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Executive Summary

This report summarizes the challenges, due to interferences, that GSM-R networks are facing today to coexist with other mobile radio systems operating in the same frequency range.

It is addressed to all interested parties (national administrations, European administrations (EC, ERA, ECC, ETSI)), and is to be used as a basis for further progress on solving this important interference issue.

Member States have the existing legal obligations to ensure appropriate protection of GSM-R according to (inter alia) European decision 2009/766/EC.

The UIC view is that such protection can only be based on European harmonised protection values for GSM-R (i.e. maximum cumulative power levels at rail tracks), which shall become legally binding within the EU / EFTA.

The work on defining European harmonised protection values needs encouragement of the interfaces between UIC, EC, ERA, CER/EIM, CEPT / ECC, ETSI, and has to be seen inside the European regulatory environment for radio equipment and spectrum. This includes the possible provision of a mandate under Directive 676/2002/EC – the Radio Spectrum Decision – and based on (inter alia) the new ERTMS MoU signed on 19th of April 2012 (article 65) to achieve an interference free coexistence between GSM-R and public mobile radio services.

The response to the mandate would be a CEPT Report, defining European harmonised protection values for GSM-R (enforced by the CCS TSI as a mandatory sub-system for ERTMS) for all EU and EEA/EFTA countries as basis for national regulations.

This document tries to describe the issue, as much as possible, in such a popularized way, that the reader is not necessarily a radio expert. Nevertheless there are some parts in this report where a deeper understanding of radio transmission and reception is essential.

All across Europe Railways have reported increasing numbers of locations where GSM-R terminals are interfered by public mobile radio services. The following problems affecting both ETCS and Train Radio have been reported in areas with good GSM-R coverage, which have been proven to be caused by external interferences:

- Total loss of network service
- Failing call attempts
- Call- drops
- Bad voice quality
- High Bit Error Rate

With the successive rollout of new radio technologies such as UMTS and LTE, deployed in adjacent frequency bands of GSM-R, the number of interferences is predicted to increase. This report describes what can be expected in the short and long term, how such interference situations could be solved, and what actions need to be taken.

In order to demonstrate the growing importance of the interference issue, the UIC Frequency Management group is creating and filling a data base to collect all available data of interference cases, including all of the actions taken by the different parties, like railways, public operators and administrations.

The aim of this database is to be able to present the issue to interested governmental departments, administrations and railway organisations in an easy and objective way; likewise extracts of this data base shall be used to support the Work Item defined in ECC WG FM to monitor the interference situation of GSM-R systems in Europe.

1 Abbreviations

3GPP	3rd Generation Partnership Project
ATP	Automatic Train Protection
BS	Base Station
BTS	Base Transceiver Station
C/I	Carrier to Interference ratio
CAB-Radio	Train Cab mounted GSM-R Mobile Station
CEPT	European Conference of Postal and Telecommunications Administration
CSD	Circuit Switched Data
CW	Continuous Wave transmission
DL	Down Link
ECC	Electronic Communications Committee
E-GSM	Extension of P-GSM to 2 X 35 MHz (UL 880 – 915 MHz and DL 925 – 960 MHz)
EIRENE	European Integrated Railway Radio Enhanced Network, UIC Project to develop the specifications for and to facilitate the standardisation of the GSM-R railway radio communication system.
EIRP	Equivalent Isotropic Radiated Power
eMLPP	Enhanced Multilevel Precedence and Pre-emption
ER-GSM	CEPT definition for the Extended frequency band of GSM-R (UL 873 – 880 and DL 918 – 925 MHz)
ERTMS	European Rail Traffic Management System (ERTMS=ETCS+GSM-R+ETML)
ETCS	European Train Control System)
ETML	European Traffic Management Layer
ETSI	European Telecommunications Standards Institute
FRS	Functional Requirements Specification
GPRS	General Packet Radio System
GSM	Global System for Mobile communications
GSM-R	GSM system for railway use
IM	Intermodulation (general)
IMP	Intermodulation product
IM3	Third order intermodulation
LTE	Long-Term Evolution
Erl	Erlang: traffic intensity in a telecommunication system, in the document mErl as the average traffic intensity of one subscriber
MC-BTS	Multi-Carrier Base Transceiver Station
MS	Mobile Station
OOB	Out Of Band
P-GSM	Primary GSM. The original 2 X 25 MHz wide GSM900 band (UL 890 – 915 MHz and DL 935 – 960 MHz)
QoS	Quality of Service
RBC	Radio Block Centre
R-GSM	CEPT definition for the frequency band of GSM-R (UL: 876 – 880 MHz and DL: 921 – 925 MHz)

SMS	Short Message Service
SRS	System Requirements Specification
UE	User Equipment
UL	Up Link
UMTS	Universal mobile telecommunication system
UMTS900	Harmonised use of UMTS in the E-GSM band
WiMAX	Worldwide Interoperability for Microwave Access

Definitions:

The following definitions are used in this document:

- UMTS installations or UMTS transmitters include UMTS transmitting equipment as found in base stations, repeaters, distributed radio-heads etc.
- Network operator includes communication service providers such as governmental, military organisations etc., using radio transmission that is likely to have an impact on GSM-R service.
- Public operator includes commercial communication service providers using radio transmission that is likely to have an impact on GSM-R service out-of-band meaning bands outside the transmitters designated transmit frequency band.
- Spectrum Emission is used to describe the content of signals frequencies and signal levels falling under the standard definition Spectrum Emission Mask.

2 Description of System (environment, functionalities)

2.1 GSM-R Overview

The digital radio system GSM-R is an essential ERTMS subsystem for:

- ETCS level 2/3, to assure the train to ground communication for safety and train control data, and
- Train radio communications including railway emergency calls.

EC directive 2011/18 and decision 2012/88 EC constitute the legal framework under which the European Rail Traffic Management System (ERTMS) is developed and specified. Key elements of ERTMS are GSM-R (Global System for Mobile Communications – Railways) as specialized railway radio communication system, ETCS (European Train Control System) as signalling framework, and ETML (European Traffic Management Layer) as the future operation management solution.

The UIC GSM-R project is responsible for developing the GSM-R specifications (EIRENE - European Integrated Railway Radio Enhanced Network) and to facilitate their standardisation.

GSM-R is based on the public standard GSM with specific rail features for operation, in particular, Priority and Pre-emption (eMLPP), functional numbering, location dependent addressing, group calls and fast call set up for Emergency Calls. The GSM-R system requirements and the applications for operational voice and data communication are specified in the EIRENE FRS (Functional Requirement Specification) and SRS (System Requirement Specification).

As a safe and efficient operation of Railway System is dependent on the availability of ERTMS services, the GSM-R subsystem is subject to strict legal requirements on their availability and performance, mentioned in the CCS TSI and ERA Application Guide for ERTMS. Railway operators have to guarantee that these requirements are met in any circumstances.

The European Railway Traffic Management System (ERTMS) is a major European railway project and contains presently two main basic components:

- ETCS, the European Train Control System, is an automatic train protection system (ATP) to complement and replace the existing different national ATP-systems on European interoperable lines (it is to be noted that today, the EC is discussing the further expansion of ERTMS on regional and urban lines, and to fully replace all existing ATP systems). ETCS level 2/3 is based on GSM-R and needs a permanent data connection with a very high quality of service, since ETCS level 2/3 replaces the line side signals.
- GSM-R, a digital radio system for providing voice and data communication between the track side and the train, based on standard GSM using frequencies specifically reserved for rail applications with a number of specific and advanced functions. GSM-R is the radio system for all Railways in Europe mandated by the CCS TSI.

In addition a growing number of future data applications to optimise the operation of the railways are possible like maintenance, electronic timetable etc.

The requirements on the GSM-R service quality and coverage conditions are based on the UIC EIRENE FRS 7.3.0 and SRS 15.3.0 specifications.

GSM-R is planned to be installed on around 160 000 kilometres of track in Europe until 2016, out of which around 70 000 kilometres are in operation.

GSM-R usage can be split into Mandatory services and Additional services (from European Interoperability point of view) for railway operations. The Mandatory services can have a direct impact on the safety of the train operation*, as GSM-R is considered by the EC to have a preventive character, which if blocked or disturbed, could increase the safety risks*. The Additional services are related to the overall operational and business processes of the railways.

Mandatory services include:

- Train Radio,
- Railway Emergency Calls,
- Voice Group Calls,
- ETCS data calls.

For more details and examples on the importance of the mandatory services, see chapter 4.

Additional, or secondary, services are services that make best use of the available connectivity and capacity of a GSM-R network. Specific GSM-R features like priority and pre-emption mechanism (eMLPP), ensure that mandatory services are always executed prior to additional services.

Secondary services could be for example:

- Voice services for platform announcements
- CSD, SMS for telemetry/monitoring applications
- GPRS for passenger information and telemetry/monitoring applications

An example where the importance of additional services is increasing is the usage of GSM-R to carry the data for passenger information systems. When such data service is interrupted due to harmful interferences, not only the railway business process is affected, but also the comfort, and indirect security of passengers waiting in the stations.

Harmful interference has and will have serious implications on the mandatory services and additional services.

2.2 GSM-R Spectrum Scenario

Railway radio services based on R-GSM have been assigned the frequency bands 876 MHz – 880 MHz for uplink and 921 MHz – 925 MHz for downlink. The ER-GSM band (873 MHz - 876 MHz for uplink and 918 MHz – 921 MHz for downlink) can optionally be used in some countries.

The R-GSM plus ER-GSM frequency band is adjacent to the one currently assigned to public mobile operators, which uses 880 MHz – 915 MHz for uplink and 925 MHz – 960 MHz for downlink. Additionally, the 800 MHz digital dividend band is also adjacent and will be used by public mobile operators. Figure 1 shows the relevant frequency spectrum.

Two sets of interference can be distinguished:

- Interferences from narrow band systems which currently represent today the most critical cases. These interferences are mainly caused by public GSM base stations operating in E-GSM Band
- Interferences caused by broadband systems (for more details, see chapter 5 and chapter 6).

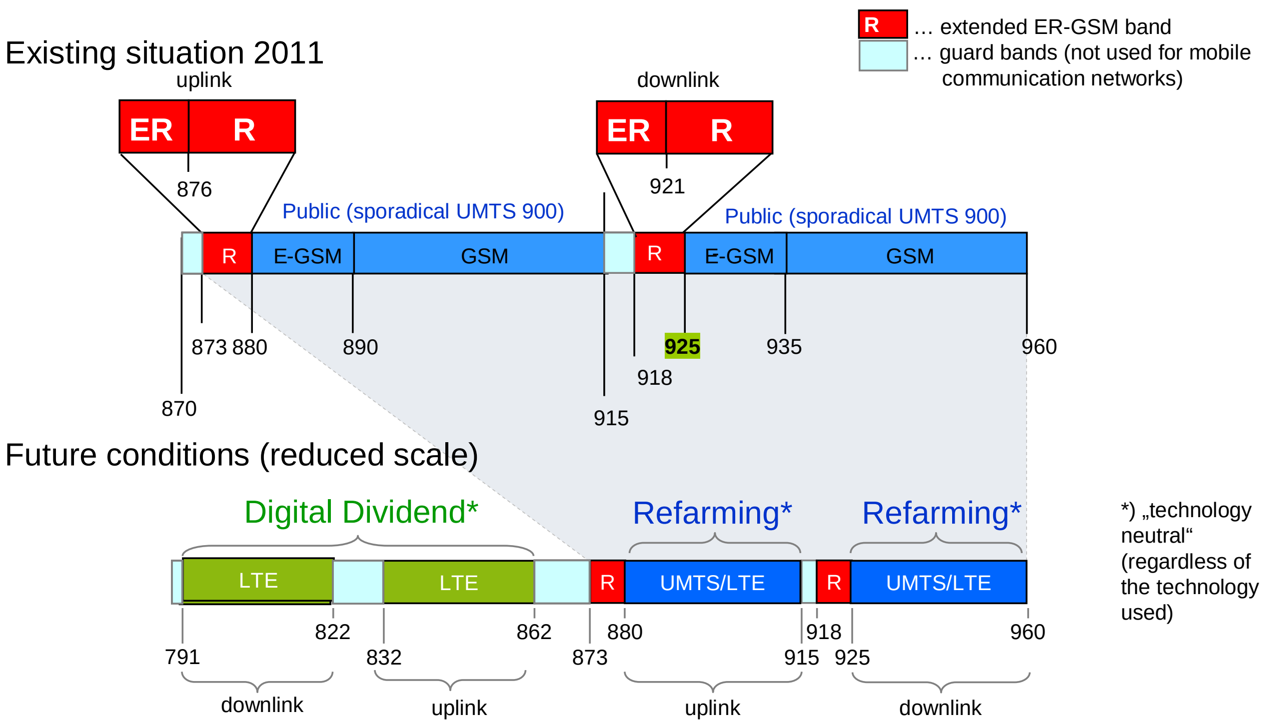


Figure 1: GSM-R frequency spectrum

2.3 Comparison of GSM-R to public mobile networks

Public GSM networks are designed to support services with lower requirements on the availability compared to GSM-R services.

Therefore, public mobile operators currently define their requirements on service availability and performance, on a costs-versus-performance trade-off (except licence requirements mainly defined in term of coverage of population).

Typically a 95% service availability per user in time and location with an average traffic load of 50 mErl per user has to be provided. Corresponding to these statistical performance requirements, Monte-Carlo simulations are used for the evaluation.

In contrast to public network requirements, GSM-R networks have to fulfil stronger requirements to meet the needs of the railway radio services and since the traffic model and the usage differs from public mobile networks. As a consequence, the evaluation of their performance requires a methodology different from the currently used Monte-Carlo simulations.

The tighter requirements are justified by the dependency of a safe railway train operation on the availability and performance of the railway radio services. The specification reflects specialities of the railway system such as the linear train movement along the tracks. EIRENE FRS 7.3.0 and SRS 15.3.0 define the performance of the railway radio services using GSM-R networks. The specified minimum coverage is defined as a probability value of at *least 95% in each location interval of 100m sections* for which the measured coverage level shall be greater or equal to the reference value.

This is in strong contrast to public GSM networks where uncorrelated locations are evaluated and the 95% criteria are applied on all possible locations.

The main differences between GSM-R systems and public GSM networks are as follows:

- GSM-R has a linear topology along railway tracks that significantly reduces options for handovers and network balancing. It also results in propagation conditions not necessarily reflected sufficiently accurately by propagation models developed for public networks.
- GSM-R mandatory needs to support services with very high requirements on availability and quality. Instead of a 95% coverage probability in time and space, 95% availability for every track interval of 100m length has to be guaranteed. Additionally, for an ETCS data call, it is only accepted to have 1 dropped call per 100 hours.
- GSM-R has to comply with a number of additional legally binding quality requirements (such as call set-up time, maximum allowed call drops etc) that require a pan-European harmonisation and restrict the technical options that could be used.

- GSM-R has only been assigned very limited spectrum so that certain techniques that would allow to avoid interference or to improve the resistance against the interference cannot be deployed (frequency hopping, frequency re-planning to avoid intermodulation).
- GSM-R equipment is subject to longer innovation cycles so that the introduction of new technical options takes more time than at commercial, public networks.
- Essential railway features like railway emergency call, group calls are implemented, and expected to be more than 99 % available.
- Different subscriber behaviour for example for the ETCS application, permanent link with very low call drop rates, and very short End-to End delay (less than 0.5 seconds for 30 bytes).

3 Impact on railway operation

3.1 General

GSM-R has been classified by the EC as an ERTMS subsystem. Therefore, Railways must implement GSM-R and ETCS on all interoperable high speed and conventional lines.

GSM-R, as an essential ERTMS subsystem, is a safety supporting radio service for railway applications, considered by the EC to have a "preventive character which means that if blocked or disturbed, it could increase the safety risks".

Specific European harmonised applications are:

- The ETCS L2/L3 signalling system
- Operational voice communication between driver and traffic control, shunting personnel and trackside workers, including the Railway Emergency Call

Depending on national decisions GSM-R is also used for other applications, e.g.:

- Trackside workers warning system
- Train departure process
- Passenger information systems
- Telemetry applications

Due to interference situation outages of the GSM-R service occur on certain track sections for each passing train and can have a dramatic effect on the railway operation.

In case of interference:

- No emergency call is possible and the prevention of dangerous situations is not possible.
- ETCS level 2/3 trains have to reduce speed or stop (depending on national rules). Consequently train delays and reduction of the line performance occurs

In ultimate cases, the unavailability of Railway Emergency Call may well result in critical situations, for example in case of a train derailment on the opposite track.

As the train traffic is becoming more and more dense, one can imagine the difficulties to restart the traffic on a big station or on high density line, e.g. a suburban train in a metropolitan area.

Specific operational rules must be implemented for train movement in an area with lack of GSM-R communication, where the train driver cannot report an emergency situation.

3.2 Impact on the ERTMS/ETCS data communication

For ETCS level 2/3, safety relevant data (Speed Profile and Movement Authorities) is transmitted between onboard and track side units via GSM-R, using Circuit Switched Data connections. For correct operation of ETCS level 2/3 at train speeds of 300 km/h, a very high Quality of Service is required - uninterrupted connectivity between train and track, with an end to end delay of max 500 ms, etc.

The impact on ETCS level 2/3 operation of harmful interferences to GSM-R (outage due to network loss with no possibility to re-establish the call in time (national values - e.g. 6 seconds) can be summarized as follows:

- Withdrawal of an existing or no transmission of a new Movement Authority (MA) at the right time resulting in stopping trains. Stopping a train automatically from e.g. 300km/h down to zero by using emergency brake could have heavy impact on passenger comfort (and causing addition wear-and-tear of the trains)
- Heavy delays of the disturbed ETCS train
- Consequential delays of other trains impacted by the disturbed ETCS train,
- Reduction in performance of line and railway networks,
- Difficult operational problems to restart train traffic.
- Increase of energy consumption
- Large number of trains will be immobilized, waiting to restart traffic

3.3 Impact on voice communications

The Train Radio voice application enables the communication between train driver and operational ground based personnel (mainly dispatchers). These communications include the Train Emergency Calls.

In an increasing number of countries permanently growing cases of harmful radio interferences are emerging, with the consequence of interruption of the GSM-R radio communication.

3.3.1 Impact on Railway Emergency Calls:

The GSM-R Railway Emergency Call is the most demanding mandatory functionality, used for urgent situations, requiring immediate response. It is the fastest, most effective and sometimes *the only remaining method to avoid dangerous situations* or to minimize the consequences of such situations.

The purpose of Railway Emergency Calls is to alert all trains within a certain area that are moving towards the danger point of a safety-affecting situation.
Railway Emergency Calls can be established from either the train driver or the dispatcher and the call set-up must require to be completed within in two seconds.

In a case of interference, an ongoing call can be interrupted. It might not even be possible to establish radio communication connections. As a result, the train's passengers' lives and health could be endangered. The following scenarios may be distinguished:

- short interference location: a stopped train cannot contact the control centre to establish a GSM-R emergency call, for instance if passengers open the doors and walk on the tracks,
- long interference location: a running train cannot receive a GSM-R emergency call and continues to run towards a danger zone without awareness of the danger.

Another impact of harmful interference is that the quality of the emergency voice call is impeded, resulting in misunderstandings and thus potential lower safety

3.3.2 Impact on operational voice calls

Examples of operational calls are the instructions to the driver to reduce speed in case of problems with level crossings, degraded infrastructure, trackside works, etc.

Due to harmful interference, establishment of a call and information exchange between a train driver and traffic management centre may be delayed or even made impossible. This potentially leads to increase of safety risks and significant delays in the overall rail traffic.

A specific voice communication is the communication between driver and shunting personnel. Both are working with (slowly) moving trains and wagons on specific locations (shunting yards, stations). Continuous communication is essential to safeguard the shunting personnel (assured through the so called "ink assurance" feature). Any interruption will lead to immediate stop of shunting operation, with consequent delays.
When interruption is more frequent – likely in the case of interference, because the work is done in a limited area – there is a risk of warning fatigue and subsequent danger.

3.3.3 Impact on other applications – e.g. trackside worker warning systems

Depending on national decisions GSM-R is also used for other applications, implementation of such application has a growing tendency in Europe, applied in static & mobile/permanent/temporary/etc. mode. Theses applications are using the GSM-R spectrum, and relates to rail applications where introduction of wireless connection is on one side lowering the costs and on another fostering the railway operations. Communication gaps when using these applications can lead to operational disturbances, and potentially to critical situations.

One example is the trackside worker warning systems. These systems alert trackside workers for approaching trains, either to leave the track or to be alert for trains on the neighbouring tracks. Continuous communication is essential to safeguard the trackside personnel. Any interruption will lead to immediate stop of trackside work. When interruption is more frequent – likely in the case of interference, because the work is done in a limited area – there is a risk of warning fatigue and subsequent danger.

3.4 Economical impact

The macroeconomic effects of train delays are substantial, but also the direct economic consequences for the railway operators (for example, the railway operators may be obliged to pay indemnities to their passengers, freight customers or regional and urban transport authorities). In addition, increasing delays of trains can become a nightmare, unacceptable from a political point of view.

Disturbances of proper GSM-R operation due to harmful interferences also have strong negative economical and ecological effects:

- Emergency braking due to ETCS level 2/3 disturbances leads to significant increase in power consumption. As several trains can be affected in addition to the train which had the emergency braking, the impact on energy consumption can be huge. One example is where an ETCS train gets stuck, and another train is called for the rescue of the passengers. Another example is the case where an ETCS freight train gets stuck in a tunnel, and needs to be pulled out with the help of additional locomotives.
- Delayed and stopped trains lead to high cost, both for the recovery of the original service, but also to claims and loss of public image
- Attractiveness to passengers is reduced; loss of confidence / bad perception. This holds similar for cargo transporters
- Delayed or stopped trains have a domino effect; more than the originally disturbed train is impacted, and often it is very difficult to recover to the original time schedule, only after several hours. This problem will increase with higher frequency of trains due to the increase of traffic.

Examples:

- A high speed line is currently performed to have a maximum of 20 trains per hour,
- A loss of ETCS level 2/3 link between each passing train and RBC will result in an emergency stop of the train
- A stopped train usually results in a delay of at least 20 minutes.

The effective railway operations of the line is, in this case, reduced to 3 trains per hour which corresponds to 15% of the possible capacity and a loss of 85% of the investment.

4 Interferences from public networks to GSM-R

4.1 Overview

Coexistence of GSM-R with public mobile networks will be more and more difficult in the future without appropriate protection of GSM-R.

The 800 MHz (Digital Dividend) and 900 MHz (GSM) frequency bands are designated to commercial mobile network operators, while the adjacent bands of 876-880 / 921-925 MHz (GSM-R) and 873-876 / 918–921 MHz (ER-GSM band) are designated to the railways as primary users.

The European Commission (EC) and their Member States have taken several measures in order to push forward the development of new mobile communication technologies such as UMTS and LTE in the 900 MHz and 800 MHz band.

Since 2006 the railways have registered an increasing number of interferences to the GSM-R systems. For example, Deutsche Bahn identified up to April 2012 a number of *266* locations in Germany (compared to 58 locations in 2006) where interference from public mobile GSM networks have been measured. A further *180* locations in other EU countries have been reported to UIC with growing tendency.

4.2 General information about interferences

GSM-R voice cab radios and ETCS Data only radio use an external antenna on the roof top of the train. The handheld antenna is located close to the body of the user. A handheld device typically receives 20 dB (1:100) lower signals than a cab radio. Cab radios are more sensitive to interferences than a handheld.

If a train is stopped in an interfered location, a train has more difficulties to re-establish a call, while a user with a handheld device can move to find a location without interference.

The combination of using wide band systems, such as UMTS / LTE / WiMAX etc, close to narrow band systems, such as GSM, is a relatively new occurrence and therefore little practical experience exists.

However, practical measurements and theoretical calculations lead to the conclusion that due to the introduction of the described technologies in adjacent frequency bands, more interferences than today will be observed.

Existing ETSI Standards do not guarantee the coexistence of Mobile Radio Systems in all cases.

In addition there are no requirements in current standards which specify the behaviour of GSM/GSM-R equipment when it is exposed to wide-band signals of the above type in adjacent frequency spectrum.

Mobile communication is a strong growing market with a tremendous pressure on capacity (e.g. for mobile internet). This leads to network expansion, high spectrum demand, and the introduction of new technologies such as UMTS and LTE.

Telecommunication Industry communicated only limited knowledge on their experiences regarding expected problems with the new types of wide-band signals. The railway community has consequently been forced to gain its own knowledge through lab and field tests.

4.3 Relevant mechanisms about interferences

According to ECC report 162, chapter 4, the relevant mechanisms by which interfering transmitters affect receivers are described below:

Receiver desensitization can be caused by different sources such as:

- unwanted emissions transmitted from various interferers
- IMP generated in the receiver - in particular 3rd and 5th order IMPs - increasing the receiver noise floor.
- Power leakage from interfering signals due to limited receiver selectivity.

In order to avoid a significant increase of the receiver noise floor causing receiver desensitization, unwanted emissions and IMPs should be sufficiently below the affected receiver noise floor.

Receiver selectivity is the ability to isolate and acquire the desired signal from all of the undesired signals that may be present on other channels. Selectivity is a central factor in the control of adjacent channel interference.

Receiver blocking is the effect of a strong out-of-band interfering signal which prevent the receiver's ability to detect the wanted signal. Receiver blocking response (or performance level) is defined as the maximum interfering signal level expressed in dBm reducing the specified receiver sensitivity by a certain number of dB's (usually 3 dB).

Remark: GSM MS blocking performance against modulated broadband signal is poorly defined in the ETSI specifications. The specification defines blocking performance, but only against CW modulated test signal signals. In this document the term blocking covers also the intermodulation products

Intermodulation products cause by the presence of two strong signals intermodulating with each other to a new signal in the receive path interfering the wanted receive signal. It should be noted, that one broadband signals can itself lead to intermodulation and so the intermodulation bandwidth is three time higher than the original signal

Receiver overload is caused by too strong signals at the receiver antenna connector resulting in IMP in nonlinear parts of the receiver chain.

Additional information about the interference mechanisms can be found in the ERC Report 68 and in the Annex 1 of the ECC Report 127.

Unwanted emissions:

- A system needs a minimum bandwidth to transmit information. Based on physical effects, a transmitter always generates unwanted emission in the adjacent frequency band. Depending on the level of unwanted emission compared to level of GSM-R serving signal, this unwanted emission may mask wanted GSM-R signal and cause interferences. Typically unwanted emissions from public 900 MHz networks are predominant mechanism when the GSM-R serving cell signal strength is relatively low. The Annex 1 shows some examples of minimum GSM-R level requirement compared to aggregated noise from public operators operating in UMTS 900 MHz.
- The OOB domain depends on the bandwidth of the transmitted signal and therefore broadband systems emit higher emissions outside it´s intended frequency band than narrowband systems like GSM.
- Aggregation of the unwanted emissions are not covered in the specifications but are essential

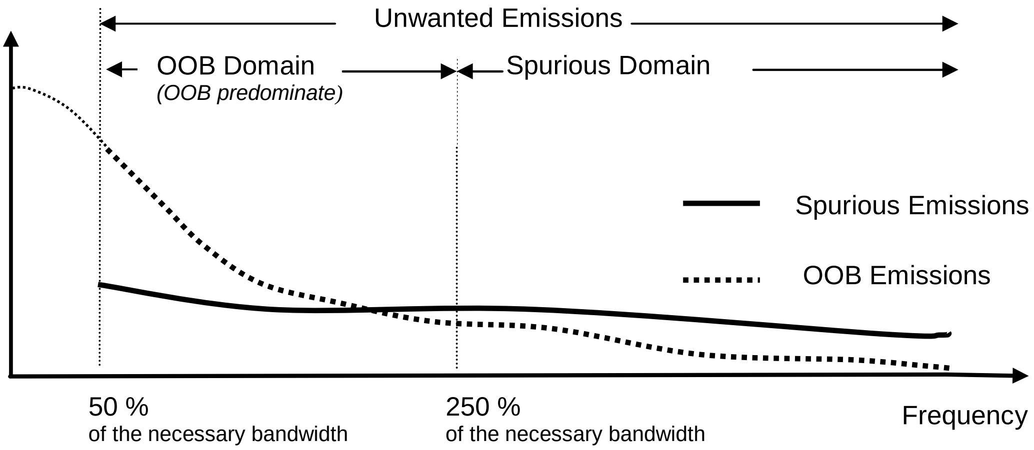


Figure 2: Unwanted emissions

4.4 Interference from UMTS base stations to the GSM-R downlink band

In several ECC studies, the compatibility between GSM-R (primary band) and UMTS900 has been investigated. The conclusion of ECC reports 96 and 162 are that UMTS900 can be deployed in the same geographical area in co-existence with GSM-R as stated in the following bullets:

- 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 below. This conclusion is based on Monte Carlo simulations assumed suitable for typical case.

- 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).
- 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.
- 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. 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. For more details about the compatibility between UMTS900 and GSM-R see section 3.2 of the ECC Report 096.

The UIC test campaign in ISPRA in December 2011 revealed that the evaluation method used in the current ECC reports needs to be revised.

4.4.1 Specific case when GSM-R channel is adjacent to UMTS transmissions

According to the 3GPP specifications, the spectrum emission from UMTS900 base station operating with a minimum carrier separation of 2.8 MHz between GSM-R (at 924.8 MHz, the upper channel in GSM-R band) and UMTS 900 (at 927.6 MHz) may produce interfering emission to GSM-R channel on a level of -7 dBm.

With the following hypothesis:

- The interfering UMTS 900 base station is located 50 m from the railway. This 50 m distance corresponds to 66 dB path loss (in free space).
- 15 dBi antenna gain for the UMTS site

The interference level at the GSM-R antenna will be: -7dBm + 15 dBi - 66 dB = -58 dBm. The wanted GSM-R signal level must be at minimum 12 dB (minimum C/I value) above the interference level e.g. -46 dBm to provide error free service.

At a -98 dBm (minimum coverage from EIRENE requirement) wanted GSM-R receiver level, interference free operation may, depending on propagation, force the UMTS900 base station installation as far away as 5 km from the railway (which is corresponding to a maximum interference signal of -110 dBm).

4.5 Composite effects

In Downlink:
The frequency bands adjacent to R-GSM will be populated by several signals using different types of systems (narrow band system like GSM, broadband system like UMTS).

The ISPRA test campaign demonstrated that it is necessary to consider the aggregated sum of all interfering signals to have an interference free GSM-R operation.

As in some administrations, the introduction of new broadband technologies is happening as we speak national specific coexistence measures have been taken.

In Sweden, National Administration has defined that there are two UMTS channels of 5 MHz, two channels of 7.5 MHz and one channel 10 MHz licensed in the 900 MHz band. The present power condition for the licenses in Sweden is to allow 0 dBm / 5MHz, except for the 5 MHz spectrum close to GSM-R which is allowed – 5 dBm all measured at the GSM-R mobile station antenna.

The composite power for the above case over the whole public mobile band (925 – 960 MHz) can aggregate to a level of + 8 dBm. This level is 30 – 40 dB higher as specified in the corresponding technical standard.

These measures require an increase of the minimum GSM-R coverage levels implying considerable additional sites and introduction of filters on GSM-R terminals (a measure that today are not in line with the EIRENE requirements and therefore with the CCS TSI).

Such example clearly shows the urgent need of European harmonised GSM-R protection values.

4.6 Interference from wide band base station transmitters to the GSM-R uplink band

Deployment of LTE and possibly other wide-band access technologies operating in frequency bands below the GSM-R up-link band (i.e. the 800 MHz band) will also cause interference to the GSM-R service in the Uplink band.

The GSM-R BTS may be in close proximity to a broadband transmitter (UMTS, LTE, etc). Coupling loss between radio equipments may be 60 dB or lower.

Based on the ETSI specifications the following example shall clarify the critical effects:

- One single 5 MHz wideband transmitter operating in the adjacent frequency band to GSM-R (carrier separation of 2.8 MHz)
- Output power of +43 dBm from broadband transmitter
- Unwanted Spectrum Emission of - 44 dBc (cf. 3GPP standard),

- The GSM-R BTS up-link reception interference may be as high as -74 dBm/ 200 kHz if the public transmitter is not equipped with extra rejection filtering.
- For error-free GSM-R service without a rejection filter on the broadband transmitter, the input signal (from the GSM-R Mobile Station) must be - 62 dBm i.e. stronger (12 dB above interference level).

This requirement of coverage GSM-R level is +36 dB higher than the EIRENE level and cannot be achieved.

4.7 Interference from wide band mobile station transmitters to the GSM-R uplink band

In the current ETSI specifications for 800MHz wideband (UMTS, LTE) mobile stations (MS), the requirements on Spectrum Emissions are very low.

Public mobile stations that can be used as fixed installation (aka xDSL replacement) operating at the 800 MHz band in close proximity to the railway tracks may create high levels of interference to the GSM-R uplink.

Furthermore, in urban areas (e.g. in railway stations) there may be many hundreds of 800MHz MS's therefore it is almost impossible to predict the GSM-R uplink interference levels from the aggregated sum of these MS's transmit signals.

These interference mechanisms need additional studies in order to be fully understood. It may be that proper filtering at the public terminal to reduce the unwanted emission will be required.

4.8 UIC Interference points database

In order to track the evolution of the interference situation at European level, UIC decided to develop in 2011 a shared database to collect all railways interferences. This database is populated by each railway operator. Out of it some statistics can be derived by UIC like:

- Total number of interferences
- Repartition by country
- Impact by application
- Size of the area disturbed
- ....

5 Expected future problems

The Railway community expects that the number of interference cases will continue to increase due to the several reasons described in the following sections:

5.1 GSM-R implementation

Taking into account the whole railway network in Europe, which is about 221.025 km; 150.650 km are foreseen to be covered with GSM-R, which means 68 % of the railway network.

Taking as reference the 1st of January 2010, 79.300 km of railway tracks were equipped with GSM-R, 65.800 km are in operation, which means that 44% of the planned network are already in operation.

In some countries GSM-R has not been completely implemented yet (e.g. in France currently 3.000 km track lines are equipped and additional 15.000 km are planned to be equipped, meaning that the current situation of interferences represent only a part of the potential interference cases).

Beginning 2012, 40.000 cab radios were declared to be activated, and around 1200 EDOR's. As ETCS implementations are growing, and ETCS Level 2 country wide cases appeared lately (Belgium, Denmark, Switzerland), the number of cab radios and EDOR's are expected to significantly grow.

5.2 Broadband 900 implementation

As part of the refarming process of the GSM bands and the technology free usage of spectrum of telecommunications, radio technologies other than GSM, e.g., UMTS 900 MHz or LTE 900 MHz might be deployed in the frequency bands currently assigned to public GSM services. Due to their different RF characteristics, these radio technologies will result in increased interference in the adjacent frequency band used for the GSM-R downlink. Adaptive antennas micro-cells, femto-cells, repeaters, and other techniques are candidate technologies used in future radio networks in order to achieve cost-efficient high-data rate coverage. Their deployment will further challenge the network planning for GSM-R.

The assignment of the Digital Dividend (790 MHz – 862 MHz) is currently ongoing. The use of this spectrum will probably result in additional challenges for the availability and performance of GSM-R services.

The change of uplink and downlink frequencies and the possibility that the user can use mobile equipments with fixed installation antennas is expected to create significant additional interference.

The narrow band GSM-R with 200 kHz spacing channel is very prone to interference by the close proximity of potential broadband radio systems.

According to the higher emissions from broadband systems which are allowed by the standards, the number of interference cases in the GSM-R band will increase dramatically compared to those caused by narrow band systems like GSM.

5.3 New technologies

The introduction of new technologies such as MC-BTS has resulted in less stringent RF requirements, which may increase the number or severity of interferences. With the growing deployment of multi carrier technologies the interfering risks will grow.

5.4 Other Broadband technologies

Radio communication is a growing market and new frequency bands and radios systems will be implemented soon. Regarding the digital dividend the uplink and downlink were changed to protect the radio broadcast services. This means a higher risk of interference problems into GSM-R caused by the used terminals. Additionally the usage of fixed home devices will worsen the situation.

5.5 ETCS Level 2/3 implementation

In 2012, only a very few lines are operated with ETCS Level 2. ETCS is planned to be implemented on all major railway lines with the focus to replace the existing different national signalling systems.

Overall there is a serious risk that ETCS Level 2/3 will have a non-acceptable performance due to harmful interferences.

Each interference case of GSM-R increases the risk of a train stop, leading to unacceptable train delays and consequently to a reduction of the capacity of the railways network.

6 Solutions

6.1 Introduction

Radio interference mechanisms can be divided into two main categories:

- The desensitisation of a mobile receiver due to unwanted emission from radio transmitters, transmitted in adjacent frequency band
- The blocking and intermodulation behaviour of the GSM-R mobile receiver. This effect is the consequence of the specified MS receiver characteristics.

These interference mechanisms are explained in more details in chapter 5.3.

UIC investigated the effect of intermodulation and blocking of GSM-R receivers in a dedicated test campaign, the results of which have been instrumental in defining the protection measures required for GSM-R as described in this document. - For more details please see annex 2.

6.2 Interference resolutions

6.2.1 General overview

In order to resolve GSM-R network interference from public mobile networks, several approaches can be considered. The following sections will address solution by regulation, coordination or by combining both methods.

For both high-speed and conventional tracks, the CCS TSI requires interoperability of trains, which in turn requires that trains meet the mandatory requirements of the EIRENE specification.

As the EIRENE specifications define minimum coverage values, and as engineering has been left to implementer’s choice, there is not a uniform implementation model in Europe. One other reason is the purpose of the GSM-R implementation – for voice applications, ETCS Level 2/3 – which leads to different coverage levels. This leads to the need to define a European harmonized solution, based on the EIRENE requirements that allows supporting these different implementation models.

Furthermore, it should be noted that, based on European decision 2009/766/EC, Member States have an existing legal obligation to ensure appropriate protection of GSM-R.

It is not to be forgotten that GSM-R networks in Europe started their rollout before the introduction wideband (UMTS, LTE) technology in the public networks.

6.2.2 Regulation approach

In order to achieve a European harmonised solution, it is the UIC's firm belief that *only an approach based on the definition of harmonised maximum conditions for all interference mechanisms will suffice*.

When GSM-R is treated as a victim for interference, the maximum limits, in railway areas, have to be set for the following interference sources (for both the 800 and 900MHz bands):

- Unwanted emissions from public networks into the GSM-R band
- Blocking signal levels from public networks

The thus defined maximum levels must be made legally binding, in order to be enforceable in case of remaining interference problems.

Within UIC, it is a common understanding that GSM-R and public networks must co-exist, since train passengers desire access to mobile communications and broadband (see UIC E-TRAIN Project Report).

UIC strongly believes that appropriate solutions - on different levels - can be found for reaching this goal.

6.2.3 Regulation and coordination approach

All interference problems cannot be solved only by regulation, but rather by a combination of regulation and coordination. Also, as explained before, due to differences in the actual design of national GSM-R networks, adequate protection may be possible with different maximum limits.

Regulation must set limits for interfering signal levels and by means of coordination these limits can be applied or even relaxed in certain conditions. Wanted signal and generated unwanted emission levels from all interfering networks are needed for coordination.

For example unwanted emissions from UMTS/LTE900 could be higher than the regulated absolute value in places where the GSM-R serving signal level is adequately high and therefore can tolerate higher interference levels.

Combined regulation and coordination may be used for coordinating time schedules. Public network operators using UMTS/LTE in the 800 or 900 MHz frequency bands should have an obligation to inform the GSM-R operator in advance that they want to increase signal levels in specific areas.

UIC considers that the regulation, based on *legally binding, European harmonised protection values for GSM-R,*combined with coordination is a key solutions to proactively overcome interference problems. *This also supports the Member States to implement (inter alia) the European decision 2009/766/EC, to ensure appropriate protection of GSM-R*.

6.2.4 Coordination approach

If regulation or combined regulation and coordination is not (yet) possible, the only remaining approach to solving interference problems is by mutual coordination. In such case, coordination is necessary with *all public operators* active in the interfered region, due to the cumulative effects of broadband interference mechanisms.

Such cases may require arbitration by the national frequency authority.

Coordination-only is expected to be used as a reactive resolution approach. Proactive resolution between all public network operators and the GSM-R operator can be done only when the time schedules of both rollouts are similar. Also, it should be noted that on the part of the public operators no commercial obligation exists to cooperate with the railways GSM-R operator.

ECC Report 162 presents several mitigation techniques that may be used with the coordination approach.

Chapter 7.6 summarizes the different mitigation techniques described in this ECC report 162.

6.3 Definition of the limits to protect GSM-R for regulation approach

This approach consists in the definition of absolute values to not be exceeded by public mobile operators in order to protect GSM-R in all situations, and it is crucial that these values are referenced in Europe in a legally binding way, as basis for coordination – implementation of different mitigation techniques – case by case.

These values refer to unwanted noise emission and GSM-R MS blocking.

6.3.1 Definition of unwanted noise emission for regulation approach

Unlike thermal noise, the UMTS/LTE900 unwanted emission level is not a constant value everywhere in railway area. The unwanted emission level depends on the distance from UMTS/LTE900 base station, the output power, the antenna configuration and the radio propagation conditions.

Figure 3 defines the aggregated maximum tolerable unwanted emission level. The hypotheses for the calculation are the following values:

- C/I ratio : 9 dB
- Ageing margin : 3 dB
- Losses between antenna and GSM-R MS : 3 dB
- Noise figure for GSM-R MS : 8 dB

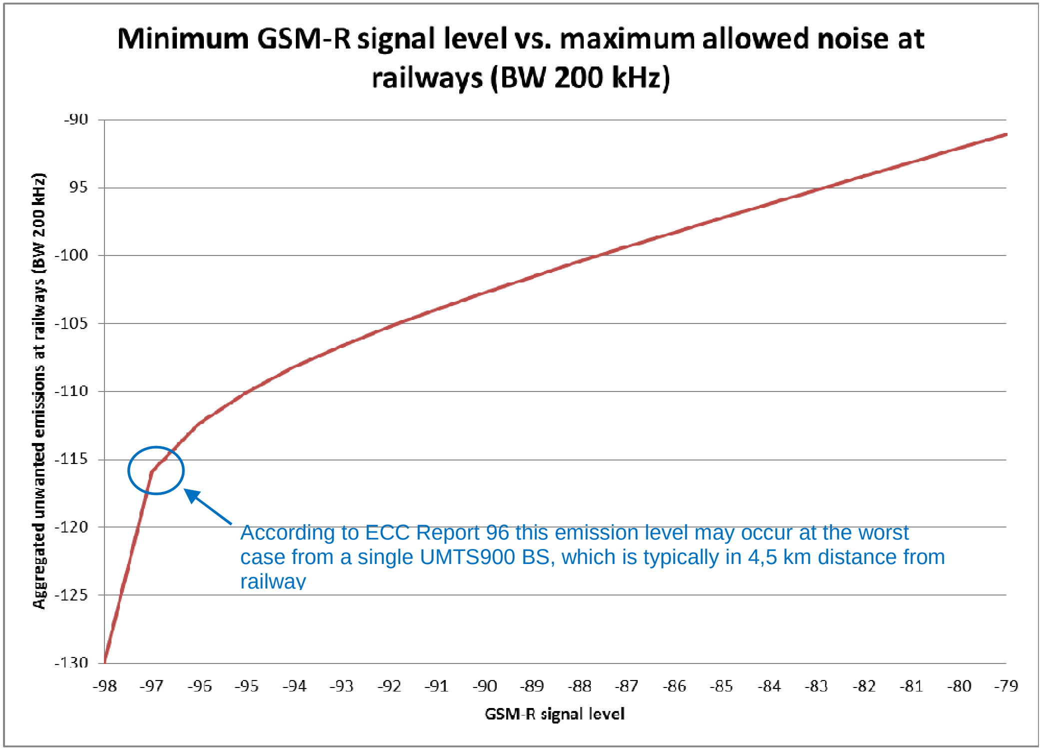


Figure 3: Minimum GSM-R signal level vs. unwanted emission

Case 1: The EIRENE minimum signal level (-98 dBm) assumes that there is no external noise and thermal noise is the only noise to limit the connection. For practical illustrative reason this “no noise” (or -∞ noise) is replaced by -130 dBm for GSM-R signal level of -98 dBm.

Case 2: for GSM-R signal level of -94 dBm a maximum unwanted emission level of -108 dBm can be tolerated, calculated according to EIRENE principles. In this case, *A single UMTS900 base station can cause this -108 dBm unwanted emission level when its total signal level is in between -55 dBm to -35 dBm at railways*. Some additional details can be seen in chapter 6.4.2 and in annex 1

6.3.2 Definition of GSM-R MS blocking for regulation approach

According to the value defined in Annex 2 (figure 12), to protect efficiency GSM-R against UMTS/LTE in 900 MHz frequency band, the maximum aggregated downlink signal levels from public mobile networks have to be limited to *-36 dBm on the railway track (measured at 4 meters height with 0 dBi antenna gain, and 0 dB cable losses).*

6.4 Resolution of interferences issues by coordination

6.4.1 Overview

Coordination is a preventive measure and should be done during the network-planning phase before the rollout starts.

National administrations are leading this task including the coordination strategy between public and railways operators. Coordination itself may have different approaches and is depending on the specific situation in each country.

A decision at national level to not apply some mitigation techniques on cab radio side could affect the way to avoid interferences in other GSM-R networks.

Note: Coordination between network operators (public and GSM-R) is preferable for all interoperable trains in order to fulfil therefore a basic requirement of the TSI

6.4.2 Definition of the input values for the coordination calculations

Following input values for the calculation have been used:

- GSM-R signal C/I : 9 dB
- MS GSM-R blocking threshold : -36 dBm (according to figure 6)

GSM-R interference effects can be compensated by increasing GSM-R serving signal level:

- The compensation ratio for unwanted emission is 1:1. This means that if unwanted emission level increases by one unit GSM-R serving signal level need to be increased by one unit.
- The blocking behaviour for GSM-R MS is different. Its compensation ratio is 1:3. This means that if UMTS/LTE900 blocking signal level increases by one unit GSM-R serving signal level need to be increased by three units. This matter is more detailed in Annex 2.

The figure 4 summarizes the input values and the assumptions for the calculations presented in figure 10 and in annex 1.

Coordination item	Input value	Effect compensation ratio	Note
Unwanted emission	9 dB below GSM-R DL signal	1:1	
GSM-R MS blocking	-36 dBm (aggregated signals)	1:3	For GSM-R signal level of -98 dBm
Filter performance	30 dB		for frequencies at 925,5 MHz and above

Figure 4: Summary of the input values for coordination and assumptions how to use other values in interference thresholds

The figure 5 presents train radio threshold value against UMTS900 signal blocking in different GSM-R serving signal levels. UMTS900 unwanted emission effects of are also taken into account. These calculations are based on train radio blocking performance, which is similar to the measurement results done in ISPRA and presented in Annex 2 / figure 9.

This means that the unwanted emission is according to 3GPP TS 53 dB lower than the wanted UMTS900 signal.

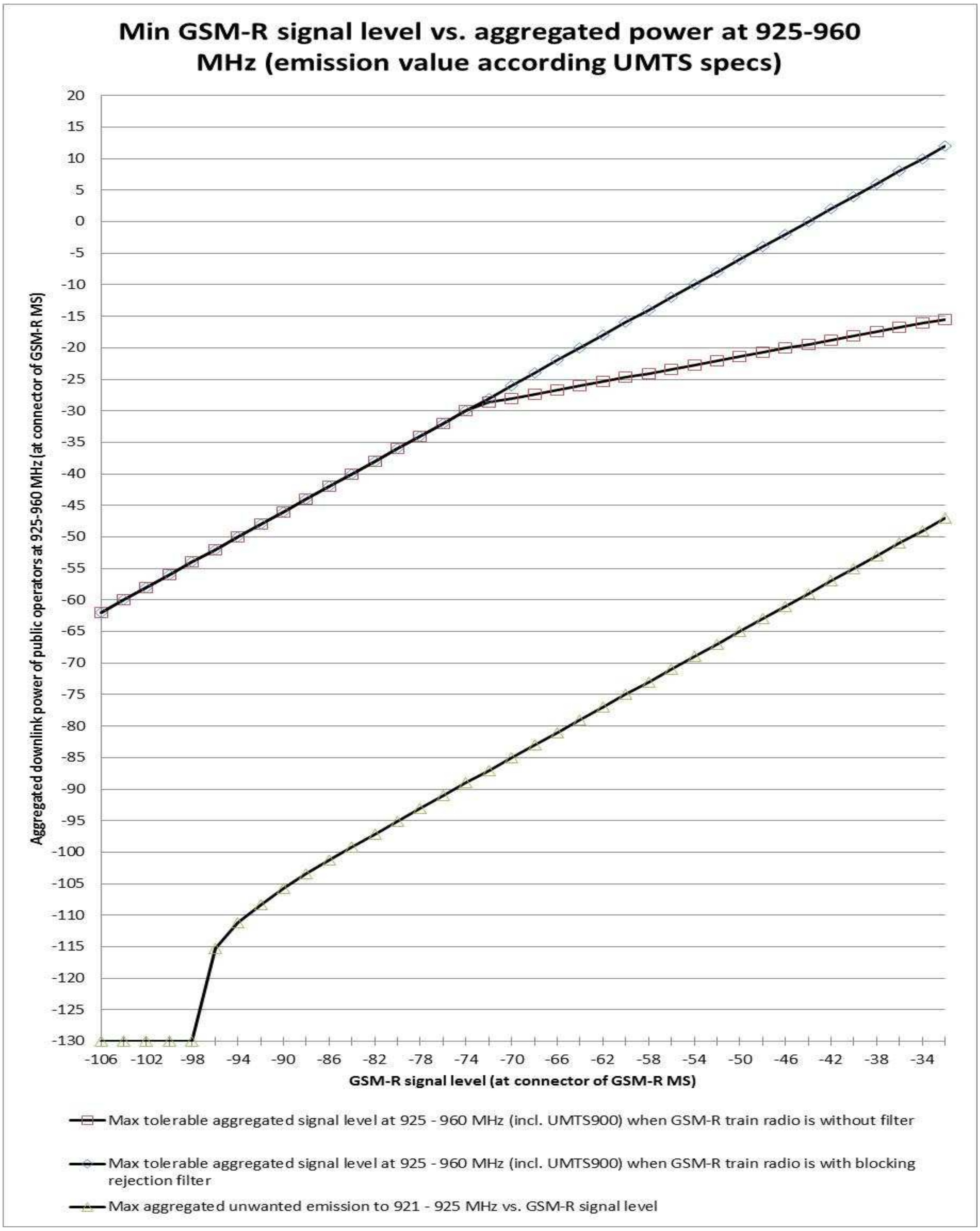


Figure 5: Minimum level of GSM-R signal compared to level of aggregated power from public networks

If the values shown in the graph are exceeded, it is needed to increase the signal level from GSM-R or to request to public operators to decrease their signals, e.g. by using the mitigation techniques of ECC 162 report.

Annex 1 presents a similar diagram for a typical UMTS900 base station (Unwanted emission can be 73 dB lower than the wanted UMST900 signal).

6.5 Generic view for future improvements

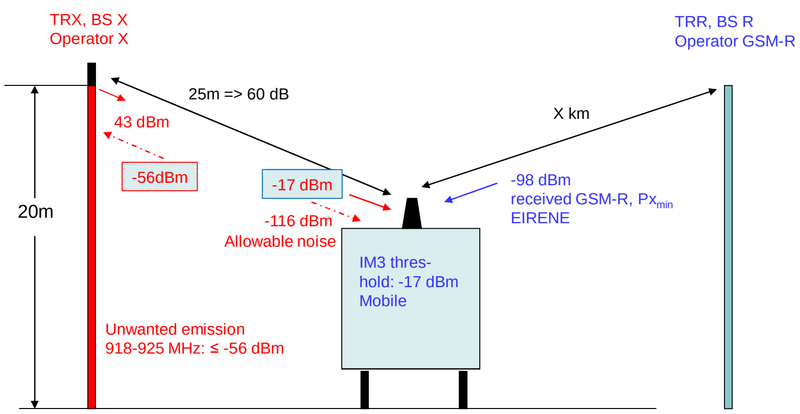
A generic view can be proposed regarding future improvement.

This view should be taken into account in revised or future standards.

Based on typical scenarios the radio parameters which guarantee the coexistence can be derived. Following the minimum distance between public base station antennas and GSM-R mobile antennas of about 25 m and therefore approximately 60 dB of isolation can be assumed. In some specific cases the distance can be shorter and other measures are necessary.

Note: This calculation based on ECC report 146 for multi carrier BTS assumes to have 0 dBi antenna gain from interfering BTS to train antenna direction.

The figure 6 shows a typical railway scenario with one interferer.



P_{PR} = ERPmax – MCL = -17 dBm = IM 3 threshold value
N_{RX} = -114 dBm (BW = 200 kHz, F = 7 dB); RX noise density = -167 dBm/Hz; F = 5 – 7 dB

Values single interference scenario: IM 3 threshold ≤ - 17 dBm; noise emission $_{BS}$: ≤ -56 dE

Figure 6: Typical scenario: railway case without mutual interferer

Typical receiver parameters:

- Public BTS output power: 43 dBm
- the proximity of 60 dB leads to an input power of -17 dBm at the GSM-R terminal
- taking into account that several carriers (2 to 4) can be used, an extra margin of 3 to 6 dB can be added
- this means that an "interfering" signal between -11 to -14 dBm can easily exist at the input of the GSM mobile.

The current specification requires a value of -43 dBm for the IM threshold; this value should be replaced in the technical specification by -14 dBm. Blocking and IM are closely connected so that also the blocking threshold would be covered.

This higher specification value should be used in every specification and will generally enhance the quality of all radio services.

Note: In figure 7, the Operator of the interfering Base station must guarantee that the coupling loss between BTS antenna connector and train radio 0 dBi antennas is at least 60 dB.

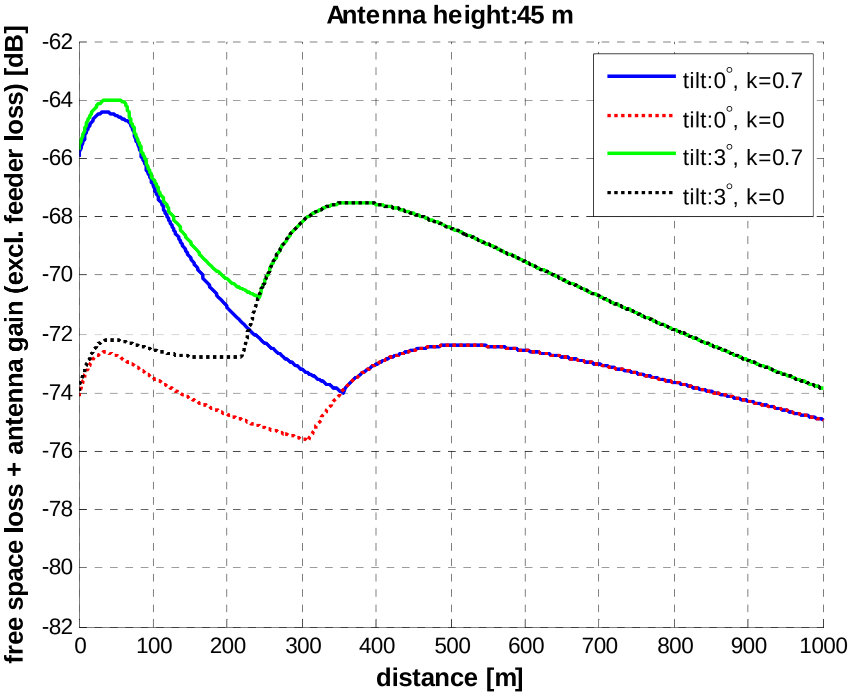


Figure 7: influence of possible antenna configuration (Source: ECC report 146 on Multi carrier BS)

Wide band noise:

Wide band noise / unwanted emission can only be handled on the source side. The following derivation is based on a bandwidth of 200 kHz. If 60 dB proximity is assumed, a C/I value of 12 dB and a receiver sensitivity of -104 dBm as specified in ETSI are used, a value of -104 dBm -12 dB + 60 dB = -56 dBm unwanted emission can be calculated and accepted, leading to a desensitisation of 3 dB.

If only a desensitization of 1 dB is accepted 6dB have to be added. Additional 3 - 6 dB has to be taken into account due to mutual interference and taking all this aspects into account in future a value of -62 dBm to -68 dBm is relevant for the unwanted emission of broadband base stations.

This value is in line with specification EN 301 908 relevant for the GSM core band.

- 935 MHz ≤ f ≤960 MHz: -79 dBm
- 925 MHz ≤ f ≤935 MHz: -67 dBm

Therefore also the specification should be added:

- 918 MHz ≤ f ≤925 MHz: -67 dBm

Note: Regarding spurious emission the value of -36 dBm / 200 kHz exists.

Consequence:
If all mentioned conditions described in chapter 6.5 are fulfilled, no real interference situations should exist based on typical railway scenarios.

7 Conclusions

This report O-8700 focuses on the interferences created by public mobile networks into GSM-R operating in the frequency band R-GSM (876-880 MHz / 921-925 MHz) and in the extended ER-GSM frequency band (873-880 MHz / 918-925 MHz).

This report O-8700 provides an overview of the interference situation (actual and forecasted) all across Europe, it describes the physical effects of interference issues and it proposes solutions to solve them.

The report notes that some of the interference problems can only be solved on the source side, whereas some can be solved on receiver side. For this some solutions are proposed.

This report gives indications on operational and economic impacts of interferences. It provides a forecast for the future situation when wideband (e.g. UMTS, LTE, WiMAX) technologies will be deployed in the field.

The overall conclusion of this report is that solutions exist to obtain the required co-existence between GSM-R and public network, but necessarily based on regulatory measures. Based on this technical mitigation techniques can be applied when coordinating network implementations.

As GSM-R is not a national but a European solution, that is used to serve the Rail System, with high availability and reliability needs, the regulatory measures should be defined in the form of European harmonised protection values for GSM-R, based on maximum cumulative signal power levels at rail tracks (values are proposed by UIC in this document), which shall become legally binding within the EU / EFTA.

Furthermore, it should be noted that, based on European decision 2009/766/EC, Member States have an existing legal obligation to ensure appropriate protection of GSM-R.

The regulatory measures must take notice of real measurement data and not only on theoretical approaches. Monte Carlo simulation is not suitable for a railway traffic model.

The regulatory measures must be designed in a future proof way, since railways shall not have to adapt every time a new broadband system is appearing; it is assumed that GSM-R will exist until at minimum 2025.

UIC introduced a database to monitor the status of the interference situation and to get an overview on the actions taken by the GSM-R operator (railways), the public operators and the national administrations.
UIC will periodically report to ECC WG FM the status in Europe, to fulfil the work item created by ECC WG FM. In this context, the Letter of Understanding agreed between UIC and the ECC in December 2011 should also be noted.

To achieve the goal of an interference free coexistence in the future, the existing standards (for GSM/GSM-R, UMTS, LTE, etc) need to be enhanced. These need to be based on a more generic and realistic view on coexistence, leading to strongly improved requirements for receivers and transmitters to prevent mobile communication systems from causing harmful interference. This development has to be started now, because the specification and implementation of new standards is a very time consuming task.

The work on defining European harmonised protection values needs encouragement of the interfaces between UIC, ERA, EC, CEPT / ECC, and possibly ETSI, and has to be seen inside the European regulatory environment for radio equipment and spectrum. This includes the possible provision of a mandate under Directive 676/2002/EC – the Radio Spectrum Decision – and the new ERTMS MoU signed on 19th of April 2012 (article 65) to achieve an interference free coexistence between GSM-R and public mobile radio services.

8 ANNEX 1

Definition of the minimum level of GSM-R signal which can operate successfully on the presence of aggregated interference from public networks using UMTS or LTE technology for a typical base station:

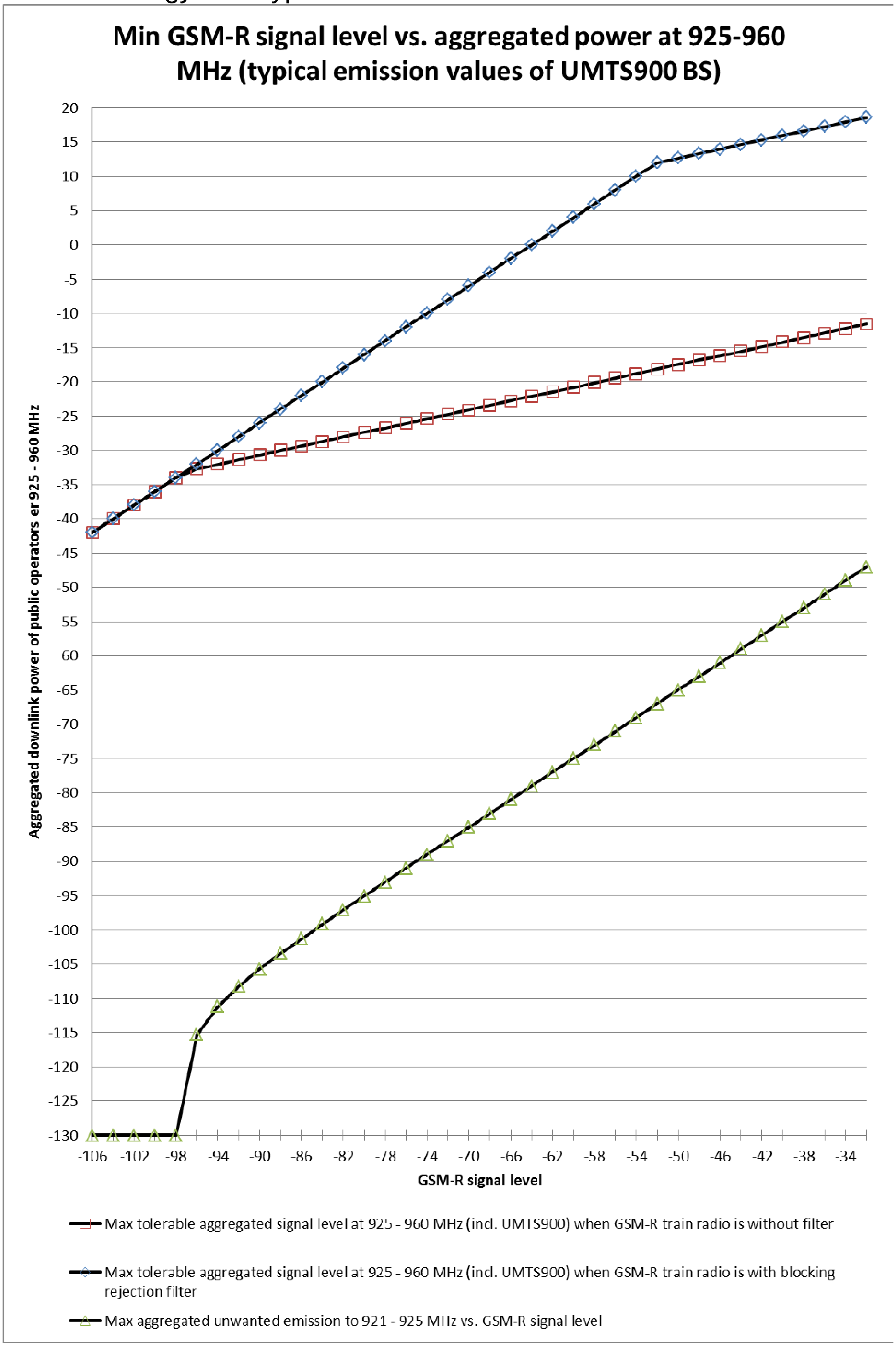


Figure 8, Minimum level of GSM-R signal compared to level of aggregated power from public networks for a typical base station

9 ANNEX 2 - Blocking of GSM-R MS

In 2010, ETSI created a task force (group STF 390) to define new parameters for GSM-R MS. One of the initial targets was also to specify the requirements for measurements with a wideband modulated signals such as UMTS/LTE. This task would have required a massive measurement campaign to verify limiting values. Due to the limited resources allocated to this task force it was not possible to create a totally new requirement for ETSI specifications. The results were two new specifications (TS 102 933-1 and TS 102 933-2) with limited improvements of some receiver parameters compared to a standard GSM MS. The improvements are limited because there are no GSM-R specific chipset available neither they will be developed.

In December 2011, UIC performed interference measurements for GSM-R MS with the kind support of the JRC (Joint Research Center) - the European Commission Laboratories in ISPRA (Italy).

The purpose of these measurements was to figure out the practical capability of GSM-R terminals to resist to interferences. UIC's team measured interference performance of three different manufacturer's train radios. These measurements were reported in the document UIC O-8725 “GSM-R MS Interference measurement at ISPRA". Some results are reused in this document.

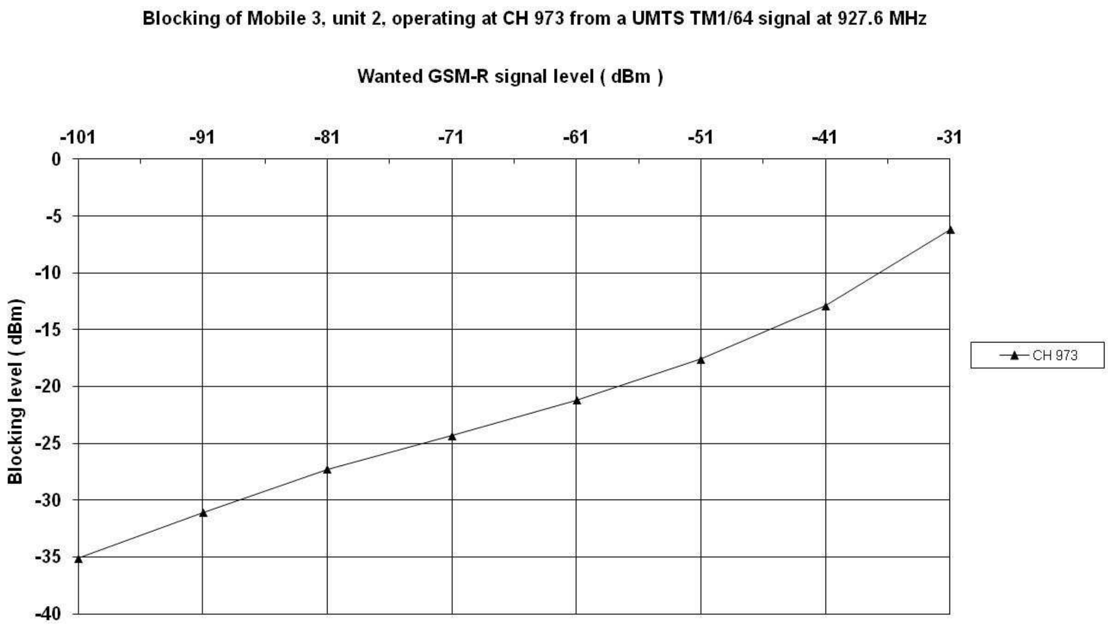
9.1 Practical results of the blocking measurements

The figure bellow represents one of the GSM-R MS blocking results from the tests done by UIC in ISPRA in December 2011.

The conditions of the test were:

- Service cell signal of GSM-R is at highest channel of the GSM-R band
- Interfering signal from the UMTS900 base station at lowest frequency of the GSM-E band.
- It should be also noted that all the measurement results of the signal levels are referred to the antenna connector of train radio (the signal thresholds in EIRENE specifications are defined at 4m height with 0 dBi antenna gain).

Figure 9: Blocking performance in static signal conditions of one GSM-R MS



Remark: this example represents the lowest performances of all measured MS but these results are still compliant to ETSI specification TS 100 910. It should be noted that the majority of GSM-R MS currently in service in Europe follow this specification.

The measurement result of GSM-R MS blocking at the minimum frequency separation was -35 dBm when interfering UMTS900 signal was at 927.6 MHz and the serving cell signal of GSM-R was at level of -101 dBm (924.8 MHz / channel 973). Both signals were static (no fading) for this measurement. Used bit error rate threshold for these measurements were set to be in GSM system scale of transition when reported RxQual changes from 4 to 5. This corresponds to bit error rates of about 3.2% value and this BER value is determined before the radio channel error correction. In practice, this limit is where a call will be dropped.

The measurement result shows that by increasing the GSM-R serving cell signal level, the ability to tolerate interfering UMTS900 base station signal is improved. This improvement ratio is approximately according to the third order with intermodulation distortion theory. If the interfering signal level increases 10 dB, then the interference effect can be compensate by increasing the GSM-R serving cell signal level by 30 dB which is not really realistic.

Measurements showed that only one interfering UMTS signal can cause approximately equal strong blocking effect than two interfering signals together (UMTS + UMTS or UMTS + GSM), if their combined level is equal than only one interfering UMTS signal power.

Operating frequency range of GSM-R MS covers also the whole public 900 MHz networks band. Due to this reason, signals of public networks appear on the receiver of train radio without additional attenuation.

Conclusion: Ispra measurements show that GSM-R MS blocking is a function of composite power in the whole 900 MHz downlink band (925 – 960 MHz). If the group of interferers includes at least one wide band signal, then the probability is high enough to provide this kind of behaviour.

9.2 Probability of blocking interference

In case of strong interfering GSM signals, IM3 can be produced inside the GSM-R MS. Depending on the frequencies used by public operators, the IM3 combination can mask partially or totally the GSM-R wanted emission (see figure 10). The probability that IM3 products will “hit” directly the GSM-R signal is quite low with narrowband GSM signals compared to broadband signals together with GSM signals. In this case, the mitigation technique consists of changing the frequency of the GSM-R serving cell.

But when the interfering signals include one wideband signal such as UMTS or LTE, then the probability is high to have the third order IM product masking a large part of the GSM-R frequency band (see figure 11).

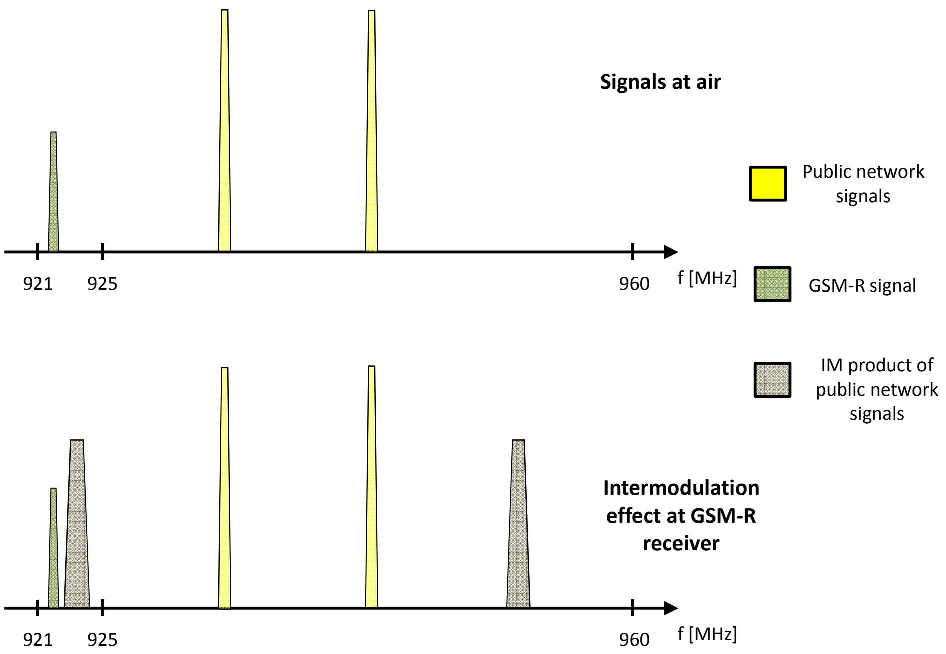


Figure 10: IM modulation distortion example from GSM

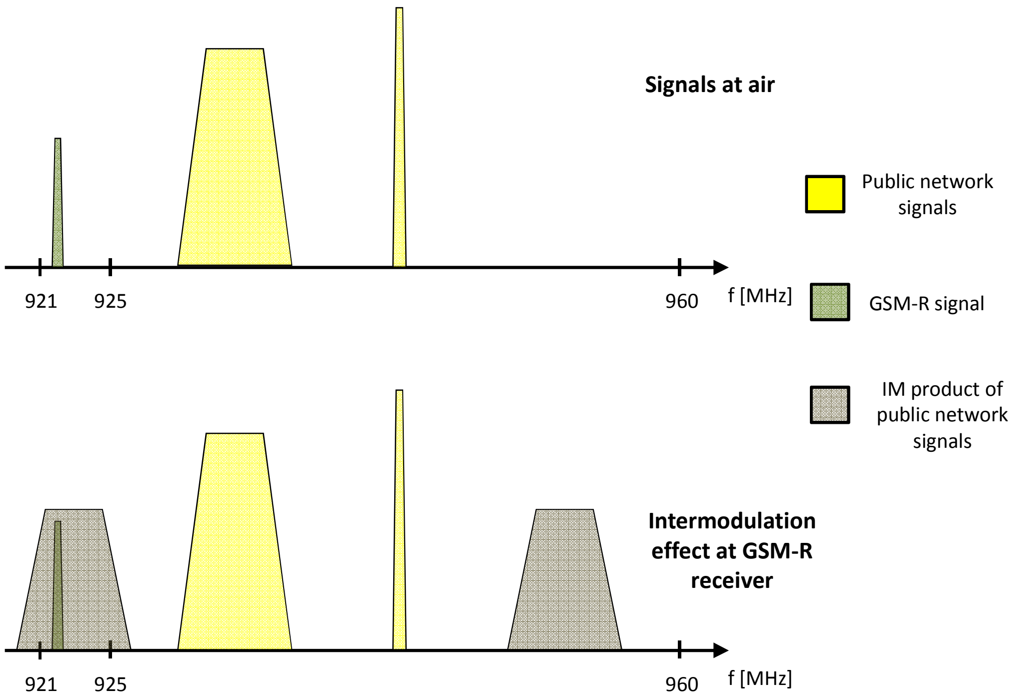


Figure 11: IM modulation example with UMTS and GSM

Conclusion: only one wideband UMTS/LTE increases the risks to have intermodulation inside GSM-R MS receiver. These IM products may mask the GSM-R serving cell.

By increasing the number of UMST/LTE broadband signals, unwanted emissions will increase the noise floor in the GSM-R frequency band which may mask the GSM-R signals.

9.3 Radio channel fading effect

During the UIC ISPRA measurements, the fading effect of the RF signals was also investigated. The measurement results showed that the GSM-R MS blocking capability declined by 2 or 3 dB (for the interfering signal!) depending on used fading profile.

Remark: All measured signal levels are referred to connector of the GSM-R MS. In standard train installation, the antenna is located on the roof-top coupled to MS by a cable. EIRENE specifications define a maximum attenuation of 3 dB for this cable; this value is also used in the calculations in the next chapters.

9.4 Definition of a practical blocking threshold

The following table presents the calculated value of receiver blocking.

Item	Value	Note
Measured blocking threshold for GSM-R train radio (RxQual 4 → 5)	-35 dBm	GSM-R is at level of -101 dBm, interfering signals are assumed to be GSM + UMTS and the blocking threshold is a composite power
Effect of dynamic GSM-R radio path	-3 dB	Train radio tolerates less interferences with dynamic radio path
Loss of train radio antenna feeder	+3 dB	This moves reference point from connector of train radio to rooftop antenna. This also changes the minimum requirement for GSM-R signal field strength from -101 dBm to -98 dBm
Correction to have GSM-R RxQual 5 → 2	-1dB	This value is estimated and needs to be further defined for improving RxQual = 2 as network design level
Threshold for blocking	**-36 dBm**	This level is referred to 0 dBi rooftop antenna (EIRENE ref. point) with GSM-R signal level of -98 dBm

Figure 12: Calculation for train radio blocking threshold

9.5 Blocking rejection filter for GSM-R train radio

The blocking capability of GSM-R MS can be improved by better chipset and/or limiting the operational frequency range of the receiver. For example, an optimized filter characteristic (external or inside the MS) can be used. The external filter have to be connected between the rooftop antenna and the GSM-R MS. Required characteristic of the filter is a deep slope fall within the transition region from pass band to rejection band (around 925 MHz).

In practice it is possible to manufacture an external filter which attenuates signals from the public network base stations of -30 dB at 925.5 MHz with a filter's insertion loss less than 3 dB. This type of filter for GSM-R MS improves the blocking performance even if the UMTS or the 5 MHz LTE operates the lowest frequencies in GSM-E band at 927.6 MHz (center frequency of interfering carrier).

Current EIRENE specification requires that all mobiles shall be capable of operation in the frequency bands 876-915/921-960 MHz. This would mean the rejection filter should be switchable which would increase the complexity of the device.

Note: filter device will not be efficient against unwanted emission using frequency close to GSM-R band.

10 ANNEX 3 - Summary of ECC REPORT 162

CEPT ECC developed a technical report called “ECC Report 162 “ which provides guidance to improve the coexistence between GSM-R and public mobile networks, and describes potential mitigation techniques which may be considered by national administrations and/or operators on both sides to address interference cases between GSM-R and public mobile networks on a local/regional/national basis.

It should be noted that the list of measures is not exhaustive and that additional spectrum engineering techniques may be considered on a case-by-case basis. Applying a single one of the measures may not be sufficient in all cases but rather a combination of methods may be necessary.

In addition preventive methods to avoid interference situations between GSM-R and public mobile networks can be applied on a national/regional basis. Interoperability and continuity of GSM-R service shall be ensured from one country to another one, as well as public operators' licence obligations have to be fulfilled.

This report was accepted in May 2011 and it mainly constitutes a tool box to handle interferences, it also describes preventive options. This preventive option consists of defining (by national administrations) a corridor along the railway tracks, within which coordination would be carried out between the operators (GSM-R and involved public mobile operators) in order to prevent the interferences.

Mitigation techniques can be allocated to railway and public operator’s side. Some of these are more efficient than others and some of these are the consequence of some others. The main target of these mitigation techniques is to reduce power density at the receiver input of the cab radio or to increase GSM-R signal level when it is close to EIRENE minimum requirements. All relevant mitigation techniques based on existing technologies are covered in ECC report 162.

The potential applicable mitigation techniques are divided in the following categories:
a) Deployment related measures,
b) Hardware/Technology related measures,
c) Spectrum related measures,

Deployment related measures	Modification on GSM-R side	Modification on public network side
Increasing GSM-R field strength	**Yes**	
Deployment of additional GSM-R base stations	**Yes**	
Deployment of fixed GSM-R	**Yes**	

repeaters		
Co-location of public mobile network and GSM-R base stations	**Yes**	**Yes**
EIRP reduction from public mobile network		**Yes**
Locating public base station in order to not exceed a maximum power density on railway tracks		**Yes**

Hardware/Technology related measures	**Modification on GSM-R side**	**Modification on public network side**
GSM-R cab-radio improvements:	**Yes**	
Additional filtering in GSM-R terminals	**Yes**	
Replacement of the train mounted radio equipment with a newer generation with a higher overloading threshold	**Yes**	
Improved filters in public mobile network BS transmitters to reduce unwanted emission/ Change of UMTS BS receiver filters (to increase selectivity		**Yes**
Downlink Power Control in public networks		**Yes**

Spectrum related measures	**Impact on GSM-R side**	**Impact on public network side**
Coordinated frequency planning of GSM-R network and public mobile networks	**Yes**	**Yes**
Use of the ER-GSM band	**Yes**	

UIC would like to state that the proposed mitigation techniques are *not optimized for economical aspects or the efficient use of spectrum.*

Therefore the major goal should be to achieve a win-win situation where all the involved parties will be able to fulfil their obligations.

11 ANNEX 4 - UIC Frequency Management Working Group Members

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