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European Standard (Telecommunications series)

Electromagnetic compatibility and Radio spectrum Matters (ERM); Ground- and Wall- Probing Radar applications (GPR/WPR) imaging systems; Part 1: Technical characteristics and test methods

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Contents

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Foreword

This European Standard (Telecommunications series) has been produced by ETSI Technical Committee Electromagnetic compatibility and Radio spectrum Matters (ERM), and is now submitted for the Vote phase of the ETSI standards Two-step Approval Procedure.

The present document is part 1 of a multi-part deliverable covering the Electromagnetic compatibility and Radio spectrum Matters (ERM); Ground- and Wall- Probing Radar applications, as identified below:

Part 1: "Technical characteristics and test methods";

Part 2: "Harmonized EN covering essential requirements of article 3.2 of the R&TTE Directive".

Proposed national transposition dates	
Date of latest announcement of this EN (doa):	3 months after ETSI publication
Date of latest publication of new National Standard or endorsement of this EN (dop/e):	6 months after doa
Date of withdrawal of any conflicting National Standard (dow):	6 months after doa

1 Scope

The present document specifies the requirements for Ground- and Wall- Probing Radar imaging systems applications. Ground Probing Radars (GPR) and Wall Probing Radars (WPR) are used in survey and detection applications.

The scope is limited to GPR andWPR radars, in which the system is in close proximity to the materials being investigated. It does not include radars operated from aircraft or spacecraft.

The GPR/WPR applications in the present document are not intended for communications purposes, and the intended signal is not radiated into free space.

NOTE: Equipment covered by the present document is intended to be used by competent professional personnel.

The present document applies to:

1) Ground Probing Radars (GPR) operating over approximately one decade in the frequency range 30 MHz to 12,4 GHz radiating directly downwards into the ground. Any horizontal radiation from this equipment is caused by leakage and is considered as undesired emission.

2) Wall Probing Radars (WPR) operating in the frequency range 30 MHz to 12,4 GHz radiating directly into a "wall". The "wall" is a building material structure, the side of a bridge, the wall of a mine or another physical structure that absorbs a significant part of the signal transmitted by the radar.

3) Equipment fitted with integral antennas and without antenna connector.

4) Equipment which uses different imaging heads (antennas) with an antenna connector, to allow operation at different frequencies.

The present document does not necessarily include all the characteristics which may be required by a user, nor does it necessarily represent the optimum performance achievable.

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.

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

[2] ETSI TR 100 028 (V1.4.1) (all parts): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Uncertainties in the measurement of mobile radio equipment characteristics".

[3] ETSI EN 302 066-2 (V1.2.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Ground- and Wall- Probing Radar applications (GPR/WPR) imaging systems; Part 2: Harmonized EN covering essential requirements of article 3.2 of the R&TTE Directive".

2.2 Informative references

[4] ETSI TR 102 070-2 (V1.1.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Guide to the application of harmonized standards to multi-radio and combined radio and non-radio equipment; Part 2: Effective use of the radio frequency spectrum".

[5] CENELEC EN 55022: "Information technology equipment - Radio disturbance characteristics - Limits and methods of measurement".

[6] ANSI C63.5-2004: "American National Standard for Electromagnetic Compatibility-Radiated Emission Measurements in Electromagnetic Interference (EMI) Control-Calibration of Antennas (9 kHz to 40 GHz)".

[7] ETSI TR 102 273-2 (V1.2.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Improvement on Radiated Methods of Measurement (using test site) and evaluation of the corresponding measurement uncertainties; Part 2: Anechoic chamber".

[8] ETSI TR 102 273-4 (V1.2.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Improvement on Radiated Methods of Measurement (using test site) and evaluation of the corresponding measurement uncertainties; Part 4: Open area test site".

3 Definitions, symbols and abbreviations

3.1 Definitions

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

integral antenna: permanent fixed antenna, which may be built-in, designed as an indispensable part of the equipment

Pulse Repetition Frequency (PRF): inverse of the Pulse Repetition Interval (PRI), averaged over a sufficiently long time to cover all PRI variations

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

3.2 Symbols

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

E	Electrical field strength
f	Frequency
f_c	Frequency at which the emission is the peak power at maximum
f_H	Highest frequency of the frequency band of operation
f_L	Lowest frequency of the frequency band of operation
P	Power
R	Distance
t	Time
λ	wavelength

3.3 Abbreviations

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

dB	decibel
dBi	gain in decibels relative to an isotropic antenna
DT	DwellTime
e.i.r.p.	equivalent isotropically radiated power
e.r.p.	effective radiated power
EMC	ElectroMagnetic Compatibility
EUT	Equipment Under Test
GPR	Ground Probing Radar, Ground Penetrating Radar
IF	Input Frequency
LNA	Low Noise Amplifier
OATS	Open Area Test Site
PRF	Pulse Repetition Frequency
PRI	Pulse Repetition Interval
PSD	Power Spectral Density
R&TTE	Radio and Telecommunications Terminal Equipment
RBW	Resolution BandWidth
RF	Radio Frequency
RMS	Root Mean Square
RNSS	Radio Navigation Satellite Service
SA	Spectrum Analyser
ST	ScanTime
UWB	Ultra WideBand
VBW	Video BandWidth
VSWR	Voltage Standing Wave Ratio
WPR	Wall Probing Radar

4 Technical requirements specifications

4.1 Presentation of equipment for testing purposes

Each equipment to be tested, where applicable, shall fulfil the requirements of the present document on all frequencies over which it is intended to operate.

The provider shall provide one or more samples of the equipment, as appropriate for testing.

Additionally, technical documentation and operating manuals, sufficient to allow testing to be performed, shall be supplied.

The performance of the equipment to be tested shall be representative of the performance of the corresponding production model. In order to avoid any ambiguity in that assessment, the present document contains instructions for the presentation of equipment for testing purposes (clause 5), conditions of testing (clause 6) and the measurement methods (clause 8).

Equipment shall be offered by the provider complete with any ancillary equipment needed for testing. The provider shall declare the frequency range(s), the range of operation conditions and power requirements, as applicable, in order to establish the appropriate test conditions.

4.1.1 Choice of model for testing

If an equipment has several optional features, considered not to affect the RF parameters then the tests need only to be performed on the equipment configured with that combination of features considered to be the most complex, as proposed by the provider and agreed by the test laboratory.

In addition, when a device has the capability of using different imaging heads, each one shall be tested independently.

4.2 Mechanical and electrical design

The equipment submitted by the provider shall be designed, constructed and manufactured in accordance with good engineering practice and with the aim of minimizing harmful interference to other equipment and services.

Transmitters and receivers may be individual or combination units.

4.3 Auxiliary test equipment

All necessary test signal sources and set-up information shall accompany the equipment when it is submitted for testing.

4.4 General requirements for RF cables

Due to the low power levels involved in the measurements, all RF cables including their connectors at both ends used within the measurement arrangements and set-ups shall be of coaxial type featuring within the frequency range they are used:

- a nominal characteristic impedance of 50 Ω;
- a VSWR of less than 1,2 at either end;
- a shielding loss in excess of 60 dB.

5 Test conditions, power sources and ambient temperatures

5.1 Normal and extreme test conditions

Testing shall be made under normal test conditions, and also, where stated, under extreme test conditions.

The test conditions and procedures shall be as specified in clauses 5.2 to 5.4.

5.2 External test power source

During tests the power source of the equipment shall be an external test power source, capable of producing normal and extreme test voltages. The internal impedance of the external test power source shall be low enough for its effect on the test results to be negligible.

The test voltage shall be measured at the point of connection of the power cable to the equipment.

During tests the external test power source voltages shall be within a tolerance of ±1 % relative to the voltage at the beginning of each test. The level of this tolerance can be critical for certain measurements. Using a smaller tolerance provides a reduced uncertainty level for these measurements.

5.3 Normal test conditions

5.3.1 Normal temperature and humidity

The normal temperature and humidity conditions for tests shall be any convenient combination of temperature and humidity within the following ranges:

- temperature: +15 °C to +35 °C;
- relative humidity: 20 % to 75 %.

When it is impracticable to carry out tests under these conditions, a note to this effect, stating the ambient temperature and relative humidity during the tests, shall be added to the test report.

5.3.2 Normal test power source

The internal impedance of the test power source shall be low enough for its effect on the test results to be negligible. For the purpose of the tests, the voltage of the external test power source shall be measured at the input terminals of the equipment.

5.3.2.1 Regulated lead-acid battery power source

The normal test voltage for equipment shall be a regulated lead-acid battery power source. For the purpose of the present document, the nominal voltage shall be the declared voltage, or any of the declared voltages, for which the equipment was designed.

When the radio equipment is intended for operation with the usual types of regulated lead-acid battery power source, the normal test voltage shall be 1,1 multiplied by the nominal voltage of the battery (e.g. 6 V, 12 V, etc.).

5.3.2.2 Other power sources

For operation from other power sources or types of battery (primary or secondary), the normal test voltage shall be that declared by the provider. Such values shall be stated in the test report.

5.4 Extreme test conditions

5.4.1 Extreme temperatures

5.4.1.1 Procedure for tests at extreme temperatures

Before measurements are made the equipment shall have reached thermal balance in the test chamber. The equipment shall not be switched off during the temperature stabilizing period.

If the thermal balance is not checked by measurements, a temperature stabilizing period of at least one hour, or such period as may be decided by the test laboratory, shall be allowed. The sequence of measurements shall be chosen, and the humidity content in the test chamber shall be controlled so that excessive condensation does not occur.

5.4.1.2 Extreme temperature ranges

For tests at extreme temperatures, measurements shall be made in accordance with the procedures specified in clause 5.4.1.1, at the upper and lower. temperatures of one of the following limits:

- temperature: -20 °C to +55 °C

5.4.2 Extreme test source voltages

5.4.2.1 Regulated lead-acid battery power source

The extreme test voltages for equipment shall be the nominal voltage ±10 %.

5.4.2.2 Other power sources

For equipment using other power sources, or capable of being operated from a variety of power sources, the extreme test voltages shall be that declared by the provider. These shall be recorded in the test report.

5.5 Combined equipment

When GPR/WPR is part of a combined equipment refer to the guidelines set out in TR 102 070-2 [4].

6 General conditions

6.1 Radiated measurement arrangements

Detailed descriptions of the radiated measurement arrangements are included in annex A. In general, measurements shall be carried out under far field conditions. The far field condition for the EUTs is considered to be fulfilled in a minimum radial distance "X" that shall be a minimum of $2d^2/\lambda$, where d = largest dimension of the antenna aperture of the EUT, for a single device measurement.

Absolute power measurements shall be made using an appropriate method to ensure that the wave front is properly formed (i.e. operating in far field conditions). The test site shall meet the appropriate requirements as defined in published guidelines/standards.

It may not be possible to measure at the power limits without low-noise amplification to reduce the overall noise figure of the overall measurement system at a separation of approximately 3 meters in an RF quite environment. A lower separation distance may be required since the instrumentation noise floor should be at least 10 dB above the limit within the instrument bandwidth.

6.2 Measuring receiver

The term measuring receiver refers to a spectrum analyser. The reference bandwidth of the measuring receiver as defined in CISPR 16-1 [1] shall be as given in table 1.

Table 1: Reference bandwidth of measuring receiver

Frequency being measured: f	Spectrum analyser bandwidth (3 dB)
30 MHz ≤ f < 1 000 MHz	100 kHz
1 000 MHz ≤ f	1 MHz

7 Measurement uncertainty

Interpretation of the results recorded in the test report for the measurements described in the present document shall be as follows:

- the measured value related to the corresponding limit shall be used to decide whether an equipment meets the requirements of the present document;
- the value of the measurement uncertainty for the measurement of each parameter shall be separately included in the test report;
- the value of the measurement uncertainty shall be, for each measurement, equal to or lower than the figures in table 2.

Table 2: Measurement uncertainty

Parameter	Uncertainty
RF frequency	$\pm 1 \times 10^{-7}$
RF power, radiated	±6 dB
Temperature	±1 °C
Humidity	±5 %

For the test methods, according to the present document the uncertainty figures shall be calculated according to the methods described in TR 100 028 [2] and shall correspond to an expansion factor (coverage factor) k = 1,96 or k = 2 (which provide confidence levels of respectively 95 % and 95,45 % in cases where the distributions characterizing the actual measurement uncertainties are normal (Gaussian)).

Table 2 is based on such expansion factors.

The particular expansion factor used for the evaluation of the measurement uncertainty shall be stated.

8 Methods of measurement and limits

Where the transmitter is designed with adjustable carrier power, then all transmitter parameters shall be measured using the highest peak power level, as declared by the provider. When making transmitter tests on equipment designed for intermittent operation, the duty cycle of the transmitter, as declared by the provider, shall not be exceeded. The actual duty cycle used shall be recorded and stated in the test report.

NOTE: The maximum duty cycle of the transmitter under test should not be confused with the duty cycle of the equipment under normal operating conditions.

When performing transmitter tests on equipment designed for intermittent operation it may be necessary to exceed the duty cycle associated with normal operation. Where this is the case, care should be taken to avoid heating effects having an adverse effect on the equipment and the parameters being measured. The maximum transmit-on time shall be decided by the provider and where applicable the test laboratory, this time shall not be exceeded and details shall be stated in the test report.

8.1 Frequency band of operation

8.1.1 Definition

For an emission, f_C is the point in the emission where the peak power is a maximum. The frequency points where the peak power is 10 dB below the f_C level at a frequency above f_C and a frequency below f_C are designated as f_H and f_L respectively.

8.1.2 Method of measurement

In both measurements for the lower and upper frequency bound f_L and f_H, there shall be no point in the emission below f_L and above f_H where the level increases above the level recorded at f_L and f_H. This ensures that peaks and valleys occurring near f_C are not used prematurely as the upper and lower bounds of the emission.

The peak of the radiated emission shall be determined by a peak power measurement, that indicates the maximum of the emission, $f_{C.}$

The peak power of the emission shall be measured by:

- Set the spectrum analyser detector to positive peak.
- Centre the span on the peak of the emission and set the span to zero.
- Set the RBW to no less than 1 MHz and the VBW to no less than the RBW.
- A VBW of three times the RBW is preferred to eliminate video averaging.

f_C shall be recorded in the test report. The EUT shall be tested by directly coupling the normal operational transmitted signal, via a free-line-of-sight towards the measuring test antenna in a manner to ensure the test antenna receives a sufficient signal.

For the lower frequency bound f_L, the emission shall be searched from a frequency lower than the peak that has, by inspection, a much lower PSD than the peak PSD -10 dB and increasing in frequency towards the peak until the PSD indicates a level of 10 dB less than at the peak of the radiated emission.

The process shall be repeated for the upper frequency bound f_H, beginning at a frequency higher than the peak that has, by inspection, a much lower PSD than the peak PSD -10 dB.

The values for f_L and f_H shall be recorded in the test report.

8.1.3 Limits

The frequency band of operation shall not exceed the limits of the 30 MHz to 12,4 GHz frequency range.

8.2 Undesired Emissions

8.2.1 Definition

Undesired Emissions are signals that are leaked or are scattered into the air within the frequency range from 30 MHz to 18 GHz.

These emissions are measured under normal operating conditions.

8.2.2 Method of measurement

The EUT shall be tested over a dry sand pit (i.e. emission of GPR/WPR is to be directed towards the sand pit) which is 50 cm deep and which is greater in area than the EUT, set into the ground with a thin plastic sheet or other suitable barrier to preserve sand condition.

The dimensions of the EUT, the sand pit, and the material used shall be recorded in the test report.

It may be necessary for specific EUTs to perform this measurement by inserting a low noise amplifier in the measuring arrangement to ensure sufficient signal level.

In all measurements the normal operational signal shall be used.

For measurements below 1 GHz, a CISPR 16-1 [1] quasi peak detector shall be used.

Using a spectrum analyser the following settings shall be applied:

a) Set the centre frequency of the SA to the frequency of interest.

b) Set the RBW to 100 kHz and the VBW to be at least equal or greater than the RBW.

For measurements above 1 GHz, a peak detector for determining the peak power amplitude measured within a 50 MHz bandwidth associated with the waveform is used.

Using a spectrum analyser the following settings shall be applied:

a) Set the centre frequency of the SA to the frequency of interest.

b) Set the span to 50 MHz.

c) Set the RBW to 1 MHz and the VBW to 3 MHz.

In order to obtain the required sensitivity a narrower bandwidth may be necessary, this shall be stated in the test report form.

The measurement shall be repeated in the frequency bands 1 164 MHz to 1 215 MHz and 1 559 MHz to 1 610 MHz measured in a 1 kHz resolution bandwidth. Using a spectrum analyser the following is applicable:

a) Search for the highest narrowband emission/spectral line and record the frequency.

b) Set the RBW to 1 kHz and the VBW to 3 kHz.

c) Set the centre frequency of the SA to the frequency recorded in a).

d) Measure and record the level of the emission recorded in step a).

During the measurement, the EUT shall be placed on the testbed of sand with its antenna pointing directly into the sand and the test antenna is placed three metres away from the boresight (vertical centre axis) of the EUT.

Measurements must be taken at a sufficient number of radials and polarizations to ensure that the maximum undesired emission is measured.

The measuring receiver configuration shall use a low noise preamplifier and a dipole antenna (for frequencies below 1 GHz) or horn antenna (for frequencies above 1 GHz). Details are given in annex C. For the undesired emission measurements, a combination of bicones and log periodic dipole array antennas (commonly termed "log periodics") could also be used to cover the entire 30 MHz to 1 000 MHz band.

A test site such as one selected from annex A (i.e. indoor test site or open area test site), which fulfils the requirements of the specified frequency range of this measurement shall be used.

The bandwidth of the measuring receiver shall be set to a suitable value to correctly measure the undesired emissions. This bandwidth shall be recorded in the test report.

The undesired emission power of the EUT shall be measured and recorded. For these measurements it is strongly recommended to use a low noise amplifier (LNA) before the spectrum analyser input to achieve the required sensitivity.

The frequency of the measuring receiver shall be adjusted over the frequency range from 30 MHz to 18 GHz. The frequency of each spurious component shall be noted. If the test site is disturbed by radiation coming from outside the site, this qualitative search may be performed in a screened room with reduced distance between the transmitter and the test antenna.

Proper pre-select filtering can be incorporated to protect the measurement system low-noise pre-amplifier from overload. In addition, persistent ambient signals can be detected to remove the ambient signal contributions present in the measured spectra. This will require post-processing of the measurement data utilizing a computer and data analysis software.

8.2.3 Limits

The effective radiated power of any undesired emission shall not exceed the values given in table 3. The limits in table 3 are derived from EN 55022 [5] Class A.

Table 3: Power limits of radiated undesired emissions

Frequency range (MHz)	Power limit values for undesired emission
30 to 230	-44,5 dBm (e.r.p)
> 230 to 1 000	-37,5 dBm (e.r.p)
> 1 000 to 18 000	-30 dBm (e.i.r.p.)

The maximum mean spectral density of the undesired emission, shall be calculated as set out in annex D and shall not exceed the values in table D.1.

Annex A (normative): Radiated measurements

A.1 Test sites and general arrangements for measurements involving the use of radiated fields

Both, an Open Area Test Site (OATS) or indoor test site may be used for radiated tests.

The distance used in actual measurements shall be recorded with the test results.

Test sites shall be flat, with no artificial ground plane and clear of under ground obstructions. The test bed shall be constructed such that the surface is flat with the surrounding test site. The EUT shall be deployed in the manner of intended use as described in the manufacturer's literature.

The method of measurement shall be in accordance with that described in CISPR 16-1 [1], as far as possible.

Near noise correction (radiometric) methods can also be used to perform accurate measurements at and below the noise floor of a spectrum analyser. The radiometer consists of a band pass filter, a low noise amplifier and a spectrum analyser. The EUT is set 3 metres away from the measuring test antenna and remotely operated from a measurement room.

To minimize coupling loss, the test antenna, filter and LNA shall be connected directly.

When the measurement equipment combines a spectrum analyser with an oscilloscope (i.e. the SA puts the IF signal as external output signal which is measured by the oscilloscope), the oscilloscope input bandwidth shall be over 500 MHz.

A.1.1 Test antenna

A test antenna is always used in radiated test methods. In emission tests (i.e. frequency error, effective radiated power, spurious emissions and adjacent channel power) the test antenna is used to detect the field from the EUT in one stage of the measurement and from the substitution antenna in the other stage. When the test site is used for the measurement of receiver characteristics (i.e. sensitivity and various immunity parameters) the antenna is used as the transmitting device.

The test antenna should be mounted on a support capable of allowing the antenna to be used in either horizontal or vertical polarization which should additionally allow the height of its centre above the ground to be varied over the specified range (usually 1 metre to 4 metres).

In the frequency band 30 MHz to 1 000 MHz, dipole antennas (constructed in accordance with ANSI C63.5 [6]) are generally recommended. For frequencies of 80 MHz and above, the dipoles should have their arm lengths set for resonance at the frequency of test. Below 80 MHz, shortened arm lengths are recommended. For spurious emission testing, however, a combination of bicones and log periodic dipole array antennas (commonly termed "log periodics") could be used to cover the entire 30 MHz to 1 000 MHz band. Above 1 000 MHz, waveguide horns are recommended although, again, log periodics could be used.

NOTE: The gain of a horn antenna is generally expressed relative to an isotropic radiator.

A.1.2 Measuring antenna

The measuring antenna is used in tests on a EUT in which a receiving parameter (i.e. sensitivity and various immunity tests) is being measured. Its purpose is to enable a measurement of the electric field strength in the vicinity of the EUT. For measurements in the frequency band 30 MHz to 1 000 MHz, the measuring antenna should be a dipole antenna (constructed in accordance with ANSI C63.5 [6]). For frequencies of 80 MHz and above, the dipoles should have their arm lengths set for resonance at the frequency of test. Below 80 MHz, shortened arm lengths are recommended. The centre of this antenna should coincide with either the phase centre or volume centre (as specified in the test method) of the EUT.

A.2 Guidance on the use of radiation test sites

This clause details procedures, test equipment arrangements and verification that should be carried out before any of the radiated tests are undertaken. These schemes are common to all types of test sites described in annex A.

A.2.1 Verification of the test site

Verification procedures, as far as applicable, for different types of test sites are given in TR 102 273-2 [7] and TR 102 273-4 [8], respectively.

A.2.2 Preparation of the EUT

The manufacturer should supply information about the EUT covering the operating frequency, polarization, supply voltage(s) and the reference face. Additional information, specific to the type of EUT should include, where relevant, carrier power and whether different operating modes are available (e.g. high and low power modes) and if operation is continuous or is subject to a maximum test duty cycle (e.g. 1 minute on, 4 minutes off).

Where necessary, a mounting bracket of minimal size should be available for mounting the EUT on the turntable. This bracket should be made from low conductivity, low relative dielectric constant (i.e. less than 1,5) material(s) such as expanded polystyrene, balsawood, etc.

A.2.3 Power supplies to the EUT

All tests should be performed using power supplies wherever possible, including tests on EUT designed for battery-only use. In all cases, power leads should be connected to the EUT's supply terminals (and monitored with a digital voltmeter) but the battery should remain present, electrically isolated from the rest of the equipment, possibly by putting tape over its contacts.

The presence of these power cables can, however, affect the measured performance of the EUT. For this reason, they should be made to be "transparent" as far as the testing is concerned. This can be achieved by routing them away from the EUT and down to either the screen, ground plane or facility wall (as appropriate) by the shortest possible paths. Precautions should be taken to minimize pick-up on these leads (e.g. the leads could be twisted together, loaded with ferrite beads at 0,15 m spacing or otherwise loaded).

A.2.4 Range length

The range length for all these types of test facility should be adequate to allow for testing in the far field of the EUT i.e. it should be equal to or exceed:

$$\frac{2(d_1 + d_2)^2}{\lambda}$$

where:

d_1 is the largest dimension of the EUT/dipole after substitution (m);

d_2 is the largest dimension of the test antenna (m);

λ is the test frequency wavelength (m).

It should be noted that in the substitution part of this measurement, where both test and substitution antennas are half wavelength dipoles, this minimum range length for far-field testing would be:

$$2\lambda$$

It should be noted in test reports when either of these conditions is not met so that the additional measurement uncertainty can be incorporated into the results.

A.2.5 Site preparation

The cables for both ends of the test site should be routed horizontally away from the testing area for a minimum of 2 m and then allowed to drop vertically and out through either the ground plane or screen (as appropriate) to the test equipment. Precautions should be taken to minimize pick up on these leads (e.g. dressing with ferrite beads, or other loading). The cables, their routing and dressing should be identical to the verification set-up.

Calibration data for all items of test equipment should be available and valid. For test, substitution and measuring antennas, the data should include gain relative to an isotropic radiator (or antenna factor) for the frequency of test. Also, the VSWR of the substitution and measuring antennas should be known.

The calibration data on all cables and attenuators should include insertion loss and VSWR throughout the entire frequency range of the tests. All VSWR and insertion loss figures should be recorded in the logbook results sheet for the specific test.

Where correction factors/tables are required, these should be immediately available.

For all items of test equipment, the maximum errors they exhibit should be known along with the distribution of the error e.g.:

- cable loss: ±0,5 dB with a rectangular distribution;
- measuring receiver: 1,0 dB (standard deviation) signal level accuracy with a Gaussian error distribution.

At the start of measurements, system checks should be made on the items of test equipment used on the test site.

A.2.6 Conversion of field strength to power limits

The limits in clause 8.2.3 are given as power limit. However, limits in EN 55022 [5] (class A) are stated as a field strength.

In order to do the conversion of a field strength level to a power level, the following equation shall be used:

$$E = \frac{\sqrt{30 \times e.r.p.}}{R}$$

where R is the distance in metres between the equipment under test and the measurement point, e.r.p. is the effective radiated power in Watts of the equipment.

Annex B (normative): Deactivation mechanism

This annex provides the information for GPR and WPR equipment manufacturers to design the equipment in such a way, that the essential requirement as stated in EN 302 066-2 [3], clause 4.2.3 is fulfilled.

The deactivation mechanism of the equipment is a function which deactivates the equipment when normal use is interrupted.

The following requirements shall be fulfilled:

- Manually operated GPR and WPR, which is intended to be used as handheld equipment, shall contain a manually operated non-locking switch (e.g. it may be a sensor for the presence of the operators hand or a movement sensor) which ensures that the equipment de-activates (i.e. the transmitter switches off) within 10 seconds of being released by the operator.

- In the case of remotely/computer controlled imaging equipment, the equipment shall be de-activated via the control system provided that de-activation takes place within 10 seconds of the control system being switched off or released by the operator.

- GPR and WPR equipment shall be designed to operate while in contact with, or in close proximity, or within one meter of, to the ground or the wall, and their emissions being directed into the ground or wall (e.g. measured by a proximity sensor or imposed by the mechanical design). Manufacturers shall provide instruction manuals for the equipment which include a description for its use and deployment (positioning) during operation.

- There are particular cases where the equipment is mounted in a vehicle for the collection of data where the de-activation time required is 60 seconds.

Annex C (informative): Measurement antenna and preamplifier specifications

The radiated measurements set-up in clause 8 specifies the use of the wide-band horn antenna and a wide-band, high gain preamplifier in order to measure the very low radiated power density level from the EUT.

Table C.1 gives examples of recommended data and features for the horn antenna and preamplifier to be used for the test set-up.

Table C.1: Recommended performance data for preamplifier and horn antenna

Pre-amplifier	
Parameter	**Data**
Bandwidth	< 1 GHz to > 15 GHz
Noise figure	< 2 dB
Output at 1 dB compression	> +10 dBm
Gain	> 30 dB
Gain flatness across band	±1,5 dB
Phase response	Linear across frequency range
Impulse response overshoot	< 10 %
Impulse response damping ratio	0,3 to 0,5
VSWR in/out across band	2:1
Nominal impedance	50 Ω
Horn antenna	
Parameter	**Data**
Gain	> 4 dBi
1 dB bandwidth	< 1 GHz to > 15 GHz
Nominal impedance	50 Ω
VSWR across band	< 1,5:1
Cross polarization	> 20 dB
Front to back ratio	> 20 dB
Tripod mountable	Yes
Robust precision RF connector	Yes

Measuring the complete emission spectrum of the operating frequency range, several measurement antennas will be required, each optimized over a distinct frequency range:

Table C.2: Recommended measurement antennas

Antenna type	Frequency range
λ/2 - dipole or biconical	30 MHz to 200 MHz
λ/2 - dipole or log periodic	200 MHz to 1 000 MHz
Horn	> 1 000 MHz

Annex D (normative): Calculation of the Mean Power Density

Maximum mean power densities and peak power densities of any undesired emission emanating from GPR/WPR imaging systems are defined below. For pragmatic reasons and for taking the mitigation factors into account, the mean power density shall be determined by formula (D.1) or (D.2) and the peak values shall be measured according to clause 8.2.2 of the present document.

NOTE: GPR/WPRs operate across a wide range of spectrum where established radio services operate. These services have diverse bandwidths, some may be susceptible to peak signal levels and others to average signal levels. There are technical and practical issues, related to bandwidth, the effective loading of the GPR/WPRs radiation by earth materials and the limitations of instrumentation. Peak signal levels are measured according to clause 8.2.2 of the present document, and average signal levels calculated based upon the duty cycle of the GPR/WPR.

a) The mean power density of any undesired emission emanating from GPR/WPR imaging systems shall be kept to a minimum and not exceed the limits in table D.1.

Table D.1

Frequency range (MHz)	**Maximum mean e.i.r.p. density (dBm/MHz)**
< 230	-65
230 to 1 000	-60
1 000 to 1 600	-65 (see note)
1 600 to 3 400	-51,3
3 400 to 5 000	-41,3
5 000 to 6 000	-51,3
> 6 000	-65
NOTE: In addition to the maximum mean e.i.r.p. density given above, a maximum mean e.i.r.p density of -75 dBm/kHz applies in the RNSS bands 1 164 MHz to 1 215 MHz and 1 559 MHz to 1 610 MHz in case of spectral lines in these bands. Peak power shall be measured according to clause 8.2.2 of the present document and mean power density shall be determined from formula (1) or (2) set out below.	

b) The measured radiated peak power of any undesired emission emanating from GPR/WPR imaging systems shall not exceed the limits as given in clause 8.2.3 (table 3), measured according to clause 8.2.2 of the present document.

c) The time domain architecture of GPR/WPRs and patterns of use imply that there is wide variation in the total power emitted in any time period. For pulsed systems this includes the duration of pulses compared to the time between pulses, the time between bursts of pulses when the system is being moved to the next measurement position and other operational factors. This should be taken into account when considering the mean power that may be incident upon a vulnerable radio service. In order to accommodate all these factors a conversion factor shall be used to evaluate the mean power that should be compared to the limits in table D.1. This conversion factor has been established as a simple and practical way to assess mean power levels based on the measurement of peak power levels.

When determining mean power values, for pulsed systems, to be compared with the values in table D.1 the following formula shall be used:

$$Power_{mean} = Power_{peak} + conversion\_factor \quad (D.1)$$

with:

$$conversion\ factor = 10 \log(PRF \times \tau)$$

where:

τ is the pulse width of the GPR/WPR transmitter measured at the 50 % amplitude points of the envelope at boresight with an UWB probe and a suitable oscilloscope. When performing this measurement, care should be taken that the pulse is properly gated, i.e. no reflectors should be allowed to influence the pulse while travelling from the GPR/WPR transmitter to the UWB probe. The UWB probe/antenna shall have a bandwidth wide enough to capture the UWB signal from the GPR/WPR properly.

PRF is the pulse repetition frequency.

For systems using step-frequency waveforms, the wideband signal is formed by transmitting a sequence of discrete frequencies each having a DwellTime (DT). The length of the total sequence is referred to as the ScanTime (ST). The Scan Time is identical to the Cycle Time in frequency hopping systems, and it is the interval between each time the transmitter is hopping back to the first frequency in the sequence.

For calculating the mean power value for a step-frequency system, the following formula shall be used:

$$Power_{mean} = Power_{peak} + conversion\_factor \quad (D.2)$$

with:

$$conversion\_factor = 10 \log(DT/ST)$$

where:

DT is measured at the 50 % amplitude points of the envelope at boresight with an UWB probe and a spectrum analyser in zero-span mode at a frequency near the maximum of the radiated spectrum using 1 MHz resolution bandwidth. ST is measured in the same way using a spectrum analyser in zero-span mode and 1 MHz resolution bandwidth.

Measurement of τ, transmit pulse width

There are two ways of measuring τ, time domain and frequency domain methods.

1) Time domain

The GPR antenna is lifted off the ground and pointed directly towards the measurement antenna, see figure D.1. The distance between the DUT and receive antenna shall be greater than one wavelength (at the lowest frequency radiated). Care shall be taken so that there are no unwanted multipath reflections included in the time interval where the pulse width measurement is carried out. The non-dispersive antenna/UWB-probe shall have a fractional bandwidth wide enough to represent the UWB, signal (GPR/WPR typically have a fractional bandwidth greater than 100 %).

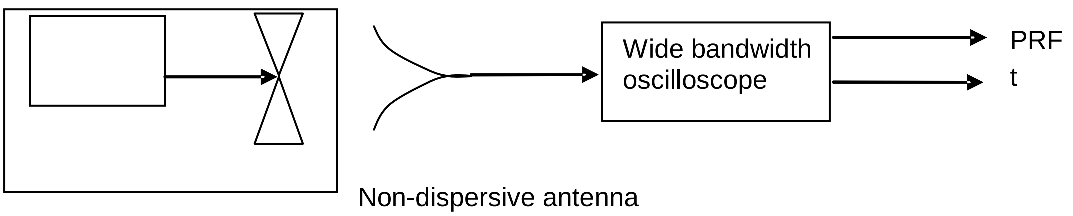

Figure D.1: Test setup 1

2) Frequency domain

The RF bandwidth of a single pulse modulated carrier is approximately =1/$_{\tau.}$ By measuring the occupied bandwidth an equivalent pulse width is calculated. There is no need to have a non-dispersive antenna or oscilloscope any more, the measurement is done with the same antenna and spectrum analyser as for the peak power measurement as per clause 8.1 in the present document, but with the GPR and measurement antenna facing each other, see figure D.2.

To avoid multipath reflections distorting the measurement, this test shall be carried out in an open test area or in an anechoic room.

τ =1/(F_{upper}-F_{lower}), -10 dB measurement points.

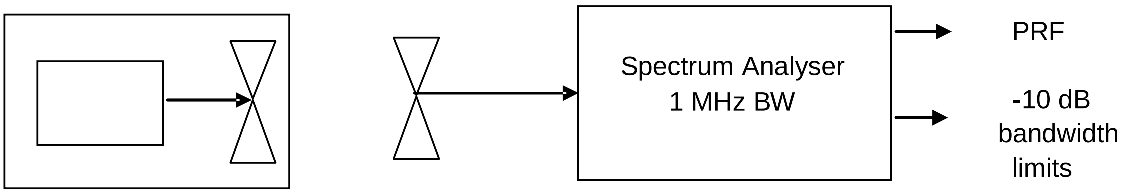

Figure D.2: Test setup 2

Annex E (informative): Bibliography

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

CISPR 22: "Information technology equipment - Radio disturbance characteristics - Limits and methods of measurement".

ETSI EN 301 489-32: "Electromagnetic compatibility and Radio spectrum Matters (ERM); ElectroMagnetic Compatibility (EMC) standard for radio equipment and services; Part 32: Specific conditions for Ground and Wall Probing Radar applications".

ECC/DEC/(06)08: "ECC Decision of 1 December 2006 on the conditions for use of the radio spectrum by Ground- and Wall- Probing Radar (GPR/WPR) imaging systems".

History

Document history				
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