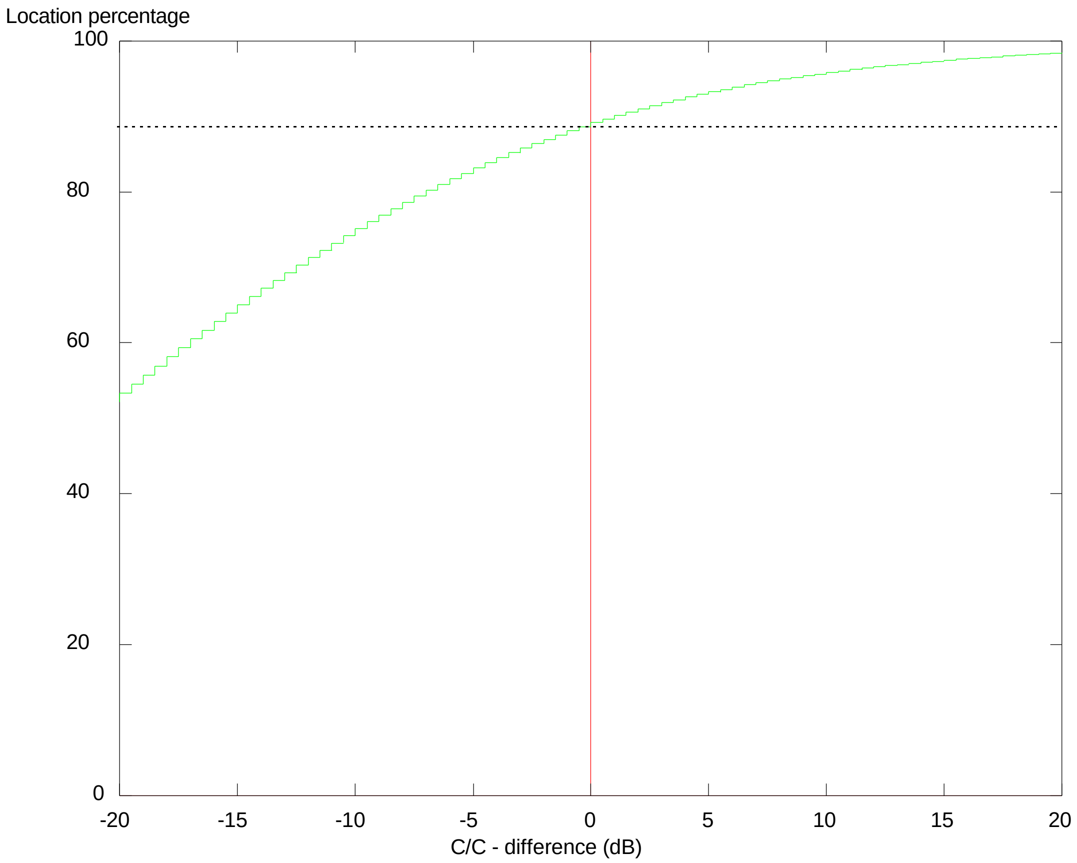
Dispite an increase in the coverage radius to 15000 m, the expected location percentage is only approximately 10 %

pi(%) = 10 % * 70 % * 1.72 % = 0.12 %

1.2.2 MSS MES Cause interference to PMR-BS

The aim of these simulations was to examine how MSS MES affect PMR BS.

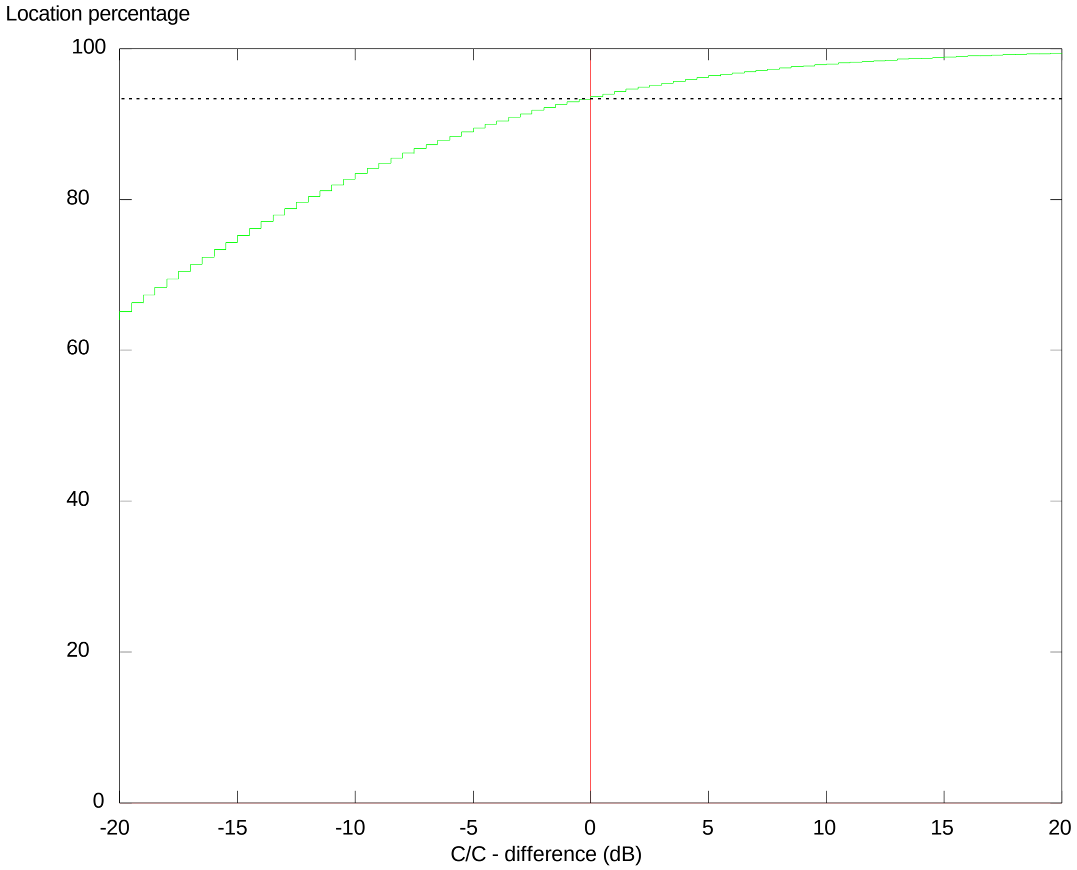
Interferer/victim scenario A: urban coverage with a PMR coverage radius of 5000 m



The location percentage that a PMR base station in urban areas is locate in the vicinity of a MSS MES is approximately 90 %. This is mainly dueto their exposed locations.

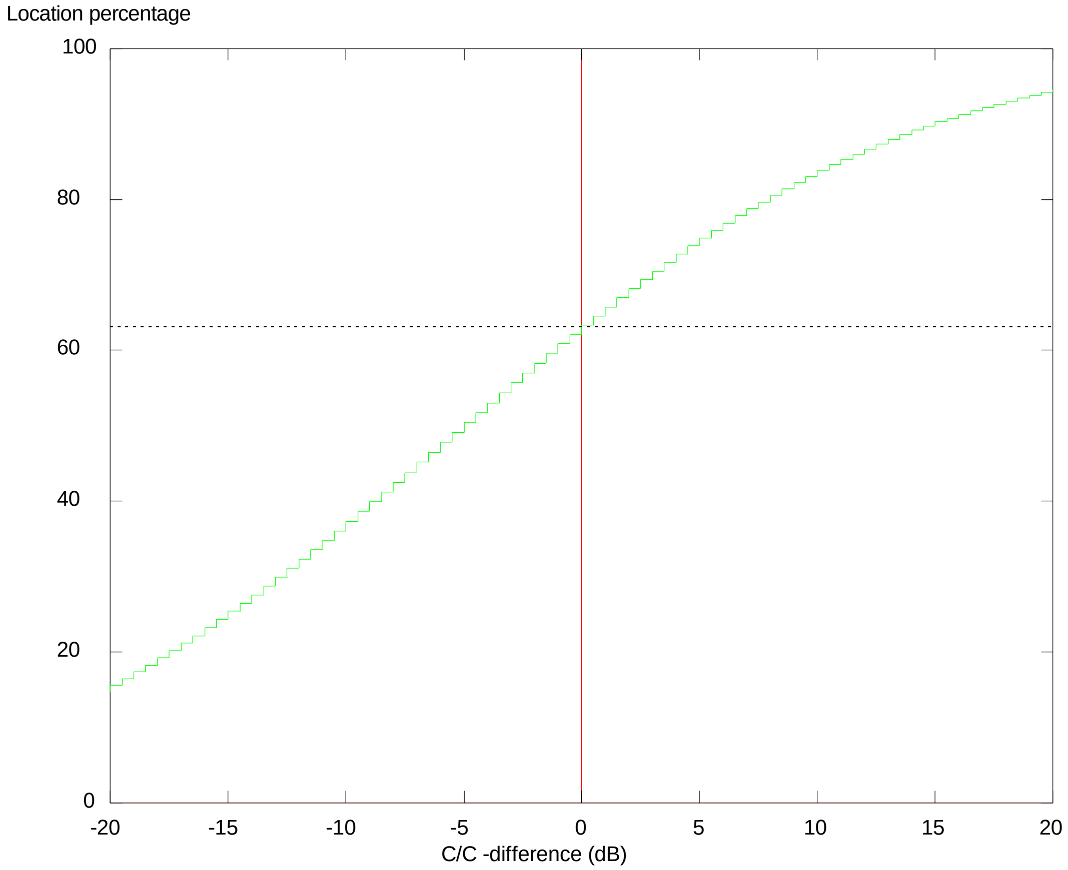
pi(%) = 90 % * 70 % * 0.19 % = 0.1 %

Interferer/victim scenario B: suburban coverage with a PMR coverage radius of 10000 m



pi(%) = 95 % * 70 % * 0.76 % = 0.5 %

Interferer/victim scenario C: rual coverage with a PMR radius of 15000 m



pi(%) = 65 % * 70 % * 1.72 % = 0.8 %

As in section 1.2.1, the location percentage in this scenario is not critical. This is essentially due to the improved propagation conditions for wanted PMR transmissions.

The interference caused by MSS MES to PMR MS is not regarded as critical, not least because the analysis not only takes account of the location percentage but also of the time percentage is considered. This is mainly due to the much less time percentage of the MSS MES.

1.3 Determination of the probability of interference Monte Carlo simulation): PMR **with** selective calling

As in section 1.2, three interferer/victim scenarios were simulated:

A Urban coverage: PMR coverage radius = 5000 m.
B Suburban coverage: PMR coverage radius = 10000 m.
C Rural coverage: PMR coverage radius = 15000 m.

Explanatory notes to the diagrams:

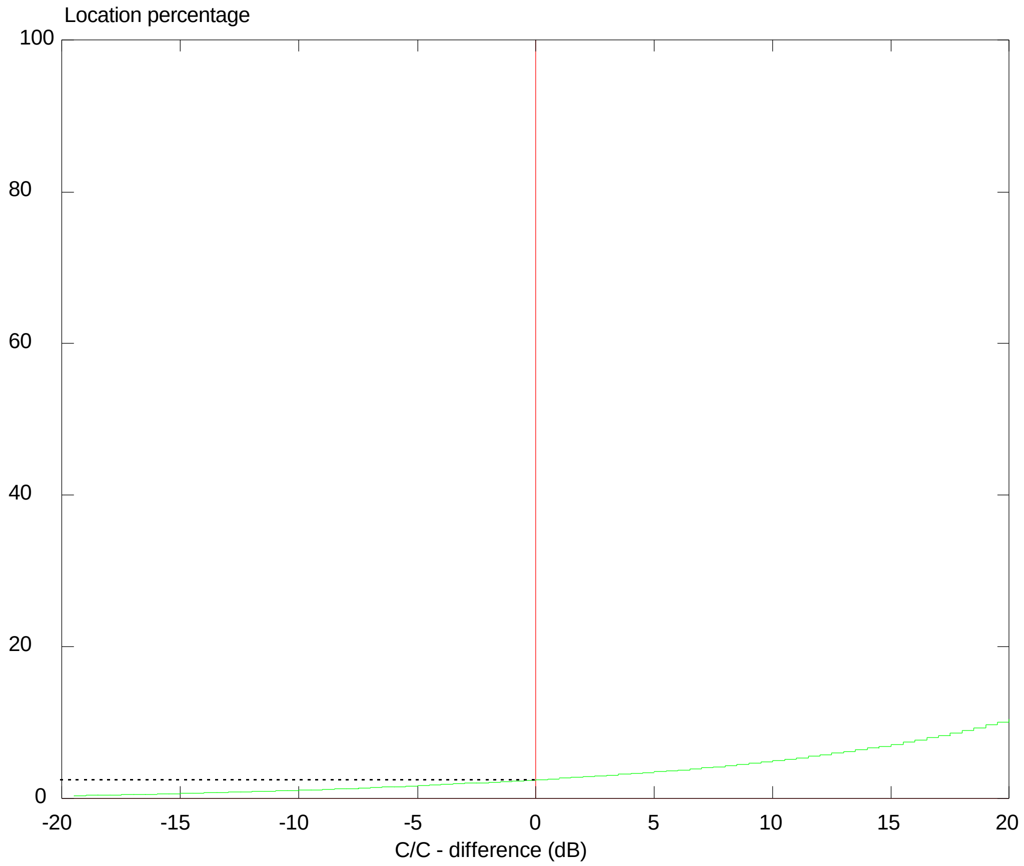
Horizontal axis: 0 dB corresponds to the receiver spectrum mask in Annex 5;
+5 dB denotes a degradation in the receiver spectrum mask of 5 dB;
-5 dB denotes an improvement in the receiver spectrum mask of 5 dB.

Vertical axis: Location percentage (%).

This will be followed by the incorporation of the time percentage in the analyses. The final outcome of these analyses is a probability of interference based on location and time percentage of both systems.

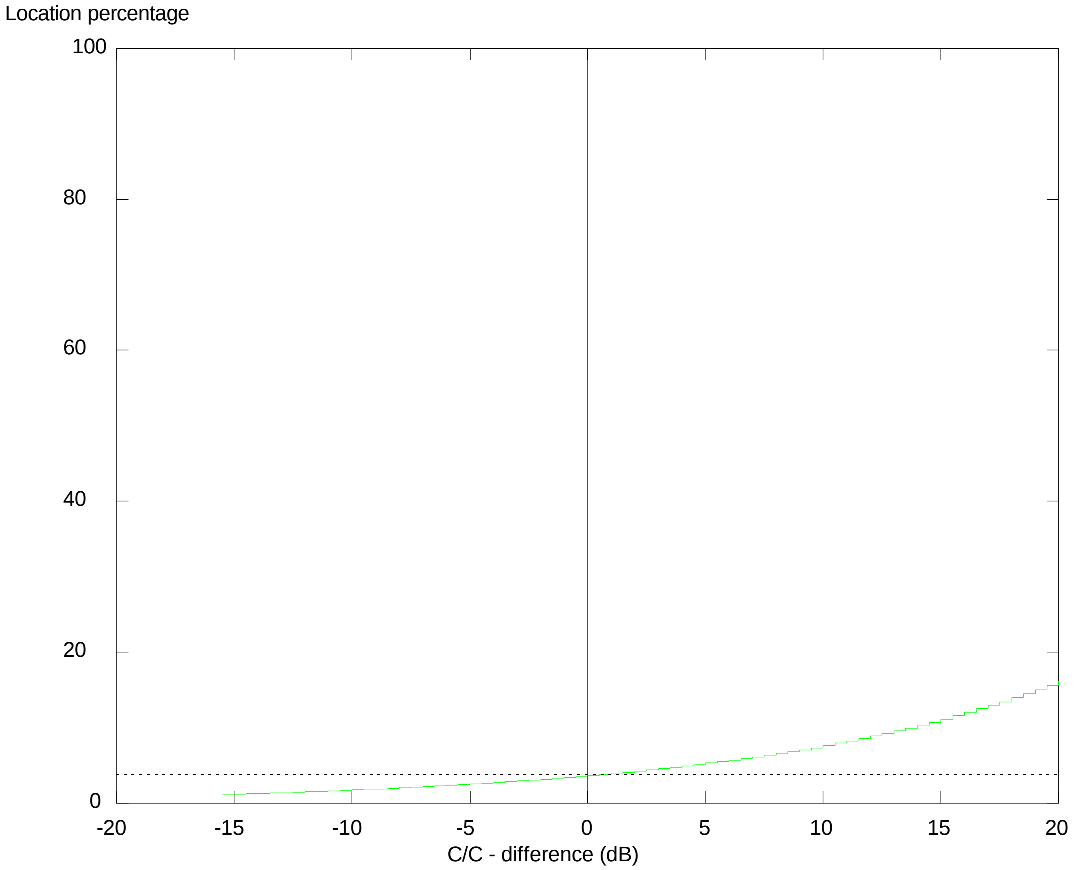
1.3.1 MSS MES cause interference to PMR-MS

Initerferer/victim scenario A: urban coverage with a PMR coverage radius of 5000 m



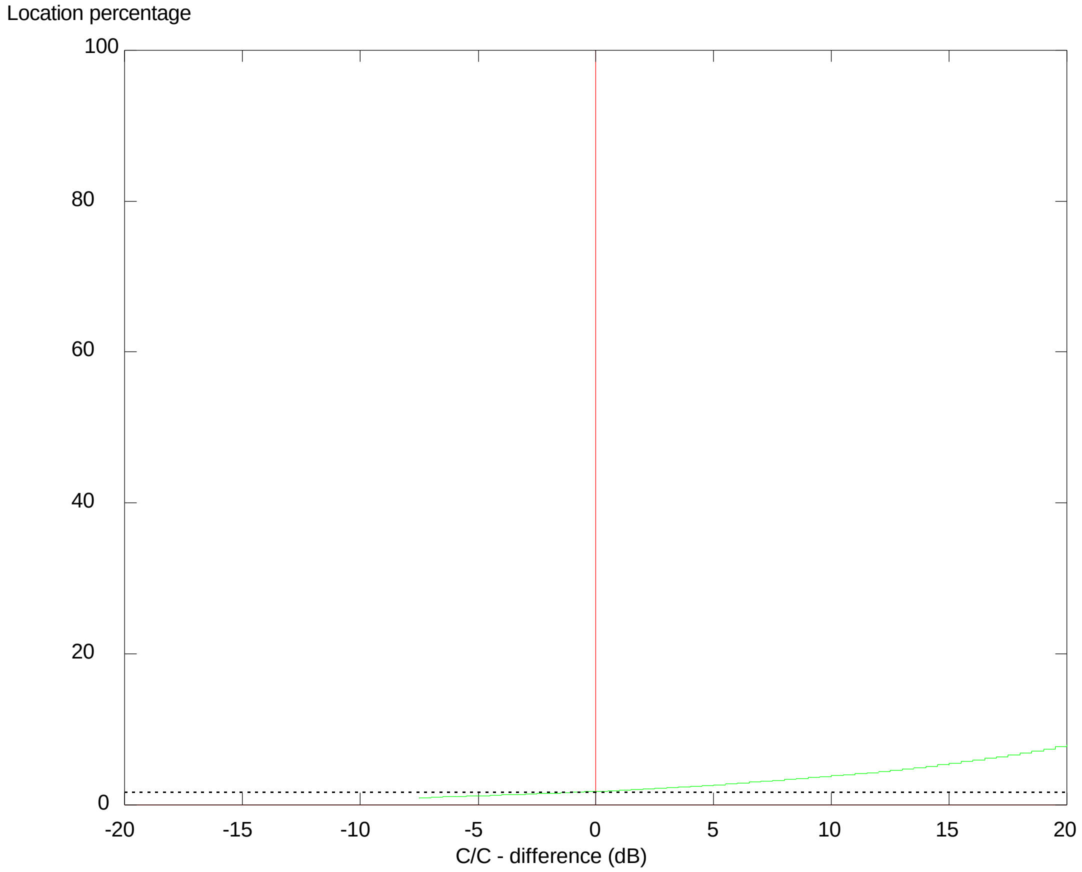
pi(%) = 2 % * 70 % * 0.19 % = 0.003 %

Interferer/Victim scenario B: suburban coverage with a PMR coverage radius of 10000 m



pi(%) = 2 % * 70 % * 0.76 % = 0.04 %

Interferer/victim scenario C: rural covaerage with a PMR coverage radius of 15000 m

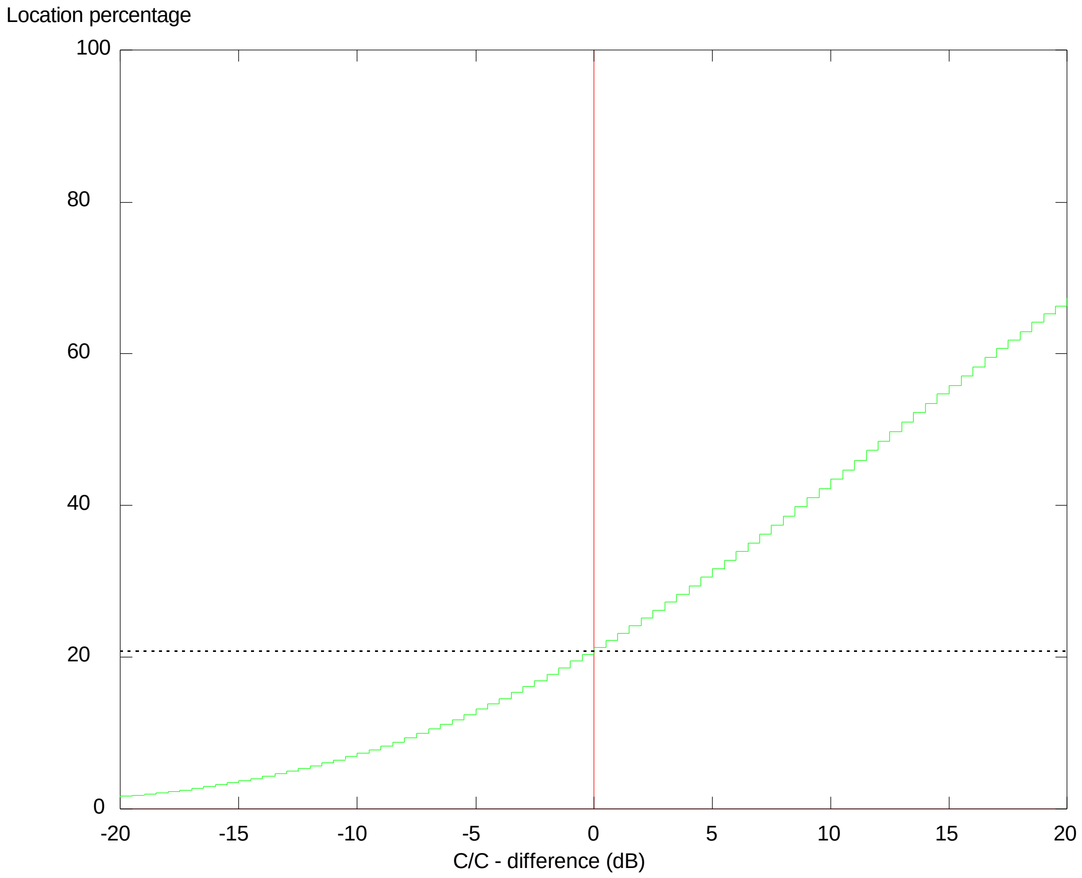


pi(%) = 1 % * 70 % * 1.72 % = 0.01 %

The probability of interferece to PMR MS is very low in all three scenarios. This is mainly due to the time percentage of the MSS MES.

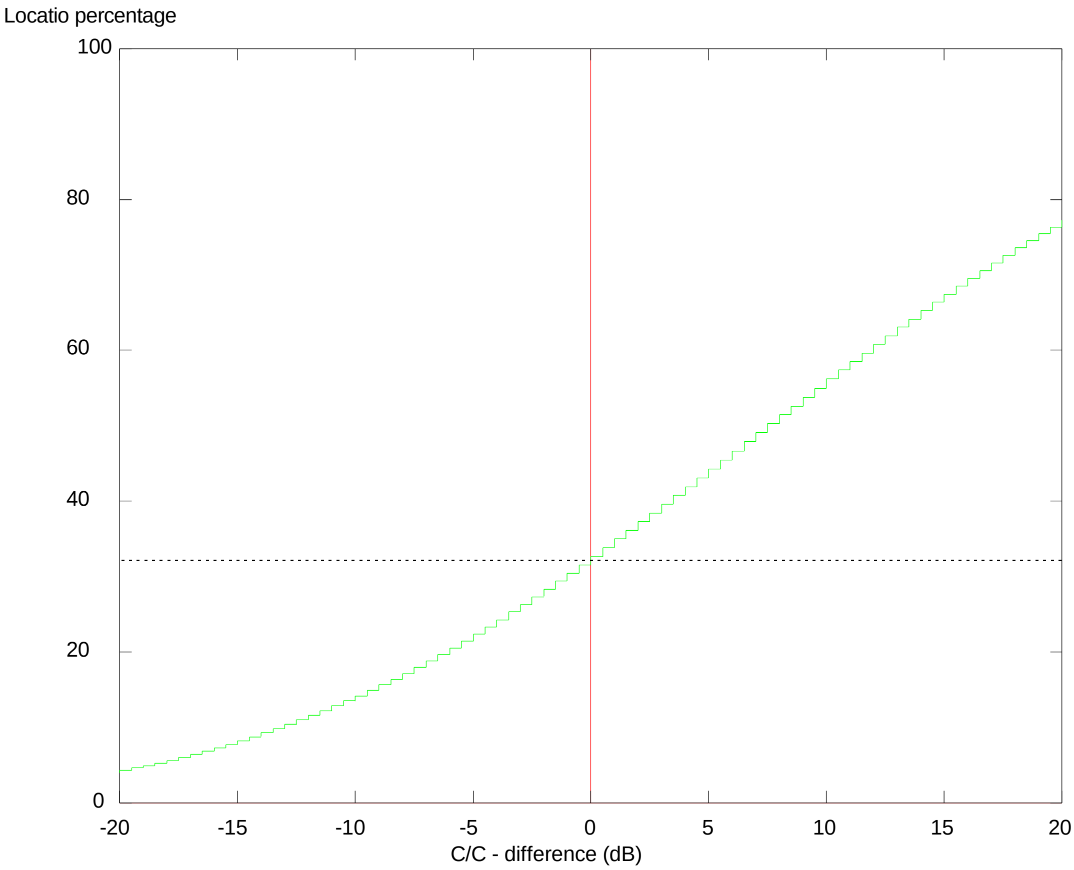
1.3.2 MSS MES cause interference to PMR-BS

Interferer/victim scenario A: urban coverage with a PMR coverage radius of 5000 m



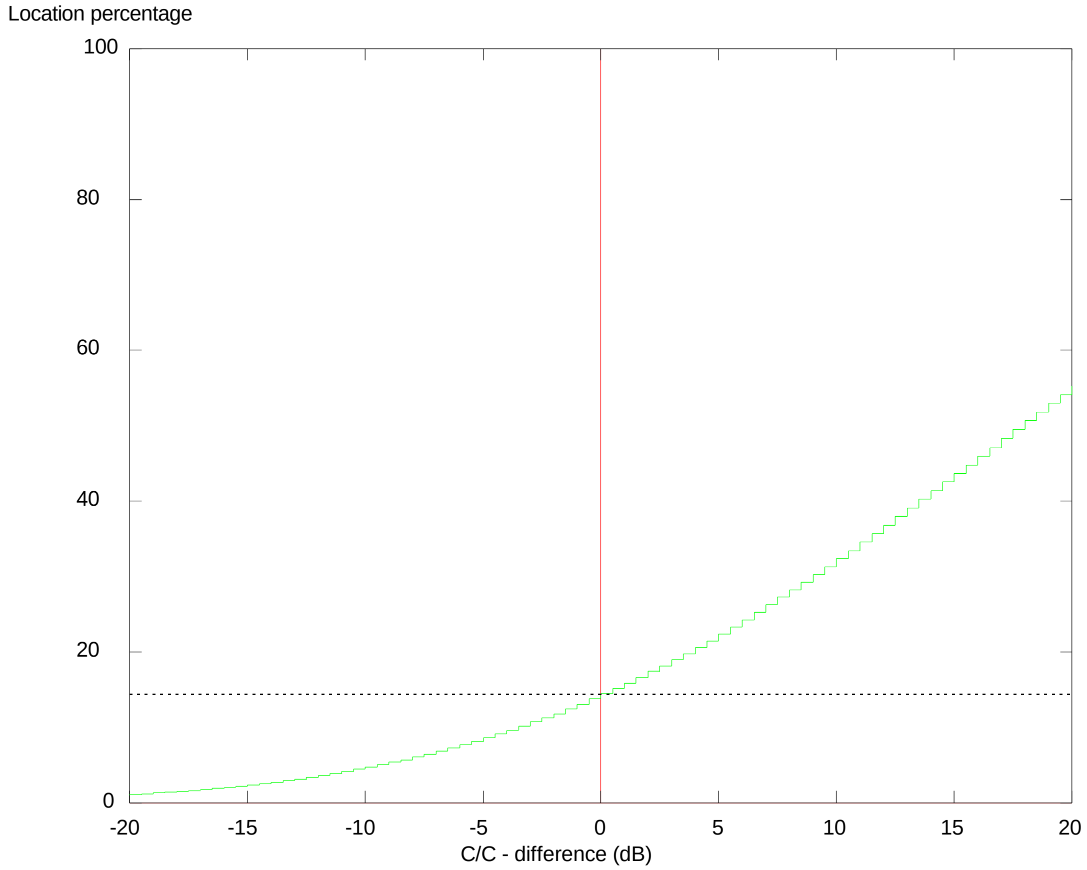
pi(%) = 21 % * 70 % * 0.19 % = 0.03 %

Interferer/victim scenario B: suburban coverage with a PMR coverage radius of 10000 m



pi(%) = 32 % * 70 % * 0.76% = 0.2%

Interferer/victim scenario C: rural coverrage with a PMR coverage radius of 15000 m



pi(%) = 15% * 70 % * 1.72 % = 0.2%

As in the previous calculations the probability of interference is low due to the time percentage of the MSS MEES. But it is clearly demonstrated that the probability of interference to PMR BS is higher than to PMR MS.

1.4 Determination of probability of interference (Monte Carlo simulation)
in „Peak traffic areas“:
PMR **with** and **without** selective calling

In this section attantion is paid to hot spots were plenty of PMR sets and lots of MES are laocated in the same area like marschalling yards or container ports of transhipment etc.

The calculations are based on the interferer/victim scenario A, urban coverage area with a PMR coverage radius of 5000 m. The time percentage of both, the PMR sets and the MSS MES sets is significantly higher than elsewhere. In this calculation the following time percentages have been taken in consideration:

PMR: 100%

Reason:
The PMR sets are tuned to their assigned frequencies. Due to the fact that dynamic channel assignment techniques can only detect used channels the probability of interference is much higer than elsewhere.

L-LEO: 20%

Reason:
In hot spots there are a lot more MSS MES sets in that area than in the countryside.

From the mathmatic point of view the same method of calculation has been used than in Annex 2 and 3. The values for the location percentage dirive from Chapters 1.2.1, 1.2.2, 1.3.1 and 1.3.2.

1 MSS MES cause interference to PMR MS
PMR without selective calling

pi(%) = 30 % * 100 % * 20 % = **6 %**

2 MSS MES cause interference to PMR-BS
PMR without selective calling

pi(%) = 90 % * 100 % * 20 % = **18 %**

3 MSS MES cause interference to PMR-MS
PMR with selective calling

pi(%) = 2 % * 100 % * 20 % = **0.4 %**

4 MSS MES cause interference to PMR-BS
PMR with selective calling

pi(%) = 21 % * 100 % * 20 % = **4.2 %**

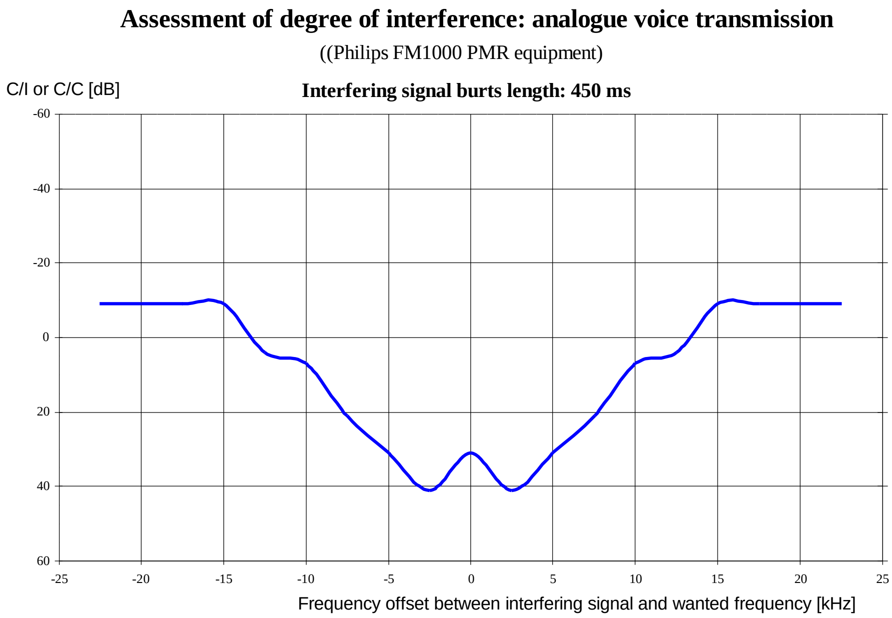
Systemparameter

Private mobile radio (PMR)

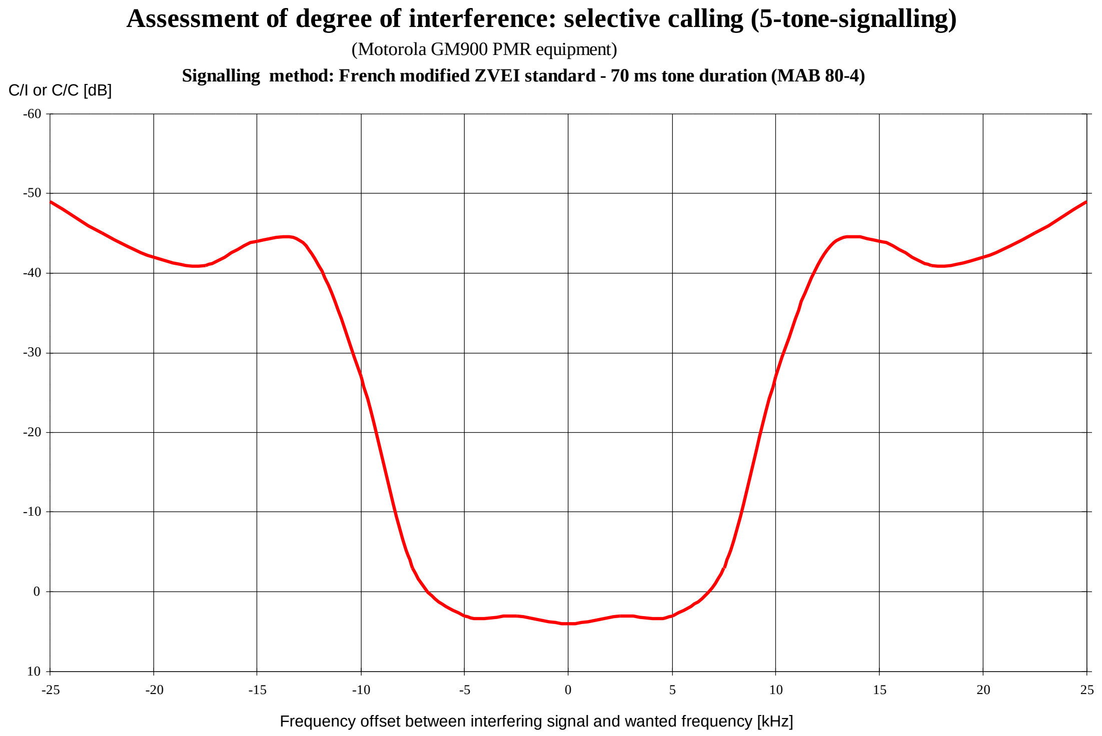
Te PMR system parameters are derived from ETS 300 086 and the results of measurements carried out by the BAPT radio monitoring service.

Output power:	37 dBm (MS); 45 dBm (BS)
Bandwidth:	20 kHz
Receiver sensitivity:	Dependent on the distance between the mobile station and the base station Minimum receiver sensitivity: -105 dBm Average receiver sensitivity: -85 dBm
Basestation antenna height:	30 m
Mobile station antenna height:	1,5 m

C/I or C/C of PMR equipment **without** selective calling:



C/I or C/C of PMR equipment **with** selective calling:



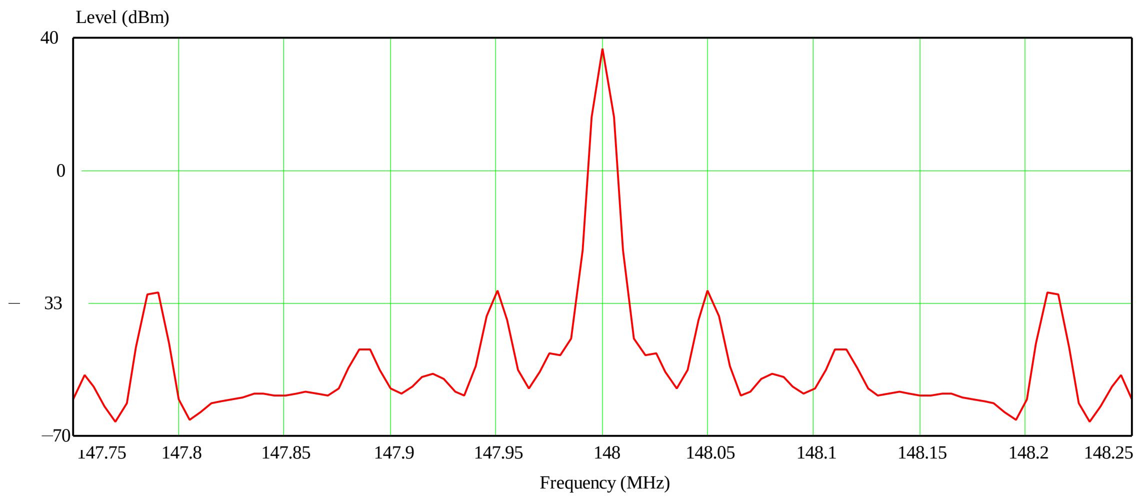
Adjacent channel attenuation: 70 dBc
Distance between transmitting and receiving PMR equipment: 5.000 m / 10.000 m / 15.000 m

<u>MSS MES</u>

The system parameters are derived from ORBCOMM proprietary information and the results of measurements carried out by the BAPT monitoring service.

Output power: 37 dBm

Sendermaske (EIRP):



Bandwidth (99%):	5 kHz
Data transfer rate:	2400 bps
Mobile station antenna height:	1,5 m

Time percentage

Betriebsfunk:

Due to measurements carried out by the monitoring service of the Federal Office for Posts and Telecommunications is has been shown that in the busy hour the time percentage for a PMR channel in the frequency band 148 -149.9 MHz is about 40 -50%. To be on the safe side, a time percentage of 70 % has been used in these analyses.

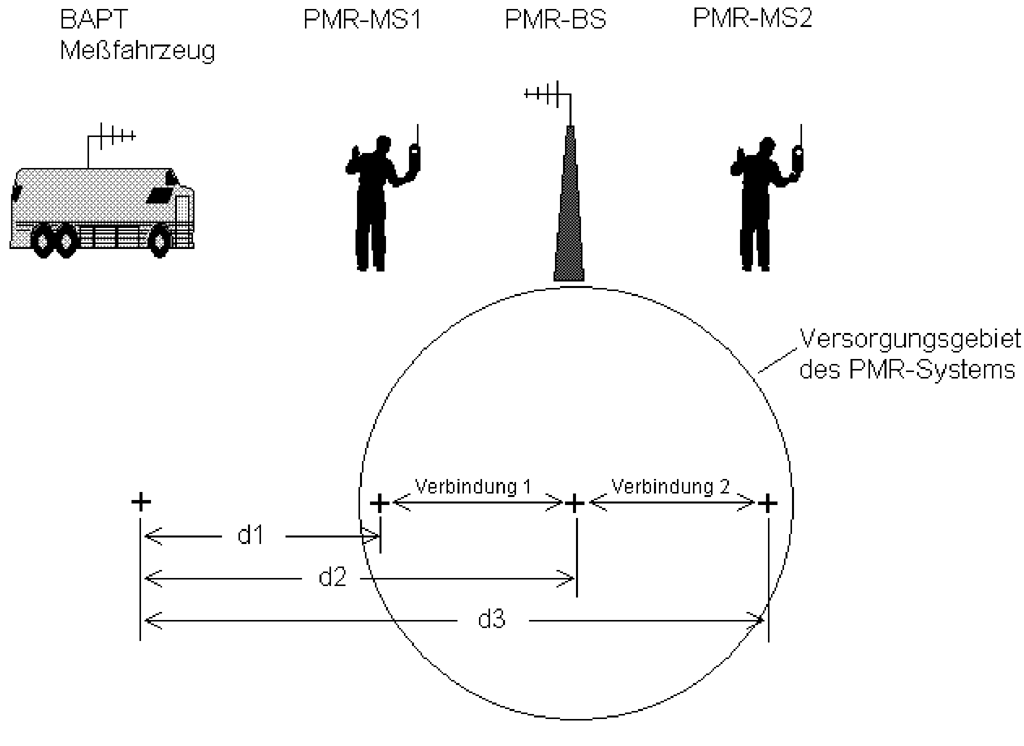


Figure 1

Link 1 and 2 (Figure 1)are two wanted radio connections which are received at the base station with minimum fieldstrength according to..... Therefore the transmission of PMR MS2 cannot be detected by the detection vehicle.

Furthermore, it has been taken into consideration that each PMR receiver tuned on it's assigned frequency can be interfered with a time percentage of 100 %.

MSS system:

Base on market research there will be about 150.000 MES sets in Germany. Based on this figure is the following table:.

Radius (km)	Area (km$^{2)}$	MES in the Area	Time percentage (%)
0,5	0,79	1	0,0006
5	78,54	33	0,19
10	314,16	132	0,76
15	706,86	297	1,72
Peak traffic area	-	-	20