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COMPATIBILITY BETWEEN UMTS 900/1800 AND SYSTEMS OPERATING IN ADJACENT BANDS

Krakow, March 2007

1 EXECUTIVE SUMMARY

This report deals with the compatibility study between UMTS900/1800 and systems operating in adjacent bands.

This report gives the description of the compatibility study methodology, co-existence scenarios, simulation assumptions, and the results for the deployment of UMTS operating in 900 MHz and in 1800 MHz bands taking into account adjacent band systems. Although best effort has been made to provide assumptions and results to encompass the widest range of possible situations, however there might be some country specific cases where different assumptions need to be made. Furthermore it has to be noted that based on the operational experience further analyses may have to be carried out.

Based on the interference analysis, the following conclusions can be made:

- UMTS900 can be deployed in the same geographical area in co-existence with GSM-R as follows:
  1) There is *a priori* no need of an additional guard band between UMTS900 and GSM-R, a carrier separation of 2.8 MHz or more between the UMTS900 carrier and the nearest GSM-R carrier is sufficient without prejudice to provisions in point 2). This conclusion is based on Monte Carlo simulations assumed suitable for typical case.
  2) However for some critical cases (e.g. with high located antenna, open and sparsely populated areas served by high power UMTS BS close to the railway tracks, blocking etc, which would lead to assumption of possible direct line of sight coupling) the MCL calculations demonstrate that coordination is needed for a certain range of distances (up to 4 km or more from railway track).
  3) It is beneficial to activate GSM-R uplink power control, especially for the train mounted MS, otherwise the impact on UMTS UL capacity could be important when the UMTS network is using the 5 MHz channel adjacent to the GSM-R band. However, it has to be recognized that this is only applicable in low speed areas as elsewhere the use of uplink control in GSM-R will cause significantly increased call drop out rates.
  4) In order to protect GSM-R operations, UMTS operators should take care when deploying UMTS in the 900 MHz band, where site engineering measures and/or better* filtering capabilities (providing additional coupling loss in order to match the requirements defined for the critical/specific cases) may be needed in order to install UMTS sites close to the railway track when the UMTS network is using the 5 MHz channel adjacent to the GSM-R band.

     * Currently, the out-of band interference level is given by 3GPP TS 25.104 V7.4.0

  It has to be noted that this study did not address tunnel coverage. Site sharing, which is expected to improve the coexistence, has not been studied either.

- When UMTS900 is deployed in the same geographical area in co-existence with PMR/PAMR (CDMA PAMR, TETRA, TAPS) operating at frequencies above 915 MHz, some potential interference from PAMR/PAMR BS to UMTS900 BS could be a problem. In order to protect UMTS900 BS, the utilization of interference mitigation techniques is necessary:
  - i) Reduced PMR/PAMR BS Tx power
  - ii) Spatial separation
  - iii) External filters
  - iv) Guard band
- The potential interference from UMTS900 to aeronautical DME operating at frequencies above 972 MHz does not represent any difficulty. The frequency range between 960-972 MHz is not currently used by aeronautical DME but is planned to be used in a near future. Some additional margins may be required for the protection of aeronautical DME operating at frequencies between 960 and 972 MHz, where the required additional margins are dependent on DME carriers and aircraft positions. The studies have shown that the only mitigation techniques, in order to ensure the compatibility between the DME system and UMTS900, that would bring sufficient isolation are: additional filtering and a larger guard band. However these two mitigation techniques are not judged applicable. It has to be noted that the impact of the DME ground station (and FRS if necessary) on the UMTS 900 mobile stations has not been studied in this report and may need additional studies. Therefore, the report suggests that a regulatory solution should be examined. It is necessary that a common approach be used within Europe to ensure the compatibility.

Further compatibility study will be necessary if this frequency range is to be used by DME systems or future aeronautical systems addressed under WRC Agenda Item 1.6.

- The compatibility study between UMTS900 and MIDS indicated that an additional margin of 17 dB of UMTS900 BS spurious emissions over the frequency range between 1000 MHz and 1206 MHz in reference to 3GPP technical specifications is required for the protection of MIDS terminal receiver. If this additional margin is obtained by the UMTS BS real performance being better than 3GPP technical specifications, no other protection means such as separation distance etc. are required for the protection of MIDS.
- Potential interference between UMTS1800 and DECT does not appear to be a problem, as the DECT system has a DCA (Dynamic Channel Allocation) mechanism which efficiently avoids an interfered channel except if both systems are deployed indoor. Indeed, although DECT uses DCA, interference analysis shows that in the case of UMTS1800 indoor pico cellular deployment using the frequency channel adjacent to the DECT frequency band, the use of some interference mitigation technique may be necessary to address potential interference to indoor DECT RFP or PP. However, in practice, GSM1800 deployment has demonstrated that no additional interference mitigation techniques are really needed. This statement can be assumed to be extended to the compatibility between UMTS1800 and DECT systems.
- The analysis indicates that the potential interference between UMTS1800 UE and METSAT Earth Stations should not be a problem.
- The preliminary interference analysis leads to the conclusion that, with a guard band of 700 kHz, the potential interference from Radio microphones to UMTS1800 BS should not be a problem if the radio microphones maximum transmit power is limited to 13 dBm (20 mW) for hand held microphones and 17 dBm (50 mW) for body worn microphones as recommended in ERC Report 63 and ERC/REC 70-03E.

It should be noted that the interference analysis between UMTS1800 UE and Fixed Services was not considered in the report.

In some European countries, civil/military aeronautical radionavigation system is using the frequency band adjacent to UMTS900, different to the frequency band of civil radionavigation DME, it is also used as safety-of-life application. The frequency plan and the characteristics of the civil/military aeronautical radionavigation system, as well as the interference analysis between UMTS900 and the civil/military aeronautical radionavigation system are not considered in this report.

Table of contents

2 INTRODUCTION

UMTS networks have been widely deployed in the frequency band 1920-1980 MHz/2110-2170 MHz), however, there are still sparsely populated and remote areas where there are difficulties to provide IMT-2000/UMTS services in a cost-efficient way. UMTS deployment in the 900 MHz band can facilitate the provision of the expected IMT-2000/UMTS services to users in those areas. The main interest for European mobile operators to deploy UMTS in the 900 MHz band is the larger coverage compared to UMTS in the 2000 MHz band. UMTS900 offers a considerably more cost effective solution for providing UMTS services in rural area with low population density.

The total bandwidth of the 1800 MHz frequency band is 2x 75 MHz. In some countries, the 1800 MHz band is not totally used by GSM systems, especially in low population density rural areas. Part of the 1800 MHz band may become a complementary band for deploying UMTS, where the interest for mobile operators to deploy UMTS comes also from the fact that it is easy to share the same GSM1800 radio sites by UMTS systems operating in 1800 MHz band.

The 900 MHz band and 1800 MHz band have been allocated to GSM systems in Europe and they are widely used. As deployment of UMTS (UTRA-FDD) systems in the 900 MHz band and 1800 MHz band does not mean the replacement of GSM systems by UMTS, good compatibility between UMTS and GSM in the 900 MHz and 1800 MHz bands is important and necessary. ECC Report 82 deals with the compatibility study for UMTS deployed in the GSM900 and GSM1800 frequency bands. The deployment scenarios of UMTS900/1800 and potential interference between UMTS and GSM operating in adjacent channels have been described in ECC Report 82.

European frequency allocation tables indicate that several systems are using frequency bands adjacent to UMTS900/1800 (GSM900/1800) systems, and several ERC and ECC Reports have been developed on the compatibility between GSM900/1800 and systems operating in adjacent bands. The intention of this report is to deal with the compatibility study between UMTS900/1800 and systems operating in adjacent bands.

This report gives the relevant parameters of systems operating in adjacent bands of UMTS900/1800, which are needed in interference studies. The interference problems are investigated by both deterministic and statistical approaches. Some scenarios are studied with detailed simulations and analysis, for example the interference scenarios between UMTS900 and GSM-R and the interference scenarios between UMTS1800 and DECT, whereas the potential interference analysis for several other cases are considered and derived from the existing ERC and ECC Reports for GSM900/1800.

In this report, chapter 3 is dedicated to the compatibility study between UMTS900 and systems operating in its adjacent bands. The compatibility study between UMTS1800 and the adjacent band systems is described in chapter 4.

3 COMPATIBILITY STUDY BETWEEN UMTS900 AND SYSTEMS OPERATING IN ADJACENT BANDS

3.1 Systems operating in adjacent bands

All systems operating in bands adjacent to UMTS900 and addressed in this report are summarized in table 3-1 below.

Frequency (MHz)	System	Note
876-880	GSM-R (UL)	
880-915	**GSM900 (UL)** **UMTS900 (UL)**	• **Including E-GSM and P-GSM**
915-921	PMR/PAMR (DL)	
921-925	GSM-R (DL)	
925-960	**GSM900 (DL)** **UMTS900 (DL)**	• **Including E-GSM and P-GSM**
960-1164	Aeronautical Radionavigation Communication systems	• DME/TACAN • MIDS (Military / NATO)

Table 3-1: Systems operating in adjacent bands of UMTS900

The sharing studies between UMTS900 and the following systems operating in adjacent bands were considered:

1) GSM-R
2) PMR/PAMR (e.g. TETRA, TAPS, CDMA)
3) DME
4) MIDS

The interference analysis between UMTS900 and GSM-R is described in section 3.2. Section 3.3 gives a brief description of the interference analysis between UMTS900 and PMR/PAMR. The co-existence scenario and the interference analysis between UMTS900 and aeronautical system DME (Distance Measuring Equipment) is described in section 3.4. The interference analysis between UMTS900 and MIDS is described in section 3.5. The conclusion is given in section 3.6.

At the same time aeronautical radionavigation systems are operating in the frequency band 862-960 MHz in some countries (see 5.323 Radio Regulations). Compatibility studies with these systems were not considered in this Report.

3.2 Compatibility study between UMTS900 and GSM-R

The UMTS900 frequency band is arranged as:

- Uplink (UE transmit, BS receive): 880 – 915 MHz
- Downlink (BS transmit, UE receive): 925 – 960 MHz
- Carrier separation: 5 MHz

The GSM-R frequency band is arranged as:

- Uplink (MS transmit, BS receive): 876 – 880 MHz
- Downlink (BS transmit, MS receive): 921 – 925 MHz
- Carrier separation: 200 kHz

The frequency band plans for GSM-R and UMTS are shown in figure 3-1.

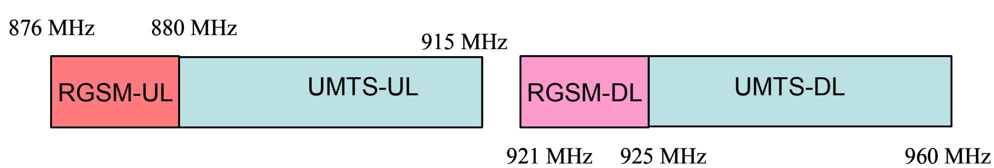


Figure 3-1: Frequency band plan for GSM-R and UMTS in 900 MHz band

3.2.1 GSM-R system characteristics

Details of the GSM-R RF performance and system parameters can be found in 3GPP technical specification TS45.005 [6]. See also [22]. The main GSM-R system characteristics are summarized in tables 3-2, 3-3, 3-4, and 3-5.

	GSM-R		
Frequency band (UL) (MHz)	876-880		
Frequency band (DL) (MHz)	921-925		
Carrier separation (kHz)	200		
Modulation	GMSK		
BS-MS MCL (dB)	60 (urban area) 70 (rural area)		
Typical cell range (km)	8		
	BS	**Hand portable MS**	**Train Mounted MS**
Maximum Tx power (W)	30	2	8
Thermal noise (dBm)	-121	-121	-121
Noise figure (dB)	5	9	7
Noise floor (dBm)	-116	-112	-114
Receiver sensitivity (dBm)	-110	-102	-104
Receiver protection ratio (dB)	9	9	9
Antenna height (m)	20 (Urban) 45 (Rural)	1.5	4.5
Antenna gain (dBi)	18	0	2
Feeder loss (dB)	3	0	0
Spectrum mask and spurious emissions	3GPP TS45.005	3GPP TS45.005	

Table 3-2: Main GSM-R system parameters

BS Tx power (dBm)	100 (kHz)	200 (kHz)	250 (kHz)	400 (kHz)	≥ 600 < 1 200 (kHz)	≥ 1 200 < 1 800 (kHz)	≥ 1 800 < 6 000 (kHz)	≥ 6 000 (kHz)
≥ 43	**+0,5**	**-30**	**-33**	**-60***	**-70**	**-73**	**-75**	**-80**
41	+0,5	-30	-33	-60*	-68	-71	-73	-80
39	+0,5	-30	-33	-60*	-66	-69	-71	-80
37	+0,5	-30	-33	-60*	-64	-67	-69	-80
35	+0,5	-30	-33	-60*	-62	-65	-67	-80
≤ 33	+0,5	-30	-33	-60*	-60	-63	-65	-80
NOTE: * For equipment supporting 8-PSK, the requirement for 8-PSK modulation is -56 dB.								

Table 3-3: Spectrum mask of GSM-R BTS*

*Note: The values given in this table are the maximum allowed level (dB) relative to a measurement in 30 kHz on the carrier as defined in 3GPP TS45.005 [6].

	BS	MS
General requirement	-36 dBm*	-36 dBm*
Co-siting with GSM900	-89 dBm/100 kHz	

Table 3-4: Spurious emission of GSM-R MS

* measurement band depends on the carrier separation, which is defined in TS45.005 [6].

Frequency band	GSM-R					
	other MS		small MS		BTS	
	dBµV (emf)	dBm	dBµV (emf)	dBm	dBµV (emf)	dBm
In-band						
600 kHz ≤ $\|f-f_o\|$ < 800 kHz	75	-38	70	-43	87	-26
800 kHz ≤ $\|f-f_o\|$ < 1,6 MHz	80	-33	70	-43	97	-16
1,6 MHz ≤ $\|f-f_o\|$ < 3 MHz	90	-23	80	-33	97	-16
3 MHz ≤ $\|f-f_o\|$	90	-23	90	-23	100	-13
out-of-band						
(a)	113	0	113	0	121	8
(b)	-	-	-	-	-	-
(c)	-	-	-	-	-	-
(d)	113	0	113	0	121	8

Table 3-5: Blocking characteristics of GSM-R

The cases (a), (b), (c), (d) are defined in 3GPP TS45.005 [6].

3.2.2 Interference analysis based on the comparison of out-of-band emissions between UMTS and GSM

3.2.2.1 Introduction

GSM has been deployed over many years and GSM-R has been deployed in some European countries, and no problem of interference from GSM emissions into GSM-R has been raised so far. This section deals with the comparison of out-of-band emissions between GSM and UMTS. The comparison of emission masks is very helpful in evaluating the potential interference from UMTS900 to GSM-R.

3.2.2.2 Comparison of UMTS900 and GSM900 out-of-band emissions

- ***Definition of out-of-band emissions***

Out-of-band emissions are defined in the GSM900 and UMTS900 technical specifications. The ACLR (Adjacent Channel power Leakage Ratio) can be obtained by the integration of the spectrum mask over 200 kHz, the ACLR profiles of GSM900 and UMTS900 are given in Annex 1.

- ***Assumptions***

In practical GSM deployment, a sector of a GSM site has several emitters (TRX) and thus, is using several 200 kHz GSM carriers over a band of 5 MHz, in order to meet the capacity requirement. It is therefore intended to derive the GSM900 out-of-band emissions with several GSM channels being aggregated.

Current GSM networks use a 1x3 re-use scheme for TCH channels; in other words, each TRX is using one carrier randomly chosen among a list of three carriers. For instance, a tri-sector GSM900 base-station using 3 TRX is using 3 GSM frequency carriers. As a consequence, it can be assumed that a GSM sector is using three carriers over 5 MHz. The case of three GSM carriers will be taken into account in the comparison of out-of-band emissions between GSM and UMTS.

Figure 3-2 below shows the spectral occupancy for the case where the GSM deployment is using a 1x3 frequency re-use scheme and three TRX are implemented in a sector with three 200 kHz carriers. It is assumed that the GSM carriers are equally distributed. A worst case scenario would be where all the GSM carriers are located close to the GSM-R allocation, whereas the best scenario in terms of interference would be to have the three carriers as far as possible from the GSM-R allocation.

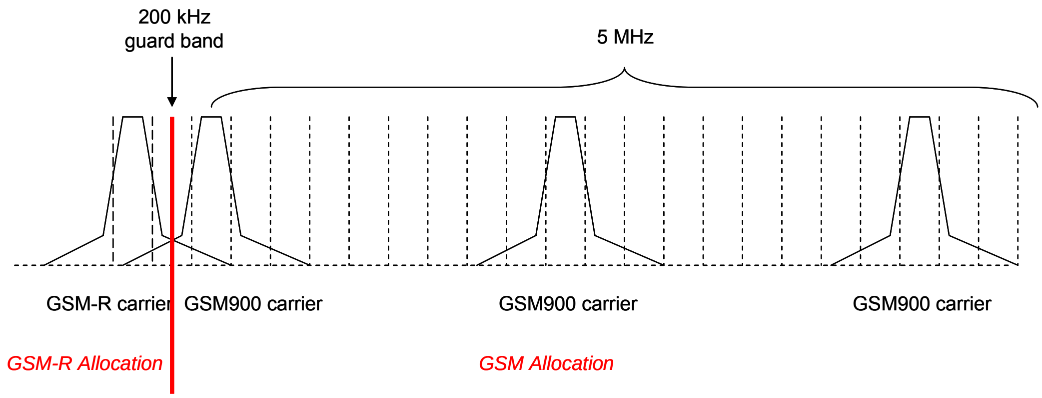


Figure 3-2: Spectral occupancy of an E-GSM sector over 5 MHz

- ***Comparison of BS out-of-band emissions***

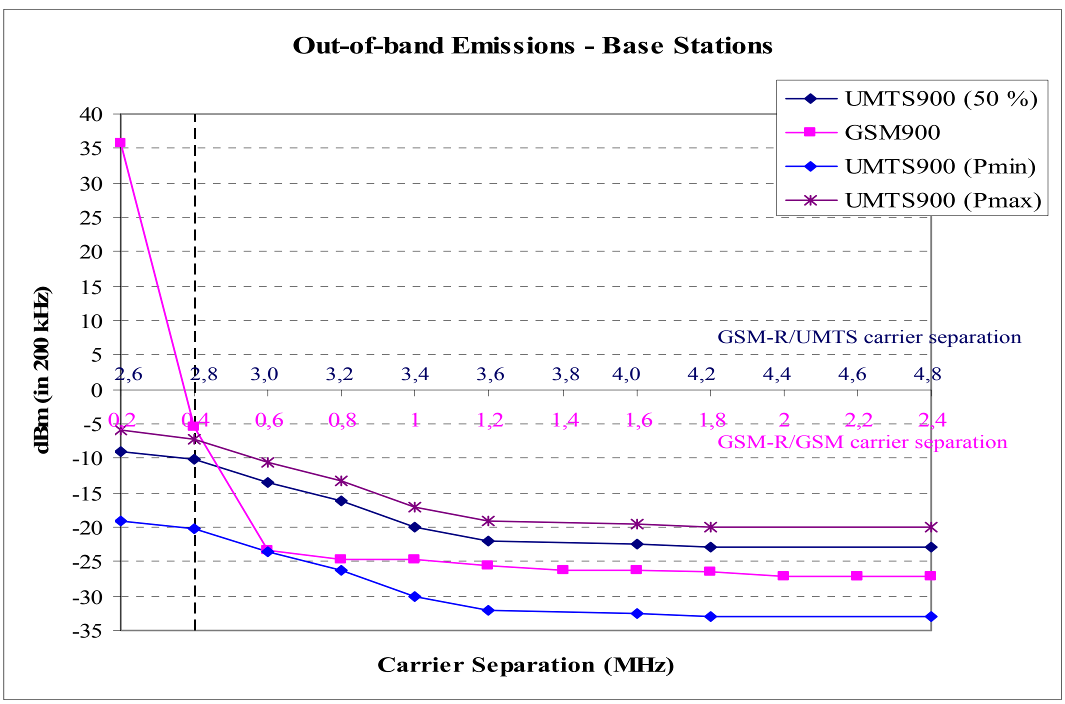


Figure 3-3: Comparison of the BS out-of-band emissions

Figure 3-3 gives the out-of-band emissions when three GSM channels are deployed as shown in figure 3-2. The GSM out-of-band profile is compared with the UMTS spectrum mask. The transmitting power of both GSM and UMTS BSs are fixed as 43 dBm.

Figure 3-3 shows the out-of-band emissions when the UMTS sector is transmitting at Pmin, Pmax and also when the cell load is at 50 %, where Pmin is the transmitting power of common channels, and the transmitter power at cell load of 50% is calculated by the addition of common channel powers and the transmitting power for traffic channels at 50% cell load. It should be noted that in the GSM mask, after 2 MHz carrier separation, it enters the spurious emission domain.

GSM BS BCCH channel's maximum transmitting power does not depend on the traffic load in the cell and is fixed at its maximum power. On other traffic channels there may be a reduction in mean transmitted power when power control is used, which can be further reduced by the use of DTX. UMTS BS transmitting power is dependent on the traffic load, where usually 10% of the BS power is allocated to the common channel (Pilot, Synch, etc) and the rest of the BS Tx power is allocated to the traffic, depending on the cell load.

When the traffic load is zero, then the Pmin = 10% of the BS transmitting power, when traffic load is 50%, the BS Tx Power = (10% +50%x90%) x Maximum TX BS Power; thus TxPower = 55% x Maximum TX BS Power or TxPower = 43 dBm – 2.6 dB = 40.4 dBm.

It should be noted that 50% of cell load is the reference cell load in UMTS network design, whereas in rural areas the reference cell load could be lower than 30% in a coverage driven design. When the cell load is 100%, then the UMTS BS will transmit at its maximum power Pmax.

It should be noted that 3GPP technical specification TS25.104 and ETSI specification TS125104 defined only the UMTS BS spectrum mask and out-of-band emission limits at the maximum transmitting power. The out-of-band emissions at reduced transmitting power Pmin and P(50%) are calculated under the assumption that the UMTS BS spectrum mask (ACLR) is the same as that at Pmax as defined in ERC Report 68.

It can be seen from the curves in figure 3-3 that at 2.8 MHz carrier separation the out-of-band emission of UMTS is lower than that of GSM900 at 400 kHz carrier separation, and at 3 MHz carrier separation it is above the GSM900 BS out-of-band emission at 600 kHz.

- ***Comparison of Terminal out-of-band emissions***

Figure 3-4 below gives the comparison of out-of-band emissions between UMTS UE and GSM MS, where the cumulative effect of three GSM channels as shown in Figure 3-3 was taken into account in the calculation of GSM MS out-of-band emissions. It should be noted that the variation in locations of the GSM MS relative to the UMTS UE are ignored as this will average out. The GSM900 terminal power is fixed at 33 dBm and the UMTS900 terminal power at 21 dBm.

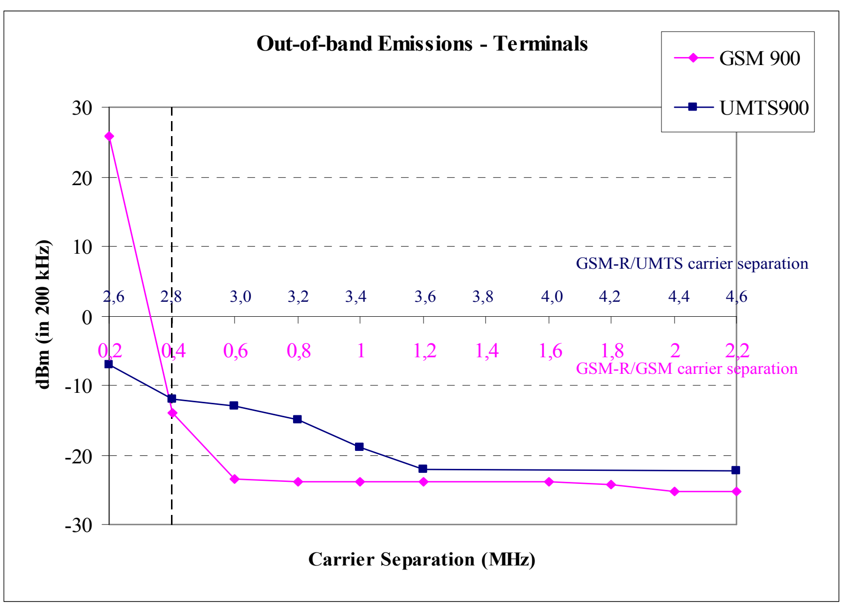


Figure 3-4: Comparison of the Terminal out-of-band emissions (Pmax)

Without taking into account the power control effect, figure 3-4 shows that at 2.8 MHz carrier separation UMTS UE out-of-band emission is at the same level as GSM900 MS, at 3.0 MHz carrier separation it is higher, but still below the out-of-band emission of GSM900 MS at 400 kHz carrier separation.

Implementing power control in GSM900 and UMTS900 terminals helps to reduce emission levels drastically. ECC Report 82 (Compatibility Study For UMTS Operating within the GSM 900 and GSM 1800 Frequency Bands) provides the CDF (Cumulative Distribution Function) of UMTS900 UE transmit power. For outdoor UE, it should be noted that 90% of terminals transmit at a power level lower than -23 dBm and 50 % at a power level lower than -32 dBm. It should also be noted that GSM MS power control is much less fast and less efficient compared to UMTS UE power control.

3.2.2.3 Analysis summary

The comparison of out-of-band emissions between GSM900 and UMTS900 shows that the UMTS900 and GSM900 out-of-band emissions do not present significant difference, which means that UMTS900 should not *a priori* cause more interference than GSM900.

GSM-R has been deployed in many European countries, although experience with uncoordinated use adjacent to the lowest E-GSM frequencies is limited.

Based on the comparison of out-of-band emissions between GSM900 and UMTS900, a 2.8 MHz carrier separation between UMTS carrier and the nearest GSM-R carrier is *a priori* sufficient to ensure the protection of GSM-R based on the above approach.

3.2.3 Interference analysis with MCL approach

3.2.3.1 Introduction

This section deals with the interference analysis between UMTS900 and GSM-R using an MCL (Minimum Coupling Loss) approach. The interference analysis described in this section covers both in-band blocking and out-of-band blocking.

3.2.3.2 Interference analysis results

3.2.3.2.1 *Out-of-band emissions*

Using the out-of-band emission figures (UMTS BS Pmax out-of-band emission curve) described in Section 3.2.2 the exclusion distances have been calculated with an MCL approach for the protection of GSM-R.

3.2.3.2.2 *Interference analysis results*

- **UMTS BS to GSM-R MS**

The calculations are provided in Annex 2, Part A. Case 1 (based on the Hata-Okumura model) shows that the interference distances for a GSM-R MS operating at minimum GSM-R network design signal level are 3.6 km for speech and 4.4 km for data in the highest GSM-R channel; and 1.8 km for speech and 2.2 km for data in the fourth channel.

Even moving to beyond the fourth channel will give interference distances of 1.5 km and 1.9 km for speech and data respectively.

This problem can be reduced by the addition of filters in the UMTS BS, however this is unlikely to solve the problem for the highest GSM-R channel unless the filter response is very sharp.

It should be noted that no account has been taken of the effect of multiple UMTS transmitters in these calculations.

Two alternative calculations are given as additional examples in Annex 2. On Case 1bis the assumptions for the calculation are considered as more conservative in order to address critical situations (including contribution of direct line of sight). One other example of calculations is provided Part B of Annex 2 for the cases where the GSM-R network is noise-limited and interference-limited.

The blocking performance of GSM-R mobiles is defined in EN300910. For the GSM-R MS it is defined as -38 dBm for 600-800 kHz carrier separation and this figure has been used below. However, it should be noted that when the difference between the centre of the GSM-R and UMTS channel is set at 2.8 MHz (band edge separation of 200 kHz) then the interference will be in-band and a worse blocking performance will be experienced.

As shown in Annex 2 - Part A, Case 2, this equates to a distance of 420 m for the high power UMTS BS. If the fading margin is ignored, the blocking distance rises to 830 m.

- **UMTS BS to GSM-R BTS**

Annex 2 - Part A, Case 3 covers the blocking of the GSM-R BTS by the high power UMTS900 BTS. This demonstrates that blocking will occur at a distance of 664 m, increasing to 1.3 km if the fading margin is ignored.

Annex 2 - Part A, Case 4 shows that even a low power medium range UMTS BS in a micro-cellular deployment will cause blocking at distances of 175 m, increasing to 320m if the fading margin is ignored.

Blocking of the GSM-R BTS could be reduced by applying filters at the GSM-R BTS.

The definition of receiver blocking is the effect of a strong out-of-band signal, present at the input of the receiver, on the receiver's ability to detect an in-band wanted signal. Thus, the blocking signal reduces the specified receiver sensitivity by a certain number of dBs.

In the case of GSM-R BS receive/UMTS-BS transmitting, the blocking effects from a UMTS BS have to be compared with what would occur from a GSM BTS.

Noting that the height of the antennas, tilt, gain, and sector aperture will be the same for GSM and UMTS BS, two elements need to be considered:

- The max EIRP from the interferer and the resultant interfering level at the victim BS, including selectivity properties of the receiver;
- The occurrence probability of blocking issues with regard to 2G/3G air interface refarming.

As gains are the same for both UMTS and GSM BS, we will just compare transmitting power of each technology. When UMTS maximum transmit power is 43 dBm/3.84 MHz, GSM BS transmit power is 43 dBm/200 kHz with a number of simultaneous channels transmitting, dependent on the size of band allocated to one operator and the frequency reuse factor. It has to be noted that UMTS downlink is power controlled in order to reduce the transmitting power to between 33 and 43 dBm/3.84 MHz. GSM BS transmits at radio frequency channels without power control such as BCCH (Broadcast Common Channel) channels using the full power of 43 dBm/200 kHz. Thus from a transmitting power point of view, GSM BS could cause more severe blocking to GSM-R than UMTS BS.

Concerning occurrence probability, using the same cell sites, a GSM network with 4x12 frequency reuse factor for radio frequency channels without power control and frequency hopping, 4x12 or 1x3 for TCH with or without frequency hopping and power control, the probability to have a GSM BTS transmitting in close geographical vicinity of a GSM-R base receiver will be the same as for a UMTS network with frequency re-use 1 scheme.

3.2.3.2.3 *Analysis summary*

Generally it is considered that the MCL method for interference analysis is the worst case where no system outage is accepted, and consequently the results are usually pessimistic. In the interference analysis with MCL approach presented above, the minimum allowed signal level used was the network design objective level of -98 dBm, and not the GSM-R MS receiver sensitivity level, which allows for a small probability of outage at the limits of coverage.

From the interference analysis results shown above with MCL approach, it is apparent that considerable interference at distances of greater than 2 km will be caused to GSM-R systems if the lower UMTS channels are used. This result will also be applicable to lower power UMTS BS, although the interference distance is reduced to 170 m.

A reduction in the effects of out-of-band emissions can be achieved by applying filtering to the UMTS BS, but it is considered that this will still require a suitable guard band.

The effect of blocking is more significant and requires that no high power UMTS900 BS is placed closer than 660 m to the railway without coordination. Even low power micro-cells will need to be placed at a distance of at least 170 m, which will rule out their deployment inside railway station areas.

3.2.4 Interference analysis with Monte-Carlo simulations

3.2.4.1 UMTS900 and GSM-R deployment and co-existence scenarios

3.2.4.1.1 *GSM-R deployment scenario*

GSM-R networks offer a linear coverage of railway lines with bi-sector radio sites installed along the railway, as shown in figure 3-5. The main system characteristics and network parameters are summarized in table 3-2.

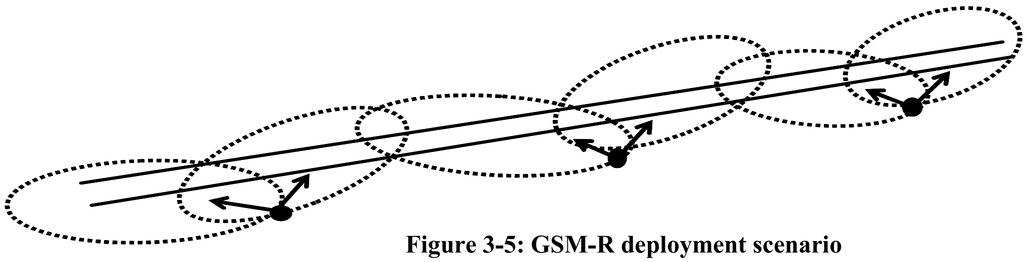


Figure 3-5: GSM-R deployment scenario

Two major characteristics of GSM-R coverage are: 1) Linear coverage; 2) High quality coverage (95% space and time availability). In Europe, most GSM-R networks are designed with a BS antenna height of about 30 m, and cell range is around 5-6 km. The assumption of BS antenna height at 45 m and cell range at 8 km represents the worst case scenario for the sharing study.

There are two types of GSM-R MS as described in table 3-2: 2W handset MS and 8W train mounted MS. As shown in figure 3-6 below, the GSM-R 8W train mounted MS is the MS that is located inside the train, connected to the external MS antenna mounted on the roof top of the train.

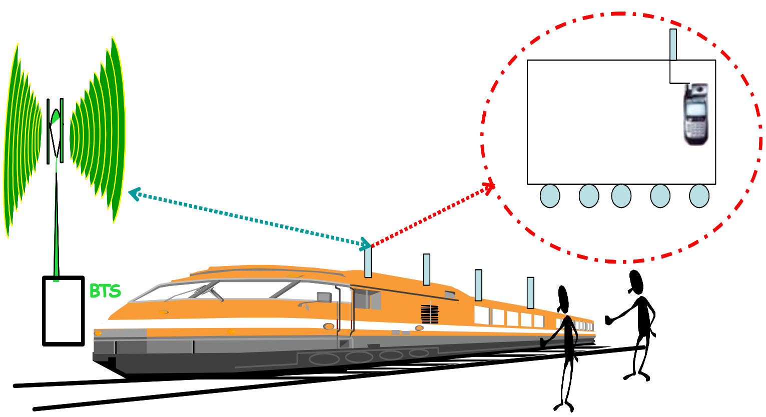


Figure 3-6: Connection between train mounted antenna and MS situated inside of the train

3.2.4.1.2 *UMTS900 deployment scenario*

The main objective of UMTS deployment in the 900 MHz band is for coverage extension, but in urban areas the deployment of UMTS in the 900 MHz band can also improve tremendously the indoor coverage quality. In rural areas the deployment of UMTS in the 900 MHz band allows mobile network operators to offer 3G services at lower cost.

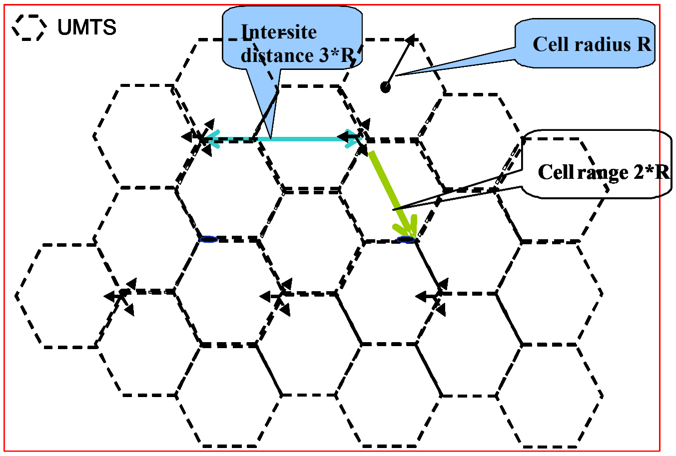


Figure 3-7: UMTS network layout

The typical UMTS900 deployment scenario considered in the sharing study with GSM-R is the rural area deployment with cell range 2*R=5000 m, where the network layout is shown in figure 3-7.

3.2.4.1.3 *Co-existence between UMTS900 and GSM-R*

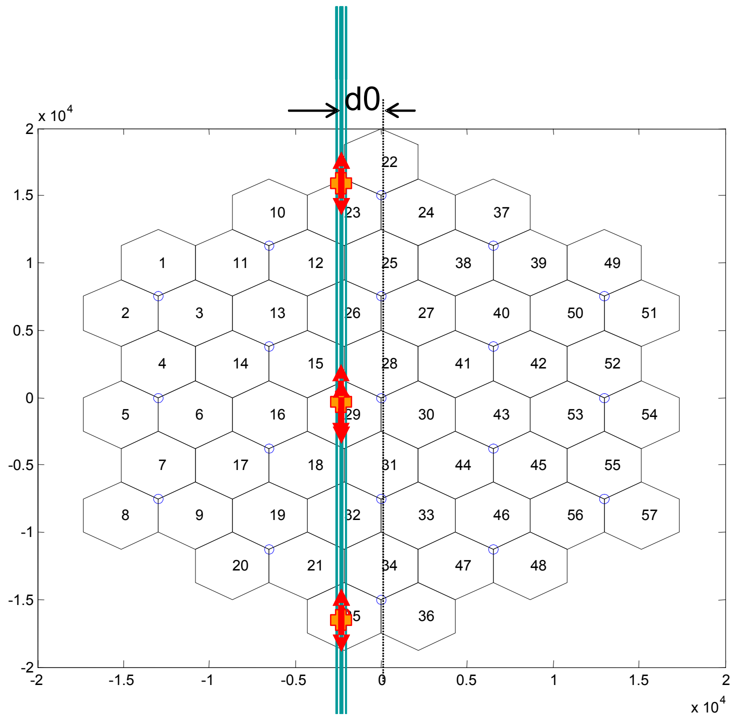
Based on the GSM-R and UMTS deployment scenarios described above, simulations were performed based on the co-existence scenario shown in figure 3-8.

As shown in figure 3-5, GSM-R BS sites are placed along the railway, where the average distance between GSM-R BS radio site and the railway is 20 m. The separation distance between the railway line and UMTS sites is represented by d0. Table 3-6 below gives three typical distance shift r=d0/4330 m and the separation distances between railway line and the nearest UMTS sites, where the distance 4330 m is obtained from 2*R*cos(30°)=5000*cos(30°)=4330 m, as shown in figure 3-8.

Distance shift r (r=d0/4330)	Separation distance d0 (m)
0	0
0.5	2165
1	4330

Table 3-6: Distance between railway line and UMTS sites

The simulation was done with a quasi-static Monte-Carlo simulator. UMTS UEs are randomly distributed within the UMTS900 coverage area, the reference UMTS network uplink and downlink capacities are simulated without the presence of GSM-R network. The UMTS uplink capacity is obtained with the threshold of 6 dB noise rise, corresponding to 75% cell load. Downlink capacity is simulated with the threshold of 5% outage.



GSM-R MS are uniformly distributed on the railway line, GSM-R downlink channel is considered as radio frequency channels without power control, but power control on uplink is activated in the simulations. The reference GSM-R performance is the uplink and downlink outages without interference from UMTS. It should be noted that this co-existence scenario is valid for rural environment.

It is important to note that these simulations didn't consider dynamic behavior of GSM-R (e.g. for the case of deployment of high speed trains) and UMTS900 systems. Additional studies for those cases may be needed on a national basis, based on practical experience.

3.2.4.2 Simulation assumptions

Simulation assumptions are summarized in table 3-7. These assumptions are similar to those used in the sharing study between UMTS900 and GSM900 described in ECC Report 82[1].

Scenario	**UMTS(macro) - GSM-R(macro) in rural area in uncoordinated operation**
Simulation cases	Two simulation cases : UMTS uplink as victim and GSM-R DL as victim *1) GSM-R Downlink* *-GSM-R (radio frequency carrier without power control) as victim for train mounted GSM-R MS* *2) UMTS Uplink* *- WCDMA UL as victim (Simulate GSM system, then add UMTS users until the total noise rise hits 6 dB)* *- GSM-R uplink power control is activated* *-No frequency hopping for GSM-R* -Run simulations with various ACIRs between UMTS carrier and the nearest GSM-R carrier for various space separations between UMTS radio site and railway (d0).

<table>
<tr><td>Network layout</td><td colspan="2">• As shown in figure 3-8 above
- Rural environment
- 3-sector configuration for UMTS network
- bisector configuration for GSM-R network
- GSM-R frequency reuse 6, as shown in figure3-9.
-19 sites (i.e., 57 cells (sectors)) with wrap-around for UMTS
- UMTS Cell radius R=2500m, cell range 2R=5000m, inter-site distance 3R= 7500 m (as shown in figure 3-7)
-GSM-R cell range : 8 km
-Distance between GSM-R radio site and railway: 20 m</td></tr>
<tr><td rowspan="2">*System parameters*</td><td>*WCDMA*</td><td>• BS antenna gain with cable loss included = 15dBi
• BS antenna height H_{bs}=45 m;
• UE antenna height H_{ms}=1.5 m
• BS-UE MCL=80 dB
• BS antenna(65° horizontal opening) radiation pattern is referred to 3GPP TR 25.896 V6.0.0 (2004-03), Section A.3 (Annex)
• UE antenna gain 0 dBi (omni-directional pattern)</td></tr>
<tr><td>*GSM-R*</td><td>• BS antenna gain with cable loss included = 15dBi
• BS antenna height H_{bs}=45 m;
• MS antenna height H_{ms}=4.5 m (train mounted MS)
• BS-MS MCL=70.5 dB
• BS antenna(65° horizontal opening) radiation pattern is referred to 3GPP TR 25.896 V6.0.0 (2004-03), Section A.3 (Annex)
• Train mounted MS antenna gain 2 dBi (omni-directional pattern)</td></tr>
<tr><td rowspan="2">*Services*</td><td>*WCDMA*</td><td>• *8 kbps Speech (chip rate: 3.84 Mcps)*
o *Eb/Nt target (downlink): 7.9 dB*
o Eb/Nt target (uplink): 6.1 dB</td></tr>
<tr><td>*GSM-R*</td><td>• *Speech*
• *SINR target (downlink): 9 dB for speech and 12 dB for data*
• *SINR target (uplink): 6 dB*</td></tr>
<tr><td>*Propagation model*</td><td>*WCDMA and GSM-R*</td><td>*Log_normal_Fading = 10 dB*
Rural area propagation model (Hata model)
$L(R) = 69.55 + 26.16 \log f - 13.82\log(H_b) + [44.9 - 6.55\log(H_b)]\log R - 4.78(\log f)^2 + 18.33 \log f - 40.94 - a(Hm)$
Hb is BS antenna height above ground in m, f is frequency in MHz, R is distance in km, Hm is the MS antenna height in m.

a (Hm) = [1.1*log(f) - 0.7]*Hm - [1.56*log(f) - 0.8]

With Hb=45m, Hm=1.5m, f=920 MHz, the propagation model for UMTS UE is simplified as

L1(R) =34.1*log(R) + 95.6

With Hb=45m, Hm=4.5m, f=920 MHz, the propagation model for GSM-R MS is simplified as

L2(R) =34.1*log(R) + 87.9

The path loss from a transmitter antenna connector to a receiver antenna connector (including both antenna gains and cable losses) will be determined by:
Path_Loss = max (L(R) + Log_normal_Fading - G_Tx – G_Rx, Free_Space_Loss + Log_normal_Fading - G_Tx – G_Rx, MCL)

where
G_Tx is the transmitter antenna gain in the direction toward the receiver antenna, which takes into account the transmitter antenna pattern and cable loss,</td></tr>
</table>

		G_Rx is the receiver antenna gain in the direction toward the transmitter antenna, which takes into account the receiver antenna pattern and cable loss, Log_normal_Fading is the shadowing fade following the log-normal distribution.
Cell selection	*WCDMA*	*As per 3GPP TR 25.942*
	GSM-R	*As for WCDMA in 3GPP TR 25.942, but with only one link selected at random within a 3 dB handover margin*
SIR calculation	*WCDMA*	*As per TR 25.942, except for the following changes:* • *Interference contributions from GSM TRXs or MSs are added to the total noise-plus-interference.* • *Processing gain is changed to 26.8 dB for 8 kbps* • *Thermal noise level is -103 dBm for uplink* • *Thermal noise level is raised to -96 dBm for downlink*
	GSM-R	*Total noise-plus-interference is sum of thermal noise, GSM-R co-channel, and WCDMA interference. Cells are synchronised on a time slot basis. Adjacent channel GSM interference is neglected.* • *Noise floor (downlink): -111 dBm* • *Noise floor (uplink): -113 dBm*
Power Control assumption	*WCDMA*	*As per 3GPP TR 25.942* • *21 dBm terminals* • *Maximum BS power: 43 dBm* • *Maximum power per DL traffic channel: 30 dBm* • *Minimum BS power per user: 15 dBm.* • *Minimum UE power: –50 dBm.* • *Total CCH power: 33 dBm*
	GSM-R	*Stabilization algorithm same as for WCDMA (C/I based) with a margin of 5 dB added to the SIR target.* • *Maximum power (TRx): 43 dBm* • *Minimum power (TRx): 10 dBm (radio frequency carrier with power control)* • *Maximum power (MS): 39 dBm* • *Minimum power (MS): 5 dBm*
Capacity	*WCDMA*	*Capacity loss versus ACIR as per 3GPP TR 25.942*
	GSM-R	*Load to maximum number of users and observe change in outage (i.e., 0.5 dB less than SINR target)*
ACIR	*WCDMA to GSM-R*	*As per spectrum masks defined in TS 25.101, TS 25.104 (applying the appropriate measurement BW correction), unless capacity loss is found to be significant.*
	GSM-R	$\text{ACIR}(f) = C(f_0) + m(f - f_0)$ (dB) *GSM-R BTS to WCDMA UE:* *Consider 3GPP TS45005 GSM BTS transmitter emission mask for 900 band and WCDMA UE receiver selectivity slope, m = 0.8 dB / 200 kHz* *GSM-R MS to WCDMA BS:* *Consider 3GPP TS45005 GSM-R MS transmitter emission mask for 900 band and WCDMA BS receiver characteristics, m = 0.5 dB / 200 kHz*

Table 3-7: Summary of simulation parameters for the co-existence between UMTS900 and GSM-R

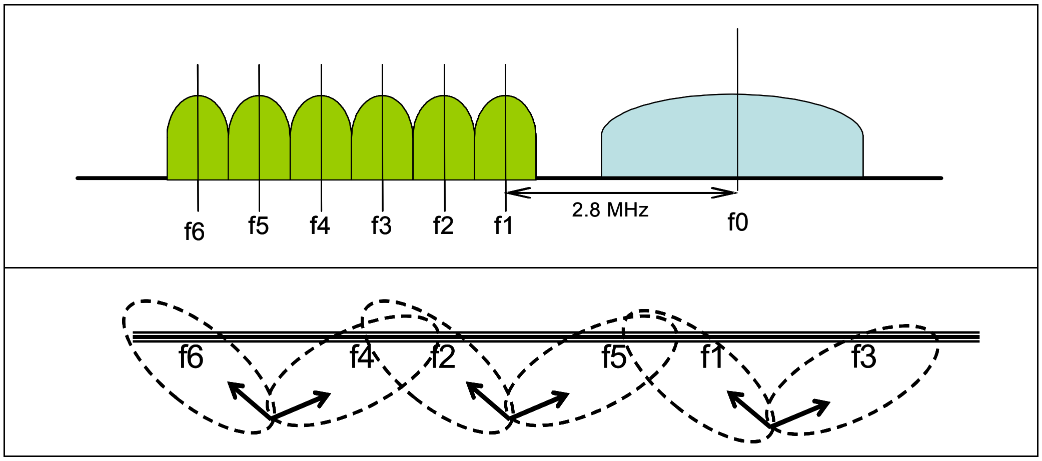


Figure 3-9: GSM-R frequency reuse

GSM-R carriers' arrangement relative to UMTS carrier and the GSM-R frequency re-use plan are given in figure 3-9.

3.2.4.3 Interference analysis method

Interference between UMTS operating in the 900 MHz band and GSM-R was analyzed with the method of Monte-Carlo simulations. The same simulation tools used for the sharing study between UMTS900 and GSM900 as described in ECC Report 82[2] was used for performing simulations for the co-existence between UMTS900 and GSM-R based on the co-existence scenario described above.

The objective of Monte-Carlo simulations is to determine the interference between UMTS900 and GSM-R at different carrier separations and at different space separations between the railway line and UMTS sites.

ACIR values for UMTS DL/UL as victims and for the GSM system (used in this study as GSM-R) DL/UL as victims at carrier separations of 2.8 MHz and 4.8 MHz are calculated and described in the ECC Report 82 [1]. They are summarized in tables 3-8 and 3-9.

Carrier separation	2.8 MHz		4.8 MHz	
	UMTS UL as victim	UMTS DL as victim	UMTS UL as victim	UMTS DL as victim
ACIR (dB)	43.1	30.5	> 47.4	> 30.5

Table 3-8: ACIR for UMTS UL/DL as victim when being interfered by GSM-R UL/DL

Carrier separation	2.8 MHz		4.8 MHz	
	GSM-R UL as victim	GSM-R DL as victim	GSM-R UL as victim	GSM-R DL as victim
ACIR (dB)	31.3	50	43.3	63

Table 3-9: ACIR for GSM-R UL/DL as victim when being interfered by UMTS UL/DL

Two simulation cases were studied:

1) GSM-R DL outage degradation based on C/I threshold due to interference from UMTS BS.
2) UMTS uplink capacity loss due to interference from GSM-R 8 W train mounted MS.

3.2.4.4 Simulation results

3.2.4.4.1 *Probability of GSM-R DL outage (%)*

The simulated GSM-R DL outage with speech service C/I=9 dB without interference from UMTS based on the frequency reuse plan given in figure 3-9 is nearly zero. The probability of GSM-R DL outage (C/I=9 dB) as a function of ACIR between UMTS carrier and the nearest GSM-R carrier for different space separation distances between UMTS BS site and railway line (d0 as indicated on figure 3-8 and distance shift r in table 3-6) was simulated. The simulation curves for different distance offsets are plotted in figure 3-10.

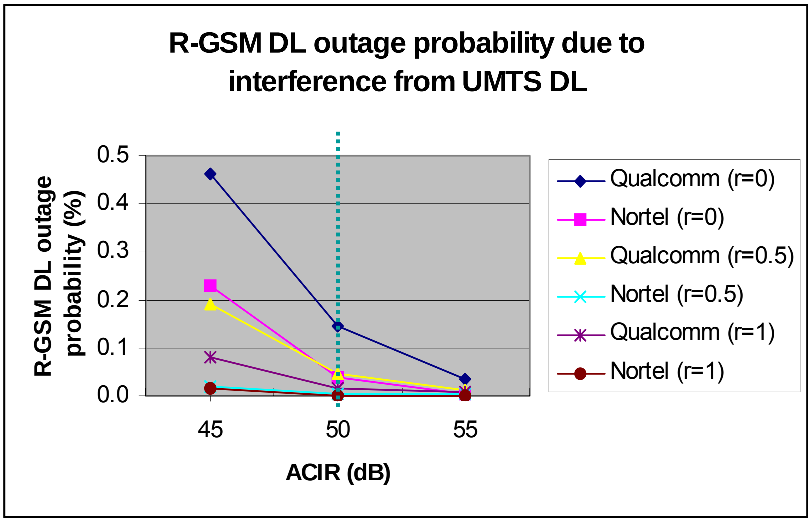


Figure 3-10. Probability of GSM-R DL Outage (%) (C/I=9 dB)

As shown in figure 3-10, at the operating point ACIR=50 dB which corresponds to a carrier separation of 2.8 MHz between the UMTS carrier and the nearest GSM-R carrier, the GSM-R DL outage probability is smaller than 0.15% for the worst case when UMTS sites are co-aligned with GSM-R railway sites. When UMTS sites are not on the railway track, the interference is even smaller. When the railway and UMTS sites are separated by 2165 m, GSM-R DL outage probability is smaller than 0.045%, and when the separation distance is 4330 m, the GSM-R DL outage probability is below 0.015%.

From the simulation results, it can be considered that the interference from UMTS DL to GSM-R DL train-mounted MS is under acceptable level, and that no additional guard band is required for the protection of GSM-R DL. Thus UMTS can be deployed in the same geographical area with a carrier separation of 2.8 MHz between the UMTS carrier and the nearest GSM-R carrier.
For the co-existence scenario between UMTS900 and GSM-R described in section 3.2.4.1 and simulation assumptions described in section 3.2.4.2, simulations on the interference from UMTS900 DL to GSM-R DL reception of train mounted MS have been performed with CEPT simulation tool SEAMCAT 3 (Version 3.1.36.2) for the thresholds of C/I=9 dB and C/I=12 dB, the simulation results are presented in figure 3-10a. The considered carrier separation between UMTS carrier and the nearest GSM-R carrier is 2.8 MHz.

The SEAMCAT scenario file for this study is attached to this report (can be found at the website http://www.ero.dk/ next to the downloadable file of this report).

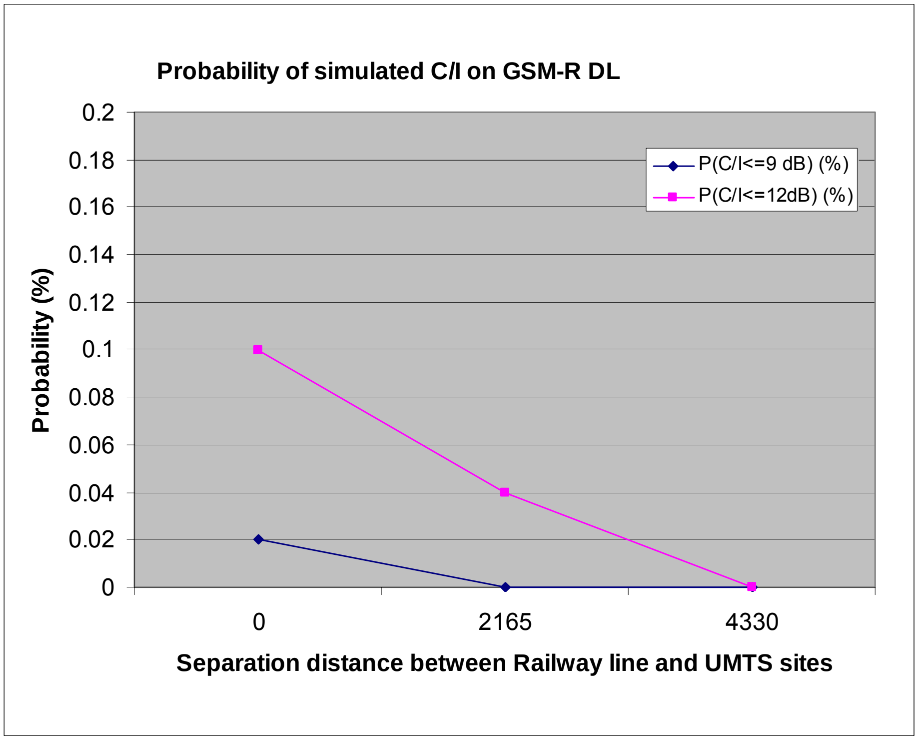


Figure 3-10a: Probability of simulated C/I on GSM-R DL due to interference from UMTS900 BS

The simulation results given in the figure 3-10a simulated with Seamcat show that for the probability of C/I≦9 dB is smaller than 0.02%, and that of C/I≦12 dB is smaller than 0.1%, which is below the required 0.5%.

Additional studies have been carried out in order to assess the worst-case situations corresponding to the GSM-R devices at the cell-edge. The considered carrier separation between UMTS and nearest GSM is 2.8 MHz.

Two distinct scenarios have been investigated. The first one is based on the scenario described in section 3.2.4.1 and 3.2.4.2, in which the BTS antenna height is fixed at 45 m and the GSM-R cell range is 8 km. The distance between the GSM-R BTS and the GSM-R train mounted MS (Hms=4.5m) is randomly drawn between 7 and 8 km for the different snapshots, in order to simulate the situation in which the GSM-R train mounted MS is far from the serving base station and is at the cell edge. The figure below shows this worst case GSM-R configuration simulated in Seamcat.

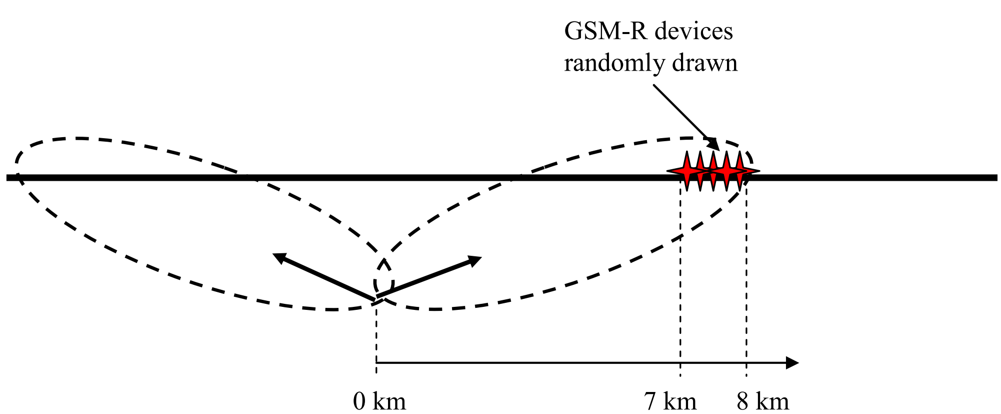


Figure 3-10b: Position of GSM-R train mounted MS relative to the serving BS

An additional scenario was also considered; the antenna height is reduced to 25 m, as well as the cell range to 5 km. For this case, the GSM-R train mounted MSs are randomly distributed between 4 and 5 km in order to simulate the situation in which the GSM-R train mounted MS is far from the serving base station and is close to the cell edge.

For both scenarios, the distance between UMTS sites and GSM-R railway is 0, i.e. the UMTS BS sites are placed along the railway. (see figure 3-8 in section 3.2.4.1.3).

The following table gives the simulated probability of interference from UMTS900 BS to the GSM-R train mounted MS when considering a C/I ratio of respectively 9 dB and 12 dB.

Antenna height	Position of GSM-R Users	Separation distance between UMTS BS and Railway	C/I (GSM-R DL)	Probability of interference
45 m	7-8 km	0	12 dB	0.25 %
			9 dB	0.06 %
25 m	4-5 km	0	12 dB	0.14 %
			9 dB	0.04 %

Table 3-9a: Probability of interference from UMTS900 BS to GSM-R train mounted MS

It can be seen that even for the C/I of 12 dB, the probability of interference is smaller than 0.25 %, which is below the required 0.5% outage level.

3.2.4.4.2 *UMTS UL Capacity Loss (%)*

Simulation results of UMTS uplink capacity loss (%) as a function of ACIR between the UMTS carrier and the nearest GSM-R carrier for different distance offsets are plotted in figure 3-11.

As shown in figure 3-11, at the operating point ACIR=43.1 dB (which corresponds to a carrier separation of 2.8 MHz between the UMTS carrier and the nearest GSM-R carrier), the UMTS UL capacity loss due to interference from GSM-R train mounted MS is smaller than 1.5%, for the worst case when UMTS sites are co-aligned with GSM-R railway (i.e. with distance offset r=0). When UMTS sites are not co-aligned with the railway track, the interference is even smaller. When the railway and UMTS sites are separated by 2165 m or 4330 m, UMTS UL capacity loss is smaller than 0.3%.

It should be noted that the UMTS uplink capacity loss is simulated for the whole UMTS network, some of the UMTS cells are more impacted by the interference from GSM-R UL than other cells. Cell no. 31 (one of the nearest cell to railway track) in the network layout shown in figure 3-8 was found to be the worst cell. The UMTS uplink cell capacity loss for a single cell can not be easily simulated, but it can be calculated based on the received noise rise recorded for a specific cell; using the N-pole capacity formula with 75% reference cell load, the uplink cell capacity loss can be estimated. The obtained UL cell capacity loss for cell no.31 is 1.95%, for the case when UMTS sites are co-aligned with the railway track (r=0).

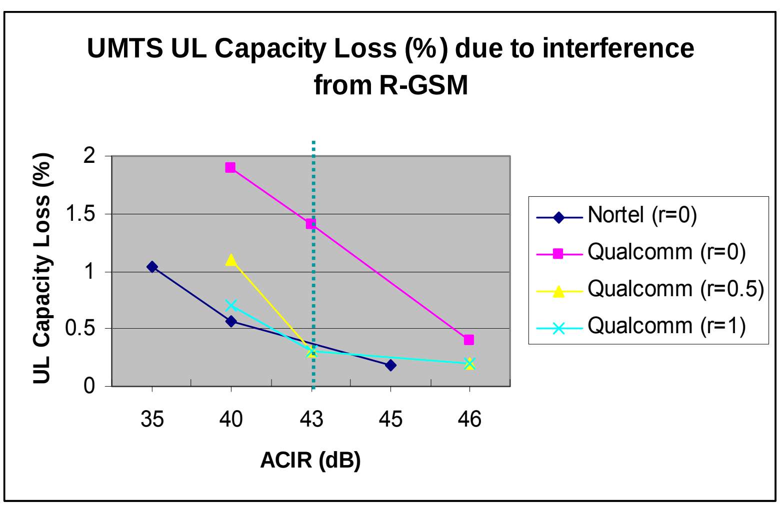


Figure 3-11: UMTS UL capacity loss (%) due to interference from GSM-R UL

As described in the above section, GSM-R UL power control is activated in the simulations. The simulated GSM-R train mounted MS Tx power distribution is plotted in figure 3-12. It can be seen that only 0.5% of MS transmit at maximum power of 39 dBm.

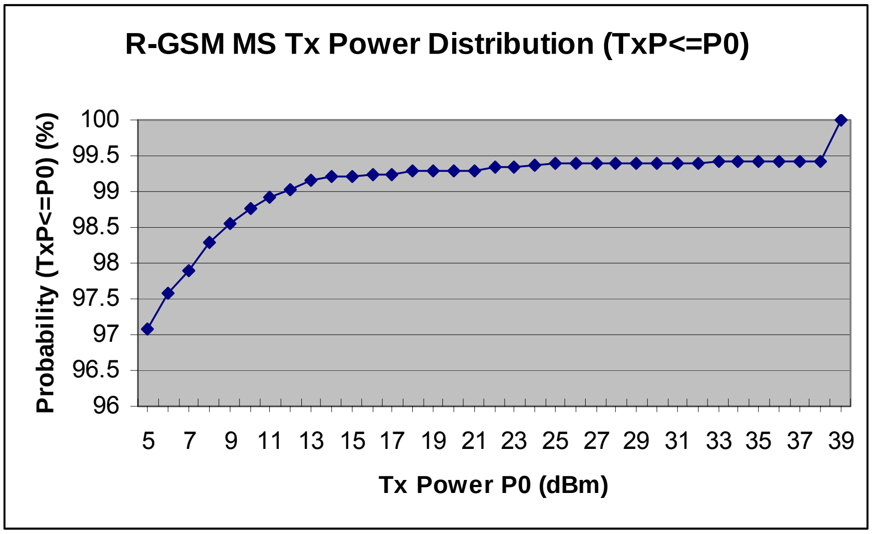


Figure 3-12: Simulated GSM-R train mounted MS Tx power distribution

If GSM-R UL power control is not activated, all GSM-R train mounted MS will transmit at maximum power of 39 dBm. For the case of UMTS sites being placed aligned with the railway track or close to the railway track, the impact on UMTS UL capacity loss due to interference from GSM-R train mounted MS could become much more important. In that case, UMTS operators may need to take care of that problem by using site engineering solutions to reduce the potential interference from GSM-R UL when the UMTS network is using the 5 MHz channel adjacent to GSM-R band.

3.2.4.5 Analysis summary

Under the assumptions described above, the Monte-Carlo simulation results show that the impact on GSM-R DL by the potential interference from UMTS DL is very low, and a carrier separation of 2.8 MHz between the UMTS900 carrier and the nearest GSM-R carrier should be enough. When GSM-R UL power is used, the simulation results indicate the UMTS900 network capacity loss is below 5% even though some of the UMTS900 cells near the railway track will have more capacity loss than other cells. In the case where GSM-R uplink power control is not used, the simulation results show that much more capacity loss on UMTS UL can occur, especially for the cells located near the railway track.

3.2.5 Conclusions

Based on the co-existence scenarios between UMTS900 and GSM-R, the simulation assumptions described in section 3.2.4, and the simulation results and analysis on GSM-R DL outage probability and UMTS UL capacity loss, the following conclusions can be made:

- UMTS900 can be deployed in the same geographical area in co-existence with GSM-R as follows:

  1) There is *a priori* no need of an additional guard band between UMTS900 and GSM-R, a carrier separation of 2.8 MHz or more between the UMTS900 carrier and the nearest GSM-R carrier is sufficient without prejudice to provisions in point 2). This conclusion is based on Monte Carlo simulations assumed suitable for typical case.

  2) However for some critical cases (e.g. with high located antenna, open and sparsely populated areas served by high power UMTS BS close to the railway tracks, blocking etc, which would lead to assumption of possible direct line of sight coupling) the MCL calculations demonstrate that coordination is needed for a certain range of distances (up to 4 km or more from railway track).

  3) It is beneficial to activate GSM-R uplink power control, especially for the train mounted MS, otherwise the impact on UMTS UL capacity could be important when the UMTS network is using the 5 MHz channel adjacent to the GSM-

R band. However, it has to be recognized that this is only applicable in low speed areas as elsewhere the use of uplink control in GSM-R will cause significantly increased call drop out rates.

4) In order to protect GSM-R operations, UMTS operators should take care when deploying UMTS in the 900 MHz band, where site engineering measures and/or better* filtering capabilities (providing additional coupling loss in order to match the requirements defined for the critical/specific cases) may be needed in order to install UMTS sites close to the railway track when the UMTS network is using the 5 MHz channel adjacent to the GSM-R band.

* Currently, the out-of band interference level is given by 3GPP TS 25.104 V7.4.0

It has to be noted that this study did not address tunnel coverage. Site sharing, which is expected to improve the coexistence, has not been studied either.

3.3 Compatibility consideration between UMTS900 and PMR/PAMR

3.3.1 Characteristics of PMR/PAMR systems

Several radio systems will potentially use the PMR/PAMR frequency band, such as TETRA, CDMA PAMR, TAPS, etc.

3.3.1.1 CDMA PAMR system characteristics

The system description of CDMA PAMR can be found in ETSI harmonized standard EN 301 449 for CDMA PAMR [8]. The main CDMA PAMR system characteristics are summarized in tables 3-10 to 3-15.

	CDMA PAMR	
Frequency band (UL) (MHz)	870-876	
Frequency band (DL) (MHz)	915-921	
Carrier separation (MHz)	1.25	
Modulation	QPSK/BPSK	
BS-MS MCL (dB)	70 (Urban area) 80 (Rural area)	
	BS	**MS**
Maximum Tx power (dBm)	43	23
Thermal noise (dBm)	-113	-113
Noise figure (dB)	5	9
Noise floor (dBm)	-108	-104
Receiver sensitivity (dBm)	-119	-114
Antenna height (m)	30 (Urban) 40 (Rural)	1.5
Antenna gain (dBi)	17	0
Feeder loss (dB)	2	0
ACS (dB)	55	68

Table 3-10: Main CDMA PAMR system parameters

For |Δf| Within the Range	Applicability	Emission Limit	
750 to 885 KHz	Single Carrier	-45-15(|Δf|-750)/135 dBc in 30 kHz	
885 to 1125 KHz	Single Carrier	-60-5(|Δf|-885)/240 dBc in 30 kHz	
1.125 to 1.98 MHz	Single Carrier	-65 dBc / 30kHz	
1.98 to 4.00 MHz	Single Carrier	-75 dBc / 30kHz	
4.00 to 6.00 MHz	Single and Multiple Carrier	-36 dBm / 100kHz	
6.00 to 45.00 MHz	Single and Multiple Carrier	-45 dBm / 100kHz	
> 45.00 MHz	Single and Multiple Carrier	-36 dBm / 1 kHz; -36 dBm / 10 kHz; -36 dBm / 100 kHz -30 dBm / 1 MHz;	9 kHz < f < 150 kHz 150 kHz < f < 30 MHz 30 MHz < f < 1 GHz 1 GHz < f < 12.5 GHz

Table 3-11: CDMA PAMR BS spectrum mask (Transmitter unwanted emission limits for Band Class 12)

For f within the range |Δf| Within the Range	Applicability	Emission Limit
1.98 to 4.00 MHz	Single Carrier	-100 dBc / 30kHz
4.00 to 6.00 MHz	Single and Multiple Carrier	-61 dBm / 100kHz
>6.00 MHz	Single and Multiple Carrier	-61 dBm / 100kHz

Table 3-12: Additional BS Transmitter unwanted emission limits for Band Class 12 within the frequency range 876-915 MHz

For |Δf| Within the Range	Emission Limit	
885 kHz to 1.125 MHz	-47 – 7 × (|Δf| – 885) / 235 dBc in 30 kHz	
1.125 MHz to 1.98 MHz	-54 – 13 × (|Δf| – 1120) / 860 dBc in 30 kHz	
1.98 MHz to 4.00 MHz	-67 – 15 × (|Δf| – 1980) / 2020 dBc in 30 kHz	
4.00 MHz to 10.0 MHz	-51 dBm in 100 kHz	
>10.0 MHz	-36 dBm/1 kHz; -36 dBm/10 kHz;-36 dBm/100 kHz;-30 dBm/1 MHz;	9 kHz < f < 150 kHz150 kHz < f < 30 MHz30 MHz < f < 1 GHz1 GHz < f < 12,75 GHz

Table 3-13: CDMA PAMR MS Spectrum mask (Unwanted emission limits for mobile stations)

Frequency	Maximum E.R.P/ reference bandwidth
30 MHz ≤ f < 1 000 MHz	-36 dBm/100 kHz
1 GHz ≤ f < 12,75 GHz	-30 dBm/1 MHz
Fc1 - 4 MHz < f < Fc2 + 4 MHz	No requirement
NOTE 1: Centre frequency of first carrier frequency (Fc1) used by the base station. NOTE 2: Centre frequency of last carrier frequency (Fc2) used by the base station. NOTE 3: Note 1 and Note 2 assume contiguous frequencies otherwise multiple exclusion bands will apply.	

Table 3-14: BS Spurious emission (Radiated unwanted emissions requirements)

Frequency	Limit (E.R.P)/ reference bandwidth idle mode	Limit (E.R.P)/ reference bandwidth traffic mode
30 MHz ≤ f < 1 000 MHz	-57 dBm/100 kHz	-36 dBm/100 kHz
1 GHz ≤ f < 12,75 GHz	-47 dBm/1 MHz	-30 dBm/1 MHz
Fc - 4 MHz < f < fc + 4 MHz	No requirement	No requirement
NOTE: fc is the nominal MS transmit centre frequency.		

Table 3-15: MS Radiated unwanted emissions requirements

3.3.1.2 TETRA system characteristics

The main TETRA system characteristics are summarized in tables 3-16 to 3-18.

	TETRA	
Frequency band (UL) (MHz)	870-876	
Frequency band (DL) (MHz)	915-921	
Carrier separation (MHz)	25 kHz	
BS-MS MCL (dB)	70 (Urban area) 80 (Rural area)	
	BS	**MS**
Maximum Tx power (dBm)	43	30
Receiver bandwidth (kHz)	18	18
Thermal noise (dBm)	-131	-131
Noise figure (dB)	5	9
Noise floor (dBm)	-128	-124
Receiver sensitivity (dBm)	-106	-103
Antenna height (m)	30 (Urban) 40 (Rural)	1.5
Antenna gain (dBi)	14	0
Feeder loss (dB)	2	0
Receiver protection ratio (dB)	19	19

Table 3-16: Main TETRA system parameters

Frequency Offset	30 dBm Mobile Station	44 dBm Base Station
25 kHz	- 30 dBm	- 16 dBm
50 kHz	-40 dBm	- 26 dBm
75 kHz	-40 dBm	- 26 dBm
100 - 250 kHz	-45 dBm	- 36 dBm
250 - 500 kHz	-50 dBm	- 41 dBm
500 kHz - f_{rb}	- 50 dBm	- 46 dBm
> f_{rb}	- 70 dBm	- 56 dBm

Table 3-17: TETRA Spectrum Mask*

*measured in an 18 kHz bandwidth.

*f_{rb} is the edge of the receive band belonging to the TETRA MS/BS. The minimum unwanted emissions requirement is - 36 dBm for frequency offsets of 25, 50 and 75 kHz and - 70 dBm for higher offsets.

Frequency Offset	MS	BS
50 - 100 kHz	- 40 dBm	-40 dBm
100 – 200 kHz	- 35 dBm	- 35 dBm
200 – 500 kHz	- 30 dBm	- 30 dBm
> 500 kHz	- 25 dBm	- 25 dBm

Table 3-18: TETRA Receiver Blocking

3.3.2 Interference analysis considerations

It can be seen that the UMTS900 UL frequency block (880-915 MHz) is adjacent to the PMR/PAMR system (CDMA PAMR or TETRA) DL frequency block (915-921 MHz) at the frequency 915 MHz. The worst interference scenario between UMTS900 uplink and PMR/PAMR system downlink (CDMA PAMR or TETRA) could potentially happen at around 915 MHz.

ECC Report 82 (section 3.5.5.3) [1] indicated that UMTS outdoor UE transmitting power is relatively small, at 90% percentile, the simulated outdoor UE transmit power is -22.4 dBm. By considering that the minimum coupling loss between UE and PMR/PAMR BS is relatively large (80 dB is used in ECC Report 82 between UE and BS in rural area) compared to the MCL between UMTS BS and GSM-R Train Mounted MS, and since the UE is moving, the interference from UMTS UE to PMR/PAMR BS should not be a problem. For detailed analysis of interference between UMTS UE and PMR/PAMR BS, Monte-Carlo simulations should be performed; this is not covered in this report.

The worst interference case is the interference from PMR/PAMR BS to UMTS BS, as shown in figure 3-13.

3.3.2.1 Potential interference between UMTS900 and CDMA PAMR at 915 MHz

Interference from CDMA PAMR BS operating between 917-921 MHz to GSM900 BS operating below 915 MHz with a frequency separation of 2.15 MHz was analyzed in ECC Report 41 [7].

As described in ECC Report 41 [7], a frequency separation of 2.15 MHz between GSM900 operating below 915 MHz and CDMA PAMR operating above 917 MHz is not sufficient for the protection of GSM900 BS receiver; coordination between GSM900 and CDMA PAMR is recommended in ECC Report 41 [7].

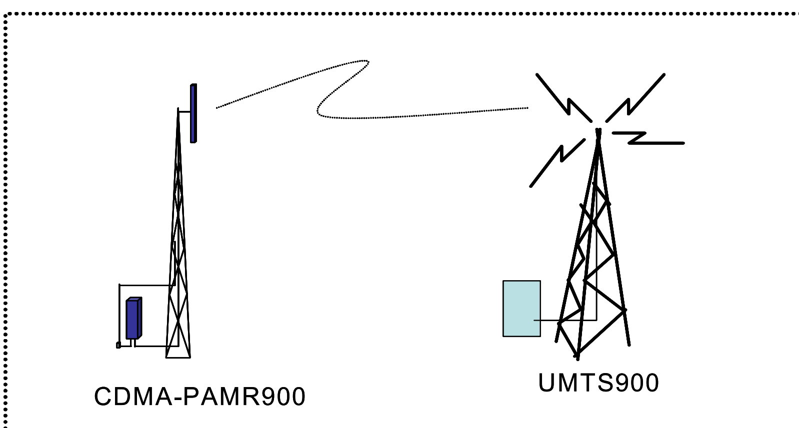


Figure 3-13: Worst Interference scenario between CDMA PAMR downlink and UMTS900 uplink

As shown in figure 3-13, the potential interference from CDMA-PAMR BS can desensitize UMTS900 BS receiver if the protection is not sufficient.

UMTS900 system parameters are described in ECC Report 82[1]. The interference protection level for UMTS900 BS receiver is -110 dBm/3.84 MHz and the ACS of UMTS900 BS receiver is 46.2 dB.

Based on the CDMA PAMR BS spectrum mask for band class 12 given in tables 3-11 and 3-12, for a guard band of 0.6 MHz between a UMTS900 carrier below 915 MHz and a CDMA PAMR carrier above 915 MHz, the required MCL between UMTS900 BS and CDMA PAMR BS is 95.6 dB. When using a free space propagation model, the space separation between UMTS900 BS and CDMA PAMR BS antennas is in the order of 8 km. However, when using the Hata propagation model, the separation distance becomes 1.5 km.

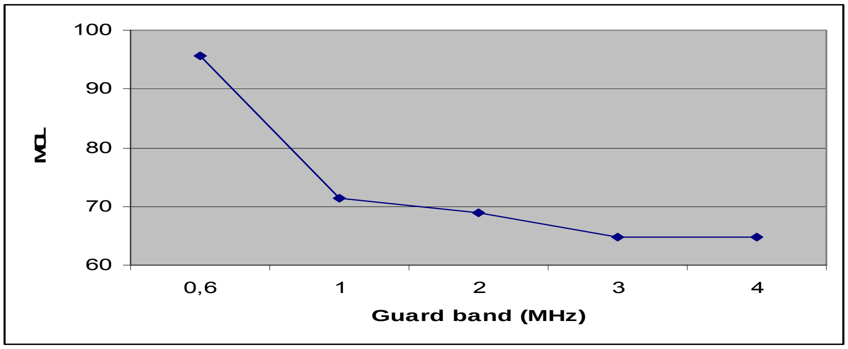


Figure 3-14: Required MCL (dB) in function of guard band

The required MCL as function of guard band is given in figure 3-14. It indicates the required MCL decreases when the guard band becomes larger.

Two possible solutions can be used to meet the required MCL between UMTS900 BS and CDMA PAMR BS: a) Space separation; b) external filter.

3.3.2.2 Potential interference between UMTS900 and TETRA at 915 MHz

The adjacent compatibility study between GSM900 and TETRA or TAPS at 915 MHz was described in ECC Report 5 [9] showing that without any guard band or other interference mitigation techniques, interference from TETRA/TAPS BS will desensitize GSM900 BS receivers. In order to protect the GSM900 BS receiver operating below 915 MHz, several interference mitigation techniques were recommended in ECC Report 5 for the protection of GSM900 BS receivers, such as guard band, filters, and/or coordination between operators.

The interference analysis method described in ECC Report 5 can be re-used for the interference analysis between UMTS900 and TETRA systems operating below and above 915 MHz respectively, by considering that UMTS900 BS is more sensitive to interference than GSM900, the maximum tolerable interference level for the protection of UMTS BS receiver is of -110 dBm/3.84 MHz. By applying the interference analysis method described in ECC Report 5, similar conclusions can be made that without interference mitigation techniques there will be serious interference from a TETRA/TAPS BS transmitter to UMTS900 BS. Thus UMTS900 BS receivers will be desensitized due to strong interference from TETRA/TAPS. The following interference mitigation techniques can be used to reduce the interference from TETRA/TAPS to UMTS900 BS:

i) Guard band;

ii) External filters;

iii) Spatial separation by coordination between UMTS900 and TETRA/TAPS operators;

iv) Reduced transmitting power of TETRA/TAPS BS.

3.3.3 Conclusions

The interference from PMR/PAMR (CDMA PAMR, TETRA, TAPS) BS operating at frequencies above 915 MHz will cause receiver desensitization of UMTS900 BS operating below 915 MHz. In order to protect UMTS900 BS, the utilization of interference mitigation techniques is necessary:

1) Reduced PMR/PAMR BS Tx power;
2) Spatial separation by coordination between operators;
3) External filters;
4) Guard band.

It is more likely that a combination of these interference mitigation techniques should be used in order to ensure the compatibility between UMTS900 operating below 915 MHz and PMR/PAMR (CDMA PAMR, TETRA, TAPS) operating above 915 MHz.

3.4 Compatibility study between UMTS900 and DME

3.4.1 DME and UMTS system characteristics

- Protection criteria for the aeronautical radionavigation service

The protection criteria for the aeronautical radionavigation service are extracted from Recommendation ITU-R M.1639.

Recommendation ITU-R M.1639 gives the equivalent power flux-density (EPFD) level which protects stations of the aeronautical radionavigation service (ARNS) from emissions of radionavigation satellites of all radionavigation-satellite service (RNSS) systems operating in the 1 164-1 215 MHz band.

It recommends that the maximum allowable epfd level from all space stations of all RNSS systems should not exceed –121.5 dB(W/(m^2 · MHz)), in order to protect the ARNS in the band 1 164-1 215 MHz.

The instantaneous epfd is calculated using the following formula:

$epfd = 10 \log_{10}\left[\sum_{i=1}^{N_a} 10^{\frac{P_i}{10}} \cdot \frac{G_t(\theta_i)}{4\pi d_i^2} \cdot \frac{G_r(\varphi_i)}{G_{r,max}}\right]$	*(Equation 1)*

where:

N_a : number of space stations that are visible from the receiver

i : index of the space station considered

P_i : RF power at the input of the antenna (or RF radiated power in the case of an active antenna) of the transmitting space station (dB(W/MHz))

θ_i : off-axis angle between the boresight of the transmitting space station and the direction of the receiver

$G_t(\theta_i)$: transmit antenna gain (as a ratio) of the space station in the direction of the receiver

d_i : distance (m) between the transmitting station and the receiver

φ_i : off-axis angle between the pointing direction of the receiver and the direction of the transmitting space station

$G_r(\varphi_i)$: receive antenna gain (as a ratio) of the receiver, in the direction of the transmitting space station (see Recommendation ITU-R M.1480)

$G_{r,max}$: maximum gain (as a ratio) of the receiver

epfd : instantaneous epfd (dB(W/(m^2 · MHz))) at the receiver

The maximum allowable aggregated EPFD levels for protecting ARNS are summarized in table 3-20.

	Parameter	Value	Reference
1	DME RNSS interference threshold (at antenna port)	–129 dB(W/MHz)	(See Note 1)
2	Maximum DME/TACAN antenna gain including polarization mismatch	3.4 dBi	(5.4 dBi antenna gain –2 dB polarization mismatch)
3	Effective area of 0 dBi antenna at 1 176 MHz	–22.9 dB(m²)	
4	RNSS (all systems) aggregate epfd in 1 MHz	–109.5 dB(W/(m² · MHz))	Combine 1, 2 and 3 (1 minus 2 minus 3)
5	Safety margin	6 dB	Recommendation ITU-R M.1477
6	Apportionment of RNSS interference to all the interference sources	6 dB	Apportion 25% of total permissible interference to RNSS
7	Maximum RNSS aggregate epfd	˜ 121.5 dB(W/(m² · MHz))	Combine 4, 5 and 6 (4 minus 5 minus 6)

Table 3-20: maximum allowable aggregated EPFD level to protect ARNS from RNSS

NOTE 1 – This value is based on a –129 dBW CW interference threshold specified for international DME systems used by civil aviation. Measurement has demonstrated that an RNSS signal spread over 1 MHz would have the same effect as a CW signal on DME performance.

- **Transposition to UMTS 900**

A more convenient way to convert the above criteria to UMTS 900 is to express it as a PSD received at the DME antenna port, including the safety margin and the apportionment, as given in table 3-21.

	Parameter	Value	Reference
1	DME interference threshold (at DME antenna port)	–129 dB(W/MHz)	
2	Safety margin	6 dB	Recommendation ITU-R M.1477
3	Apportionment of UMTS interference to all the interference sources (MIDS, FRS, etc.)	6 dB	Apportion 25% of total permissible interference to UMTS. It is noted that higher percentage could be considered in the band 960-966.5 MHz.
4	Maximum UMTS aggregate PSD, received at the DME receiver input, including the safety margin and the apportionment	−141 dB(W/MHz)	Combine 1, 2 and 3 (1 minus 2 minus 3)

Table 3-21: Maximum allowable aggregated PSD level to protect ARNS from UMTS900

The following aggregated PSD value must not exceed -141 dB(W/MHz):

$$PSD = 10\log_{10}\left[\sum_{i=1}^{N_a} 10^{\frac{P_i}{10}} \cdot G_t(\theta_i) \cdot G_r(\varphi_i) \cdot \left(\frac{\lambda}{4\pi d_i}\right)^2\right]$$

(Equation 2)

where :

- N_a : number of UMTS 900 base stations that are visible from the receiver (DME)
- i : index of the base station considered
- P_i : RF power at the input of the antenna the transmitting UMTS 900 base station (dB(W/MHz))
- λ : wave length
- θ_i : off-axis angle between the boresight of the transmitting UMTS 900 base station and the direction of the receiver (DME)
- $G_t(\theta_i)$: transmit antenna gain of the base station in the direction of the receiver (DME)
- d_i : distance (m) between the transmitting base station and the receiver
- φ_i : off-axis angle between the pointing direction of the receiver and the direction of the transmitting UMTS 900 base station
- $G_r(\varphi_i)$: receive antenna gain of the receiver (DME), in the direction of the transmitting UMTS 900 base station
- PSD : instantaneous PSD (dB(W/(MHz))) at the receiver (DME)

It has to be noted that the threshold above was established by measurement of a number of DME airborne receivers (interrogator receiver) under various signal conditions and confirmed that the effect of an RNSS signal, when spread over 1 MHz, had the same effect on the DME receiver as does CW. As the DME specification requires correct performance in the presence of CW at -129 dB(W/MHz), this was given as the appropriate maximum level for all RNSS interference.

The same assumption was made when modelling the effect of the interference from UMTS900 on DME. This is justified by the nature of the UMTS900 signal (W-CDMA spread signal).

- **Set of DME parameters**
  - Frequency of band of operation: 960-1215 MHz
  - Receiving frequency (in the simulation) : 962, 964, 966 and 971 MHz
  - Polarization: linear, vertical (so no polarization loss should be considered)
  - Maximum DME antenna gain : 5.4 dBi
  - Channelization: 1 MHz
  - Bandwidth : 1 MHz
  - ARNS station location: the ARNS station altitude should be taken at worst case (40 000 ft, i.e. 12 192 m), which gives maximum visibility of potentially interfering base stations from the ARNS receiving antenna.
  - DME Selectivity mask:
    - **DME 442 Rockwell Collins. The attenuations are**

      6 dB at -0.38 MHz/+0.32 MHz (-0.88 MHz/+0.82 MHz from the central frequency)
      20 dB at -0.55 MHz/+0.49 MHz (-1.05 MHz/+0.99 MHz from the central frequency)
      40 dB at -0.80 MHz/+0.62 MHz (-1.30 MHz/+1.12 MHz from the central frequency)
      60 dB at -0.96 MHz/+0.64 MHz (-1.46 MHz/+1.14 MHz from the central frequency)

    - **KN 62A Honeywell. The attenuations are**

      6 dB at -0.15 MHz/+0.34 MHz (-0.65 MHz/+0.84 MHz from the central frequency)
      20 dB at -0.26 MHz/+0.48 MHz (-0.76 MHz/+0.98 MHz from the central frequency)
      40 dB at -0.29 MHz/+0.49 MHz (-0.79 MHz/+0.99 MHz from the central frequency)
      60 dB at -0.30 MHz/+0.50 MHz (-0.80 MHz/+1.00 MHz from the central frequency)
      It has to be noted that the values of the selectivity masks have set to 70 dBc beyond 250% of the bandwidth (+/- 2.5 MHz) with a linear interpolation between 60 and 70 dBc.

- **ARNS antenna characteristics**

The information in the following Fig. 15(a).a is extracted from Recommendation ITU-R M.1642 and provides the antenna gain for different elevation angles. For intermediate elevation angles (between two defined values), a linear interpolation should be used. The $G_{r,\,max}$ value is 5.4 dBi as specified in Recommendation ITU-R M.1639. It is assumed that the elevation and gain pattern is the same for all azimuth angles.

The relevant range of elevation angles for the study to be conducted is: -90°…0°, as shown in Fig. 15(a).

	Extract from Rec. ITU-R M.1642
Elevation angle (degrees)	**Antenna gain $G_r/G_{r,\,max}$ (dB)**
–90	–17.22
–80	–14.04
–70	–10.51
–60	–8.84
–50	–5.4
–40	–3.13
–30	–0.57
–20	–1.08
–10	0
–5	–1.21
–3	–1.71
–2	–1.95
–1	–2.19
0	–2.43

Elevation angle definition

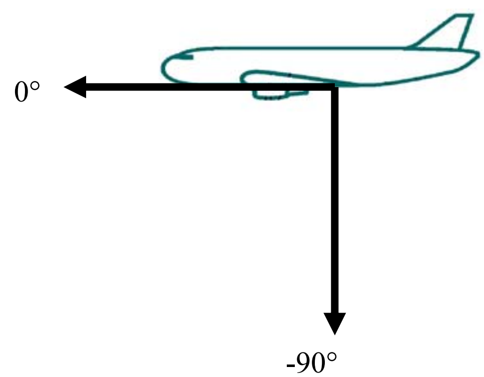


Figure 3-15(a): DME antenna gain for elevation angles between 0°…-90°

- **Proposed parameters for UMTS 900**

Therefore, the scenario worth studying is the situation where multiple base stations produce interference to onboard DME:

- Antenna input Power: 43 dBm/channel (for Macro base stations). Micro and pico base stations have not been considered. It has to be noted that this figure represents a fully loaded cell.
- Average cell radius : 5 km
- Unwanted emissions characteristics : see Table 3.22 below
- Channel Spacing : 5 MHz
- Maximum antenna gain including the feeder loss : 15 dBi
- Receiver Bandwidth : 3840 KHz
- Elevation antenna pattern : Recommendation ITU-R F.1336-2
- Azimuth antenna pattern : omni-directional
- Downtilt : 2.5°
- Antenna height : 30 m

For information, a comparison between the out-of-band emissions of UMTS-900 and GSM 900 is available in section 3.2.2.2.

	Frequency offset to the UMTS central frequency	Power density (cabinet output)	Power in 5 MHz	Level in dBc
Out of band domain	2.5 MHz ≤ Δf < 2.7 MHz	-14 dBm/30 kHz	8 dBm	-35 dBc
	2.7 MHz ≤ Δf < 3.5 MHz	Linear interpolation	Linear interpolation	Linear interpolation
	Δf = 3.5	-26 dBm/30 kHz	-4 dBm	-47 dBc
	3.5 MHz < Δf ≤12.5 MHz	-13 dBm/1 MHz	-6 dBm	-49 dBc
Spurious domain	Δf =12.5 MHz to frequency=1 GHz	-36 dBm/100 kHz	-19 dBm	-62 dBc
	Frequency>1 GHz	-30 dBm/1 MHz	-23 dBm	-66 dBc

Table 3-22: Unwanted emissions characteristics for UMTS900

- **Common parameters**
  - Frequency plan is given in table 3-23

880 MHz		**915 MHz**	**925 MHz**		**960 MHz**		
	UMTS-UL			UMTS-DL	DME		

Table 3-23: frequency plans

- **Propagation model:**
  - Free space loss (Recommendation ITU-R P.525) : all the base stations are visible from the aircraft, without any obstacle.

3.4.2 Case Study

The interference on the DME comes from all the base stations which have visibility of the aircraft at its altitude, see Fig. 3-15(b). Considering a frequency re-use scheme of 1, each base station transmits 3 carriers at full power. The base stations generate 3 sub-interferences at the following frequencies:

f_1=957.5 MHz (1^{st} adjacent channel interference to be considered)

f_2=952.5 MHz (2^{nd} adjacent channel interference to be considered)

f_3=947.5 MHz (3^{rd} adjacent channel interference to be considered)

In practise, each UMTS900 base station may transmit more than 3 carriers but the other ones are not considered in these simulations.

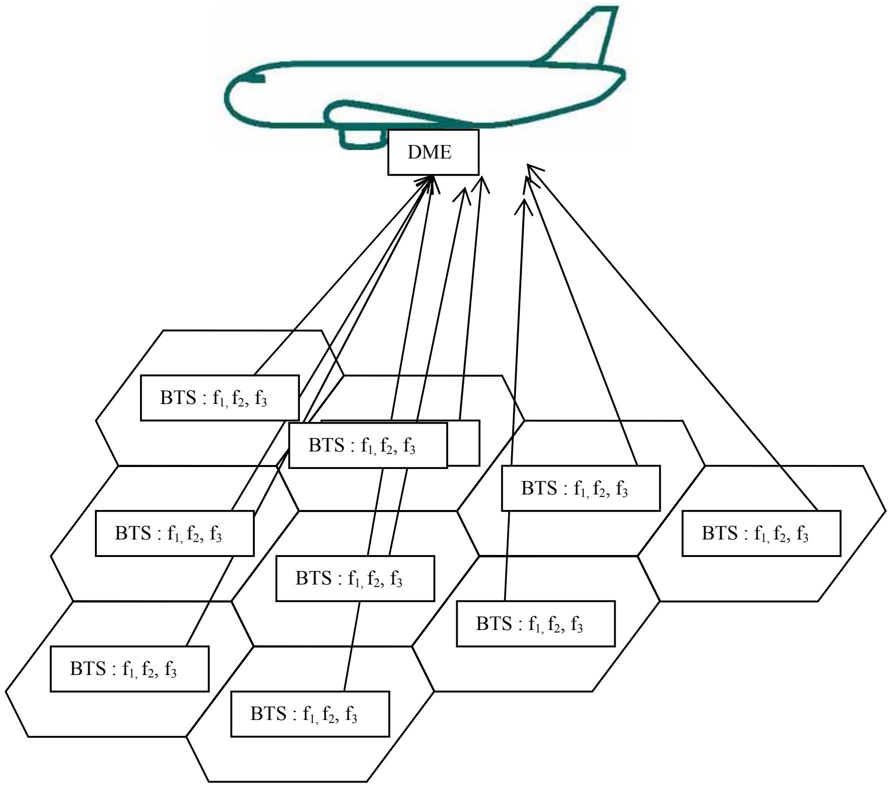


Figure 3-15(b): Scenario of the study

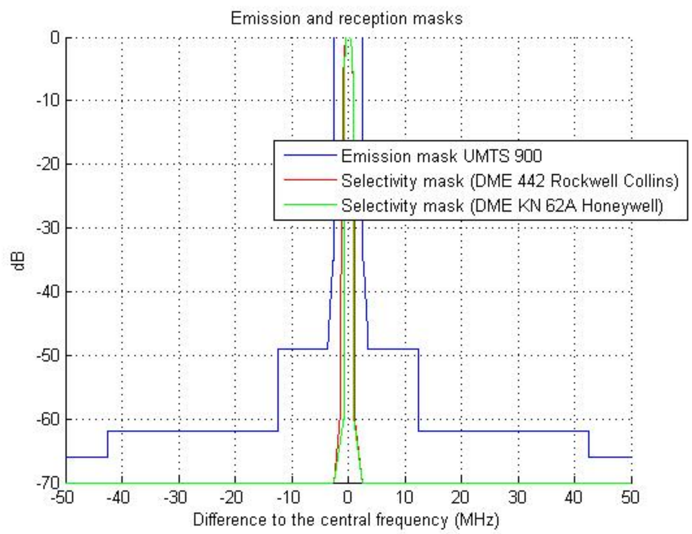
The principles are:

- To distribute the base stations on the terrestrial dome seen by the DME (placed every 10 km);
- To assess the aggregated signal generated by signals from the base stations at f_1, f_2 and f_3;
- To compare this aggregated signal to the threshold of -141 dB(W/MHz).

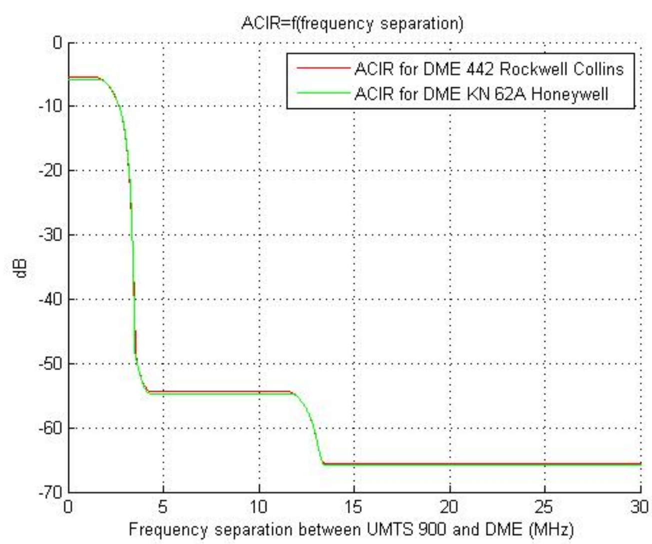
3.4.3 Interference analysis results

- **Calculation of the ACIR**

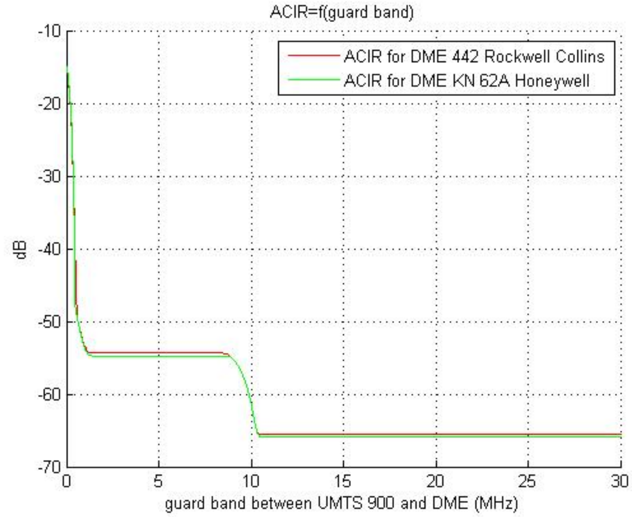
The UMTS900 ACLR and DME ACS are plotted in figure 3-16(a), ACIR of DME as function of frequency separation and as guard band are respectively given in figures 3-16 (b) and (c).



(a) UMTS900 ACLR and DME ACS



(b) ACIR as function of frequency separation



(c) ACIR as function of guard band

Figure 3-16: Calculation of the ACIR

- **Number of visible base stations**

The number of visible base stations as a function of aircraft altitude is given in figure 3-17.

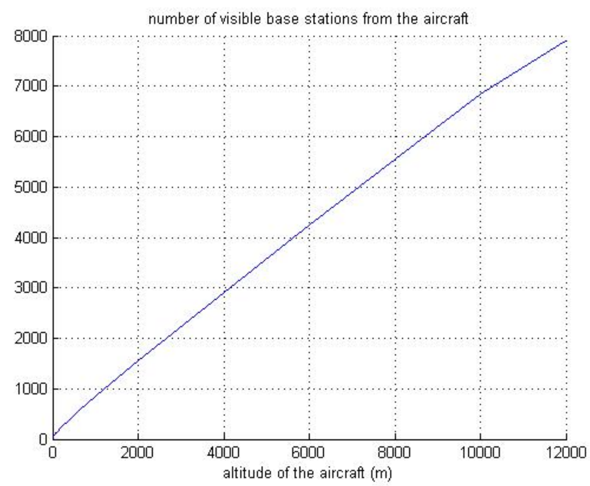
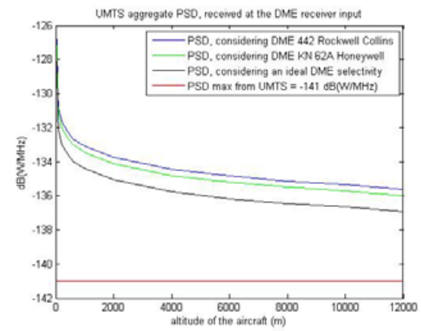
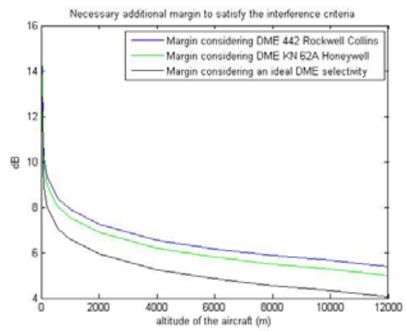


Figure 3-17: Number of visible base stations

- **Calculation of the UMTS aggregate PSD**

The calculated UMTS aggregate PSD and corresponding margin to add for satisfying the interference criteria for three DME frequencies are given in Fig. 3-18.

It has to be noted that the two DME equipments mentioned previously have been considered in the calculations.
Additionally, the results inherent to an ideal DME filter are given in the following table for information.

<table>
<tr><th>DME freq</th><th>calculated UMTS aggregate PSD</th><th>additional margin needed</th></tr>
<tr><td>968 MHz</td><td>
</td><td>
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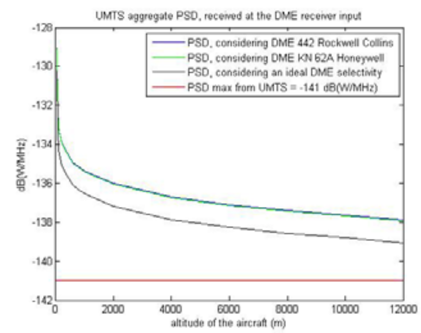
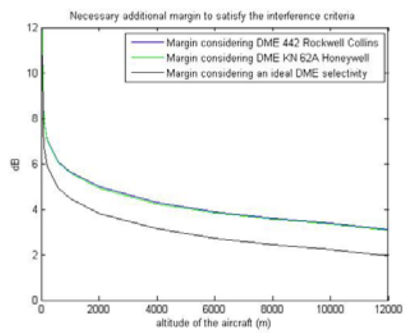
<tr><td>970 MHz</td><td>
</td><td>
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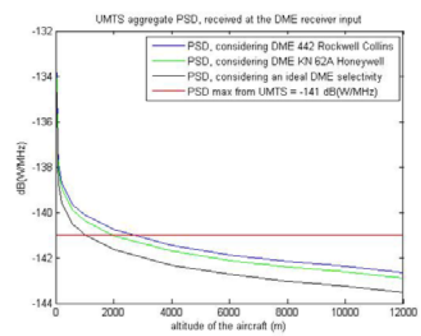
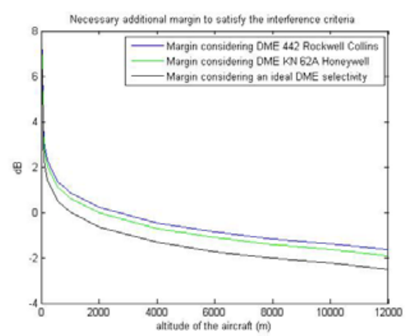
<tr><td>972 MHz</td><td>
</td><td>
</td></tr>
</table>

Figure 3-18: Calculated UMTS aggregate PSD and corresponding margin to add to satisfy the interference criteria

3.4.4 Analysis of the results

- The selectivity of two DME airborne receivers has been measured. However, the characteristics of the receiving filter are only given for the range 0.5-1.5 MHz from the central frequency. One can easily assume that the filter continues to decrease after this value but in the absence of data, the filter has been considered as flat after these values.
- The parameters of the UMTS equipment are based on the 3GPP standards, except for the base station antenna pattern which is based on the Recommendation ITU-R F.1336-2.
- The results depend on the altitude of the aircraft. There is a difference of around 3 dB between the low altitudes (100m<Altitude<500m and the cruise situations (12000 m).
- The results are nearly the same for the two DME equipments considered.
- Given the data which have been taken into account (and expressed in the previous paragraphs), some additional isolation (to satisfy the interference criteria) may be needed to make the compatibility between UMTS900 and DME possible, and particularly if the DME frequency is below 972 MHz. It has to be noted that the value of this additional isolation depends on the value of the DME carrier:

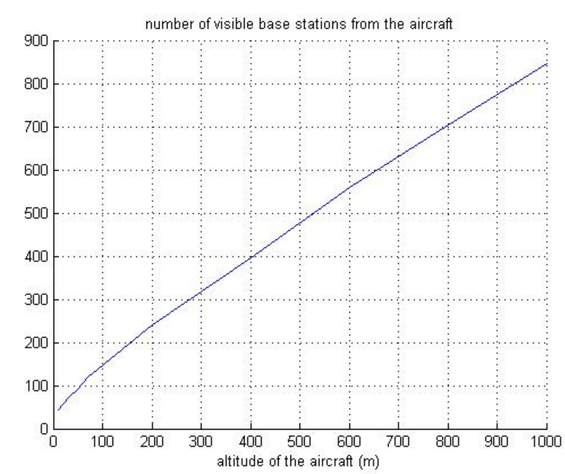
Flight phase	**DME 442 Rockwell Collins and DME KN 62A Honeywell**					
	DME carrier					
	962 MHz	964 MHz	966 MHz	968 MHz	970 MHz	972 MHz
0 m<altitude<100m	15	15	15	13	12	7
100 m<altitude<500m	12	12	9	9	7	2
500 m<altitude<2000 m	10	10	8	8	6	0
Cruise	9	9	6	6	4	0

Table 3-24: additional margin needed (dB)

It has to be noted that certain factors or parameters, relating to the deployment and/or the definition of the UMTS900 system are not stabilized yet. These factors/parameters are:

- A traffic load factor: The global load is referring to the distribution of traffic load within the UMTS network. Even when considering the peak of traffic, a minority of UMTS BS is fully loaded and is transmitting at Pmax. The operators and manufacturers have confirmed the consideration of a traffic load factor for the design of their networks. The maximum value for a loaded cell is assumed to be 80%, whereas an average value is 50%.

  It is recognized that a safety aeronautical system such as DME has to examine the worst case in terms of interference for UMTS900, when the number of UMTS900 cells considered is low (i.e. when the altitude of the aircraft is low). However, when the altitude of the aircraft is higher, it is reasonable to consider the average load factor value (because the number of the base stations considered is high). Given the number of visible base stations as shown in the following figure:



it may be assumed that the average value can be applied from an altitude of 100m (150 base stations seen by an aircraft):

	Value of the traffic load factor
Altitude of the aircraft <100m	**80%**
Altitude of the aircraft >100m	**50%**

- Maximum antenna gain of the UMTS900 base stations: The value of 15 dBi (including feeder loss) has been considered which corresponds to the rural case. However, it is recognized that the antennas deployed in urban areas have commonly a gain of 12 dBi (including feeder loss). The ratio of one antenna type compared to the other one is currently not defined.

It has also to be noted that if certain parameters are adjusted according to the previous bullets, those adjustments have to be consistent (E.g : a rural case could correspond to an antenna gain of 15 dBi including feeder loss associated to a low traffic load).

It should be emphasized that there may be a need for additional calculations to model the approach phase (or other phase) when an aircraft rolls. In this configuration, the maximum gain of the DME (reception) corresponds to an elevation angle of -20/-25° (see table 3-22).

It should also be noted that no compatibility study between GSM900 and systems operating in adjacent band had been performed prior to the deployment of GSM900. This has not been represented a problem so far since the aeronautical equipments do not currently use the part of the band just above 960 MHz:

- The lowest frequency used by DME is 977 MHz;
- The lowest frequency used by TACAN is 978 MHz.

According to the recognized international aviation standards, the frequency range for the DME is 962-1215 MHz and carriers lower than 977 MHz, such as 962 MHz, may also be deployed in the future. In any case, the use of TACAN/DME below 970 MHz requires additional protection so that the compatibility in adjacent band with UMTS900 can be ensured.

Moreover, it has to be noted that the frequencies just above 960 MHz are also under consideration under the AI 1.6 of the next WRC for the development of new aeronautical mobile systems in that band.

3.4.5 Mitigation techniques and mitigation effects

Mitigation techniques and mitigation effects are therefore required, such as:

- The reduction of the out-of-band UMTS900 emission: this is achieved with the use of UMTS900 base stations with out-of-band performances better than the requirement defined in the 3GPP specifications (e.g.: filtering); this may not be technically feasible to ensure the protection of all DME frequencies. (e.g.: 962 to 966 MHz);

- Site engineering for the UMTS 900 base stations situated in/near the airports to achieve additional protection for the takeoff/landing phases ; this can be implemented only on a limited number of base stations (which depends on the nature of the specific site engineering measures);

- Consideration of a sufficient guard band, considering that there is already a 1.5 MHz guard band (960-961.5 MHz);

- Examination of lower apportionment margin: it has to be noted that the military MIDS system does not operate in the lower part of the band (960-966.5 MHz); therefore, the apportionment margin can be reduced. This reduction has not been considered in the above calculations. The appropriate value of the apportionment is 3 dB if the interferences to DME are assumed to equally come from UMTS900 and the potential FRS system (Futur Radio System) considered under the agenda item 1.6 of the WRC-07. This is subject to the result of the WRC-07. It has also to be noted that the FRS system is not likely to be deployed before 2020. Therefore the apportionment should be alleviated as follows:

	Before the deployment of the FRS system (before 2020)	After the deployment of the FRS system (before 2020)
960 – 966.5 MHz	**Apportionment = 0 dB**	**Apportionment = 3 dB**

In the upper part of the band (966.5 – 970 MHz), the interferences from the MIDS have also to be considered. However, MIDS is a frequency hopping system that hopes on 51 frequencies, the first ones of which are 969, 972 and it is recognized that the interferences from UMTS900 above 972 are negligible. The value of the apportionment is calculated as follows:

2/51*X (MIDS) +X (UMTS900) =1 (before 2020)

X=0.96 %= 0.16 dB

2/51*X (MIDS) +X (FRS) +X (UMTS900) =1

X=0.49%= 3.1 dB

Which gives:

	Before the deployment of the FRS system (before 2020)	After the deployment of the FRS system (before 2020)
966.5 -972MHz	**Apportionment = 0.16 dB**	**Apportionment = 3.1 dB**

This leads to the conclusion that the interferences from MIDS have a negligible effect.

3.4.6 Conclusions

Under the assumptions described above, the following preliminary conclusions can be made based on simulation results and interference analysis:

- Nowadays, the lowest DME frequency is 977 MHz. Lower frequencies are planned to be used for DME in a near future;
- As long as the DME frequencies are above 972 MHz, the electromagnetic compatibility between DME and UMTS 900 is ensured without any care to be taken;
- Regarding the frequencies from 960 to 972 MHz, the only mitigation techniques, in order to ensure the compatibility between the DME system and UMTS900, that would bring sufficient isolation are: additional filtering and a larger guard band. However these two mitigation techniques are not judged applicable for the following reasons:
    - Additional filtering: the UMTS900 manufacturers have clearly indicated that, nowadays, it is not technologically feasible to provide the sufficient margin needed (compared to the specified out-of-band emission mask considered in the above calculations) without affecting the level of the transmitted power in the transmitting band (it is recognized that the introduction of additional filtering creates insertion losses of several dBs on base stations transmission power level that need to be balanced by increasing deployment density);
    - Larger guard band: the above calculations have shown that an additional 10 MHz guard band (to the existing 1.5 MHz guard band) is needed. This is unacceptable for both UMTS900 and civil aviation communities;
- There is a need for consideration of this issue on a European context, on the regulatory aspect. It is necessary that a common approach be used within Europe to ensure the compatibility.

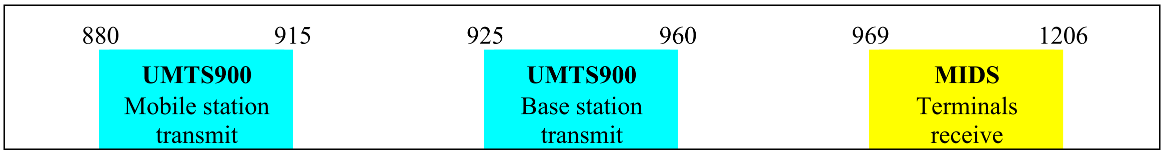
It has to be noted that the impact of the DME ground station (and FRS if necessary) on the UMTS 900 mobile stations has not been studied in this report and may need additional studies.

3.5 Compatibility study between UMTS900 and MIDS

3.5.1 System parameters and co-existence scenario

3.5.1.1 Frequency band plan

The frequency band plans for MIDS and UMTS900 are shown in figure below:



UMTS900 frequency band is arranged as follows:

- Uplink (UE transmit, BS receive) : 880 – 915 MHz
- Downlink (BS transmit, UE receive) : 925-960 MHz
- Carrier separation: 5 MHz

MIDS frequency band is arranged as follows:

MIDS operates in the 960 to 1215 MHz band, with MIDS frequencies occurring every 3 MHz between 969 to 1206 MHz. Two sub-bands centered on 1030 MHz and 1090 MHz are excluded because they are used by IFF.

3.5.1.2 System parameters

3.5.1.2.1 UMTS900 parameters

The characteristics of UMTS900 system are summarized in the table3.25 below.

Parameter	**IMT-2000 CDMA Direct Spread (UMTS900)**		
Carrier spacing	5 MHz ± n × 0.2 MHz		
Duplex method	FDD		
Cell type	Macro	Micro	Pico
Transmitter power dBm(3)	43	38	24
Antenna gain(4), (5) (dBi/120° sector)	15 (6)	5	0
Cable loss	3	1	0
Antenna height (m)	40	5	1.5
Tilt of antenna (degrees down)	2.5	0	0
Access techniques	CDMA		
Data rates supported	Pedestrian: 384 kbit/s, Vehicular: 144 kbit/s, Indoors: 2 Mbit/s Higher data rates up to 10 Mbit/s are supported by technology enhancements (HSDPA)		
Modulation type	QPSK		
Emission bandwidth	3GPP TS25.104		
Transmitter ACLR for macro/micro/ pico BS	3GPP TS25.104		
1st adjacent	45 dB @ ± 5 MHz		
2nd adjacent	50 dB @ ± 10 MHz		
Transmitter spurious emissions	3GPP TS25.104		
Receiver blocking levels	3GPP TS25.104		

Table 3.25: UMTS900 base station parameters

(3) May not be appropriate for all scenarios.
(4) Feeder losses are not included in the values and should be considered in the sharing/compatibility issues.
(5) The reference pattern is specified in Recommendation ITU-R F.1336 with (k = 0.2).
(6) Cable loss is included in the antenna gain.

In order to have a realistic representation of UMTS900 equipments, two types of cells have been considered: macro and micro:

	Macro Cell	**Micro Cell**
Transmission power	+43 dBm (20W)	+38dBm (6,3W)
Cable loss	3dB (included in antenna gain)	1dB
Antenna gain	15dBi (120° sector)	5dBi (omni-directional or directive)
PIRE	58dBm	42dBm
Antenna height	40m	5m
Vertical aperture	6°	
Downtilt	2,5°	0°

For micro cell and macro cells, unwanted emission limits in the out-of band domain and in the spurious domain are defined below:

	ΔF		**LIMIT**
Out of band domain	1st adjacent channel	± 5 MHz	*45 dBc*
	2nd adjacent channel	± 10 MHz	*50 dBc*
Spurious domain (in accordance with ITU-R SM329)	Between 960MHz and 1 GHz		-36dBm in 100kHz or-19 dBm in 5 MHz
	Between 1GHz and 12 GHz		-30dBm in 1MHz or -23 dBm in 5 MHz

Other assumptions taken in the study:

- Emission frequency of the base station: 957.4 MHz (highest UMTS900 channel between 955 and 960 MHz);
- It is assumed that the UMTS900 antenna has no attenuation in the receiving band of MIDS (969-1206 MHz). This represents a worst case;
- The UMTS900 base station transmits continuously.

3.5.1.2.2 *MIDS parameters*

MIDS (Multifunctional Information Distribution System) is a tactical military system. The MIDS receiver to consider is the MIDS terminal, integrated in a shelter. The antenna is mounted on a 16 metres mast. The terminal mode to consider is the frequency hopping mode (51 frequencies). The lowest frequency is 969 MHz.

Receiver	MIDS terminal
Bandwith	5 MHz
Feeder loss	5 dB
Antenna gain	9 dBi
Antenna height	16 metres
Equivalent downtilt	+ 3°
3 dB beam width in the vertical plane	16°
Horizontal plan	omni

Table 3.26: MIDS terminal parameters

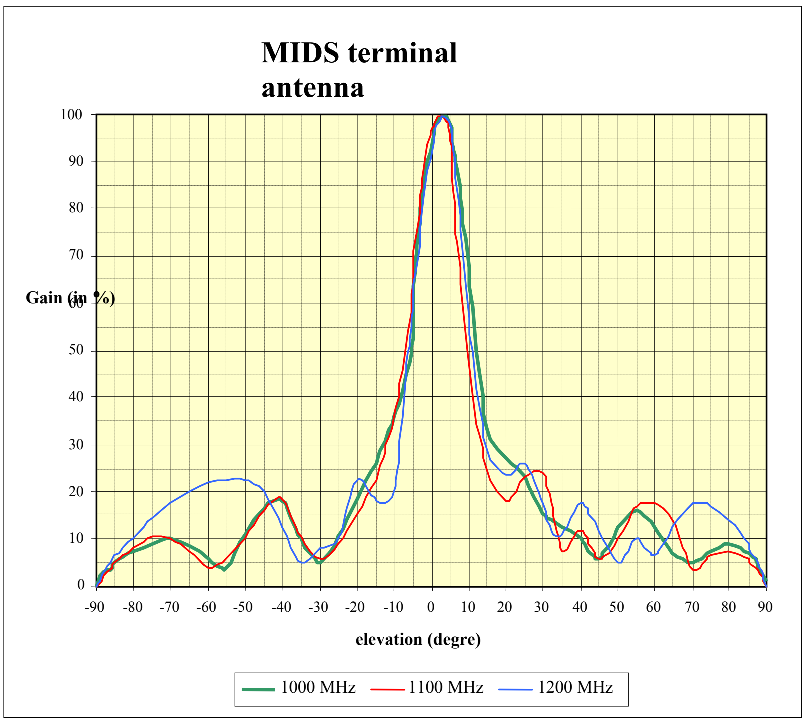


Figure 3-19: MIDS terminal elevation antenna diagram

Other assumptions taken in the study:

- The frequency used in the simulation is 970 MHz;
- The hopping frequencies are as follows:

N°	Frequency (MHz)	N°	Frequency (MHz)	N°	Frequency (MHz)
0	969	17	1062	34	1158
1	972	18	1065	35	1161
2	975	19	1113	36	1164
3	978	20	1116	37	1167
4	981	21	1119	38	1170
5	984	22	1122	39	1173
6	987	23	1125	40	1176
7	990	24	1128	41	1179
8	993	25	1131	42	1182
9	996	26	1134	43	1185
10	999	27	1137	44	1188
11	1002	28	1140	45	1191
12	1005	29	1143	46	1194
13	1008	30	1146	47	1197
14	1053	31	1149	48	1200
15	1056	32	1152	49	1203
16	1059	33	1155	50	1206

- Protection from the unwanted emissions of an interfering system: criterion n°1

Measurements have been performed in a French DoD laboratory to assess the protection criteria of MIDS receiver. The curves of the permissible level of a signal which is out of the MIDS band, have been picked out: for a transmission at 960 MHz, there is no degradation of the MIDS terminal performances as long as the power of the transmitter remains below -10 dBm (the reference is a CW signal).

- Noise level permissible in the MIDS channel: criterion n°2

On the same line as in the previous paragraph, measurements on MIDS receiver give a permissible noise level equal to -103dBm, for one of the 51 channels, i.e. -104 dBm/5 MHz, taking into account 1dB margin

This tolerated value allows to obtain an acceptable MIDS sensitivity referred to MIDS SSS (System Segment Specification).

- Interference threshold expressed as an interfered frequencies rate

The MIDS receiver can tolerate a certain number of interfered channels amongst the 51 channels used, without any performance degradation. This threshold is classified and is not given in this document. This interference threshold, without being communicated in the report for security reason, is covered by the criterion n°2, when assessing the number of frequencies for which the permissible noise floor is exceeded.

3.5.1.3 Propagation model

Propagation model used is ITS. This model is usually used for MIDS studies, in France as well as in USA (NTIA).

3.5.1.4 Simulation configuration

The simulation configuration is given in the figure 3-20 below.

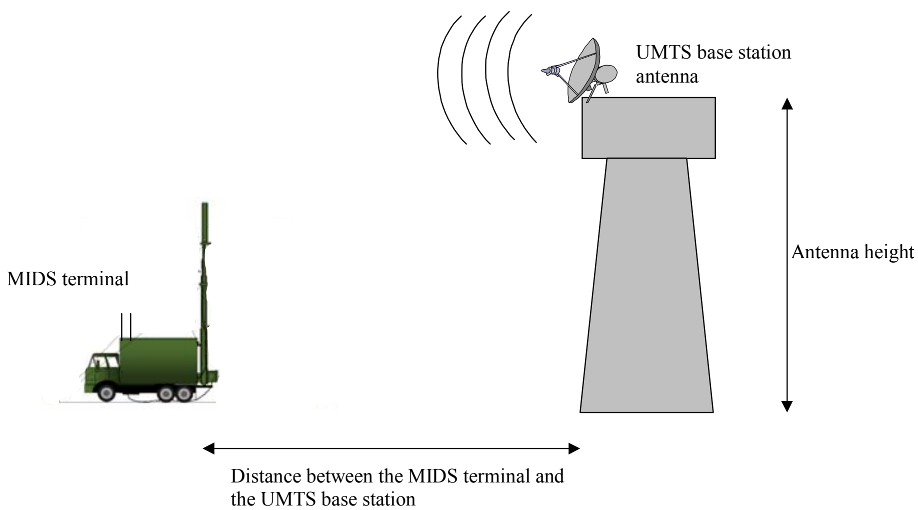


Figure 3-20: Illustration of the simulation configuration

3.5.2 **Interference analysis and simulation results**

3.5.2.1 Level of the UMTS900 signal received by the MIDS terminal (out of the MIDS receiving band)

The aim of this section is to assess the interference from the UMTS900 base station in the UMTS900 band, according the **criterion n°1** described above.

3.5.2.1.1 Simulation results

- Macro cell

The following curves give the level of the UMTS900 signal as a function of the distance between the UMTS900 base station and the MIDS terminal:

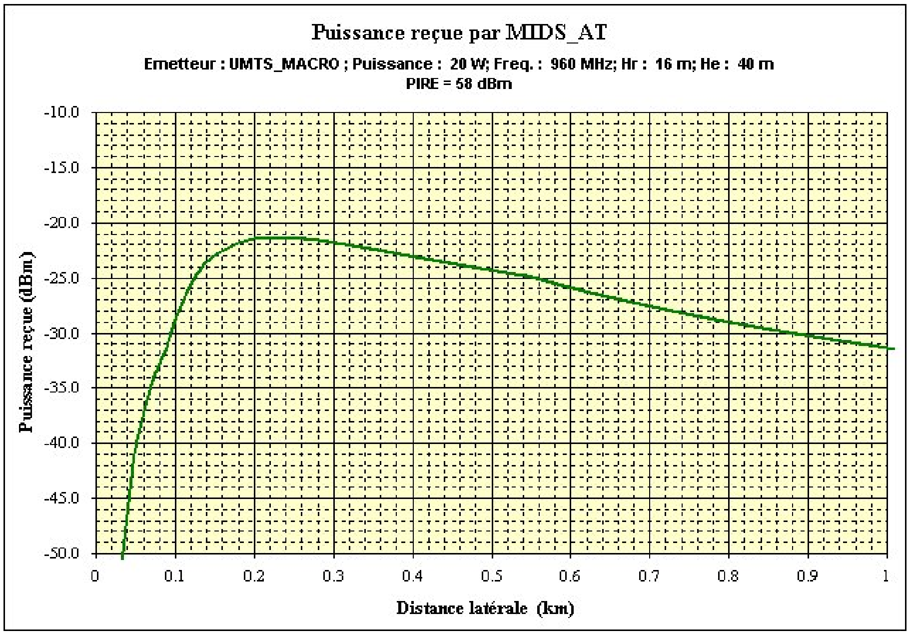


Figure 3-21: MACRO base station transmitted power received by the MIDS terminal (distance<1km)

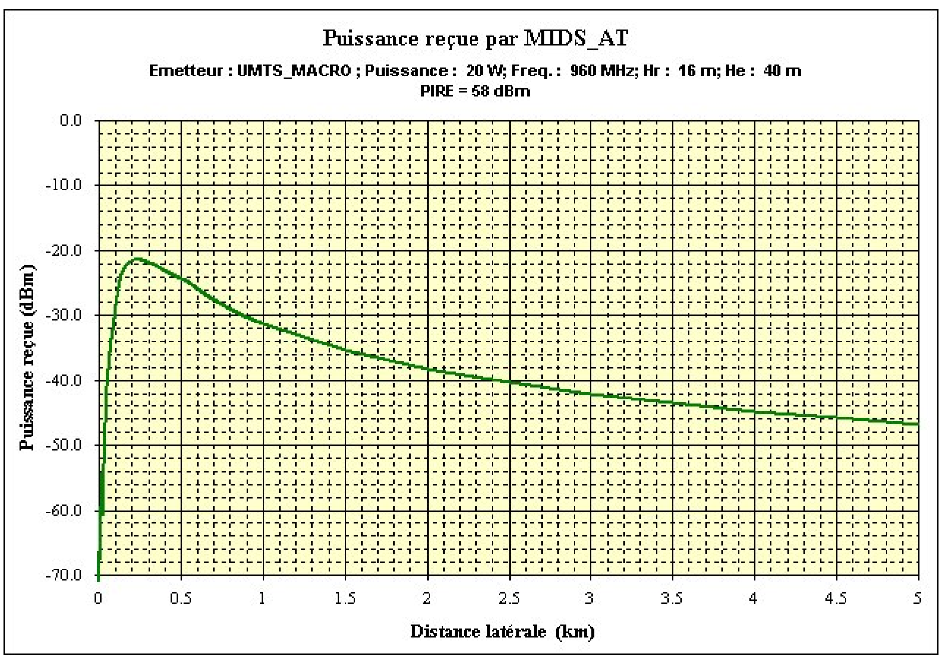


Figure 3-22: MACRO base station transmitted power received by the MIDS terminal (distance<5km)

Analysis:

Whatever the distance between the UMTS900 base station and the MIDS terminal is, the maximum authorized level of -10 dBm is not exceeded. Maximum level equal to -21dBm is reached for a distance from 200m to 280m.

- Micro cell

The following curves give the level of the UMTS900 signal as a function of the distance between the UMTS900

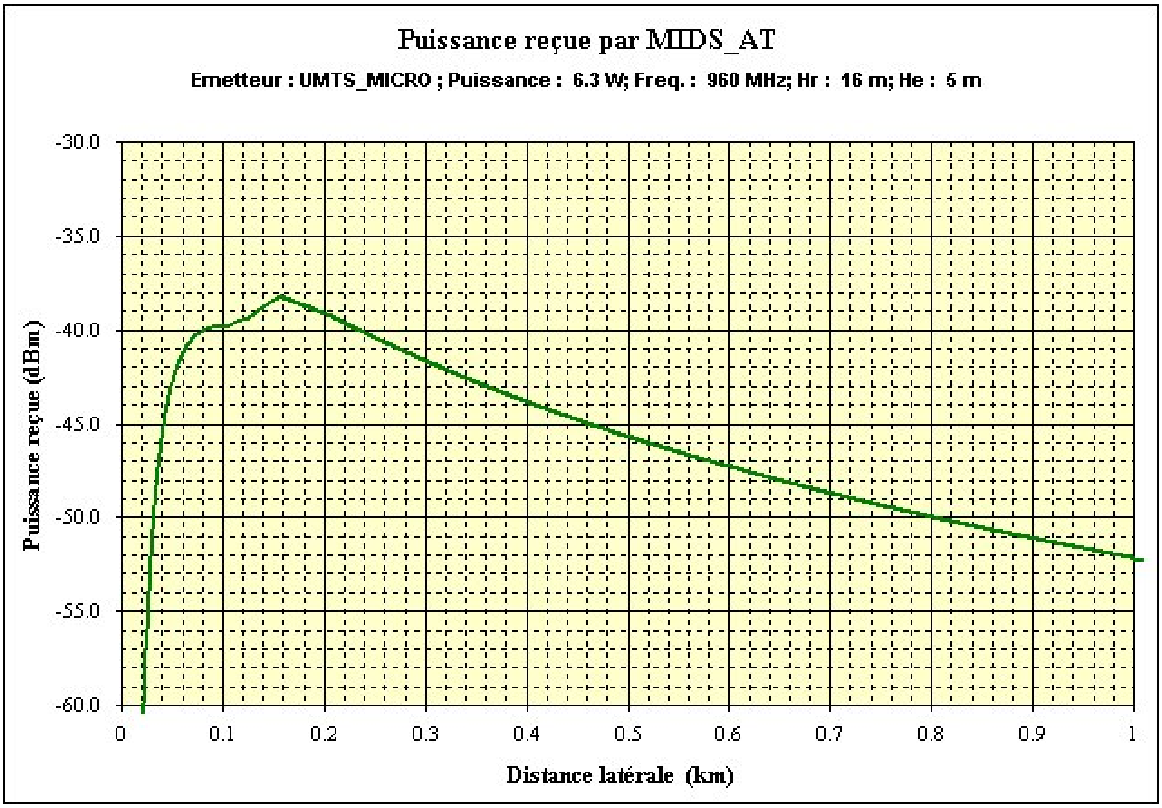


Figure 3-23: MICRO base station transmitted power received by the MIDS terminal (distance<1km)

Analysis:
The level of -10 dBm is never reached. Maximum level equal to -38dBm is reached for a distance of 160m.

3.5.2.1.2 Conclusion according to criterion n°1

Considering the protection curves of MIDS receiver, there is no risk of saturation caused by UMTS signal.

3.5.2.2 Level of the UMTS900 signal received by the MIDS terminal (in the MIDS receiving band)

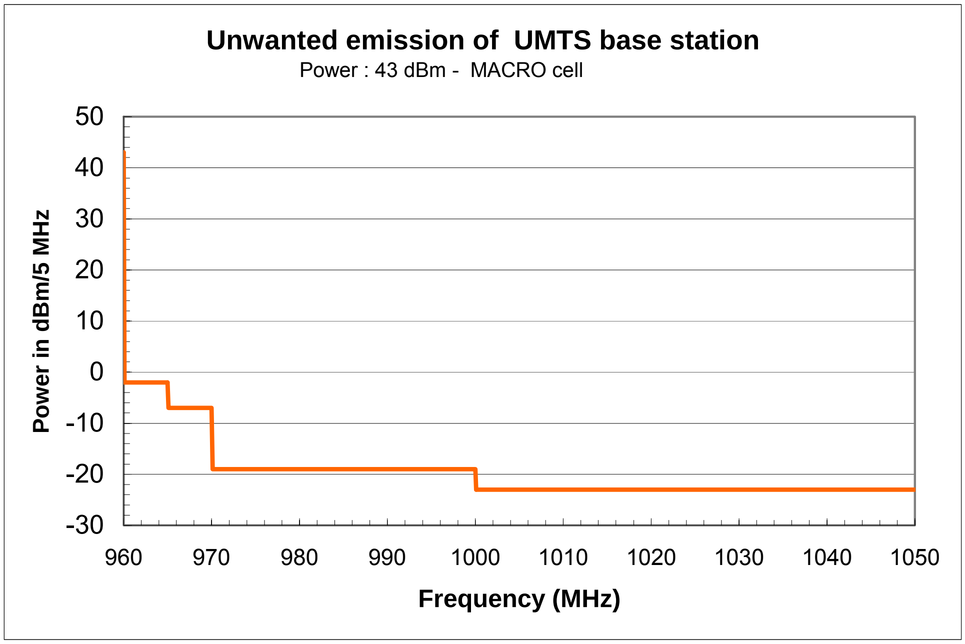
The aim of this section is to assess the interference from the UMTS900 base station in the UMTS900 band, according the **criterion n°2** described above.
The out-of band and spurious emissions of the UMTS900 are considered in this section.

3.5.2.2.1 UMTS900 BS unwanted emissions

- UMTS900 Macro-cell (Power = 43 dBm, e.i.r.p. = 58dBm)

UMTS900 Transmission band	Level in dBc in 5 MHz	e.i.r.p. in dBm in 5 MHz	MIDS channels impacted
965 – 970 MHz	50 dBc	+8 dBm	969 MHz (1 channel)
970 MHz to 1 GHz	*(62dBc)*	-4 dBm	972 to 999 MHz (10 channels)
1 GHz to 12,75 GHz	*(66dBc)*	-8 dBm	1002 to 1206MHz (40 channels)

Figure 3-24: UMTS900 BS unwanted emission (macro cell)



- UMTS900 Micro-cell (Power = 38 dBm, e.i.r.p. = 42dBm)

Transmission band	Level in dBc in 5 MHz	e.i.r.p. in dBm in 5MHz	MIDS channels impacted
965 – 970 MHz	50 dBc	-8 dBm	969 MHz (1 channel)
970 MHz to 1 GHz	*(57dBc)*	-15 dBm	972 to 999 MHz (10 channels)
1 GHz to 12,75 GHz	*(61dBc)*	-19 dBm	1002 to 1206MHz (40 channels)

3.5.2.2.2 Application of the criterion n°2

The tolerated level of -104 dBm for the noise floor was settled above. This level is applicable to each hopping frequency. The UMTS masks, as expressed in section 3.5.2.2.1 generate the following categorization:

- The frequency 969 MHz (1 MIDS channel)
- The frequencies from 972 MHz to 1000 MHz (10 MIDS channels)
- The frequencies from 1000 to 1206 MHz (40 MIDS channels)

This gives four cases to consider:

- Case 1: none of the MIDS channels are interfered
- Case 2: 1 MIDS channel is interfered
- Case 3: 11 MIDS channel are interfered
- Case 4: 51 MIDS channel are interfered

As stated above, the permissible interfered frequency rate is not given in the document but it is possible to say that:

- the MIDS terminal is not affected in the cases 1 and 2.

- the MIDS terminal communication performance is acceptable in case 3, but the ability to tolerate additional intentional or non-intentional interfere is reduced: MIDS electronic anti-jamming performances are degraded.

- the MIDS terminal performance is degraded in case 4. The jam threshold is between 11 and 51 interfered channels.

3.5.2.2.3 Conclusion according to the criterion n°2

Note: it is considered that MIDS is more often deployed in rural and suburban areas; so the only case studied below corresponds to the UMTS macro-cell.

The maximum calculated value of UMTS signal (macro-cell), for the frequency 960 MHz, is -21 dBm at the input of the MIDS receiver terminal. The corresponding distance is from 200 to 280 metres. This gives (based on the section 5.1.1):

- A level of -71 dBm/5 MHz in the 969 MHz MIDS channel,
- A level of -83 dBm/5 MHz in the 10 following MIDS channel,
- A level of -87 dBm/5MHz for the rest of the MIDS channels.

Whatever the channel is, the threshold of the noise level of -104 dBm/5MHz is exceeded. To respect this level of -104 dBm/5MHz:

- for the 10 channels in the 970-1000MHz band, an additional isolation of 21 dB is necessary to ensure the nominal performances of MIDS. However, as mentioned previously, performance degradation is tolerated in this frequency range.
- for the highest 40 channels, an additional isolation of 17 dB is necessary.

3.5.2.2.4 Minimum separation distance for the protection of MIDS

If we consider an UMTS spurious level of -104dBm/5MHz in the 1000 - 1206MHz, that means an UMTS signal of -38dBm (*66dBc*): the separation distance between UMTS and MIDS equivalent to the necessary propagation loss can be read on figure 5: the minimum separation distance is 2km.

If we consider an UMTS spurious level of -104dBm/5MHz in the 970-1000MHz, that means an UMTS signal of -42dBm (*62dBc*): the minimum separation distance between UMTS and MIDS is 3 km.

3.5.2.2.5 Sensitivity analysis on the UMTS parameters

It is likely that one of the most important assumptions in the study is the compliance of the unwanted (out-of-band and spurious) emission of the UMTS900 base stations with the 3GPP specifications. One can assume that the equipments will have better performances than their specifications without knowing how.

The previous section showed that, in order to be certain to respect the criteria n°2 every time for every distance, an additional isolation of 17 dB (or 21dB if we consider the 970-1000MHz band) would be needed. This occurs for a distance from 200m to 280 metres between the UMTS900 base station and the MIDS receiver.

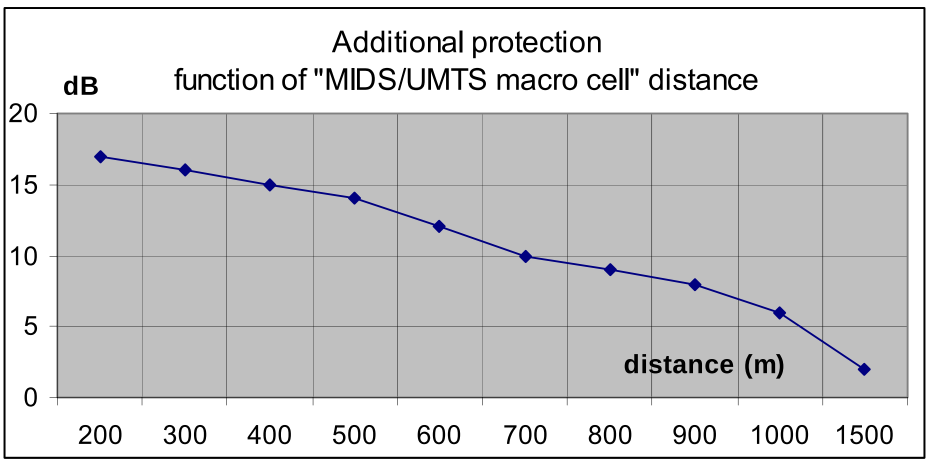
If 200 metres between both system is a satisfactory distance (from 200m to 280, there is no change), which correspond to a value of -21 dBm (MACRO base station) at the input of the MIDS receiver, this leads to a level of:

- A level of -71 dBm in the 969 MHz MIDS channel,
- A level of -83 dBm in the 10 following MIDS channel,
- A level of -87 dBm for the rest of the MIDS channels.

To respect this level of -104 dBm for the highest 40 channels, an additional isolation of 17 dB would be necessary.

A distance of 200 metres would be sufficient if the spurious mask of UMTS900 is 17 dB better than the specifications. The additional protection can be calculated function of the separation distance:

Separation Distance	Level on MIDS receiver	Level received on the last MIDS frequencies	Additional protection
<200 m	<-21 dBm	<-87 dBm	>17 dB
200 m	-21 dBm	-87 dBm	17 dB
300 m	-22 dBm	-88 dBm	16 dB
400 m	-23 dBm	-89 dBm	15 dB
500 m	-24 dBm	-90 dBm	14 dB
600 m	-26 dBm	-92 dBm	12 dB
700 m	-28 dBm	-94 dBm	10 dB
800 m	-29 dBm	-95 dBm	9 dB
900 m	-30 dBm	-96 dBm	8 dB
1000 m	-32 dBm	-98 dBm	6 dB
1500 m	-36 dBm	-102 dBm	2 dB
2000 m			0 dB



3.5.2.2.6 Practical performance of unwanted emissions of UMTS 900 base stations

The section 3.5.2.2.5 provides the required separation distance as a function of the level of the UMTS 900 base stations unwanted emissions. If there is an additional isolation of 17 dB on the spurious emissions of the UMTS 900 base station above 1 GHz, then there is no required separation distance.

Some manufacturer stated that the spurious emissions of the UMTS900 BS for the frequency range between 1 GHz and 1.2 GHz will be lower than the specifications with a margin > 17 dB as required for the protection of MIDS terminals.

However, the above elements are based only on the information available to date about the performance of a base station designed by a single manufacturer. It is important to ensure that the performances of other base stations would also enable to draw the same conclusions.

3.5.3 Conclusions

This adjacent band compatibility study between UMTS900 (operating below 960 MHz) and the MIDS (operating above 969 MHz) considers the impact of the main UMTS900 signal in its band (below 960 MHz) and the unwanted emissions (above 960 MHz). It shall be noted than the assessment of interferences from MIDS on the UMTS900 has not been taken into account in theses compatibility studies. In this context, it should be noted that this study does not take into account the regulatory status of JTIDS/MIDS, which operates in the band 960-1215 MHz under the conditions of provision 4.4 of the Radio Regulations.

To avoid any interference on each MIDS frequency the protection distance between UMTS900 base station and MIDS stations should be up to 2 km accordingly to the table of section 5.5.

However, the protection should be reduced if the real unwanted emission level of the equipment is better than 3GPP specifications. To fully protect MIDS without any protection distance, the unwanted emission level should be:

- 21 dB better than present 3GPP specification in the 970-1000 MHz band,
- 17 dB better than present 3GPP specification in the 1000 - 1206MHz MIDS band (corresponding to the 1-12.75GHz spurious band),

However, a performance degradation of the MIDS can be tolerated: this corresponds to interferences on the first 11 MIDS channels. Consequently, if there is an additional isolation of 17 dB above 1 GHz no additional separation distance is required to protect the MIDS receiver.

Information available to date about the performance of a base station designed by a single manufacturer shows that practical level of unwanted emission provides isolation higher than the 17 dB required, according to section 3.5.2.2.6. However, it will be important to ensure that the performances of other base stations which will be effectively deployed would also enable to provide the required protection to MIDS.

3.6 Conclusions

In this chapter, the compatibility studies between UMTS900 and systems operating in adjacent bands, including GSM-R, PMR/PAMR (TETRA, CDMA PAMR, TAPS), Aeronautical DME, MIDS have been described. Based on the interferences analysis, the following conclusions can be made:

1) There is *a priori* no need of an additional guard band between UMTS900 and GSM-R, a carrier separation of 2.8 MHz or more between the UMTS900 carrier and the nearest GSM-R carrier is sufficient without prejudice to provisions in point 2). This conclusion is based on Monte Carlo simulations assumed suitable for typical case.

2) However for some critical cases (e.g. with high located antenna, open and sparsely populated areas served by high power UMTS BS close to the railway tracks, blocking etc, which would lead to assumption of possible direct line of sight coupling) the MCL calculations demonstrate that coordination is needed for a certain range of distances (up to 4 km or more from railway track).

3) It is beneficial to activate GSM-R uplink power control, especially for the train mounted MS, otherwise the impact on UMTS UL capacity could be important when the UMTS network is using the 5 MHz channel adjacent to the GSM-R band. However, it has to be recognized that this is only applicable in low speed areas as elsewhere the use of uplink control in GSM-R will cause significantly increased call drop out rates.

4) In order to protect GSM-R operations, UMTS operators should take care when deploying UMTS in the 900 MHz band, where site engineering measures and/or better* filtering capabilities (providing additional coupling loss in order to match the requirements defined for the critical/specific cases) may be needed in order to install UMTS sites close to the railway track when the UMTS network is using the 5 MHz channel adjacent to the GSM-R band.

   * Currently, the out-of band interference level is given by 3GPP TS 25.104 V7.4.0

   It has to be noted that this study did not address tunnel coverage. Site sharing, which is expected to improve the coexistence, has not been studied either.

5) Potential interference between UMTS900 BS operating below 915 MHz and PMR/PAMR (CDMA PAMR, TETRA, TAPS) BS operating at frequencies above 915 MHz could be a problem. In order to protect UMTS900 BS, the utilization of interference mitigation techniques is necessary:

   v) Reduced PMR/PAMR BS Tx power

   vi) Spatial separation

   vii) External filters

   viii) Guard band

- The potential interference from UMTS900 to aeronautical DME operating at frequencies above 972 MHz does not represent any difficulty. The frequency range between 960-972 MHz is not currently used by aeronautical DME but will be used in a near future. Some additional margins may be required for the protection of aeronautical DME operating at frequencies between 960 and 972 MHz, where the required additional margins are dependent on DME carriers and aircraft positions. The studies have shown that the only mitigation techniques, in order to ensure the compatibility between the DME system and UMTS900, that would bring sufficient isolation are: additional filtering and a larger guard band. However these two mitigation techniques are not judged applicable. Therefore, the report suggests that a regulatory solution should be examined. It is necessary that a common approach be used within Europe to ensure the compatibility.
- Further compatibility study will be necessary if this frequency range is to be used by DME systems or future aeronautical systems addressed under WRC Agenda Item 1.6.

5) The compatibility study between UMTS900 and MIDS indicated that an additional margin of 17 dB of UMTS900 BS spurious emissions over the frequency range between 1000 MHz and 1206 MHz in reference to 3GPP technical specifications is required for the protection of MIDS terminal receiver. Information available to date about the performance of a base station designed by a single manufacturer shows that practical level of unwanted emission provides isolation higher than the 17 dB required, according to section 3.5.2.2.6. However, it will be important to ensure that the performances of other base stations which will be effectively deployed would also enable to provide the required protection to MIDS.

It should be noted that all studies in section 3 assumed a UMTS900 base station antenna gain of 15 dBi (including feeder loss). A value of 12dBi was, however, considered more realistic based on real network deployment. As a consequence the interference is overstated by 3dB.

4 COMPATIBILITY STUDY BETWEEN UMTS1800 AND SYSTEMS OPERATING IN ADJACENT BANDS

4.1 Systems operating in adjacent bands

All systems operating in bands adjacent to UMTS1800 are summarized in table 4-1.

Frequency (MHz)	System	Note
1700-1710	METSAT Fixed - Telemetry	• Weather Satellite • Defense
1710-1785	**GSM1800 (UL) UMTS1800 (UL)**	
1785-1800	Radio Microphones Fixed & mobile	Guard bands have been defined between radio microphones and GSM1800 Wireless Broadband
1800-1805	Under study in CEPT	Wireless Broadband, Flexible use
1805-1880	**GSM1800 (DL) UMTS1800 (DL)**	
1880-1900	DECT	

Table 4-1: Systems operating in adjacent bands of UMTS1800

Based on the list of systems adjacent to the UMTS1800 frequency band in table 4-1, the sharing studies between UMTS1800 and the following systems are considered in this report:

1) DECT
2) METSAT
3) Radio microphone
4) Fixed service

4.2 Compatibility study between UMTS1800 and DECT

4.2.1 DECT system characteristics

Main DECT system characteristics are summarized in tables 4-2 to 4-6.

	DECT	
Frequency band (UL & DL) (MHz)	1880-1900	
Carrier separation (MHz)	1.728	
Modulation	GMSK	
	BS	**MS**
Maximum Tx power (dBm)	24 dBm (250 mW)	24 dBm (250 mW)
Receiver bandwidth (MHz)	1.152	1.152
Thermal noise (dBm)	-113	-113
Noise figure (dB)	10	10
Noise floor (dBm)	-103	-103
Receiver sensitivity (dBm)	-93	-93
Antenna height (m)	0.8	1.5
Antenna gain (dBi)	0	0
Feeder loss (dB)	0	0

Table 4-2: Main DECT system parameters

Emissions on RF channel "Y"	Maximum power level	Maximum power level	Frequency Offset
1. Y=M±1	160 µW	-8 dBm	ΔF=+/ -1.728 MHz
2. Y=M±2	1 µW	-30 dBm	ΔF=+/ -3.456 MHz
3. Y=M±3	80 nW	-41 dBm	ΔF=+/ -5.184 MHz
4. Y>M±3	40 nW	-44 dBm	any other channel

Table 4-3: Spectrum mask

Note: "M" is the Equipment Under Test (EUT) transmitting channel (carrier) and "Y" is a legal DECT channel other than the EUT transmit channel.

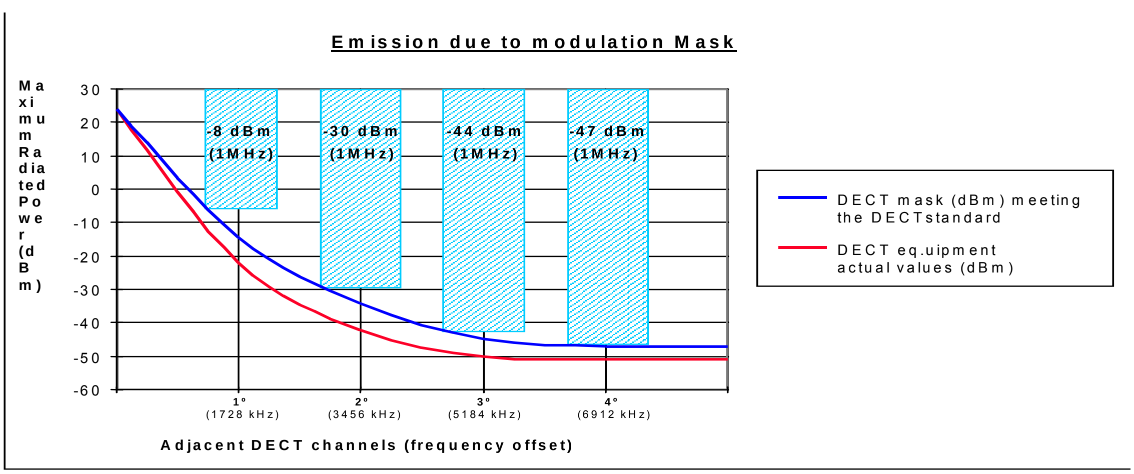


Figure 4-1: DECT emission mask

The spurious emissions shall not be greater than -36 dBm (250 nW) at frequencies below 1 GHz and -30 dBm (1 µW) at frequencies above 1 GHz. The measurement bandwidth is given in table 4-4.

Frequency offset from edge of band	Resolution Bandwidth
0 - 2 MHz	30 kHz
2 - 5 MHz	30 kHz
5 - 10 MHz	100 kHz
10 - 20 MHz	300 kHz

Table 4-4: Spurious emission measurement filter bandwidth

The C/I requirements are set with respect to the ability of DECT equipment to continue receiving in the presence of an interfering signal on the same or different DECT RF channel. Wanted signal level: -73dBm

Interferer on RF channel	Interfering signal strength	C/I	Frequency Range (MHz)	Frequency at GSM band edge (MHz)
$Y=M=F_0$	-84 dBm	11 dB	ΔF= 0	1881.792
Y=M +/- 1	-60 dBm	-13 dB	ΔF =+/- 1.728	1880.064
Y=M +/- 2	-39 dBm	-34 dB	ΔF =+/- 3.456	1878.336
Y=M +/- 3	-33 dBm	-40 dB	ΔF =+/- 5.184	1876.606

Table 4-5: C/I requirement

The RF carriers “Y” shall include the three nominal DECT RF carrier positions immediately outside each edge of the DECT band.

Frequency (f)	**Continuous wave interferer level**	**Comments**
25 MHz ≤ f ≤ 1780 MHz	-23 dBm	GSM MS transmitter band
1780 ≤ f ≤ **1875 MHz**	-33 dBm	GSM BTS transmitter band
$\|f-F_C\| > 6$ MHz	-43 dBm	GSM BTS transmitter band
1905 MHz < f ≤ 2000 MHz	-33 dBm	not relevant
2000 MHz <f ≤ 12.75 GHz	-23 dBm	not relevant

Table 4-6: Receiver blocking

*F_C is DECT RF channel (carrier) for wanted signal: c = 0, 1, ... ,9.

4.2.2 UMTS1800 system characteristics

UMTS1800 system parameters can be found in ECC Report 82. The UMTS1800 BS system parameters used in the compatibility study between UMTS1800 and DECT are summarized in table 4-7.

	UMTS FDD 1800MHz			
Downlink band (MHz)	1805-1880			
Uplink band (MHz)	1710-1785			
Carrier separation (MHz)	5			
Channel raster	200			
	BS		**UE**	
	Urban indoor	Rural outdoor	Urban indoor	Rural outdoor
Maximum Tx power (dBm)	24	43	21	21
Receiver bandwidth (MHz)	3.84	3.84	3.84	3.84
Thermal noise (dBm)	-108	-108	-108	-108
Noise figure (dB)	5	5	12	12
Noise floor (dBm)	-103	-103	-96	-96
Receiver sensitivity (dBm)	-111	-121	-117	-117
Antenna height (m)	2	30	1.5	1.5
Antenna gain (dBi)	0	17	0	0
Feeder loss (dB)	3	3	0	0
Cell radius (km)	0.3	10	0.3	10

Table 4-7: UMTS system parameters

Indoor penetration parameters:
- Wall Loss (indoor / indoor)= 5dB
- Wall Loss (outdoor / indoor)= 12dB

4.2.3 Interference analysis between UMTS1800 and DECT

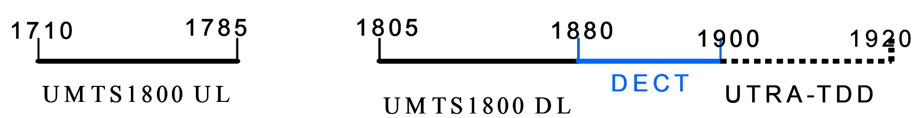


Figure 4-2: DECT frequency band is adjacent to UMTS1800 DL

As shown in figure 4-2, the DECT frequency band 1880-1900 MHz is adjacent to the UMTS1800 downlink block 1805-1880 MHz band. It is also adjacent to the UTRA-TDD band 1900-1920 MHz. The adjacent band compatibility study between DECT and UTRA-TDD has been described in ERC Report 65 [11]. The adjacent band compatibility study between DECT and DCS1800 was described in ERC Report 31 [15] and ERC Report 100 [16].

The aim is to assess the impact of DECT on UMTS FDD 1800MHz DL and vice versa. The frequency band 1800 MHz, currently used by GSM1800, is envisaged for new UMTS FDD where the frequency plan will be: 1710-1785 MHz for the Uplink and 1805-1880 MHz for the Downlink. DECT (Digital Enhanced Cordless Telecommunications) is a digital wireless technology that is most commonly used for local cordless coverage in both home and corporate phone systems. Indoor RFP (Radio Fixed Part) with indoor PP (Portable Part) is the most common DECT installation. Only the impact on the UMTS 1800 Downlink is assessed because the frequency band is closest to the DECT band.

To evaluate interference between DECT and UMTS1800 DL, the studies were done with the Monte-Carlo software SEAMCAT 3, except when scenarios imply two fixed bases.

SEAMCAT (Spectrum Engineering Advanced Monte Carlo Analysis Tool) is a generic radio compatibility analysis software tool developed within the frame of the CEPT Working Group Spectrum Engineering (SE). It quantifies the interference level in scenarios involving victim and interfering radio systems, by taking into account the statistical nature of received signals.

When assessing the impact on UMTS CDMA DL, calculations were done with SEAMCAT 3 and consequently results are expressed in term of capacity losses and number of dropped users. For the impact on DECT mobiles, the results are expressed in term of probability of interference.

The main parameters can be seen in Table 4-2. DECT uses Dynamic Channel Allocation (DCA) to combat interference. In case interference occurs on one channel, DECT has the ability to select another one, without loss of communication. To illustrate DCA in SEAMCAT 3, the interfering frequency was set to an equal probability distribution of frequency between 1880 MHz and 1900 MHz. The distance between RFP and PP was set to 100 m, the common DECT range indoor.

ERC Report 65 describes the sharing study between UMTS UTRA-TDD 1900-1920 MHz and DECT, and the worst co-existence scenarios of that report have been taken for this study. There are two main scenarios, where DECT interferes with UMTS1800 and when UMTS1800 interferes with DECT. The list of co-existence scenarios is given below:

a) Interference from DECT to UMTS1800

- DECT DL indoor on UMTS 1800 DL indoor
- DECT UL indoor on UMTS 1800 DL indoor
- DECT DL indoor on UMTS 1800 DL outdoor
- DECT UL indoor on UMTS 1800 DL outdoor

b) Interference from UMTS1800 to DECT

- UMTS 1800 DL indoor on DECT DL indoor
- UMTS 1800 DL indoor on DECT UL indoor
- UMTS 1800 DL outdoor on DECT DL indoor
- UMTS 1800 DL outdoor on DECT UL indoor

The characteristics of two types of BS are used for two different cases of simulation for network UMTS1800 DL. For the first case, an above-roof macro BTS (Wide Area BS) with indoor UE, and, in the other case, an indoor pico BS (Local area BS) with indoor UE.

4.2.4 Interference analysis and simulation results

For different co-existence interference analysis scenarios described above, Monte-Carlo simulations with SEAMCAT have been performed and summarised below.

i) Interference from DECT RFP to UMTS 1800 DL

- ***UMTS 1800 indoor picocell DL as victim***

The simulation results of the interference from DECT RFP to indoor pico-cell UMTS1800 UE are given in table 4-8.

Distance RFP-UE	iRSS unwanted (dBm)	iRSS blocking (dBm)	Capacity loss (%)
5 m	-179.7	-146.9	3.53
10 m	-180.3	-147.7	3.23
250 m	-183.5	-150.2	3.06
500 m	-189	-156.5	2.54

Table 4-8: Simulation results of interferences from DECT to pico-cell UMTS1800 DL (indoor)

These simulation results show that DECT has very limited impacts on UMTS1800 DL. In the case *DECT DL on UMTS 1800 DL indoor*, the capacity loss never exceeds 4% and the number of dropped users never exceeds 5% of the total users.

The difference between the DECT Downlink and Uplink is not very relevant because the maximum Tx power, the sensitivity and antenna gain are the same for the DECT RFP and PP. So, it can be assumed that there are no differences for the simulations between DECT DL and DECT UL. The results confirm this hypothesis. Between *DECT DL on UMTS 1800 DL* indoor and *DECT UL on UMTS 1800 DL* indoor, there is no difference, the capacity loss of the UMTS1800 DL never exceeds 4%.

- ***UMTS 1800 above roof macro cell***

The simulation results of the interference from DECT RFP to macro-cell UMTS1800 DL (indoor) are given in table 4-9.

Distance RFP-UE	iRSS unwanted (dBm)	iRSS blocking (dBm)	Capacity loss (%)
5m	-230.6	-197.3	3.48
10m	-230.6	-197.4	3.45
250m	-230.8	-197.5	3.31
500m	-231	-197.9	3.27

Table 4-9: Simulation results of interferences from DECT to macrocell UMTS1800 DL (indoor)

It can be seen that the results are similar to that for the case of interference from DECT DL to the picocell UMTS 1800 DL indoor, UMTS1800 DL capacity loss due to interference from DECT RFP is below 4%.

ii) Interference from UMTS1800 to DECT

For theses scenarios where the victim link is not a CDMA system, the results are not expressed in term of capacity loss or dropped user. The interference criterion is chosen as the probability of interference C/I≤10dB.

- ***Interference from indoor pico-cell UMTS1800 to DECT PP***

The simulation results of the interference from indoor pico-cell UMTS1800 to indoor DECT PP are given in table 4-10.

Distance BS-PP	iRSS unwanted (dBm)	iRSS blocking (dBm)	Interference probability (%)
10m	-81.8	-76.9	74.6
20m	-95.5	-90.7	46.3
30m	-104.1	-99.2	27.7
40m	-113.9	-109.2	17.6
50m	-116.1	-111.2	12.9
60m	-121	-116.2	6.5
65m	-125.8	-120.9	4.1
70m	-130.2	-125.4	2.8

Table 4-10: Simulation results of interferences from indoor pico-cell UMTS1800 to DECT PP (indoor)

These results show that, for not exceeding an interference probability of 5%, an exclusion zone of 65 m has to be set between the indoor pico-cell UMTS1800 Base Station and DECT PP receivers. Otherwise, without an exclusion zone, and since interference is from indoor fixed pico-cell base stations, if an operator plans such a deployment, additional filtering on these base stations might be needed to prevent the potential interference from pico-cell UMTS1800 BS to DECT PP.

- ***Interference from outdoor macro-cell UMTS1800 to DECT PP***

The simulation results of the interference from outdoor macro-cell UMTS1800 to indoor DECT PP are given in table 4-11.

Distance BS-PP	iRSS unwanted (dBm)	iRSS blocking (dBm)	Interference probability (%)
50m	-81.5	-76.6	77.2
100m	-100.4	-95.6	37.3
200m	-107.3	-102.4	26.6
300m	-111.5	-106.7	19.5
400m	-114.6	-109.8	13.5
500m	-116.8	-111.9	9.3
600m	-118.2	-113.3	6.8
700m	-119.6	-113.8	4.9

Table 4-11: Simulation results of interferences from outdoor macro-cell UMTS1800 to DECT PP (indoor)

These results show that, so as not to exceed the interference probability of 5%, the first base station must be at 700 m distance from the DECT building. Noting that such an occurrence is very low in a rural environment, a separation distance from base stations to buildings using DECT technology inside should not create any difficulty for UMTS1800 deployment.

4.2.5 Conclusions

The simulation results described above for the defined co-existence scenarios between UMTS1800 and DECT lead to the following conclusions:

1) UMTS1800 macro-cells can be deployed in the same geographical area in co-existence with DECT which is deployed inside of the buildings, as the interference between DECT RFP and PP and macro-cellular UMTS1800 BS and UE is not a problem;

2) When pico-cellular UMTS1800 BS is deployed inside of the building in co-existence with DECT RFP and PP deployed in the same building indoor area, some potential interference is likely to exist from indoor pico-cellular UMTS1800 BS to DECT if they are placed too close and they are operating in the adjacent channel at 1880 MHz;

3) The following interference mitigation techniques could be used to address the potential interference from indoor pico-cellular UMTS1800 to indoor DECT RFP and PP when they are operating at the adjacent frequency point of 1880 MHz;

   a) Space separation between indoor pico-cell UMTS1800 BS and DECT RFP or PP of 65 m or more;

   b) External filter on indoor pico-cellular UMTS1800 BS;

   c) Avoiding the adjacent frequencies of 1880 MHz for indoor pico-cellular UMTS1800 BS and DECT or operate with reduced transmitting power if necessary.

In term of interference analysis, the DECT system has the DCA (Dynamic Channel Allocation) mechanism which allows it to avoid efficiently an interfered channel, except if both systems are deployed indoors.

Indeed, although DECT uses DCA, interference analysis shows that, in the case of UMTS1800 indoor pico-cellular deployment with the frequency channel adjacent to the DECT frequency band, the usage of some interference mitigation technique may be necessary to prevent potential interference to indoor DECT RFP or PP.

However, in practice, GSM1800 deployment has demonstrated that no additional interference mitigation techniques are really needed. This statement can be assumed to be extended to the compatibility between UMTS1800 and DECT systems.

4.3 Compatibility consideration between UMTS1800 and METSAT

4.3.1 Main characteristics of METSAT

Meteorological satellite service (Space to earth) system characteristics are described in ITU-R Recommendation SA.1158 [10]. The main system parameters of the meteorological satellite system operating in the frequency range 1698-1710 MHz are summarized in table 4-12.

Meteorological satellite Earth Stations are normally receiving data at elevation angles above typically 5° but have to support occasional satellite passes with lower elevation angles.

Satellite	Orbit height (km)	Inclination (degrees)	Lower frequency (MHz)	Upper frequency (MHz)
FY-1	870 870	98.7 98.7	1 698 1 705.5	1 703 1 710
METOP	827 827	98.7 98.7	1 698.75 1 704.75	1 703.25 1 709.25
SPOT	822	98.7	1 703	1 705
METEOR	1 020 1 020	99.6 99.6	1 698.5 1 703.5	1 701.5 1 706.5
NOAA	850 850	98.7 98.7	1 698.75 1 704.75	1 703.25 1 709.25
ADMIN1-A	840	98.7	1 698	1 702
ADMIN1-B	840	98.7	1 702	1 706
ADMIN2-A	840	98.7	1 702	1 706
ADMIN2-B	840	98.7	1 706	1 710
ADMIN3	840	98.7	1 706	1 710

Table 4-12: Meteorological satellite data used for the simulation

4.3.2 Interference analysis considerations

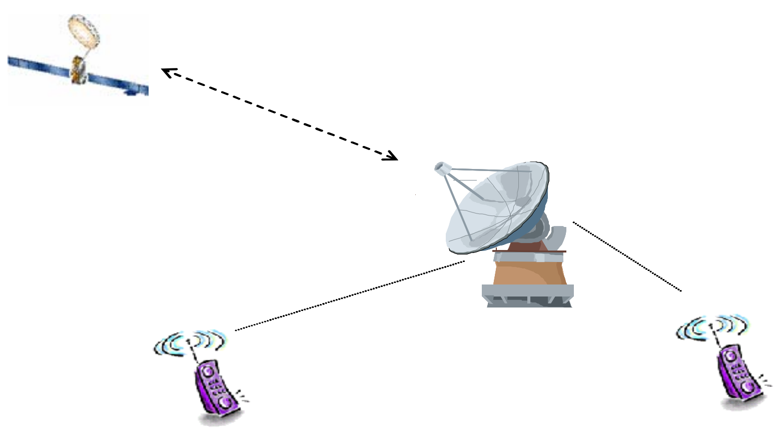


Figure 4-3: Interference scenario between UMTS (GSM) UL and METSAT DL

The compatibility between meteorological satellite and MSS (Mobile Satellite System) has been studied and described in ITU-R Recommendation SA.1158 [10]. The compatibility between meteorological satellite Earth Stations operating in the frequency range 1700-1710 MHz and GSM1800 has not been studied. GSM1800 has been deployed and in extensive use over many years, and there has been no interference problem between GSM1800 and METSAT. As shown in figure 4-3 the interference scenario between UMTS/GSM mobile station and METSAT Earth Station takes into account that the METSAT Earth Station antenna radiation pattern has very small back lobes or side lobe, and that the possible interference signal, if any, from ground mobile station is in principle strongly attenuated.

As shown in table 4-1, the METSAT operating frequency range of 1700-1710 MHz is adjacent to the UMTS1800/GSM1800 uplink frequency block at 1710-1785 MHz. The ACLR of GSM1800 mobile stations and UMTS1800 UE are given in ECC Report 82. GSM1800 MS adjacent channel leakage power ratio at 5 MHz is ACLR=43.8 dB/3.84 MHz; for UMTS1800 UE ACLR = 33 dB/3.84 MHz.

GSM1800 MS maximum Tx power is of 30 dBm, without uplink power control, the leakage power of GSM1800 MS at its 5 MHz adjacent frequency range is 30 – 43.8 = -13.8 dBm.

UMTS1800 UE maximum Tx power is 21 dBm, without uplink power control, the leakage power of UMTS1800 UE at its 5 MHz adjacent frequency range is 21 – 33 = -12 dBm. But in fact, UMTS uplink power control is always activated, and the simulated outdoor UMTS UE Tx power distribution results were described in ECC Report 82. At the 90% percentile, the UMTS UE Tx power is -22.4 dBm, and with this more realistic UMTS UE Tx power, the UMTS UE leakage power at its 5 MHz adjacent frequency range is -22.4 – 33 = -55.4 dBm, which is much lower than that of GSM1800 MS.

The potential interference from METSAT DL to UMTS1800 UE is not covered in this report; this issue is left for future further study if it appears necessary.

4.3.3 Conclusions

From the frequency arrangement between METSAT and UMTS1800, the possible interference scenario is the interference from UMTS UE into METSAT Earth Station. The METSAT system has been in adjacent operation with GSM1800 for many years, and as a matter of fact METSAT Earth Stations were not interfered with by GSM MS transmissions. A comparison of adjacent leakage power between GSM MS and UMTS UE indicates that the effective UMTS UE adjacent channel leakage power is much lower than GSM adjacent channel leakage power, so it is believed that the interference from UMTS UE to METSAT Earth Stations operating in adjacent frequency band is unlikely to be a problem.

4.4 Compatibility consideration between UMTS1800 and Radio microphones

4.4.1 Main characteristics of Radio Microphones

Radio microphone system characteristics are described in ERC Report 63[13], ERC/REC 70-03E [21], ETSI standard EN300422 [14], they are summarized in table 4-13.

Parameter	Value
Transmitter output power hand held	13 dBm (20 mW)
Transmitter output power body worn	17 dBm (50 mW)
Transmitter spectrum mask	as set out in ETSI EN 300 422, shown in figure 4-4
Bandwidth (-60 dB)	analogue as set out in ETSI EN300 422 (max. 200 kHz) digital approx. 300 kHz (which is not in compliance with ETSI EN 300 422)
Body effect loss hand held	6 dB
Body effect loss body worn	14 dB
Receiver input power	Analogue : - 68 dBm/74 dB(µV/m); Digital: - 85 dBm/57 dB(µV/m)
C/I ratio	Analogue: 25 dB Digital: 18 dB
Max. interfering field strength	Analogue: 49 dB(µV/m) Digital: 39 dB(µV/m)
Receiver spectrum mask	Shown in figure 4-5
Operating modes	indoor and outdoor
Channel selection	no dynamic channel selection, frequency tuning possible throughout the frequency range.

Table 4-13: Main characteristics of radio microphone

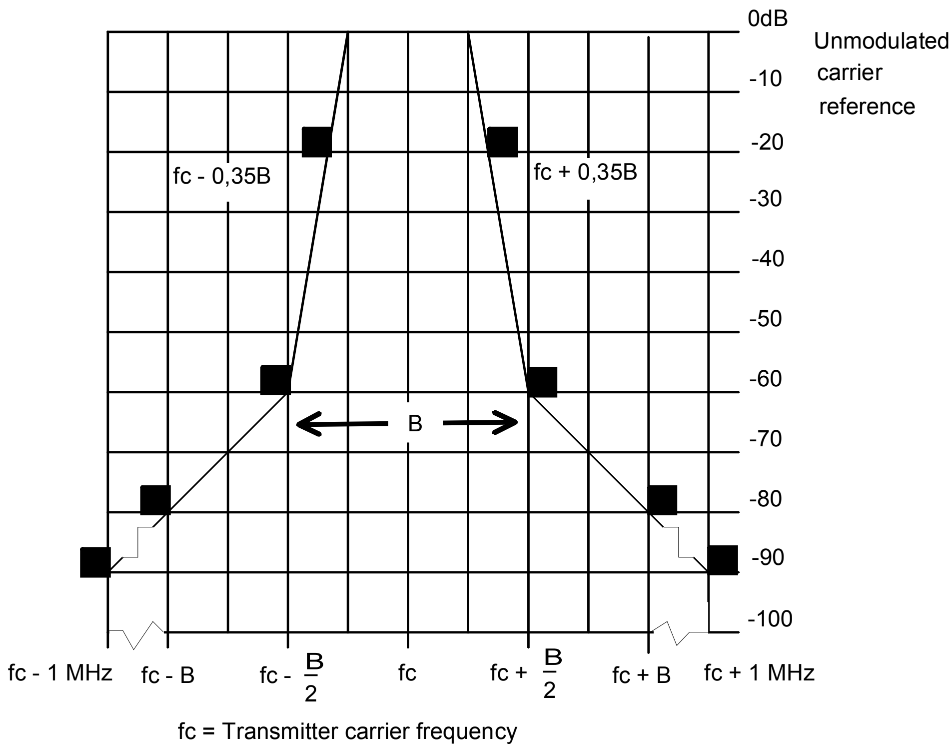


Figure 4-4: Microphone transmitter spectrum mask (normalized to channel bandwidth B)

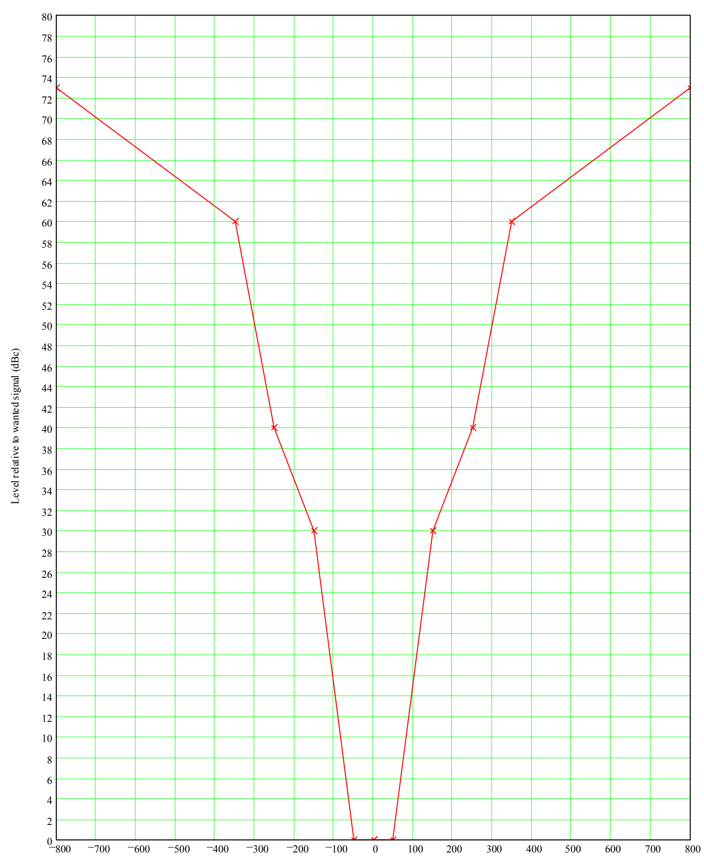


Figure 4-5: Microphone receiver mask

4.4.2 Interference analysis

Interference analysis between GSM1800 and Radio Microphones operating in adjacent frequency bands was described in ERC Report 63[13]. The same interference analysis method can be used for the interference analysis between UMTS1800 and Radio Microphones operating in adjacent bands. The conclusion of the interference analysis between GSM1800 and Radio Microphones was that a guard band of 700 kHz (1785 - 1785.7 MHz) was recommended for avoiding potential interference problems between radio microphones and GSM1800.

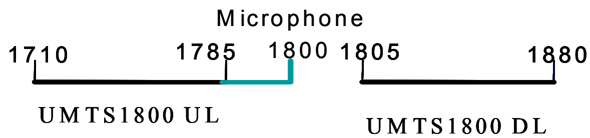


Figure 4-6: Radio Microphone frequency band is adjacent to UMTS1800 UL

For the compatibility between radio microphones and UMTS1800, there is a need to verify through interference analysis whether the recommended guard band of 700 kHz in ERC Report 63 [10] is sufficient for ensuring the good compatibility between UMTS1800 and radio microphones operating in the adjacent band.

UMTS1800 BS receiver narrow band blocking is defined in 3GPP TS25.104 (Rel-7), wide area BS receiver narrow band blocking was defined as -47 dBm at 2.8 MHz from its central carrier frequency. The ACS of UMTS BS receiver calculated with the narrow band blocking is 51.3 dB as described in ECC Report 82.

With a 700 kHz guard band, the nearest digital radio microphone carrier will be at 1785.85 MHz. The UMTS1800 carrier would normally be at 1782.5 MHz, thus the carrier separation between UMTS carrier and the nearest digital radio microphone is 2.5+0.7+0.15=3.35 MHz, which is more than 2.8 MHz.

As UMTS1800 BS narrow band blocking was defined based on simulations that GSM1800 MS transmitting at its maximum power of 30dBm (1 W), and by considering that radio microphones transmit at a maximum power of 13 dBm, the interference from radio microphone to UMTS1800 BS will be much less than the possible interference from GSM1800 MS. It can be considered that the interference from radio microphones to UMTS BS should not be a problem.

4.4.3 Conclusions

Based on the interference analysis considerations between UMTS1800 and radio microphones, it can be considered that the proposed guard band of 700 kHz in ERC Report 63 and ERC/REC 70-03E is sufficient for protecting UMTS1800 BS receivers under the condition that the radio microphone maximum transmitting power is limited to 13 dBm (20 mW) for hand held microphones and 17 dBm (50 mW) for body worn microphones, as recommended in ERC Report 63 and ERC/REC 70-03E.

4.5 Compatibility study between UMTS1800 and Fixed Services

Compatibility between UMTS and Fixed Services operating in co-frequency and adjacent bands was studied and reported in ERC Report 65 [11] and ERC Report 64 [12]. As described in these two ERC Reports, the critical interference scenarios are between UMTS BS and Fixed Service stations, the interference between UMTS UE and Fixed Services was not considered.

As indicated in table 4-1, the Fixed Service frequency range is adjacent to UMTS1800 UL, and the potential interference, if any, will be between Fixed Service and UMTS1800 BS. The interference analysis method used in the two ERC Reports can be used to derive the coordination distance, that is the space separation between UMTS BS and Fixed Service stations as a function of frequency separations between UMTS base station and Fixed service station, as an interference prevention solution, as described in ERC Reports 64 and 65.

4.6 Conclusions

The compatibility between UMTS1800 and systems operating in adjacent bands, including DECT, METSAT and Radio microphones, has been studied and described in this chapter. Based on the interference analysis, the following conclusions can be made:

1) Interference analysis shows that potential interference between UMTS1800 and DECT does not appear to be a problem, except for the case where an UMTS1800 pico BS is installed in indoor environment close to DECT PP or RFP. For this deployment scenario, an additional filter could be required for preventing the potential interference from indoor pico-cellular UMTS1800 BS to DECT PP or RFP when they are close to each other and operating at the adjacent frequencies of 1880 MHz. In practice, DECT system has a DCA (Dynamic Channel Allocation) mechanism which allows it to avoid interference. GSM1800 deployment has demonstrated that no additional interference mitigation techniques are really needed in practice.
2) The preliminary analysis indicates that the potential interference between UMTS1800 UE and METSAT Earth Stations should not be a problem.
3) The preliminary interference analysis leads to the conclusion that with the existing guard band of 700 kHz from the radio microphones frequency band the potential interference from radio microphones to UMTS1800 BS should not be a problem, if the radio microphone maximum transmit power is limited to 13 dBm (20 mW) for hand held microphones and 17 dBm (50 mW) for body worn microphones, as recommended in ERC Report 63 and ERC/REC 70-03E.

5 REFERENCES

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ANNEX 1 - GSM900 AND UMTS900 ACLR PROFILES

This section presents the ACLR (Adjacent Channel power Leakage Ratio) of GSM and UMTS when they are deployed in the GSM 900 band. The ACLR figures are calculated for a receiver bandwidth of 200 kHz in order to be able to estimate the out-of-band emissions into an adjacent GSM-R receiver channel.

- ***Base Station ACLR***

The UMTS900 Base Station ACLR is derived from the 3GPP technical specification TS 25.104 v7.3.0 (2006-03).

The GSM900 Base Station ACLR is derived from the 3GPP technical specification TS 45.005 v7.5.0 (2006-04).

UMTS and GSM BS and UE out-of-band emissions are also given in ECC Report 82 section 4.2.

Figure A1-1 below presents the ACLR figures in a 200 kHz channel bandwidth. The UMTS900 ACLR is at the same level as the GSM900 ACLR when a 200 kHz guard band is kept between UMTS channel and the GSM-R channel (see circle in red).

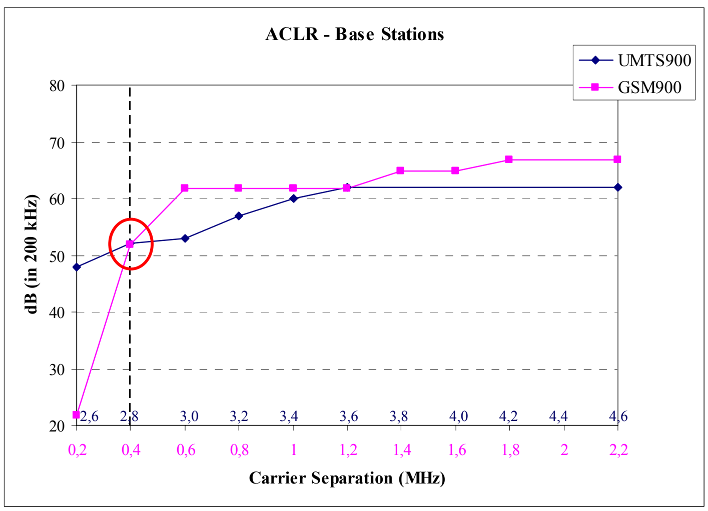

Figure A1-1: BS ACLRs

It is a fundamental operational requirement for any communications system that the out-of-band emissions from the transmitter do not desensitise a co-located receiver. All macro base stations use receiver diversity, and macro cell sites use two antennas per sector. Therefore, the macro base station will include a duplexer, which will provide additional filtering of the transmitted signal. The duplexer must provide sufficient attenuation of the transmitted signal in the receive band to reduce the out-of-band emissions of the transmitter to well below the noise floor of the receiver. For, UMTS900, the transmit and receive band are quite close together, so the band-pass component of duplex filter will need roll-off very quickly outside the transmit band.

- **Terminal ACLR**

The UMTS900 Terminal ACLR is derived from the 3GPP technical specification TS 25.101 v7.3.0 (2006-03).

The GSM900 Terminal ACLR is derived from the 3GPP technical specification TS 45.005 v7.5.0 (2006-04).

Figure A1-2 below presents the ACLR figures in a 200 kHz channel bandwidth.

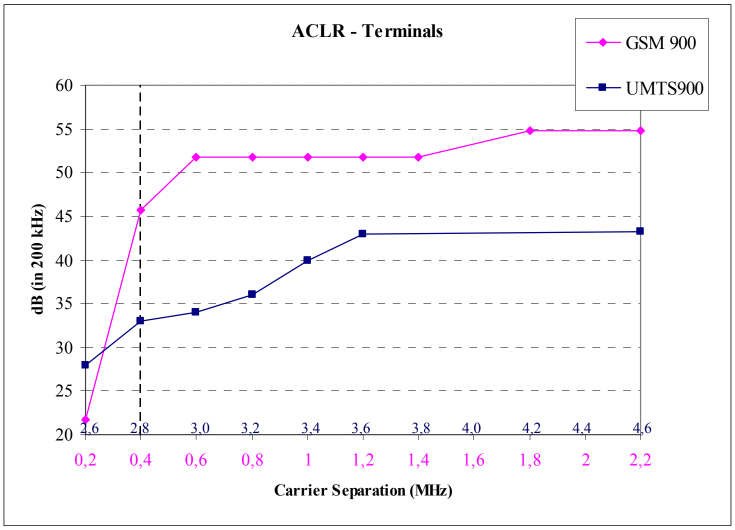

Figure A1-2 - Terminal ACLRs

ANNEX 2 - INTERFERENCE ANALYSIS CALCULATION WITH MCL APPROACH FOR THE CO-EXISTENCE BETWEEN UMTS900 AND GSM-R

PART A. THE BASIC INTERFERENCES CASES

The same Rural area propagation model (Hata model) and simulation parameters as used in the Monte-Carlo simulations for UMTS 900-GSM-R compatibility, are used in the following calculations.

System parameters	*WCDMA*	• BS antenna gain with cable loss included = 15dBi • BS antenna height H_{bs}=45 m; • BS Transmit power +43dBm • UE antenna height H_{ms}=1.5 m • UE antenna gain 0 dBi (omni-directional pattern) • UE transmit power -55.8dBm in 1MHz
	GSM-R	• BS antenna gain with cable loss included = 15dBi • BS antenna height H_{bs}=20 m • MS antenna height H_{ms}=4.5 m (train mounted MS) • Train mounted MS antenna gain 2 dBi (omni-directional pattern)
Services	*GSM-R*	• *Limit of coverage as defined in UIC Eirene Specification is -98dBm at 95% probability in any 100m length of track* • *Speech - SINR target (downlink): 9 dB* • *Maximum Outage or Call Drop ratio: 1%* • *SINR target (uplink): 6 dB* • *Data* • *SINR target (downlink): 12 dB* • *Maximum Outage or Call Drop ratio: 0.5%*
Propagation Model	*WCDMA and GSM-R*	Rural area propagation model(Hata model) $L(R) = 69.55 + 26.16 \log f - 13.82\log(H_b) + [44.9 - 6.55\log(H_b)]\log R - 4.78(\log f)^2 + 18.33 \log f - 40.94 - a(Hm)$ Hb is BS antenna height above ground in m, f is frequency in MHz, R is distance in km, Hm is the MS antenna height in m. a (Hm) = [1.1*log(f) - 0.7]*Hm - [1.56*log(f) - 0.8]
Transmitter/receiver characteristics	*WCDMA*	*As per spectrum masks defined in TS 25.101, TS 25.104 (applying the appropriate measurement BW correction)*
	GSM-R	*As defined in EN300910*

Table A2-1: System parameters

Case 1. Out-of-band emissions UMTS 900 BS to GSM-R MS

Using a frequency of 925MHz and the parameters in the table above the propagation model is simplified to L(R) = 34.1xlogR +88 dB.

<u>GSM-R Highest channel (speech)</u>

UMTS emission at carrier separation of 2.8 MHz -15dBm in 30kHz =		-7 dBm in 200kHz
Allowed Received Signal level (-98-9) =	-107dBm	
Transmit Antenna Gain	+15dB	
Receive Antenna Gain	+2dB	
Fading Margin	-10dB	
Resulting allowed path loss	107dB	
LogR =(107-88)/34.1	R = 3.6 km	
Without Fading Margin	R = 7.1 km	

GSM-R Highest channel (data)

UMTS emission at carrier separation of 2.8 MHz -15 dBm in 30kHz = -7 dBm in 200kHz
Allowed Received Signal level (-98-12) = -110dBm
Transmit Antenna Gain +15dB
Receive Antenna Gain +2dB
Fading Margin -10dB
Resulting allowed path loss 110dB
LogR =(110-88)/34.1 R = 4.4km
Without fading Magin R = 8.7 km

GSM-R Fourth channel (speech)

UMTS emission at carrier separation of 3.4 MHz -25dBm in 30kHz = -16.8dBm in 200kHz
Allowed Received Signal level (-98-9) = -107dBm
Transmit Antenna Gain +15dB
Receive Antenna Gain +2dB
Fading Margin -10dB
Resulting allowed path loss 97.2dB
LogR =(97.2-88)/34.1 R = 1.8km
Without fading margin R = 3.6 km

GSM-R Fourth channel (data)

UMTS emission at carrier separation of 3.4 MHz -25dBm in 30kHz = -16.8dBm in 200kHz
Allowed Received Signal level (-98-12) = -110dBm
Transmit Antenna Gain +15dB
Receive Antenna Gain +2dB
Fading Margin -10dB
Resulting allowed path loss 100.2dB
LogR =(100.2-88)/34.1 R = 2.2km
Without fading margin R = 4.8 km

GSM-R Remaining channels (speech)

UMTS emission at carrier separation higher than 3.4 MHz -28dBm in 30kHz = -19.8dBm in 200kHz
Allowed Received Signal level (-98-9) = -107dBm
Transmit Antenna Gain +15dB
Receive Antenna Gain +2dB
Fading Margin -10dB
Resulting allowed path loss 94.2dB
LogR =(94.2-88)/34.1 R = 1.5km
Without fading Margin R = 3.0 km

GSM-R Remaining channels (data)

UMTS emission at carrier separation higher than 3.4 MHz -28dBm in 30kHz = -19.8dBm in 200kHz
Allowed Received Signal level (-98-12) = -110dBm
Transmit Antenna Gain +15dB
Receive Antenna Gain +2dB
Fading Margin -10dB
Resulting allowed path loss 97.2dB
LogR =(97.2-88)/34.1 R = 1.9km
Without Fading Margin R = 3.7 km

Case 1bis.

GSM-R Highest channel (carrier separation =2.8 MHz)

Propagation model: Free space
Transmit Power = -7 dBm in 200kHz
Noise level -121 dBm/200 kHz
Transmit Antenna Gain +18 dBi

Feeder cable loss	3 dB
Receive Antenna Gain	+0dBi
Receive cable feeder loss	2
Noise Figure	5 dB
C/I	9 dB
Sensitivity of GSM-R (-121+2+5+9) =	-105 dBm
Free space loss (distance=500 m)	85.7 dB
Sensitivity decrease (eirp UMTS – free space loss + C/I- sensitivity of GSM-R)	36.3 dB

GSM-R Highest channel (UMTS900 central frequency =957.4 MHz)

Propagation model:	Free space
Transmit Power =	-23 dBm in 200 kHz
Noise level	-121 dBm/200 kHz
Transmit Antenna Gain	+18 dBi
Feeder cable loss	3 dB
Receive Antenna Gain	+0dBi
Receive cable feeder loss	2 dB
Noise Figure	5 dB
C/I	9 dB
Sensitivity of GSM-R (-121+2+5+9) =	-105 dBm
Free space loss (distance=500 m)	85.7 dB
Sensitivity decrease (Eirp UMTS – free space loss + C/I- sensitivity of GSM-R)	20.3 dB

Case 2. Blocking UMTS 900 BS to GSM-R MS[1]

Using a frequency of 925MHz and the parameters in the table above the propagation model is simplified to L(R) = 34.1logR +88 dB.

Transmit Power +43dBm in 3840 kHz =		30.2 dBm in 200kHz
Allowed Received Signal level		-38dBm
Transmit Antenna Gain		+15dBi
Receive Antenna Gain		+2dBi
Fading Margin		-10dB
Resulting allowed path loss		75.2dB
LogR =(75.2-88)/34.1	R =	420m
Without Fading Margin	R=	830m
With LOS model and without fading margin	R=	470m

Case 3. Blocking UMTS 900 BS (wide area BS) to GSM-R BTS [1]

Using a frequency of 925MHz and the parameters in the Table above the propagation model is simplified to L(R) = 34.1logR +48.3 dB.

Transmit Power +43dBm in 3840kHz =		30.2dBm in 200kHz
Allowed Received Signal level		+8dBm
Transmit Antenna Gain		+15dBi
Receive Antenna Gain		+15dBi
Fading Margin		-10dB
Resulting allowed path loss		42.2dB
LogR =(42.2-48.3)/34.1	R =	665m
Without Fading Margin	R=	1.3km
With LOS model and without fading margin	R=	11 m

[1] These calculations are based on the requirements for blocking taking into account an unmodulated signal.

Case 4. Blocking UMTS 900 BS (medium area BS) to GSM-R BTS[1]

Using a frequency of 925MHz and setting the UMTS Micro BTS antenna height to 10m the propagation model is simplified to L(R) = 38.4logR +57.3dB.

Transmit Power +38dBm in 3840kHz =		25.2dBm in 200kHz
Allowed Received Signal level		+8dBm
Transmit Antenna Gain		+6dB
Receive Antenna Gain		+15dBi
Fading Margin		-10dBi
Resulting allowed path loss		28.2dB
LogR =(28.2-57.3)/38.4	R =	175m
Without fading margin	R=	320m
With LOS model and without fading margin R=		2m

PART B. ADDITIONAL EXAMPLES APPLYING MCL

In the following, an MCL analysis of the impact of the UMTS900 BS interference on the GSM-R MS is presented. It assumes a worst case scenario as shown in Figure A2-1 below. For this analysis the relation of the wanted signal and the signal of the interferer has to be considered.

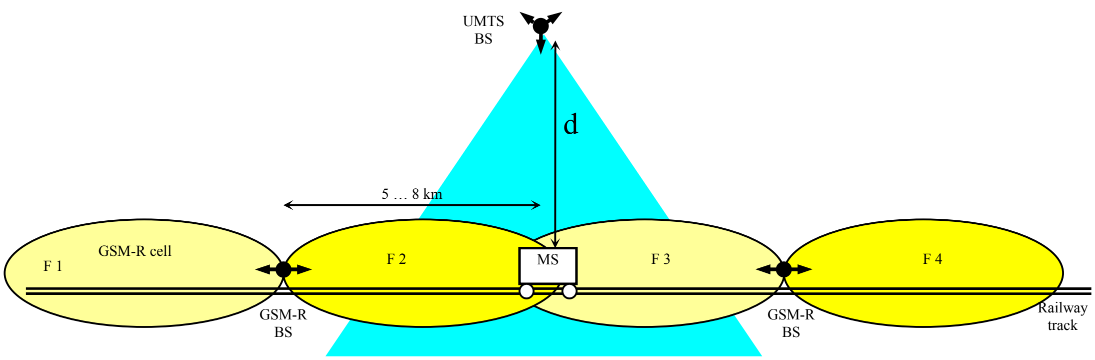

Figure A2-1 Worst case scenario: UMTS900 BS interference to GSM-R MS

The worst case interference occurs when a GSM-R MS is located near the edge of its serving cell, and a UMTS900 BS is located with closest distance to the railway track just at the GSM-R cell edge area, and its sector antenna points right to this area. The wideband noise emission of the UMTS900 BS would then add to the thermal noise floor of the MS RX and the GSM-R inter-cell interference.

In the following, two calculations examples are given for different GSM-R cell ranges 8 km and 5 km.

Example 1: GSM-R cell range = 8 km (according Table 3.2)

Inter cell interference power:

Assumptions: frequency re-use = 6, 2-sector sites (see figure Figure); GSM-R BTS antenna height = 45 m, MS antenna height = 4.5 m
Propagation loss at interferer distance 48 km acc. to ITU-R Rec. P370-7: 179 dB
(Hata model would result in 150 dB, but is not applicable at this long distance)
Co-channel interference at MS: 60 dBm (EIRP) – 179 dB = -119 dBm (isotropic)
Thermal noise floor of GSM-R MS at antenna: -121 +2 (feeder) + 7 (noise figure) = -112 dBm;
N + I at MS antenna = -111.2 dBm.
I.e. the GSM-R network is effectively thermal noise limited.

<u>Wanted signal at MS at cell edge</u>:

GSM-R BTS TX power	45 dBm (30 W)
Feed line loss	3 dB
TX Antenna gain	18 dBi

EIRP	60 dBm
Propagation loss	124 dB (at cell edge / 8 km, Hata rural quasi-open, ant. heights 45 m / 4.5 m)
Shadow fading margin	8 dB (σ = 5 dB, location prob. cell border 95%, cell area 98.9%)
Wanted signal power	**-72 dBm** (isotropic)

Interference at MS for Δf = 2.8 MHz (worst case assumptions for UMTS parameters):

UMTS BS interference	-7 dBm / 200 kHz	
Feed line loss	3 dB	
TX Antenna gain	15 dBi	
EIRP	5 dBm	
Type of GSM-R transmission / required C/I	voice / C/I = 9 dB	data / C/I = 12 dB
Acceptable Interference* (isotropic)	-81 dBm	-84 dBm
Required Propagation loss	86 dB	89 dB
Min. distance d (free space/LOS)	**515 m**	**727 m**

*) inter-cell interference -119 dBm is negligible

Interference at MS for Δf = 2.8 MHz (realistic assumptions for UMTS parameters):

UMTS BS interference	-13 dBm/ 200 kHz (50% load and 3 dB margin against 3GPP limit)	
Feed line loss	3 dB	
TX Antenna gain	15 dBi	
EIRP	-1 dBm	
Type of GSM-R transmission / required C/I	voice / C/I = 9 dB	data / C/I = 12 dB
Acceptable Interference* (isotropic)	-81 dBm	-84 dBm
Required Propagation loss	80 dB	83 dB
Min. distance d (free space/LOS)	**258 m**	**364 m**

*) inter-cell interference -119 dBm is negligible

Interference at MS for Δf = 3 MHz (realistic assumptions for UMTS parameters):

UMTS BS interference	-16 dBm/ 200 kHz (50% load and 3 dB margin against 3GPP limit)	
Feed line loss	3 dB	
TX Antenna gain	15 dBi	
EIRP	-4 dBm	
Type of GSM-R transmission / required C/I	voice / C/I = 9 dB	data / C/I = 12 dB
Acceptable Interference* (isotropic)	-81 dBm	-84 dBm
Required Propagation loss	77 dB	79 dB
Min. distance d (free space/LOS)	**188 m**	**237 m**

*) inter-cell interference -119 dBm is negligible

Just for information below the case of
Interference at MS with realistic UMTS BS parameters / Δf = 12.8 MHz, lowest 10 MHz segment of EGSM band not used by UMTS):

UMTS BS interference	-29 dBm/ 200 kHz (50% load, 3 dB margin against 3GPP limit)	
Feed line loss	3 dB	
TX Antenna gain	15 dBi	
EIRP	-17 dBm	
Type of GSM-R transmission / required C/I	voice / C/I = 9 dB	data / C/I = 12 dB
Acceptable Interference* (isotropic)	-81 dBm	-84 dBm
Required Propagation loss	64 dB	67 dB
Min. distance d (free space/LOS)	**41 m**	**58 m**

With additional filtering this situation could be further improved.
*) inter-cell interference -119 dBm is negligible

Example 2: GSM-R cell range = 5 km (according Draft Rep. 96 chapter 3.2.4.1.1)

Inter cell interference power:

Assumptions: frequency re-use = 6, 2-sector sites (see figure Figure); GSM-R BTS antenna height = 45 m, MS antenna height = 4.5 m
Propagation loss at interferer distance = 30 km: acc. to ITU-R Rec. P370-7: 168 dB
Co-channel interference at MS: 60 dBm (EIRP) – 168 dB = -108 dBm
Thermal Noise floor of GSM-R MS at antenna: -121 +2 (feeder) + 7 (noise figure) = -112 dBm;
N + I at MS antenna = -106.5 dBm.
I.e. the GSM-R network is interference limited.

Wanted signal at MS at cell edge:

GSM-R BTS TX power	45 dBm (30 W)
Feed line loss	3 dB
TX Antenna gain	18 dBi
EIRP	60 dBm
Propagation loss	117 dB (at cell edge / 5 km, Hata rural quasi-open, ant. heights 45 m / 4.5 m)
Shadow fading margin	8 dB (σ = 5 dB, location prob. cell border 95%, cell area 98.9%)
Wanted signal power	**-65 dBm** (isotropic)

Interference at MS for Δf = 2.8 MHz (worst case assumptions for UMTS parameters):

UMTS BS interference	-7 dBm/ 200 kHz		
Feed line loss	3 dB		
TX Antenna gain	15 dBi		
EIRP	5 dBm		
Type of GSM-R transmission / required C/I		voice / C/I = 9 dB	data / C/I = 12 dB
Acceptable Interference* (isotropic)		-74 dBm	-77 dBm
Required Propagation loss		79 dB	82 dB
Min. distance d (free space/LOS)		**230 m**	**325 m**

*) inter-cell interference -108 dBm is negligible

Interference at MS for Δf = 2.8 MHz (realistic assumptions for UMTS parameters):

UMTS BS interference	-13 dBm/ 200 kHz (50% load and 3 dB margin against 3GPP limit)		
Feed line loss	3 dB		
TX Antenna gain	15 dBi		
EIRP	-1 dBm		
Type of GSM-R transmission / required C/I		voice / C/I = 9 dB	data / C/I = 12 dB
Acceptable Interference* (isotropic)		-74 dBm	-77 dBm
Required Propagation loss		73 dB	76 dB
Min. distance d (free space/LOS)		**115 m**	**163 m**

*) inter-cell interference -108 dBm is negligible

Interference at MS for Δf = 3 MHz (realistic assumptions for UMTS parameters):

UMTS BS interference	-16 dBm/ 200 kHz (50% load and 3 dB margin against 3GPP limit)		
Feed line loss	3 dB		
TX Antenna gain	15 dBi		
EIRP	-4 dBm		
Type of GSM-R transmission / required C/I		voice / C/I = 9 dB	data / C/I = 12 dB
Acceptable Interference* (isotropic)		-74 dBm	-77 dBm
Required Propagation loss		70 dB	73 dB
Min. distance d (free space/LOS)		**84 m**	**119 m**

*) inter-cell interference -108 dBm is negligible

Just for information below is provided the case of:
Interference at MS with realistic UMTS BS parameters / Δf = 12.8 MHz, lowest 10 MHz segment of EGSM band not used by UMTS):

UMTS BS interference	-29 dBm/ 200 kHz (50% load and 3 dB margin against 3GPP limit)	
Feed line loss	3 dB	
TX Antenna gain	15 dBi	
EIRP	-17 dBm	
Type of GSM-R transmission / required C/I	voice / C/I = 9 dB	data / C/I = 12 dB
Acceptable Interference* (isotropic)	-74 dBm	-77 dBm
Required Propagation loss	57 dB	60 dB
Min. distance d (free space/LOS)	**18 m**	**26 m**

Again with additional filtering this situation could be further improved.
*) inter-cell interference -108 dBm is negligible

ANNEX 3 - ABBREVIATIONS

ACLR	Adjacent Channel power Leakage Ratio
ACS	Adjacent Channel Selectivity
ARNS	Aeronautical Radio Navigation Service
CDF	Cumulative Distribution Function
CDMA	Code Division Multiple Access
C/I	Carrier to Interference ratio
DECT	Digital Enhanced Cordless Telecommunications
DME	Distance Measurement Equipment
EPFD	Equivalent Power Flux Density
FRS	Future Radio System
GSM	Global System for Mobile communications
GSM-R	Railway System for Mobile communication
IST	Institute for Telecommunication Sciences
ITM	Irregular Terrain Model (Longley-Rice)
MCL	Minimum Coupling Loss
MIDS	Multifunctional Information Distribution System
NTIA	National Telecommunications & Information Administration (U.S. Department of Commerce)
PAMR	Public Access Mobile Radio
PMR	Professional Mobile Radio
PSD	Power Spectral Density
RNSS	Radio Navigation Satellite Service
S/N	Signal to Noise ratio
TETRA	Terrestrial Trunked Radio
UE	User Equipment
UMTS	Universal Mobile Telecommunications System
WCDMA	Wideband CDMA
4-PSK	4-states Phase Shift Keying modulation