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Technical Report

Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Technical characteristics for SRD equipment using Ultra Wide Band technology (UWB); Part 2: Ground- and Wall- Probing Radar applications; System Reference Document

Reference

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Contents

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Foreword

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

The present document is part 2 of a multi-part deliverable covering Short Range Devices (SRD); Technical characteristics for SRD equipment using Ultra Wide Band technology (UWB), as identified below:

Part 1: "Communications applications";

Part 2: "Ground- and Wall- Probing Radar applications; System Reference Document".

Introduction

Ultra Wide Band is a new emerging SRD technology with potential benefits for security applications, consumers and businesses. There are at least three separate groups of probing radar applications:

- Ground Probing Radars (GPR);
- Wall Probing Radars (WPR); and
- Through-Wall Probing Radars (TWPR).

The emphasis in the present document is clearly put on the commercial use of Ground Probing Radars and Wall Probing Radars. The market information and figures in annex A of the present document apply only to GPR and WPR.

Ground Probing Radars or also named Ground Penetrating Radars, as both terms are accepted and used internationally, operate only when in contact with or within close proximity of the ground for the purpose of detecting or obtaining the images of buried objects. Wall-Probing Radars or also named Wall Penetrating Radars, are designed to detect the location of objects contained within a wall. This includes examining a concrete structure, e.g. the side of a bridge or the wall of a mine.

Commercial application of UWB technology for Ground Probing Radars and Wall Probing Radars are expected to operate between 30 MHz and 12,4 GHz with a very high bandwidth and a very low radiated power density. In addition, some applications for e.g. glacier sounding or usage in hydrogeology additionally use frequencies down to 1 MHz.

Through-Wall Probing Radar applications are only included in the present document as a matter of completeness. These are normally only considered for military agencies and governmental services usage. Through-Wall Probing Radars can detect the location or movement of persons or objects that are located on the other side of a structure such as a wall. Possible commercial use of this application or its usage by the public is not described and addressed in the present document. Therefore, Through-Wall Radars should be recognized as a unique class of device distinct from GPR/WPR. For Through-Wall Probing Radars (TWPR) the band of operation is from 3,1 GHz to 10,6 GHz. Post-911, there are also some low-frequency TWPR activities which are not addressed in the present document as it is believed that this work is being undertaken under military regime.

In addition, GPRs are also used in underground excavations, mines and drill holes where leakage of signal into the air is virtually impossible. Higher powers for equipment which intended use is not to be operated in the open air can be beneficial. This should also be taken into account.

The present report includes necessary information to support the co-operation under the MoU between ETSI and the Electronic Communications Committee (ECC) of the European Conference of Post and Telecommunications Administrations (CEPT) for amending the ERC Recommendation 70-03 [1].

1 Scope

The present document provides information on the intended applications, the technical parameters and the radio spectrum requirements for UWB Ground- and Wall Probing Radar equipment operating in the frequency band from 30 MHz to 12,4 GHz. It describes Ground Probing (GPR) and Wall Probing (WPR) systems that are used in survey and detection applications. These applications require wide frequency bandwidths that cannot be provided by alternative technologies and/or at spot frequencies.

The scope is limited to radars operated as short range devices (because of their usage and design), in which the system is in close proximity to the materials being investigated. It does not include radars operated from aircraft or spacecraft which may sometimes be referred to as GPRs but do not fall into the category of short range devices.

The radar applications in the present document are not intended for communications purposes. Their intended usage excludes radiation into the free space, unlike for UWB communications equipment.

Additional information is given in the following annexes:

- annex A: detailed market information;
- annex B: technical information;
- annex C: expected compatibility issues.

2 References

References are either specific (identified by date of publication and/or edition number or version number) or non-specific.

- For a specific reference, subsequent revisions do not apply.
- Non-specific reference may be made only to a complete document or a part thereof and only in the following cases:
  - if it is accepted that it will be possible to use all future changes of the referenced document for the purposes of the referring document;
  - for informative references.

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

For online referenced documents, information sufficient to identify and locate the source shall be provided. Preferably, the primary source of the referenced document should be cited, in order to ensure traceability. Furthermore, the reference should, as far as possible, remain valid for the expected life of the document. The reference shall include the method of access to the referenced document and the full network address, with the same punctuation and use of upper case and lower case letters.

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

2.1 Normative references

The following referenced documents are indispensable for the application of the present document. For dated references, only the edition cited applies. For non-specific references, the latest edition of the referenced document (including any amendments) applies.

Not applicable.

2.2 Informative references

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

[2] ITU-R SG1 TG1-8 Report from the 1st meeting of ITU-R SG1 TG 1-8, Geneva 21-24 January 2003 (Document 1-8/047).

[3] FCC 03-03: "Revision of Part 15 of the Commission's Rules Regarding UWB Transmission Systems".

[4] CENELEC EN 55022 (1998): "Limits and methods of measurement of radio disturbance characteristics of information technology equipment".

[5] ITU-R Radio Regulations.

[6] Convention on the Prohibition of the Use, Stockpiling, Production and Transfer of Anti-personnel Mines and on their Destruction, available via http://www.mineaction.org/.

[7] CISPR/I/105/CDV: "EMC of information technology, multimedia equipment and receivers", date of circulation 2004-04-30, closing date for voting 2004-10-01.

[8] CISPR/I/106/CDV: "EMC of information technology, multimedia equipment and receivers", date of circulation 2004-04-23, closing date for voting 2004-09-24.

[9] CISPR 16-1-1: "Specification for radio disturbance and immunity measuring apparatus and methods - Part 1-1: Radio disturbance and immunity measuring apparatus - Measuring apparatus".

[10] ETSI EN 302 065: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD) using Ultra Wide Band technology (UWB) for communications purposes".

[11] ETSI EN 302 066: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD) using Ultra Wide Band technology (UWB) for purposes other than communications".

3 Definitions, symbols and abbreviations

3.1 Definitions

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

deactivation switch: function of the equipment which deactivates the equipment when normal use is interrupted

range resolution: ability to resolve two targets at different ranges

3.2 Symbols

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

c	velocity of light in a vacuum
δR	Range resolution
δt	time interval between the arrival of two signals from targets separated in range by δR
E_R	relative dielectric constant of earth materials
T_P	pulse rise time

3.3 Abbreviations

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

A/D	Analogue to Digital Converter
APMBC	Antipersonnel Mine Ban Convention
BW	Bandwidth
CEPT	European Conference of Post and Telecommunications Administrations
dB	decibel
ECC	Electronic Communications Committee
Euro-GPR	The European GPR Association
GPR	Ground Probing Radar, Ground Penetrating Radar, Sub-surface Radar or Ground Radar
ISM	Industrial, Scientific and Medical
PRF	Pulse Repetition Frequency
SRD	Short Range Device
TEM	Transverse Electromagnetic wave
TWPR	Through-Wall Probing Radar
UWB	Ultra Wide Band
VHF	Very High Frequency
WPR	Wall Probing Radar

4 Executive summary

The present document provides a basis for a general, non-individual, licensing arrangement for probing radar systems, replacing the system of temporary or experimental licences that has been in use in parts of Europe for many years.

Despite the restriction that these licences have placed upon the development of such systems, they are now internationally used for a wide range of applications where information about objects is not readily obtainable by other means. Apart from reducing risk and accidents, GPR often has a pivotal role in the economic direction of major infrastructure projects. It also has a major potential role in areas like detection of anti-personnel mines.

The objective of designers and operators of radar equipment is to direct signals into earth materials and not to allow radiation into the air where reflections cause unwanted responses. The required signals necessarily demand a high bandwidth to provide sufficient depth resolution. Earth materials act as low pass filters and in order to maximize the information from the ground, equipment are designed and selected to match local ground conditions. This leads to a wide variation in equipment bandwidth.

Given the similarity in bandwidth and the unwanted nature of radiations into the air, the present document proposes that a general EMC standard should be used to specify the radiation from GPR and other probing radar systems. This essentially follows the situation that has been carefully implemented and monitored in the UK by the Radiocommunications Agency/OFCOM and the European GPR Association (Euro-GPR).

GPR and other probing radar equipment does not communicate any information via the radar signal to any other equipment, therefore no protocol communications standard is required for all probing radars.

Market information, technical information including the required spectrum, and a discussion of compatibility issues are presented in the annexes of the present document.

4.1 Status of the present document

Draft version 1.1.1_1.0.1, prepared by ERM TG31A, was discussed at ERM RM # 27. The preliminary draft V1.1.1_1.0.4 was forwarded to the ECC for information. An ERM-RM approval by correspondence was initiated. Comments received during part of the ERM-RM initial collection of comments (until July 15th, 2004) were discussed at ERM TG31A#8bis meeting, July 6th, 2004. The version 1.1.1_2.0.8 was approved by ERM-RM and forwarded to ECC-TG3.

The present document was amended by ERM#33 in November 2007.

4.2 Market information

For detailed market information, see annex A.

4.3 Technical system description

For detailed technical UWB information, see annex B.

5 Current regulations

There are no current regulations permitting the operation of UWB in Europe.

Article No. 4.4 of the Radio Regulations [5] has been relied upon by national administrations (and CEPT as well) in many contexts to authorize applications not conforming with the Table of Frequency Allocations in the Radio Regulations (e.g. Short Range Devices which are operated in ISM frequency bands). UWB equipment, as described in the present document, might also be operated under Article RR No. 4.4.

The status of radio licensing of GPR within Europe is highly variable between different member states. This has been a major hindrance to the EC's investment in GPR for anti-personnel mine detection.

In the UK GPRs operate on a temporary use licence and temporary arrangements negotiated by the European GPR Association (Euro-GPR) for its members. These were implemented on the basis of allowing limited and supervized use while working out a more regular arrangement.

The U.S.A has specified radiation limits for Through-Wall Probing Radars in FCC 03-03 [3].

6 Main conclusions

The systems described in the present document have a major role to play in security and sustainability of life, including civil engineering, environmental management and anti-personnel mine detection.

These systems are diverse because of the range of applications. In particular the GPR systems do not readily fit into established radio licensing requirements.

The users of GPR and WPR are normally professional service providers, scientists, and engineers.

7 Expected ECC actions

Mandate M/329 covering UWB calling for completion of Harmonized Standards for UWB by the end of the year 2004 was received by ETSI. ETSI accepted this mandate (see EN 302 065 [10] and EN 302 066 [11]).

Therefore, ETSI requests ECC to consider the present document, which includes necessary information to support the co-operation under the MoU between ETSI and the Electronic Communications Committee (ECC) of the European Conference of Post and Telecommunications Administrations (CEPT) for amending the CEPT Recommendation 70-03 [1].

Therefore, ETSI asks CEPT-ECC to perform the relevant studies to determine whether the emissions described in the present document are appropriate to protect all the other radio services and to provide the practical measures to ensure the protection of all other radio services in the band from 30 MHz to 12,4 GHz.

ETSI believes that procedures for administrating and ensuring adherence to regulations should be kept minimal both for the regulator as well as for the users of GPR and WPR. A possible way of managing proper use is to mandate that user training occur and/or to limit usage to trained/professional providers.

It should be stressed that the present document contains information not yet considered in the currently on-going co-existence studies within CEPT-ECC spectrum engineering project team SE24.

Annex A: Detailed market information

A.1 Range of applications

The use of GPR has grown exponentially since the early 1980's, and the technology is now central to security and sustainability aspects of civil engineering, environmental management and humanitarian mine clearance and for purposes associated with, for example, law enforcement, fire fighting , emergency rescue, scientific research, commercial mining and construction.

The total value of surveys using GPR may seem relatively low in comparison with other users of the radio spectrum, but the impact of the technique in safety critical applications, and the impact of investigations on the planning and execution of very high value construction and development projects should be considered.

Advanced systems, often linked to radionavigation systems data, enable unrivalled options for inspection and assessment of major infrastructure such as highways, bridges, railways, tunnels and airports. The technique delivers safety, technical, economic, environmental, and humanitarian benefits. A number of example applications are summarized below.

Highway inspection

Applications include:

- Determining highway pavement construction type and thickness.
- Mapping defects such as voids, moisture or cracking.
- Quality assurance on construction projects, such as checking the effectiveness of new sustainable practices such as pavement material recycling and soil stabilization, which greatly reduce energy use and landfill demand.

This information is widely used by government agencies, local authorities, and the consultants responsible for highways. At least 10 000 km of highway are surveyed per year within Europe. Surveys can be conducted from vehicles driven at a traffic speed that does not disrupt traffic flows and does not require road closures. Such closures are required for alternative methods such as core drilling and are known to multiply the risk of road traffic accidents by a factor of 10. Other key benefits are:

- Effective targeting of funding for maintenance and repair.
- More accurate analysis of other test data.
- Reduced waste of construction materials: accurate knowledge of existing materials enables selection of what to leave intact, what to remove, and what to overlay.
- Reduced damage to the structure, such as that caused by core drilling or "trial holes".
- Determination of materials suitable for recycling.

Airport runway inspection

Applications include:

- Recording runway and taxiway pavement construction type and thickness.
- Mapping defects such as voids, moisture, or cracking.
- Targeting funding for maintenance and repair.

This information is used at airports throughout the world to provide similar deliverables to highway inspection. Key benefits of this method in comparison with alternative methods are:

- The ability to complete the inspection of a runway in a short overnight closure with minimal disruption to airport operators.
- The very low risk of foreign object debris that presents a major safety hazard to airport operators.

Utility management

Applications include:

- Mapping buried utility cables, pipes and ducts.
- Measuring the depth to buried utilities.

This application is in widespread use and is frequently specified in major construction contracts (e.g. Dublin light rail scheme, London Paddington Station redevelopment). GPR is the only method that can trace both conductive (e.g. metal) and non-conductive (e.g. plastic) utilities. Key benefits are:

- Improved health and safety and minimal disruption by reducing accidental damage to power and gas lines.
- Better cost control by better planning and reduced delays.
- Less damage than alternative methods, such as "trial holes", which damage roads and delay traffic.
- Enables "trenchless technology" methods for laying new utilities without trenching. This non-disruptive and sustainable practice requires reliable knowledge of existing utilities in order to avoid hitting them.

Rail

Applications include:

- Surveys of track bed to determine ballast thickness and condition.
- Embankment studies including safety critical rapid response surveys after landslips.
- Investigation of rail structures such as buildings, bridges and tunnels.

GPR is widely specified and used by Europe's rail operators to provide construction and condition information. The modernization of the UK West Coast mainline for example involved investigation of more than 300 sites. There is growing pressure within the industry to reduce downtime and to reduce the need for people working on the track. Key benefits are:

- Improved health and safety by reducing the need for people working on the track digging "trial holes" etc.
- Better project planning and consequent cost saving by improved knowledge of site conditions.

Humanitarian and military landmine detection

Applications include:

- Detection of anti-personnel and anti-tank mines for humanitarian purposes.
- Detection of mines for military purposes.

GPR is the most effective technique for detecting landmines, and manufacturers are developing high-resolution equipment in order to satisfy the demands of the Antipersonnel Mine Ban Convention (APMBC) [6] which calls for all existing minefields to be cleared within 10 years. It is estimated that between 65 million and 110 million landmines are laid in 67 countries, and the European Commission is probably the world's biggest donor for mine clearance. Key benefits are:

- Detection of the plastic case and explosive rather than the relatively small metal fuse which is targeted by other methods.
- Better differentiation between landmines and fragments of benign metal such as shrapnel in the ground.
- Military benefits of improved mobility and safety to the armies of Europe who face the prospect of operating in mined areas.

Geophysical applications

Applications include:

- Mapping subsurface voids such as former mine or caves.
- Tracing foundations and other obstructions in the ground.
- Tracing washout from pipes.
- Profiling ground layers.

GPR is one of a number of geophysical methods widely used for ground investigation to a relatively shallow (predominantly less than 5 m) depth. It is particularly useful for locating geological hazards that may pose a risk to construction activity or human habitation. Key benefits are:

- Rapid coverage of large areas.
- Effective both for profiling continuous layers and for locating discrete features.
- Minimizing risk of striking dangerous materials/features during construction.
- Minimizing risk of ground stability problems.

Archaeology

Applications include:

- Mapping buried structures and artefacts.
- Mapping changes in ground conditions in relation to former habitation and land-use.
- Investigation of standing structures, buildings and monuments of heritage value.

GPR is an important technology amongst the range of geophysical methods available for archaeological investigation. The technique is used to check sites ahead of construction and with increasing demand for land for development there will be a growing need for effective investigation to safeguard significant archaeological features. Key benefits are:

- Effectiveness in wetland sites such as through peat where other geophysical methods are less effective.
- Rapid coverage compared to other methods.
- Ability to resolve location as well as depth of archaeological features.

Security and police use

Applications include:

- Detecting buried bodies.
- Forensic investigation to detect evidence of crimes, arms caches etc.

There is growing use of this technique for high profile and routine criminal investigation. Security agencies are keen to exploit the method for searching buildings and other properties. Key benefits are:

- Rapid coverage of large areas enabling excavations to be efficiently targeted.
- Non-destructive investigation enabling areas to be searched without damage to private property.

Environmental applications

Applications include:

- Detecting ground contamination such as hydrocarbon plumes and hazards such as storage tanks and drums.
- Determining depth of peat.
- Checking the safety and integrity of reservoir dams.

GPR is widely used within environmental management as part of environmental and risk assessment studies, particularly in managing or re-developing brownfield sites. Use of this technique in agricultural studies is an area in which significant growth is expected in order to underpin efficiency in agricultural land use. Key benefits are:

- Rapid coverage, for example in agricultural studies to document the existence of ground drainage and better understand underlying soil structures.
- Improved management of wetland sites to protect peat environments from unlicensed exploitation and to better manage licensed extraction of peat.
- Minimize the requirement for chemicals in agriculture.

Miscellaneous applications

There are a host of other applications of the technology both in use and under consideration. Examples include:

- Locating snow avalanche victims.
- Mapping badger sets.
- Tree management.

A.2 Market size and value

At present the European market for these equipment is small. The major activity is in the provision of specialist surveying services to professionals such as civil engineers, planners, architects, environmentalists, police forces etc. Often these services are provided as part of a package of surveying measures that provide a more extensive assessment of the condition of an installation.

At present, the industry predominately consists of many small surveying companies, and it is difficult to obtain an accurate estimate of their total turnover and the contribution made by GPR. At this time there are at most 3 000 to 4 000 units worldwide, whereof much less than 50 % are in Europe. It is estimated that the total number of units in Europe could rise to between 3 000 and 6 000 units in ten years.

There is a growing acceptance that GPR is a highly cost effective tool providing key information that is not available by other non-invasive methods. The major economic impact of the technique should not be measured by the size of the industry but by the possible savings in infrastructure capital projects.

It has been estimated by the GPR/WPR industry experts that the wide adoption of the technique would allow a significant reduction in the overall cost of all major construction projects.

This makes no allowance for the direct improvements in health and safety through the avoidance of accidents.

A.3 Traffic evaluation

GPR equipment is essentially a professional tool. In the foreseeable future it is unlikely to be used either in offices or in the home. Its use is associated with construction either in the planning stage, during excavation or as an inspection tool.

With an established infrastructure, such as is found in much of Western Europe, the most widespread use of future systems may be for maintenance purposes. It could be foreseen, for example, that if the technology was much reduced in cost compared to the present, that every utility truck associated with excavation could carry a GPR.

This may be the most widespread implementation of the technology, but the pattern of use of this technique would be intermittent. The radar would be used for a brief period after arriving on-site to locate services, and plan excavation. It would then be put away while the works were carried out.

There are currently estimated to be around 3 000 to 4 000 units of this technology in the world. The equipment is expected to be used by trained professional operators. The pattern of use will be intermittent with an extremely low duty cycle of less than 0,1 % on average per unit (it is common to make measurements with an operational duty cycle of 1 in 10 to 1 in 100 followed by a long period of no usage while moving to the next survey position or planning the next measurement sequence), this figure relates to the transmitting time at a fixed location. In the case of mobile use, e.g. inspection of a motorway, the actual on-time is higher.

Annex B: Technical information

B.1 Detailed technical description

A simple block diagram of a GPR system is shown in figure B.1.1.

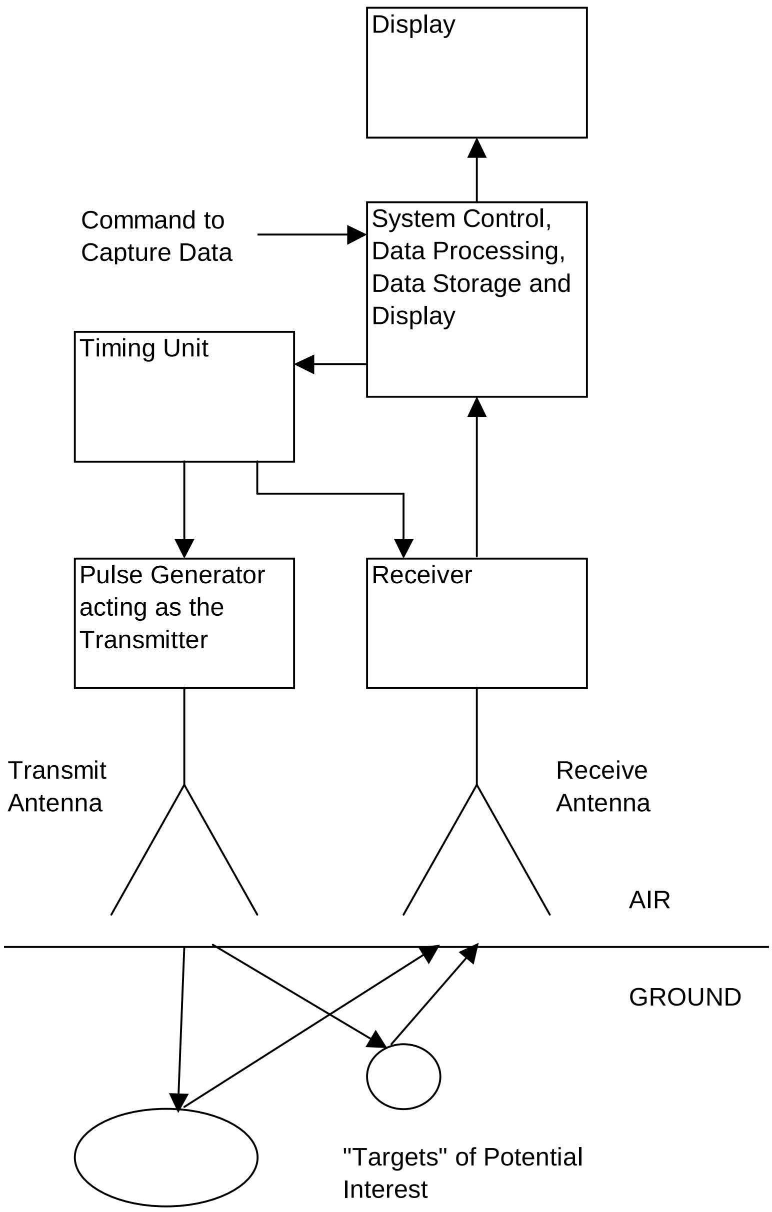

Figure B.1.1: Block diagram of a GPR system

The system is designed to radiate a sequence of pulses into the ground and capture a waveform corresponding to the received signal scattered by objects in the ground. A single waveform does not allow the buried objects to be characterized. Typically the radar is moved over the ground and a sequence of waveforms is recorded to build up a pattern of waveforms and to allow the spatial information to be decoded. Such a sequence of measurements generates a radar scan. The position at which each waveform is recorded may be triggered automatically by position sensors or manually by the operator.

When the radar is positioned at the next measurement position, the timing unit generates the precise trigger pulse required to control the measurement sequence. The pulse generator acting as the transmitter generates a sequence of pulses, the number often corresponding to the number of points required in the receive waveform. These pulses are fed to the transmit antenna and radiated into ground.

GPR antennas are required to radiate pulses with minimum dispersion. Few antenna types meet this requirement. Below 1 GHz most GPR antennas are based upon heavily resistively loaded dipoles. At higher frequencies other antenna types, for example TEM horns become viable. The antenna is used in close proximity to high dielectric constant earth materials which dielectrically load the antenna, thus coupling a high proportion of the radiated signal directly into the ground. Shielding further controls unwanted emissions. In use, the antenna is moved over the ground and the variation in the returned signal determines the presence and nature of radar targets. GPRs are designed not to radiate into the air, and the antenna characteristics and the equipment shielding ensure that unwanted emissions are kept to a minimum.

The signal illuminates the target, and a small proportion of the energy is scattered back to the surface.

It should be noted that earth materials typically have a low pass characteristic with attenuations varying from a few dB per metre at VHF in low loss soils to many tens of dBs per metre in high loss soil at microwave. The requirement to detect these often very low signals requires the scattering from above ground objects with low loss transmission paths to be severely limited.

The receiver is typically a wide band (decade) low noise pulse amplifier followed by an Analogue to Digital (A/D) converter, or a high frequency sampler and A/D converter for higher frequency systems where direct conversion is not readily implemented.

The Pulse Repetition Frequency (PRF) of the transmitted pulse may vary widely dependent upon the application. The range is from 1 kHz to 10 MHz, with most commercial products in the 100 kHz range.

The characteristics of the radiation from the antenna are defined by the following parameters:

1) the peak transmitted pulse amplitude;

2) the pulse width and rise and fall times;

3) the pulse repetition frequency;

4) the antenna type directivity and screening properties.

B.2 Technical justification for spectrum

The objective of GPR systems is to radiate an electromagnetic pulse into the ground or wall and to receive a very small fraction of that signal in order to detect and characterize a hidden or buried object. The nature of a pulse implies that it is wideband. Generally the sharper the pulses' edges, the greater the bandwidth necessary.

Radars are also in use for a wide range of applications and depths. In the case of GPR, the low pass nature of earth materials implies that to find an object at depth, a frequency in the VHF band is required; while to find much smaller objects at much shorter range, microwave signals are used.

In all cases the objective of the radar designer and user is to couple the pulse into the ground.

Signals that leak into the air are regarded as unwanted radiation, with reflections from adjacent objects confusing the required response.

B.3 Bandwidth requirement

GPRs operate by radiating a short pulse into the ground which is reflected back from a target and received by the receive antenna. The range resolution of the system or the ability of the radar to resolve two targets at different ranges is determined by the width of the received pulse.

Two targets at different ranges (R_1 and R_2) can be separated if the time interval δt for the signal to travel between the two targets is greater than the pulse width. δt is a function of the radio wave velocity in the ground which depends on the dielectric constant of the ground E_R.

$$\delta t = \frac{2 \times \delta R \times \sqrt{ER}}{c}$$

where δR is the difference in range between the two targets (R_1 - R_2) and c is the velocity of light in a vacuum.

The bandwidth required to generate a pulse with a pulse width T_P is approximately $\left(\frac{1}{2TP}\right)$.

In turn this implies that the bandwidth (BW) requirement for a GPR is given by:

$$BW = \frac{c}{\left(4 \times \delta R \times \sqrt{ER}\right)}$$

In extreme circumstances, the E_R of dry sand may be as low as 4 rising to 81 for fresh water. Typically Western European soils have a range of from 6 to 20.

In order to measure the thickness of different road layers with a resolution of 10 mm, a requirement of highway inspection would require a bandwidth of at least 3 GHz.

Earth materials act as low pass filters. In general above 5 GHz, attenuation is very high in most materials resulting in limited use for GPR.

For surveys at progressively greater depth, the low pass characteristics of the ground imply that the bandwidth and resolution should be reduced. In order to achieve the greatest penetration the radar is manually operated within the lowest potential frequency range. Typical parameters are presented in table B.3.1.

Table B.3.1: Bandwidth Requirements

Depth of search (R - Range) m	Range resolution (δ_R) mm	Bandwidth of pulse
0,1 to 0,3	10	0,2 GHz to 12,4 GHz
1 to 2	30	0,1 GHz to 1 GHz
2 to 5	100	400 MHz to 700 MHz
5 to 10	200	200 MHz to 350 MHz
10 to 20	600	30 MHz to 130 MHz

B.4 Radiation limits

For Ground Probing and Wall Probing Radars operating in the band from 30 MHz to 12,4 GHz there is no applicable standard for radiation limits so far.

Because of the nature of the application it is proposed that the limits specified in EN 55022 Class A [4] would be appropriate, even though the scope of the standard does not include information technology equipment.

NOTE 1: It may be worth noting that, due to the UWB nature of this type of equipment, the power may have to be integrated over several GHz which may result in a value for the total power up to 40 dB higher than in power densities expressed per MHz.

The present version of EN 55022 [4] provides limits up to 1 GHz, but is under revision now and will be amended to include limits up to 6 GHz / 18 GHz. The values proposed in CISPR/I/105/CDV [7] and CISPR/I/106/CDV [8] are respectively:

NOTE 2: The resolution bandwidth of these limits is contained in CISPR 16-1-1 [9]. The "conditional testing procedure" may not be directly applicable for UWB signals. Instead of the "highest frequency of internal sources", it was proposed that it might be appropriate to use the "maximum 1/T" where T is the minimum pulse duration.

QUOTE

6.2 Limits above 1 GHz

The EUT shall meet the limits of Table 7 when measured in accordance with the method described in clause 11 and the conditional testing procedure described below.

Table 7 - Limits for radiated disturbance of all ITE at a measurement distance of 3 m

Frequency range GHz	Average limit dB(µV/m)	Peak limit dB(µV/m)
1 to 3	50	70
3 to 6	54	74
NOTE 1 - The lower limit shall apply at the transition frequency.		

A relaxation of 6 dB applies to equipment intended for Class A environment as defined in Clause 4 of CISPR 22.

Conditional testing procedure:

The highest internal source of an EUT is defined as the highest frequency generated or used within the EUT or on which the EUT operates or tunes.

…/…

6.2 Limits above 1 GHz

The EUT shall meet the limits of Table 7 when measured in accordance with the method described in clause 11 and the conditional testing procedure described below.

Table 7 - Limits for radiated disturbance of all ITE at a measurement distance of 3 m

Frequency range GHz	Average limit dB(µV/m)	Peak limit dB(µV/m)
6 to 18	54	74

A relaxation of 6 dB applies to equipment intended for Class A environment as defined in Clause 4 of CISPR 22.

Conditional testing procedure:

The highest internal source of an EUT is defined as the highest frequency generated or used within the EUT or on which the EUT operates or tunes.

…/…

UNQUOTE

Means should be provided to ensure that the transmitter ceases operation within 10 seconds of the completion of a planned measurement sequence. In the case of a manually controlled system this may be by the release of the deactivation switch by the operator.

Annex C: Expected compatibility issues

C.1 Coexistence issues

The pattern of use of GPR systems shows no coexistence problems. Some operators routinely operate with a GPS antenna mounted directly upon the radar antenna so that the position of the radar scan may be accurately and automatically recorded. Radar operators typically operate away from their base and company health and safety policies may require them to carry a mobile telephone.

On occasions radiations from other transmitters has been reported as causing interference to GPR but there are no recorded incidents of GPR causing interference to other radio systems.

In formal investigations carried out in the UK by Euro-GPR for the Radiocommunications Agency/OFCOM a number of tests were undertaken. Initially a number of radars were supplied to the Radiocommunications Agency's/OFCOM's Whyteleafe Laboratory, where their radiation characteristics were measured. This showed that the radiation level was in some cases difficult to measure but it was always at a lower level than that specified by EN 55022 [4].

For a year following this, Euro-GPR members kept a comprehensive log of GPR use, recording place and time of use, and equipment type. This log was assembled centrally by a professional secretariat and passed to the Radiocommunications Agency/OFCOM as an Excel file. This file was then passed to all the Agency's Regional Offices and correlated with their record of known interference events. There was no correlation, GPR was not responsible for any known interference event.

Similar investigations have been conducted in other countries outside Europe as well, e.g. over the past 30 years there have been no reported interference cases attributed to GPR systems in Canada.

C.2 Current ITU allocations

None.

C.3 Sharing issues

None expected.

History

Document history		
V1.1.1	November 2004	Publication
V1.1.2	March 2008	Publication