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ADJACENT BAND COMPATIBILITY OF UIC DIRECT MODE WITH UIC GSM AND 900 MHZ TETRA.- AN ANALYSIS COMPLETED USING A MONTE CARLO BASED SIMULATION TOOL

Vilnius, June 2000

EXECUTIVE SUMMARY

This report reviews the compatibility issues associated with the proposal by the International Union of Railways to introduce an FM analogue direct mode of operation at the lower end of the UIC 900MHz frequency band. The adjacent systems considered are Railway GSM and 900MHz TETRA. The study considers the interference scenarios between the systems and identifies those which are most critical. Various user densities are chosen to model different geographic areas. The minimum frequency separation for an acceptable level of interference is determined.
The study concludes that there is no risk of interference to UIC Direct Mode from TETRA at the minimum proposed frequency separation although in the reverse direction there is a risk of interference to TETRA from the UIC direct mode at high interferer densities. The proposed UIC usage of Direct Mode is unlikely to reach these high interferer densities.
From the results of the simulations it is concluded that there is a significant risk of interference to GSM-R from UIC Direct Mode for the lowest three GSM-R channels.. With the proposed UIC usage of Direct Mode in areas where there is no GSM-R coverage or system failure there is not expected to be a problem In any event the UIC will be managing the use of DMO and GSM-R. For the reverse scenario where the UIC GSM-R MS is the interferer with the UIC DMO MS the victim, the results of the simulations indicate that there is no significant risk of interference.

The study concludes that there is no risk of interference to E-GSM from UIC Direct Mode and for the reverse scenario where the E-GSM MS is the interferer with the UIC DMO MS the victim, the results indicate that there is no detectable risk of interference.

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ADJACENT BAND COMPATIBILITY OF UIC DIRECT MODE WITH UIC GSM AND 900 MHZ TETRA.- AN ANALYSIS COMPLETED USING A MONTE CARLO BASED SIMULATION TOOL

1 SCOPE

This report reviews the compatibility issues associated with the proposal by the International Union of Railways to introduce a FM analogue direct mode of operation at the lower end of the UIC 900MHz frequency band. The adjacent systems considered are Railway GSM, E-GSM and 900MHz TETRA. The study considers the interference scenarios between the systems and identifies those which are most critical. Various user densities are chosen to model different geographic areas. The minimum frequency separation for an acceptable level of interference is determined.

2 INTRODUCTION

2.1 Background

Within ERC Recommendation T/R25-09 the frequency band 876-880MHz paired with 921-925MHz is identified as the preferred band (GSM-R) for railway operations.
The UIC member railways are operating services to the GSM Phase 2+ standards in this band. However there has always been a requirement within some railways to have available a Direct Mode capability for use when the railway network is not available.
Studies have taken place within the UIC EIRENE project and the EC funded MORANE Trial on the optimum method of providing this facility. The conclusions were that the preferred method is to use 12.5kHz FM equipment in the GSM-R guard band.

2.2 Basic Requirements for UIC Direct Mode

The following are the basic requirements for Direct Mode as extracted from the EIRENE Functional Requirements Specification Version 2.1 which was approved by the UIC Board of Management in June 1998.

The operational requirement for direct mode is to:

1. provide short range fall-back communications between train drivers and trackside personnel in the event of failure of mobile telephony services normally available;
2. provide short range communications for railway personnel operating in remote areas where no mobile telephony facilities are available.
3. Implementation of direct mode is optional. Where the facility is provided, the following requirements are mandatory.

Principal requirements are:

- a range of up to at least 2000m in open terrain between a direct mode transmitter and receiver;
- a voice only capability that supports the use of the link assurance signal (for shunting movements);
- ‘open channel’ mode of operation such that all users employing direct mode receive transmissions when in range of the transmitting user;
- it is sufficient that the user may talk or listen only, but not both. The ability to talk shall be achieved through use of the push-to-talk function;
- where equipment provides both normal and direct mode capability, the user shall be able to switch between the two modes in a straightforward manner (but not by accident);
- the user may only select direct mode when the normal mobile telephony services are not available;

This leads to some basic technical requirements:

- Dual mode handsets and mobiles, i.e. GSM-R and UIC DMO
- The equipment will employ Simplex PTT operation

2.3 UIC Technical proposal for Direct Mode

Both the EIRENE Project team and the MORANE project team have examined the alternative technologies available for Direct Mode and decided that there is currently no frequency efficient digital standard available. Originally it was envisaged that DSRR would meet the requirement but this standard was withdrawn. TETRA Direct Mode is not seen as a viable alternative, at the present or foreseeable future, in the frequency band. GSM Cordless Telephony (CTS) as currently specified will not provide the required service due to its need for a line connected base station.
It was therefore proposed that 12.5kHz channel spacing, single frequency simplex, frequency modulated equipment to ETS 300 086 should be used.
The maximum transmit power is 1.0W erp and the receiver sensitivity is -107dBm.
A number of frequency bands have been considered and the optimum identified as the UIC 900MHz band. This band will allow the UIC members to manage the use of Direct Mode without the need to share with other users.

The proposed frequencies to be used are the five channels within the lower end of the GSM-R Mobile Tx band between 876.0125MHz and 876.0625MHz. This requires no further allocation of frequencies to the railways.

2.4 Objectives

The objectives of this study are to:

- identify all interference scenarios between UIC Direct mode and adjacent services
- determine which scenarios are most critical
- determine minimum frequency separation requirements for acceptable levels of interference

Levels of interference are quantified using a statistical Monte Carlo simulation tool. The tool used is based upon that being specified within CEPT WG SE [1] and has been used previously by CEPT PT SE7. A brief description of the tool is provided in Appendix A.

3 Study

The first step of analysing adjacent band compatibility between two systems is identifying all of the interference scenarios.

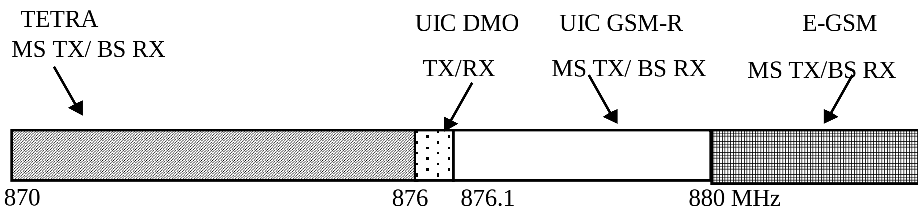

Figure 1 – UIC DMO and adjacent systems

The following six interference scenarios can be identified:

- UIC DMO MS interfering with TETRA BS
- UIC DMO MS interfering with UIC GSM-R BS
- UIC DMO MS interfering with E-GSM BS
- TETRA MS interfering with UIC DMO MS
- UIC GSM-R MS interfering with UIC DMO MS
- E-GSM MS interfering with UIC DMO MS

[1] CEPT ERC Report 68, Monte Carlo Radio Simulation Methodology, http://www.ero.dk/eroweb/seamcat/seamcat.html

This leads to the following report format:

Additional sub-sections are included to investigate the effect of specific simulation parameters.

The simulations completed include the effects of interferer unwanted emissions and victim receiver blocking. Intermodulation is a third type of interference mechanism but is not included as it is believed to be an unlikely scenario.

The characteristics for unwanted emissions and receiver blocking for each equipment as specified by the relevant standards have been used. This leads to a worst case result which assumes that the transmitters and receivers have a performance equal to the specification. These and other assumed parameters are provided in Appendix B.

4 THE EFFECT OF UIC DIRECT MODE ON ADJACENT SYSTEMS

4.1 The Effect of UIC DMO MS on TETRA BS

For the following simulation the TETRA link is on 875,6 MHz; with the TETRA MS transmitting with 40 dBm; The UIC DMO interferer is on the closest channel at 876,0125 MHz; and the UIC DMO MS is transmitting at 30 dBm.
Simulations have been carried out for a range of active interferer densities and cell radii, using a modified Hata propagation model.

TETRA cell Radius	Interf. prob. for AID= 1 / Km^2	Interf. prob. for AID = 3 / Km^2	Interf. prob. for AID = 5 / Km^2	Interf. prob. for AID = 10 / Km^2	Interf. prob. for AID = 20 / Km^2
2 Km	0,1 %	0,1 %	0,2 %	0,2 %	0,2
3 Km	0,1 %	0,1 %	0,4 %	0,7 %	0,8
4 Km	0,2 %	0,3 %	0,4 %	1,8 %	2,0
5 Km	0,4 %	0,8 %	0,9 %	2,2 %	2,8
6 Km	0,5 %	1,4 %	1,9 %	4,3 %	4,4
10 Km	1,9 %	2,9 %	5,5 %	7,0 %	7,2

Table 4.1

It is concluded from the results in Table 4.1 that the interference potential is starting to become significant at high active interferer densities, which are not expected to occur in practise given the UICs proposed usage for DMO.

4.2 The effect of UIC DMO MS on GSM-R BS

For the following simulation the GSM-R link is on 876,6 MHz; with the GSM-R MS transmitting with 36dBm (no power control); The UIC DMO interferer is on 876,0625 MHz; and the UIC DMO MS is transmitting at 30 dBm. The UIC GSM-R BS RX is victim
Simulations have been carried out for a range of active interferer densities and cell radii, using a modified Hata propagation model.

GSM cell radius	AID= 2/Km^2	AID= 5/Km^2
2 Km	12 %	20 %
4Km	15 %	20 %
6Km	15 %	26 %

Table 4.2

The interference mechanism is blocking which results in a serious incompatibility for a guard band lower than 600 KHz. The use of the specified GSM receiver mask in the simulation rather than the mask from a practical equipment represents the worst case.

This simulation is repeated with the same conditions but the GSM-R channel is raised to 876,8 MHz , so that the UIC DMO Transmitter is outside the receiver mask.

GSM cell radius	AID= 2/Km^2	AID= 5/Km^2	AID= 10/Km^2	AID= 20/Km^2
2 Km	0 %	0 %	0 %	0 %
4 Km	0 %	0 %	0,2 %	0,3 %
6 Km	0 %	0,12 %	0,3 %	0,45 %
8 Km	0 %	0,16 %	0,3 %	0,46 %
10 Km	0 %	0,34 %	0,53 %	0,56 %

Table 4.3

The outcome in Table 4.3 shows that an acceptable interference level has now been reached.

4.3 The effect of UIC DMO MS on E-GSM BS

For the following simulation 880.0 MHz, the lowest channel, was selected for the E-GSM link; with the E-GSM MS transmitting with 36dBm (no power control); The UIC DMO interferer is on 876,0625 MHz; and the UIC DMO MS is transmitting at 30 dBm. The E-GSM BS RX is victim
Simulations have been carried out for a range of active interferer densities and cell radii, using a modified Hata propagation model.

GSM cell radius	AID= 2/Km^2	AID= 5/Km^2	AID= 10/Km^2	AID= 20/Km^2
2 Km	0 %	0 %	0 %	0 %
4 Km	0 %	0 %	0 %	0 %
6 Km	0 %	0 %	0 %	0 %
8 Km	0 %	0 %	0,01 %	0,01 %
10 Km	0 %	0 %	0,03 %	0,03 %

Table 4.4

The results of the simulation in Table 4.4 demonstrate that moving to the E-GSM band from the lower end of the GSM-R band reduces the interference still further (compared with Table 4.3).

5 THE EFFECT OF ADJACENT SYSTEMS ON UIC DIRECT MODE

5.1 The Effect of TETRA MS on UIC DMO MS

For the following simulation the TETRA interferer is on 875,6 MHz; with the TETRA MS transmitting with 40 dBm; The UIC DMO link is on the closest channel at 876,0125 MHz; and the UIC DMO MS is transmitting at 30 dBm.

Simulations have been carried out for a range of active interferer densities and cell radii, using a free space propagation model, as these are direct MS-MS links.

UIC DMO link distance	Interf. prob. for AID = 5 / Km^2	Interf. prob. for AID = 10 / Km^2	Interf. prob. for AID = 20 / Km^2	
200 m	0 %	0 %	0 %	
400 m	0 %	0 %	0 %	
600 m	0 %	0,001 %	0,002 %	
800 m	0 %	0,001 %	0,008 %	
1 Km	0,005 %	0,01 %	0,09 %	
1,5 Km	0,01 %	0,18 %	0,24 %	
2 Km	0,1 %	0,8 %	1,6 %	

Table 5.1

It is concluded that there is no significant interference for this scenario.

5.2 The effect of GSM-R MS on UIC DMO MS

For the following simulation the GSM-R interferer is on 876,8 MHz (i.e. the same guard band as has been found to be acceptable for the reverse scenario); with the UIC GSM-R MS transmitting with 33 dBm without power control The UIC DMO link is on the highest channel at 876,0625MHz; and the UIC DMO MS is transmitting at 30 dBm. The UIC DMO MS RX is the victim.

Simulations have been carried out for a range of active interferer densities and cell radii, using a free space propagation model as these are direct MS-MS links.

UIC DMO link distance	Interf. prob. for AID = 5 / Km^2	Interf. prob. for AID = 10 / Km^2	Interf. prob. for AID = 20 / Km^2	
200 m	0 %	0 %	0 %	
400 m	0 %	0 %	0 %	
600 m	0 %	0 %	0 %	
800 m	0 %	0 %	0 %	
1,0 Km	0 %	0 %	0 %	
1,5 Km	0 %	0 %	0 %	
2,0 Km	0 %	0 %	0,2 %	

Table 5.2

It is concluded that there is no significant interference for this scenario.

5.3 The effect of E-GSM MS on UIC DMO MS

For the following simulation 880.0 MHz, the lowest channel, was selected for the E-GSM link; with the E-GSM MS interferer transmitting with 33dBm (no power control); The UIC DMO interferer is on 876,0625 MHz; and the UIC DMO MS is transmitting at 30 dBm. The UIC DMO MS RX is the victim
Simulations have been carried out for a range of active interferer densities and cell radii, using a free space propagation model as these are direct MS-MS links.

UIC DMO link distance	Interf. prob. for AID = 5 / Km^2	Interf. prob. for AID = 10 / Km^2	Interf. prob. for AID = 20 / Km^2
200 m	0 %	0 %	0 %
400 m	0 %	0 %	0 %
600 m	0 %	0 %	0 %
800 m	0 %	0 %	0 %
1,0 Km	0 %	0 %	0 %
1,5 Km	0 %	0 %	0 %
2,0 Km	0 %	0 %	0 %

Table 5.3

It is concluded that there is no significant interference for this scenario.

6 CONCLUSIONS

6.1 UIC DMO and TETRA

From the results of the simulations as set out in Sections 4.1 and 5.1 it is concluded that there is no risk of interference to UIC Direct Mode from TETRA at the minimum proposed frequency separation. In the reverse direction there is a risk of interference to TETRA from the UIC Direct Mode at high interferer densities. With the proposed UIC usage of Direct Mode in areas where there is no GSM-R coverage or system failure has occurred these high interferer densities are unlikely to be reached.

6.2 UIC DMO and GSM-R

From the results of the simulations as set out in Sections 4.2 (Tables 4.2 & 4.3), it is concluded that there is a significant risk of interference to UIC GSM-R from UIC Direct Mode for the lowest three GSM-R channels.. With the proposed UIC usage of Direct Mode in areas where there is no GSM-R coverage or system failure there is not expected to be a problem In any event the UIC will be managing the use of DMO as and GSM-R.
For the reverse scenario where the UIC GSM-R MS is the interferer with the UIC DMO MS the victim, the results in Table 5.2 indicate that there is no significant risk of interference.

6.3 UIC DMO and E-GSM

From the results of the simulations as set out in Section 4.3 (Tables 4.4), it is concluded that there is no risk of interference to E-GSM from UIC Direct Mode.
For the reverse scenario where the E-GSM MS is the interferer with the UIC DMO MS the victim, the results in Table 5.3 indicate that there is no detectable risk of interference.

APPENDIX A – DESCRIPTION OF MONTE CARLO SIMULATION METHOD

The Monte Carlo simulation tool used for this study is based upon that specified by WG SE[2]. A general description is provided below followed by an explanation of some assumptions which are not explicitly stated in the WG SE specification.

A.1 General Description

A Monte Carlo simulation is a statistical technique that functions by considering many trials, that means many independent instants in time and many locations in space. For each simulation trial, a scenario is built up using a number of different random variables i.e. where the interferers are with respect to the victim, how strong the victim's wanted signal strength is, which channels the victim and interferer are using etc. If a sufficient number of trials are considered then the probability of a certain event occurring can be calculated with a high level of accuracy.

The Monte Carlo simulation used for this study models a victim receiver operating amongst a population of interferers. The interferers are distributed around the victim using a uniform random distribution. Only a proportion of the interferers are active at any one time. Figure A1 illustrates how the interferers and victim may appear for one simulation trial.

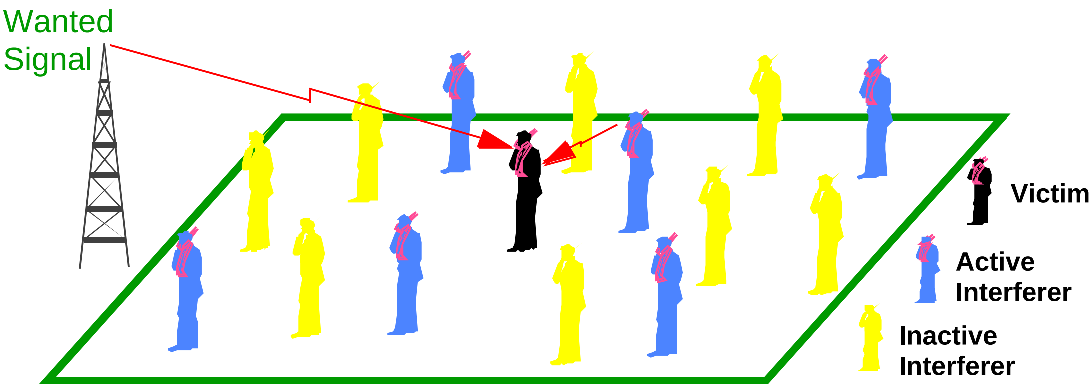

Figure A1 - An Illustration of the Monte Carlo Simulation Model

In general the effect of each interferer upon the victim is determined using mean path loss, slow fading, transmit power, antenna gains, transmitter wideband noise characteristic, receiver blocking and frequency separation. It can be found that for relatively low densities of interferers, for each trial one interferer dominates. This means that once the dominant interferer has been found then the remainder can be ignored without deeply affecting the final result. This means also that only one RF carrier is assumed to be active per interferer, so in the case that the BS are the interferers, the density of BS is equal to the density of sites and also to the density of active RF downlink carriers.

The victim's wanted signal strength is calculated based upon the transmit power, antenna gains, mean path loss and slow fading.

Figure A1 illustrates a population of mobile stations interfering with a victim mobile. This is an example used for illustration purposes and in fact either or both the victim and interferer can be base stations.

The interfering power from the dominant interferer and wanted signal strength from the wanted signal transmitter are used to determine whether or not interference is occurring. Interference is said to occur when the resultant C/I is less than the protection ratio. Figure A2 illustrates the various signal levels.

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[2] CEPT ERC Report 68, Monte Carlo Radio Simulation Methodology, http://www.ero.dk/eroweb/seamcat/seamcat.html

Interference is defined as occuring when the Resultant C/I is less than the C/I used to define Sensitivity

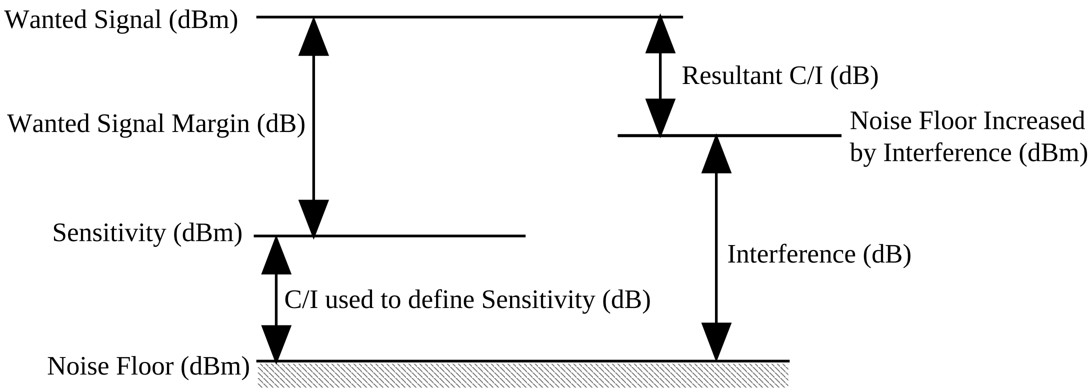

Figure A2 - The Signal Levels used to Determine Whether or Not Interference is Occurring

The left hand side of the diagram represents the situation when there is no interference. In this case the resultant C/I ratio is equal to the sum of the protection ratio and the margin. The right hand side of the diagram illustrates what happens when interference is introduced. The interference may be caused by wideband noise or receiver blocking. The interference adds to the noise floor and the resultant C/I is the difference between the increased noise floor and the wanted signal strength. To avoid interference the resultant C/I must be greater than the protection ratio.

A.2 Specific Assumptions

The following sections provide an explanation to the aspects of the simulation methodology used in this study which may be different to that specified by CEPT ERC Report 68

A.2.1 Calculating the Victim's Receive Frequency

Only one case has been considered for this study. The victim system has only a single channel assigned and for each simulation trial the victim is assigned this channel.
When the victim is a base station, the level of interference calculated is for only one among the set of receivers at the base station site i.e. if a victim base station receives on four frequencies and has a probability of interference of 1 %, each of the four frequencies has a probability of interference of 1 %.

A.2.2 Calculating the interferers Transmit Frequency

The interfering radio system is assumed to operate on the designated channel for each simulation trial. When the interferer is a base station, only one transmitter (i.e. one frequency) is assumed to be active, although this transmitter is assumed to transmit all the power of the base station.

A.2.3 Placing the Closest Interferer

A Rayleigh distribution is used to randomly place the closest interferer with respect to the victim. The density of active interferers is used to calculate the standard deviation of the Rayleigh distribution. When the victim and interferer are both base stations then a Rayleigh distribution is still used to place the closest interferer. This means that from one trial to the next the distance between base stations is not fixed modelling a range of possible separations. In this report the closest interferer has been considered in place of the dominant one. The closest interferer is not necessary the dominant one, but the closest has been considered for simplification reasons, the algorithm to determine the dominant being much more complicated because it has to take into account not only the distance but also the frequency separation, the shadowing, the transmit power etc. all these parameters being frequently random and to determine what is the dominant combination of them. Due to this simplification the results of the report could be considered as a little optimistic.

Moreover only the closest interferer is included in the interference calculation. The inclusion of other interferers increases simulation run time without significantly affecting the result. This has been found to be true for relatively low densities of interferers – as experienced in PMR scenarios. For simulations where high densities of interferers are modelled i.e. public cellular systems in hotspots, then all interferers must be considered due to the much higher possibility of a more distant interferer having greater influence due to the effects of fading.

A.2.4 Power Control

Power control may be used to reduce transmit power when there is a low path loss between transmitter and receiver. In this study power control has not been used for any of the mobiles or base stations. By doing so, simulation complexity and run time can be reduced without affecting the results. The results are not changed because a 20 dB margin above sensitivity has been assumed before power control is activated. Thus when power control is used then there is always at least 20 dB of wanted signal strength margin. In these cases there is a very low chance of interference occurring. Interference is more likely to occur when the wanted signal strength is relatively low and the margin is below 20 dB.

A.2.5 Path Loss

The path loss model for an outdoor urban area specified by WG SE in the Monte Carlo specification[3] has been used for this study between MS and BS. This path loss model is a combination of free space and Hata models. For distances below 40 m then free space propagation is assumed. For distances above 100 m then modified Hata propagation is assumed. Between these two limits the propagation loss is given by the interpolation between the free space loss at 40 m and the modified Hata loss at 100 m. The effect of shadowing is included using a lognormal distribution with standard deviation dependent upon distance.
Where the simulation is for MS to MS a free space propagation model has been used.

A.2.6 Interference Mechanisms

This study has considered the effects of unwanted emissions and receiver blocking. These are believed to be the dominant interference mechanisms for compatibility between TETRA and FM and between GSM and FM

A.2.7 Calculating the Wanted Signal Strength

The wanted signal strength is calculated based upon transmit power, path loss between transmitter and receiver and antenna gains. So the victim cell radius has to be known. In this report the radius values correspond to an intrinsic (only limited by receiver internal noise) ‘worst link’ area availability of 90 %. The wanted signal strength obtained is compared with the interfering signal strength as illustrated in Figure A.2 to determine whether or not the desired C/I ratio is being obtained.

A.2.8 Parameters used by the simulation

Channel Spacing - The channel bandwidth defined for the system i.e. the separation in frequency between adjacent carriers.

Transmit Power - The nominal transmit power.

Receiver Bandwidth - The bandwidth of the receiver. It may be less than the channel spacing dependant upon the filtering in the terminal’s receive path.

Antenna Height - The height of the antenna in metres.

Antenna Gain - Antennas in this study are assumed to have equal gain in all directions i.e. a spherical gain pattern. The value specified includes cable and connector losses.

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[3] CEPT ERC Report 68, Monte Carlo Radio Simulation Methodology, http://www.ero.dk/eroweb/seamcat/seamcat.html

Active Interferer Density Range - A range of interferer densities have been considered in this study to include a range of scenarios from what may be considered a 'hot spot' to what may be considered normal operating conditions.

Receiver Sensitivity - The sensitivity defined for the receiving terminal.

Receiver Protection Ratio - The protection ratio defines the number of dB between the thermal noise floor of the receiver and sensitivity.

TDMA users / carrier - The number of TDMA users that can simultaneously operate in the same geographic area on a single carrier. This parameter has an effect upon the interferer density being used by the simulation. **Unwanted Emissions Characteristic** - The out-of-band emissions characteristic for a transmitter. Defined by a power measured in a specific bandwidth at a specific frequency offset from the nominal transmit frequency.

Receiver Blocking Characteristic - The receiver blocking performance defined by a power level at a specific frequency offset which the receiver can sustain which receiving its wanted signal 3 dB above sensitivity.

A.3 Interpretation of the Results

The probability of interference evaluated is the probability of a victim receiver not obtaining its desired C/I requirement. It can be thought of as a reduction of the system area availability.

A radio system may have an area availability of 90 % meaning that either over 10 % of the area, coverage is not provided or that for 10 % of the time a user will be out of coverage (assuming the user to move around the cell occupying both outer and inner cell positions). Likewise the probability of interference can be interpreted in this way and a 1 % probability of interference would reduce a 90 % area availability to 89.1 %.

The probability of interference is the probability for a single receive channel. In the case of a base station where multiple channels are being used then the probability is that for each channel considered in isolation. In the same way, when the interferers are base stations, it is assumed that only one interfering RF carrier is activated per base station and per trial. This RF carrier is assumed to be active 100 % of the time.

It should be kept in mind that in the case of group calls interference to a single base station channel can affect the reception of multiple mobile stations.

APPENDIX B – TECHNICAL CHARACTERISTICS

B.1 UIC DIRECT MODE

The ETSI standard ETS 300 086 has been used to obtain most of the UIC DMO system parameters. Tables A1.1, A1.2 and A1.3 list all of the parameters required by the Monte Carlo simulation to model a UIC DMO system.

Parameter	Mobile Station
Channel Spacing	12.5 kHz
Transmit Power	30 dBm
Receiver Bandwidth	8 kHz
Antenna Height	1.5 m
Antenna Gain	0 dBi
Active Interferer Density Range	variable
Receiver Sensitivity	- 107 dBm
Receiver Protection Ratio	21 dB
Power Control Characteristic	not used

Table B1.1 - Parameters Assumed for 12.5 kHz FM Systems

Frequency Offset	Mobile Station
12.5 kHz	- 23 dBm
100 - 250 kHz	- 43 dBm
250 - 500 kHz	- 60 dBm
500 kHz - 1 MHz	- 64 dBm
1 MHz - 10 MHz	- 69 dBm
> 10 MHz	- 71 dBm
Linear interpolation (in dB) is used between 12.5 kHz and 100 kHz	

Table B1.2 - Unwanted Emissions for 12.5 kHz FM Systems (measurement bandwidth of 8 kHz)

Frequency Offset	Mobile Station
50 - 100 kHz	- 23 dBm

Table B1.3 - Receiver Blocking for 12.5 kHz FM Systems

B.2 TETRA

The ETSI standard ETS 300 392-2 has been used to obtain most of the TETRA system parameters. This standard is titled ‘Radio Equipment and Systems (RES); Trans-European Trunked Radio (TETRA); Voice plus Data (V+D); Part 2: Air Interface (AI)’. Those parameters which cannot be obtained from the standard are assumed values believed to accurately model operational TETRA systems. Tables B2.1, B2.2 and B2.3 list all of the parameters required by the Monte Carlo simulation to model a TETRA system.

Parameter	**Mobile Station**	**Base Station**
Frequency Band Range	870 - 876 MHz	915 - 921 MHz
Minimum Size of Frequency Band Required for System Operation	2 MHz	2 MHz
Channel Spacing	25 kHz	25 kHz
Number of Channels	80	80
Transmit Power	30 dBm	44 dBm
Receiver Bandwidth	18 kHz	18 kHz
Antenna Height	1.5 m	30 m
Antenna Gain	0.0 dBi	9 dBi
Receiver Sensitivity	-103 dBi	- 106 dBi
Receiver Protection Ratio	19 dB	19 dB
TDMA users / carrier	4	4
Power Control Characteristic	5 dBm steps to a minimum of 15 dBm. Threshold = - 86 dBm	not used

Table B2.1 - Parameters Assumed for the TETRA System

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 B2.2 - The Specification for TETRA Unwanted Emissions 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 B2.3 - The Specification for TETRA Receiver Blocking

B.3 GSM

The ETSI standard ETS 300 577 has been used to obtain most of the GSM system parameters. This standard is titled ‘European digital cellular telecommunications system (Phase 2); Radio transmission and reception (GSM 05.05)’. Those parameters which cannot be obtained from the standard are assumed values believed to accurately model operational GSM systems. Tables B3.1, B3.2 and B3.3 list all of the parameters required by the Monte Carlo simulation to model a GSM system.

Parameter	**Mobile Station**	**Base Station**
Frequency Band Range	890 - 915 MHz	935 - 960 MHz
Channel Spacing	200 kHz	200 kHz
Number of Channels	124	124
Transmit Power	33 dBm	43 dBm
Receiver Bandwidth	200 kHz	200 kHz
Antenna Height	1.5 m	30 m
Antenna Gain	0 dBi	9 dBi
Receiver Sensitivity	- 102 dBm	-104 dBm
Receiver Protection Ratio	9 dB	9 dB
TDMA users / carrier	8	8
Power Control Characteristic	2 dBm steps to a minimum of 5 dBm Threshold = - 84 dBm	not used

Table B3.1 - Parameters Assumed for the GSM System

Frequency Offset	**Mobile Station**	**Base Station**
100 kHz	25.5 dBm	35.5 dBm
200 kHz	- 5 dBm	5 dBm
250 kHz	- 8 dBm	2 dBm
400 kHz	- 35 dBm	- 25 dBm
600 - 1200 kHz	- 35 dBm	- 35 dBm
1200 - 1800 kHz	- 35 dBm	- 38 dBm
1800 - 3000 kHz	- 43 dBm	- 45 dBm
3000 - 6000 kHz	- 45 dBm	- 45 dBm
> 6000 kHz	-51 dBm	- 50 dBm

Table B3.2 - The Specification for GSM Unwanted Emissions measured in a 30 kHz Bandwidth

Frequency Offset	**MS**	**BS**
600 - 800 kHz	- 43 dBm	- 26 dBm
800 - 1600 kHz	- 43 dBm	- 16 dBm
1600 - 3000 kHz	- 33 dBm	-16 dBm
> 3000 kHz	- 23 dBm	- 13 dBm

Table B3.3 - The Specification for GSM Receiver Blocking

B.4 GSM-R

The GSM-R system is based upon GSM. For this reason most of the parameters are those of GSM. Parameters which are different include antenna gains and heights. Train mounted as well as hand portable mobile stations are included. Tables B4.1, B4.2 and B4.3 list all of the parameters required by the Monte Carlo simulation to model a GSM-R system.

Parameter	**Train Mounted Mobile Station**	**Hand Portable Mobile Station**	**Base Station**
Frequency Band Range	876 - 880 MHz	876 - 880 MHz	921 - 925 MHz
Channel Spacing	200 kHz	200 kHz	200 kHz
Number of Channels	19	19	19
Transmit Power	39 dBm	33 dBm	39 dBm
Receiver Bandwidth	200 kHz	200 kHz	200 kHz
Antenna Height	4 m	1.5 m	30 m
Antenna Gain	2 dBi	0 dBi	16 dBi
Receiver Sensitivity	- 102 dBm	-102 dBm	- 104 dBm
Receiver Protection Ratio	9 dB	9 dB	9 dB
TDMA users / carrier	8	8	8
Power Control Characteristic	2 dBm steps to a minimum of 5 dBm Threshold = - 84 dBm	2 dBm steps to a minimum of 5 dBm Threshold = - 84 dBm	not used

Table B4.1 - Parameters Assumed for the GSM-R System

Frequency Offset	**HandPortable Mobile Station**	**Train Mounted Mobile Station**	**Base Station**
100 kHz	25.5 dBm	31.5 dBm	31.5 dBm
200 kHz	- 5 dBm	1.0 dBm	1 dBm
250 kHz	- 8 dBm	- 2.0 dBm	- 2 dBm
400 kHz	- 35 dBm	- 29.0 dBm	- 29 dBm
600 - 1200 kHz	- 35 dBm	- 29.0 dBm	- 37 dBm
1200 - 1800 kHz	- 35 dBm	- 29.0 dBm	- 40 dBm
1800 - 3000 kHz	- 43 dBm	- 37.0 dBm	- 47 dBm
3000 - 6000 kHz	- 45 dBm	- 39.0 dBm	- 47 dBm
> **6000 kHz**	- 51 dBm	- 45.0 dBm	- 54 dBm

Table B4.2 - The Specification for GSM-R Unwanted Emissions measured in a 30 kHz Bandwidth

Frequency Offset	**MS**	**BS**
600 - 800 kHz	- 43 dBm	- 26 dBm
800 - 1600 kHz	- 43 dBm	- 16 dBm
1600 - 3000 kHz	- 33 dBm	-16 dBm
> **3000 kHz**	- 23 dBm	- 13 dBm

Table B4.3 - The Specification for GSM-R Receiver Blocking

APPENDIX C – ABBREVIATIONS

BS	Base Station
CEPT	European Conference of Posts and Telecommunications Administrations
DMO	Direct Mode
EIRENE	European Integrated Railway Radio Network(UIC Project for standardisation of the GSM-R network)
ERC	European Radio Commission
ETSI	European Telecommunications Standards Institute
FDD	Frequency Division Duplex
FM	Frequency Modulation
MORANE	Mobile Radio Advanced Network (EC project for development and trials of EIRENE)
MS	Mobile Station
PAMR	Public Access Mobile Radio
PMR	Private Mobile Radio
PT	Project Team
RES	Radio Equipment and Systems
SE	Spectrum Engineering
TDMA	Time Division Multiple Access
TETRA	Terrestrial Enhanced Trunked Radio
UIC	Union Internationale des chemin der fer (The world wide association of railways).