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Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Equipment for Detection and Movement; Tanks Level Probing Radar (TLPR) operating in the frequency bands 5,8 GHz, 10 GHz, 25 GHz, 61 GHz and 77 GHz; Part 1: Technical characteristics and test methods

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Foreword

This European Standard (Telecommunications series) has been produced by ETSI Technical Committee Electromagnetic compatibility and Radio spectrum Matters (ERM).

For non-EU countries, the present document may be used for regulatory (Type Approval) purposes.

The present document is part 1 of a multi-part deliverable covering Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Equipment for Detection and Movement; Tanks Level Probing Radar (TLPR) operating in the frequency bands 5,8 GHz, 10 GHz, 25 GHz, 61 GHz and 77 GHz, as identified below:

Part 1: "Technical characteristics and test methods";

Part 2: "Harmonized EN under article 3.2 of the R&TTE Directive".

National transposition dates	
Date of adoption of this EN:	24 March 2006
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1 Scope

The present document specifies the requirements for Tank Level Probing Radar (TLPR) applications based on pulse RF, FMCW, or similar wideband techniques, operating in the following frequency bands or part hereof:

- 4,5 GHz to 7 GHz;
- 8,5 GHz to 10,6 GHz;
- 24,05 GHz to 27 GHz;
- 57 GHz to 64 GHz;
- 75 GHz to 85 GHz.

TLPRs are used for tank level measurement applications.

The scope is limited to TLPRs operating as Short Range Devices, in which the devices are installed in closed metallic tanks or reinforced concrete tanks, or similar enclosure structures made of comparable attenuating material, holding a substance, liquid or powder.

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

The present document applies to TLPRs radiating RF signals directly from the tank top downwards to the surface of a substance contained in a closed tank. Any radiation outside of the tank is caused by leakage and is considered as unintentional emission. It applies only to TLPRs fitted with dedicated antennas. 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.

The present document contains the technical characteristics and test methods for TLPR applications and references CEPT/ERC Recommendation for SRDs, CEPT/ERC/Recommendation 70-03 [1].

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- 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.
- For a non-specific reference, the latest version applies.

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

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

[2] CISPR 16: "Specification for radio disturbance and immunity measuring apparatus and methods".

[3] ETSI TR 102 215: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Recommended approach, and possible limits for measurement uncertainty for the measurement of radiated electromagnetic fields above 1 GHz".

[4] 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)".

[5] ETSI TR 102 273 (all parts): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Improvement on Radiated Methods of Measurement (using test site) and evaluation of the corresponding measurement uncertainties".

[6] ETSI EN 302 372-2: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Equipment for Detection and Movement; Tanks Level Probing Radar (TLPR) operating in the frequency bands 5,8 GHz, 10 GHz, 25 GHz, 61 GHz and 77 GHz; Part 2: Harmonized EN under article 3.2 of the R&TTE Directive".

3 Definitions, symbols and abbreviations

3.1 Definitions

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

dedicated antenna: antenna that is designed as an indispensable part of the equipment

Device Under Test (DUT): TLPR under test without a test tank

duty cycle: ratio of the total on time of the transmitter to the total time in any one-hour period reflecting normal operational mode

emissions: signals that leaked or are scattered into the air within the frequency range (that includes harmonics) which depend on equipment's frequency band of operation

NOTE: For TLPRs there is no intended emission outside the tank.

Equipment Under Test (EUT): TLPR under test mounted on a test tank

equivalent isotropically radiated power (e.i.r.p.): total power transmitted, assuming an isotropic radiator

NOTE: e.i.r.p. is conventionally the product of "power into the antenna" and "antenna gain". e.i.r.p. is used for both peak and average power.

Frequency Modulated Continuous Wave (FMCW) radar: radar where the transmitter power is fairly constant but possibly zero during periods giving a big duty cycle (such as 0,1 to 1)

NOTE: The frequency is modulated in some way giving a very wideband spectrum with a power versus time variation which is clearly not pulsed.

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

operating frequency (operating centre frequency): nominal frequency at which equipment is operated

pulsed radar (or here simply "pulsed TLPR"): radar where the transmitter signal has a microwave power consisting of short RF pulses

power spectral density (psd): amount of the total power inside the measuring receiver bandwidth expressed in dBm/MHz

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

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

radiation: signals emitted intentionally inside a tank for level measurements

3.2 Symbols

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

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
t	Time
k	Boltzmann constant
T	Temperature
G	Efficient antenna gain of radiating structure
G_a	Declared measurement antenna gain
d	Largest dimension of the antenna aperture of the TLPR
d_1	Largest dimension of the DUT/dipole after substitution (m)
d_2	Largest dimension of the test antenna (m)
D	Duty cycle
D_U	Duty cycle determined by the users transmission time
D_X	Duty cycle determined by the transmitters modulation type
P_s	Output power of the signal generator measured by power meter
Δf	Bandwidth
X	Minimum radial distance (m) between the DUT and the test antenna
λ	Wavelength

3.3 Abbreviations

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

dB	deciBel
dBi	antenna gain in deciBels relative to an isotropic antenna
DUT	Device Under Test
e.i.r.p.	equivalent isotropically radiated power
EMC	ElectroMagnetic Compatibility
ERC	European Radiocommunication Committee
EUT	Equipment Under Test
FMCW	Frequency Modulated Continuous Wave
LNA	Low Noise Amplifier
OATS	Open Area Test Site
ppm	parts per million
PRF	Pulse Repetition Frequency
PSD	Power Spectral Density
R&TTE	Radio and Telecommunications Terminal Equipment
RBW	Resolution BandWidth
RF	Radio Frequency
SA	Spectrum Analyser
SRD	Short Range Device
TLPR	Tank Level Probing Radar
Tx	Transmitter
VBW	Video BandWidth
VSWR	Voltage Standing Wave Ratio

4 Technical requirements specifications

4.1 Presentation of equipment for testing purposes

Equipment submitted for testing, where applicable, shall fulfil the requirements of the present document on all frequencies over which it is intended to operate.

The provider shall submit 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 submitted for testing 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 4), conditions of testing (clauses 5 and 6) and the measurement methods (clause 8).

The provider shall offer equipment complete with any auxiliary equipment needed for testing. The provider shall also submit a suitable test tank, as described in annex E.

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.

4.2 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 create the highest unintentional emissions outside the tank structure.

In addition, when a device has the capability of using different dedicated antennas, tank connections or other features that affect the RF parameters, at least the worst combination of features from an emission point of view as agreed between the provider and the test laboratory shall be tested.

The choice of model(s) for testing shall be recorded in the test report.

4.3 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.

4.3.1 Marking (equipment identification)

The equipment shall be marked in a visible place. This marking shall be legible and durable. Where this is not possible due to physical constraints, the marking shall be included in the user's manual.

4.3.1.1 Equipment identification

The marking shall include as a minimum:

- the name of the manufacturer or his trademark;
- the type designation.

4.4 Auxiliary test equipment

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

4.5 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 or waveguide 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.

4.6 Interpretation of the measurement results

The interpretation of the results recorded on the appropriate test report for the measurements described in the present document shall be as follows:

- the measured value relating to the corresponding limit shall be used to decide whether an equipment meets the requirements of the present document;
- the measurement uncertainty value for the measurement of each parameter shall be included in the test report.

The measurement uncertainty is explained in clause 7. Additionally, the interpretation of the measured results depending on the measurement uncertainty is described in clauses 4.6.1 and 4.6.2.

4.6.1 Measurement uncertainty is equal to or less than maximum acceptable uncertainty

The interpretation of the results when comparing measurement values with specification limits shall be as follows:

a) when the measured value does not exceed the limit value the equipment under test meets the requirements of the present document;

b) when the measured value exceeds the limit value the equipment under test does not meet the requirements of the present document;

c) the measurement uncertainty calculated by the test technician carrying out the measurement should be recorded in the test report;

d) the measurement uncertainty calculated by the test technician may be a maximum value for a range of values of measurement, or may be the measurement uncertainty for the specific measurement undertaken. The method used should be recorded in the test report.

4.6.2 Measurement uncertainty is greater than maximum acceptable uncertainty

The interpretation of the results when comparing measurement values with specification limits should be as follows:

a) when the measured value plus the difference between the maximum acceptable measurement uncertainty and the measurement uncertainty calculated by the test technician does not exceed the limit value the equipment under test meets the requirements of the present document;

b) when the measured value plus the difference between the maximum acceptable measurement uncertainty and the measurement uncertainty calculated by the test technician exceeds the limit value the equipment under test does not meet the requirements of the present document;

c) the measurement uncertainty calculated by the test technician carrying out the measurement should be recorded in the test report;

d) the measurement uncertainty calculated by the test technician may be a maximum value for a range of values of measurement, or may be the measurement uncertainty for the specific measurement undertaken. The method used should be recorded in the test report.

5 Test conditions, power sources and ambient temperatures

5.1 Normal and extreme test conditions

Testing shall be made under normal test conditions, and 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 Mains voltage

The normal test voltage for equipment to be connected to the mains shall be the nominal mains voltage. 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.

The frequency of the test power source corresponding to the ac mains shall be between 49 Hz and 51 Hz.

5.3.2.2 Regulated lead-acid battery power source

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.).

5.3.2.3 Other power sources

For operation from power sources or types of battery other than lead acid (primary or secondary), the normal test voltage and frequency 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.

In the case of equipment containing temperature stabilization circuits designed to operate continuously, the temperature stabilization circuits shall be switched on for 15 minutes after thermal balance has been obtained, and the equipment shall then meet the specified requirements.

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 accredited 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 at following temperature range as a minimum requirement:

- Temperature: -20 °C to +55 °C.

For special applications, the manufacturer can specify a different temperature range than given as a minimum above. This shall be reflected in manufacturer's product literature.

The test report shall state which range is used.

5.4.2 Extreme test source voltages

5.4.2.1 Mains voltage

The extreme test voltages for equipment to be connected to an ac mains source shall be the nominal mains voltage ±10 %.

The frequency of the test power source corresponding to the ac mains shall be between 49 Hz and 51 Hz.

5.4.2.2 Regulated lead-acid battery power source

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

5.4.2.3 Other power sources

For equipment using other power sources than lead acid, 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.

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 requires a minimum radial distance "X" that shall be a minimum of $2d^2/\lambda$, where d = largest dimension of the antenna aperture. An equivalent formulation of $2d^2/\lambda$ is 0,2 λG where G is the efficient antenna gain of the radiating structure. The diffuse emission outside of the tank has a low gain G (~ a few dB) and thus measurements on a small distance does not violate the $2d^2/\lambda$ condition in spite of rather big size of tank, for further details see annex F.

Absolute power measurements shall be made only in the far field. The test site shall meet the appropriate requirements as defined in published guidelines/standards (e.g. for OATS, the requirements are described in CISPR 16 [2]).

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 quiet environment. A move to lower separation distance may be required since the instrumentation noise floor should be below 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 [2] 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
f ≥ 1 000 MHz	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 equipment meets the requirements of the present document.

Table 2: Maximum measurement uncertainties

Parameter	Uncertainty
Radio frequency	±0,1 ppm
Radiated RF power	±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 102 215 [3] 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. The duty cycle of the transmitter as declared by the provider shall not be exceeded. The actual duty cycle used during the measurements shall be recorded in the test report.

8.1 Frequency band of operation

8.1.1 Definition

The range of operating frequencies includes all frequencies on which the equipment operates within one or more of the assigned frequency bands.

f_C is the point in the radiation where the power is at maximum. The frequency points where the power falls 10 dB below the f_C level and above f_C level are designated as f_L and f_H respectively.

The operating frequency range (i.e. the frequency band of operation) is defined as f_H - f_L.

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 radiation 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 radiation.

The maximum of the radiation is determined by a power measurement that indicates the maximum of the radiation at f_C.

The maximum power of the radiation is measured by:

a) Set the spectrum analyser detector to positive peak.

b) Centre the span on the peak of the radiation and set the span to zero.

c) 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 DUT is 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 radiation is 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 radiation.

The process is 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 peak PSD -10 dB.

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

8.1.3 Limits

The permitted ranges of operating frequencies for radiation are given in table 3. Outside the permitted ranges of operating frequencies the radiations shall be reduced by no less than 10 dB.

Table 3: Frequency bands of operation

Frequency bands of operation
4,5 GHz to 7 GHz
8,5 GHz to 10,6 GHz
24,05 GHz to 27 GHz
57 GHz to 64 GHz
75 GHz to 85 GHz

8.2 Duty cycle

Duty cycle, D, is defined as:

$$D = \frac{t_{on}}{t_{on} + t_{off}}$$

where:

- t_{on} is the time where the transmitter is active;
- t_{off} is the time where the transmitter is switched off.

The total equipment duty cycle is the result from the duty cycle, D_U, by the application, see clause 8.2.1 and the duty cycle, D_X, by the modulation, see clause 8.2.2.

8.2.1 Duty cycle resulting from application

The duty cycle D_U, is under control of the user, determined by the users transmission time and is normally declared by the user or applicant.

The provider shall declare the duty cycle D_U and the respective duty cycle class for the DUT as indicated in table 4. This declaration shall be stated in the test report.

Table 4: Duty Cycle, D_U

Duty cycle Class	Duty cycle ratio
1	≤ 0,1 %
2	≤ 1,0 %
3	≤ 10 %
4	Up to 100 %

8.2.2 Duty cycle resulting from modulation

8.2.2.1 Method of measurement

The duty cycle D_X, is determined by the transmitters modulation type and shall be measured by means a diode detector and an oscilloscope or another appropriate instrument. The duty cycle D_X is important when the radiated power is measured and the modulation cannot be switched off. This is specifically the case when the equipment is using a pulsed type of modulation:

- Using suitable attenuators, the output power of the transmitter shall be coupled to a matched diode detector. The output of the matched diode detector shall be connected to the vertical channel of an oscilloscope.
- The combination of the matched diode detector and the oscilloscope shall be capable of faithfully reproducing the envelope peaks and the duty cycle of the transmitter output signal.
- The observed duty cycle of the transmitter (Tx on/(Tx on +Tx off)) shall be noted as D_X ($0 < D_X \leq 100$ %), and recorded in the test report. For the purpose of testing, the equipment shall be operated with a duty cycle that is equal to or greater than 10 %. Where this duty cycle is not possible, then this shall be stated on the test report and the actual duty cycle shall be declared.

The duty cycle limits are given in table 5.

Table 5: Duty Cycle, D_X

Duty cycle Class	Duty cycle ratio
1	≤ 0,1 %
2	≤ 1,0 %
3	≤ 10 %
4	Up to 100 %

Pulsed systems shall only be duty cycle, D_X, class 1 or 2.

The limit for the duty cycle is observed over any one-hour period.

8.3 Equivalent isotropically radiated power (e.i.r.p.)

8.3.1 Definition

The radiated power (e.i.r.p.) is defined as the emitted power of the transmitter including antenna gain according to the procedure given in the following clause.

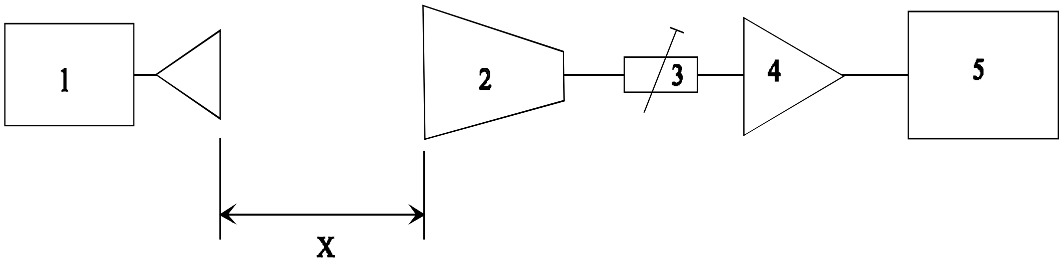
The measurement shall be performed under both normal and extreme test conditions.

8.3.2 Method of measurement

The measurement shall be performed in an anechoic chamber using normal operation of the equipment, i.e. for FMCW modulated TLPR the sweep is not suspended and for the pulsed TLPR the pulse gating is not suspended.

The TLPR is not mounted on a tank for this test.

The test set-up is shown in figure 1.



Key:
1. Device under test with integrated or dedicated antenna.
2. Wideband test antenna.
3. Variable step attenuator (optional).
4. Low noise, pulse rated, high gain, wideband preamplifier.
5. Power meter.

Figure 1: Measurement set-up

The minimum performance data for preamplifier (key 4) and horn antenna (key 2) are shown in annex C.

The test procedure is the following:

a) The tests shall be made in an anechoic chamber.

b) Set the DUT in normal operation mode.

c) The test antenna (2) is positioned at a measurement distance, X, of approximately 3 m from the DUT (1). The distance shall be stated in the test report.

d) The device under test (1) and the wide band test antenna (2) are orientated for maximum reading at the power meter (5).

e) The average output power of the transmitter shall be determined using a wideband calibrated RF power meter with a matched thermocouple detector or an equivalent thereof and with an integration period that exceeds the repetition period of the transmitter by a factor 5 or more. The observed value shall be noted as "A" (in dBm).

f) The device under test (1) is substituted by a unmodulated signal generator connected to a measurement antenna having gain, G_a. The antenna is positioned in front of the test wide band antenna (2) at the same measurement distance, X, as for c) above and is orientated for maximum reading at the power meter.
The signal generator frequency is adjusted to f_c and its output power adjusted until the power meter (5) reading is identical with the maximum level of the radiated power according to point e) above (observed power A).The radiated power (e.i.r.p.) shall be calculated from the above measured power from the signal generator, P_s, the observed duty cycle, D_X, and the declared measurement antenna's gain "G_a" in dBi, according to the formula:

$$P = P_s + G_a + 10 \log (1/D_X) \text{ (dBm).}$$

The above measurement may also be performed as a conducted measurement. For this purpose, the DUT needs a temporary or permanent antenna connector. The provider shall declare the maximum antenna gain and this shall be stated in the test report.

For measurements under extreme conditions relative measurements shall be performed. If tests under extreme conditions cannot be carried out using the conducted method, a test fixture shall be used.

8.3.3 Limits

The radiated power (e.i.r.p.), under normal and extreme conditions, shall not exceed the values given in table 6.

Table 6: Radiated power limit

Frequency band of operation	Max. radiated power (e.i.r.p.)
4,5 GHz to 7 GHz	+24 dBm
8,5 GHz to 10,6 GHz	+30 dBm
24,05 GHz to 27 GHz	+43 dBm
57 GHz to 64 GHz	+43 dBm
75 GHz to 85 GHz	+43 dBm

8.4 Emissions

8.4.1 Definition

Emissions are leakage signals from a tank structure including an installed TLPR.

8.4.2 Method of measurement

Measurements shall be performed in the frequency ranges given in table 7.

Table 7: Frequency ranges within which the emission shall be measured

Frequency band of operation	Frequency range within which the emissions shall be measured
4,5 GHz to 7 GHz	30 MHz to 26 GHz
8,5 GHz to 10,6 GHz	30 MHz to 26 GHz
24,05 GHz to 27 GHz	30 MHz to 2 × carrier frequency
57 GHz to 64 GHz	30 MHz to 2 × carrier frequency
75 GHz to 85 GHz	30 MHz to 2 × carrier frequency

For this test, the EUT is defined as a TLPR mounted on a test tank as described in annex E. Relevant information concerning leakage from the EUT is given in annex D.

The dimensions of the test tank shall be recorded in the test report.

An example of the test set-up is illustrated in figure 2.

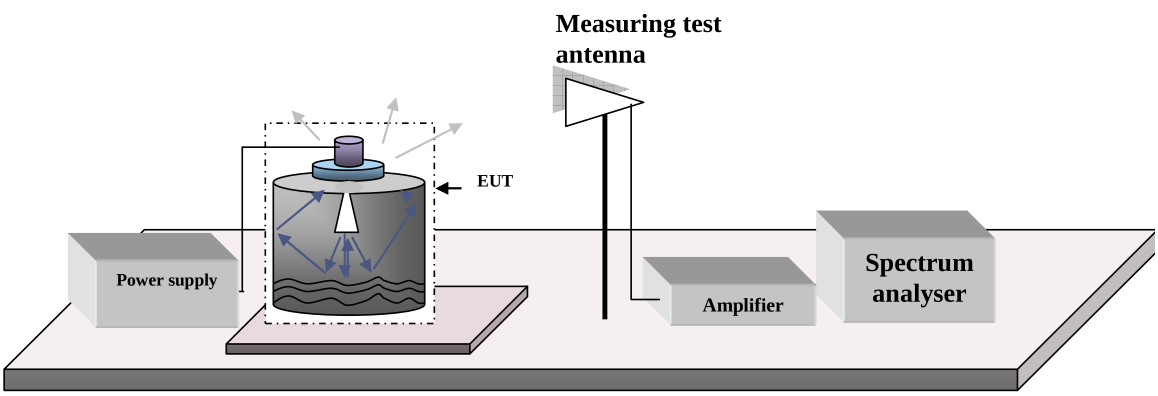


Figure 2: An example of test set-up for emission measurement

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.

The recommended performance data for the measurement antenna and preamplifier are given in annex C.

The measurement shall be performed under normal test condition.

The measurement shall be performed using normal operation of the equipment

The frequency of the spectrum analyser shall be adjusted over frequency bands given in table 7.

For measurements below 1 GHz, a CISPR 16 [2] quasi peak detector shall be used.

Using a spectrum analyser (SA), the following settings are applicable:

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 spectrum analyzer with an average detector is used.

Using the following settings are:

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

b) Set the span to 50 MHz or less.

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 test procedure shall be the following:

- 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 frequency of the measuring receiver shall be adjusted over the frequency range in accordance to table 7. 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.
- During the measurement, the test antenna is placed three metres away from the EUT. It may be necessary for specific EUTs to perform this measurement with the test antenna placed closer to the EUT. The distance between EUT and the test antenna shall be recorded in the test report.
- Measurements must be taken at a sufficient number of radials and polarizations to ensure that the maximum unintentional emission is measured.

The measuring receiver configuration uses 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 unintentional emission measurements, a combination of biconical and log periodic dipole array antennas (commonly termed "log periodic") could also be used to cover the entire 30 MHz to 1 000 MHz band.

- The measured spectrum curve at the spectrum analyser shall be recorded. For these measurements it is strongly recommended to use a LNA (low noise amplifier) before the spectrum analyser input to achieve the required sensitivity. Measurements below -60 dBm e.i.r.p (measured in a 1 MHz bandwidth) are not required.

8.4.3 Limits

The effective radiated power of any emission shall not exceed the values given in table 8.

Table 8: Power limits of radiated emissions

<table>
<tr><th>Frequency band of operation
[GHz]</th><th>Frequency band of SA</th><th>Max. emissions outside the tank enclosure structure inside the band of operation</th><th>Max. emissions outside the tank enclosure structure and outside the band of operation</th></tr>
<tr><td>4,5 to 7</td><td>30 MHz to 26 GHz</td><td rowspan="5">< 1 GHz: -51,3 dBm

≥ 1 GHz: -41,3 dBm</td><td rowspan="5">< 1 GHz: -61,3 [dBm]

≥ 1 GHz: -51,3 [dBm]
(see note)</td></tr>
<tr><td>8,5 to 10,6</td><td>30 MHz to 26 GHz</td></tr>
<tr><td>24,05 to 27</td><td>30 MHz to 2 × carrier frequency</td></tr>
<tr><td>57 to 64</td><td>30 MHz to 2 × carrier frequency</td></tr>
<tr><td>75 to 85</td><td>30 MHz to 2 × carrier frequency</td></tr>
<tr><td colspan="4">NOTE: For the frequency range 10,6 GHz to 10,7 GHz, the emission shall be ≤ - 60 dBm.</td></tr>
</table>

Annex A (normative): Radiated measurement

This annex has been drafted so it covers test sites and methods to be used with integral antenna equipment or dedicated antenna for equipment having an antenna connector. In the present annex the word "EUT" is representing both EUT and DUT.

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

This annex introduces three most commonly available test sites, an anechoic chamber, an anechoic chamber with a ground plane and an Open Area Test Site (OATS), which may be used for radiated tests. These test sites are generally referred to as free field test sites. Both absolute and relative measurements can be performed in these sites. Where absolute measurements are to be carried out, the chamber should be verified. A detailed verification procedure is described in the relevant parts of TR 102 273 [5] or equivalent.

NOTE: To ensure reproducibility and tractability of radiated measurements only these test sites should be used in measurements in accordance with the present document.

A.1.1 Anechoic Chamber

An anechoic chamber is an enclosure, usually shielded, whose internal walls, floor and ceiling are covered with radio absorbing material, normally of the pyramidal urethane foam type. The chamber usually contains an antenna support at one end and a turntable at the other. A typical anechoic chamber is shown in figure A.1.

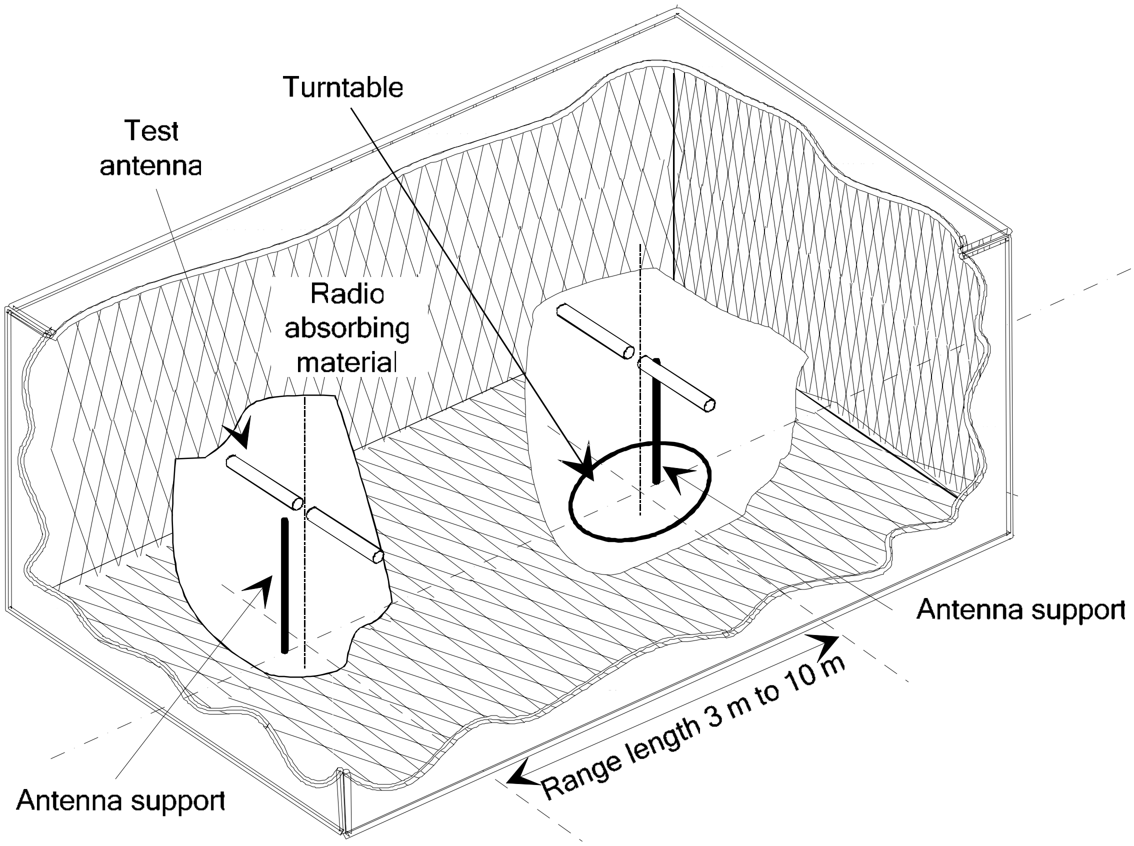


Figure A.1: A typical Anechoic Chamber

The chamber shielding and radio absorbing material work together to provide a controlled environment for testing purposes. This type of test chamber attempts to simulate free space conditions.

The shielding provides a test space, with reduced levels of interference from ambient signals and other outside effects, whilst the radio absorbing material minimizes unwanted reflections from the walls and ceiling which can influence the measurements. In practice it is relatively easy for shielding to provide high levels (80 dB to 140 dB) of ambient interference rejection, normally making ambient interference negligible.

A turntable is capable of rotation through 360° in the horizontal plane and it is used to support the test sample (EUT) at a suitable height (e.g. 1 m.) above the ground plane. The chamber shall be large enough to allow the measuring distance of at least 3 m or $2(d_1 + d_2)^2/\lambda$ (m), whichever is greater (see clause A.2.4). For further information on measurements at shorter distances see annex F. The distance used in actual measurements shall be recorded with the test results.

The anechoic chamber generally has several advantages over other test facilities. There is minimal ambient interference, minimal floor, ceiling and wall reflections and it is independent of the weather. It does however have some disadvantages which include limited measuring distance and limited lower frequency usage due to the size of the pyramidal absorbers. To improve low frequency performance, a combination structure of ferrite tiles and urethane foam absorbers is commonly used.

All types of emission, sensitivity and immunity testing can be carried out within an anechoic chamber without limitation.

A.1.2 Anechoic Chamber with a conductive ground plane

An anechoic chamber with a conductive ground plane is an enclosure, usually shielded, whose internal walls and ceiling are covered with radio absorbing material, normally of the pyramidal urethane foam type. The floor, which is metallic, is not covered and forms the ground plane. The chamber usually contains an antenna mast at one end and a turntable at the other. A typical anechoic chamber with a conductive ground plane is shown in figure A.2.

This type of test chamber attempts to simulate an ideal Open Area Test Site whose primary characteristic is a perfectly conducting ground plane of infinite extent.

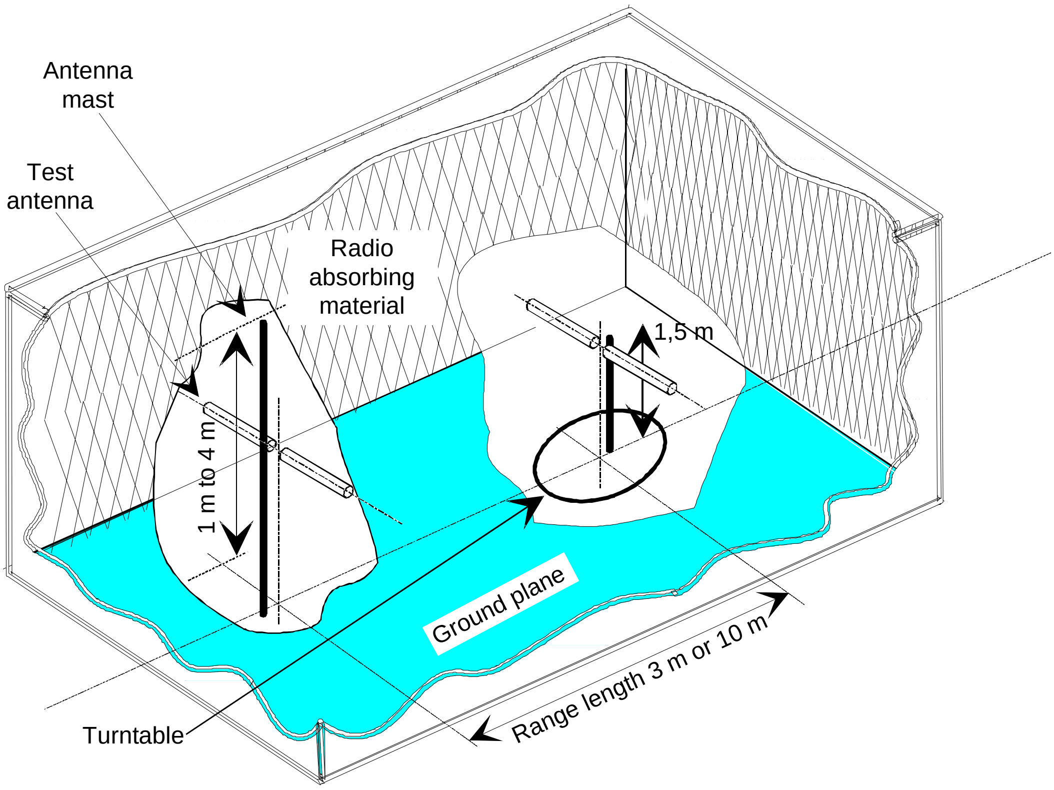


Figure A.2: A typical Anechoic Chamber with a conductive ground plane

In this facility the ground plane creates the wanted reflection path, such that the signal received by the receiving antenna is the sum of the signals from both the direct and reflected transmission paths. This creates a unique received signal level for each height of the transmitting antenna (or EUT) and the receiving antenna above the ground plane.

The antenna mast provides a variable height facility (from 1 m to 4 m) so that the position of the test antenna can be optimized for maximum coupled signal between antennas or between an EUT and the test antenna.

A turntable is capable of rotation through 360° in the horizontal plane and it is used to support the test sample (EUT) at a specified height, usually 1,5 m. above the ground plane. The chamber shall be large enough to allow the measuring distance of at least 3 m or $2(d_1 + d_2)^2/\lambda$ (m), whichever is greater (see clause A.2.4.). For further information on measurements at shorter distances see annex F. The distance used in actual measurements shall be recorded with the test results.

Emission testing involves firstly "peaking" the field strength from the EUT by raising and lowering the receiving antenna on the mast (to obtain the maximum constructive interference of the direct and reflected signals from the EUT) and then rotating the turntable for a "peak" in the azimuth plane. At this height of the test antenna on the mast, the amplitude of the received signal is noted. Secondly the EUT is replaced by a substitution antenna (positioned at the EUT's phase or volume centre) which is connected to a signal generator. The signal is again "peaked" and the signal generator output adjusted until the level, noted in stage one, is again measured on the receiving device.

Receiver sensitivity tests over a ground plane also involve "peaking" the field strength by raising and lowering the test antenna on the mast to obtain the maximum constructive interference of the direct and reflected signals, this time using a measuring antenna which has been positioned where the phase or volume centre of the EUT will be during testing. A transform factor is derived. The test antenna remains at the same height for stage two, during which the measuring antenna is replaced by the EUT. The amplitude of the transmitted signal is reduced to determine the field strength level at which a specified response is obtained from the EUT.

A.1.3 Open Area Test Site (OATS)

An Open Area Test Site comprises a turntable at one end and an antenna mast of variable height at the other end above a ground plane which, in the ideal case, is perfectly conducting and of infinite extent. In practice, whilst good conductivity can be achieved, the ground plane size has to be limited. A typical Open Area Test Site is shown in figure A.3.

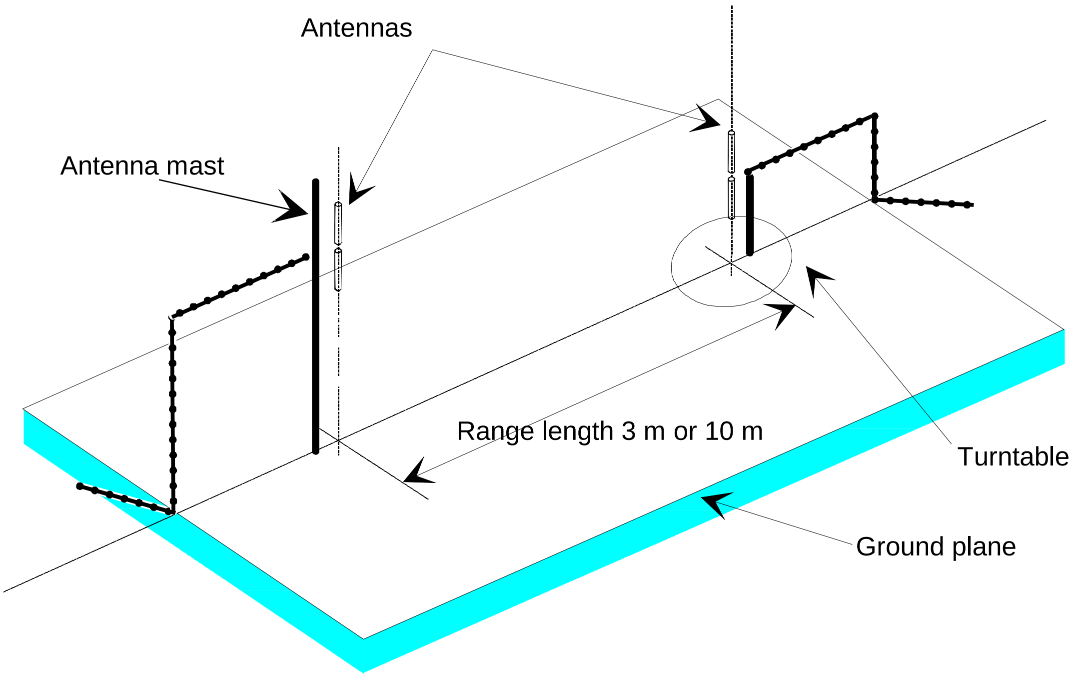


Figure A.3: A typical Open Area Test Site

The ground plane creates a wanted reflection path, such that the signal received by the receiving antenna is the sum of the signals received from the direct and reflected transmission paths. The phasing of these two signals creates a unique received level for each height of the transmitting antenna (or EUT) and the receiving antenna above the ground plane.

Site qualification concerning antenna positions, turntable, measurement distance and other arrangements are same as for anechoic chamber with a ground plane. In radiated measurements an OATS is also used by the same way as anechoic chamber with a ground plane.

Typical measuring arrangement common for ground plane test sites is presented in the figure A.4.

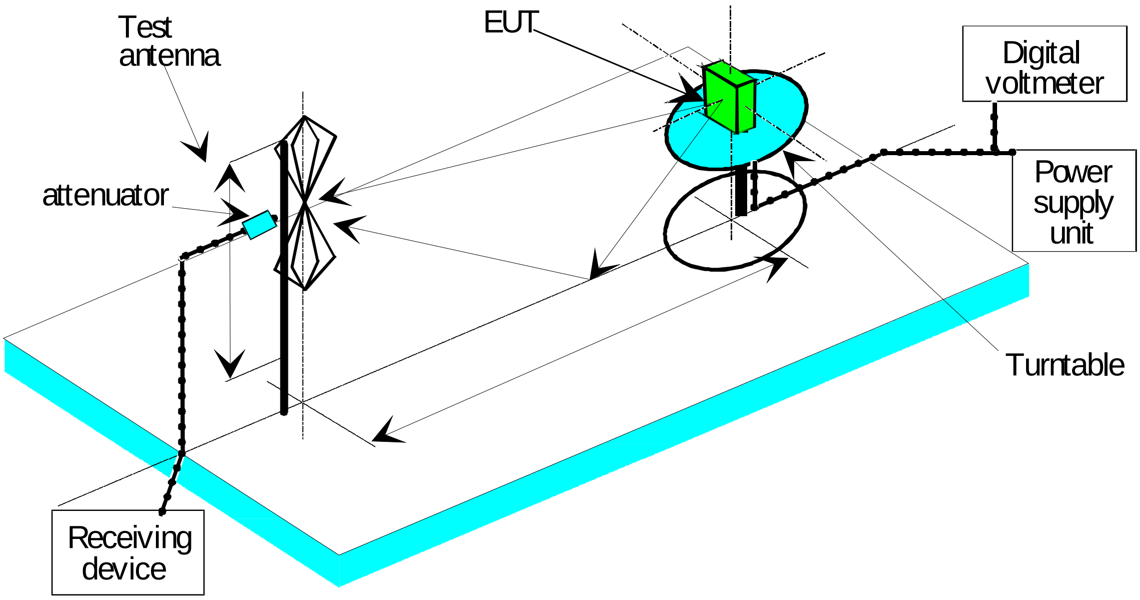


Figure A.4: Measuring arrangement on ground plane test site (OATS set-up for spurious emission testing)

A.1.4 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, on ground plane sites (i.e. anechoic chambers with ground planes and Open Area Test Sites), should additionally allow the height of its centre above the ground to be varied over the specified range (usually 1 to 4 metres).

In the frequency band 30 MHz to 1 000 MHz, dipole antennas (constructed in accordance with ANSI C63.5 [4]) 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.1.5 Substitution antenna

The substitution antenna is used to replace the EUT for tests in which a transmitting parameter (i.e. frequency error, effective radiated power, spurious emissions and adjacent channel power) is being measured. For measurements in the frequency band 30 MHz to 1 000 MHz, the substitution antenna should be a dipole antenna (constructed in accordance with ANSI C63.5 [4]. 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 measurements above 1 000 MHz, a waveguide horn is recommended. The centre of this antenna should coincide with either the phase centre or volume centre.

A.1.6 Measuring antenna

The measuring antenna is used in tests on an 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 [4]. 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 test are undertaken. These schemes are common to all types of test sites described in annex A.

A.2.1 Verification of the test site

No test should be carried out on a test site, which does not possess a valid certificate of verification. The verification procedures for the different types of test sites described in annex A (i.e. anechoic chamber, anechoic chamber with a ground plane and Open Area Test Site) are given in the relevant parts of TR 102 273 [5] or equivalent.

A.2.2 Preparation of the EUT

The provider 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, channel separation, 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, balsa wood, 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 the test report when either of these conditions is not met so that the additional measurement uncertainty can be incorporated into the results.

For further information on measurements at shorter distances see annex F.

NOTE 1: For the fully anechoic chamber, no part of the volume of the EUT should, at any angle of rotation of the turntable, fall outside the "quiet zone" of the chamber at the nominal frequency of the test.

NOTE 2: The "quiet zone" is a volume within the anechoic chamber (without a ground plane) in which a specified performance has either been proven by test, or is guaranteed by the designer/manufacture. The specified performance is usually the reflectivity of the absorbing panels or a directly related parameter (e.g. signal uniformity in amplitude and phase). It should be noted however that the defining levels of the quiet zone tend to vary.

NOTE 3: For the anechoic chamber with a ground plane, a full height scanning capability, i.e. 1 to 4 m, should be available for which no part of the test antenna should come within 1 m of the absorbing panels. For both types of Anechoic Chamber, the reflectivity of the absorbing panels should not be worse than -5 dB.

NOTE 4: For both the anechoic chamber with a ground plane and the Open Area Test Site, no part of any antenna should come within 0,25 m of the ground plane at any time throughout the tests. Where any of these conditions cannot be met, measurements should not be carried out.

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 (unless, in the case either type of anechoic chamber, a back wall is reached) 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.

NOTE: For ground reflection test sites (i.e. anechoic chambers with ground planes and Open Area Test Sites) which incorporate a cable drum with the antenna mast, the 2 m requirement may be impossible to comply with.

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 log book 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.3 Coupling of signals

A.3.1 General

The presence of leads in the radiated field may cause a disturbance of that field and lead to additional measurement uncertainty. These disturbances can be minimized by using suitable coupling methods, offering signal isolation and minimum field disturbance (e.g. optical and acoustic coupling).

Annex B (normative): Installation requirements of Tank Level Probing Radar (TLPR) Equipment

This annex provides the information for TLPR equipment manufacturers and installers to design the equipment and the installation in the tank in such a way, that the essential requirements as stated in EN 302 372-2 [6], are fulfilled.

The following installation requirements shall be fulfilled:

a) TLPR are required to be installed at a permanent fixed position at a closed (not open) metallic tank or reinforced concrete tank, or similar enclosure structure made of comparable attenuating material;

b) flanges and attachments of the TLPR equipment shall provide the necessary microwave sealing by design.

c) sight glasses shall be coated with a microwave proof coating when necessary (i.e. electrically conductive coating);

d) manholes or connection flanges at the tank shall be closed to ensure a low-level leakage of the signal into the air outside the tank.

e) whenever possible, mounting of the TLPR equipment shall be on top of the tank structure with the orientation of the antenna to point in a downward direction;

f) installation and maintenance of the TLPR equipment shall be performed by professionally trained individuals only.

The provider is required to inform the users and installers of TLPR equipment about the installation requirements and, if applicable, the additional special mounting instructions (e.g. by putting it in the product manual)

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 mounted in a metallic tank.

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

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

Pre-amplifier					
Bandwidth	0,1 GHz to 26 GHz	26 GHz to 40 GHz	40 GHz to 60 GHz	50 GHz to 75 GHz	75 GHz to 110 GHz
Noise figure	< 3 dB	< 3 dB	< 6 dB	< 5 dB	< 5,5 dB
Output at 1dB compression	5 dBm	8 dBm	0 dBm	-1 dBm	-8 dBm
Gain	27 dB	25 dB	18 dB	17 dB	15 dB
Gain flatness across band	±2,5 dB	±2,5 dB	±2,5 dB	±3 dB	±5 dB
Phase response	Linear	Linear	Linear	Linear	Linear
VSWR in/out across band	2,5:1	2:1	2,75:1	2,5:1	2,5:1
Nominal impedance RF Connector or waveguide size	50 Ω	50 Ω	WR19	WR15	WR10

Antenna					
Type of Antenna	**Log. Periodic/Horn**	**Horn**	**Horn**	**Horn**	**Horn**
Bandwidth	0,1 GHz to 26GHz	26 GHz to 40 GHz	40 GHz to 60 GHz	50 GHz to 75 GHz	75 GHz to 110 GHz
Gain	8,5 dBi	15 dBi	24 dBi	24 dBi	24 dBi
Nominal Impedance	50 Ω	50 Ω	50 Ω	50 Ω	50 Ω
VSWR across band	< 2,5:1	< 1,5:1	< 1,5:1	< 1,5:1	< 1,5:1
Connector or waveguide connection	PC 3,5 (SMA)	PC 2,4 (K)	WR19	WR15	WR10

Measuring the complete emission spectrum, 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 (informative): Electromagnetic leakage from a EUT

D.1 General

EUT is defined as a tank with an installed TLPR.

The most common mounting of a TLPR is a flange on a top of a tank with the antenna lobe pointing downwards (in order to allow the vertical line to be contained within the main lobe of the antenna). The main part of the discussion below is around leakage of the radar frequency and its harmonics but leakage at lower frequency (clock frequencies, etc.) is measured as a part of the EMC-testing.

D.2 Survey of sources of leakage

Generally, the electromagnetic leakage measured outside the EUT can conceptually be divided as coming from four sources:

1) Leakage from the TLPR enclosure and cabling including components measured in a standard EMC test. Most leakage here is at frequencies below the radar frequency.

2) Leakage around the mounting flange of the TLPR. Typically, this is the dominating part of the total leakage for the radar frequency and its harmonics as there will be comparatively strong fields close to the antenna. The flange gasket typically allows some leakage. Frequencies far below radar frequency have small possibilities to be radiated by the radar antenna.

3) Leakage through other flanges on the tank than the mounting flange of the TLPR. The radar beam will bounce around inside the tank, be scattered and soon absorbed by the tank content or the tank walls. Some scattered radar beam may hit other flanges. However, the bigger the tank the less leakage will occur. This can be understood by a comparison between the areas of the flange gasket (as seen from the inside) with the total area of the inside of the tank.

4) Leakage through the tank wall. For a metal tank this is negligible as the attenuation through a metal is 5 dB to 10 dB per µm. For a tank made of concrete with or without reinforcement the attenuation in the wall, according to experience, make the leakage negligible. This is explained by the thickness of the material and the high attenuation not the least due to the natural moisture content in the concrete.

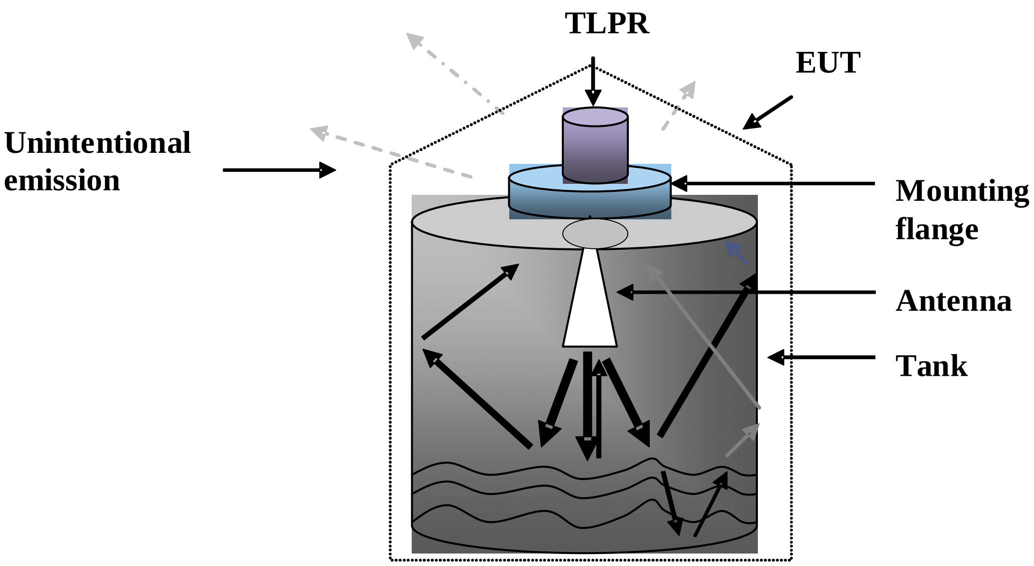


Figure D.1: A typical unintentional emission pattern from the EUT

Thus, the total leakage outside of the tank will have the character of a diffuse leakage with small directivity. During the test procedure the total leakage can be measured essentially following standard EMC-procedures (with extended frequency range) searching for the direction of maximum radiation where the e.i.r.p. is measured.

Annex E (normative): Requirements on Test Tank

The following requirements shall apply for a test tank:

- The test tank material shall be metal to demonstrate worst case for resonances and any unwanted tank radiation leakage.
- Test tank shall provide at least one mechanical connection for installing the TLPR. The method of mounting including the recommended product sealing used during the measurement shall be described in the Test report.
- The test tank shall be of cubic or cylinder shape with height/diameter ratio of 2 to 3 and volume shall not exceed 500 litres to demonstrate worst case power density inside the tank.

It shall be noted:

The dimension of a real-life tank is several orders of magnitude larger than the wavelength and thereby minimizes any resonance effect in the tank. The TLPR providers have not experienced high narrow band resonance effects for test tanks.

The test tank specified is used as a worst-case scenario for measuring the total emission outside the tank including the flange coupling and/or any potential tank resonance.

Annex F (informative): Practical test distances for accurate measurements

F.1 Introduction

Conventional antenna-pattern measurement practice may imply impossible distances for accurate measurements. For this purpose, a lower distance limit is discussed. When measuring outside of the tank smaller distances can be used without loss of accuracy as long as the measurements are restricted to maximum power or amplitude.

F.2 Conventional near-field measurements distance limit

A measurement of radiated power is made in front of an antenna. If the measurements are made too close to an antenna this will result in erroneous power readings. To avoid this, a minimum distance for antenna pattern measurements in an anechoic chamber shall be in accordance with table F.1.

Table F.1: Uncertainty contribution: range length (test methods)

Range length (i.e. the horizontal distance between phase centres)	Standard uncertainty of the contribution
$(d_1 + d_2)^2/4\lambda \leq$ range length $< (d_1 + d_2)^2/2\lambda$	1,26 dB
$(d_1 + d_2)^2/2\lambda \leq$ range length $< (d_1 + d_2)^2/\lambda$	0,30 dB
$(d_1 + d_2)^2/\lambda \leq$ range length $< 2(d_1 + d_2)^2/\lambda$	0,10 dB
range length $\geq 2(d_1 + d_2)^2/\lambda$	0,00 dB
NOTE: d_1 and d_2 are the maximum dimensions of the EUT and the test antenna used in one stage and are the maximum dimensions of the two antennas in the other stage.	

Two or even four times distance reduction may be applied. A further reduction will cause severe decrease of the accuracy. Further information can be found in TR 102 215 [3].

F.3 Near-field conditions outside a test tank

Like any radiating structure, the outside of a test tank has an equivalent antenna gain G (with corresponding directivity). A well-focused antenna may have a small physical area, while a less effective radiating structure, with a larger area, may give the same gain. In the case of a low directivity radiator (such as a closed tank containing a TLPR), the gain seldom exceeds 10 dBi. Assuming a minimum test distance of $2G\lambda/\pi^2$ (or $0.2G\lambda$), the minimum distance is therefore between one and only a few wavelengths. This is not a practical limitation for radar frequencies and in any case far below the nominal EMC measuring distance of 3 m. In many practical cases the low leakage outside of the tank makes it necessary for sensitivity reasons to measure at much smaller distance than 3 m and this will not cause accuracy problems as the product $0,2\ G\lambda$ hardly ever will exceed 0,1 m in practical TLPR test cases.

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