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Technical Report

Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD) intended for operation in the band 865 MHz to 868 MHz; Guidelines for the installation and commissioning of Radio Frequency Identification (RFID) equipment at UHF

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Foreword

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

Every TR prepared by ETSI is voluntary. This text should be considered as guidance only and does not make the present document mandatory.

The present document has been produced by ETSI in response to a perceived need by RFID manufacturers, installers and end users for general guidance on the installation and commissioning of RFID systems operating at UHF.

1 Scope

The present document provides recommendations to system integrators and installers on good practice for the installation and commissioning of RFID systems operating at UHF at power levels up to 2 W e.r.p. Guidance is given on making best use of the available spectrum as envisaged within the ETSI standard EN 302 208 [1]. In addition the present document covers the use of reduced power RFID devices at UHF, such as hand held readers and proximity printers, operating in accordance with EN 300 220 [2]. This includes operation in the sub-bands 869,40 MHz to 869,65 MHz at power levels of 500 mW and 869,7 MHz to 870,0 MHz at power levels of 5 mW. In particular the present document considers the practices necessary to minimize interference in situations where multiple interrogators are co-located in close proximity. Failure to take the necessary precautions could lead to degradation in system performance. The present document also endeavours to cover the approaches necessary to ensure that the operational requirements of the end-user are met.

The present document concerns itself with radio matters only. It does not provide any guidance on computer hardware and software that may be used to process the data recovered from tags.

Many of the techniques recommended in the present document have been subject to practical tests in a working distribution centre. However each application is different and the techniques recommended in the present document may not be applicable in all situations.

End users may wish to make use of the present document as a general guide.

The present document does not cover matters related to Health and Safety. End-users and system integrators should familiarise themselves with the relevant national and international standards.

2 References

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2.1 Informative references

[1] ETSI EN 302 208 (Parts 1 and 2): "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] ETSI EN 300 220 (Parts 1 and 2): " Electromagnetic compatibility and Radio spectrum Matters (ERM); Technical characteristics and test methods for radio equipment to be used in the 25 MHz to 1 000 MHz frequency range with power levels up to 500 mW".

[3] CEPT ERC/REC 70-03: "Relating to the use of Short Range Devices (SRD)".

[4] CEPT ECC Report 037: "Compatibility of planned SRD applications in 863 - 870 MHz".

[5] ISO 18000-6: "CD Information Technology RFI for item management Part 6 Parameters for air interface communications at 860 - 960 MHz".

3 Definitions, symbols and abbreviations

3.1 Definitions

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

assigned frequency band: frequency band within which the device is authorized to operate

dense-interrogator mode: RFID operating mode in which multiple, nearby interrogators can transmit simultaneously in a channel without incurring noticeable performance degradation

frequency agile technique: technique used to determine an unoccupied sub-band in order to minimize interference with other users of the same band

interrogator: equipment that will activate an adjacent tag and read its data

NOTE: It may also enter or modify the information in a tag.

link frequency: frequency offset of the tag backscatter with respect to the centre frequency of the interrogating signal

load: collection of tagged items that are carried on a transportable device

listen before talk: action taken by an interrogator to detect an unoccupied sub-band prior to transmitting (also known as "listen before transmit")

preferred channel: channel assigned to an interrogator which, provided it is available, is selected automatically as the channel of first choice

radiated measurements: measurements which involve the absolute measurement of a radiated field

reading range: maximum range at which a tag may be read by an interrogator

secondary channel: channels assigned to an interrogator, which is selected in the event that use of the primary preferred channel is not possible

tag: transponder that holds data and responds to an interrogation signal

3.2 Symbols

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

dB	decibel
dBm	power in decibels relative to 1 mW
d	distance
λ	wavelength

3.3 Abbreviations

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

AFA	Adaptive Frequency Agility
AM	Amplitude Modulated
CEPT	European Conference of Postal and Telecommunications Administrations
E.M.	ElectroMagnetic
e.r.p.	effective radiated power
ECC	Electronic Communications Committee
EMC	ElectroMagnetic Compatibility
ERC	European Radio communication Committee
FM	Frequency Modulated
LBT	Listen Before Talk
PIB	PolyIsoButylene
PM	Phase Modulated
R&TTE	Radio and Telecommunications Terminal Equipment
RCD	Residual Current Devices
RF	Radio Frequency
RFID	Radio Frequency IDentification
SRD	Short Range Device
UHF	Ultra High Frequency

4 Principles of operation

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 1.

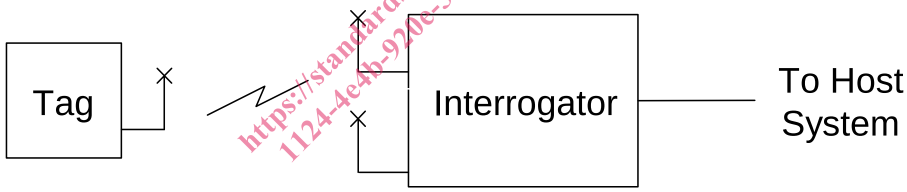

Figure 1: Principle of RFID

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.

4.1 Characteristics of RFID at UHF

UHF transmission takes place by means of electromagnetic (E.M.) waves. At these frequencies E.M. 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 E.M. transmissions and near field coupling.

4.1.1 Antennas

At UHF the shape of the interrogation field generated by the E.M. 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). The variation of reading range with orientation in the z plane is considered under "Recommendations for mounting tags" in clause 6.5.

4.1.2 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/CEPT 70-03 [3] and is effectively a fixed parameter. For channels of 200 kHz channel spacing as defined in annex 11 of ERC/CEPT 70-03 [3] 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 18000-6 [5].

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.

4.1.3 Intermodulation Products

Where two or more devices are sited close to each other and are transmitting at similar frequencies, they may interfere with each other. This can arise through the generation of intermodulation products. These are unwanted transmissions that occur at frequencies that are at multiples of the sums and difference 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.

4.1.4 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 1: 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.

4.1.5 Shielding

A particular difficulty with systems operating at UHF is that the E.M. 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.