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Technical Specification

Electromagnetic compatibility and Radio spectrum Matters (ERM); RF conformance testing of radar level gauging applications in still pipes

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Contents

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Foreword

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

Introduction

The radar level gauges covered by the present document do not use the time domain UWB short pulses. Instead the radar level gauges covered by the present document use the frequency domain FMCW and/or SFCW. Thus the emission bandwidth generated by the FMCW and/or SFCW radars is strictly controlled.

The specified requirements in the present document describe the worst case scenario (i.e. the highest emissions to the environment) and shall be seen as a feasible test method to prove compliance of radar level gauging applications in still pipes.

The background and related applications have been described in TR 102 750 [i.2] where the applications have been considered indoor like systems.

1 Scope

The present document specifies the requirements for radar level gauging applications in still pipes using UWB technology operating in the 9 to 10,6 GHz frequency range.

2 References

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

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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 (2003): "Specification for radio disturbance and immunity measuring apparatus and methods - Part 1: Radio disturbance and immunity measuring apparatus".

[2] ANSI C63.5 (2006): "American National Standard for Electromagnetic Compatibility - Radiated Emission Measurements in Electromagnetic Interference (EMI) Control - Calibration of Antennas (9 kHz to 40 GHz)".

[3] Commission Decision 2007/131/EC of 21 February 2007 on allowing the use of the radio spectrum for equipment using ultra-wideband technology in a harmonised manner in the Community.

[4] ISO 4266-1 (2002): "Petroleum and liquid petroleum products -- Measurement of level and temperature in storage tanks by automatic methods -- Part 1: Measurement of level in atmospheric tanks".

[5] API MPMS 3.1A and 3.1B: "Manual of Petroleum Measurement Standards Chapter 3 - Tank Gauging, Section 1A - Standard Practice for the Manual Gauging of Petroleum and Petroleum Products, published on 1 of August 2005 / Tank Gauging Section 1B - Standard Practice for Level Measurement of Liquid Hydrocarbons in Stationary Tanks by Automatic Tank Gauging, published on 1 of June 2001".

[6] ITU-R Recommendation P.526-10 (02/07): "Propagation by diffraction".

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

[8] ETSI TR 102 273 (all parts) (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".

2.2 Informative references

The following referenced documents are not essential to the use of the present document but they assist the user with regard to a particular subject area. For non-specific references, the latest version of the referenced document (including any amendments) applies.

[i.1] ITU-R Recommendation SM.1754: "Measurement techniques of ultra-wideband transmissions".

[i.2] ETSI TR 102 750: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Radar level gauging applications in still pipes".

3 Definitions, symbols and abbreviations

3.1 Definitions

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

dedicated waveguide antenna: device/structure to excite a certain waveguide mode that propagates inside a waveguide only

duty cycle: ratio of the total on time of the transmitter to the total time

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

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

EUT: radar level gauge with a dedicated waveguide antenna on a dedicated still pipe

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.

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

pulsed radar: radar where the transmitter signal has a microwave power consisting of short RF pulses

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

radiation: signals emitted intentionally inside a tank for level measurements

Stepped Frequency Continuous Wave (SFCW) radar: radar where the transmitter sequentially generates a number of frequencies with a step size

NOTE: At each moment of transmission, a monochromatic wave is emitted. It is distinguished from FMCW that has the instantaneous frequency band rather than a single frequency wave. The SFCW radar bandwidth is synthesized by signal processing to achieve required resolution bandwidth.

still pipe: still-well, stilling-well, guide pole: Vertical, perforated pipe built into a tank to reduce measurement errors arising from liquid turbulence, surface flow or agitation of the liquid

NOTE: Any equipment made of a perforated steel pipe with diameters varying from a few centimetres up to several decimetres. The perforations enable the liquid to freely flow into and out of the still pipe at all levels in a tank. Still pipes are the preferred installation point of a Tank Level Probing Radar inserted inside a floating or open roof tanks.

3.2 Symbols

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

cl1	cable loss 1
cl2	cable loss 2
dB	deciBel
dBi	gain in deciBel relative to an isotropic antenna
dBm	deciBel reference to 1 mW
E	Electrical field strength
E_R	relative dielectric constant of earth materials
E_{rms}	Average electrical field strength measured as root mean square
f	frequency
f_c	frequency at which the emission is the peak power at maximum
G	Efficient antenna gain of radiating structure
G_{LNA}	Gain of the measurement LNA
G_A	Gain of the measurement antenna
G(f)	Antenna gain over frequency
f_H	Highest frequency of the frequency band of operation
f_L	Lowest frequency of the frequency band of operation
k	Boltzmann constant
P	Power
$P_{e.i.r.p.}$	power spectral density
P_m	measured spectral power
$P_{wall, e.i.r.p.}$	unwanted power spectral density
R	Distance
rms	Root mean square
t	time
T	Temperature
T_P	pulse rise time
Z_{F0}	Free space wave impedance
λ	wavelength
c	velocity of light in a vacuum
δR	range resolution
δt	time interval between the arrivals of two signals from targets separated in range by δR
D	Duty cycle
P_s	Output power of the signal generator measured by power meter
Δf	Bandwidth
X	Minimum radial distance (m) between the EUT and the test antenna
λ	Wavelength

3.3 Abbreviations

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

e.i.r.p.	equivalent isotropically radiated power
EUT	Equipment Under Test
FMCW	Frequency Modulated Continuous Wave
IT	Information Technology
LNA	Low Noise Amplifier
OATS	Open Area Test Site
OE	Other Emissions
RBW	Resolution BandWidth
RF	Radio Frequency
RMS	Remote Management System
SFCW	Stepped Frequency Continuous Wave
TLPR	Tank Level Probing Radar

TP	Total Power
UWB	Ultra WideBand
VBW	Video BandWidth
VSWR	Voltage Standing Wave Ratio

4 General testing requirements

4.1 Presentation of equipment for testing purposes

The manufacturer 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 (see clause 4), conditions of testing (see clauses 5 and 6), interpretation of results (see clause 7) and the measurement methods (see clause 8).

The manufacturer shall offer equipment complete with any auxiliary equipment needed for testing.

4.2 Choice of model for testing

One or more samples of the EUT, as described in annex C, shall be tested.

4.2.1 Declarations by the manufacturer

The manufacturer shall submit the necessary information regarding the equipment with respect to all technical requirements set by the present document.

4.2.2 Marking and equipment identification

The equipment shall be marked in a visible place. This marking shall be legible and durable.

The marking shall include as a minimum:

- The name of the manufacturer or his trademark.
- The type designation. This is the manufacturer's numeric or alphanumeric code or name that is specific to particular equipment.

4.3 Mechanical and electrical design

4.3.1 General

The equipment submitted by the manufacturer 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.

4.4 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 together with the appropriate mitigation factors as described in clause 8.4 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 4.4.1 and 4.4.2.

For radiated UWB emissions measurements below 9 GHz and above 10,6 GHz it may not be possible to reduce measurement uncertainty to the levels specified in clause 7, table 2 (due to the very low signal level limits and the consequent requirement for high levels of amplification across wide bandwidths). In these cases alone it is acceptable to employ the alternative interpretation procedure specified in clause 4.4.2.

4.4.1 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 shall 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 shall be recorded in the test report.

4.4.2 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 shall 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 shall be recorded in the test report.

5 Test conditions, power sources and ambient temperatures

5.1 Normal conditions

All testing shall be made under normal test conditions.

The test conditions and procedures shall be as specified in clause 5.2.

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 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.

The test power source used shall be stated in the test report.

5.2.1 Internal test power source

For radiated measurements on portable equipment with integral antenna, fully charged internal batteries should be used. The batteries used should be as supplied or recommended by the manufacturer. If internal batteries are used, at the end of each test the voltage shall be within a tolerance of less than ±5 % relative to the voltage at the beginning of each test.

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

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.

5.3.2.2 Other power sources

For operation from other power sources (primary or secondary), the normal test voltage shall be that declared by the equipment manufacturer and agreed by the test laboratory. Such values shall be stated in the test report.

6 General conditions

6.1 Radiated measurement arrangements

For guidance on radiation test sites and general arrangements for radiated measurements, see annexes A and C.

Informative descriptions of radiated measurement arrangements for UWB devices can be found in ITU-R Recommendation SM.1754 [i.1].

All reasonable efforts should be made to clearly demonstrate that emissions from the UWB transmitter do not exceed the specified levels, with the transmitter in the far field. To the extent practicable, the equipment under test should be measured at the distance specified in annex A and with the specified measurement bandwidths. However, in order to obtain an adequate signal-to-noise ratio in the measurement system, radiated measurements may have to be made at distances less than those specified in annex A and/or with reduced measurement bandwidths. The revised measurement configuration should be stated on the test report, together with an explanation of why the signal levels involved necessitated measurement at the distance employed or with the measurement bandwidth used in order to be accurately detected by the measurement equipment, and calculations demonstrating compliance.

Where it is not practical to further reduce the measurement bandwidth (either because of limitations of commonly-available test equipment or difficulties in converting readings taken using one measurement bandwidth to those used by the respective limit table), and the required measurement distance would be so short that the device would not clearly be within the far field, the test report shall state this fact, the measurement distance and bandwidth used, the near field/far field distance for the measurement setup (see clause A.2.4), the measured device emissions, the achievable measurement noise floor and the frequency range(s) involved.

6.2 Modes of operation of the transmitter

For the purpose of the measurements according to the present document, there shall be a facility to operate the transmitter in a continuous state, whereby the radar signal is transmitted repeatedly and any gating techniques switched off.

6.3 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
30 MHz ≤ f < 1 000 MHz	100 kHz
1 000 MHz ≤ f	1 MHz

7 Interpretation of results

7.1 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 wherever possible equal for each measurement, equal to or lower than the figures in table 2, and the interpretation procedure specified in clause 4.4.1 shall be used.

Table 2: Measurement uncertainty

Parameter	Uncertainty
Radio frequency	$\pm 1 \times 10^{-7}$
Radiated emission of transmitter	±6 dB
Temperature	±1 K
Humidity	±5 %
NOTE: For radiated UWB emissions measurements below 9 GHz and above 10,6 GHz it may not be possible to reduce measurement uncertainty to the levels specified herein (due to the very low signal level limits and the consequent requirement for high levels of amplification across wide bandwidths). In these cases alone it is acceptable to employ the alternative interpretation procedure specified in clause 4.4.2.	

For the test methods, according to the present document the uncertainty figures shall be calculated according to the methods described in TR 100 028 [7] 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.

NOTE: Information on uncertainty contributions, and verification procedures are detailed in TR 102 273 [8].

8 Methods of measurement and limits for transmitter parameters

8.1 General

The radar level gauging applications covered by the present document use a stillpipe (a hollow waveguide) to convey the radar signal to the liquid surface in the pipe and back again (see annex C). The system is functionally shielded by the still pipe but due to the perforations necessary to make the liquid level inside the pipe exactly the same as that in the tank, a small amount of RF leakage may unintentionally occur. The measurements described below aim to measure the worst case of that RF leakage.

8.2 Permitted range of operating frequencies

8.2.1 Definition

The permitted range of operating frequencies is the frequency range over which the equipment is intended to operate.

8.2.2 Method of measurement

The minimum and maximum frequencies outside of the permitted range of frequencies of clause 8.2.3 shall be measured using the radiated method shown in figure 1.

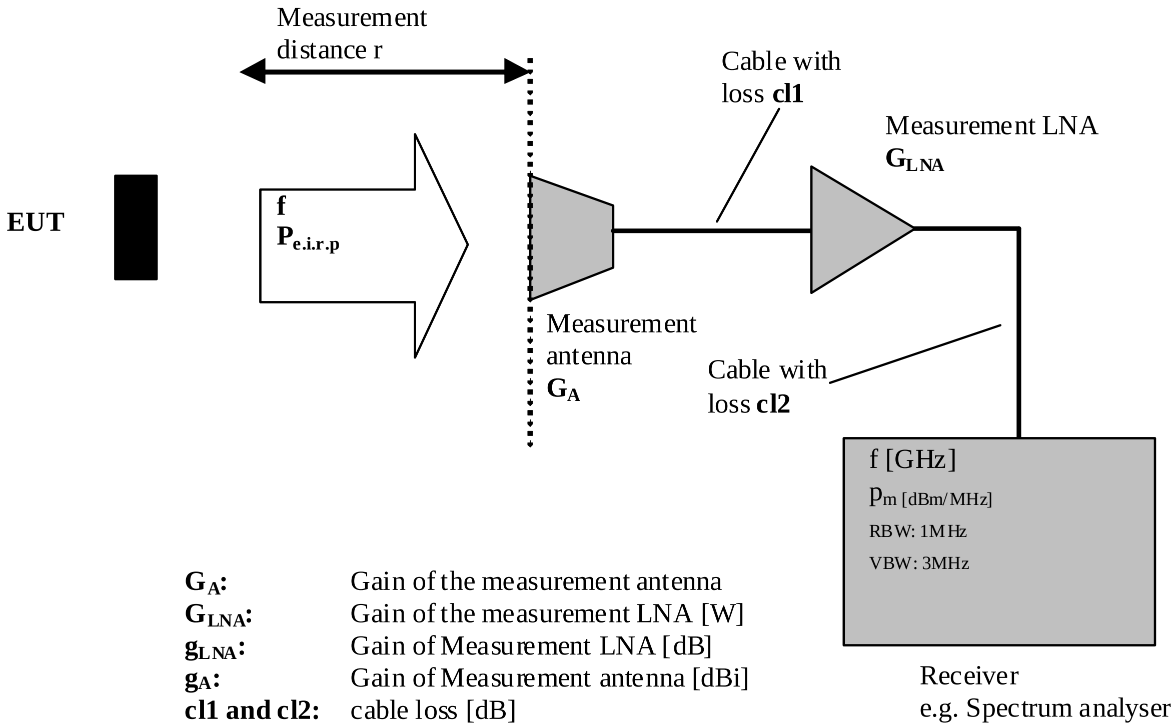


Figure 1: Test set-up for measuring the operating frequency range

Conversion:

$$g_{LNA} = 20\log(G_{LNA})$$

$$g_A = 10\log(G_A)$$

$$cl_x = 10^{\left(\frac{Cl_x}{20}\right)}$$

Equation (Values [dB]):

[dBm/MHz]

The values of the cable loss Cl1 and Cl2 are smaller than one. Consequently the logarithmic values cl1 and cl2 are negative!

A test site selected from annex A (i.e. indoor test site or open area test site), which fulfils the requirements of the specified frequency range and undisturbed lowest specified emission levels of this measurement shall be used.

The measurement procedure shall be as follows:

- place the spectrum analyser in video averaging mode and max hold mode with a minimum of 50 sweeps selected and activate the transmitter with normal radar signal applied;
- find lowest frequency below the operating bandwidth at which spectral power density decreases to the level given in clause 8.2.3. This frequency shall be recorded;

- find the highest frequency at which the spectral power density decreases to the level given in clause 8.2.3. This frequency shall be recorded;
- the difference between the lowest frequency and highest frequency measured is the frequency range which shall be recorded.

This measurement shall be repeated for each operating bandwidth as declared by the manufacturer.

The results obtained shall be compared to the limit in clause 8.2.3.

8.2.3 Limits Frequency range

The permitted range of operating frequencies for radiation is given in table 3. Outside the permitted range of operating frequencies the emissions shall be reduced by no less than 10 dB.

Table 3: Frequency band of operation

Frequency band of operation
9 GHz to 10,6 GHz

8.3 Emissions

8.3.1 Definition

The total of emissions is the sum of wanted UWB emissions in the permitted frequency range of operation and outside of the permitted frequency range of operation as well as the other emissions. Other emissions can occur inside as well as outside of the frequency range of operation.

8.3.2 UWB emissions

UWB emissions are any UWB leakage signals from the still pipe perforations. The UWB emission limits are to be in accordance with the Commission Decision 2007/131/EC [3] on UWB devices. The radar level gauges intended for the use in above mentioned frequency range do not use the time domain UWB short pulses. Instead the radar level gauges covered by the present document use the frequency domain FMCW and/or SFCW. Thus the frequency band generated by the FMCW and/or SFCW radars is strictly controlled.

8.3.2.1 Method of measurement

Radiated measurements shall be performed according to the method using the measurement setup and test pipe as described in annexes A and C.

Measurements shall be carried out over the frequency ranges as shown in clause 8.3.3.2, tables 5a, 5b and 6.

When measuring maximum mean power spectral density from the equipment under test, the spectrum analyser or equivalent shall be configured as follows unless otherwise stated:

- Resolution bandwidth: 1 MHz.

NOTE 1: in order to obtain an adequate signal-to-noise ratio in the measurement system, radiated measurements may have to be made using narrower resolution bandwidths where it is practical. In these cases, the revised measurement configuration should be stated in the test report, together with calculations which permit the measurements taken to be compared with the appropriate limits and an explanation of why the signal levels involved necessitated measurement using the resolution bandwidth employed in order to be accurately determined by the measurement equipment.

- Video bandwidth: Not less than the resolution bandwidth.
- Detector mode: RMS.

NOTE 2: RMS average measurements can be accomplished directly using a spectrum analyser which incorporates an RMS detector. Alternatively, a true RMS level can be measured using a spectrum analyser that does not incorporate an RMS detector (see ITU-R Recommendation SM.1754 [i.1] for details).

- Average time (per point on spectrum analyser scan): 1 ms or less.

  Frequency Span: Equal to or less than the number of displayed samples multiplied by the resolution bandwidth. The measurement results shall be determined and recorded over the frequency ranges as shown in clause 8.3.3.2, tables 5a, 5b and 6.

The measurements shall be repeated at the frequency band edges at 9 GHz and 10,6 GHz. The measurements at the frequency band edges shall be performed at the frequency offsets as shown in table 4.

Table 4: Frequency offsets for band edge measurements

Band edge frequency (GHz)	Frequency with frequency offset applied
9	9 GHz to 20 MHz
10,6	10,6 GHz + 20 MHz

This frequency offset that is shown in table 4 is necessary since measurements at the exact frequency edges with a spectrum analyser may integrate energy from both sides of the respective band edge frequency. This is caused by the filter bandwidth of the test equipment. When measuring maximum peak power in the wanted frequency range from the device under test, the spectrum analyser used should be configured as follows:

- Frequency: The measurement shall be centred on the frequency at which the maximum mean power spectral density occurs.
- Resolution bandwidth: Equal or greater than 10 MHz but not greater than 50 MHz.

NOTE 3: For peak power measurements, the best signal to noise ratio is usually obtained with the widest available resolution bandwidth.

- Video bandwidth: Not less than the resolution bandwidth.
- Detector mode: Peak.
- Display mode: Maximum Hold.
- Measurements shall be continued until the displayed trace no longer changes.

NOTE 4: To the extent practicable, the device under test is measured using a spectrum analyser configured using the settings described above. However, in order to obtain an adequate signal-to-noise ratio in the measurement system, radiated measurements may have to be made using narrower resolution bandwidths. In these cases, the revised measurement configuration should be stated in the test report, together with calculations which permit the measurements taken to be compared with the appropriate limits and an explanation of why the signal levels involved necessitated measurement using the resolution bandwidth employed in order to be accurately determined by the measurement equipment.

8.3.2.2 Limits

The maximum mean equivalent isotropically radiated power spectral density and the maximum peak e.i.r.p. measured shall not exceed the limit given in tables 5a, 5b and 6.

Table 5a: Maximum mean e.i.r.p. spectral density limit

Frequency range (GHz)	Maximum mean e.i.r.p. spectral density (dBm/MHz)
9 to 10,6	-65

Table 5b: Maximum peak e.i.r.p. limit

Frequency range (GHz)	Maximum peak e.i.r.p (dBm)
9 to 10,6	-25

The maximum mean equivalent isotropically radiated power spectral density measured outside the permitted frequency band of operation shall not exceed the limits given in table 6.

Table 6: Maximum mean e.i.r.p. density limit outside the band

Frequency range (GHz)	Maximum mean e.i.r.p. density (dBm/MHz)
6 to < 9	-75
> 10,6 to 22	-85

8.3.3 Other Emissions (OE)

8.3.3.1 Definition

UWB transmitters emit very low power radio signals, comparable with the power of spurious emissions from digital and analogue circuitry. If it can be clearly demonstrated that an emission from an Ultra WideBand device is not an UWB emission (e.g. by disabling the device's UWB transmitter) or it can clearly be demonstrated that it is impossible to differentiate between other emissions and the UWB transmitter emissions, that emission or aggregated emissions shall be considered against the other emission limits.

Proper pre-select filtering can be incorporated to protect the measurement system low-noise pre-amplifier from overload. In addition, all ambient signals can be detected prior to the activation of the UWB transmitter in order 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.

8.3.3.2 Method of measurement

The transmitter shall be switched on, with normal radar signal and the spectrum analyzer shall be tuned to the frequency of the signal being measured. The test antenna shall be oriented for vertical polarization and shall be raised or lowered through the specified height range until a maximum signal level is detected on the test receiver.

The transmitter shall be rotated horizontally through 360° until the highest maximum signal is received.

NOTE: This maximum may be a lower value than the value obtainable at heights outside the specified limits.

The transmitter shall be replaced by a substitution antenna and the test antenna raised or lowered as necessary to ensure that the maximum signal is still received. The input signal to the substitution antenna shall be adjusted in level until an equal or a known related level to that detected from the transmitter is obtained in the test receiver.

The carrier power is equal to the power supplied to the substitution antenna, increased by the known relationship if necessary.

The measurement shall be repeated for any alternative antenna supplied by the provider.

A check shall be made in the horizontal plane of polarization to ensure that the value obtained above is the maximum. If larger values are obtained, this fact shall be recorded in the test report.

Test shall be performed under normal test conditions.

One test site selected from annex A shall be used.

The applicable spectrum shall be searched for emissions that exceed the limit values or that come to within 6 dB below the limit values given in clause 8.3.3.3. Each occurrence shall be recorded.

Measurements shall be carried out over the frequency range from 30 MHz to 22 GHz.

The measurements shall be performed only under the following conditions:

- The measurements are made with a spectrum analyser, the following settings shall be used for narrowband emissions:
  - resolution BW: 100 kHz below 1 GHz; 1 MHz above 1 GHz;
  - video BW: 300 kHz below 1 GHz; 3 MHz above 1 GHz;
  - detector mode: positive peak;
  - averaging: off;
  - span: 100 MHz;
  - amplitude: adjust for middle of the instrument's range;
  - sweep time: 1 s.

For measuring emissions that exceed the level of 6 dB below the applicable limit, the resolution bandwidth shall be switched to 30 kHz and the span shall be adjusted accordingly. If the level does not change by more than 2 dB, it is a narrowband emission; the observed value shall be recorded. If the level changes by more than 2 dB, the emission is a wideband emission and its level shall be measured and recorded.

The results obtained shall be compared to the limits in clause 8.3.3.3 in order to prove compliance with the requirements.

8.3.3.3 Limits

Other narrowband emissions shall not exceed the values in tables 7 in the indicated bands.

Table 7: Other narrowband emission limits

Frequency range	Limit
30 MHz to 1 GHz	-57 dBm (e.r.p.)
above 1 GHz to 22 GHz	-47 dBm (e.i.r.p.)

The above limit values apply to narrowband emissions, e.g. as caused by local oscillator leakage. The measurement bandwidth for such emissions may be as small as necessary to get a reliable measurement result.

Other wideband emissions shall not exceed the values given in table 8.

Table 8: Other wideband emission limits

Frequency range	Limit
30 MHz to 1 GHz	-47 dBm/MHz (e.r.p.)
above 1 GHz to 22 GHz	-37 dBm/MHz (e.i.r.p.)

8.4 Mitigation techniques

The still pipe applications covered by the present document do not use the time domain UWB short pulses. Instead the frequency domain FMCW and/or SFCW is used. Thus the frequency band generated by the FMCW and/or SFCW radars are strictly controlled. The mitigation techniques described here are intended to be applied to the emission limits as described in clause 8.3.2 (except for clause 8.4.1, for emissions above 3 GHz). The measured values recorded shall be reduced by the values provided by the mitigation techniques applied according to the following equation:

Final value (dBm/MHz) = Measured value (dBm/MHz) - total mitigation factor (dB)

The mitigations can be classified into following categories.

8.4.1 Shielding effects

A radar level gauge with its dedicated still pipe is a completely shielded system with a very high screening attenuation.

The excited EM field has the unique property that confines the energy propagating inside the cylindrical pipe along axis. In this way, the unintentional emission is limited by this special installation.

An external floating roof is made of metallic material such as aluminium. The roof acts as a shielding to prevent the leaked energy from the still pipe. Furthermore, the tank wall screens the leaked signal from the still pipe perforations. The tank shell by knife-edge diffraction makes the emission in the direction around the horizontal line quite small according to the calculations from ITU-R Recommendation P.526-10 [6]. The perforations always at least begin at 0,8 m below the top of the tank shell which is a natural upper limit for the liquid movements. No openings above the floating roof exist in practice. The reduction factor of the tankwall shielding applicable for still pipe applications is 30 dB according to ITU-R Recommendation P.526-10 [6]. This mitigation applies to all emissions above 3 GHz.

8.4.2 Frequency domain mitigation

For SFCW/FMCW modulation, the instantaneous bandwidth of the radar signal is close to zero. The mitigation naturally offered by SFCW/FMCW radar is the zero instantaneous bandwidth. The swept band over longer time is not able to generate simultaneous interferences to the victim receivers. For instance, the stepped Frequency Radar sweeps ca. 1 000 steps, within a period of approx. 100 ms. At each step the radar transmits a different frequency with dwell time of 100 µs within 1 MHz. For a 10 MHz victim receiver bandwidth, the equivalent duty cycle is 10×100 µs / 100 ms = 1 %. This is equivalent to a mitigation factor of 20 dB.

8.4.3 Thermal Radiation

All external floating roof tanks are big (Φ=30 m to 80 m and ≈ 20 m high), which implies a low density of TLPRs installed in still pipes, and are always located in industrial hazardous areas with very restricted admittance. Only a very low percentage of such installed areas exist in a country. 100 floating roof tanks in a single area are considered as a big tank farm.

At high elevation angles towards a possible satellite receiver front end or an aeronautical onboard aircraft receiver the edge diffraction will not contribute.

According to the Planck's law, the thermal radiation from a "black" surface is calculated by $4\pi kTB/\lambda^2$ and equals at 10 GHz to about -73 dBm/MHz × m^2. An outdoor tank with diameter of 40 meters has got a thermal radiation of approximately -42 dBm/MHz.

Thus the average of the emitted power from the tank surface will be well below the thermal noise as seen from the sky.

Annex A (normative): Radiated measurements

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.

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 [8] 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.

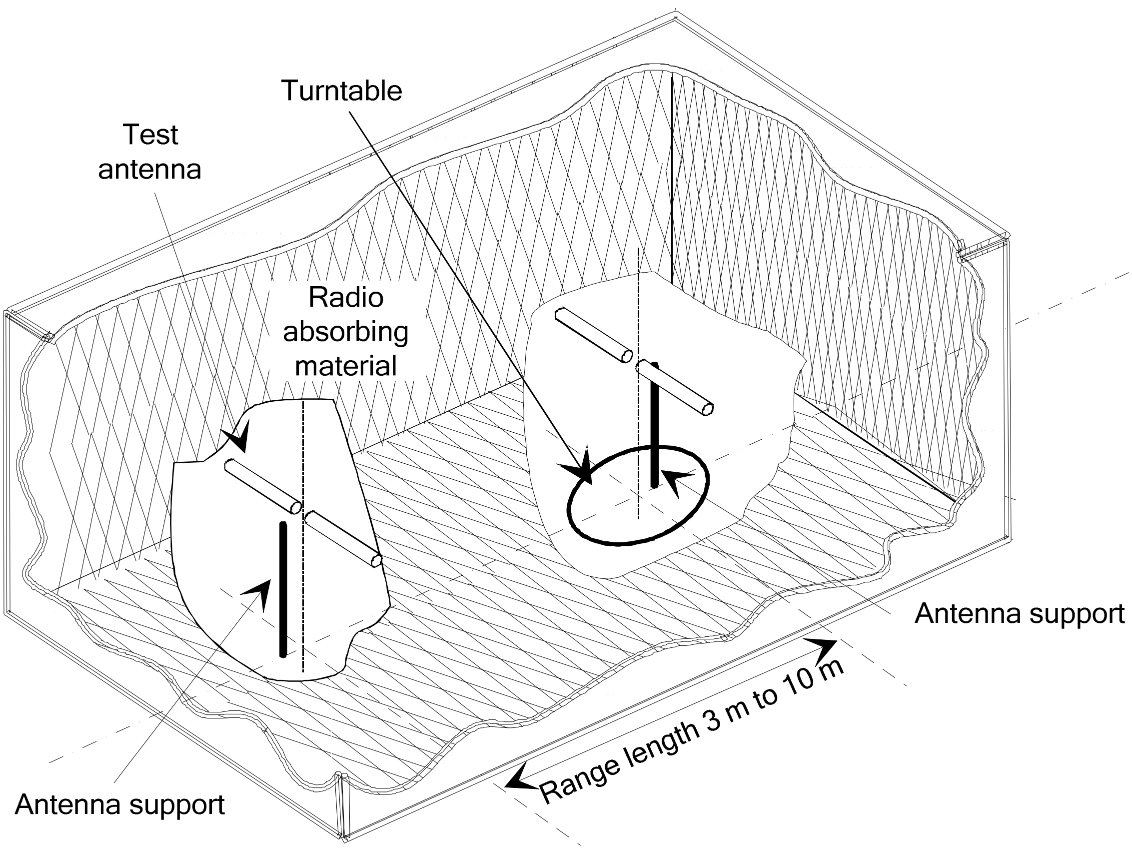


Figure A.1: A typical Anechoic Chamber

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.

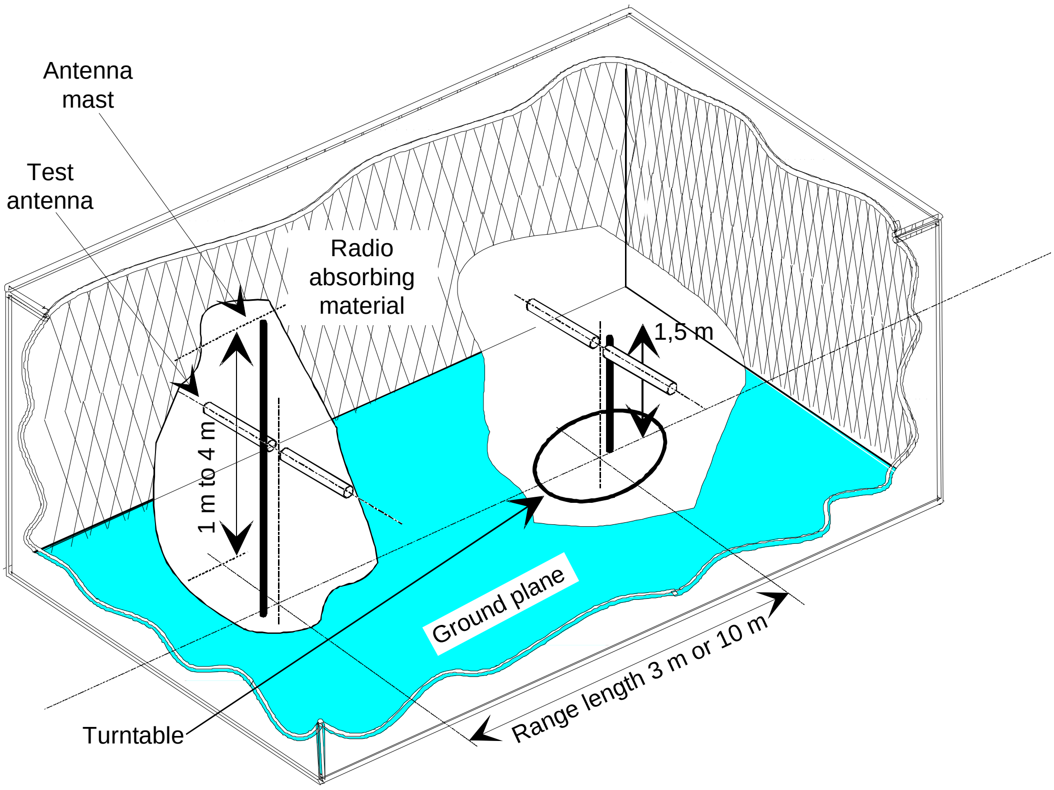


Figure A.2: A typical Anechoic Chamber with a conductive ground plane

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.

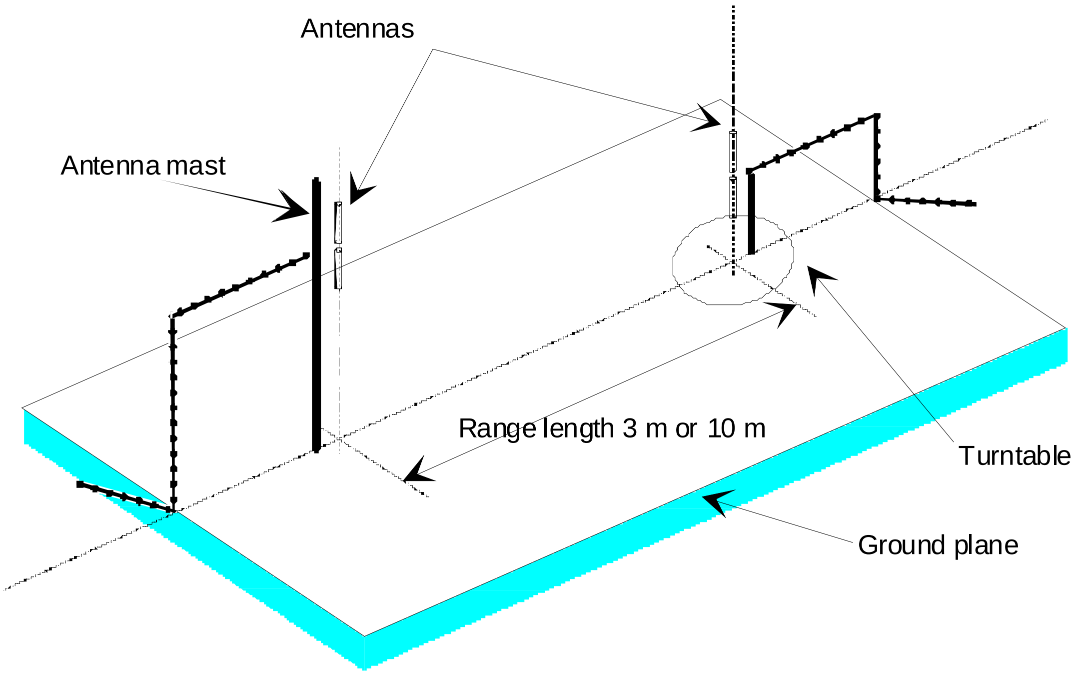


Figure A.3: A typical Open Area Test Site

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.

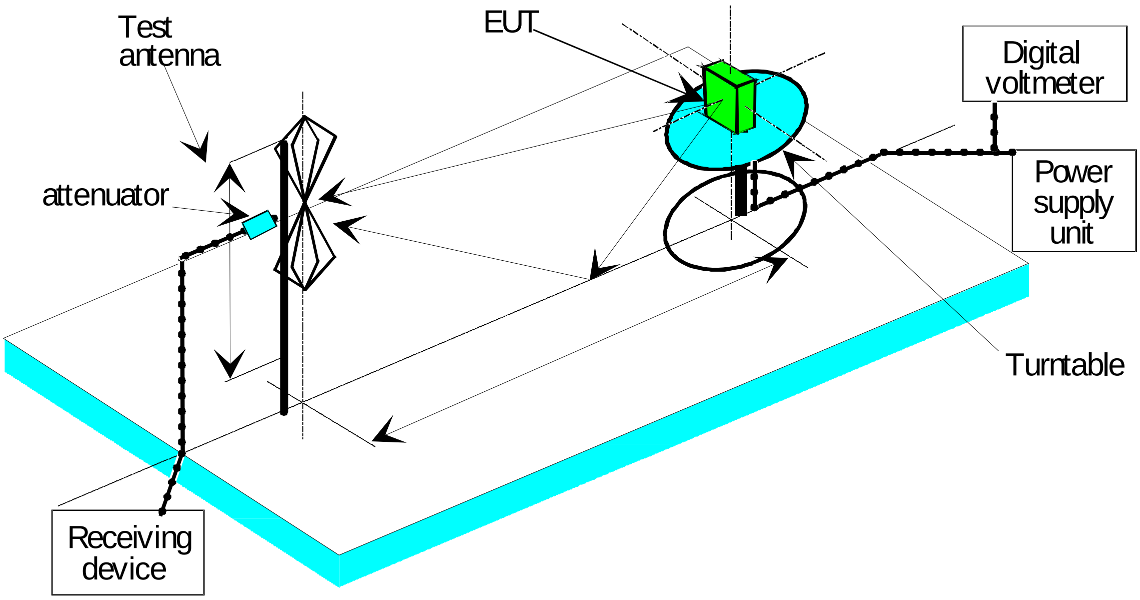


Figure A.4: Measuring arrangement on ground plane test site (OATS set-up for unwanted emission testing)

A.1.4 Test antenna

A test antenna is always used in radiated test methods. In emission tests 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 m).

In the frequency band 30 MHz to 1 000 MHz, dipole antennas (constructed in accordance with ANSI C63.5 [2]) 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 unwanted 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 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 [2]. 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 [2]. 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 [8] or equivalent.

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, 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 min on, 4 min 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 m 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 for radar level gauging applications in still pipes

This annex provides the information for radar level gauges manufacturers and installers to design the equipment and the installation in the tank in such a way, that the requirements as stated in Commission Decision 2007/131/EC [3] on UWB devices are fulfilled.

The following installation requirements shall be fulfilled:

a) Radar level gauging applications together with the dedicated still pipe are required to be installed at a permanent fixed position in a floating roof tank.

b) Flanges and attachments of the radar head on the still pipe shall provide the necessary microwave sealing by design.

c) Installation and maintenance of the radar level gauging equipment shall be performed by professionally trained individuals only.

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

Annex C (normative): Requirements on a test pipe

C.1 General

The following requirements shall apply for a test pipe:

- The test pipe shall have the same proportions as an original size still pipe according to ISO 4266-1 [4] or API Chapter 3.1B [5] while the maximum size of the test pipe shall be 3 m to 3,5 m.
- In its original application the pipe's perforations are always absent 0,5 m to 1 m below the top of the tank shell. Thus the upper part (screening/shielding part) of the test pipe where the radar level gauge is installed shall either have the original size and proportions or a maximum of 1,5 m.
- The lower part (leaking part) of the test pipe shall have a length of 2 m and shall be perforated as worst case scenario according to the original perforations as per ISO 4266-1 [4] and/or API Chapter 3.1B [5].
- Although the test pipe shall be made of metal with its original proportions the pipe together with the radar level gauge shall have a weight that is convenient enough for the test laboratory to conduct the tests.

The specified test pipe is used as a worst-case scenario for measuring the total emission outside a floating roof tank.

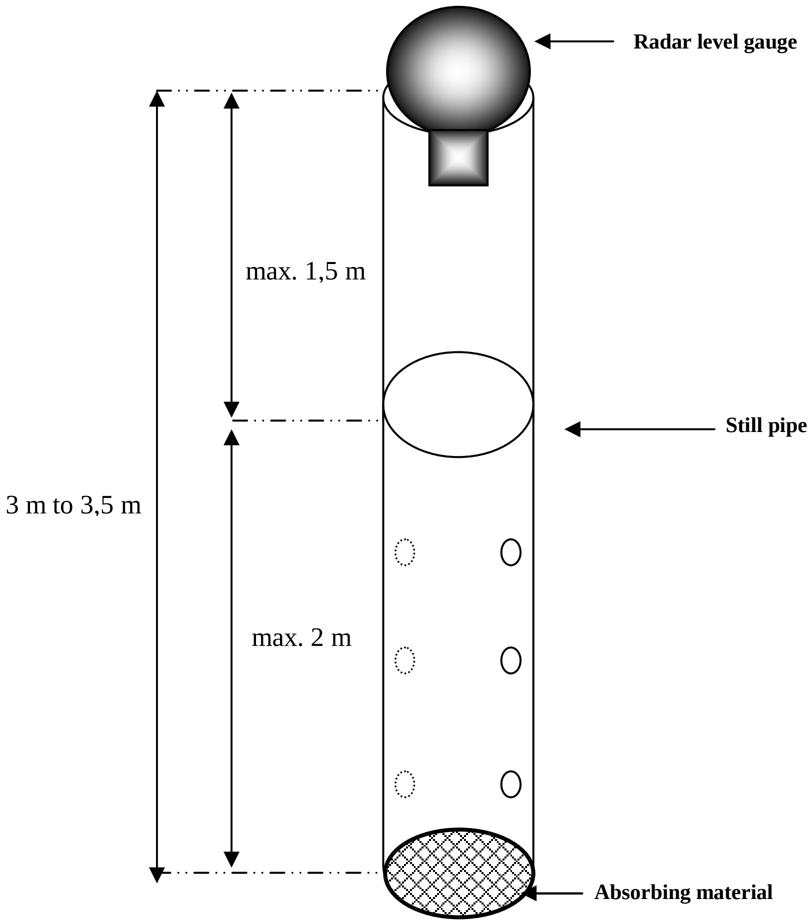
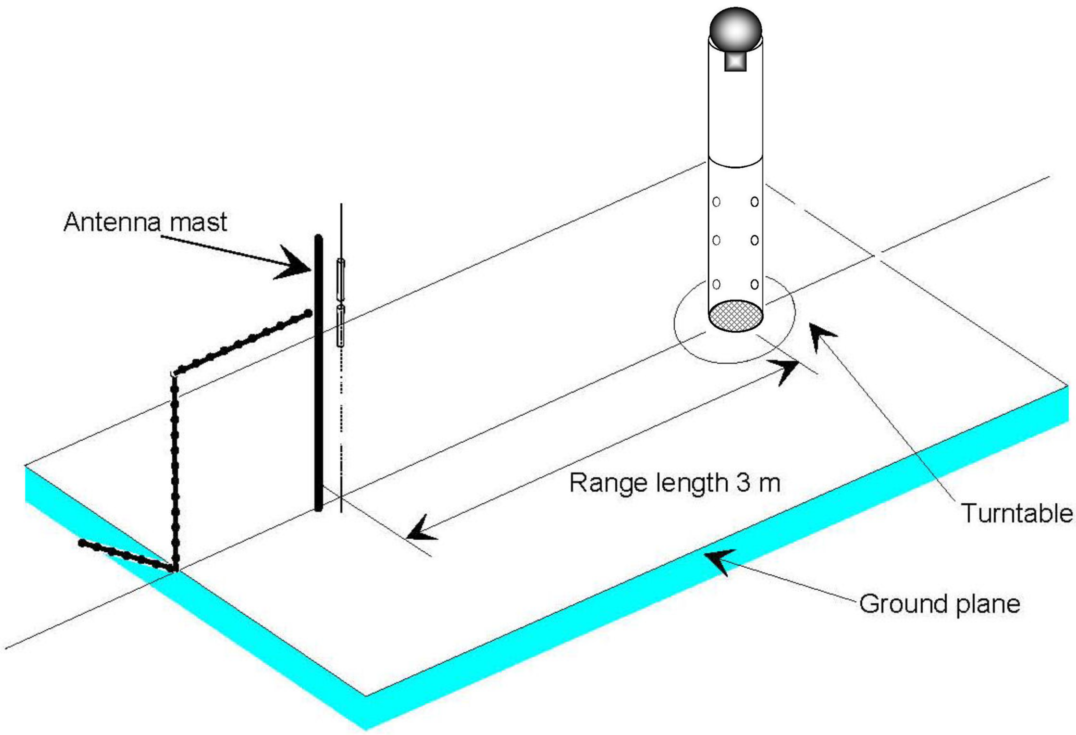


Figure C.1: Test set-up for measuring the operating frequency range

C.2 Measurement setup



NOTE: Should the sensitivity not be sufficient, the measurement distance can be reduced to 1 m.

Figure C.2: Test set-up example for measurements with a test pipe in an OATS

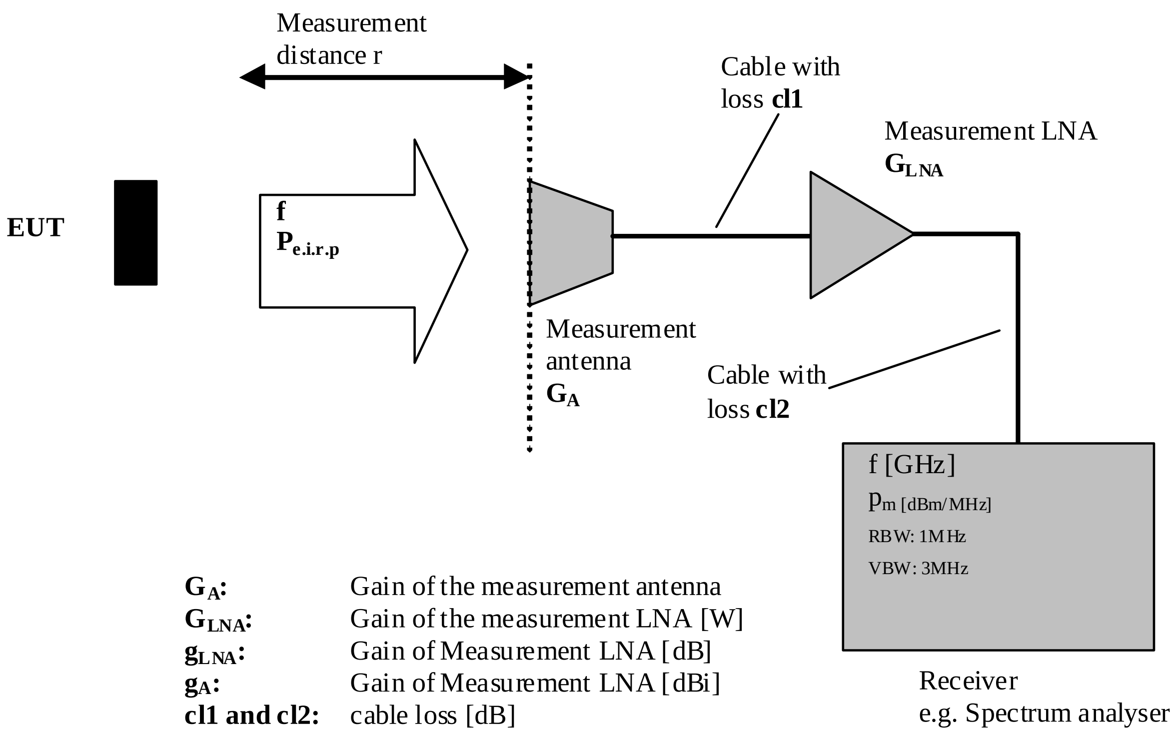


Figure C.3: Test set-up for emission measurements

Conversion:

$$g_{LNA} = 20\log(G_{LNA})$$

$$g_A = 10\log(G_A)$$

$$cl_x = 10^{\left(\frac{Cl_x}{20}\right)}$$

Equation (Values [dB]):

$$p_{e.i.r.p} = p_m - g_A - cl1 - cl2 - g_{LNA} + 20 \cdot \log\left(\frac{4\pi r}{\lambda}\right) \quad \text{[dBm/MHz]}$$

The values of the cable loss Cl1 and Cl2 are smaller than one. Consequently the logarithmic values cl1 and cl2 are negative!

A test site selected from annex A, which fulfils the requirements of the specified frequency range and undisturbed lowest specified emission levels of this measurement shall be used.

Annex D (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 spectral density level from the EUT mounted in a still pipe.

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

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

Pre-amplifier	
Bandwidth	30 MHz to 22,5 GHz
Noise figure	< 3 dB
Output at 1dB compression	5 dBm
Gain	27 dB
Gain flatness across band	±2,5 dB
Phase response	Linear
VSWR in/out across band	2,5:1
Nominal impedance RF Connector or waveguide size	50 Ω

Antenna	
Type of Antenna	**Log. Periodic/Horn**
Bandwidth	30 MHz to 22,5 GHz
Gain	8,5 dBi
Nominal Impedance	50 Ω
VSWR across band	< 2,5:1
Connector or waveguide connection	PC 3,5 (SMA)

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

Table D.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

History

Document history		
V1.1.1	June 2009	Publication