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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
DTS/ERM-TG34-010

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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.

In the present document a set of these mechanisms will be defined together with the necessary parameters to avoid interference with the ER-GSM system in the frequency band 918 MHz to 921 MHz. Besides 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 assumption and therefore this values have to be verified in practical measurements and adopted to the state of the art technology.

The present document will be complemented by TR 102 903 [i.11], which will include the results of an initial practical evaluation of the proposed mechanisms, and a description of the conformance test procedures necessary for testing compliant 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) (V1.2.1): "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 TR 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] 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.

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 shall sense the channel within its operative bandwidth in order to detect the possible presence of other systems. If another system is detected, the first system shall 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 Transceive 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
BCCH	Broadcast Control Channel
BCH	Broadcast Channel
BTS	Base Transceive Station
CRS	Cognitive Radio System
DAA	Detect and Avoid
DFA	Dynamic Frequency Allocation
DL	DownLink
DPC	Dynamic Power Control
e.r.p.	effective radiated power
EM	ElectroMagnetic
ER-GSM	Extended Railways GSM
FM	Frequency
GSM	Global System for Mobile Communication
LBT	Listen before Talk
LDC	Low Duty Cycle
LoS	Line-of-Sight
LTE	Long term evolution
NLoS	Non-Line-of-Sight
PM	Phase
PoS	Point of sales system
RF	Radio Frequency
RFID	Radio Frequency Identification
R-GSM	Railway GSM
RX	Receiver
SLA	Service Level Agreement
SRD	Short Range Device

TCH	Traffic Channel
TX	Transmitter
UHF	Ultra High Frequency
UL	UpLink

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], 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 915,5 MHz 916,7 MHz 917,9 MHz 919,1 MHz 920,3 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 925 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.				

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

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

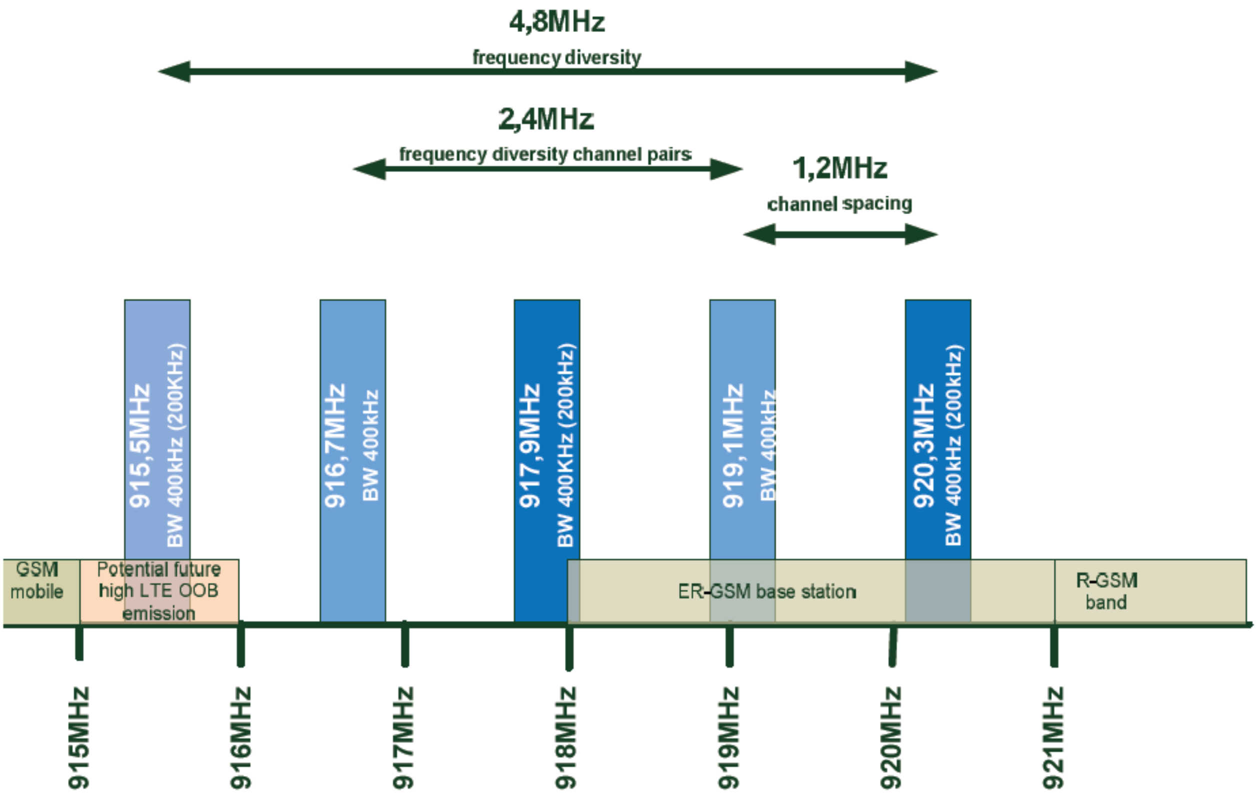


Figure 1: Revised proposal for high performance RFID applications

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

- A 100 kHz carrier offset between GSM/ER-GSM/GSM-R 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. 915,7 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 a ER-GSM/GSM-R carrier and an RFID carrier should be 700 kHz under worst case conditions. For more realistic cell edge conditions a separation of 500 kHz would be sufficient.
- For indoor applications the minimum frequency separation between a ER-GSM/GSM-R carrier and an RFID carrier should be 500 kHz under worst case conditions. For more realistic cell edge conditions a separation of 300 kHz would be sufficient.

Furthermore, the spacing between the high power channels should be the same to avoid the creation of IM3 products in the tags and interrogators.

In summary a channel plan should be considered with the first high power channel at a center frequency of 915,5 MHz and the remaining high power channels spaced at 1,2 MHz. This is depicted in figure 1. An alternative channel spacing of 1,0 MHz should also be considered. Use of the channel at 915,5 MHz may not be possible due to the probable future deployment of LTE in the frequency band below 915 MHz and its potential to cause adjacent channel interference.

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.

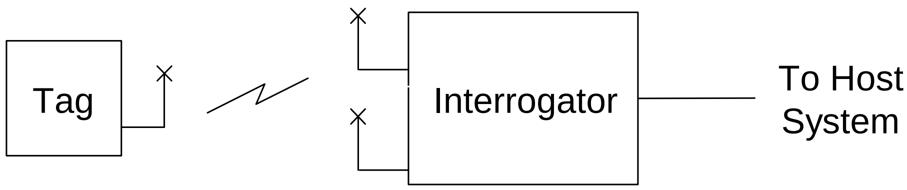


Figure 2: Principle of RFID

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 mm	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 frequently, in the case of overhead rails, individually suspended.

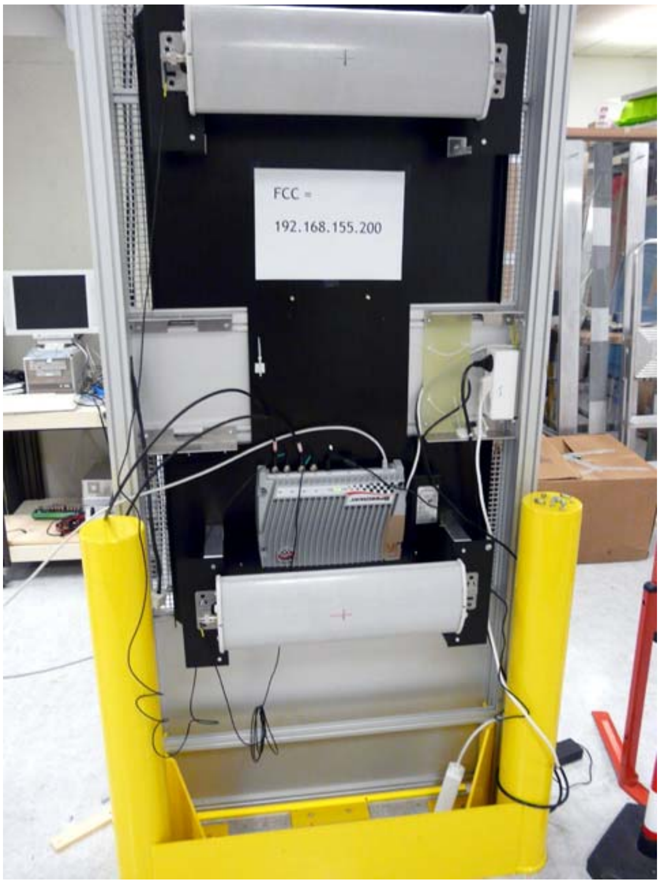


Figure 3: Dock door for testing (one side of dock door shown)

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 center 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 must 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.

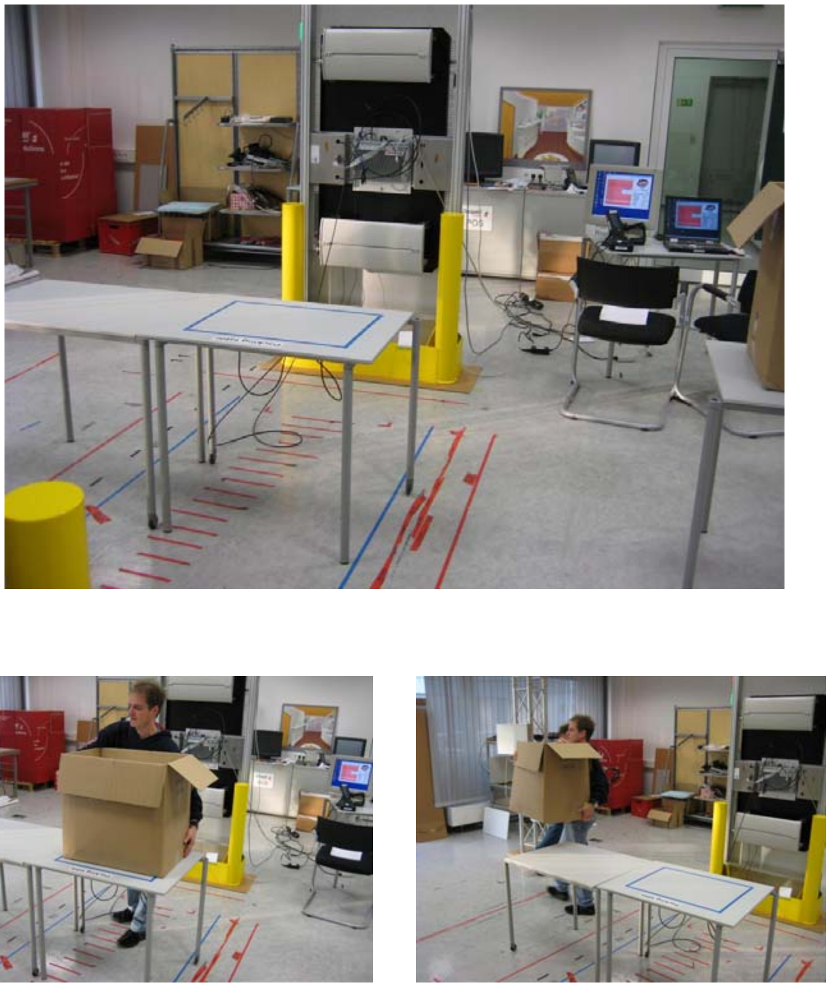


Figure 5: Typical use case of a RFID equipped packaging table

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 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.

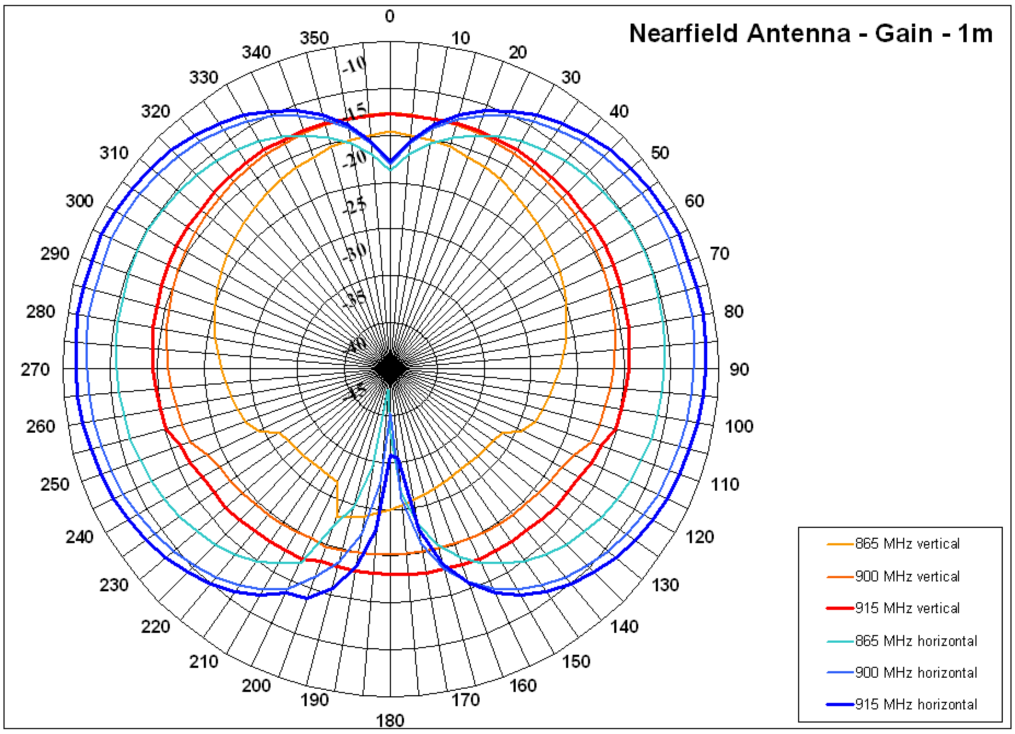


Figure 7: Measured antenna diagram of an antenna used in PoS and packaging applications

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. In this case other mitigation factors and techniques might be necessary under some critical conditions.

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 harmonised 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 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 -92 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.

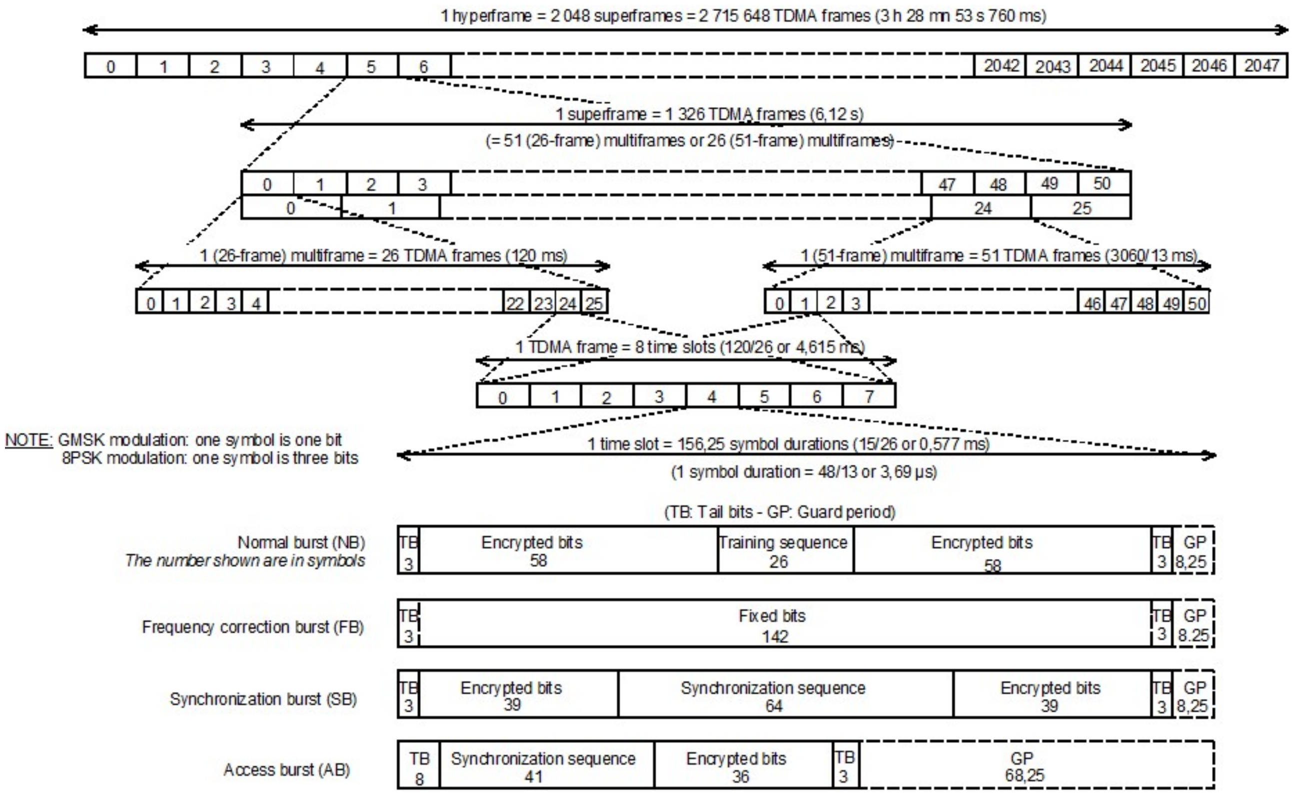


Figure 10: Overall Burst structure of a GSM System

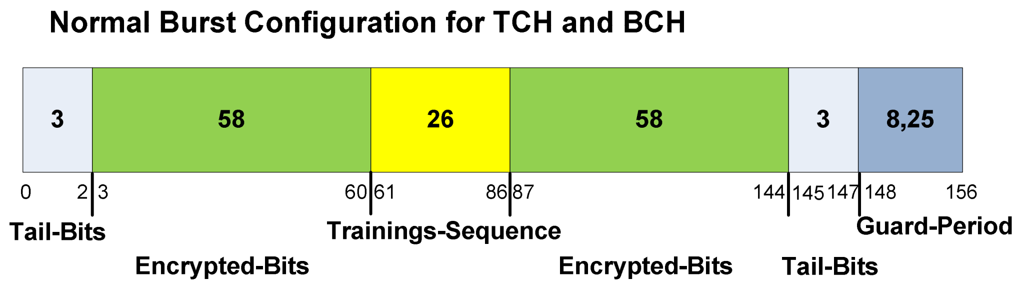


Figure 11: Burst structure of Normal Burst TCH and BCH

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 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 sites. An ER-GSM system will not operate in a noise limited environment but rather where the band is heavily utilised. 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)

5.6 Summary

It is reasonable to assume that during the initial introductionary 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 take 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 this 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 firstly be split into regulatory methods like site licensing and the definition of mitigation zones around the operational areas of potential victim systems like ER-GSM. Secondly dynamic mitigation techniques are possible relying 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 occupy the new band (915 Mz 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 2 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.

The dynamic mitigation techniques will relay on an active slow spectrum monitoring process with an update rate of some days or weeks combined with a fast monitoring process with an update rate of below a second. The slow process can recognise the deployment areas of the victim service by indentifying any traffic in the DL such as detection of the BCCH in the R-GSM and ER-GSM systems. The identification of a BCCH in the R-GSM DL need to be complemented by a TCH detection and identification process in the ER-GSM band. 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. Both the BCCH and TCH identification approach uses a slow monitoring process but because of the characteristics of the BCCH and TCH, the detection method is different. It means that the BCCH can be identified immediately the RFID system is switched on. However the TCH will only be identified during normal operation of the RFID system when the TCH is used on an ER-GSM Channel. In the future where only the TCH is allocated in the ER-GSM bands, time sharing between a RFID system and the TCH will be possible. However this will first require the development of suitable detection techniques with sufficiently fast response times to be built into RFID interrogators.

In the case of the fast monitoring technique, the RFID system would monitor the spectrum and would be able to share based on the actual usage.

In the following clause the different techniques will be presented in more detail.

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. In conjunction with the regulation on mitigation zones presented in the next clause, it can be seen as a starting point for an unlimited license. This will mainly depend on the geographical locations of individual RFID sites.

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 Mitigation zone definition

6.3.1 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 level at operational ER-GSM terminals need to 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 $\alpha = 3,5$. 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 in the case of 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:

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

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 center 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.

6.3.2 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. 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 -95 dBm. It should be noted that the ER-GSM terminal in idle mode can operate with an interference level 3 dB above this limit. 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:

$$I_{req} = 36 \text{ dBm} - (-86 \text{ dBm}) + 9 \text{ dB} = 131 \text{ dB}$$

with 36 dBm: e.r.p. TX power of the RFID interrogator, -86 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 131 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.

6.3.3 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 131 dB as calculated in the preceding clause. In all cases it will be assumed that the RFID channel plan is based on the conclusions in the Kolberg report of June 2010. This 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.

6.3.3.1 Non specific RFID systems (Portal 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, antenna not directed towards the GSM terminal).

Protection distance needed 380 m → Proposal: 500 m.

Under these conditions the additional theoretical safety margin is in the range of 4 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 500 m for an interrogator operating at 36 dBm e.r.p. is probably 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.

6.3.3.2 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 30 dBm e.r.p. max power.

Mitigation distance needed: 132 m → Proposal: 150 m.

6.3.3.3 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: 90 m → Proposal: 100 m.

6.4 Dynamic Mitigation techniques

6.4.1 Overview

Besides the mitigation techniques based on regulatory and licensing mechanisms, which can be seen as static mitigation techniques, the RFID interrogator itself can implement mitigation mechanisms These mechanisms can be mainly split into two categories:

- Service area detection and mitigation, downlink detection and identification.
- Victim terminal detection and mitigation, uplink detection and identification.

In the first case a service area will be protected even if no ER-GSM terminal is operating in this area, whereas in the second case only the relevant ER-GSM terminals will be protected. These mitigation techniques need only to be implemented when a RFID system is operated within one of the defined mitigation zones (see clause 6.1).

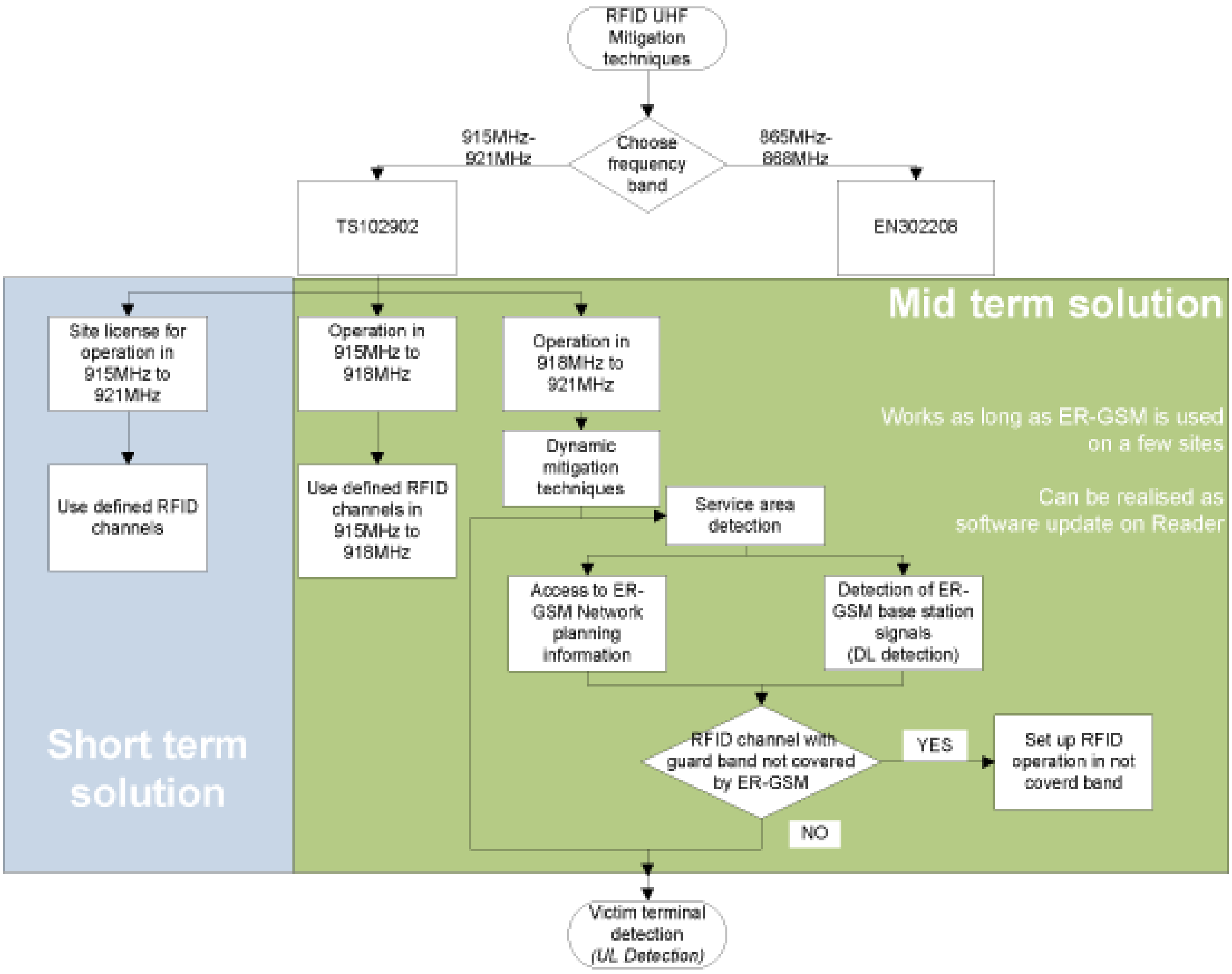


Figure 15: Short term and midterm solution for the sharing in the band 918 MHz to 921 MHz

6.4.2 Service area detection and identification

6.4.2.1 Access to ER-GSM Network planning information

The most efficient way of identifying the frequency channels to be protected, and thus the service area, is through access to the planning information of the victim network operator. In this case the deployment of the RFID frequencies can be planned in a way that prevents interference to victim terminals that are within the coverage area of a RFID site. In the worst case two cells may need to be protected.

Figure 16 illustrates the typical coverage of an ER-GSM system. It can be seen in the diagram that primarily only two cells and thus two frequencies have to be protected from the RFID system. The other cells and frequencies might by detectable at the RFID site but, due to the greater distance to the potential victim terminal positioned on the tracks, no specific mitigation actions have to be taken.

Different levels of information might be provided by the network operator that could be used in both the planning and deployment phase of a RFID system. The most helpful information would come from access to the full planning information of the network operator. Less detailed information could also be useful such as the positions of base stations in conjunction with the used frequency bands, the transmission power and the antenna beam characteristics. This information could then be combined with energy detection or other mitigation procedures at the RFID site. The network information would need to be updated on a regular basis whenever the configuration of the ER-GSM network changed.

Based on the available information, the RFID system could define the necessary level of protection for the identified cells. Here the relative positions of the railway tracks and the cell coverage of the RFID site could be used to calculate the maximum permitted TX power of the interrogators in the relevant bands to be protected.

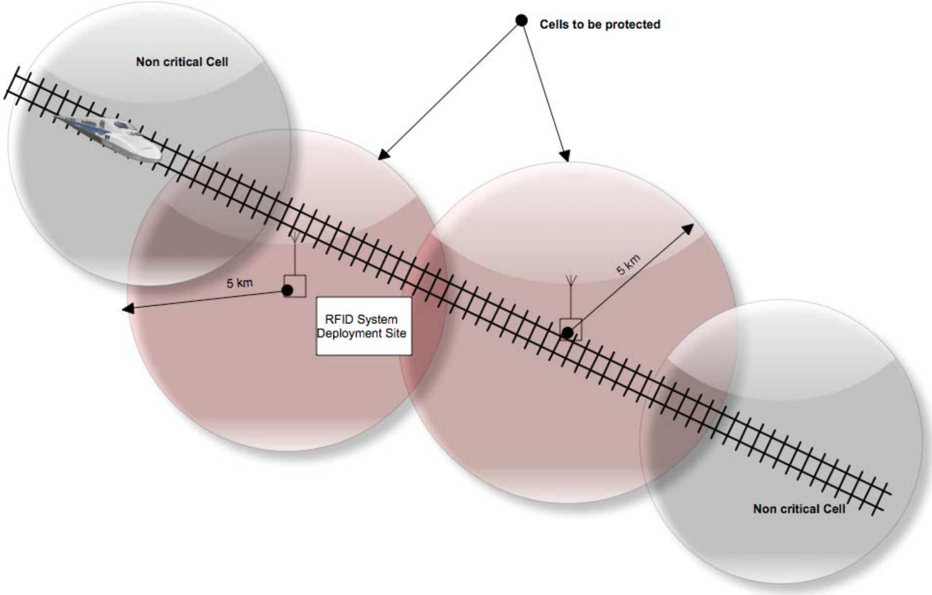


Figure 16: ER-GSM network coverage

6.4.2.2 Detection of ER-GSM base station signals (DL detection)

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 DL 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 process of scanning for BCCH or TCH channels will take place immediately an interrogator starts to operate. Thereafter, assuming the interrogator is switched on continuously and no BCCH has been detected, BCCH channel scanning will be repeated at least once every 24 hours. The detection threshold shall be -86 dBm at the center frequency of the ER-GSM or R-GSM channel.

When the interrogator detects a BCCH in the ER-GSM, the interrogator shall not be allowed to use any RFID channel with a centre frequency located in a range of ±500 kHz around the detected BCCH frequency. This takes into account the cell edge condition of the ER-GSM operational terminal.

When the interrogator detects a BCCH in the R-GSM band, the interrogator shall scan for a TCH in the ER-GSM channels. The threshold level for the TCH detection shall be the same as for the BCCH detection at -86 dBm. Since the TCH signal will be present only intermittently, scanning needs to be carried out on a regular basis. This will ensure the prompt detection of a new TCH transmission. While scanning is taking place use by RFID of the sub-band 918 MHz to 921 MHz will be prohibited. Instead the RFID channels allocated in the band 915 MHz to 918 MHz can be used.

In the event that no TCH has been identified in the relevant channels, they may be allocated for use by RFID. In order to allow for the later use of these channels by the ER-GSM, the scanning process should be repeated every 24 hours.

Where a TCH has been identified in the ER-GSM channels, the RFID system should avoid the adjacent channels by applying a separation of at least ±500 kHz. In this situation the scanning information can be updated regularly in order to allow for reuse of the channels by RFID interrogators once the TCH is no longer in use.

An extension of this concept could be the fast detection of the TCH in parallel with the long-term detection method described above. In this case identified TCH channels shall be monitored continuously. This would allow an RFID system to avoid a TCH channel within 1 sec of detection of a new TCH signal. Once an RFID interrogator has detected activation of the TCH, it will avoid use of that channel. The call setup process will be performed on the BCCH in the E-GSM channel and the TCH in the ER-GSM band will only be allocated when required. In order to implement fast detection it would be necessary to design a more sophisticated.

6.4.2.3 Combination of database access and DL detection

The detection process of an RFID interrogator can be optimized by using the information available in database systems. An RFID system which has access to this information can determine if there are any ER-GSM systems within its vicinity. The active listening and identification of a TCH in the ER-GSM band is only needed when a victim channel has a smaller or equal separation than 500 kHz from the centre frequency of the RFID system. The information available in a data base will also permit identification of the serving Base Transceive Station (BTS) in the service area. Thus only the assigned ER-GSM channel needs to be protected in a given area. This avoids the need for the unnecessary protection of other unused ER-GSM channels detectable in the area.

6.5 Victim terminal detection (UL Detection)

6.5.1 Overview

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 (±500 kHz), 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 effect 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 interference protection.

Detection of the victim terminal is by the sensing 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 then can estimate the path loss between the RFID interrogator and the operating terminals. For an estimated path loss larger than the threshold value, operation of a RFID system would be allowed without any restrictions. The path loss between the ER-GSM terminal 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.

All this requires 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 detection of an ER-GSM terminal can be split into a slow victim terminal detection and a fast victim terminal detection. In the following clause the two victim terminal detection techniques will be presented as the long term solution for the coexistence of RFID systems with ER-GSM systems in the band 915 MHz to 921 MHz. The split into slow and fast detection is illustrated in figure 17.

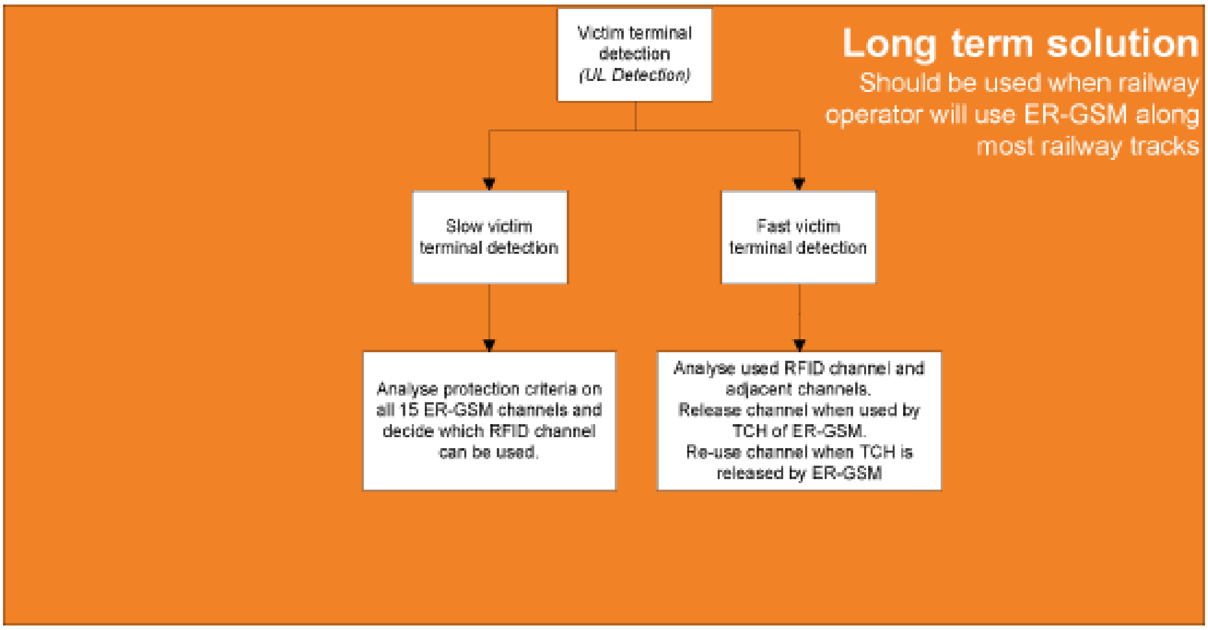


Figure 17: Additional mechanisms for the long term solution for the sharing in the band 918 MHz and 921 MHz

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 -86 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 ER-GSM terminal is I_{req_high} = 122 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} = 113 dB. Thus the threshold for the received signal inband at a high power RFID interrogator is $P_{thres\_high} = P_{TX\_term} - I_{req\_high}$ = -89 dBm For a low power RFID interrogator the threshold is $P_{thres\_low} = P_{TX\_term} - I_{req\_low}$ = -80 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. In what follows only the 33 dBm TX values will be considered.

Taking into account the recommended channel allocation (100 kHz offset from the ER-GSM centre frequencies) of the RFID system and the possibility of 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} = -80 dBm for high power interrogators; and

→ P_{thres_low} = -71 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 to:

→ P_{thres_high} = -34 dBm for high power interrogators; and

→ P_{thres_low} = -25 dBm for low power interrogators.

For larger frequency separations no additional mitigation measures are necessary. Thus an RFID system intending to operate on a specific channel located in the band 918 MHz to 921 MHz has to sense only four neighbouring channels with offset frequencies of ±100 kHz and ±300 kHz. If the corresponding threshold levels are exceeded the relevant RFID channel cannot be used without risking interference to the ER-GSM system.

6.5.2 Slow victim terminal detection and identification

Slow victim detection is based on a learning approach in which the potential interfering system (the RFID interrogator) monitors the relevant UL channels of the potential victim system (ER-GSM) for a longer period of time. This period of time could be from several days up to one month. Based on these monitoring activities, the interfering system can identify potential operational terminals, which need to be protected, in the ER-GSM band.

Using this information the interrogator can now define the operational channels or operational conditions (RFID TX power, LDC, manual optimization of antenna directions, etc.) to minimize interference to potential victims. Following the identification of the unused operational channels or by means of suitable operational adjustments, the interrogator can be switched into its normal operational mode. The channels which might cause interference to a victim terminal will be unavailable.

The monitoring operation should be repeated on a regular base to allow for the introduction of new operational channels by the victim system. It is considered that a repetition period of one month would be sufficient.

6.5.3 Fast victim terminal detection and identification

In slow detection of a victim terminal the RFID system identifies the used ER-GSM channels and avoids them for an extended period even though there is no actual activity. In practice the actual usage time of an ER-GSM channel might be very small and will only be occupied by a few ER-GSM terminals. Fast 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 3 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 order of 2 sec or 3 sec 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.

6.6 Combination of Service Area detection (DL Detection) and Victim terminal detection (UL Detection)

In an actual system implementation a combination of the service area detection and the victim terminal detection could be envisaged in order to simplify design of the terminal detection element. In the service area detection process the RFID system will indentify the deployed ER-GSM DL channels (BCCH or TCH only). If the RFID interrogator is not operated in an ER-GSM service area, it doesn't need to listen for the victim terminal and can operate without restrictions. In areas where ER-GSM is present the UL detection process can be focused on the allocated UL channel or channels.

7 Summary and Conclusion

In the present document operational requirements have been proposed 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.

The TS shows that operation of RFID systems in the ER-GSM band is possible so long as appropriate mitigation techniques are applied. Under the conditions assumed in the present document, un-restricted sharing is possible once the mitigation distance exceeds 500 m. This figure represents an absolute maximum and needs to be verified based on realistic field measurements. Initial results of the interference potential from RFID portal systems can be found in [i.7] where in band attenuations of more than 129 dB were measured at a distance of 120 m. Taking into account the channel planning mitigation factor of 9 dB this would lead to a attenuation of 138 dB at 120 m separation distance. This result could show the way towards a lower figure for protection distances.

Based on the feasibility measurements carried out at Kolberg, a revised channel plan (see figure 1) is proposed. It is recommended that the centre frequency of the third RFID high power channel should be 917,9 kHz. This gives a separation of 300 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 ER-GSM 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 three time frames:

- Short term solution based on a site licensing for the fast introduction of RFID system in the band.
- Mid-term solution based on the specification of mitigation zones based on protection distances in regulations combined with service area detection. Here a fast DL detection of the TCH could be added if technically feasible.
- Long-term solution based on slow and fast victim terminal detection in combination with service area detection.

The proposed time frames are based on the complexity of implementing the solutions into RFID interrogators. The proposed solutions in the present document will need to be evaluated with real field tests as soon as possible in order to confirm or amend the proposed figures and techniques.

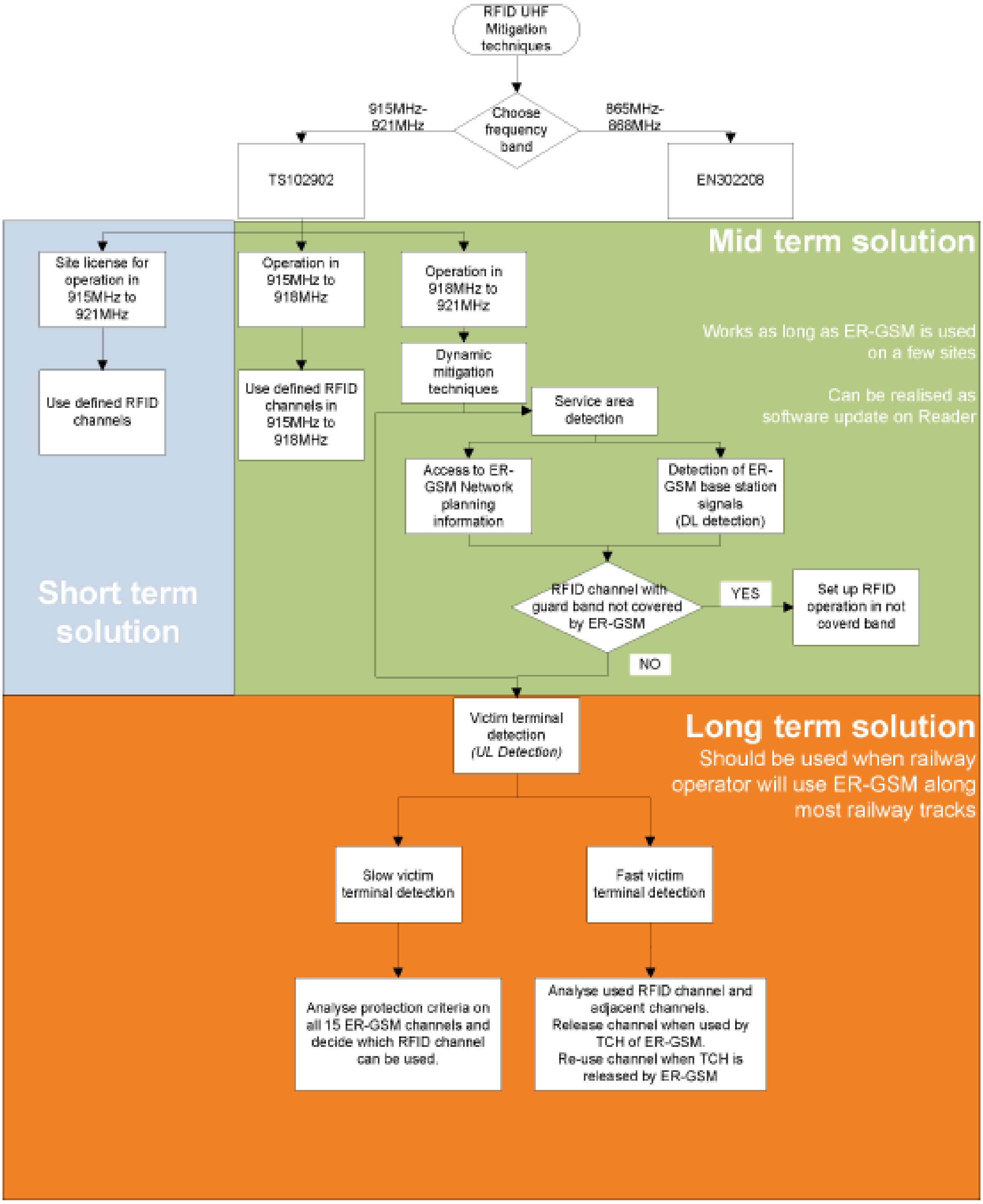


Figure 18: Overall coexistence strategy between ER-GSM and RFID

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 UHF RFID. 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.

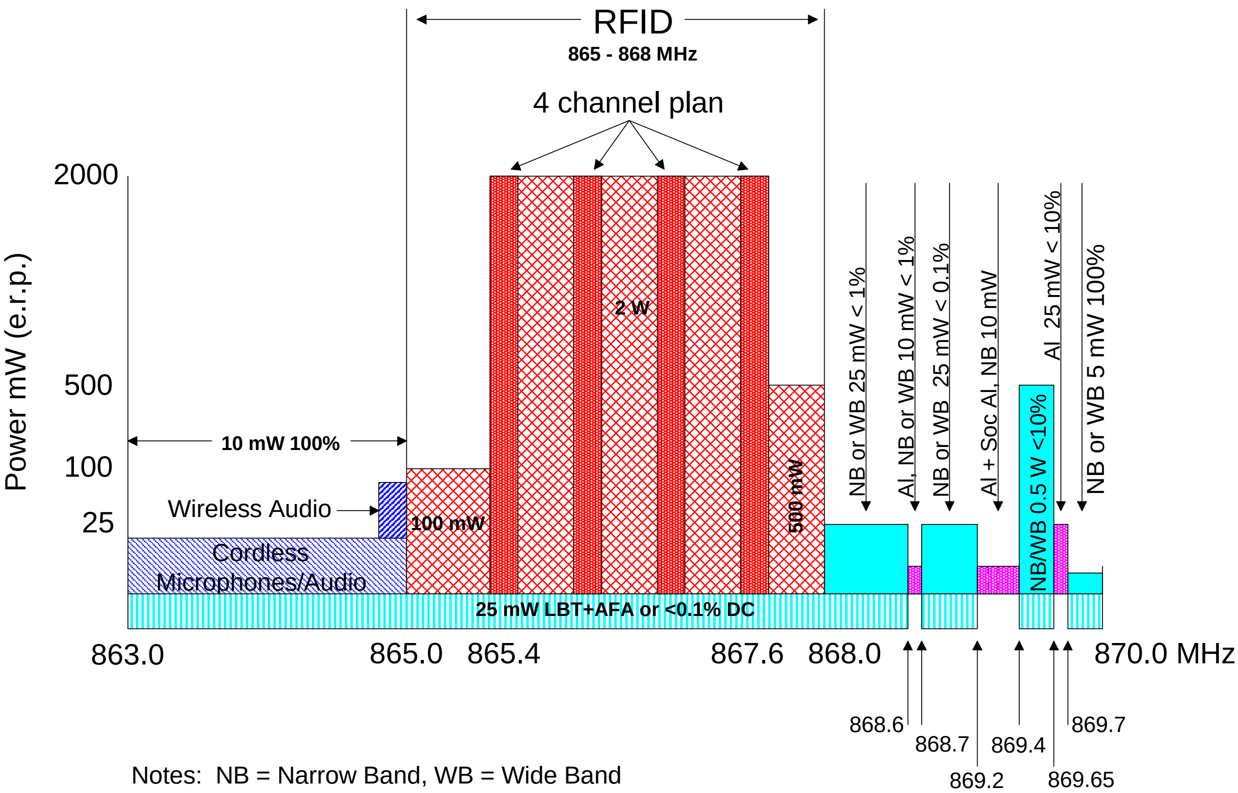
Many of these applications require reading ranges of at least 2 meters, and in certain logistics applications ranges from 5 meters to 10 meters. These ranges cannot be provided by alternative technologies and at any other frequency due to the regulatory constraints.

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 . In addition ERC Recommendation 70-0 [i.12], 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

For more information please refer to [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.1.1.

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.

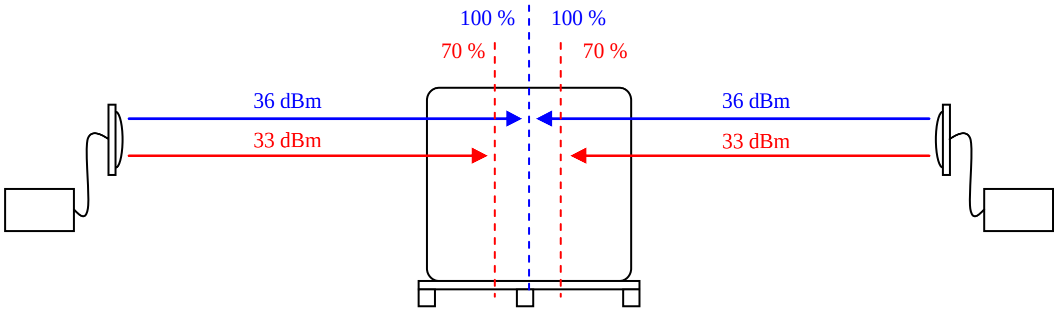


Figure C.1: Comparison of the read range within a pallet

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 only 200 kHz. This restricts UHF RFID in Europe to a reading rate of about 200 tags per second versus a need for 500 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 wide 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.

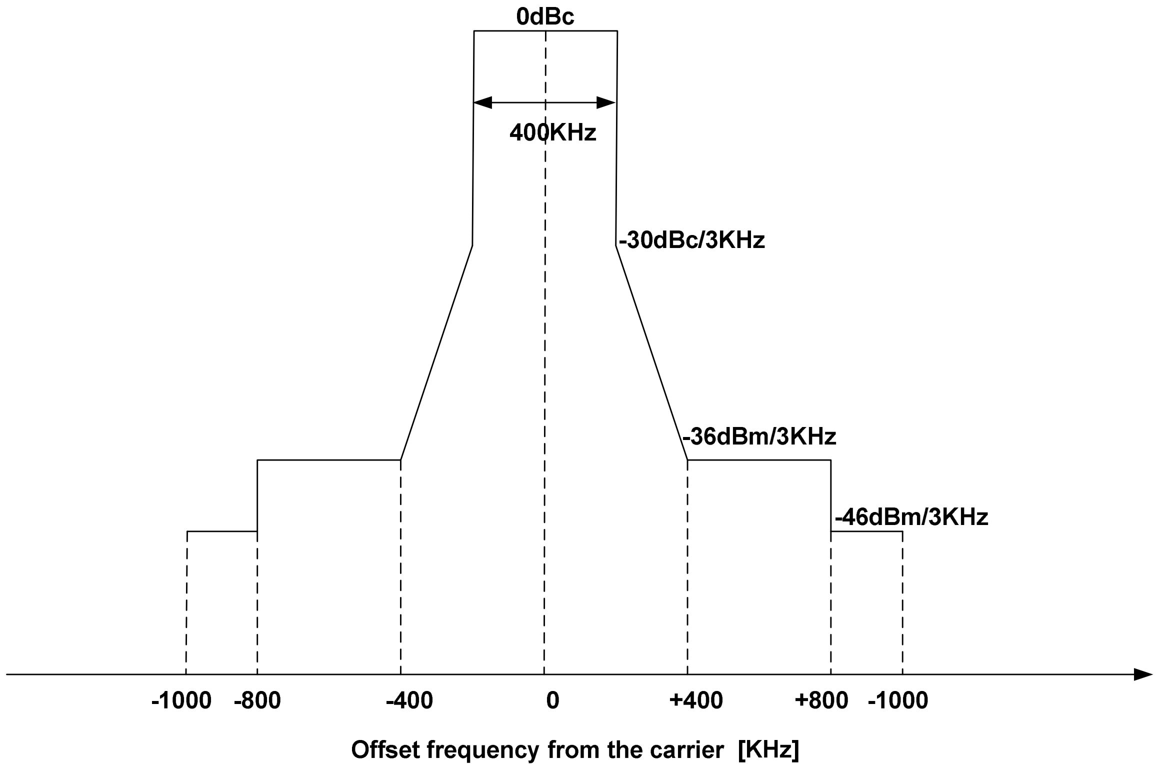


Figure C.2: High performance interrogator channel mask

Receiver parameters:

1) The beamwidth of the antenna(e) in the horizontal orientation should be ≤ 70 degrees.
2) The interrogator should identify a tag with a power level of -65 dBm.
3) The interrogator should identify a tag with a 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 avoidance;
- frequency avoidance;
- 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 of the interfering system transmission power on the operational band to the required level.

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 where 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 done 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 selected 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 power for the given frequency band but restricting the transmission in duration.

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.

More detailed parameters for the LDC protection mechanism relevant to the RFID/ER-GSM interference/protection pair need to be evaluated.

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 nearfield 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 transmission power below the maximum avoidance level.

D.7.2 Maximum avoidance power level

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

Annex E (informative): Bibliography

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History

Document history		
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