ETSI TS 102 902 V1.2.1 (2013-04)

Technical Specification

Electromagnetic compatibility and Radio spectrum matters (ERM); Methods, parameters and test procedures for cognitive interference mitigation towards ER-GSM for use by UHF RFID using Detect-And-Avoid (DAA) or other similar techniques

Reference
RTS/ERM-TG34-21

Keywords
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Foreword

This Technical Specification (TS) has been produced by ETSI Technical Committee Electromagnetic compatibility and Radio spectrum Matters (ERM).

Introduction

In order to accommodate the spectrum needs for the increasing number of RFID devices and systems, an extension band for high power RFID systems in the frequency range between 915 MHz and 921 MHz is under discussion. This band is already used by RFID in several countries worldwide and its availability in Europe would simplify the global movement of tagged goods. In Europe, part of this new frequency band will be shared between the primary user ER-GSM and RFID. In order to guarantee an interference-free coexistence between the two systems, mechanisms have to be implemented on the RFID side to reduce the probability of interference to a minimum. These mechanisms can be regulatory, technical mechanisms or operational restrictions.

The present document proposes a set of these mechanisms which, together with the necessary parameters, will avoid interference with the ER-GSM system in the frequency band 918 MHz to 921 MHz. In addition to the main goal of reducing the potential for interference with ER-GSM, the overall achievable performance of RFID systems should be optimized. The main strategy adopted in the present document has been to split the task into phases with three different time horizons:

- Short term solution for the next 1 to 3 years;
- Mid term solutions for the coming 3 to 6 years; and
- Long term solutions for a stable deployment of RFID systems in the shared bands.

This strategy will allow for the fast implementation of initial systems in the band without having to wait for the full implementation of the final solution. Some of the proposed techniques will be based on software upgrades of existing systems and only the mechanisms for the long term solution will require additional hardware and the implementation of new reader systems. On the other hand the long term solution will use all available mechanisms and procedures and thus will guarantee the best performance.

The values used in the present document are working assumptions and therefore these values have to be verified in practical measurements and adapted to the state of the art technology.

The present document will be complemented by TS 102 903 [i.11], which will include the results of an initial practical evaluation of the proposed mechanisms, and a description of the test procedures necessary for verifying the compliance of RFID devices and systems.

1 Scope

The present document provides the technical specifications for mitigation techniques and procedures for the coexistence of ER-GSM 900 terminals and RFID systems in the frequency range of 918 MHz to 921 MHz.

2 References

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the reference document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found at http://docbox.etsi.org/Reference.

NOTE: While any hyperlinks included in this clause were valid at the time of publication ETSI cannot guarantee their long term validity.

2.1 Normative references

The following referenced documents are necessary for the application of the present document.

[1] ETSI EN 302 208 (all parts) (V1.4.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Radio Frequency Identification Equipment operating in the band 865 MHz to 868 MHz with power levels up to 2 W".

2.2 Informative references

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] TEDDI database.

NOTE: See http://webapp.etsi.org/Teddi/.

[i.2] ISO/IEC 18000-6: "Information technology - Radio frequency identification for item management - Part 6: Parameters for air interface communications at 860 MHz to 960 MHz".

[i.3] ETSI TR 102 649-2: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Technical characteristics of Short Range Devices (SRD) and RFID in the UHF Band; System Reference Document for Radio Frequency Identification (RFID) and SRD equipment; Part 2: Additional spectrum requirements for UHF RFID, non-specific SRDs and specific SRDs".

[i.4] J. D. Jackson: "Classical Electrodynamics", John Wiley, 1975.

[i.5] T. Rappaport: "Wireless Communications", Prentice Hall, 1996.

[i.6] ETSI ERM TG34: "Report: Kolberg Measurements", June 2009 and June 2010.

[i.7] ETSI ERM TG34: ERM-TG34#15-04r1: "ETSI tests at a Distribution Centre", September 2006.

[i.8] CEPT Report 14 (July 2006): "Develop a strategy to improve the effectiveness and flexibility of spectrum availability for Short Range Devices (SRDs) in response to the EU Commission mandate".

[i.9] Study on legal, economic & technical aspects of "Collective Use of Spectrum" in the European Community (November 2006) by order of EU Commission.

[i.10] ERC Recommendation 70-03: "(Tromso 1997 and subsequent amendments) relating to the use of Short Range Devices".

[i.11] ETSI TS 102 903: "Electromagnetic compatibility and radio spectrum matters (ERM); Compliance tests for cognitive interference mitigation for use by UHF RFID using Detect-And-Avoid (DAA) or other similar techniques".

[i.12] Void.

[i.13] ETSI TS 144 018:"Digital cellular telecommunications system (Phase 2+); Mobile radio interface layer 3 specification; Radio Resource Control (RRC) protocol (3GPP TS 44.018)".

[i.14] ETSI TS 145 002: "Digital cellular telecommunications system (Phase 2+); Multiplexing and multiple access on the radio path (3GPP TS 45.002)".

[i.15] EIRENE System Requirements Specification Version 15.1.

[i.16] Decision No 804/2004/EC of the European Parliament and of the Council of 21 April 2004 establishing a Community action programme to promote activities in the field of the protection of the Community's financial interests (Hercule programme).

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

NOTE: Further/other definitions can be found in Terms and Definitions Interactive Database (TEDDI) [i.1].

Cognitive Radio System (CRS): Radio system (optionally including multiple entities and network elements), which has the following capabilities:

- to obtain the knowledge of radio operational environment and established policies and to monitor usage patterns and users' needs;
- to dynamically, autonomously and whenever possible adjust its operational parameters and protocols according to this knowledge in order to achieve predefined objectives, e.g. minimize a loss in performance or increase spectrum efficiency;

and to learn from the results of its actions in order to further improve its performance.

Detect And Avoid (DAA): technology used to protect radio communication services by avoiding co-channel operation

NOTE: Before transmitting, a system senses the channel within its operative bandwidth in order to detect the possible presence of other systems. If another system is detected, the first system should avoid transmission until the detected system disappears.

Downlink (DL): direction from a hierarchic higher network element to the one below, in the case of a typical RFID system direction from the interrogator to tag or from the (E)R-GSM Base Transceiver Station to the terminal

Dynamic Frequency Allocation (DFA): protocol that allows for changing transmit frequency during operation

Dynamic Power Control (DPC): capability that enables the transmitter output power of a device to be adjusted during operation in accordance with its link budget requirements or other conditions

fixed: physically fixed, non- moving device; includes temporary event installations as well

link adaptation: result of applying all of the control mechanisms used in Radio Resource Management to optimize the performance of the radio link

Listen before Talk (LBT): spectrum access protocol requiring a cognitive radio to perform spectrum sensing before transmitting

location awareness: capability that allows a device to determine its location to a defined level of precision

master: controls the radio resource changing actions

mobile: physically moving device

radio environment map: integrated multi-domain database that characterizes the radio environment in which a cognitive radio system finds itself

NOTE: It may contain geographical information, available radio communication services, spectral regulations and policies, and the positions and activities of co-located radios.

Service Level Agreement (SLA): defined level of service agreed between the contractor and the service provider

slave: performs the commanded actions by the Master

Uplink (UL): direction from Slave to Master

white space: label indicating a part of the spectrum, which is available for a radio communication application at a given time in a given geographical area on a non-interfering / non-protected basis with regard to other services with a higher priority on a national basis

3.2 Symbols

For the purposes of the present document, the following symbols apply:

α	Pathloss Exponent in the Friis Equation
dB	decibel
d	distance
f	frequency measured under normal test conditions
fc	centre frequency of carrier transmitted by interrogator
λ	wavelength

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

AM	Amplitude
ARFCN	Absolute Radio Frequency Channel Number
ASCI	Advanced Speech Call Items
BCCH	Broadcast Control Channel
BCH	Broadcast Channel
BSC	Base Station Controller
BTS	Base Transceiver Station
CA	cell allocation
CBCH	Call Broadcast CHannel
CRS	Cognitive Radio System
DAA	Detect and Avoid
DFA	Dynamic Frequency Allocation
DL	DownLink
DPC	Dynamic Power Control
e.r.p.	effective radiated power
EECC	European EPC Competence Center
EM	ElectroMagnetic
ER-GSM	Extended Railways GSM
FM	Frequency
FRS	Functional Requirement Specification
GSM	Global System for Mobile Communication
GSM-R	GSM for Railways
HF	High Frequency
LBT	Listen before Talk
LDC	Low Duty Cycle
LoS	Line-of-Sight
LTE	Long term evolution
MA	mobile allocation

MS	Mobile System
NCC	Network Control Centre
NCH	Notification Channel
NLoS	Non-Line-of-Sight
PM	Phase
PoS	Point of sales system
RACH	Random Access Channel
RF	Radio Frequency
RFID	Radio Frequency Identification
R-GSM	Railway GSM
RSCOM	Radio Spectrum Committee
RSL	Radio Signalling Link
RX	Receiver
SI	System Information
SLA	Service Level Agreement
SRD	Short Range Device
SRS	System Requirement Specification
TCH	Traffic Channel
TDMA	Time Division Multiple Access
TX	Transmitter
UHF	Ultra High Frequency
UIC	Union Internationale des Chemins de fer
UL	UpLink
VBS	Voice Broadcast Service
VGCS	Voice Group Call Service

4 UHF RFID deployment scenario

4.1 Introduction

RFID systems are used in item management, logistics and in a wide range of other applications.

Many of these applications require reading ranges of at least 2 meters, and in certain logistics applications extended ranges from 5 meters to 10 meters. These extended ranges cannot be achieved by alternative technologies and in the existing designated UHF band due to regulatory constraints.

In this clause different deployment scenarios for RFID systems will be described and the need for additional mitigation factors will be considered. After an initial introduction to the proposed frequency plan in clause 4.2 and a general description of the operational principle of an RFID system, the RFID systems will be split into two main categories:

- Static systems, which are fixed RFID read-only systems; and
- Dynamic systems, like portable interrogator systems and RFID interrogators integrated into consumer devices (e.g. Mobile phones, Cameras, etc.).

The two categories should be treated in different ways in order to guarantee the right level of protection towards the potential victim system (ER-GSM).

4.2 Frequency plan

It is proposed to designate spectrum for UHF RFID high performance interrogators as shown in table 1 within the frequency range from 915 MHz to 921 MHz.

This proposal is in accordance with the recommendations of the EC (including RSCOM) [i.9] and of CEPT [i.8], as proposed in TR 102 649-2 [i.3] and the Kolberg Measurements [i.6]. These recommendations promote the co-existence of multiple types of equipment within bands by the use of common technical characteristics.

Table 1: Proposal for high performance RFID interrogators

Frequency bands	Power	Duty cycle	Maximum Channel bandwidth	Notes
Interrogators: 915 MHz to 921 MHz Interrogator centre frequencies f_c 916,3 MHz 917,5 MHz 918,7 MHz 919,9 MHz	≤ 4 W e.r.p. on a single interrogator channel for each individual interrogator	No mandatory limit for transmitter on-time. However interrogators will not be allowed to transmit longer than is necessary to perform the intended operation	f_c ± 200 kHz	Interrogators may operate in any of the four high power channels
Tags: Between 915 MHz to 921 MHz	< -10 dBm e.r.p. per tag		f_c ± 1 000 kHz for tag response	
NOTE: f_c are the carrier frequencies of the interrogators.				

NOTE: Some member states (France, Germany, Italy and The Nederland's) have allocated the band 915 MHz to 918 MHz exclusively for governmental and military use.

Figure 1 shows the current draft proposal for high performance RFID interrogators as in TR 102 649-2 [i.3].

Note that the situation for SRDs will be very different since they occupy the low power channels and their power is limited to 25 mW.

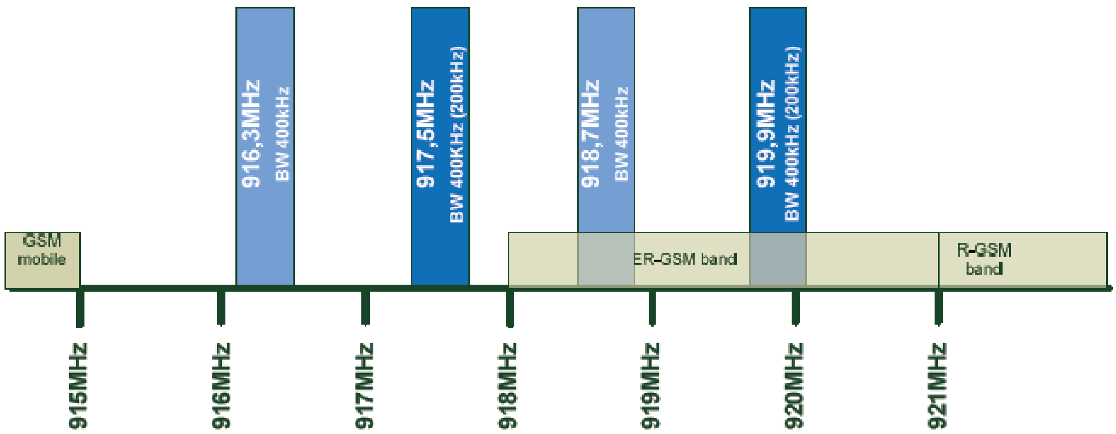


Figure 1: Revised proposal for high performance RFID applications

The Kolberg measurements [i.7] concluded that the following should be considered in the channel plan:

- A 100 kHz carrier offset between RFID and GSM/ER-GSM/R-GSM channels will result in an additional mitigation factor of 9 dB. As GSM/ER-GSM/GSM-R use even multiples of 100 kHz (e.g. 914,8 MHz, 918,2 MHz and 921,2 MHz), RFID should use odd multiples of 100 kHz (e.g. 916,3 MHz).
- A 300 kHz carrier offset between GSM/ER-GSM/GSM-R channels will result in an additional mitigation factor of 55 dB.
- The minimum frequency separation between an ER-GSM/R-GSM carrier and an RFID carrier should be 700 kHz under worst case conditions.

In summary a channel plan should be considered with the first high power channel at a centre frequency of 916,3 MHz and the remaining high power channels spaced at 1,2 MHz. This is depicted in figure 1.

4.3 Basic operational principal of RFID technology

4.3.1 Introduction

A basic RFID system comprises an interrogator with its associated antennas and a collection of tags. The antennas are arranged to transmit their signal within an interrogation zone. Tags are attached to either animate or inanimate objects that are to be identified. When a tag enters an interrogation zone, it is activated by the transmitted signal from the interrogator. Typically the tag will respond by sending its identity and possibly some associated data. The identity and data from the tag is validated by the receiver in the interrogator and passed to its host system. A block diagram of the principle is shown in figure 2.

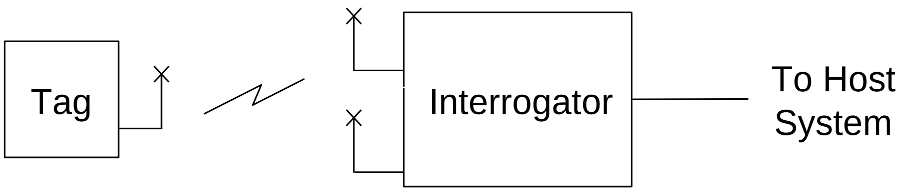


Figure 2: Principle of RFID

A sophisticated protocol is used to handle the transfer of data between the interrogator and tags. This ensures the integrity of data transfer and may include error checking and correction techniques. In addition the protocol handles the process for writing data to the tag and controls the procedure for reading multiple tags that may be present simultaneously within the same interrogation zone.

Across the whole of the radio spectrum three different forms of communication are used for the transfer of information between interrogators and tags. These are:

- Electrostatic.
- Inductive.
- Electromagnetic waves.

The present document confines itself solely to electromagnetic waves and near field techniques since they are the only forms of communication that are relevant for RFID at UHF.

To transfer information between an interrogator and a tag it is necessary to superimpose the data on a carrier wave. This technique is known as modulation. Various schemes are available to perform this function. They each depend on changing one of the primary features of an alternating sinusoidal source in accordance with the transmitted data. The most frequent choices of modulation are Amplitude (AM), Frequency (FM) and Phase (PM).

Tags exist in a range of shapes and sizes to satisfy the particular needs of their intended application. Many tags are passive and derive the power for their operation from the field generated by the interrogator. However some tags are fitted with batteries, which may provide additional features (e.g. sensors) and may enable them to operate at significantly greater ranges.

4.3.2 Characteristics of RFID at UHF

UHF transmission takes place by means of electromagnetic (EM) waves. At these frequencies EM waves have properties that have many similarities to light. Transmissions travel in a straight line and the power of the received signal is a function of the inverse square of the distance from its source. For example if the distance from a transmit antenna is doubled the received power drops to one quarter. This property means that it is possible with UHF systems to achieve significant reading ranges. Operation in the UHF band also makes it possible to transfer information at high data rates. Both of these characteristics make UHF systems well suited for use in applications where tags are moving at speed or in which there are multiple tags present in an interrogation zone.

UHF can present the installer with a number of challenges. Electromagnetic transmissions at UHF are readily reflected from many surfaces. The reflections can cause the activation of unwanted tags and can also give rise to an effect known as standing wave nulls. These can produce points within the interrogation zone where there are very low levels of signal. UHF signals also experience significant levels of attenuation in the presence of water. In applications where water may be present, system integrators must therefore make suitable provision for a reduction in reading range during the design and configuration of the installation.

Operation is also possible using near field coupling between an interrogator and tags. This technique is useful in situations where there are many tags in a confined area and it is necessary to control the transmitted field. Near field systems generate magnetic fields that attenuate in accordance with the inverse cube of distance. Their properties therefore make them useful for reading tags at close range while avoiding activation of tags outside the area of interest. Near field techniques require the use of special antennas that are configured in the shape of a loop. Some tags have antennas that are capable of operating with both EM transmissions and near field coupling.

4.3.2.1 Antennas

At UHF the shape of the interrogation field generated by the EM antennas of an interrogator will typically be in the form of a cone. The angle subtended between the half power (or 3 dB) points of this cone is known as the beamwidth. Often beamwidth is specified in both horizontal and vertical values, which need not necessarily be the same. In many installations the long reading ranges possible at UHF mean that tags outside the wanted interrogation zone are inadvertently activated. The use of antennas with a narrow beamwidth provides one means by which it is possible to limit the area where tags may be read.

The most common type of antenna used at UHF is the patch antenna. This typically has a beamwidth of the order of 70 degrees. The patch antenna is fully satisfactory for many short to medium range applications where there are no other interrogators and unwanted tags in the immediate vicinity. In applications where longer reading ranges are required it may be necessary to control the extent of the interrogation zone more precisely. A first order of improvement may be achieved by using a variant of the standard patch antenna that is physically larger. This makes it possible to produce antennas with a horizontal beamwidth down to 30 degrees. Other types of antenna exist with narrower beamwidths. One of these is the helical antenna, which can have a beamwidth of as little as 10 degrees. This narrow beamwidth makes it possible to generate an interrogation zone that is very directional.

As the beamwidth of an antenna is reduced the transmitted power is compressed into a smaller volume, which produces increased field intensity. This effect is quantified by the term "antenna gain". Since the radio regulations limit the maximum field level that is permitted, it is necessary to reduce the level of power generated by the interrogator to compensate for the increased gain of the antenna. Where the use of different antennas is allowed by the manufacturer, details of how this adjustment should be carried out should be included within the product manual for the interrogator.

Generally transmissions from the antenna of the interrogator will be circularly polarized. This eliminates differences in the reading range of tags caused by their orientation in the x and y planes (but not the z plane, which is the direction of travel of the radio wave).

4.3.2.2 Data Rates

The maximum data rate of the communication link from the interrogator to the tag (sometimes called the downlink) is determined by the size of the permitted channel of operation of the interrogator. The size of the channel is specified in ERC Recommendation 70-03 [i.10] and is effectively a fixed parameter. For channels of 200 kHz channel spacing as defined in annex 11 of ERC Recommendation 70-03 [i.10] the maximum possible data rate is of the order of 40 kbits per second. However the protocol used for transferring the information includes error checking and other features, which reduce the effective speed of information transfer. Details of the agreed standard data rates are included in ISO/IEC 18000-6 [i.2].

In most situations the response from the tag (sometimes called the uplink) will lie in the same, or adjacent channels as the downlink. This will place a practical limit on the achievable data rate. Where interrogators operate in accordance with the 4 channel plan as specified in EN 302 208 [1], the tag may be set to operate at link frequencies of approximately 300 kHz. In such circumstances data rates of 75 kbits per second are achievable.

However EN 302 208 [1] also permits the wanted signal from the tag to occupy the entire designated band from 865 MHz to 868 MHz provided that the levels specified in the spectrum mask are met. For some applications this provides scope for manufacturers to create systems with substantially faster uplinks, which could provide significant benefits. Where this technique is used, system designers must ensure that any transmissions from other nearby interrogators do not block the response from the tag. This implies the need for some form of system planning to manage either the timing of transmissions or the permissible sub-bands of operation.

4.3.2.3 Intermodulation Products

Where two or more devices are sited close to each other and are transmitting at closely spaced frequencies, they may interfere with each other. This can arise through the generation of intermodulation products. These are unwanted emissions that occur at frequencies that are at multiples of the sums and differences of the transmitting frequencies. Intermodulation products can adversely affect the performance of both interrogators and tags.

The effect of intermodulation products may be reduced to an acceptable level by reducing the power received from adjacent transmitters. This may be achieved either by the introduction of shielding or by increasing the physical separation between transmitters. As a general guide for acceptable operation the power received by an interrogator or tag from an adjacent transmitter should be at least 20 dB less than the power received from the wanted transmission.

An alternative mitigation technique is to arrange for adjacent transmitters to operate on different channels. The frequencies must be sufficiently spaced apart that any intermodulation products do not degrade the performance of the device. From practical tests and measurements it has been determined that for adjacent interrogators and their tags to operate satisfactorily, the frequency separation between them should be at least 1 MHz.

4.3.2.4 De-tuning and absorption

The proximity of certain materials to UHF tags may cause a significant reduction in their reading range. This effect is due predominantly to de-tuning of the resonant frequency of the tag. Spacing the tag a small distance away from the material can significantly reduce this effect. However the application may impose a restriction on the extent to which spacing is acceptable. Alternatively where the material to be tagged is known in advance, it may be possible to adjust the tuning of the tag to compensate. Nevertheless recovery of the full free space reading range is unlikely to be achieved. This difference is due to power absorption by the material.

In situations where an electromagnetic wave meets a boundary between two dissimilar materials, some of the energy is reflected at the surface and some of the energy passes into the material. The proportion of the energy that passes into the material is a function of its physical properties (known as its dielectric constant). This process is repeated at each boundary between two dissimilar materials.

Where a tag is read through an object the consequent reduction in the level of signal reaching the tag will reduce its reading range. Some indication of the scale of reduction in reading range caused by different materials is given in table 1. The figures in the table are based on some informal tests and are illustrative only.

Table 2: Typical effect of materials on performance

Scenario	Reference Distance (cm)	Range (cm)	(R/Rref)**2	Loss dB
Air	200	200	1,00	0,00
Tag on front of plastic case	200	180	1,23	0,90
Tag on front of plywood sheet	200	131	2,33	3,68
Tag on front of wood block 2,5 cm deep	200	120	2,78	4,44
Tag on front of paper 3 cm thick	200	108	3,43	5,35
Tag on front of empty plastic jug	200	149	1,80	2,56
Tag on rear of empty plastic jug	200	138	2,10	3,22
Tag on front of plastic jug filled with tap water	200	46	18,90	12,77
Tag on rear of plastic jug filled with tap water	200	31	41,62	16,19
Tag behind metal mesh 10 x 10 cm	200	28	51,02	17,08
Tag behind metal mesh 1 x 1 m	200	10	400,00	26,02
NOTE: For the purpose of making these measurements the transmit level from the interrogator was set to a constant value.				

An associated effect, which can also reduce the reading range of a tag, is its proximity and orientation with respect to other adjacent tags. The effect is greatest where tags are parallel with each other since this produces the highest level of mistuning and absorption. A similar situation arises where a second tag is positioned a short distance behind the first one and in line with the transmission path from an interrogator. The tag nearest to the interrogator creates a "shadow", which reduces the field available to power the tag that is further away.

It is important for end-users to understand and assess the impact of all of the above effects on their application.

In applications in which near field techniques are used the above effects will be significantly reduced.

4.3.2.5 Shielding

A particular difficulty with systems operating at UHF is that the EM signal transmitted by an antenna may extend over a significant distance. Situations may therefore arise where tags outside the wanted interrogation zone may inadvertently be activated. The responses from these unwanted tags may be read by the interrogator and passed to its host. It is important for installers to be aware of this problem and ensure that the size of the interrogation field is the minimum necessary and does not extend into areas that may contain unwanted tags. This requirement may create particular difficulties in situations where adjacent interrogation zones and storage areas are physically close to each other. One technique that may be used to contain the interrogation zone is shielding. There are two possible approaches, which are:

- Reflection of the transmitted signal.
- Absorption of the transmitted signal.

The reflective approach involves placing an electrically conductive surface in the path of the transmitted signal. The radio signal is unable to pass through the conductive surface but instead is reflected off it in a similar manner to light reflected by a mirror. While this stops the transmitted signal from passing into the unwanted area, consideration must be given to the path of the reflected signal. Since very little power is dissipated in the reflection process, the reflected signal may bounce off yet further surfaces and end up in unwanted areas. It has also to be remembered that reflections may create holes in the field (due to standing wave nulls), which may prevent the activation of wanted tags. Not all situations are therefore amenable to the use of reflective materials.

Materials with good properties of electromagnetic absorption may assist in overcoming the problems of unwanted reflections. As the transmitted signal passes into the absorptive material its energy is largely dissipated. What energy remains either passes through the material or is reflected by it to emerge at much reduced levels. If electromagnetic absorption materials are used, it is important that the material selected is of the correct thickness and suitable for the intended frequency. Materials with phase shifting properties may also provide a means to reduce field levels but they should be used with great care. Correctly applied, EM absorbent materials will help overcome the problem of reading unwanted tags outside the interrogation zone. The reduced reflections will also lower the ambient signal level within the installation, which will assist the operation of multiple interrogators.

Reflective materials have the advantage that they are low cost. A thin metal sheet works well although it is also possible to achieve a very acceptable performance using wire mesh materials. Absorption materials are significantly more expensive and less robust. Furthermore in outdoor applications it may be necessary to protect them from the environment, which may reduce their efficiency. However in situations where the presence of reflected waves is not acceptable, absorption materials may provide the most satisfactory technical solution.

4.3.2.6 Transparent materials

Transparent materials permit radio frequency waves to pass through them at the frequency of interest with very low loss. An example of where transparent materials can perform an important role is as a means of physical protection. This may be particularly relevant in the case of antennas and EM absorbent materials, which may be exposed to the elements and to possible physical damage. Note that if a transparent material is permanently mounted in front of an antenna, it may be beneficial to increase the power supplied to the antenna to compensate for any loss through the transparent material.

4.4 Static deployment scenario

4.4.1 Overview

In this clause the main deployment scenarios for RFID interrogator systems will be described, where the interrogator is installed in a fixed position and cannot be easily moved. The present document principally addresses these static scenarios within the frequency band of interest.

Each scenario will be analysed in terms of its interference potential to ER-GSM systems and the possible inherent mitigation factors.

4.4.2 RFID equipped portal system

The portal or dock door application represents a standard portal /dock door encountered in goods warehouses. Products are usually manually pushed through the portal in plastic trolleys, pulled through on over-head rails, or moved in cartons on pallets by a fork lift or a hand jack. The goods typically will be either stacked (packed in cartons), or, in the case of overhead rails, individually suspended.

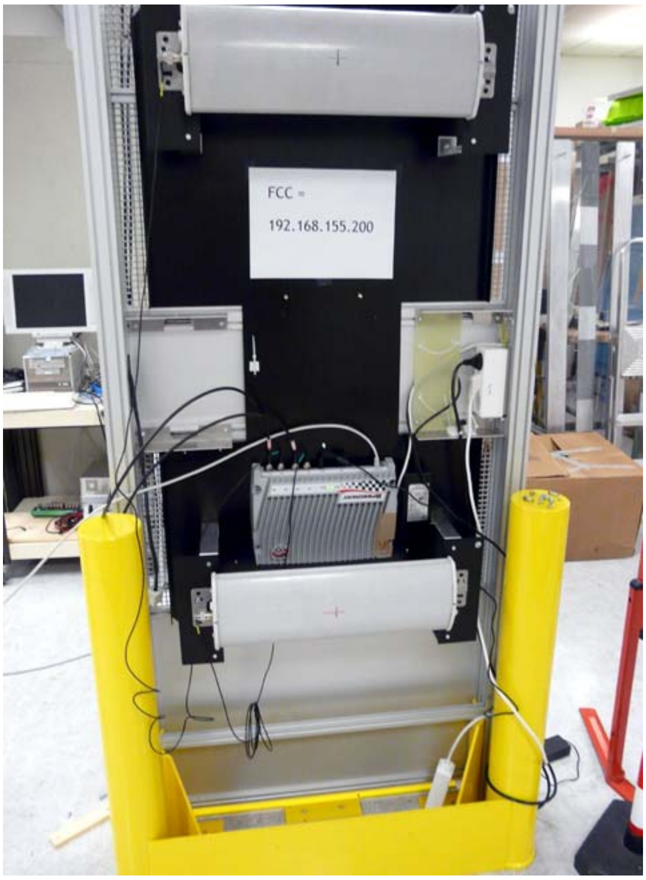


Figure 3: Dock door for testing (one side of dock door shown)

A portal frame is constructed with 1 or 2 antennas mounted each side of the interrogator. The antennas are mounted horizontally. The separation between two portals monitoring a dock door is typically 330 cm. An example of a single portal frame using two antennas is shown in figure 3.

red: Loading gate for trucks.
blue: Railway (Neuss - Köln via Dormagen).

Figure 4: Loading gate position in relation to R-GSM equipped rail way track (Metro EECC Neuss, Germany)

Figure 4 shows a typical case where a RFID portal system might be installed. Here a distribution centre with loading bays for trucks and nearby railway lines is depicted. It can be seen that the interrogators would be positioned at distance of at least 50 m from the railway tracks.

The example in figure 4 clearly represents a worst case situation for potential interference to an ER-GSM terminal. Here the interrogators are quasi outdoor and might be positioned very close to railway tracks using ER-GSM terminals.

4.4.3 Packing table

The packing table application is designed to represent the pick and pack process in a warehouse. Items are picked from storage locations and placed into cartons in accordance with order sheets.

The packing is done at a table and is the one time where multiple tags at item level shall be read as they are placed into the cartons on the packing table. This is because tags associated with individual items are automatically correlated with the RFID shipping label attached to each carton.

Figure 5: Typical use case of a RFID equipped packaging table

A typical example of this scenario is shown in figure 5 where deployment is restricted to indoor use only. In this scenario an additional mitigation factor of at least 20 dB can be assumed due to wall attenuation and the antenna directivity (the main field radiates vertically). A further mitigation factor in this scenario is the use of a specific antenna configuration and a reduction in radiated power, leading to an additional mitigation factor of around 10 dB to 15 dB.

It can be assumed that a Non-Line-of-Sight (NLoS) propagation path between the interfering RFID system and the potential outdoor victim systems will exist. The overall additional mitigation factor for this application is thus in the range of 30 dB.

4.4.4 Point of sales system (PoS)

The point of sales application is designed to represent the sales process at a sales desk in a shop store. Typically up to five items (usually one at a time as often the security tag must be removed) will be swept across the PoS table. In some applications all 5 items may simultaneously be swept across the table, or alternatively placed on the table. In such a situation the tags could be closely coupled.

Figure 6: Typical PoS table with RFID readers

Figure 6 shows a typical PoS table fitted with an RFID interrogator. Operation is limited to indoor use, which implies an additional mitigation factor due to wall attenuation and N-LoS (near line of sight) conditions of at least 20 dB. Additional mitigation techniques can be implemented here, due to the requirements for a short reading distance. Antenna design using near field antenna techniques could be a very efficient means of increasing mitigation. The typical antenna gain of such antennas is in the order of -10 dBi and -15 dBi in the direction of the main beam. A typical polar diagram of such an antenna is given in figure 7. Taking into account the upwards direction of the transmission, an additional mitigation factor of 10 dB can be added, leading to an overall mitigation factor of around 25 dB as compared to a portal system.

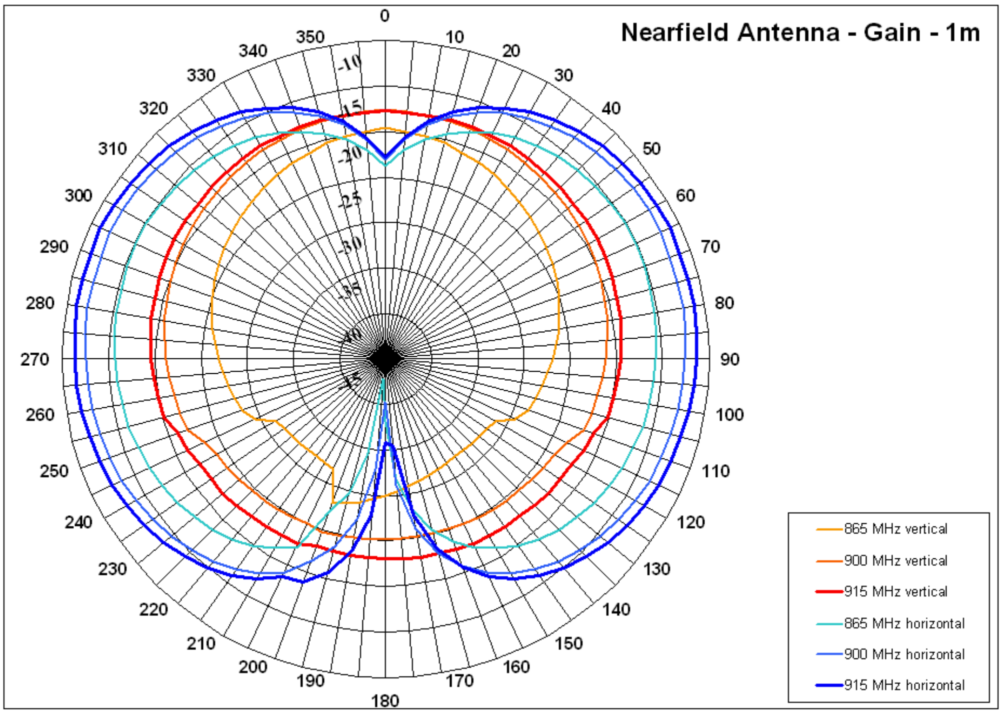


Figure 7: Measured antenna diagram of an antenna used in PoS and packaging applications

4.4.5 Industrial applications

RFID has been used in industrial environments for more than 20 years. It is used in many automation applications and provides benefits in flexible production, documentation, traceability and logistics.

While HF based systems were very common in the past, there is a growing demand for UHF solutions due to the many advantages offered by the technology. With lower cost transponders it has become possible to tag individual items during manufacture, monitor the material flow to the customer and verify correct procedures during each assembly phase. Also, the increased reading range and the availability of very small antennas are additional reasons for using UHF in production plants.

It is not uncommon at a production site for at least 500 interrogators to be in operation at each production stage. Frequently these interrogators will both read and write to the transponders. However, the interrogators rarely operate at the maximum permitted output power. Because of the relatively small reading ranges (e. g. < 1 m), a transmit power of 0,5 W e.r.p. is often sufficient. This contributes significantly to interoperability in a setup with a very high density of readers. Triggering is also used to minimize the interference level and frequency planning is often necessary to avoid interference between interrogators.

Industrial applications are very demanding in terms of reading reliability. Failure to read a tag or the need for multiple read attempts is usually unacceptable since it may lead to long delays in the process. Such events always initiate a requirement for manual override. This is undesirable because production has to be stopped to investigate the cause, which in turn creates additional cost. If spectrum is to be shared with a primary user, the impact on operational reliability will require careful consideration.

The presence of metal is very common in many industrial applications. This is often found next to industrial equipment for reasons of safety or noise reduction. Sheets of metal can act as large reflectors for UHF signals creating interference and standing wave nulls. One method to reduce these effects is by the use of frequency hopping over a large frequency band. The availability of spectrum in addition to the current band will help to solve this problem.

Figure 8: Industrial application: assembly line requiring very small read range

Figure 9: Typical production scenario in automotive industry with read range 1 metre to 2 metres

4.5 Dynamic deployment scenario

4.5.1 Introduction

Besides the fixed RFID systems at UHF presented in the preceding clause, portable and mobile applications are also used. These applications normally operate at a much lower duty cycle and require less TX power.

One specific issue for portable and mobile readers is that they might move from one regulatory region to another. This would be the case for systems used on trucks, ships and in planes. Here specific implementation will be necessary to avoid any conflicts.

Some examples are given in the following clauses.

4.5.2 Hand held readers

Unlike fixed interrogators, the location of handheld readers within a site is indeterminate and furthermore they may be pointed in any direction. Another characteristic is that in many applications handheld readers will be used only intermittently. For example where it is necessary to read only a single tag, the interrogation time will be significantly less than the physical handling time. In such situations a duty cycle limit of 10 % in one hour may well be operationally acceptable. The TX power of these devices is normally below 500 mW e.r.p.

Not all applications using handheld readers will lend themselves to this approach. For example situations may arise where the operator wishes to scan a large number of tagged items - such as collections of tagged clothes on display racks. In this situation a duty cycle restriction of 10 % in one hour may be unacceptable. Under some critical conditions other mitigation factors and techniques might be necessary.

The additional mitigation factors in this case are:

- low power TX (< 500 mW e.r.p.);
- low duty cycle below 10 %;
- mainly indoor applications.

4.5.3 Vehicle mounted readers

Vehicle mounted readers have characteristics that are very similar to handheld readers. Typically the readers will be mounted on forklift trucks, which are operated anywhere on a site and with their antennas pointing in any direction. In order to avoid interference with other interrogators and the primary users of the band, it may be necessary to implement additional mitigation techniques. This is an acceptable constraint since the operation of vehicle mounted readers is (within reason) not time critical. Also the required duty cycle is typically less than 1 % since the transported goods remain on the forklift truck for a long time relative to the time required to identify them at the collection point.

When pallets are picked up by a forklift truck, in addition to reading the wanted tags, the vehicle mounted reader may read a large number of unwanted tags from goods that are in close proximity. By performing a number of interrogations while the truck is moving, it should be possible to eliminate the unwanted tag reads.

In many applications vehicle mounted readers may have to read tags mounted on RF unfriendly materials, which are in sub-optimal orientations, under tight spatial restrictions. To achieve acceptable performance vehicle mounted readers may frequently have to transmit at power levels up to 2 W e.r.p.

There are some applications where vehicle mounted readers operate over a very limited range. In such cases acceptable performance may be achieved at power levels below 500 mW e.r.p.

Vehicle mounted readers have the potential to transmit directly into the antennas of fixed interrogators and even towards the antennas of primary users of the band that are installed on the same site or operated nearby. Consideration should be given to the risk of physical damage to electronic components that might occur under such conditions.

The beamwidth of antennas fitted to forklift trucks will be determined by the requirements of each application.

The additional mitigation factors in this case are:

- mostly low power TX (< 500 mW e.r.p.);
- low duty cycle below 10 % and mostly below 1 %.

5 ER-GSM 900 system deployment scenario and protection criteria

5.1 Introduction

Germany began deployment of GSM-R in 2002. Today Germany is the country in Europe with the biggest GSM-R network in operation. At least 24 000 km of tracks are equipped with GSM-R. In contrast to public mobile GSM, GSM-R constitutes a non-public network of the European Railways. GSM-R radio networks serve exclusively the operational communication needs of railway companies. GSM-R supports safety-related services for train-network management by command and control of trains at speeds up to 500 km/h (voice and data) as well as corresponding speech communications.

5.2 Frequency plan

In CEPT countries, the frequency ranges 880 MHz to 915 MHz (uplink) and 925 MHz to 960 MHz (downlink) are allocated to mobile GSM services. The frequency ranges 876 MHz to 880 MHz (uplink) and 921 MHz to 925 MHz (downlink) are harmonized within CEPT for the purpose of operational communication of railway companies (GSM-R). In addition, the frequency ranges 873 MHz to 876 MHz (uplink) and 918 MHz to 921 MHz (downlink) may be used within CEPT as extension bands for GSM-R. In Germany these extension bands are already licensed to Deutsche Bahn AG. Currently Deutsche Bahn AG is the only company that has requested the extended bands for railway operation. Several other European countries have also announced their interest in applying for a license to operate in the extension bands although there are some countries that currently have no plans to use them.

5.3 Basic operational principle

Compared to public GSM networks, railway radios have to fulfil tighter requirements. The latest minimum performance requirements for railway radio services using GSM-R networks are defined in UIC EIRENE [i.15] FRS V7 and SRS V15. The specified probability for minimum coverage is defined as a probability value of at least 95 % for any length of 100 m of track for which the measured signal level shall be greater than or equal to the reference value of -95 dBm / -98 dBm depending on the speed of trains. In contrast public GSM networks are evaluated at uncorrelated locations and the 95 % criteria is averaged over all possible locations The GSM-R air-interface itself is fully radio-compatible with the GSM standard. Within the upper layers there are some additional functions like ASCI (advanced speech call items) with call arbitration and pre-emption. In contrast to public mobile radio networks, the GSM-R network permits point to multipoint calls.

5.4 Signal Formats

In this clause typical signal formats for an ER-GSM terminal and base station will be presented. This information will be used for the development of appropriate test cases for the conformance tests of RFID systems. The signal formats can be split mainly into two categories:

- Downlink (DL) signals from the Base Station; and
- Uplink (UL) signals from the terminals.

The basic burst structure of an ER-GSM signal is identical to the signal formats of a public GSM system.

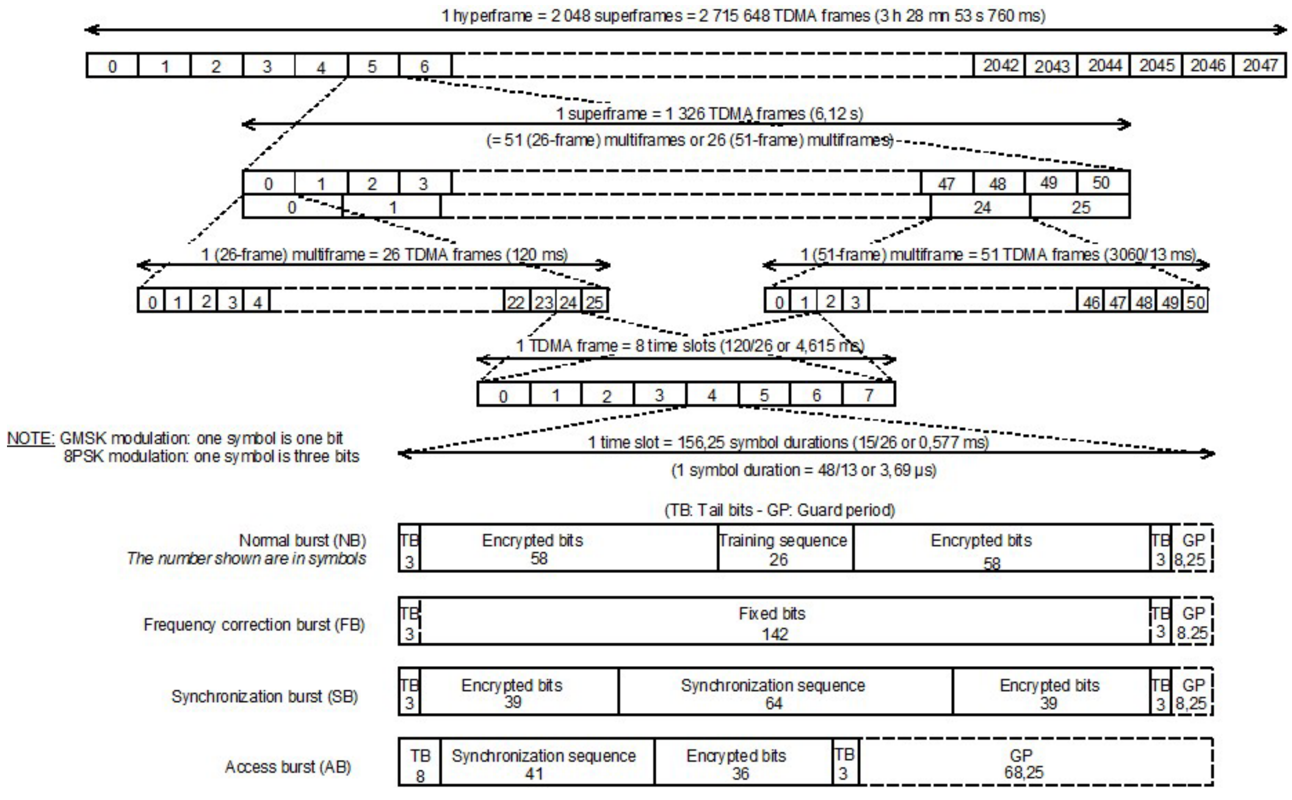


Figure 10: Overall Burst structure of a GSM System

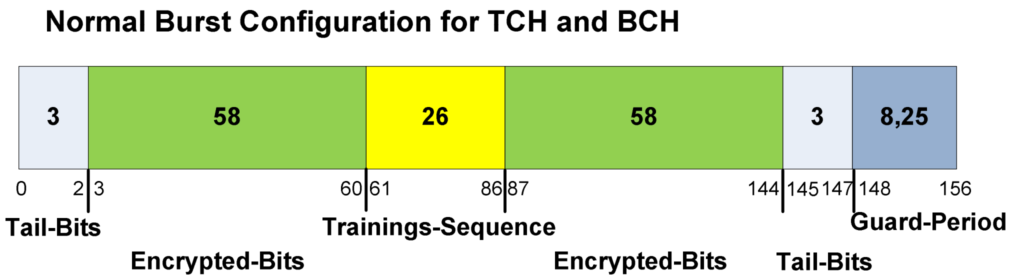


Figure 11: Burst structure of Normal Burst TCH and BCH

Configuration of Training Sequence for Normal Burst

Training SequenceCode (TSC)	Training sequence bits(BN61, BN62 .. N86)
0	(0,0,1,0,0,1,0,1,1,1,0,0,0,0,1,0,0,0,1,0,0,1,0,1,1,1)
1	(0,0,1,0,1,1,0,1,1,1,0,1,1,1,1,0,0,0,1,0,1,1,0,1,1,1)
2	(0,1,0,0,0,0,1,1,1,0,1,1,1,0,1,0,0,1,0,0,0,0,1,1,1,0)
3	(0,1,0,0,0,1,1,1,1,0,1,1,0,1,0,0,0,1,0,0,0,1,1,1,1,0)
4	(0,0,0,1,1,0,1,0,1,1,1,0,0,1,0,0,0,0,0,1,1,0,1,0,1,1)
5	(0,1,0,0,1,1,1,0,1,0,1,1,0,0,0,0,0,1,0,0,1,1,1,0,1,0)
6	(1,0,1,0,0,1,1,1,1,1,0,1,1,0,0,0,1,0,1,0,0,1,1,1,1,1)
7	(1,1,1,0,1,1,1,1,0,0,0,1,0,0,1,0,1,1,1,0,1,1,1,1,0,0)

Figure 12: Training Sequences in a Normal Burst

5.5 Information contained in the BCCH

The BCCH contains a number of mandatory and optional broadcast messages called SYSTEM INFORMATION. The content of those messages is generated inside the BSC based on operator-specific configuration and then forwarded once at boot time to the BTS inside the Radio Signalling Link (RSL) BCCH INFORMATION messages. The content is generated by the BSC and intended for the MS, the BTS simply schedules transmission of those messages on the radio interface.

According to TS 144 018 [i.13], the Layer3 content of the basic and most important SYSTEM INFORMATION messages can be described as follows:

Table 3: SYSTEM INFORMATION description

SYSTEM INFORMATON type	Clause of TS 144 018 [i.13]	Payload
1	9.1.31	Cell Channel Description, RACH Control Parameters, SI 1 Rest Octets
2	9.1.32	BCCH Frequency List, NCC Permitted, RACH Control Parameters
3	9.1.35	Cell Identity, Location Area Identification, Control Channel Description, Cell Options, Cell Selection Parameters, RACH Control Parameters
4	9.1.36	Location Area Identification, Cell Selection Parameters, RACH Control Parameters, CBCH Channel Description (optional), CBCH Mobile allocation (optional)

Each cell serves 1 to N number of radio channels. The list of those channels is known as Cell Allocation, as defined by TS 145 002 [i.14], clause 4.2.1:

> *Each cell is allocated a subset of these channels, defined as the cell allocation (CA). One radiofrequency channel of the cell allocation shall be used to carry synchronization information and the BCCH, this shall be known as BCCH carrier. The subset of the cell allocation, allocated to a particular mobile, shall be known as the mobile allocation (MA).*

This Cell Allocation is contained in the Cell Channel Description information element inside the SYSTEM INFORMATION 1 message. Its content and formatting is described in TS 144 018 [i.13], clause 10.5.2.1b, where it is described as:

The purpose of the Cell Channel Description information element is to provide the reference frequency list to be used to decode the mobile allocation information element.

The mobile allocation information element (TS 144 018 [i.13], clause 10.5.2.21) in turn is described as:

The purpose of the Mobile Allocation information element is to provide that part of the RF channels belonging to the cell allocation (coded with a "1" in the cell channel description information element) which is used in the mobile hopping sequence.

As such, the mobile allocation is only used in radio channel assignments (IMMEDIATE ASSINGMENT, ASSIGNMENT COMMAND) of frequency-hopping GSM channels. This in turn means that the Cell Channel Description is technically only required in networks that employ frequency-hopping.

TS 144 018 [i.13], clause 9.1.31 lists the Cell Channel Description as a mandatory field, no matter if frequency hopping is ever used or not. However, it could be argued that the information element must be present but could be an empty list, as long as the network never allocates frequency-hopping dedicated channels.

The mapping, i.e. which SYSTEM INFORMATION types are to be sent at which TDMA frames within the BCCH is defined in TS 145 002 [i.14], clause 6.3.1.3. This specification states:

System Information Type 1 need only be sent if frequency hopping is in use or when the NCH is present in a cell.

R-GSM networks normally do not use hopping (yet), so they would not be required to send the SYSTEM INFORMATION 1. However, R-GSM uses ASCI, which in turn require the use of VBS / VGCS. Both VBS and VGCS are impossible to use without a NCH 15, and a NCH cannot be used without SYSTEM INFORMATION 1, as the position of the NCH in the multiplex is described by the SI 1 Rest Octets 16 present at the end of SYSTEM INFORMATION 1.

As a summary, it can be derived from the GSM specifications, that:

- any GSM-R network has to use a NCH (notification channel).
- the use of a NCH requires the presence of SYSTEM INFORMATION 1.
- SYSTEM INFORMATION 1 has a mandatory Cell Channel Description IE.
- The Cell Channel Description contains a list of all ARFCN that the cell might ever use in a Mobile Allocation
- This List may be empty in a network that never uses frequency hopping, but in practice is always populated by the BSC in real-world GSM networks.

All information present on the BCCH can be received and decoded with a purely passive receiver. No transmission capabilities on the GSM uplink are required.

5.6 Deployment scenarios

From a deployment point of view, GSM-R has an almost linear topology along railway tracks. The initial systems using the ER-GSM frequency band (918 MHz and 921 MHz) will be deployed in dense areas with a large number of railway tracks as extensions to existing R-GSM installations. In this application the BCCH will be transmitted in the R-GSM bands and additional TCH will only be allocated to the ER-GSM bands on an as-required basis. Typical areas of use are shunting yards with very high traffic and terminal deployment density. A typical shunting yard is depicted in figure 13. In Germany around 30 of these large shunting yards exist but this number will decrease in the future. Other installations using ER-GSM will be at large railway stations and in the corresponding surrounding area, like in Frankfurt.

The ER-GSM systems deployed in these areas will provide increased capacity for the overall R-GSM system. Thus the main goal of the ER-GSM deployment will not be to increase coverage but to increase capacity at a limited number of sites. An ER-GSM system will not operate in a noise limited environment but rather where the band is heavily utilized. In such situations the typical RX power at all points on the site will be well above the absolute sensitivity limit of the equipment. This scenario was investigated in the Kolberg tests as cell edge measurements using a RX signal level of -86 dBm at the ER-GSM terminal. This value should be taken into account during calculation of the required mitigation distances and thresholds.

It can be assumed that the present R-GSM frequencies are sufficient for existing services in rural environments for normal railway tracks. In the future possible extensions of the service in rural areas might require use of the new ER-GSM frequencies.

Figure 13: Shunting area near Mannheim, Germany

A typical R-GSM base station is shown in figure 14.

NOTE: See http://de.wikipedia.org.

Figure 14: Typical R-GSM transceiver antenna at the Nuremberg-Ingolstadt high-speed railway line (S. Terfloth)

5.7 Summary

It is reasonable to assume that during the initial introductory phase of ER-GSM, the system will be used to extend the capacity of the existing R-GSM system. This means that the BCCH will be allocated in R-GSM bands and a TCH will only be allocated to ER-GSM when required. At a later stage BCCHs might be allocated to the ER-GSM bands.

The characteristics of BCCH and TCH channels need to be taken into account when considering the proposed detection process. A BCCH transmission is continuous, whereas a TCH transmission is intermittent. The detection of a TCH in the DL might be more difficult, but the interference potential is also smaller since the call setup will be handled using the BCCH in the R-GSM bands. Where a TCH only is allocated, time sharing will be possible based on fast detection of the transmission. However time sharing will not be possible where a BCCH is allocated in the ER-GSM band since in this situation a continuous protection of the BCCH has to be guaranteed.

6 Mitigation techniques

6.1 Introduction

In this clause a set of possible mitigation techniques will be presented for use in a future RFID system deployed in the band 915 MHz to 921 MHz. The techniques can be split firstly into regulatory methods like site licensing, and secondly dynamic mitigation techniques. The latter rely on monitoring of the environment at the RFID system and taking appropriate action in the event that a potential victim is detected in the immediate vicinity.

In the short term regulatory methods can be used in order to allow operators of RFID systems a simple way to use the new band (915 MHz to 921 MHz). In particular the band 915 MHz to 918 MHz will be of special interest since suitable RFID channel planning will give interference free operation in two channels. In the mid-term and long-term active mitigation techniques should be implemented in RFID systems. This will permit more flexible deployment across all of the new band without adding interference risks to potential victim systems sharing the band.

Both fast and slow dynamic mitigation techniques are possible. An active slow spectrum monitoring process will perform an update once per day. The slow process will recognize the deployment areas of the victim service by identifying any traffic in the DL such as detection of the BCCH in the R-GSM and ER-GSM bands. By decoding the channel allocations contained in the System Information, it will be possible for interrogators to avoid operation in channels that might interfere with E-GSM-R.

In the case of the fast monitoring technique, the RFID system would monitor the spectrum and share it based on the actual usage. This will require a monitoring process with a response time of below a second. The identification of a BCCH in the R-GSM DL will need to be complemented by detection and identification of a TCH in the ER-GSM band. However, the detection of a BCCH in the ER-GSM DL band will lead to the avoidance of specific ER-GSM DL channels by RFID systems.

Evaluation of the involved systems and result in the following options for RFID operation:

- For operation in the 865 MHz to 868 MHz band, with the defined duty cycle specified in EN 302 208 [1] applies.
- In case of the 915 MHz to 921 MHz band, a site license for specified channels as defined in Table 1 and Figure 1 may be acquired from the national administration for a particular site.
- In general the use of the 915 MHz to 921 MHz band may be handled in three ways, which means 3 interrogator categories:
    - **Category 1** interrogators only use the 915 MHz to 918 MHz band and therefore do not require a mitigation method in respect to GSM-R as there is no overlap with the ER-GSM band.
    - **Category 2** interrogators use the 915 MHz to 918 MHz band without restrictions and apply downlink detection for the 918 MHz to 921 MHz band. Downlink detection is a geographic sharing method that performs detection of a service area and avoids those parts of the band that may be used by an E-GSM-R installation either permanently or from time to time.
    - **Category 3** interrogators principally operate in the same way as Category 2 interrogators. In addition they monitor those channels in the ER-GSM UL band from 873 MHz to 876 MHz whose paired channel have been identified for GSM-R use by DL detection in the 918 MHz to 921 MHz band. If there is no E-GSM-R terminal operating in the respective channel of the ER-GSM band then the RFID system may use the unoccupied channel. However, as soon as an uplink communication is detected then the RFID system shall stop operation in the respective channels. This method is called uplink detection and relies on the detection of a victim terminal. The combination of downlink and uplink detection results in a more effective geographic and time sharing method.

Figure 15 shows an overview about the possibilities to use UHF RFID.

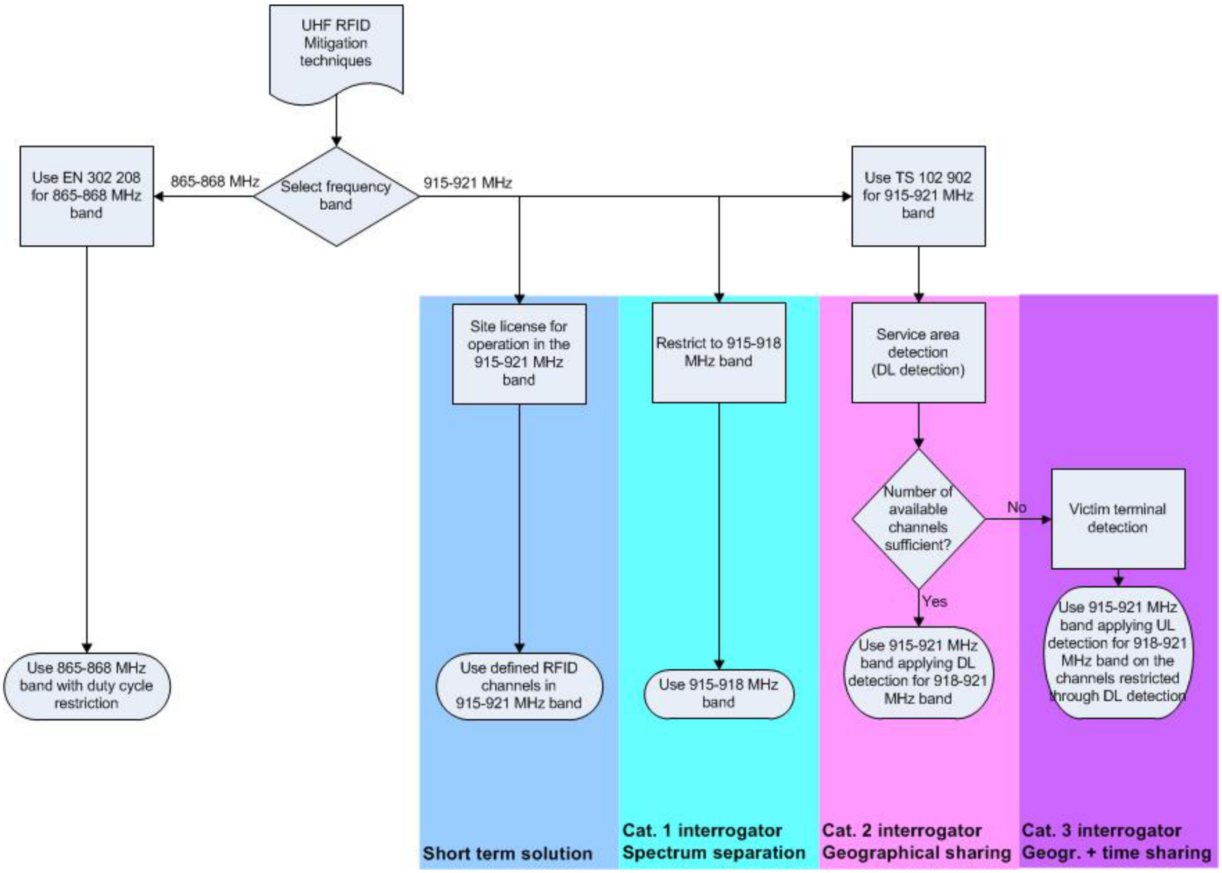


Figure 15: Short term and midterm solution for the sharing in the band 918 MHz to 921 MHz

Category 1 interrogators shall be limited to the 915-918 MHz band, while Category 2 and Category 3 interrogators may operate in the full 915-921 MHz band.

6.2 Site licensing

In order to allow rapid occupation of the new band, a user can acquire a temporary license for the installation of an RFID system at a specific site. Typically these site licenses have to be renewed every year. In general they are intended for experimental use only.

A site license is an individual license limited to a single installation at a single location. It does not guarantee long-term availability of the frequency. In the case where the license would be restricted to the interference free band 915 MHz to 918 MHz, it would probably be possible to extend the duration.

The site licenses are issued by national regulators.

6.3 Service area detection (DL detection)

Service area detection is based on the detection of signals from ER-GSM base station where, in order to provide flexibility in band sharing between ER-GSM and RFID, interrogators will scan the ER-GSM and R-GSM bands for BCCH and TCH downlink channels. Depending on the situation different sharing options are possible. In the case of the allocation of a BCCH in the ER-GSM band, this channel will need to be protected on a long-term basis since it has to be available continuously. In the case of a TCH allocation in the ER-GSM band, protection of the channel is only necessary short term, leading to a more dynamic avoidance approach. In this situation the TCH is only used intermittently and the call set-up is performed using a BCCH in the R-GSM bands. The latter is described in clause 6.4.

The process of scanning for carriers with BCCH or TCH channels will take place on start-up of an interrogator prior to any RFID communication on the transmit channels between 918 MHz to 921 MHz. Thereafter, assuming the interrogator is switched on continuously, BCCH channel scanning will be repeated at least once every 24 hours. The detection threshold shall be -98 dBm at the centre frequency of each of the ER-GSM or R-GSM channels.

The RFID interrogator shall scan the whole of the (E)R-GSM downlink band and receive signals from the BCCH channels. The RFID interrogator shall successfully receive and decode every BCCH transmission identified in that spectrum. The message of relevance within the Broadcast Channel is the SYSTEM INFORMATION TYPE 1 (See clause 9.1.31 of TS 144 018 [i.13]) message containing the Cell Channel Description IE.

From the received information corresponding to the BCCH Cell Channel Description IE, the RFID interrogator shall create a list of all ARFCN used by (E)R-GSM in the local area of operation.

The detection of the BCCH information shall be possible down to -98 dBm, which is the minimum coverage power specified for non-high-speed railways tracks (see [i.15]).

An interrogator shall not use any of the RFID TX channels with a centre frequency of less than 700 kHz from any channel stored in the ARFCN list, if the received GSM-R power level is ≥ -98 dBm.

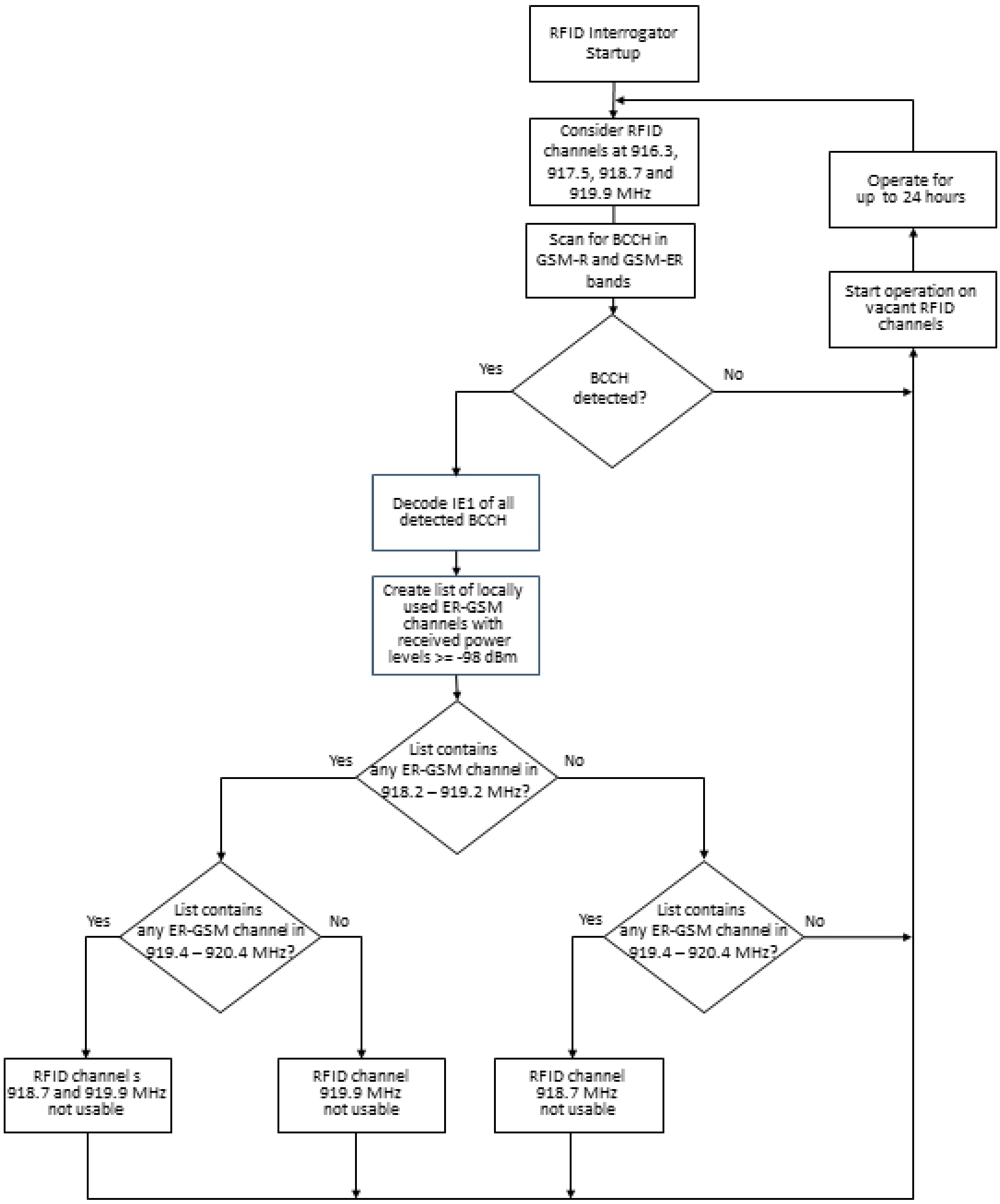


Figure 16: GSM-R Downlink detection for ER-GSM band and RFID DAA process

Figure 16 shows which ER-GSM channels prevent the use of either the 918,7 MHz or the 919,9 MHz RFID TX channel.

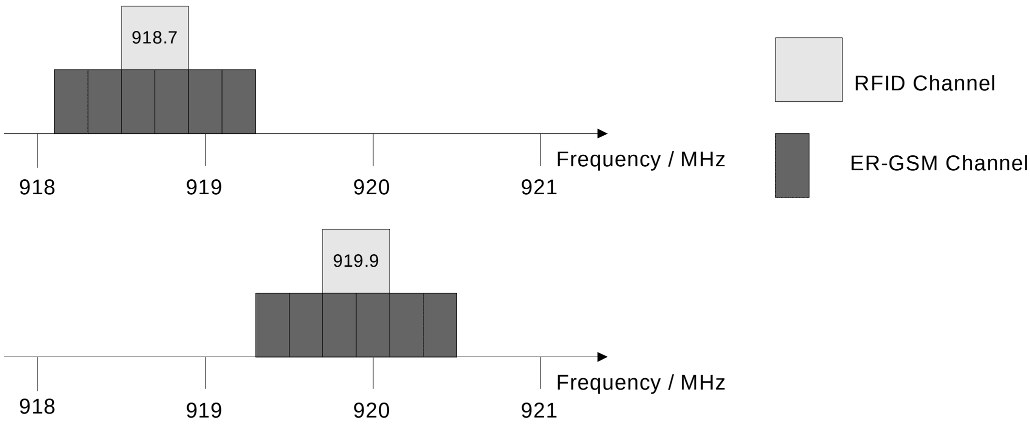


Figure 17: Illustration of interference between ER-GSM and RFID channels

The detection of BCCH channels and the defined action shall happen at power-up of the RFID interrogator and shall be repeated at least every 24h hours.

6.4 Victim terminal detection (UL Detection)

6.4.1 Considerations

Situations may arise where the service area detection (DL detection) unacceptably restricts the availability of RFID channels. In such cases the victim terminal detection (UL detection) may be used in order to gain access to channels in the 918 MHz to 921 MHz band, which are unoccupied by GSM-R.

The potential service area of a BTS in an ER-GSM system is much larger than the actual used area. By detecting a service area and avoiding the corresponding frequency channels, a much larger area than is actually necessary would be protected. The interference of the RFID system in the band 918 MHz to 921 MHz will only affect the ER-GSM down link and thus the ER-GSM terminals operating in the close vicinity (see protection area calculation). Therefore only the nearby operating terminals require protection from interference.

Detection of the victim terminal is by the sensing of transmissions on occupied uplink ER-GSM channels (from the terminal to the BTS) in the band 873 MHz to 876 MHz. Based on the received signal strength the RFID system can then estimate the path loss between the RFID interrogator and the operating terminals. For an estimated path loss larger than the threshold value, operation of an RFID system would be allowed without any restrictions. The path loss between the ER-GSM terminal and the interrogator, and thus the isolation can be estimated based on the assumption that the ER-GSM terminal has a minimum TX power of 33 dBm e.r.p. (for ER-GSM train mounted devices this value is 39 dBm) and no power control is used.

To implement uplink detection it is only necessary for the RFID interrogator to sense the signal from an ER-GSM terminal at its own antenna and calculate the path loss. If the signal level from the ER-GSM terminal is above a specified threshold, the terminal will require protection by avoidance of the corresponding DL channel in the band 918 MHz to 921 MHz.

The values for threshold levels can be calculated based on the following assumptions.

The TX power of an operational ER-GSM terminal will be P_{TX_term} = 33 dBm (2 W), the maximum allowed interference level at an ER-GSM terminal is -98 dBm. Taking into account a TX power of 36 dBm e.r.p. from a RFID interrogator, the resulting minimum needed isolation for an interference free operation of an GSM-R terminal in the band is I_{req_high} = 134 dB. For a low power RFID interrogator with a power of only 27 dBm e.r.p. (500 mW) the minimum isolation will be I_{req_low} = 125 dB. Thus the threshold for the received in-band signal at a high power RFID interrogator is $P_{thres\_high} = P_{TX\_term} - I_{req\_high}$ = -101 dBm. For a low power RFID interrogator the threshold is $P_{thres\_low} = P_{TX\_term} - I_{req\_low}$ = -92 dBm, respectively. For train mounted devices with a 6 dB higher TX power this approach will lead to an additional safety margin since the RX power at the RFID interrogator will be higher and thus the threshold will be reached earlier. The following analysis considers transmissions by the ER-GSM terminal of 33 dBm.

Taking into account the recommended channel allocation (100 kHz offset from the ER-GSM centre frequencies) of the RFID system and the possibility for the RFID system to listen at the ER-GSM UL center frequency, the thresholds for the measurement in the centre frequency can be reduced by another 9 dB leading to the following results:

→ P_{thres_high} = -92 dBm for high power interrogators; and

→ P_{thres_low} = -83 dBm for low power interrogators.

These threshold levels are valid for the neighbouring ER-GSM channels with a frequency separation of ±100 kHz. In the case of an additional channel separation of ±300 kHz these threshold values should be increased by 46 dB and another 14 dB for ±500 kHz leading to the following:

Table 3: Power threshold for UL detection

Center frequency separation between E(R)-GSM and RFID channel	Allowed interference / dBm	Mitigation	P_{thres_low} / dBm (for 27 dBm e.r.p. RFID transmitter)	P_{thres_high} / dBm (for 36 dBm e.r.p. RFID transmitter)
±100 kHz	-98	-9	-83	-92
±300 kHz	-98	-55	-55	-46
±500 kHz	-98	-69	-41	-32
≥ ±700 kHz	-98		No limitations	No limitations

6.4.2 Realization

Victim terminal detection will allow full time sharing of the spectrum between RFID interrogators and potential ER-GSM victims by identifying active terminals and protecting them for only a short period. This will require the implementation of fast avoidance techniques within interrogators.

In order to perform full time sharing of the spectrum, the RFID system must identify an active terminal in much less than 1 sec because the railway requirement for an call establishment e.g. for the emergency call is 2 sec. Fast victim terminal detection will use the results of the slow victim terminal detection process and normally will only continuously monitor the allocated channels. If an active ER-GSM terminal enters the vicinity of the RFID system and the isolation between the terminal and the RFID system drops below the minimum threshold, the RFID system needs to take immediate avoiding measures. In order to improve the reaction time the detection process should take into account signals which are well below the specified threshold level. By doing so the RFID system can identify terminals approaching the protection zone well before the threshold levels are reached. By decreasing threshold levels the reaction time can be correspondingly improved. ER-GSM terminals trying to set up a new call when already in the protection zone will be able to connect to the BTS and initiate a dialogue. This dialogue will be detectable by the RFID system and a fast response in the order of 5 ms would be required to protect set-up of the new call. Here additional investigation of the call setup process is required to specify the detection and protection mechanism.

Interrogators with victim detection shall monitor those channels of the ER-GSM UL band from 873 MHz to 876 MHz whose paired channel have been identified for GSM-R use by DL detection in the 918 MHz to 921 MHz band. If there is no GSM-R terminal operating in the respective channel of the ER-GSM band then the RFID system may use the respective channels. However, as soon as an uplink communication is detected then the RFID system shall stop operation in the respective channels. In the worst case the shortest package to be detected in the uplink transmit channel has a duration of slightly less than 4,5 ms.

7 Summary and Conclusion

The present document proposes operational requirements for the sharing of spectrum between RFID systems and the R-GSM/ER-GSM systems operating in the frequency band from 915 MHz to 921 MHz.

Based on the feasibility measurements carried out at Kolberg and also considering both the RFID system parameters and the neighbouring band below 915 MHz, a revised channel plan (see figure 1) is proposed. It is recommended that the centre frequency of the second RFID high power channel should be 917,5 MHz. This gives a separation of 700 kHz from the centre frequency of the lowest ER-GSM channel, which is 918,2 MHz. Due to the steeper filter in the transmitter of the interrogator compared to filter in the GSM-R receiver, it makes no difference whether the RFID interrogator operates with a channel bandwidth of 200 kHz or 400 kHz.

The present document proposes a phased approach towards the use of RFID systems in the ER-GSM bands. The different phases are shown in figure 18 and are split into four scenarios for use in the 915 MHz to 921 MHz band:

- Site license.
- Category 1 interrogators characterized that they only use the 915 MHz to 918 MHz band.
- Category 2 interrogators characterized that they support Category 1 operation and additionally downlink detection in the 918 MHz to 921 MHz band.
- Category 3 interrogators characterized that they support Category 2 operation and additionally apply uplink detection in respect to those channels in the 918 MHz to 921 MHz band where downlink detection prevents their use.

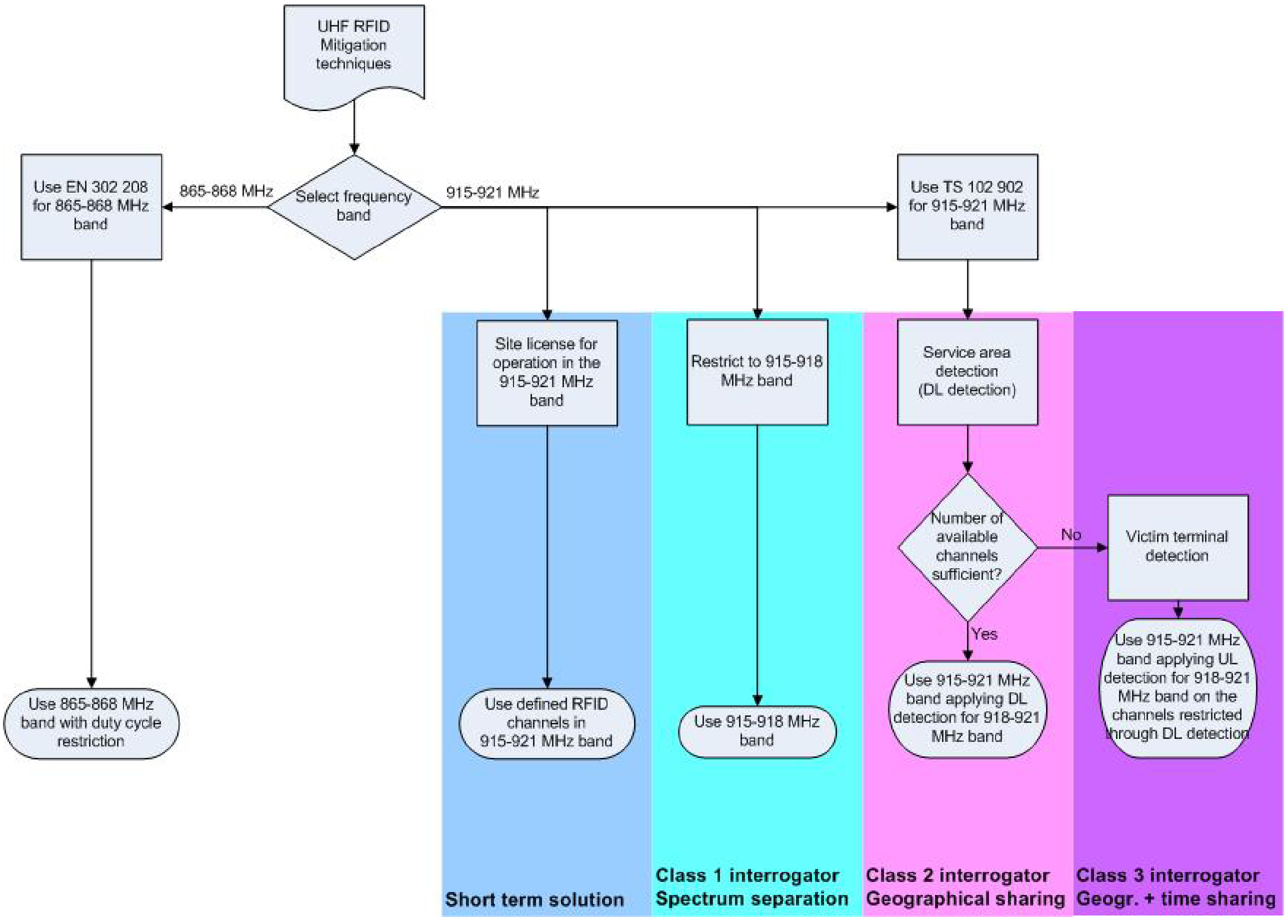


Figure 18: Overall coexistence strategy between ER-GSM and RFID

Annex A (informative):
Future requirements for RFID

A.1 General

The common view of the RFID industry, the European Commission, and CEPT is that the 865 MHz to 868 MHz band will be sufficient to cover the immediate spectral needs of RFID at UHF. However a lack of spectrum in the UHF frequency range will arise. Unless addressed, this will seriously restrict the forecasted exponential market growth of the RFID industry.

The situation for non-specific and specific SRDs is the same because of their rapidly increasing density and their expansion into a wider range of applications. In particular this is illustrated by the new generation of SRDs in Home and Building automation, metering, alarms and automotive.

A more detailed description of the SRD applications and the justification for additional spectrum is given in clauses A.2 and A.3.

NOTE: The military use of the bands under consideration should be assessed by ECC during consideration of the present document.

A.2 RFID applications

RFID Systems are used in item management, logistics and in a wide range of other applications. Details are provided in clause A.1.

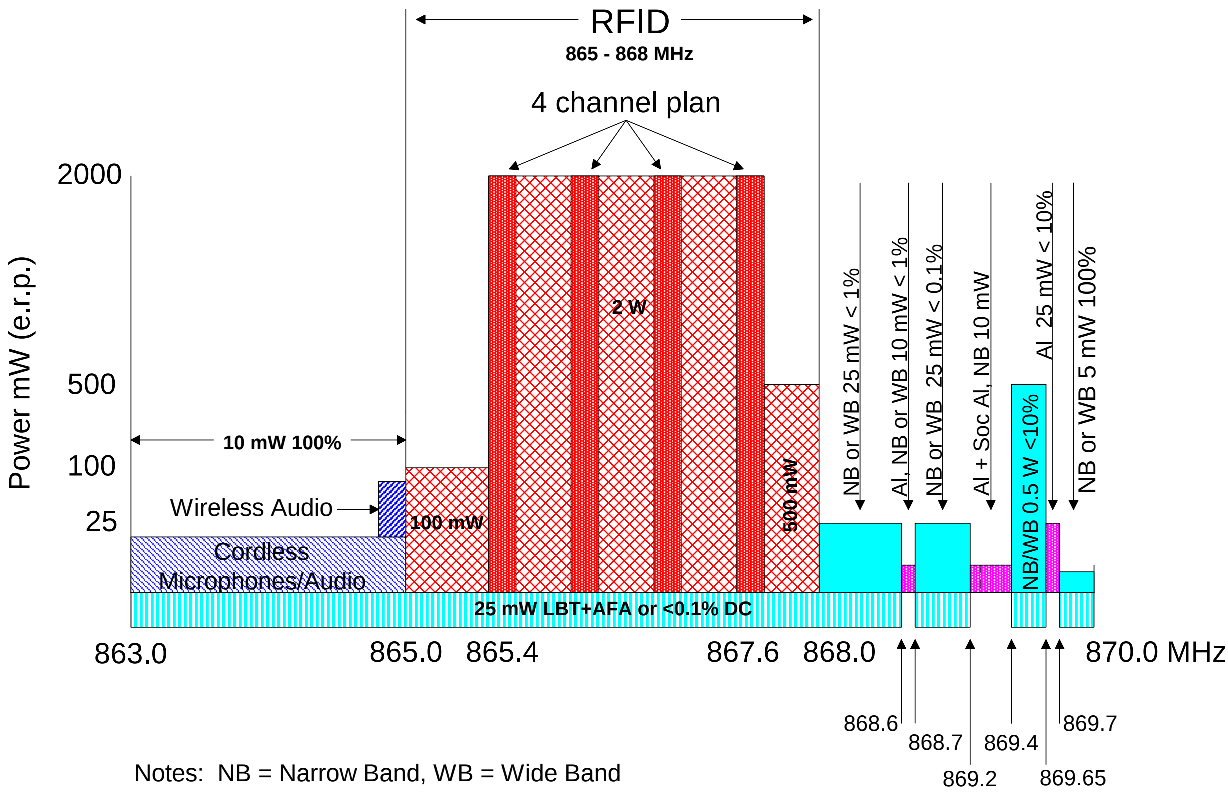
Many of these applications require reading ranges of at least 2 meters, and in certain logistics applications ranges from 5 meters to 10 meters. These ranges cannot be provided by alternative technologies and at any other frequency due to the regulatory constraints.

Additional spectrum needs are based on increased RFID usage densities, greater operating distances, and higher data speeds that will permit applications where large numbers of RFID tags are read reliably and quickly.

A.3 Technical Radio Spectrum requirements and justification

A.3.1 Current regulations for RFID

Operation of RFID in the band 865 MHz to 868 MHz falls under EC Decision 2004/804/EC [i.16]. In addition ERC Recommendation 70-03 [i.10], annex 11 contains a recommendation for RFID in the band 865 MHz to 868 MHz based on 200 kHz reader channels with power levels of up to 2 watts e.r.p., see figure 19. The present document proposes the designation of an additional UHF band to meet the future requirements of RFID.



Notes: NB = Narrow Band, WB = Wide Band

Band 869.2 - 869.4 sub-divided as follows:-

869.2 - 869.25 Social alarms < 0.1%

869.25 - 869.3 Alarms <0.1%

869.3 - 869.4 Alarms < 1%

NOTE: For latest and more detailed information consult the latest version of the ERC Recommendation 70-03 [i.10].

Figure A.1: Overview of existing SRD band allocations according to ERC Recommendation 70-03 [i.10]

Annex B (informative): Detailed market information - Market size, Applications and requirements

Comprehensive information is provided in [i.3].

Annex C (informative): Technical information

C.1 RFID

C.1.1 Performance requirements from leading RFID manufacturers and users

The main market requirements are noted in clause A.1.

Tags that are used globally are manufactured with their centre frequencies tuned to around 915 MHz. Since tags have a fractional bandwidth of approximately 5 % to 8 %, there will be a noticeable performance penalty if such tags are read by interrogators complying with the present European standard EN 302 208 [1]. This is due to the frequency off-set of approximately 45 MHz and the higher transmit powers permitted in other non-European countries.

For comparable performance in Europe, interrogators should operate at around 915 MHz at power levels up to 4 W e.r.p.

C.1.2 Power

By comparison with the limit of 2 W e.r.p. in the current frequency range of 865 MHz to 868 MHz, an increase in the limit to 4 W e.r.p. in the new proposed frequency range of 915 MHz to 921 MHz would lead to the following:

- The read range in free space increases by a factor of 1,4.
- The power absorbed by tags in a pallet is doubled for a given range.
- If the reading performance for tagged items on a pallet reaches 70 % at 2 W, the reading performance increases to 100 % at 4 W. Thus the read probability can be increased from 70 % at 2 W up to 100 % at 4 W (see figure C.1).
- Transponders, which should be aligned parallel to the antenna at their maximum reading range, can be mis-aligned in the same position by up to 60° and still be read.

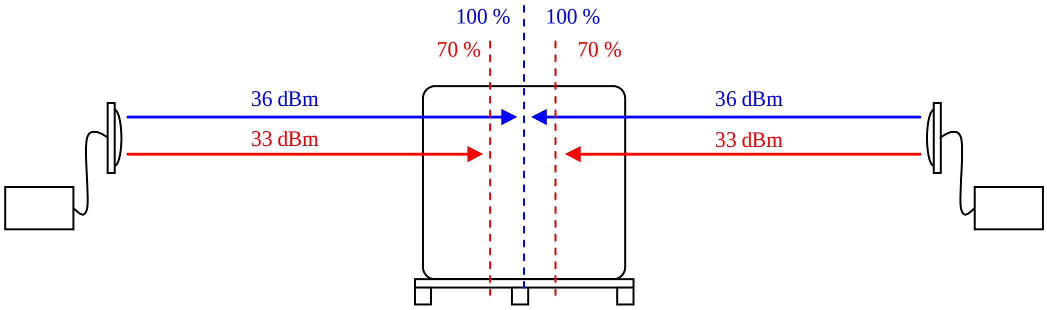


Figure C.1: Comparison of the read range within a pallet

C.1.3 Bandwidth

The current performance of UHF RFID in the logistic and supply chain market in Europe is limited by the channel bandwidth of 200 kHz. This restricts UHF RFID in Europe to a reading rate of about 200 tags per second versus a market requirement of tags to 1 500 tags per second for future applications.

To achieve the large-scale roll-out of RFID in Europe, the performance has to fulfil the requirements of all end users. Many end users in the logistic and supply chain market require item level tagging or tagging of small sized cases. Typically this could mean that there might be 1 500 tagged objects on a single pallet. In order to read these objects on a conveyor belt or in dock door scenario, a higher data rate is required combined with greater penetration of goods by the energizing field.

To achieve an acceptable reading performance the proposed spectrum values are based on the highest data rate in ISO/IEC 18000-6 [i.2]. In addition to achieve the highest Reader to Tag data rate specified in ISO/IEC 18000-6 [i.2], a new European UHF RFID band is proposed with the following spectrum parameters:

- The bandwidth for each high power channel should be ~400 KHz to allow a Tari of 6,25 µs as specified in ISO/IEC 18000-6 [i.2].
- The channel for the tag response should be 0,8 MHz on both sides of each high power channel. This allows a return link frequency of 640 KHz, which is equivalent to a data rate of 320 kbps.

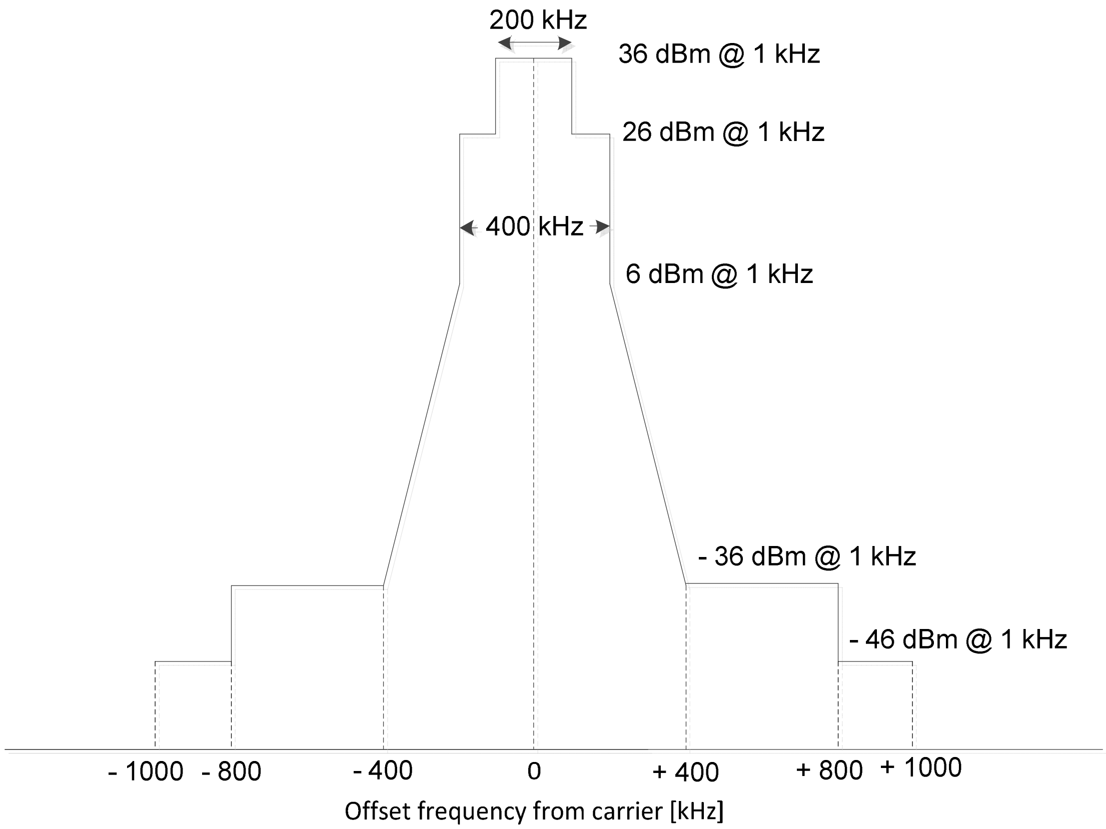


Figure C.2: High performance interrogator channel mask

Receiver parameters:

1) The beamwidth of the antenna(e) in the horizontal orientation should be ≤ 70 degrees.
2) The interrogator should identify a tag at a received a power level of -65 dBm.
3) The interrogator should identify a tag at a received power level of -62 dBm in the presence of an un-modulated blocker with a power level of -35 dBm at a frequency that lies +2 MHz or -2 MHz away from the carrier frequency of the interrogator.
4) The receiver of the interrogator should have a bandwidth of (fc ± 1 MHz).

Annex D (informative): Avoidance options

D.1 Introduction

The aim of the avoidance process in the mitigation operation is to protect the victim service receiver while maintaining the best possible performance of the RFID system.

Following the detection and identification of a victim system the selected avoidance option has to ensure the required protection level at the victim receiver.

The avoidance options fall into four major categories:

- power reduction;
- spatial separation;
- frequency separation;
- time sharing.

Any of these techniques may be used individually or in combination to protect the victim services provided that the avoidance levels needed to protect the potential victim systems are met.

The proposed methods for the protection of the victim ER-GSM system can be deployed independently of the detection and identification operation used.

D.2 Transmit power management

Transmit power management is the reduction in the transmitted power to the required level of the interfering system within its operational band.

In the case of RFID applications needing a short reading distance, such as the PoS scenario or the packaging table scenario, a reduction in the permitted power level could be sufficient to achieve the mitigation factor (9 dB) necessary to protect the ER-GSM system.

D.3 Band relocation

Band relocation is an avoidance technique in which the operating band of the RFID system/interrogator is changed in the frequency domain to eliminate interference with the victim service. This protection may be achieved either by band shifting or band switching.

Band shifting is a partial relocation of the used RFID channel, whereas band switching means that another allocated RFID channel would be used is by the RFID system. In an RFID system only band switching to another RFID channel is realistic.

D.4 LDC

Low duty cycle techniques decrease the total transmitted energy integrated over a period of time. This is achieved by transmitting at the maximum permitted power for the given frequency band but restricting the duration of the transmission.

This technique is an unsynchronized time sharing avoidance method. As a consequence the LDC technique does not eliminate interference to the victim services but it may reduce the effect of the interference. The LDC technique could be a very good approach for the use in portable and mobile RFID system introduced in clause 4.5.

D.5 Antenna techniques

Antenna techniques in general rely on the spatial distribution of the transmitted RFID signal. The spatial distribution of the signal may be controlled by the directivity of the antenna used. Possible examples include: switching, re-orientation, phased arrays.

Further possibilities are the deployment of near-field antenna systems in the case of the PoS and packaging scenario.

D.6 Combinations

In order to achieve the required protection criteria and maintain satisfactory operation of the RFID system, it may be necessary to combine a number of the avoidance techniques mentioned above.

D.7 Avoidance parameters

D.7.1 Minimum avoidance bandwidth

This is the minimum bandwidth over which RFID systems have to reduce their transmitted power below the maximum avoidance level.

D.7.2 Maximum avoidance power level

The maximum avoidance power level is the RFID transmitted power that will ensure acceptable protection of the victim service.

Annex E (informative): Mitigation zone definition

E.1 Introduction

In order to guarantee a proper interference free operation of RFID systems in the ER-GSM DL bands between 918 MHz to 921 MHz, the in-band interference at operational E-GSM-R terminals should be limited to a specific level. This level has been evaluated during measurements using RFID systems and real R-GSM terminals and R-GSM BTS emulators [i.6]. The main parameters to be taken into account are the sensitivity of the GSM terminal under worst case operational conditions, the transmit power of the RFID interrogator and the required C/I value at the ER-GSM terminal. Based on these parameters a minimum required isolation can be calculated. For given link budgets between the RFID interrogator and the potential victim ER-GSM terminal, a protection distance can be calculated using a path loss formula. In our case we have used the Friis equation [i.4] and [i.5] for Non-Line-of-Sight (NLoS) conditions with a pathloss exponent of α = 3,5. In the case of a Line-of-Sight (LoS) condition the path loss exponent α would equal to 2,0. The Friis equation calculates the pathloss L_{free} in free space between isotropic radiators as:

$$L_{free} = -27{,}55 + 20\log_{10}(f) + \alpha \cdot 10 \cdot \log_{10}(d) \text{ [dB]}$$

where *f* is the frequency in MHz, *d* is the distance between the two antennas in meters and α the pathloss exponent equal to 2,0 for free space transmission (LoS). In the case of a transmission with obstacles and without a line-of-sight component the typical assumption is a pathloss exponent α of 3,5. Based on this equation for the pathloss, the required mitigation distances d_{req} can be calculated as follows:

$$d_{req} = 10^{\frac{I_{req} + 27{,}55 - 20\log_{10}(f)}{10\alpha}} \text{ [m]}$$

where I_{req} is now the required isolation in dB between the RFID interrogator and the ER-GSM terminal.

Three different protection distances will be proposed based on different mitigation factors such as low power terminals and indoor applications. In all cases a mitigation factor of 9 dB, based on the proposed channel allocations for RFID systems, will be taken into account. This figure is derived from the measurement results obtained in Kolberg in June 2010 [i.6].

For all operational RFID systems we can assume a non-LoS pathloss between interrogators and potential ER-GSM victim terminals. This assumption is supported by the measurements made in a distribution centre in 2006 [i.7] where values for pathloss of around 129 dB were recorded at a distance of 120 m from a portal system. Taking into account the additional channel planning mitigation factor this would lead to an isolation of at least 138 dB between the portal system and a potential ER-GSM victim terminal at 120 m separation distance.

E.2 Required Isolation

The maximum permitted TX power of an RFID interrogator used in portal systems is either 33 dBm e.r.p (2 W) or 36 dBm e.r.p (4 W) depending on the frequency band of operation. Lower power interrogators are used for portable applications and for PoS and packaging table applications. The power of these low power systems is typically between 20 dBm e.r.p. and 27 dBm e.r.p., which leads to an additional mitigation factor to be included in the isolation calculations.

Based on the measurements performed in Kolberg in June 2010 [i.6] operation of an ER-GSM terminal at the cell edge typically took place at a RX level of -86 dBm, which has been revised by the railways to -98 dBm. The C/I requirement for interference free operation of the terminal is 9 dB, leading to a maximum allowed interference level from a RFID interrogator at the antenna of the ER-GSM terminal of -107 dBm. Taking into account these values the minimum required isolation between a RFID interrogator and a potential ER-GSM victim terminal can be calculated.

Required Isolation I_{req} for 4 W (36 dBm) RFID interrogator:

$$I_{req} = 36 \text{ dBm} - (-98 \text{ dBm}) + 9 \text{ dB} = 143 \text{ dB}$$

with 36 dBm: e.r.p. TX power of the RFID interrogator, -98 dBm: operational RX level of the ER-GSM system, 9 dB C/I protection criterion.

Under the condition that the isolation between the RFID interrogator and the potential ER-GSM victim terminal is equal or larger then I_{req} no interference will occur. This value of 143 dB, which is the required isolation, will now be used to calculate the protection distance around the ER-GSM terminals.

In the next step of this analysis additional mitigation factors will be considered in order to determine the minimum required protection distance between a RFID interrogator and a potential victim ER-GSM terminal under specific operating conditions.

E.3 Protection distances

In this clause protection distances for different classes of RFID systems will be evaluated. These protection distances will be based on the worst case isolation figure for I_{req} equal to 143 dB as calculated in the preceding clause. The RFID channel plan of figure 1 recommends a carrier offset of 100 kHz between the centre frequencies of the RFID high power channels and the centre frequencies used by ER-GSM. This leads to an additional mitigation factor of 9 dB. This value is taken into account as the channel planning mitigation factor in the following clauses.

E.3.1 Non specific RFID systems (Portal Systems)

Additional mitigation factors:

- 9 dB for channel planning.
- 10 dB shielding due to the portal construction.
- Non Line of Sight path loss exponent = 3,5 (RFID system only 2 m above ground, GSM Terminal only 2 m above ground).

Mitigation distance needed with shielding: $10^{\frac{143-9-10+27,55-20\log(918)}{10*3,5}}\text{ m} - 433\text{ m}$ → Proposal: 500 m.

Mitigation distance needed without shielding: $10^{\frac{143-9+27,55-20\log(918)}{10*3,5}}\text{ m} = 837\text{ m}$ → Proposal: 1000 m.

Under these conditions the additional theoretical safety margin is in the range of 3 dB. However measurements performed at a METRO distribution center in 2006 [i.7] recorded an interfering power of below -96 dBm at a distance of 120 m from a portal system where the interrogator was transmitting at 33 dBm e.r.p. This result shows that the proposed protection distance of 1000 m for an interrogator operating at 36 dBm e.r.p. is probably considerably greater than really necessary. The results also show that the assumption of a NLoS propagation behaviour with a pathloss exponent of 3,5 is realistic.

E.3.2 Indoor RFID systems (Handheld Systems)

Additional mitigation factors:

- 9 dB for channel planning.
- Non Line of Sight path loss exponent = 3,5 (RFID system only 2 m above ground, GSM Terminal only 2 m above ground).
- Indoor only applications: 10 dB.
- Low power with 27 dBm e.r.p. max power.

Mitigation distance needed: $10^{\frac{27+98+9-9-10+27,55-20\log(918)}{10*3,5}}\text{ m} = 240\text{ m}$ → Proposal: 300 m.

E.3.3 Indoor low power RFID systems (PoS, Packaging Table)

Additional mitigation factors:

- 9 dB for channel planning.
- Non Line of Sight path loss exponent = 3,5 (RFID system only 2 m above ground, GSM Terminal only 2 m above ground).
- Indoor only applications: 10 dB.
- Low power systems, e.g. PoS, Packaging (27 dBm, 500 mW) and antenna directivity (3 dB): 12 dB.

Mitigation distance needed: $10^{\frac{27+98+9-9-10-12+27,55-20\log(918)}{10*3,5}}\ \mathrm{m} = 109\ \mathrm{m}$ → Proposal: 150 m.

Annex E (informative): Bibliography

Directive 1999/5/EC of the European Parliament and of the Council of 9 March 1999 on radio equipment and telecommunications terminal equipment and the mutual recognition of their conformity (R&TTE Directive).

CEPT/ECC Decision (02)05 amended: "ECC Decision of 5 July 2002 on the designation and availability of frequency bands for railway purposes in the 876-880 MHz and 921-925 MHz bands amended 26 June 2009".

Commission Decision of 23 November 2006 on harmonization of the radio spectrum for radio frequency identification (RFID) devices operating in the ultra high frequency (UHF) band.

ETSI EN 300 220 (all parts) (V2.1.2): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Radio equipment to be used in the 25 MHz to 1 000 MHz frequency range with power levels ranging up to 500 mW".

OFCOM UK: Cognitive Device Proposal.

NOTE: See http://www.ofcom.org.uk/consult/condocs/cognitive/

ETSI TR 102 683 (V1.1.1): "Reconfigurable Radio Systems (RRS); Cognitive Pilot Channel (CPC)".

J. Mitola and GQ Maguire:"Cognitive radio: making software radios more personal," IEEE Personal Communications, vol. 6, no. 4, pp. 13-18, Aug. 1999.

Li, Y., Quang, T. T., Kawahara, Y., Asami, T., and Kusunoki, M. 2009: "Building a spectrum map for future cognitive radio technology" in Proceedings of the 2009 ACM Workshop on Cognitive Radio Networks (Beijing, China, September 21 - 21, 2009). CoRoNet '09. ACM, New York, NY, 1-6.

ETSI TS 102 754 (V1.1.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Technical characteristics of Detect-And-Avoid (DAA) mitigation techniques for SRD equipment using Ultra Wideband (UWB) technology".

ETSI TR 102 627: "Electromagnetic compatibility and Radio spectrum Matters (ERM); System Reference Document; Land Mobile Service; Additional spectrum requirements for PMR/PAMR systems operated by railway companies (GSM-R)".

Council Decision of 30 March 2004 on the conclusion of the Agreement in the form of an Exchange of Letters between the European Community and Barbados, Belize, the Republic of Congo, Fiji, the Cooperative Republic of Guyana, the Republic of Côte d'Ivoire, Jamaica, the Republic of Kenya, the Republic of Madagascar, the Republic of Malawi, the Republic of Mauritius, the Republic of Suriname, Saint Christopher and Nevis, the Kingdom of Swaziland, the United Republic of Tanzania, the Republic of Trinidad and Tobago, the Republic of Uganda, the Republic of Zambia and the Republic of Zimbabwe concerning the accession of the Republic of Mozambique to Protocol No 3 on ACP Sugar of Annex V to the ACP-EC Partnership Agreement.

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