ETSI TR 102 436 V1.1.1 (2005-12)

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

Reference
DTR/ERM-TG34-002

Keywords
ID, radio, UHF

ETSI

650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - NAF 742 C
Association à but non lucratif enregistrée à la
Sous-Préfecture de Grasse (06) N° 7803/88

Important notice

Individual copies of the present document can be downloaded from:
http://www.etsi.org

The present document may be made available in more than one electronic version or in print. In any case of existing or perceived difference in contents between such versions, the reference version is the Portable Document Format (PDF). In case of dispute, the reference shall be the printing on ETSI printers of the PDF version kept on a specific network drive within ETSI Secretariat.

Users of the present document should be aware that the document may be subject to revision or change of status. Information on the current status of this and other ETSI documents is available at
http://portal.etsi.org/tb/status/status.asp

If you find errors in the present document, please send your comment to one of the following services:
http://portal.etsi.org/chaircor/ETSI_support.asp

Contents

Intellectual Property Rights

IPRs essential or potentially essential to the present document may have been declared to ETSI. The information pertaining to these essential IPRs, if any, is publicly available for **ETSI members and non-members**, and can be found in ETSI SR 000 314: *"Intellectual Property Rights (IPRs); Essential, or potentially Essential, IPRs notified to ETSI in respect of ETSI standards"*, which is available from the ETSI Secretariat. Latest updates are available on the ETSI Web server (http://webapp.etsi.org/IPR/home.asp).

Pursuant to the ETSI IPR Policy, no investigation, including IPR searches, has been carried out by ETSI. No guarantee can be given as to the existence of other IPRs not referenced in ETSI SR 000 314 (or the updates on the ETSI Web server) which are, or may be, or may become, essential to the present document.

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 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 potentially lead to a serious degradation in system performance. The 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 familiarize themselves with the relevant national and international standards.

2 References

For the purposes of this Technical Report (TR), the following references apply:

[1] ETSI EN 302 208 (all parts): "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 (all parts): "ElectroMagnetic Compatibility and Radio Spectrum Matters (ERM); Short Range Devices (SRD); Radio equipment to be used in the 25 MHz to 1 000 MHz frequency range with power levels ranging up to 500 mW".

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

[4] ECC Report 037: "Compatibility of planned SRD applications with currently existing radiocommunication applications in the frequency band 863-870 MHz".

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

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

[7] ETSI EG 200 053 V1.5.1: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Radio site engineering for radio equipment and systems".

[8] ETSI EN 301 489-1: "Electromagnetic compatibility and Radio spectrum Matters (ERM); ElectroMagnetic Compatibility (EMC) standard for radio equipment and services; Part 1: Common technical requirements".

[9] ETSI EN 301 489-3: "Electromagnetic compatibility and Radio spectrum Matters (ERM); ElectroMagnetic Compatibility (EMC) standard for radio equipment and services; Part 3: Specific conditions for Short-Range Devices (SRD) operating on frequencies between 9 kHz and 40 GHz".

[10] CENELEC EN 50357: "Evaluation of human exposure to electromagnetic fields from devices used in Electronic Article Surveillance (EAS), Radio Frequency Identification (RFID) and similar applications ".

[11] CENELEC EN 50364: "Limitation of human exposure to electromagnetic fields from devices operating in the frequency range 0 Hz to 10 GHz, used in Electronic Article Surveillance (EAS), Radio Frequency Identification (RFID) and similar applications".

[12] CENELEC EN 60950-1: "Information technology equipment - Safety - Part 1: General requirements".

[13] CENELEC EN 50174 (all parts): "Information Technology - Cabling Installation".

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

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

global scroll: mode in which an interrogator is able continuously to read the same tag

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

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

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")

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

scan mode: specific test mode of an interrogator that detects a signal on a pre-selected sub-band and transmits automatically on another sub-band (as defined in EN 302 208)

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

talk mode: transmission of intentional radiation by an interrogator

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:

A.C.	Alternating Current
AM	Amplitude Modulation
CEPT	European Conference of Postal and Telecommunications Administrations
e.r.p.	effective radiated power
ECC	Electronic Communications Committee
EMC	ElectroMagnetic Compatibility
ERC	European Radio communication Committee
FM	Frequency Modulation
PM	Phase Modulation
R&TTE	Radio and Telecommunications Terminal Equipment
RF	Radio Frequency
RFID	Radio Frequency IDentification
SRD	Short Range Device

4 Principles of operation

A basic RFID system comprizes 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.

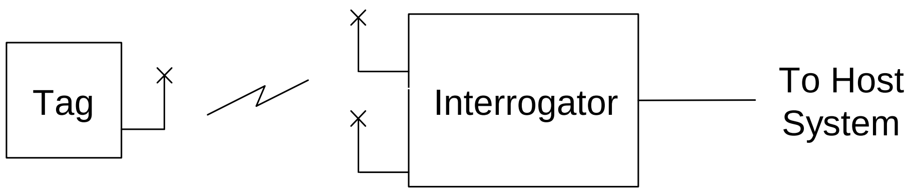


Figure 1: Principle of RFID

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 since they are the only form of communication that is relevant 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 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.

However UHF can present the installer with a number of challenges. Transmissions at UHF are readily reflected from many surfaces. These can cause the activation of unwanted tags and can also give rise to an effect known as standing wave nulls. This 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.

4.1.1 Antennas

At UHF the shape of the interrogation field generated by the 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 expressed as both a horizontal and vertical value, 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 of the interrogation zone.

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 version 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 an 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 6.6.

Where the orientation of the tag is known it is possible to use a linear antenna, which will provide an increase of about 40 % in the maximum achievable reading range. The reason for this is that with a linear antenna, the tag will continuously be in its optimum orientation. For a circularly polarized transmission the tag will experience optimum orientation for only some of the time because the transmit field is rotating. In the later case less power is transferred to the tag, which therefore operates at less range.

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, or sub-band, of operation of the interrogator. The size of the sub-band is specified in CEPT document ERC Recommendation 70-03 [3] and is effectively a fixed parameter. For sub-bands with 200 kHz channel spacing as defined in annex 11 of ERC Recommendation 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, sub-band as the downlink. This will place a practical limit on the achievable data rate. However in the case of EN 302 208 [1] the wanted signal from the tag is permitted to occupy the entire allocated 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 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 achievable. 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	Range - cm	$(R/Rref)^2$	Loss dB
	Distance - cm			
Air	200	200	1,00	0,00
Tag on front of plastic case	200	180	1,23	0,92
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.

4.1.4 Shielding

A particular difficulty with systems operating at UHF is that the 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 off a mirror. While this stops the transmitted signal from passing into the unwanted area, consideration must be given to the likely destination 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, e.m. 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.

4.1.5 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 e.m. absorbent materials, which may be exposed to the elements and to possible physical damage.

NOTE: If 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.

4.2 Operation in the band 865 MHz to 868 MHz according to EN 302 208

In response to a need from the market, ETSI has developed a standard (EN 302 208 [1]) specifying the minimum requirements for RFID systems at UHF. At about the same time CEPT undertook a major compatibility study, which included an investigation into the probability of interference by RFID to other equipment operating in the same and nearby bands. The results from this study are contained in ECC Report 37 [4] and show that with the use of certain mitigation techniques RFID may co-exist with other devices in the band.

4.2.1 Permitted power levels and frequencies

EN 302 208 [1] specifies operation of RFID equipment in the band 865 MHz to 868 MHz at power levels up to 2 W e.r.p.. Interrogators operate in sub-bands of 200 kHz channel spacing. A diagram showing the allocation of sub-bands and the permitted maximum levels for transmission within the sub-bands is provided in figure 2.

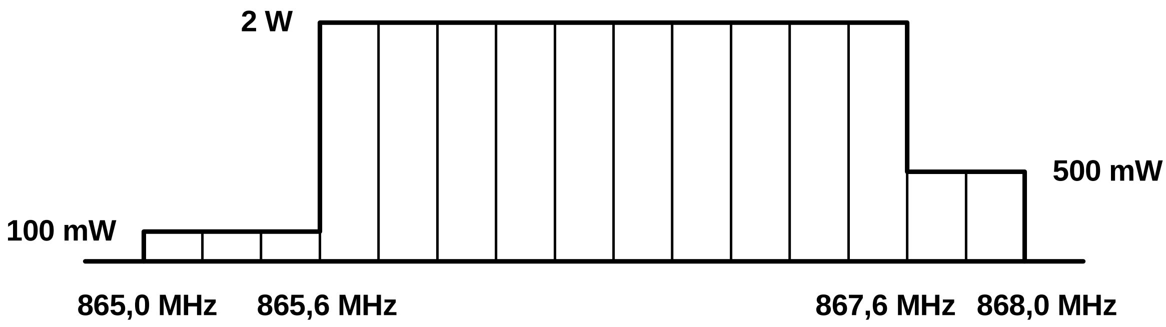


Figure 2: Illustration of permitted power levels and frequencies

It will be seen from figure 2 that the three lowest sub-bands are restricted to a maximum power level of 100 mW e.r.p. The next 10 sub-bands may operate at power levels of up to 2 W e.r.p. and the upper two sub-bands may transmit at power levels up to 500 mW e.r.p.

4.2.2 Listen before talk (LBT) and frequency agility

To ensure optimum use of the band and compatibility with other users, RFID interrogators use a technique called "listen before talk". Usually this will be combined with frequency agility, which is the ability of interrogators to switch under software control between sub-bands. At the start of each interrogation cycle an interrogator first checks that the sub-band on which it intends to operate is not already occupied by another user. If the sub-band is available the interrogator is permitted to transmit. However if the sub-band is already in use, the interrogator must search the other sub-bands until it finds one that is unoccupied. Alternatively the interrogator may continue to listen on the original sub-band until it has verified that the sub-band has become available.

During the "listen" mode the receiver element associated with the interrogator operates at a high level of sensitivity. This is to ensure that it detects the presence of any other devices that may be operating within range of the interrogator. Once the interrogator has established that it is clear to transmit, its sensitivity is reduced to a level that is no greater than necessary to receive the responses from tags in its immediate area.

To ensure equitable sharing between users of the band the standard imposes a number of rules. For example an interrogator may not transmit continuously on the same sub-band for more than 4 seconds. Once the interrogator has stopped transmitting it may not re-transmit on the same sub-band for a further 100 ms. However an interrogator may switch immediately to another sub-band that is unoccupied. There are also rules covering the minimum listen time, which is at least 5 ms.

The standard EN 302 208 [1] requires that interrogators transmit for no longer than is necessary to perform the intended operation. This clause is included to ensure that maximum productive use is made of the available spectrum by all users of the band.

4.2.3 Implications for multiple interrogators

This clause considers operation of interrogators in the asynchronous mode. By means of both frequency agility and time-sharing it should be possible to accommodate a significant number of interrogators at a single site. Using this approach the key factors that will determine the maximum size of a system are the level of use of each of the interrogators and the average time to read each load.

The principle is best understood by an example. Consider a building that is fitted initially with 10 interrogators. Since 10 channels are allocated for use by RFID, and provided no channel is occupied by an outside user, it will be possible to operate all 10 interrogators simultaneously. This is because each interrogator will automatically select an unoccupied channel.

If the site is subsequently expanded to say 14 interrogators, the number of available channels will be less than the number of interrogators. It will therefore be necessary for interrogators to share time on the same channels. This is conceptually similar to the principle used by an Ethernet system in a busy office. Fortunately the process takes place automatically.

From this example it will be clear that the shorter the transmit time of an interrogator in relation to the "off" time, (known as the duty cycle) the more time will be available for other interrogators to use the system.

Techniques for estimating the total channel occupancy of multiple integrators at a site are considered in clause 6.2.

Situations may arise in very busy large sites where the operational requirements may exceed the available spectrum capacity. This could also occur where a number of sites, each equipped with RFID, attempt to operate in the same geographic area. The distance between buildings at which interference might be evident will be very site dependent. At one extreme it may be 500 m or less. At the other extreme it may extend to 10 km or beyond.

Where the spectrum capacity is exceeded all users in the area will experience a degradation in performance. Techniques for addressing this problem will be covered in a later revision of the present document.

4.2.4 Fixed and portable readers

Interrogators are fixed devices that are often connected to an antenna array configured to cover a defined interrogation zone. Portable devices also exist which are frequently referred to as hand held readers. A further example of a portable device is where readers are fitted to forklift trucks. There will frequently be situations where end users will wish to operate combinations of all three devices on the same site. To minimize problems of incompatibility, there may be benefits in operating fixed and portable devices at different frequencies. This is covered in more detail in clause 4.3.

4.3 Operation in the band 868 MHz to 870 MHz under EN 300 220

Operation of RFID in two other sub-bands within the band 868 MHz to 870 MHz is permissible under the ETSI standard EN 300 220 [2]. The first of these sub-bands is in the frequencies 869,40 MHz to 869,65 MHz at power levels up to 500 mW e.r.p. Operation in this sub-band is permitted using either a duty cycle restriction of 10 % or LBT. The second sub-band is in the frequency range 869,7 MHz to 870 MHz at power levels up to 5 mW e.r.p. Due to the low limit on transmitted power in this second sub-band, there is no restriction on duty cycle.

4.3.1 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 % may well be operationally acceptable. For this type of use it may be advantageous to configure handheld readers for operation in the sub-band 869,4 MHz to 869,65 MHz. Such an arrangement will minimize any possible interaction between handheld readers and fixed interrogators. Provided there is adequate physical separation it may also permit the asynchronous use of multiple handheld readers within the same installation.

Not all applications using handheld readers will lend themselves to this approach. For example situations may arise where the operator wishes to scan a number of tagged items - such as a collection of tagged clothes on a display rack. In this situation a duty cycle restriction of 10 % may be unacceptable. Instead it will be necessary to operate the handheld reader using LBT. Preferably the reader should operate in either the band 869,4 MHz to 869,65 MHz, or in the sub-bands allocated for use at 100 mW or 500 mW under EN 302 208 [1].

4.3.2 Vehicle mounted readers

To be included in a later version of the present document.

4.3.3 Proximity printers

Industrial printers that are used to encode RFID labels are called proximity printers. In many applications proximity printers will experience periods when they will be required to function almost continuously. It is thus desirable from both a financial and technical standpoint for them to operate with no restriction on duty cycle and without the need for LBT. The antenna of a proximity printer is usually enclosed and it operates over a short reading range. It is therefore technically feasible to design a proximity printer so that the intentional field radiated outside the equipment is less than 5 mW e.r.p. For this reason proximity printers should preferably operate in the sub-band 869,7 MHz to 870 MHz under EN 300 220 [2]. This has the further advantage that the printers will be using a frequency that is removed from the bands occupied by 2 W interrogators and handheld readers.

5. Preliminary considerations

Many potential problems can be eliminated if the capabilities and limitations of RFID are clearly explained at the start of the sales process. Detailed discussions should be held with the end user to ensure that any implications associated with use of the RFID system can be accommodated within the operational procedures on the site. (This may require the end user to modify his existing procedures to derive maximum benefit from RFID.) At this stage it will also be important to explore with the end user how the data captured from the tags should be processed in order to integrate with existing data management systems.

If this is the end user's first experience of RFID he should be encouraged initially to install a pilot system. The pilot should be sufficiently extensive to enable the end user to exercise all of the essential features of his system. This will give the end user some early exposure to RFID and will allow him to assess the impact of any effects that had not been previously anticipated.

5.1 Acceptance Tests

At an early stage in the project it is important to agree with the customer a set of tests that will demonstrate performance of the installed system in accordance with the agreed requirements.

6 Site considerations

Sites may be classified as small to medium sized installations and as large installations. Small to medium sized systems may loosely be defined as having up to 25 interrogators, not all of which would transmit simultaneously. (Clause 6.2 provides further information.) Large systems are defined as systems that comprise more than 25 interrogators. The techniques recommended for these two types of installation are different. The treatment of large systems falls outside the scope of the present version of this document. However it is anticipated that it will be covered in a later version that will be published shortly.

Before work can commence on the design of a system it is first necessary to carry out a site survey. The points to be covered in the site survey are the same for all types of installation.

6.1 Site survey

The importance of conducting a thorough site survey cannot be over emphasized. If possible the following points, which are not exhaustive, should be covered. In particular the relevance of each of these points should be considered with reference to the characteristics of the RF environment.

- The construction of the building should be noted including the materials used for the walls and roof.
- A drawing of the site should be obtained.
- The operation of the site should be fully understood including tagged volumes and traffic levels at different times during the day.
- The locations of suitable interrogation points should be agreed.

- Any restrictions on the mounting of antennas or the use of shielding must be identified.
- Any restriction on cable runs should be recorded.
- The need for hand held readers or any other portable interrogators should be noted.
- The end user's requirements for tagging of objects must be understood and the effect that these requirements may have on readability should be explained.
- The impact of Health and Safety regulations and other site procedures should be assessed.
- Sources of possible interference should be noted including the possibility of RFID systems in nearby buildings.
- The availability or specification of suitable power points, data points and earthing should be marked up on the drawing of the site.

Any potential issues involved with the installation, including necessary support material, should be highlighted at this stage.

6.2 Sizing systems

This clause is aimed primarily at system integrators and installers.

Classification of a site by the number of interrogators is not very meaningful since it does not provide a measure of channel occupancy. This particularly becomes an issue when a system comprises more than 10 interrogators, which are all in use. A better approach is to assess the conditions for each of the interrogators on the site at peak operation. This will provide a guide as to whether the operational demands are compatible with the system's capabilities. One possible technique for doing this is described below.

Begin by defining the average duty cycle for each interrogator when the site is running at maximum capacity. The duty cycle for each of the interrogators should be normalized and the results summed together then the total divided by the number of available channels. The result is a figure that gives the *average* channel occupancy while the site is operating at peak load. From a system perspective interrogators will start their interrogation cycles on a random basis. So in practice there will be times when the actual channel occupancy is both greater and less than the average figure.

The method for deriving channel occupancy may best be understood by means of a worked example. Consider a very busy site comprising 12 interrogators all in continuous use and each having the following duty cycles:

a) 6 interrogators transmitting for 2 s in every 8 s;

b) 4 interrogators transmitting for 4 s in every 20 s;

c) 2 interrogators transmitting for 1 s in every 5 s.

For the interrogators in group a) each interrogator will transmit for 2 s in every 8 s. This may be expressed as a normalized figure of 2/8 or 0,25. In other words each interrogator will transmit on average for 0,25 sec in every second. Therefore all 6 interrogators in group a) will transmit for 6 × 0,25 or 1,5 sec in every second. Similarly the interrogators in group b) will transmit for 0,8 sec in every second (derived from 4/20 × 4) and the interrogators in group c) will transmit for 0,4 sec in every second (derived from 1/5 × 2). The total transmit time for all interrogators is the sum of the three groups, which is 1,5 + 0,8 + 0,4 or 2,7. Thus in total the interrogators will transmit on average for 2,7 s in every second. Since there are 10 channels available in which to share the transmissions, this equates to 0,27 sec per second of transmission on each channel. This represents channel occupancy of 27 %.

The figure for channel occupancy gives an indication of the demand that is placed on a system. As this figure increases above a certain level, the overall performance of the system will be progressively degraded. Initially this will appear as an occasional small but perceptible delay before an interrogator detects a clear channel. Above about 90 % channel occupancy it is probable that queuing for a clear channel will be necessary.

The level at which a degradation in performance will first be apparent will be a function of the operational requirements of the installation and the ability of the LBT routine in the interrogator to locate a clear channel. Site engineers should quickly gain an appreciation of acceptable levels for channel occupancy based on practical experience. This may allow recommendations for channel occupancy to be included in future versions of this document. In the meantime it is hoped that system integrators will regard this technique as a useful tool during their initial discussions with the customer.

6.3 Basic principles

Begin by reviewing the distances between the antennas of the interrogators. This should include consideration of anything that might influence the radio path, such as partitions or reflective surfaces. An assessment should then be made of the risk of interference between interrogators taking into account the transmitted power levels and the sensitivity of the tags. In particular care must be taken during the planning stage to ensure that, during normal operation, tagged items to be read by one interrogator will not pass sufficiently close to other interrogators to cause unwanted readings. Also if two interrogation areas are located side by side it may be possible for the interrogator in one interrogation zone to read the tags passing through the adjacent interrogation zone. Possible portal designs to mitigate against these situations are covered in clause 6.4.

Next, it is essential to obtain from the end-user details of the maximum number of tags on a load and the highest speed at which loads will travel. Knowing the beam-width of the antenna, the highest speed should be used to determine the minimum time for which the load will be present in the interrogation zone. This time should be compared against the anticipated reading rates for multiple tags. In some applications it may be necessary to verify these predictions with some practical tests. If it is impossible to read all of the tags in a load within the time available, it will be necessary to discuss with the end-user acceptable means either to reduce the speed of movement of the load or reduce the maximum number of tags in a load or to consider re-configuration of the antennas.

In addition it is important to consider the design of the interrogation zones. Maximum capacity will be achieved across the whole system where the transmission time at each interrogation zone is kept to a necessary minimum. The activation of each read operation may be initiated by some form of trigger. For example the read operation might be triggered by a passing load as it breaks a light beam.

Interrogators should cease transmitting as soon as reasonably possible once they have completed reading the tags on the load. There are a number of means by which this might be implemented. For example a second trigger device might be fitted on the exit side of each interrogation zone. Alternatively the software in the interrogator might be configured to cease transmission a set period after it was initially triggered. A third approach could be for interrogators to stop transmitting a specified period after they had ceased to read any further tags. Typically this period might be of the order of 100 ms, although the actual figure will be application specific.

6.4 Antenna Configurations

The configuration of antennas will be highly dependent on individual applications. The present document therefore is able only to provide broad guidelines on the subject.

It should be appreciated that transmissions at UHF are capable of travelling over considerable distances. To minimize the risk of interference with other nearby systems, the beamwidth selected for antennas should be no greater than is required for the application. Similarly, where it is feasible to do so, the power transmitted by the interrogator should be limited to no more than is necessary for satisfactory operation. Of course other factors may also influence the choice of antenna. For example some applications may require the antenna to be kept to a minimum size or there may be severe constraints on cost.

In applications where interrogators are required to read single tags, or a small number of tags grouped closely together, the operation can usually be performed using only one antenna. This may well apply for example in the use of hand held readers or to antennas mounted on forklift trucks. Similarly there may be a requirement to read tagged items moving along a conveyor. For such applications often it will be convenient to mount the antenna overhead and place a tag on the top face of each item. This will enable the transmission from the antenna to be directed downwards onto the top of the passing items.

The situation is more complex for fixed interrogators that read large loads containing multiple tags in random orientation. Here it is frequently necessary to position a number of antennas at points that optimize the probability of reading the tags in their various positions on the load. Many manufacturers supply interrogators that are capable of driving multiple antennas by means of multiplexers. These drive each antenna in turn in accordance with a pre-arranged sequence that is configurable.

An example of an antenna configuration to read loads as they pass through a control point is shown in figure 3. The configuration consists of two pairs of circularly polarized antennas placed one above the other on either side of the path of the load. As the load passes through the interrogation zone the tags are subjected to transmissions from a variety of directions, maximizing the opportunity for their detection.

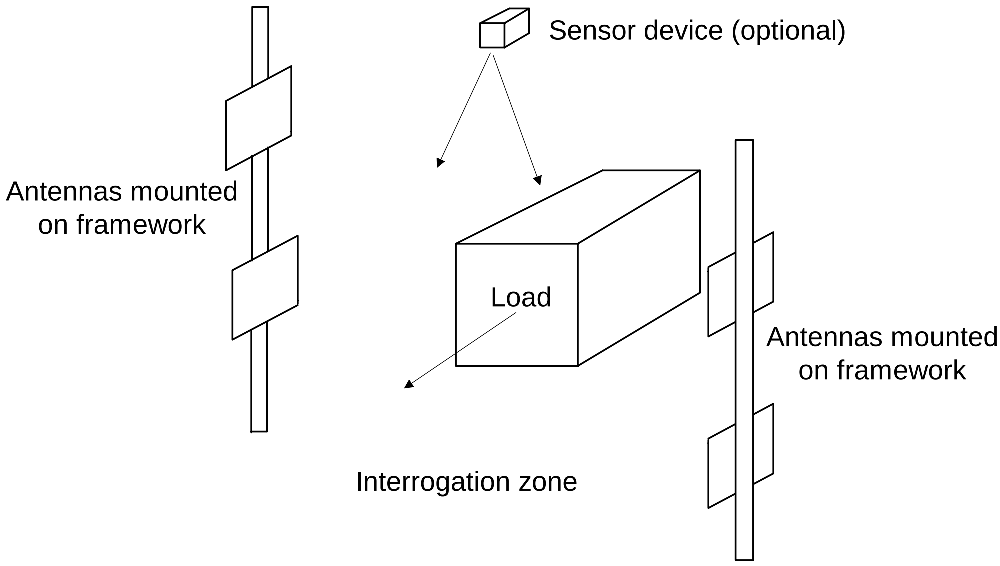


Figure 3: Antenna configuration for an isolated control point

In certain applications it may be desirable to provide some form of indication to the operator that the interrogator is in a ready state and a further indication that the read operation has been successful. This may be achieved for example by means of either audible or visual signals.

There may be situations where the direction that the load passes through the interrogation zone is important. It this is the case, it may be necessary to incorporate sensors on both sides of the interrogation zone in order to determine from which side the load is approaching. It is important to remember that in areas with a lot of movement, directional sensors can be confused.

Where an interrogation zone is sited in a remote location, the possibility of interference with other interrogators on the site is low. It should be noted however that there might be sources of noise from other devices in the area. (See clause 6.7.) If the risk of interference at the interrogation zone is believed to be low, no special precautions are necessary.

In situations where interrogators are sited close together, there is a significant risk of interference between them. To minimize these effects it may be necessary to consider specialist techniques, such as the use of antennas with a narrow horizontal beam-width and e.m. absorbent materials. An example illustrating these techniques is provided in annex C, which describes a pre-fabricated portal for the dock-doors of warehouses.

A disadvantage of an antenna with a narrow horizontal beamwidth is that it reduces the width of the interrogation zone. Thus for an antenna with a narrow horizontal beamwidth, the time available in which to read the tags on a load is less than with a wider horizontal beamwidth. This may place a restriction on the speed at which loads may travel or on the maximum number of tags on a load. It may also restrict the ability to read tags that are mounted in non-preferred orientations.

6.5 LBT receivers

Some interrogators include a separate LBT receiver and antenna. This operates independently of the receiver that is used to read the replies from the tags. Where interrogators are fitted with a separate LBT receiver, their antenna(s) may be mounted at a point away from the main lobes of the transmit antennas. The LBT antenna(s) will frequently be in the form of a half wave dipole and should therefore be mounted vertically.

6.6 Tags

Where possible tags should be used that offer a consistent reading range. This optimizes the probability of activating wanted tags on loads that are in the interrogation zone read and minimizes the possibility of reading unwanted tags that are positioned elsewhere.

The exact point chosen for mounting the tag on an object may have an important effect on its range. Where feasible a position (known as the sweet spot) should be located where the reading range is least affected by the contents of the object. If it is possible to locate a sweet spot for a particular object, this position should be adopted for all other objects of the same type.

In the event that a satisfactory sweet spot cannot be found, it may be possible to insert a spacer between the tag and the object. A spacer of about 5 mm in thickness will, in many cases, recover much of the lost reading range. In the case of metal objects, special tags are available that are suitable for mounting directly on metal surfaces. However their increased cost in many cases may make their use unattractive.

Optimum reading range is achieved when the antenna of the tag lies in the same plane as the front face of the antenna of the interrogator. If the signal from the interrogator is circularly polarized, the tag may be rotated in this plane without any reduction in reading range. However as the antenna of the tag is orientated to a position where it is at right angles to the front face of the antenna of the interrogator, its range will be progressively reduced. The effect of tag orientation on reading range is illustrated in figure 5. In this example if the antenna for the tag is mounted horizontally on an object and the orientation of the object is unknown, the reading performance will be variable. Where the application permits, this problem may be simply overcome by mounting the antenna of the tag vertically.

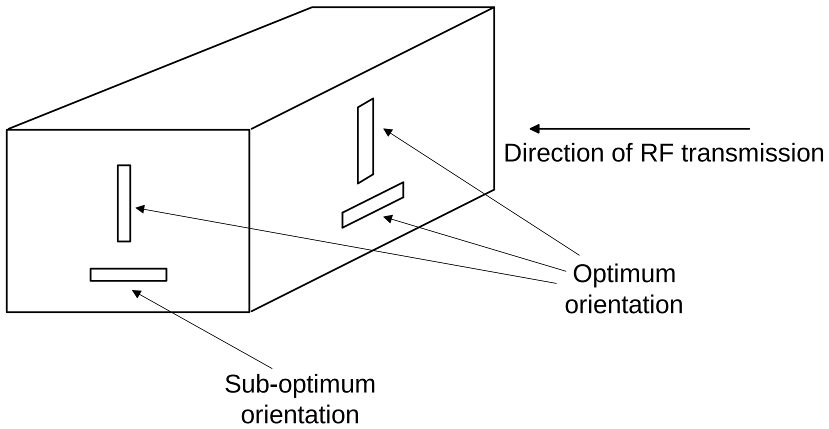


Figure 4: Effect of tag orientation on tag activation

Some tag manufacturers are offering tags where the reading range is claimed to be substantially the same irrespective of their orientation with respect to the antenna of the interrogator. Existing versions may be larger than conventional tags and they are likely to be somewhat more expensive. However in applications where the orientation of the tag is unknown their use may be justified.

If possible tags should be positioned on the outside of loads. Where items are orientated so that their tags face inwards, their reading range may be reduced. This is for two reasons. Firstly the tag will be in contact with another object that may adversely affect its range. Secondly the path between the tag and interrogator may be attenuated by the presence of other objects. Therefore wherever possible avoid orienting objects so that their tags face towards the centre of the load.

6.7 Sources of interference

Fortunately the level of interference generated at UHF by most electronic devices is low and is unlikely to cause any difficulties. However there are a number of sources of interference that may adversely affect performance. Typically these include other SRDs, mobile phones, inter-modulation products generated by some electronic devices such as lighting systems and wideband noise generators such as electric arc welders. The influence of some of these effects may be reduced by either shielding and e.m. absorption materials, or the use of a portal similar to that described in annex C.

Less obvious sources of noise may be the consequence of unwanted reflections from the fabric of the building. Other sources of noise may be caused by the movement of people near the interrogation zone or by reflections from loads passing through or close to interrogation zones. The more the transmission from the interrogator can be localized within the wanted interrogation zone, the more these effects may be minimized. Once again the use of a portal arrangement similar to that described in annex C represents a good starting point.

A source of interference not to be overlooked is that from another RFID system operating in an adjacent building. If this is suspected it may be necessary to use a detection device, such as a portable spectrum analyser connected to a directional antenna, to locate the source. If the source of interference is traced to another Short Range Device (SRD) in the area, it should firstly be understood that RFID operates in an unprotected band within the radio spectrum. No operator of an RFID system has any exclusive rights to the use of the band. It will be necessary therefore for the respective end-users to meet and reach agreement on an amicable arrangement whereby they may co-exist.

7 Recommendations for installation

This clause covers the standard practices and procedures that should be observed by system integrators during the installation and commissioning of systems on site.

7.1 Antenna fixtures

During their normal working life antenna fixtures will be subject to occasional blows from heavy objects moving at speed. It is therefore essential that any exposed antennas are given adequate physical protection. Similarly it will be necessary to ensure that any frames used for mounting antennas are suitably robust. If the frames are manufactured from metal care should be taken to ensure that the choice of metal does not give rise to corrosion. Steel frames should be galvanized or covered with a suitable protective coating. Where dissimilar metals are in contact with each other wherever possible they should be selected from the yellow metal series such as copper, brass, silver, nickel, or gold. All parts of the frame should be in good electrical contact with each other and the structure should be earthed at a single point.

Aluminium structures should not be anodized as this is likely to insulate the different components and lead to problems with their conductivity and earthing.

7.2 Selection of antennas

Having determined the necessary beamwidth of the antenna, it will be important to check with the manufacturer of the interrogator that the combination of the antenna and interrogator is compliant with the R&TTE Directive [6]. If the manufacturer of the interrogator has no knowledge of the selected antenna, the system integrator must approach the manufacturer of the antenna. Alternatively the system integrator may take the steps necessary to ensure compliance.

When mixing equipment such as interrogators, cables and antennas from different manufacturers, ultimately it is the responsibility of the systems integrator to ensure and document that the combination of equipment satisfies the requirements of the Directive and that the radiated power does not exceed the permitted limits.

The maximum permissible power supplied by the interrogator to the antenna will be dependent on the gain of the selected antenna and its associated cabling. The interrogator should be adjusted to ensure that the power radiated by the selected antenna falls within the limits permitted by the country in which the equipment will be operated.

The manufacturer of the interrogator should be asked to provide the documentation on how to make the necessary adjustments to the transmitter drive signal.

7.3 Positioning of the antenna

Wherever possible fixed antennas should be mounted such that the radiation path is clear of any significant metalwork. Failure to do this will lead to a reduction in the gain of the antenna and a consequent reduction in the range at which tags may be read. Care must also be taken to ensure that any nearby metalwork does not cause unwanted reflections, e.g. by the use of e.m. absorbent material. In certain applications it may be necessary to protect the front of the antenna with a suitable RF transparent material.

7.4 Outside Antennas

Antennas that may be exposed to outside conditions, such as at dock doors, must be sufficiently robust to survive the environment over a number of years. Where necessary they must be protected against strong winds and must be resistant to rain and high humidity. The outer casings of the antennas must be made of a material that will withstand prolonged exposure to ultra-violet light. They must also be capable of operating satisfactorily over the anticipated temperature range. In addition it may be prudent to include some form of protection against lightning. Unless guidance on lightning protection is provided in the manual for the interrogator, the manufacturer of the antenna should be asked for advice.

Weather conditions may be the cause of a reduction in system performance. This may be particularly evident where antennas are sited at an entrance to a building. A reduction in reading range will often be observed in damp or foggy conditions.

All external connectors to the antenna should be suitable for outside use, e.g. either protected against humidity or water proof. For example they may be protected by means of PolyIsoButylene (PIB) self-amalgamating tape. Particular attention should also be paid to the shedding of surface water.

7.5 Cabling

Use the feeder cables and connectors recommended by the manufacturer of the interrogator. Wherever possible feeders should be run over the most direct and shortest route since this will give minimum radiation from the cable and the least insertion loss. Cables should be run in accordance with the recommended bending radii. Consideration should also be given to the insertion loss of RF cables of different lengths. If it is necessary for feeders to cross mains or data cables, they should do so at right angles.

Mains and data cables should be protected by means of surge arrestors.

Mains cabling should be run in accordance with local and national regulations. The minimum requirement as far as the user is concerned is the inclusion of Residual Current Devices (RCD).

All cables from interrogators to the computer room should be protected so that they cannot easily be damaged. Where possible interrogator cables and mains cables to the computer room should be run through separate inputs.

All cables should be identified at each end and their details recorded in the installation records for the site.

7.6 Earthing (fixed interrogators)

A satisfactory earthing system (e.g. standard earth provided in the building) is an important and often neglected aspect of any installation. It is recommended that the measured earth value should be less than 10 Ohms. However the important feature is that the system should be equipotential across the site.

It is important to ensure that all interrogators are adequately earthed. In addition all portals or antenna mounting structures that are constructed from metal should be bonded to earth at a single point on the structure.

Connections to the site earth (where corrosion may be unavoidable) should be made using sacrificial anodes of a material compatible with the structure being earthed.

A method of measurement to determine the value of the earth at a site is described in annex B.

Before making any changes to an earthing system, it is important to consult the owners of the site and the relevant electricity supply authority.

8 Commissioning

8.1 Setting to work

It is essential that the system is set to work in a thorough and logical manner. Before starting a plan should be prepared listing the steps in preferred sequence necessary to commission each interrogator and its associated equipment. Suitable paperwork should be prepared to record the key set-up conditions for all equipment forming part of the installation.

A suggested procedure for commissioning is provided in annex D.

In many installations not all parts of the system will be supplied by the same sub-contractor. In this situation the components provided by each supplier will most probably be subject to separate commissioning and acceptance.

Once the different parts of the system have been accepted, the full system will usually be tested and accepted against pre-agreed performance criteria.

Any maintenance agreement and warranty will often commence once the end user has formally accepted the system, or sub-system, provided by a supplier. This is frequently set out in the terms of the supply contract.

8.2 Site records

Comprehensive and accurate records are essential for efficient fault finding and for the proper maintenance of the installation. The records should include cable schedules giving details of all cables that form part of the installation. The records should also include any final measurements made at each interrogator during commissioning. In addition the records should contain manufacturers' documentation for each item of equipment that makes up the total system.

A minimum of two copies of the records should be produced. One copy should be passed to the customer while the second copy should be retained by the installer.

9 Maintenance

To ensure continued satisfactory performance of the system it is vital that arrangements are made with the customer for regular maintenance. In general maintenance will fall into two categories. There will be periodic site maintenance that will be performed by the end-user on a regular basis. In addition the organization responsible for overall maintenance of the installation may undertake planned maintenance visits to site to check that the essential parameters of the system are correct. Amongst other things this may include inspection of both cabling and earthing and a check of all key system parameters. All periodic tasks to be undertaken by the end-user and by the organization responsible for overall maintenance of the installation should be detailed thoroughly in a maintenance document and agreed by the parties.

The maintenance agreement may contain a list of recommended spare parts to be held by the end-user.

The agreement on maintenance may also include arrangements for call-out in the event of a system failure.

Annex A: Conversion of units of measurement

A.1 Measurements of power

Measurements of power that are made in electronics frequently span many orders of magnitude. The handling of these figures is made simpler if logarithmic units are used. For convenience measurements are made in terms of relative power in units of decibels (dB). For two power levels P1 and P2 the relative power expressed in dB is:

$$dB = 10 \times Log_{10} (P_1/P_2)$$

It is common practice to measure changes of power in terms of voltage across a fixed load. Since power is proportional to the square of the voltage, the relationship in dB in terms of voltages V1 and V2 becomes:

$$dB = 10 \times Log_{10} (V_1^2/V_2^2)$$

or

$$dB = 20 \times Log_{10} (V_1/V_2)$$

It is often useful to refer to power levels relative to a known value. For radio signals the level of 1 milliwatt is frequently used as a reference point and this is written as dBm. In this case the relationship becomes

$$dBm = 10 \times Log_{10} (P_1/1)$$

where P_1 is in milliwatt.

Similarly power levels may be based on a range of other common parameters. The most frequently used are listed below:

- dBc a measurement of power relative to the power of the carrier signal;
- dBi a measurement of power from an antenna relative to the same power radiated by an isotropic antenna an isotropic antenna is a theoretical antenna that radiates power equally in all directions).

In Europe measurements of radiated power at UHF are made using a half wave dipole and recorded as e.r.p. (effective radiated power) The relationship between the radiated power from an isotropic antenna (eirp) and e.r.p. is the gain of a half wave dipole, which is 2,1 dB.

Annex B: Earthing systems

B.1 Earth System Minimum Requirements

The following criteria need to be met or exceeded:

a) A low resistance path to earth with a low inductance such that the overall impedance does not exceed 10 ohms.

b) Life expectancy of the earth system to be at least equal to that of the structure it is protecting.

c) Arrangements for regular testing by the provision of removable test links at strategic points.

An earth termination should be comprised of a) a ring connected to vertical electrodes (rods) not less than 9 m total length, or b) an earth "mat" of radial conductors of not less than 20 m total length and buried at least 500 mm below ground level.

Where electrodes cannot be buried to the minimum 500 mm depth, it should be noted that there is an increased risk of a step potential, e.g. electrodes terminated at surface level produce an 80 % greater potential gradient along the surface.

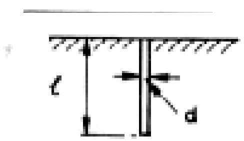
B.2 Typical Electrode and Array characteristics

B.2.1 Vertical Rod

It is recommended that lower earth resistivity will be obtained by driving several thin copper rods interconnected, rather than a single rod of the same overall mass.

These should be at least 1 m apart and driven to a depth of at least 2 m.

The basic calculation for assessing earth resistance for a vertical high conductivity rod.



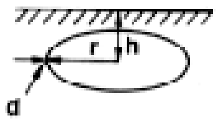
$$R = \frac{P}{2\pi \ell}\left(\log_e \frac{8\ell}{d} - 1\right)$$

Where P = soil resistivity ohm metres.

All dimensions in metres.

B.2.2 Buried Ring

When used as a primary electrode. Not to be confused with vertical electrode interconnecting conductors.

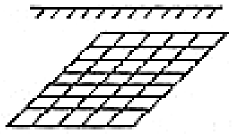


$$R = \frac{P}{4\pi^2 r}\left(\log_e \frac{64r^2}{dh}\right)$$

Where P =soil resistivity ohm metres.

All dimensions in metres.

B.2.3 Buried Grid



$$R = \frac{P}{4r} + \frac{P}{L}$$

WHERE L = LENGTH OF BURIED CONDUCTOR

$$r = \sqrt{\frac{A}{\pi}}$$

AND A = AREA OF GRID

Where P = soil resistivity ohm metres.

All dimensions in metres.

B.2.4 Measurement of Soil Resistivity

Soil Resistivity

The most important remaining factor influencing the impedance of the earthing system is the impedance of the medium in which the earth electrodes are situated, i.e. the soil.

Because soil resistivity is such an important factor governing the performance of earth electrodes, it needs to be discussed in some detail. Soil resistivity is expressed in Ohm-metres. This unit is the resistance between the two opposite faces of a one metre cube of uniform soil. The value obtained is thus in Ohm-metre^2 per metre, which is traditionally shortened to Ohm-metres. Some typical resistivity values are given in table B.1.

Table B.1: Typical values of resistivity for different soils

Type	Resistivity (Ohm-metre)
Garden soil/alluvial clay	5 to 50
London clay	5 to 100
Clay, sand and gravel	40 to 250
Porous chalk	30 to 100
Quartzite/crystalline limestone	300+
Rock	1 000 to 10 000
Gneiss/igneous rock	2 000+
Dry concrete	2 000 to 10 000
Wet concrete	30 to 100
Ice	10 000 to 100 000

Temperature and water content have an important influence on the soil resistivity and hence the performance of the earthing system. An increase in water content causes a steep reduction in resistivity until the 20 % level is reached when the effect begins to level out. Dissolved minerals and salts in the water may help further to reduce the resistivity, particularly where these are naturally occurring and do not become diluted over time. The water content will vary seasonally and is likely to cause variations in the impedance of the earthing system. The very high resistivity of ice (see table 1) compared to water, shows why it is necessary to install the electrodes beneath the freezing line. This is typically between 0,4 m and 0,6 m, but may be deeper in exposed, mountainous locations.

Measurement of Soil Resistivity

It is important that the resistivity is assessed as accurately as possible, since the value of the resistance of the electrode is directly proportional to the soil resistivity. If the incorrect value of soil resistivity is used at the design stage, the measured impedance of the earthing system may prove to be significantly different to that planned. This could, in turn, have serious financial consequences.

The test is traditionally carried out using a four-terminal earth test (Wenner Method). Four spikes are driven into the ground as shown in the diagram, spaced a distance of "a" metres apart. The depth to which each spike is driven should not exceed "a" divided by 20 and is not normally greater than 0,3 m.

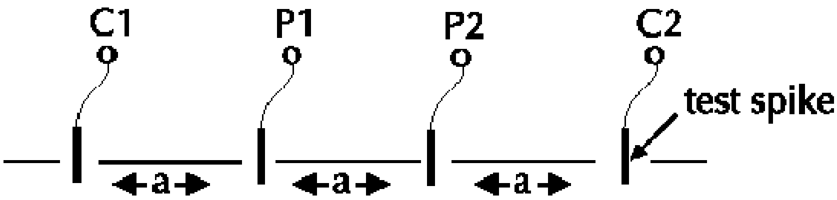


Figure B.1

It is important to ensure that the test spikes are not inserted in line with buried metal pipes or cables, as these will introduce measurement errors.

A known current from a constant current generator is passed between the outer electrodes. The potential drop (a function of resistance) is then measured between the two inner electrodes.

All of the parameters may be related in the expression below to give the soil resistivity value ρ:

$$\rho = \frac{4\pi AR}{\dfrac{1 + 2A}{\sqrt{(4A^2 + 4B^2)}} - \dfrac{2A}{\sqrt{(4A^2 - 4B^2)}}}\ \Omega - \text{metres}$$

Where A = distance between electrodes in meters;

B = Electrode depth in meters;

R = Resistance in ohms.

If A > 20B, the expression becomes:

- $\rho = 2\pi AR$ Ohm-metres.

B.3 Earthing of support structures and buildings

B.3.1 Ancillary equipment external to buildings

Fuel tanks, air conditioning enclosures, etc. should be bonded separately to the building earth system.

B.3.2 Metal support poles on buildings

In addition any poles, brackets, bracing stays, etc. should be bonded to the building earth system.

B.3.3 Metal security fences

Where a close metal fence is within 2,5 m of the site it should be directly bonded between a contact point and the earth ring.

Where long perimeter fences are in place it is clearly impractical to use this method. Moreover there is an increased risk under certain strike conditions where the fence will conduct high potentials to points distant from the bonding point. It is therefore recommended that where long fences are present, these should be directly earthed at intervals along the perimeter.

B.4 Interconnection of lightning protection systems with power supply earthing arrangements

Consideration of overall site safety indicates that equipotential bonding of all metal objects on and within site structures should be an ideal to be pursued if possible.

However, examination of the various scenarios that exist for all types of site, shows that A.C. power supply arrangements vary widely between sites and are further complicated by national standards appropriate to country of origin. This is particularly true of practices adopted for earth paths provided by electricity supply organizations, where application will depend on the prevailing terrain and the supply chain configuration.

In some circumstances it is possible that the integrity of the A.C. supply earth, may be compromised by incorrect interconnection of lightning protection and supply related earthing arrangements.

It is therefore strongly recommended, when planning overall site protection, that the relevant power supply authority is consulted in the process at an early stage.

Annex C: Prefabricated portals

The portal illustrated in this annex is intended for use at dock doors in warehouses. However it may be possible to adapt the principles for use in other applications.

Typically the portal would be approximately 3 m wide, 3 m high and 1,6 m in depth. Portals may be constructed as pre-fabricated units, which reduce the installation effort required on site.

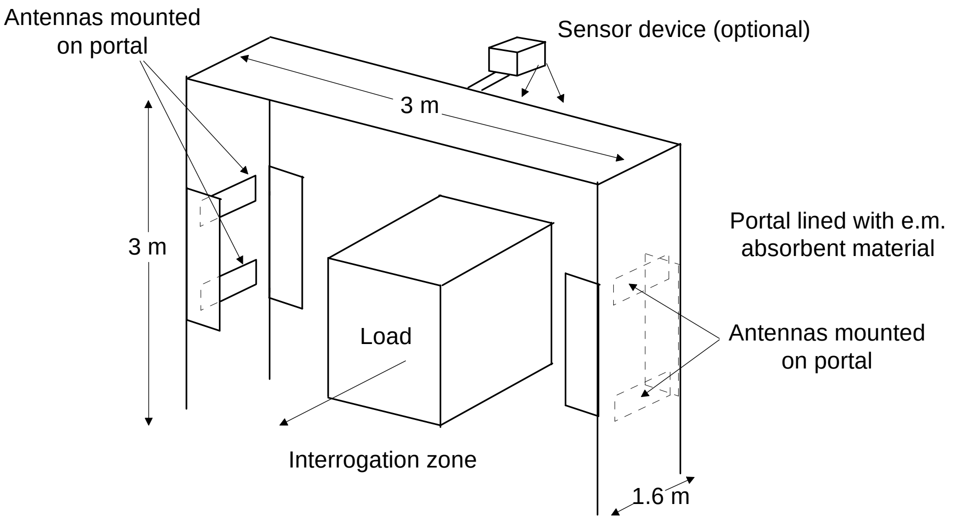


Figure C.1: Illustration of portal configuration

The arrangement for the antennas is very similar to figure 3 in clause 6.4. Note that the horizontal beamwidth of each antenna is limited to not more than 30 degrees although typically the vertical beamwidth may be as much as 70 degrees. The sides of the portal are lined with e.m. absorbent material. Flaps, made from e.m. absorbent material, are fitted on both sides of antennas to minimize the transmission of side lobes. The combined effect of the reduced beam-width and the e.m. absorbent material is to lower the strength of the field from the main lobe of each antenna into the adjacent lane. An attenuation up to 20 dB may be achievable. Similarly the signal strength received from any activated tags in adjacent lanes is much less. Thus the possibility of interference between adjacent lanes is greatly reduced. A further benefit is that the field strength of signals transmitted into the building is also much lower. This greatly reduces the possibility of unintentionally activating unwanted tags on loads that are being moved some distance from the interrogation zone.

Annex D: Commissioning procedure

Since each site is different it is impossible to describe every eventuality. This annex should therefore only be used as a general guide. The setting to work procedures cover only interrogators and their associated equipment. They do not include the equipment in the computer room or the process of setting to work the full system.

The commissioning of the interrogators may be undertaken prior to installation, either on site, or at the premises of the solution provider, as laid down in the agreement.

Once the equipment has been installed in many cases final adjustments will be necessary to meet the specific requirements of the site. These may arise as a consequence of environmental considerations, performance objectives, antenna alignment and regulatory compliance. These adjustments may require the use of a laptop for connection to individual interrogators.

Although this list is not exhaustive, commissioning may cover the following activities:

- Adjustment of settings to the transmit power of the interrogator. Note that this may vary across antenna ports to accommodate differences in antenna cable lengths.
- Adjustment of settings for the required tag protocol(s) and data lengths.
- Correct setting of the network infrastructure identification parameters i.e. IP Address, Device Name, SNMP Community String, etc.
- If necessary the upload of firmware to the level agreed with the customer.
- Configuration of any pre-agreed radio frequency sub-band mapping.
- Configuration, if required, of general interrogator parameters to handle the operation of external devices such as external triggers and audio/visual outputs.
- Configuration, if required, of any customized functions within the system i.e. a write-only station or a re-work station.
- Completion of a full set of documentation covering all equipment that falls within the responsibility of the installer.

NOTE: The process of commissioning a system is a separate activity to an acceptance test, which will take place afterwards.

History

Document history		
V1.1.1	December 2005	Publication