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European Standard (Telecommunications series)

Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Level Probing Radar (LPR) equipment operating in the frequency ranges 6 GHz to 8,5 GHz, 24,05 GHz to 26,5 GHz, 57 GHz to 64 GHz, 75 GHz to 85 GHz; Part 1: Technical characteristics and test methods

Reference

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Contents

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Foreword

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

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); Level Probing Radar (LPR) equipment operating in the frequency ranges 6 GHz to 8,5 GHz, 24,05 GHz to 26,5 GHz, 57 GHz to 64 GHz, 75 GHz to 85 GHz, as identified below:

Part 1: "Technical characteristics and test methods";

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

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

Introduction

Clauses 1 and 3 provide a general description on the types of equipment covered by the present document and the definitions and abbreviations used.

Clause 2 provides the information on normative and informative reference documentation.

Clause 4 provides a guide as to the number of samples required in order that tests may be carried out, and any markings on the equipment which the provider should provide. It also includes the general testing requirements and gives the maximum measurement uncertainty values.

Clauses 5 and 6 give guidance on the test and general conditions for testing of the LPR device.

Clause 7 specifies the LPR spectrum utilization parameters which are required to be measured. The clauses provide details on how the equipment should be tested and the conditions which should be applied. It also includes information on applicable interference mitigation techniques for LPR.

- Annex A (normative) provides specifications concerning radiated measurements.

- Annex B (normative) provides specifications concerning conducted measurements.
- Annex C (informative) provides specifications concerning the installation requirements for LPR.
- Annex D (informative) covers information on recommended Measurement antenna and preamplifier specifications.
- Annex E (informative) contains information on the practical test distances for accurate measurements.
- Annex F (normative) provides the range of modulation schemes for LPR.
- Annex G (informative) contains information on atmospheric absorptions and material dependent attenuations In the frequency range between 40 GHz and 246 GHz.
- Annex H (informative) Bibliography covers other supplementary information.

Test and measurement limitations

The ERA report 2006-0713 [i.7] has shown that there are practical limitations on measurements of RF radiated emissions. The minimum radiated levels that can be practically measured in the lower GHz frequency range by using a radiated measurement setup with a horn antenna and pre-amplifier are typically in the range of about -70 dBm/MHz to -75 dBm/MHz (e.i.r.p.) to have sufficient confidence in the measured result (i.e. EUT signal should be at least 6 dB above the noise floor of the spectrum analyser and the measurement is performed under far-field conditions at a onemetre distance).

The present document therefore recognizes these difficulties and provides a series of radiated test methods suitable for the different LPR technologies.

1 Scope

The present document specifies the requirements for Level Probing Radar (LPR) applications based on pulse RF, FMCW, or similar wideband techniques.

LPR radio equipment types are capable of operating in all or part of the frequency bands as specified in table 1:

Table 1: Frequency bands designated to Level Probing Radars (LPR)

	Frequency Bands/frequencies (GHz)
Transmit and Receive	6 to 8,5
Transmit and Receive	24,05 to 26,5
Transmit and Receive	57 to 64
Transmit and Receive	75 to 85

Table 1 shows a list of the frequency bands as designated to Level Probing Radars in the draft CEPT ECC Decision on harmonised deployment conditions for industrial Level Probing Radars (LPR) [i.1] as known at the date of publication of the present document.

LPRs are used in many industries concerned with process control to measure the amount of various substances (mostly liquids or granulates). LPRs are used for a wide range of applications such as process control, custody transfer measurement (government legal measurements), water and other liquid monitoring, spilling prevention and other industrial applications. The main purposes of using LPRs are:

- to increase reliability by preventing accidents;
- to increase industrial efficiency, quality and process control;
- to improve environmental conditions in production processes.

LPR always consist of a combined transmitter and receiver and are used with an integral or dedicated antenna. The LPR equipment is for professional applications to which installation and maintenance are performed by professionally trained individuals only.

NOTE: LPR antennas are always specific directive antennas and no LPR omnidirectional antennas are used. This is also important in order to limit the illuminated surface area as well as to control and limit the scattering caused by the edges of the surface.

The scope is limited to LPRs operating as Short Range Devices.

The LPR applications in the present document are not intended for communications purposes.

2 References

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the reference document (including any amendments) applies.

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

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

2.1 Normative references

The following referenced documents are necessary for the application of the present document.

[1] 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".

[2] CISPR 16 (2006) (parts 1-1, 1-4 and 1-5): "Specification for radio disturbance and immunity measuring apparatus and methods; Part 1: Radio disturbance and immunity measuring apparatus".

[3] 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".

[4] ANSI C63.5 (2006): "American National Standard for Calibration of Antennas Used for Radiated Emission Measurements in Electro Magnetic Interference".

2.2 Informative references

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] Draft CEPT ECC Decision of [Day Month Year] on harmonised deployment conditions for industrial Level Probing Radars (LPR) in frequency bands 6-8.5 GHz, 24.05-26.5 GHz, 57-64 GHz and 75-85 GHz.

[i.2] ITU-R Recommendation SM.1755: "Characteristics of ultra-wideband technology".

[i.3] CEPT/ERC/REC 74-01 (2005): "Unwanted emissions in the spurious domain".

[i.4] Directive 1999/5/EC of the European Parliament and of the Council of 9 March 1999 on radio equipment and telecommunications terminal equipment and the mutual recognition of their conformity (R&TTE Directive).

[i.5] ITU-R Recommendation SM.1754: "Measurement techniques of Ultra-wideband transmissions".

[i.6] ETSI TS 103 051: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Expanded measurement uncertainty for the measurement of radiated electromagnetic fields; EMU".

[i.7] ERA Report 2006-0713: "Conducted and radiated measurements for low level UWB emissions".

[i.8] FCC: "Revision of part 15 of the Commission"s Rules Regarding Ultra- Wideband Transmission Systems, ET Docket No. 98-153, First Report and Order, April 2002".

[i.9] ITU-R Recommendation P.526-10 (02/07): "Propagation by diffraction".

[i.10] ETSI TS 103 052: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Radiated measurement methods and general arrangements for test sites up to 100 GHz".

[i.11] ITU-R Recommendation P.676-5: "Attenuation by atmospheric gases", 2001.

[i.12] CEPT ECC Report 139: "Impact of Level Probing Radars Using Ultra-Wideband Technology on Radiocommunications Services, Rottach-Egern, February 2010".

[i.13] ETSI TR 102 601: "Electromagnetic compatibility and Radio spectrum Matters (ERM); System reference document; Short Range Devices (SRD); Equipment for Detecting Movement using Ultra Wide Band (UWB) radar sensing technology; Level Probing Radar (LPR)-sensor equipment operating in the frequency bands 6 GHz to 8,5 GHz; 24,05 GHz to 26,5 GHz; 57 GHz to 64 GHz and 75 GHz to 85 GHz".

[i.14] European Commission Decision 2009/343/EC Commission Decision 2009/343/EC amending Decision 2007/131/EC on allowing the use of the radio spectrum for equipment using ultra-wideband technology in a harmonised manner in the Community.

[i.15] 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".

3 Definitions, symbols and abbreviations

3.1 Definitions

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

Activity Factor (AF): See annex F for definition and explanation.

Adaptive Power Control (APC): automatic function implemented to offer a dynamic power control that delivers maximum power only during deep fading; in this way for most of the time the interference is reduced

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

Duty Cycle (DC): See annex F for definition and explanation on duty cycle.

Equipment Under Test (EUT): LPR under test

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

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

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

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 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 LPR
d_1	Largest dimension of the EUT/dipole after substitution (m)
d_2	Largest dimension of the test antenna (m)
D	Duty cycle
λ	Wavelength
dB	deciBel
dBi	antenna gain in deciBels relative to an isotropic antenna

3.3 Abbreviations

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

AF	Activity Factor
DC	Duty Cycle
DUT	Device Under Test
e.i.r.p.	equivalent isotropically radiated power
emf	electromagnetic field
EMU	Expanded Measurement Uncertainty
ERC	European Radiocommunication Committee
EUT	Equipment Under Test
FH	Frequency Hopping
FMCW	Frequency Modulated Continuous Wave
FSK	Frequency Shift Keying
FSL	Free Space Loss
IF	Intermediate Frequency
LO	Local Oscillator
LPR	Level Probing Radar
OATS	Open Area Test Site
PRF	Pulse Repetition Frequency
PRI	Pulse Repetition Interval
PSD	Power Spectral Density
R&TTE	Radio and Telecommunications Terminal Equipment
RBW	Resolution BandWidth
RF	Radio Frequency
RMS	Root Mean Square
SFCW	Stepped Frequency Carrier Wave
SRD	Short Range Device
Tx	Transmitter
UWB	Ultra-WideBand
VBW	Video BandWidth
VSWR	Voltage Standing Wave Ratio

4 General 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 7).

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

The provider shall declare the frequency range(s), the range of operation conditions and power requirements, as applicable, in order to establish the appropriate test conditions.

4.2 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 one sample of the equipment configured with that combination of features considered to create the highest unintentional emissions.

In addition, when a device has the capability of using different dedicated antennas 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.

Where the transmitter is designed with adjustable output power, then all transmitter parameters shall be measured using the highest maximum mean power spectral density 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.

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 and product information

All necessary set-up information shall accompany the LPR equipment when it is submitted for testing.

The following product information shall be provided by the manufacturer:

- the type of modulation technology implemented in the LPR equipment (e.g. FMCW or pulsed);
- the operating frequency range(s) of the equipment;
- the intended combination of the LPR transceiver and its antenna and their corresponding e.i.r.p. levels in the main beam;
- the nominal power supply voltages of the LPR radio equipment;

- for FMCW, FH and FSK or similar carrier based modulation schemes, it is important to describe the modulation parameters in order to ensure that the right settings of the measuring receiver are used. Important parameters are the modulation period, deviation or dwell times within a modulation period, rate of modulation (Hz/s);
- the implementation of features such as gating, hopping or stepped frequency hopping;
- the implementation of any mitigation techniques;
- for pulsed equipment, the Pulse Repitition Frequency (PRF) is to be stated.

4.5 General requirements for RF cables

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

When using coaxial cables for frequencies above 40 GHz attenuation features increase significantly and decrease of return loss due to mismatching caused by joints at RF connectors and impedance errors shall be considered.

All RF cables and waveguide interconnects shall be routed suitably in order to reduce impacts on antenna radiation pattern, antenna gain, antenna impedance. Table 2 provides some information about connector systems that can be used in connection with the cables.

Table 2: Connector systems

Connector System	Frequency	Recommended coupling torque
N	18 GHz	0,68 Nm to 1,13 Nm
SMA	18 GHz (some up to 26 GHz)	~ 0,56 Nm
3,50 mm	26,5 GHz	0,8 Nm to 1,1 Nm
2,92 mm	40 GHz (some up to 46 GHz)	0,8 Nm to 1,1 Nm
2,40 mm	50 GHz (some up to 60 GHz)	0,8 Nm to 1,1 Nm
1,85 mm	65 GHz (some up to 75 GHz)	0,8 Nm to 1,1 Nm

4.6 RF waveguides

Wired signal transmission in the millimeter range is preferably realized by means of waveguides because they offer low attenuation and high reproducibility. Unlike coaxial cables, the frequency range in which waveguides can be used is limited also towards lower frequencies (highpass filter characteristics). Wave propagation in the waveguide is not possible below a certain cutoff frequency where attenuation of the waveguide is very high. Beyond a certain upper frequency limit, several wave propagation modes are possible so that the behaviour of the waveguide is no longer unambiguous. In the unambiguous range of a rectangular waveguide, only H10 waves are capable of propagation.

The dimensions of rectangular and circular waveguides are defined by international standards such as 153-IEC for various frequency ranges. These frequency ranges are also referred to as waveguide bands. They are designated using different capital letters depending on the standard. Table 3 provides an overview of the different waveguide bands together with the designations of the associated waveguides and flanges.

For rectangular waveguides, which are mostly used in measurements, harmonic mixers with matching flanges are available for extending the frequency coverage of measuring receivers. Table 3 provides some information on waveguides.

Table 3: Waveguide bands and associated waveguides

Band	Frequency	Designations				Internal dimensions of waveguide		Designations of frequently used flanges		
	in GHz	MIL-W-85	EIA	153-IEC	RCSC (British)	in mm	in inches	MIL-F-3922	UG-XXX/U equivalent (reference)	Remarks
Ka	26,5 - 40,0	3-006	WR-28	R320	WG-22	7,11 x 3,56	0,280 x 0,140	54-006 68-002 67B-005	UG-559/U - UG-381/U	Rectangular Rectangular Round
Q	33,0 - 55,0	3-010	WR-22	R400	WG-23	5,69 x 2,84	0,224 x 0,112	67B-006	UG-383/U	Round
U	40,0 - 60,0	3-014	WR-19	R500	WG-24	4,78 x 2,388	0,188 x 0,094	67B-007	UG-383/U-M	Round
V	50,0 - 75,0	3-017	WR-15	R620	WG-25	3,759 x 1,879	0,148 x 0,074	67B-008	UG-385/U	Round
E	60,0 - 90,0	3-020	WR-12	R740	WG-26	3,099 x 1,549	0,122 x 0,061	67B-009	UG-387/U	Round
W	75,0 - 110,0	3-023	WR-10	R900	WG-27	2,540 x 1,270	0,100 x 0,050	67B-010	UG-383/U-M	Round

As waveguides are rigid, it is inpractical to set up connections between antenna and measuring receiver with waveguides. Either a waveguide transition to coaxial cable is used or - at higher frequencies - the harmonic mixer is used for frequency extension of the measuring receiver and is directly mounted at the antenna.

4.6.1 Wave Guide Attenuators

Due to the fact that external harmonic mixers can only be fed with low RF power it may be necessary to attenuate input powers in defined manner using wave guide attenuators. These attenuators shall be calibrated and suitable to handle corresponding powers.

4.7 External harmonic mixers

4.7.1 Introduction

Measuring receivers (test receivers or spectrum analyzers) with coaxial input are commercially available up to 67 GHz. The frequency range is extended from 26,5/67 GHz up to 100 GHz and beyond by means of external harmonic mixers. Harmonic mixers are used because the fundamental mixing commonly employed in the lower frequency range is too complex and expensive or requires components such as preselectors which are not available. Harmonic mixers are waveguide based and have a frequency range matching the waveguide bands. They must not be used outside these bands for calibrated measurements.

In harmonic mixers, a harmonic of the Local Oscillator (LO) is used for signal conversion to a lower Intermediate Frequency (IF). The advantage of this method is that the frequency range of the local oscillator may be much lower than with fundamental mixing, where the LO frequency must be of the same order (with low IF) or much higher (with high IF) than the input signal (RF).The harmonics are generated in the mixer because of its nonlinearity and are used for conversion. The signal converted to the IF is coupled out of the line which is also used for feeding the LO signal.

To obtain low conversion loss of the external mixer, the order of the harmonic used for converting the input signal should be as low as possible. For this, the frequency range of the local oscillator must be as high as possible. LO frequency ranges are for example 3 GHz to 6 GHz or 7 GHz to 15 GHz. IF frequencies are in the range from 320 MHz to about 700 MHz. If the measured air interface is wider than the IF bandwidth, then it is advisable to split the measurement in several frequency ranges, i.e. a one step total RF output power measurement should not be performed.

Because of the great frequency spacing between the LO and the IF signal, the two signals can be separated by means of a simple diplexer. The diplexer may be realized as part of the mixer or the spectrum analyzer, or as a separate component. Mixers with an integrated diplexer are also referred to as three-port mixers, mixers without diplexers as two-port mixers. Figure 1 shows an example where a diplexer is used to convey both, the IF and LO frequencies.

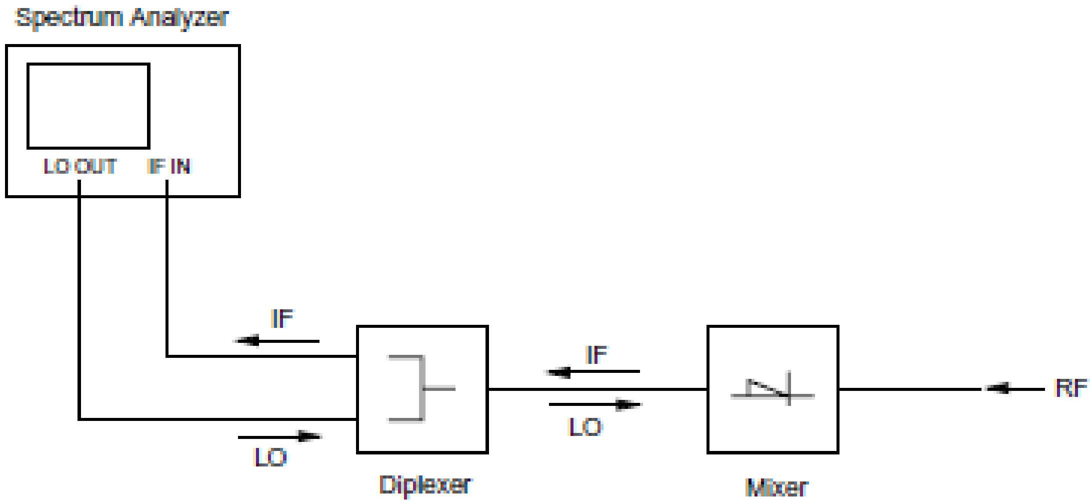


Figure 1: Set-up of measurement receiver, diplexer and mixer

Coaxial cable connections to an external mixer (diplexer) shall be calibrated as well and in conjunction when calibrating the mixer and the measuring receiver. Those cables shall not be replaced in concrete measurements. In particular the cable length shall not be varied.

It shall be regarded that the mixer inputs are sufficiently insulated towards the antenna port with regard to the injected signal (mixed signal) so that the mixed signal, multiplied by the LO, is sufficiently absorbed.

4.7.2 Signal identification

A setup with Harmonic mixers without pre-selection displays always a pair of signals with a spacing of $2 \times f_{IF,}$ as there is no image suppression. For a modulated signal with a bandwidth of > $2 \times f_{IF}$ both, wanted and image response overlap and cannot be separated any more.

Depending on the width of the analyzed frequency bands additional responses created from other harmonics may be displayed. In these cases it has to be determined by signal identification techniques, which of the displayed responses are false responses. Signal identification techniques implemented in spectrum analyzers are based on the fact that only responses corresponding to the selected number of harmonic show a frequency spacing of $2 \times f_{IF.}$

This can be used for automated signal identification: Apart from the actual measurement sweep, in which the lower sideband is defined as "wanted", a reference sweep is performed. For the reference sweep, the frequency of the LO signal is tuned such that the user-selected harmonic of the LO signal (order m´) is shifted downwards by $2 \times f_{IF}$ relative to the measurement sweep.

Parameters which influence the signal identification routines are:

- Number of harmonic: the higher the harmonic number the more false responses will be created. A high LO frequency range which results in a lower harmonic number for a given frequency range is desirable.
- IF Frequency: The higher the IF frequency of the spectrum analyzer, the greater the spacing at which image frequency response is displayed on the frequency axis. For a single modulated or unmodulated input signal displayed on the frequency axis, an image-free range of $2 \times f_{IF}$ is obtained around this signal in which no signal identification is necessary.

4.7.3 Measurement hints

To obtain accurate and reproducible results, the following points should be observed:

- A low-loss cable with a substantially flat frequency response should be used for feeding the LO signal to the mixer. The conversion loss of the mixer is normally specified for a defined LO level. It is therefore important to maintain this level at the LO port of the mixer in order to achieve the desired accuracy. This is especially essential if the antenna/mixer combination is located away from the measuring receiver.

- In level correction on the spectrum analyzer, the insertion loss of the cable used for tapping the IF signal is to be taken into account.
- If an external diplexer is used for connecting a two-port mixer, the insertion loss of the IF path of the diplexer is to be taken into account in level correction on the spectrum analyzer.

Additional information on radiated measurements up to 100 GHz is available in TS 103 052 [i.10].

4.8 Preamplifier

Preamplifiers shall have asymmetric inputs and outputs with an impedance of 50 Ω. Preamplifier shall be sufficiently calibrated with regard to frequency response, amplification factor, linearity and compression. Should this not be obtainable, the amplification factor shall be determined at a certain frequency with a certain input power by substitution with a certain signal which is similarly defined as the original signal.

When using a preamplifier it shall be regarded that the amplifier has sufficient impulse response and that it is not overloaded with a too high input signal, which can lead to erroneous measurement results.

4.9 Interpretation of the measurement results

The interpretation of the results for the measurements described in the present document shall be as follows:

1) the measured value related to the corresponding limit shall be used to decide whether an equipment meets the requirements of the present document;
2) the measurement uncertainty value for the measurement of each parameter shall be recorded;
3) the recorded value of the measurement uncertainty shall be wherever possible, for each measurement, equal to or lower than the figures in table 4, and the interpretation procedure specified in clause 4.6.1 shall be used.

For the test methods, according to the present document, the measurement uncertainty figures shall be calculated in accordance with the guidance provided in TR 100 028 [1] 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 the case where the distributions characterizing the actual measurement uncertainties are normal (Gaussian)).

Table 4 is based on such expansion factors.

Table 4: Maximum measurement uncertainties

Parameter	Maximum expanded measurement Uncertainty
Radio frequency	±1 x 10^{-7}
Radiated RF power (up to 40 GHz)	±6 dB
Radiated RF power (above 40 GHz up to 66 GHz)	±8 dB
Radiated RF power (above 66 GHz up to 100 GHz)	±10 dB (see note 1)
Radiated RF power (above 100 GHz)	See note 2
Conducted Measurements (up to 18 GHz)	±1,5 dB
Conducted Measurements (up to 40 GHz)	±2,5 dB
Conducted Measurements (up to 100 GHz)	±4 dB
Conducted measurements (above 100 GHz)	(see note 2)
Temperature	±1 °C
Humidity	±5 %
DC and low frequency voltages	±3 %
NOTE 1: Achieved sensitivity and measurement uncertainty are a direct result of the chosen test suites. The values mentioned together with the concerns should therefore be considered illustrational rather than absolute for radiated measurements above 66 GHz, given the absence of some relevant information.For radiated emissions above 66 GHz the given measurement uncertainties are based on the assumption of the deployment of a cable based measurement set-up. NOTE 2: For measurements above 100 GHz, the expanded measurement uncertainty shall also be recorded in the test report and a detailed calculation be added. A future revision of the present document may include a value for frequencies above 100 GHz for expanded measurement uncertainty that is still under development.	

"Standard" measurement equipment is only available up to a frequency range of around 66 GHz with a sensitivity of -72 dBm at 18 GHz down to around -64 dBm at 40 GHz (1 MHz RBW, 3 MHz VBW, 100 MHz span). For higher frequencies the sensitivity will further decrease.

The commercially available calibration capability (only equipment specific calibration, no closed loop to an international norm) is currently limited to around 66 GHz. Thus no such possibility is freely available on the market above that limit. As a consequence measurement results above 66 GHz of different laboratories are not fully comparable since the equipment will not be calibrated for the needed operational range.

The measurement uncertainty of measurements in the range above 40 GHz (millimetre domain) will be clearly above the initially assumed 6 dB for radiated measurements below 40 GHz. A value of 8 dB seems to be more adequate. Precise values of measurement uncertainty require calibration, and there are limitations as mentioned on above.

This maximum uncertainty value above 40 GHz is also dependent upon the maximum dimensions of the antenna of the equipment under test and is also dependent upon gain specifications of antennae.

4.9.1 Conversion loss data and measurement uncertainty

Calibrated conversion loss data for harmonic mixers are given for a dedicated number of harmonic, IF frequency and LO power. They cannot be used for a different number of harmonic. It is equally essential that the LO level at the harmonic mixer matches the LO level for which the conversion loss data have been derived.

The above conditions adhered to a measurement uncertainty including the measuring receiver of < ±3 dB to 5 dB at the frequency of the calibration points can be expected, depending on the waveguide band.

EXAMPLE: 75 GHz to 110 GHz 3-port harmonic mixer: < 4,5 dB (K = 2, 5 to 45 °C).

Harmonic mixers frequently have a low return loss (typically 6 dB to 7 dB), which increases the measurement uncertainty. It is therefore expedient to insert an attenuator or isolator between the mixer and the antenna in order to improve measurement uncertainty. However, the insertion loss caused by such a component will reduce the sensitivity of the spectrum analyzer and mixer setup. This insertion loss has also to be taken into account for level measurements.

Mixers with integrated isolator are preferable, as they are already calibrated with the isolator included.

As frequency ranges increase it may be difficult to conclude a maximum allowable value for the expanded measurement uncertainty due to lack of knowledge of the new methods of test and determining the uncertainty components:

- The commercially available calibration capability is limited to around 66 GHz. Thus no such possibility is freely available on the market above that limit. As a consequence measurement results above 66 GHz of different labs are not fully comparable since the equipment will not be calibrated for the needed operational range and also for radiated unwanted emission measurements above the operational range.
- The expanded measurement uncertainty of measurements in the range between 66 GHz and 100 GHz will be clearly above the values valid for below 66 GHz. Precise values of expanded measurement uncertainty require calibration, and there are limitations as mentioned above.
- In general it has to be mentioned that these values become the higher the frequency will become the more a guideline.
- Starting from around 65 GHz the limits of coaxial systems are reached and the frontend has to switch to wave guide based technologies adding an additional attenuation and also decreasing the sensitivity. Commercially available analyzers can only measure up to around 67 GHz, thus making the use of external mixers unavoidable.

Guidance is provided in TS 103 051 [i.6] that presents an evaluation of maximum acceptable measurement uncertainty for Radio Frequency (RF) electromagnetic field (emf) measurements for the frequency range from 30 MHz to 100 GHz for inclusion within ETSI documents on radio products used for compliance testing.

4.10 Other emissions from device circuitry

Some of the measured radiated UWB transmissions can be 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 the LPR device is not associated to the ultra-wideband emissions used for level probing (e.g. by disabling the device's UWB transmitter) or it can clearly be demonstrated that it is impossible to differentiate between other unwanted emissions and the UWB transmitter emissions that emission or aggregated emissions shall be considered against the other emissions limits (see clause 7.6).

5 Test conditions, power sources and ambient temperatures

5.1 Normal test conditions

Testing shall be made under normal test conditions.

The LPR equipment is for professional applications to which installation and maintenance are performed by professionally trained individuals only. In addition, due to its usage of UWB technology there are no strict requirements on frequency stability. The power supply is normally provided via the mains. Consequently, there is no need for testing at extreme temperature and/or extreme low voltage conditions specified in the present document.

The test conditions and procedures shall be as specified in clauses 5.2 to 5.3.

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.

6 General conditions

6.1 Radiated measurement arrangements

The test site, test antenna and substitution antenna used for radiated measurements shall be as described in clause A.1.

For guidance on use of radiation test sites, coupling of signals and standard test positions used for radiated measurements, see clauses A.2 to A.4.

Detailed descriptions of radiated measurement arrangements for UWB devices can be found in ITU-R Recommendation SM.1754 [i.5].

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 device under test shall be measured at the distance specified in clause A.2.4 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 clause A.2.4 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 emission limits in clause 7, 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.

NOTE: This is called "best measurement practise".

6.2 Conducted measurement arrangements

For the purpose of the present document, conducted measurements are limited to the intended LPR frequency band of operation (see clause 7.1.3, table 6). Additional information on conducted measurements are given in annex B.

6.3 Shielded anechoic chamber

The recommended test environment to be used for LPR equipment as a test site is the shielded anechoic chamber.

A typical anechoic chamber is shown in figure 2. This type of test chamber attempts to simulate free space conditions.

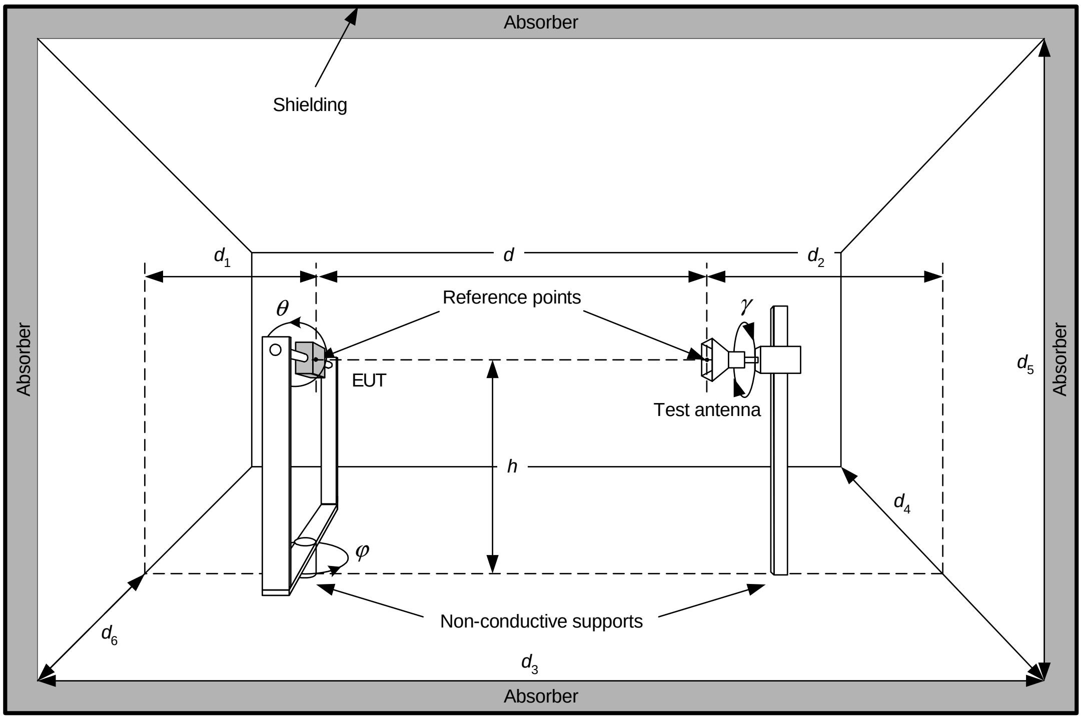


Figure 2: Typical anechoic chamber

The chamber contains suitable antenna supports on both ends.

The supports carrying the test antenna and EUT shall be made of a non-permeable material featuring a low value of its relative permittivity.

The anechoic chamber shall be shielded. Internal walls, floor and ceiling shall be covered with radio absorbing material. The shielding and return loss for perpendicular wave incidence vs. frequency in the measurement frequency range shall meet:

- 105 dB shielding loss;
- 30 dB return loss.

Both absolute and relative measurements can be performed in an anechoic chamber. Where absolute measurements are to be carried out the chamber shall be verified. The shielded anechoic chamber test site shall be calibrated and validated for the frequency range being applicable. This is normally only possible up to 40 GHz. Measurements at higher frequencies are therefore recommended to use down mixing.

NOTE: Information on uncertainty contributions, and verification procedures are detailed in clauses 5 and 6, respectively, of TR 102 273-2 [3].

Further information on shielded anechoic chambers is given in clause A.1.1.

6.4 Measuring receiver

The term "measuring receiver" refers to a frequency-selective voltmeter or a spectrum analyser. The measurement bandwidth of the measuring receiver shall, where possible, be according to CISPR 16 [2]. In order to obtain the required sensitivity, a narrower measurement bandwidth may be necessary. In such cases, this shall be stated in the test report form. The bandwidth of the measuring receiver and the deployed detectors shall be as given in table 5.

Table 5: Measurement receiver parameters

Frequency range: (f)	Measuring receiver bandwidth	Detector
30 MHz ≤ f ≤ 1 000 MHz	100 kHz or 120 kHz	peak/RMS (see note 1)
1 000 MHZ < f ≤ 40 GHz	1 MHz	peak/RMS
f > 40 GHz	1 MHz (see note 2)	peak/RMS
NOTE 1: With the values from the peak and the RMS detector the quasi peak value can be calculated for particular measurement applications. NOTE 2: The actual frequency accuracy shall be taken into account to determine the minimum measurement bandwidth possible.		

In case a narrower measurement bandwidth was used, the following conversion formula has to be applied:

$$B = A + 10 \log \frac{BWref}{BW_{MEASURED}}$$

Where:

- A is the value at the narrower measurement bandwidth;
- B is the value referred to the reference bandwidth; or
- use the measured value, A, directly if the measured spectrum is a discrete spectral line. (A discrete spectrum line is defined as a narrow peak with a level of at least 6 dB above the average level inside the measurement bandwidth.)

7 LPR methods of measurement and limits

7.1 Frequency band of operation

7.1.1 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 20 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 $f_H - f_L$.

7.1.2 Method of measurement

Measurements for the LPR frequency bands from 57 GHz to 64 GHz as well as 75 GHz to 85 GHz may use down mixing. The local oscillator used to downconvert the received signals shall be stable and with a phase noise of better than -80 dBc/Hz at 100 kHz offset. The local oscillator frequency shall be selected such that the downconverted signal is within the accepted band of the spectrum analyser, and maintaining an adequate IF bandwidth to capture the full spectrum of the signal.

If the measuring receiver is capable of measuring the signals directly without any down mixing, the fundamental or harmonic mixer can be omitted.

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. Conducted measurements can be performed instead of radiated measurements for the DUT when the equipment provides an antenna connector.

Radiated measurements shall be conducted under far field conditions.

Testing shall be conducted under normal test conditions.

The radiated method is shown in figure 3.

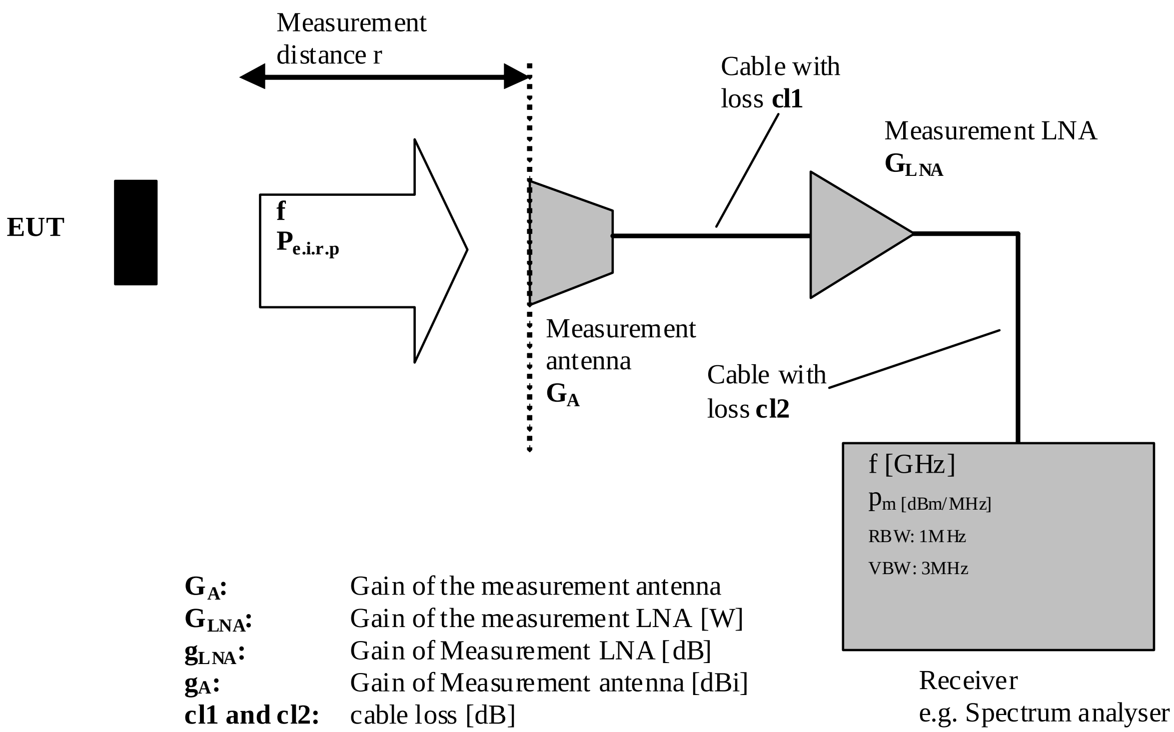


Figure 3: Test set-up for measuring the operating frequency range

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.

For radiated measurments, 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. Radiated measurements shall be carried out in an anechoic environment or may also be carried out at an OATS where no physical obstruction shall be within a sector defined as "three times the 3 dB beamwidth of the antenna" during this test.

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 -20 dB and increasing in frequency towards the peak until the PSD indicates a level of -20 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 -20 dB.

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

7.1.3 Limits

The permitted ranges of operating frequencies for radiation are given in table 6. Outside the permitted ranges of operating frequencies the radiations shall be reduced by no less than 20 dB.

Table 6: Frequency bands of operation

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

7.2 Maximum value of mean power spectral density (within main beam)

7.2.1 Definition

The maximum mean power spectral density (specified as e.i.r.p.) of the device under test, at a particular frequency, is the average power per unit bandwidth (centred on that frequency) radiated in the direction of the maximum level under the specified conditions of measurement.

7.2.2 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
6 GHz to 8,5 GHz	30 MHz to 26 GHz
24,05 GHz to 26,5 GHz	30 MHz to 2 × carrier frequency
57 GHz to 64 GHz	30 MHz to 2 × carrier frequency (see note)
75 GHz to 85 GHz	30 MHz to 2 × carrier frequency (see note)
NOTE: In accordance with recommendation 3) of ERC/REC 74-01 [i.3], the spurious domain emission limits are applicable up to 300 GHz. However, for practical measurement purposes only, the frequency range of spurious emissions may be restricted. This shall be recorded in the test report.	

This test shall be performed using a radiated or conducted test procedure for the frequencies as shown in table 7. Measurements for the LPR frequency bands from 57 GHz to 64 GHz as well as 75 GHz to 85 GHz may use down mixing. The local oscillator used to downconvert the received signals shall be stable and with a phase noise of better than -80 dBc/Hz at 100 kHz offset. The local oscillator frequency shall be selected such that the downconverted signal is within the accepted band of the spectrum analyser, and maintaining an adequate IF bandwidth to capture the full spectrum of the signal.

If the measuring receiver is capable of measuring the signals directly without any down mixing, the fundamental or harmonic mixer can be omitted.

See clause 5.3 for the test conditions.

For radiated measurments, 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. Radiated measurements shall be carried out in an anechoic environment or may also be carried out at an OATS where no physical obstruction shall be within a sector defined as "three times the 3 dB beamwidth of the antenna" during this test.

The maximum mean power spectral density shall be determined and recorded.

The following shall be applied to the combination(s) of the radio device and its intended antenna(e). In the case that the RF power level is user adjustable, all measurements shall be made with the highest power level available to the user for that combination.

Conducted measurements can be conducted instead of radiated measurements for the frequency band of operation as assessed in claused 7.1 for the equipment under test when the equipment provides an antenna connector.

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

Resolution bandwidth: 1 MHz

For impulse technology the resolution bandwidth shall cover at least 5 times the PRF. If this is not possible due to a PRF of greater than 200 kHz it needs to be ensured that the amplitude of the spectral line(s) are included in the RBW pass-band.

NOTE 1: To the extent practicable, the radio device under test is measured using a spectrum analyser configured using the setting described below. 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 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.5] for details).

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

A measurement time (averaging time) of 1ms per measurement point is not sufficient to measure FMCW signals. The maximum signal time must be taken into account to set the sweep time of the spectrum analysator.

$$sweeptime \geq tp \times \frac{total\_measurement\_BW}{RBW}$$

To ensure coincidence, the measurement should also be repeated using different analyzer sweep times fulfilling the condition stated above. The FMCW period of time for modulation used in the formula above is (t p).

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 table 7.

For LPR operating within the frequency band of operation within 6 GHz to 8.5 GHz, this test shall be repeated at the frequencies at the frequency band edges at 1,73 GHz, 2,7 GHz, 5 GHz, 6 GHz, 8,5 GHz and 10,6 GHz as shown in table 8.

For LPR operating within any other frequency band of operation, this test shall be repeated at the the respective frequency band edges at 24,05 GHz and 26,5 GHz or 57 GHz and 64 GHz or 75 GHz and 85 GHz as shown in table 8.

The measurements at the frequency band edges shall be performed at the frequency offsets as shown in table 8.

Table 8: Frequency offsets for band edge measurements

Band edge frequency (GHz)	Frequency with frequency offset applied
1,73	1,73 GHz - 20 MHz
2,7	2,7 GHz - 20 MHz
5	5 GHz - 20 MHz
6	6 GHz - 20 MHz
8,5	8,5 GHz + 20 MHz
10,6	10,6 GHz + 20 MHz
24,05	24,05 GHz - 20 MHz
26,5	26,5 GHz + 20 MHz
57	57 GHz - 20 MHz
64	64 GHz + 20 MHz
75	75 GHz - 20 MHz
85	85 GHz + 20 MHz

This frequency offset that is shown in table 8 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.

7.2.3 Limits

The maximum mean power spectral density measured using the above test procedure shall not exceed the limits stated in tables 9 to 11.

The measured values recorded during performing the measurement procedure in clause 7.2.2 may be reduced by the values provided by the mitigation techniques as described in clause 7.6 before comparing to the limits in tables 9 to 11.

Table 9: Limits of LPR emissions in the LPR operating frequency ranges

Frequency band of operation	Maximum Mean e.i.r.p. spectral density (dBm/MHz) within the LPR operating frequency bands *(within main beam)*	Equivalent maximum radiated field strength levels (dBμV/m) at 3 m in case of radiated field strength measurement (within main beam) (see note)
6 GHz to 8,5 GHz	-33	62,26
24,05 GHz to 26,5 GHz	-14	81,26
57 GHz to 64 GHz	-2	93,26
75 GHz to 85 GHz	-3	92,26
NOTE: The limits are stated as e.i.r.p. and are converted to field strength at 3 m distance using the approved conversion, i.e. E(dBμV/m) = e.i.r.p. (dBm/MHz) + 95,26 dB. Further information on FCC Digital Device and UWB field strength limits at 3 m using an RBW on 1 MHz can be found in the ERA Report [i.7] and the FCC Revision of part 15 of the Commission Rules Regarding Ultra- Wideband Systems [i.8]. The preferred test distance for radiated measurements is 3 m provided that far field conditions are achieved, i.e. $d > 2*D^2/\lambda$, where D is the maximum aperture dimension of the measuring antenna and λ is the wavelength of the measurement. Radiated measurements may be made at 1 m or 10 m and the data would need to be adjusted to the 3 m values using free space propagation conditions.		

Table 10: Limits of unwanted emissions for LPR operating in the 6 GHz to 8,5 GHz frequency range

Frequency (GHz)	Maximum value of mean power spectral density (dBm/MHz)	Equivalent maximum radiated field strength levels (dBµV/m) at 3 m in case of radiated field strength measurement (see note)
f ≤ 1,73	-63	32,26
1,73 < f ≤ 2,7	-58	37,26
2,7 < f ≤ 5	-48	47,26
5 < f < 6	-43	52,26
8,5 < f ≤ 10,6	-43	52,26
f > 10,6	-63	32,26
NOTE: The limits are stated as e.i.r.p. and are converted to field strength at 3 m distance using the approved conversion, i.e. E(dBµV/m) = EIRP (dBm/MHz) + 95,26 dB. Further information on FCC Digital Device and UWB field strength limits at 3 m using an RBW on 1 MHz can be found in the ERA Report [i.7] and the FCC Revision of part 15 of the Commission Rules Regarding Ultra-Wideband Systems [i.8]. The preferred test distance for radiated measurements is 3 m provided that far field conditions are achieved, i.e. $d > 2*D^2/\lambda$, where D is the maximum aperture dimension of the measuring antenna and λ is the wavelength of the measurement. Radiated measurements may be made at 1 m or 10 m and the data would need to be adjusted to the 3 m values using free space propagation conditions.		

Table 11: Limits of unwanted emissions for LPR operating outside of the 6 GHz to 8,5 GHz frequency range

Operating frequency range	Frequency (GHz)	Maximum value of mean power spectral density (dBm/MHz)
For LPR operating in the frequency band 24,05 GHz to 26,5 GHz	f < 24,05	For LPR operating in one of these frequency band of operation the maximum value of mean power spectral density (dBm/MHz) shall be 20 dB less than the in-band density specified in table 9.
For LPR operating in the frequency band 24,05 GHz to 26,5 GHz	f > 26,5	
For LPR operating in the frequency band 57 GHz to 64 GHz	f < 57	
For LPR operating in the frequency band 57 GHz to 64 GHz	f > 64	
For LPR operating in the frequency band 75 GHz to 85 GHz	f < 75	
For LPR operating in the frequency band 75 GHz to 85 GHz	f > 85	

7.3 Maximum value of peak power

7.3.1 Definition

The peak power specified as e.i.r.p. contained within a 50 MHz bandwidth at the frequency at which the highest mean radiated power occurs, radiated in the direction of the maximum level under the specified conditions of measurement.

7.3.2 Method of measurement

This test shall be performed using a radiated or conducted test procedure.

For all LPR UWB modulations the maximum peak power (e.i.r.p.) shall be measured at the frequency of the maximum mean power spectral density as recorded under clause 7.2.

Measurements for the LPR frequency bands from 57 GHz to 64 GHz as well as 75 GHz to 85 GHz may use down mixing. The local oscillator used to downconvert the received signals shall be stable and with a phase noise of better than -80 dBc/Hz at 100 kHz offset. The local oscillator frequency shall be selected such that the downconverted signal is within the accepted band of the spectrum analyser, and maintaining an adequate IF bandwidth to capture the full spectrum of the signal.

If the measuring receiver is capable of measuring the signals directly without any down mixing, the fundamental or harmonic mixer can be omitted.

See clause 5.3 for the test conditions.

For radiated measurements, 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. Radiated measurements shall be carried out in an anechoic environment or may also be carried out at an OATS where no physical obstruction shall be within a sector defined as "three times the 3 dB beamwidth of the antenna" during this test.

The maximum value of peak power shall be determined and recorded.

The following shall be applied to the combination(s) of the radio device and its intended antenna(e). In the case that the RF power level is user adjustable, all measurements shall be made with the highest power level available to the user for that combination.

Conducted measurements can be conducted instead of radiated when the equipment provides an antenna connector.

When measuring maximum peak power 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 to or greater than 3 MHz or at least 5 × the PRF but not greater than 50 MHz for impulsive technology.

NOTE 1: For FMCW LPR, this measurement is basically a repetition of the measurement under clause 7.2 using a peak detector. Proper spectrum analyzer settings should be used to ensure coincidence between the measuring receiver and the FMCW modulation.

NOTE 2: For peak power measurements, the best signal to noise ratio is usually obtained with the widest available resolution bandwidth. On the other side, spectrum analyzers tend to be too slow for higher resolution bandwidths. A suitable resolution bandwidth and applying a scaling down factor of 20 log (50/X) should be applied.

- Video bandwidth: Not less than the resolution bandwidth.
- Detector mode: Peak.
- Display mode: Max. Hold.
- Measurements shall be continued with the transmitter emitting the normal operating signal until the displayed trace no longer changes.

NOTE 3: 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.

The power reading on the spectrum analyser can be directly related to the peak power limit when a spectrum analyser resolution bandwidth of 50 MHz is used for the measurements. If a spectrum analyser resolution bandwidth of X MHz is used instead, the maximum peak power limit shall be scaled down by a factor of 20 log (50/X), where X represents the measurement bandwidth used.

EXAMPLE: If the maximum peak power in a particular frequency band is 0 dBm/50 MHz, and a 3 MHz resolution bandwidth is used in case of an impulsive technology, then the measured value shall not exceed -24,4 dBm.

7.3.3 Limits

The maximum peak power limit measured using the above test procedure shall not exceed the limits given in table 12.

The measured values recorded during performing the measurement procedure in clause 7.3.2 may be reduced by the values provided by the mitigation techniques as described in clause 7.6 before comparing to the limits in table 12.

Table 12: Maximum peak power limit

Frequency (GHz)	Maximum peak power (dBm, measured in 50 MHz)	Equivalent maximum radiated field strength levels (dBμV/m) at 3 m in case of radiated field strength measurement (see note)
6 < f ≤ 8,5	7	102,26
24,05 < f ≤ 26,5	26	121,26
57 < f ≤ 64	35	130,26
75 < f ≤ 85	34	129,26
NOTE: The limits are stated as e.i.r.p. and are converted to field strength at 3 m distance using the approved conversion, i.e. E(dBμV/m) = EIRP (dBm/MHz) + 95,26 dB. Further information on FCC Digital Device and UWB field strength limits at 3 m can be found in the ERA Report [i.7] and the FCC Revision of part 15 of the Commission Rules Regarding Ultra- Wideband Systems [i.8]. The preferred test distance for radiated measurements is 3 m provided that far field conditions are achieved, i.e. $d > 2*D^2/\lambda$, where D is the maximum aperture dimension of the measuring antenna and λ is the wavelength of the measurement. Radiated measurements may be made at 1 m or 10 m and the data would need to be adjusted to the 3 m values using free space propagation conditions.		

7.4 LPR antenna characteristics

7.4.1 Definition

The maximum antenna beamwidth is defined by -3 dBr levels relative to the maximum antenna gain and expressed as ± HalfBeamWidth (here also referred to as the total opening angle).

NOTE 1: Being the main important source of the scattering of LPR emissions, the edges and interaction with edges of the surface under surveillance are to be avoided as much as possible. Therefore, the maximum antenna beamwidth for LPR is limited to ensure limitation of the scattering and consequently the interference potential of LPR towards other radio services and applications.

NOTE 2: The antenna gain relative to the maximum antenna gain in the main beam and in horizontal direction (> 60° to the mainbeam direction) is also limited to ensure compliance with the maximum mean e.i.r.p. spectral density in horizontal direction as assumed in ECC Report 139 [i.12].

7.4.2 Method of measurement

Measurement of the antenna characteristics shall be conducted in both, H- plane and E-plane. The measurement shall be conducted at the frequency of the maximum emission intended for the LPR. These characteristics are taken by radiated measurements of the E-plane or H-plane at a recommended distance of 1,5 m to 3 m.

Examples are given in figure 4. It is important to assess the maximum antenna gain in the main lope.

LPR antennas are typically horn antennas or parabolic antenna.

NOTE: These measurements, together with the measurement of the emission levels in the main beam direction will enable manufacturers to declare conformance with regulatory limits expressed in a half sphere (see ECC Report 139 [i.12]).

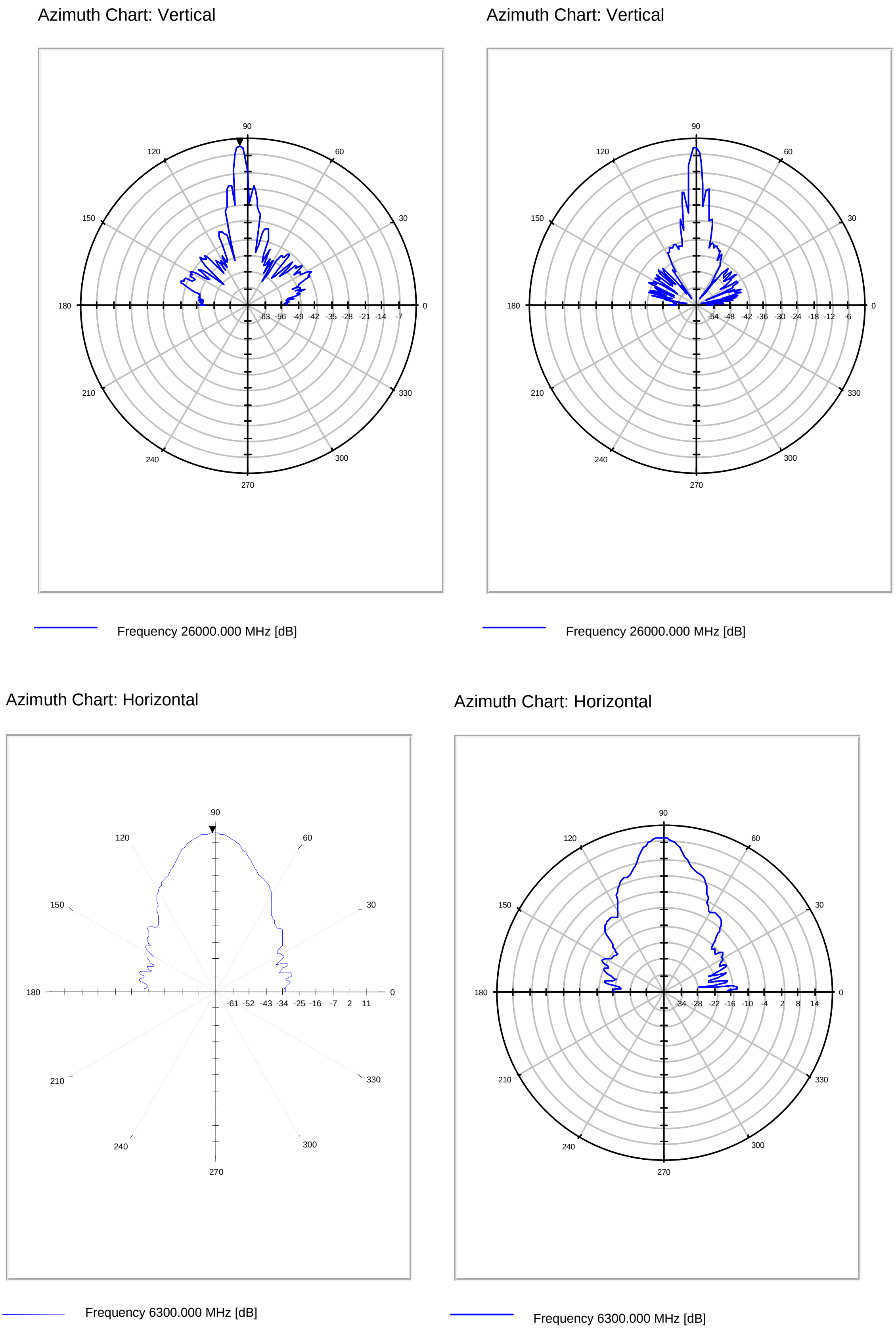


Figure 4: Examples of LPR antenna characteristics

7.4.3 Limits

The antenna gain in the elevation angles above 60 degrees from the main beam has to fulfil a maximum value of -10 dBi. The maximum antenna total opening angle is shown in table 13.

Table 13: Maximum peak power limit

Frequency band of operation	Maximum antenna beamwidth, in degree (°)
6 GHz to 8,5 GHz	12
24,05 GHz to 26,5 GHz	12
57 GHz to 64 GHz	8
75 GHz to 85 GHz	8

The LPR antenna is designed in a manner that is installed at a permanent fixed position pointing in downward direction. In addition the antenna positioning, or height from the ground, should have to observe two restrictions as follows.

- A separation distance of 4 km from Radio Astronomy sites in 6 GHz to 8,5 GHz (A), 24,05 to 26,5 GHz (B)and 75 GHz to 85 GHz (C) frequency bands, unless a special authorization has been provided by the responsible National regulatory authority (a list of Radio Astronomy sites is provided in annex C).
- Between 4 km to 40 km around any Radio Astronomy site the LPR antenna height shall not exceed 15 m height above ground.

The provider is required to inform the users and installers of LPR equipment about the two restrictions above and, if applicable, the related additional special mounting instructions (e.g. by putting it in the product manual).

7.5 Range of modulation parameters

The permitted range of modulation parameters is shown in annex F. Manufacturers shall declare the parameters and the respective values for their equipment in case of impulsive technology, FMCW or similar wideband modulation schemes such as frequency hopping or stepped frequency modulation.

7.6 Other Emissions (OE)

7.6.1 Definition

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 LPR device is not an UWB emission (e.g. by disabling the device's 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.

7.6.2 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 7.6.3. Each occurrence shall be recorded.

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

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 7.6.3 in order to prove compliance with the requirements.

7.6.3 Limits

Other narrowband emissions shall not exceed the values in table 14 in the indicated bands.

Table 14: Other narrowband emission limits

Frequency range	Limit
below 1 GHz	-57 dBm (e.r.p.)
above 1 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 15.

Table 15: Other wideband emission limits

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

7.7 Mitigation techniques

The LPR applications covered by the present document shall use one or several interference mitigation technques. The mitigation techniques described here are intended to be applied to the emission limits as described in clauses 7.2.3 and 7.3.3. 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 or) = Measured value (dBm/MHz) - total mitigation factor (dB)

The mitigation factors are classified into following categories:

- shielding effects;
- frequency domain mitigation;
- activity factor;
- thermal radiation;
- Adaptive Power Control (APC);
- equivalent mitigation techniques.

Mitigation factors are declared and need sufficiently be demonstrated and documented by the provider before taking into account in the above stated equation. The Adaptive Power Control (APC) functionality, if implemented, shall be tested as described in clause 7.7.5.2.

7.7.1 Shielding effects

In this way, the unintentional emission is limited by its special installation.

An external floating roof is made of metallic material such as aluminium. The roof acts as a shielding to prevent the scattering energy from the LPR. Furthermore, walls may make the emissions in the direction around the horizontal line quite small according to the calculations from ITU-R Recommendation P.526-10 [i.9]. No openings above the floating roof exist in practice. The reduction factor of the basin and floating roof shielding applicable for LPR applications is 30 dB according to ITU-R Recommendation P.526-10 [i.9]. This mitigation applies to all emissions above 3 GHz. LPR equipment installed in such a shielded environment may therefore use higher emission levels. the manufacturer shall provide sufficient information in the possible combination of emission levels and shielded installation environment.

7.7.2 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.

7.7.3 Activity Factor (AF)

For impulse technology, the activity factor of the LPR device can be taken into account for addition mitigation considerations. This activity factor is also sometimes referred to as "duty cycle resulting from user" in some sources dealing with UWB devices. The AF as well as spreading of subsequent pulses on different frequencies can be used as additional mitigation technique. Further information is given in annex F on LPR modulation schemes. An AF and/or spreading of subsequent pulses on different frequencies of 10 % represents an interference mitigation of 10 dB. Examples are:on-/off-gating, dithering, etc.

7.7.4 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 LPRs installed in such an environment, 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 40metres 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.

7.7.5 Adaptive Power Control (APC)

7.7.5.1 Definition and description of the APC

The Adaptive Power Control (APC) is an automatic mechanism to avoid interference to other radio services and applications. The APC basically regulates the transmitter power to control emissions. It is controlled by the received energy within the total LPR receiver bandwidth. The dynamic range for the APC should be at least 20 dB and incremental steps shall be 5 dB or less.

NOTE: SEAMCAT simulations in the ECC Report on LPR [i.12] showed that Adaptive Power Control (APC) with a dynamic range of about 20 dB, as proposed in the ETSI System Reference Document TR 102 601 [i.13] is able to reduce the probability of interference and therefore APC should be considered as an essential technical requirement for license exempt regulation, while for a licensing solution the APC requirement may be not required.

APC can be implemented in the following frequency ranges: 6 GHz to 8,5 GHz, 24,05 GHz to 26,5 GHz, 57 GHz to 64 GHz or 75 GHz to 85 GHz.

7.7.5.2 Method of measurement for APC

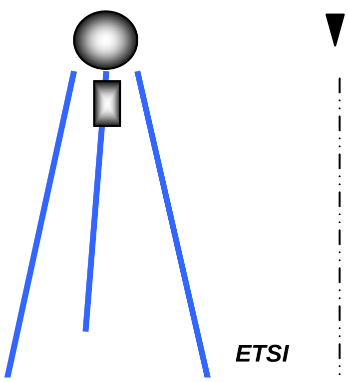
An LPR is equipped with Adaptive Power Control (APC), the automatic control of transmit power shall be tested for proper functionality. The following test procedure describes the power measurement in the main beam of the LPR for two extreme situations:

- The first situation has a metal plate (steal, iron, copper, or similar with a smoth surface) of dimensions 0,6 m × 0,6 m at a distance of 0,8 m with an open ended waveguide protruding in the centre. This situation represents maximum reflection and therefore requires the lowest transmit power.

- The other extreme situation represents an absorbing foam surface (0,6 m × 0,6 m) at the same distance that incorporates the open ended waveguide for transmit power testing while the reflection of the setup is minimal. This situation will allow the LPR to switch to the highest transmit power. The absorbing foam needs an absorbtion of at least 40 dB in the frequency range in which measurements are to be conducted.

The APC procedure will work appropriately for a 20 dB APC range when the maximum output power is within 15 dB of the maximum specified emission power for LPR as in clauses 7.2.3 and 7.3.3.

Figure 5 shows the measurement setup for APC.



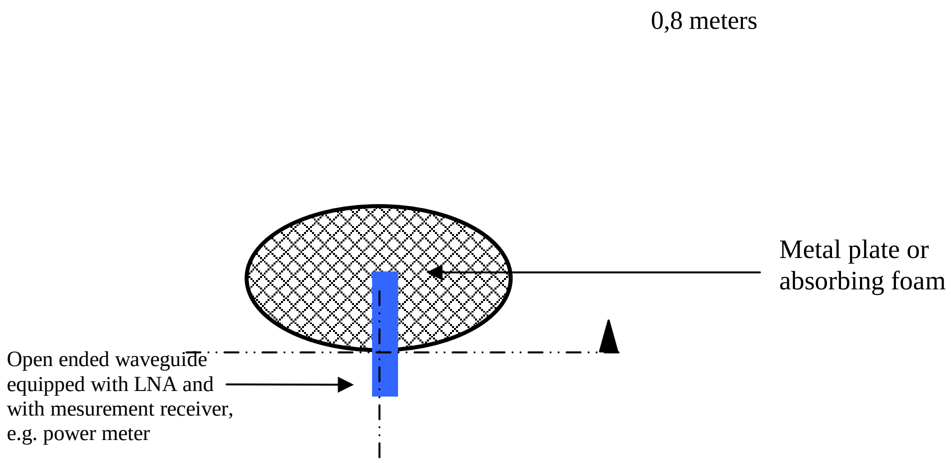


Figure 5: APC measurement setup

For LPRs that emit lower levels of e.i.r.p. of more than 15 dB below the maximum limits as defined in clauses 7.2.3 and 7.3.3 the equipment is unable to provide sufficient signal to noise to accommodate an APC swing of 20 dB. In these cases, an alternative conducted method shall be used. The LPR shall be equipped with an antenna port on the transceiver. The APC function shall then be tested in a conducted configuration. Since the radar has no target reflection the APC shall be controlled by special test software in the LPR.

The radar cross section of an open ended waveguide shall be sufficiently low resulting in a low echo detected by the radar.The test setup shall use one or two LNAs besides the open ended waveguide. The recommended total goin of the(se) amplifiers is recommended to be in the order of 25 dB. The gain of the open ended waveguide can not be increased since this would mean that antennas with a larger aperture are to be used and these inhibit larger radar cross sections and would result in higher radar echoes and thus jeopardize APC functionality. In addition, interferences into the open endedwaveguide caused by the metal reflector plate shall be minimized.

Figures 6 and 7 show examples of open ended waveguides fitted into the absorbing foam and metal plates.

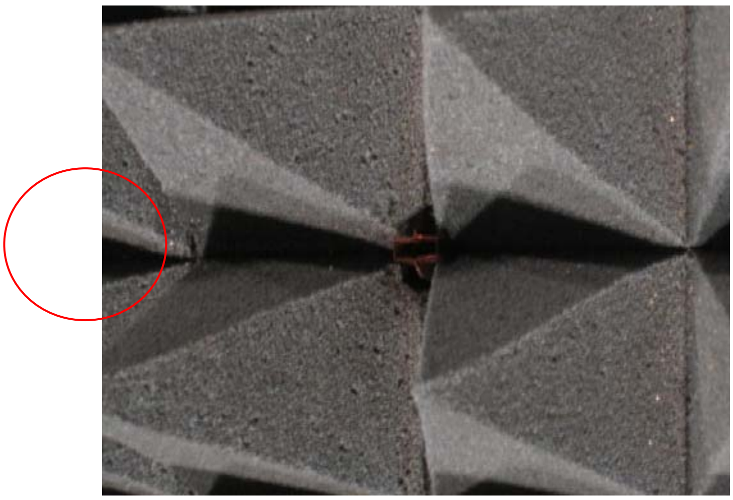


Figure 6: APC measurement setup - open ended waveguide fitted in absorbing foam

Figure 7: APC measurement setup - Details of open ended waveguide trough the metal

When performing the APC measurement with the metal plate (representing the maximum output emission case), the deviation compared to the normal main beam measurement in clause 7.2 shall not exceed 2 dB.

The APC range is assessed by comaring the output power from both measurement cases, i.e. with metal plate and with absorbing foam and shall be recorded.

7.7.5.3 APC Range Limits

The APC functionality, when implemented in the LPR, shall achieve at least a range of 20 dB.

7.7.6 Equivalent mitigation techniques

Other mitigation techniques and mitgation factors can be taken into account for the calculation of the maximum allowed TX power of an LPR radio device as long as the reached mitigation factors are equivalent or higher than the mitigation factors reached using the presented techniques which have been accepted by the CEPT/ECC and are documented in the ECC report 139 [i.12]. Examples for additional mitigation factors could be the deployment of the radio device in a restricted indoor area with a higher wall attenuation, shielding or the deployment and installation of the UWB system in a controlled manner where the use of victim radio services or applications is not allowed or coordinated with the deployment of the LPR system. The additional mitigation factors need to be weighted against the specific services to be protected.

The manufacturer shall provide sufficient information for determining compliance with the LPR emission limits in clauses 7.2.3 and 7.3.3 when using equivalent mitigation techniques.

NOTE: Regulations in the EC decision 2007/131/EC [i.14] and its amendment allow for other equivalent mitigation techniques to be used across all frequency bands, where these offer at least equivalent protection to that provided by the limits in the decision.

8 Methods of measurement and limits for receiver parameters

8.1 Receiver spurious emissions

Separate radiated spurious measurements need not to be made on receivers co-located with transmitters.

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 [3] 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.

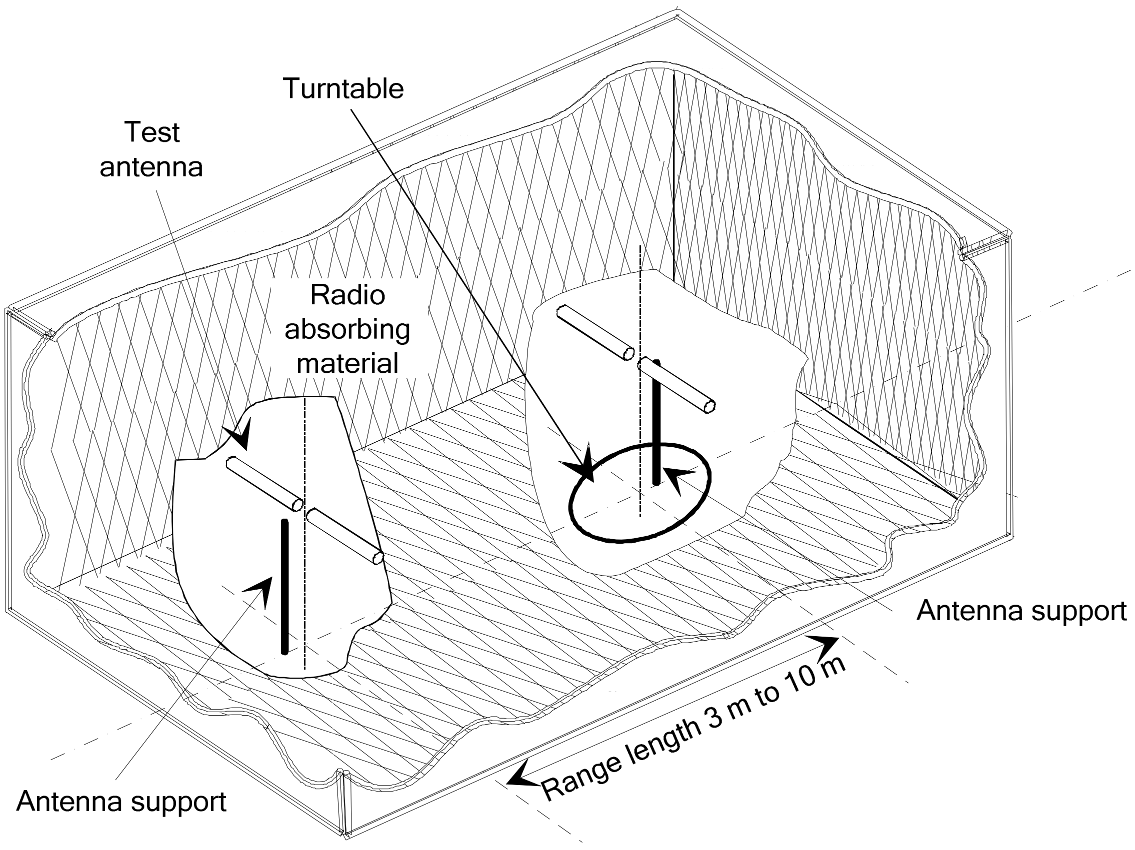


Figure A.1: A typical Anechoic Chamber

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 E. 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.

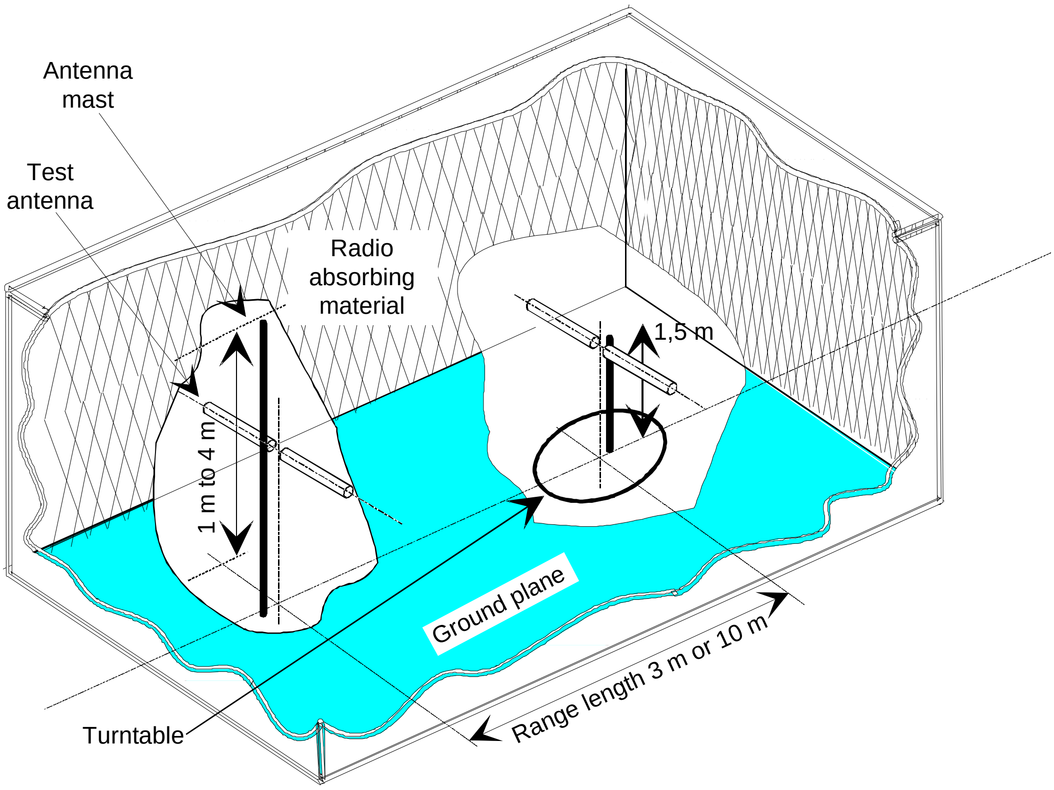


Figure A.2: A typical Anechoic Chamber with a conductive ground plane

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 E. 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 OATS is shown in figure A.3.

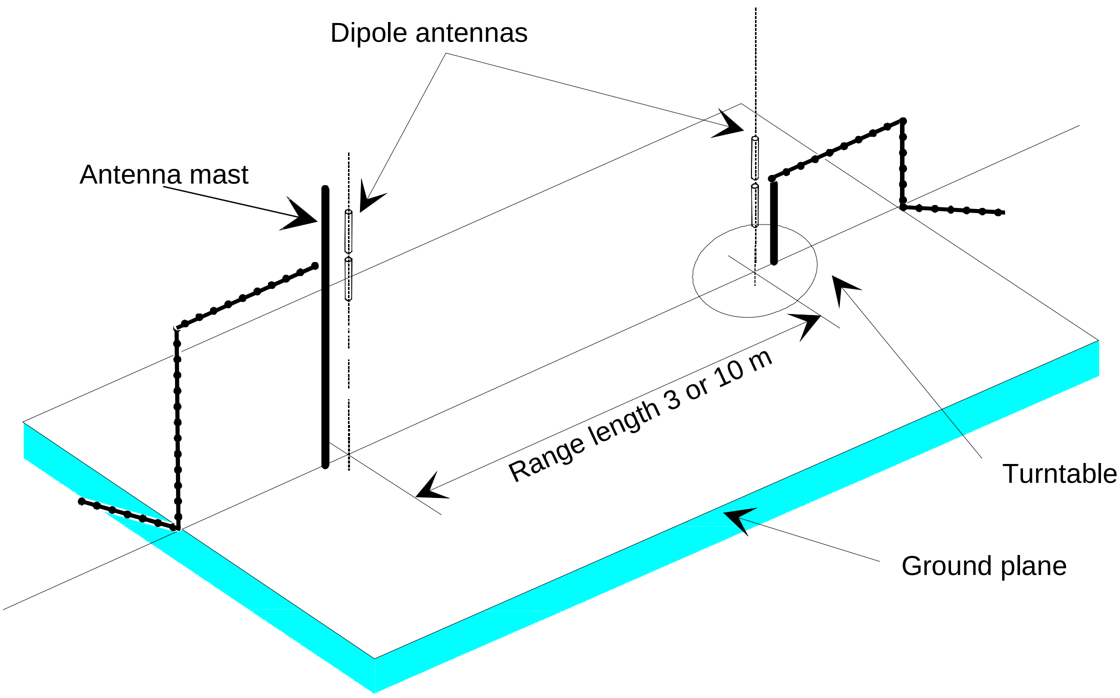


Figure A.3: A typical Open Area Test Site

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.

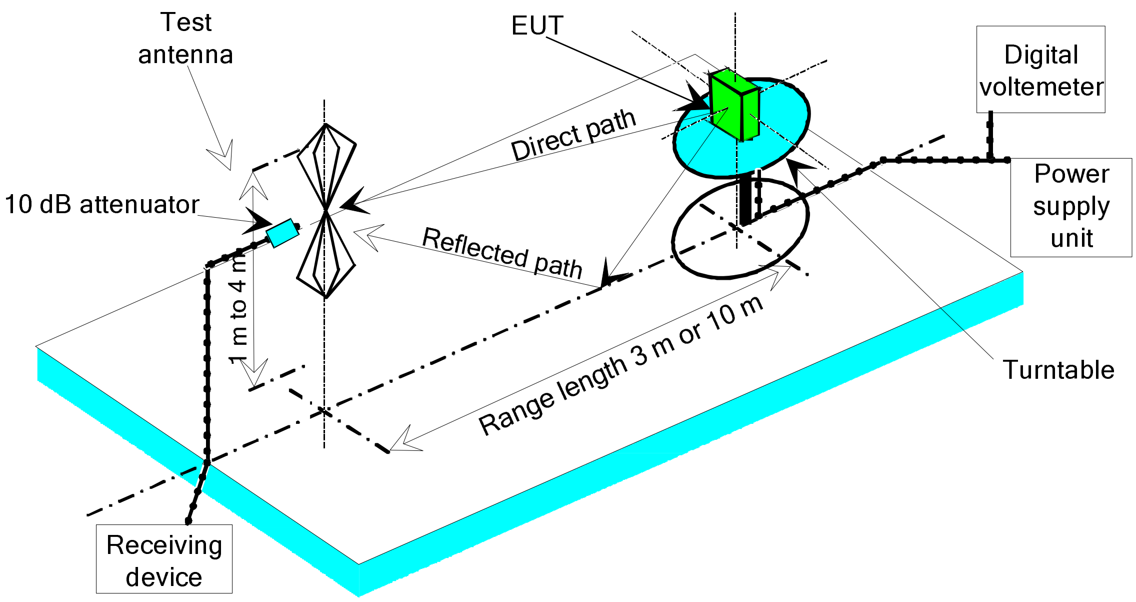


Figure A.4: Measuring arrangement on ground plane test site (OATS set-up for spurious emission testing)

A.1.4 Minimum requirements for test sites for measurements above 18 GHz

Generally the test site shall be adequate to allow for testing in the far field of the EUT. The test site should therefore consist of an electromagnetic anechoic room where either at least the ground surface is covered with radio absorbing material or up to six surrounding surfaces are covered with radio absorbing material. The absorbing material shall have a minimum attenuation of 30 dB. It shall be verified that reflections are sufficiently reduced. The test site shall have the following dimensions:

- Width of 2 metres.
- Length of 3 metres.
- Height of 2 metres (only applicable for a room with more than one reflecting surface).

Highly directional receiving antennas help in reducing reflections. The use of standard gain horn antennas is recommended. It shall be noted that if the antenna aperture is smaller than the EUT, sufficient measurements in both azimuth and elevation shall be conducted in order to ensure that the maximum radiation is determined.

The measuring distance shall be selected in such way that antenna coupling effects are avoided. A distance of at least 0,5 m is therefore recommended. The EUT may be positioned at any height that minimizes reflections from the floor.

Due to high loss of coaxial cables at higher frequencies, the connection from the receiving antenna to the measuring receiver should not exceed 1 m, thus making it necessary to place the measuring receiver very close. This is especially the case when using external harmonic mixers with very short connections to the measuring receiver. Therefore the measuring receiver should somehow be covered with radio absorbing material in direction to the measuring field in order to reduce reflections. Figure A.5 shows an example of a test site above 18 GHz with one reflecting surface.

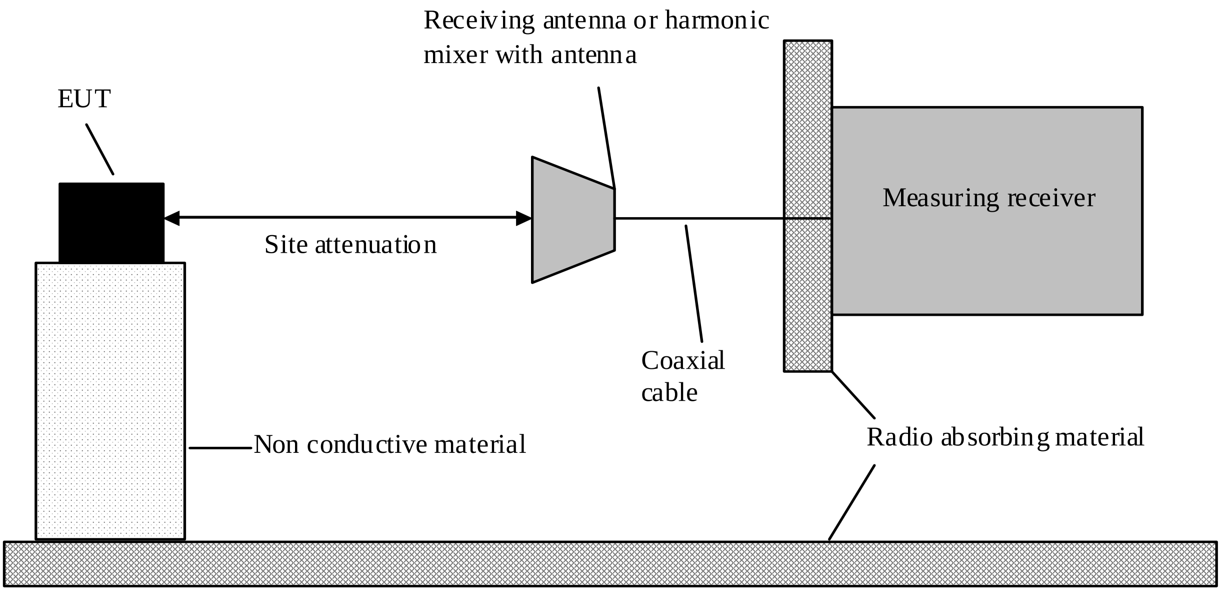


Figure A.5: Example of a test site above 18 GHz with one reflecting surface

The site attenuation of the test site can be determined. Should the test site in its characteristics be nearly ideal, it may be possible to use the theoretical Free Space Loss (FSL) as site attenuation as shown in the examples in the tables A.1 to A.3.

Table A.1: Example of Free Space Loss at 1 m distance

Measuring distance/m	f/GHz	λ/ 1 m	[FSL]/dB
1	24,2	0,012397	60,12
	48,4	0,006198	66,14
	72,6	0,004132	69,66
	96,8	0,003099	72,16

Table A.2: Example of Free Space Loss at 0,5 m distance

Measuring distance/m	f/GHz	λ/ 1 m	[FSL]/dB
0,5	24,2	0,012397	54,1
	48,4	0,006198	60,12
	72,6	0,004132	63,64
	96,8	0,003099	66,14

Table A.3: Example of Free Space Loss at 0,25 m distance

Measuring distance/m	f/GHz	λ/ 1 m	[FSL]/dB
0,25	72,6	0,004132	57,62
	96,8	0,003099	60,12

Whereas:

$\lambda = c/f$

$[FSL] = 10 \log (4\pi r/\lambda)^2$

A.1.5 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 metre 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. 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.1.6 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.1.7 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 [3] 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, output power, 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 E.

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).

A.4 Standard test methods

Two methods of determining the radiated power of a device are described in clauses A.4.1 and A.4.2.

A.4.1 Calibrated setup

The measurement receiver, test antenna and all associated equipment (e.g. cables, filters, amplifiers, etc.) shall have been recently calibrated against known standards at all the frequencies on which measurements of the equipment are to be made. A

On a test site according to clause A.1, the equipment shall be placed at the specified height on a support, and in the position closest to normal use as declared by the provider.

The test antenna shall be oriented initially for vertical polarization and shall be chosen to correspond to the frequency of the transmitter.

The output of the test antenna shall be connected to the spectrum analyser via whatever (fully characterized) equipment is required to render the signal measurable (e.g. amplifiers).

The transmitter shall be switched on, if possible without modulation, and the spectrum analyser shall be tuned to the frequency of the transmitter under test.

The test antenna shall be raised and lowered through the specified range of height until a maximum signal level is detected by the spectrum analyser.

The transmitter shall then be rotated through 360° in the horizontal plane, until the maximum signal level is detected by the spectrum analyser.

The test antenna shall be raised and lowered again through the specified range of height until a maximum signal level is detected by the spectrum analyser.

The maximum signal level detected by the spectrum analyser shall be noted and converted into the radiated power by application of the pre-determined calibration coefficients for the equipment configuration used.

A.4.2 Substitution method

On a test site, selected from clause A.1, the equipment shall be placed at the specified height on a support, as specified in clause A.1, and in the position closest to normal use as declared by the provider.

The test antenna shall be oriented initially for vertical polarization and shall be chosen to correspond to the frequency of the transmitter.

The output of the test antenna shall be connected to the spectrum analyser.

The transmitter shall be switched on, if possible without modulation, and the measuring receiver shall be tuned to the frequency of the transmitter under test.

The test antenna shall be raised and lowered through the specified range of height until a maximum signal level is detected by the spectrum analyser.

The transmitter shall then be rotated through 360° in the horizontal plane, until the maximum signal level is detected by the spectrum analyser.

The test antenna shall be raised and lowered again through the specified range of height until a maximum signal level is detected by the spectrum analyser.

The maximum signal level detected by the spectrum analyser shall be noted.

The transmitter shall be replaced by a substitution antenna as defined in clause A.1.5.

The substitution antenna shall be orientated for vertical polarization and the length of the substitution antenna shall be adjusted to correspond to the frequency of the transmitter.

The substitution antenna shall be connected to a calibrated signal generator.

If necessary, the input attenuator setting of the spectrum analyser shall be adjusted in order to increase the sensitivity of the spectrum analyser.

The test antenna shall be raised and lowered through the specified range of height to ensure that the maximum signal is received. When a test site according clause A.1.1 is used, the height of the antenna shall not be varied.

The input signal to the substitution antenna shall be adjusted to the level that produces a level detected by the spectrum analyser, that is equal to the level noted while the transmitter radiated power was measured, corrected for the change of input attenuator setting of the spectrum analyser.

The input level to the substitution antenna shall be recorded as power level, corrected for any change of input attenuator setting of the spectrum analyser.

The measurement shall be repeated with the test antenna and the substitution antenna orientated for horizontal polarization.

The measure of the radiated power of the device is the larger of the two levels recorded at the input to the substitution antenna, corrected for gain of the substitution antenna if necessary.

Annex B (normative): Conducted measurements

In view of the low power levels of the equipment to be tested under the present document, conducted measurements may be applied to equipment provided with an antenna connector. Where the equipment to be tested does not provide a suitable termination, a coupler or attenuator that does provide the correct termination value shall be used.

The equivalent isotropically radiated power is then calculated from the measured value, the known antenna gain, relative to an isotropic antenna, and if applicable, any losses due to cables and connectors in the measurement system.

The Voltage Standing Wave Ratio (VSWR) at the 50 Ω connector shall not be greater than 1,5:1 over the frequency range of the measurement. For the purpose of the present document, conducted measurements are limited to the intended LPR frequency band of operation (see clause 7.1.3, table 6).

Annex C (informative): Installation of Level Probing Radar (LPR) Equipment in the proximity of Radio Astronomy sites.

This annex provides the information for LPR equipment manufacturers and installers on European Radio Astronomy sites as known, according to available information at the time of creation of the present document.

Table C.1: List of radio astronomy sites exclusion zones

Country	Name of the station	Geographic Latitude	Geographic Longitude	Frequency Band
Finland	Metsähovi	60°13'04" N	24°23'37" E	B
	Tuorla	60°24'56" N	22°26'31" E	B
France	Plateau de Bure	44°38'01" N	05°54'26" E	B and C
	Floirac	44°50'10" N	00°31'37" W	B
	Bordeaux	insert	insert	C
Germany	Effelsberg	50°31'32" N	06°53'00" E	A, B and C
Hungary	Penc	47°47'22" N	19°16'53" E	B
Italy	Medicina	44°31'14" N	11°38'49" E	B
	Noto	36°52'34" N	14°59'21" E	B
	Sardinia	39°29'50" N	09°14'40"E	A, B and C
Latvia	Ventspils	57°33'12" N	21°51'17" E	B
Poland	Kraków - Fort Skala	50°03'18" N	19°49'36" E	B
	Toruń - Piwnice	52°54'48" N	18°33'30" E	A
Russia	Dmitrov	56°26'00" N	37°27'00" E	B
	Kalyazin	57°13'22" N	37°54'01" E	B
	Pushchino	54°49'00" N	37°40'00" E	B
	Zelenchukskaya	43°49'53" N	41°35'32" E	B
Spain	Yebes	40°31'27" N	03°05'22" W	B and C
	Robledo	40°25'38" N	04°14'57" W	B
	Pico Veleta	insert	insert	C
Switzerland	Bleien	47°20'26" N	08°06'44" E	B
Sweden	Onsala	57°23'45" N	11°55'35" E	A, B and C
The Netherlands	Westerbork	insert	insert	A
Turkey	Kayseri	insert	insert	A
UK	Cambridge	52°09'59" N	00°02'20" E	B
	Darnhall	53°09'22" N	02°32'03" W	B
	Jodrell Bank	53°14'10" N	02°18'26" W	A and B
	Knockin	52°47'24" N	02°59'45" W	B
	Pickmere	53°17'18" N	02°26'38" W	B

NOTE: Table C.1 is based on available information at the time of creation of the present document. Additional information on the list of Radio Astronomy Stations may be available under www.craf.eu .

Annex D (informative): Measurement antenna and preamplifier specifications

The radiated measurements set-up in clause 7 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 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	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 26 GHz	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 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

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

E.1 Introduction

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

E.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 should be in accordance with table E.1.

Table E.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 [i.15].

Annex F (normative): Range of modulation parameters

F.1 Pulse modulation

F.1.1 Definition

For pulse modulation, the Tx "amplitude" is periodically switched on for a short time (called pulse duration) and switched off during the subsequent reception period. A typical example is shown in figure F.1.

The time between the rising edges of the pulsed output power is called the Pulse Repetition Interval (PRI). The PRI may vary between subsequent pulses, in which case the modulation is called staggered PRI.

The Pulse Repetition Frequency (PRF) is the inverse of the PRI averaged over a time sufficiently long to cover all PRI variations.

The duty cycle is the product of the PRF and the pulse duration.

The radiated power averaged over the pulse duration is called the peak output power.

The peak output power multiplied by the average duty cycle is called the average output power.

Subsequent pulses may be on different frequencies (i.e. stepped frequency).

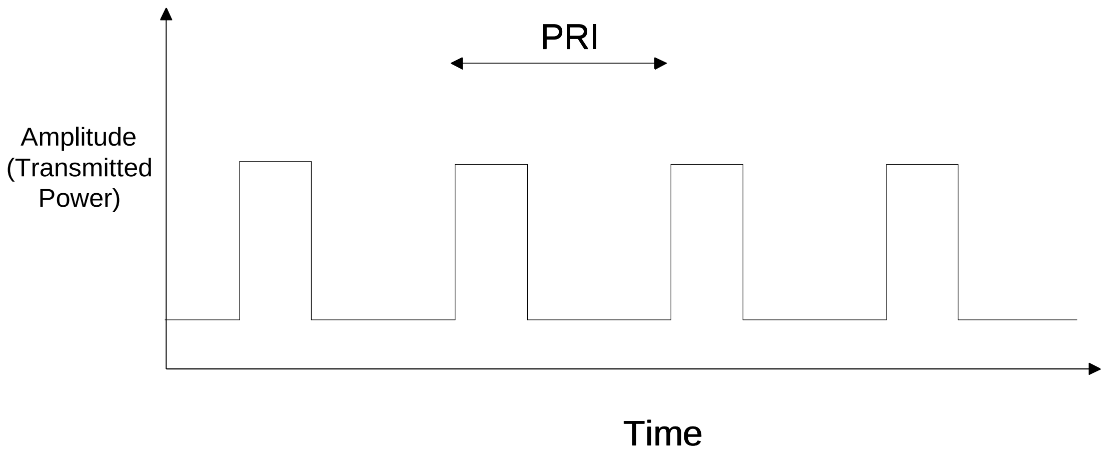


Figure F.1: Typical pulse modulation scheme

DC defined here is also sometimes referred to as "DC resulting from modulation" in some sources dealing with UWB devices. This DC is important for defining the relation between mean and peak power of transmitter The Duty Cycle described above but also the additional consideration on Activity Factor (AF) are the terms used to completely describe different activity levels of LPR devices. This additional AF defined here is also sometimes referred to as "DC resulting from user" in some sources dealing with UWB devices:

- Activity Factor (AF) - is the ratio of active measurement periods (bursts, sweeps, scans) within the overall repetitive measurement cycle, i.e. T_{meas}/T_{meas_cycle}.

The AF as well as spreading of subsequent pulses on different frequencies can be used as additional mitigation technique.

F.1.2 Operating parameters

The peak and average (RMS) power limits are given in clauses 7.2.3 and 7.3.3. Operating parameters are given in table F.1.

Table F.1: operating parameters for pulse modulation

Parameter	Value
PRF	shall not exceed 5 MHz
PRI	shall be 0,2 µs or more
Pulse length (typical)	1,5 ns

Examples of DC and AF values for various types of previously existing LPR devices are shown below in table F.2.

Table F.2: DC/AF examples for various LPR types

	Pulsed LPR
DC, %	0,05 to 1
AF, %	0,5 to 50

F.2 Frequency modulated continuous wave

F.2.1 Definition

For FMCW, FH, FSK , stepped frequency hopping or similar carrier based modulation schemes, it is important to describe the modulation parameters in order to ensure that the right settings of the measuring receiver are used. Important parameters are the modulation period, deviation or dwell times within a modulation period, rate of modulation (Hz/s).

For Frequency Modulated Continuous Wave (FMCW) modulation, the transmitted waveform is frequency modulated over a period of time (P). This period of time may be constant, or may be varied. An example of a typical modulation scheme is shown in figure F.2. During the time (P), the frequency may either increase or decrease. The modulation may assume (but is not limited to) the form of a "saw tooth", "triangular" or a "sinusoidal" waveform. Also a constant frequency may be maintained and transmitted during one or more periods of time. Furthermore, the transmitted power may be switched off during one or more periods of time (e.g. Frequency Modulated Interrupted Continuous Wave (FMCW)). The modulation waveform may be repeated or varied over several periods of time, and at the beginning or end of each period of time (P), there may be a time "G" (the "blanking period") where the transmitted waveform is adjusting to the requirements of the beginning of the next period.

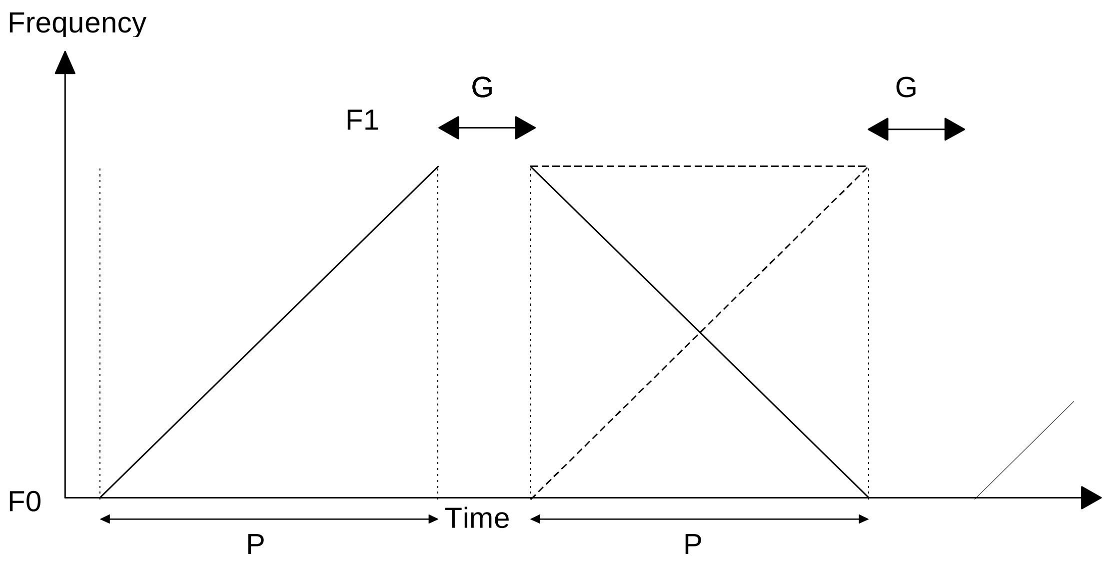


Figure F.2: Typical FMCW modulation scheme

F.2.2 Operating parameters

The peak and average (RMS) power limits are given in clauses 7.2.3 and 7.3.3. Operating parameters are given in table F.3.

Table F.3: operating parameters for FMCW modulation

Parameter	Minimum Limit	Maximum Limit
Frequency deviation in one period	0 Hz	4 000 MHz
Rate of frequency modulation during a period (t p)	0 Hz/ms	800 MHz/ms
Period of time for modulation (t p)	50 us	400 ms

Annex G (informative): Atmospheric absorptions and material dependent attenuations

In the frequency range between 40 GHz and 246 GHz the specific absorptions and material attenuations are an important factor for the compatibility of the different services potentially sharing the same operational band. In this annex an overview over the relevant parameters will be given for different materials and the atmospheric absorption.

G.1 Atmospheric absorptions

With higher frequencies the effect of the atmospheric absorption gets more and more important in the investigation of the coexistence behaviour of short range wireless systems. In figure G.1 the specific absorption in the band between 1 GHz and 350 GHz is depicted. The diagram shows the absorption behaviour of dry air, of H_2O and the combination of both. It can be seen that under normal conditions the absorption due to H_2O is the most significant effect. Only in two spectral regions around 60 GHz and 120 GHz the dry air already shows a very significant absorption behaviour. That means these absorptions are independent of the amount of H_2O in the air. Especially the absorption peak around 60 GHz will be used to increase the isolation behaviour between different wireless systems. The absorption peak around 60 GHz originates from several oxygen absorption lines. A more detailed description of the behaviour around 60 GHz is depicted in figure G.2 for different altitudes between 0 km (sea level) and 20 km. Especially the 20 km diagram shows nicely the different absorption lines. The absorption peak around 60 GHz reaches 16 dB/km.

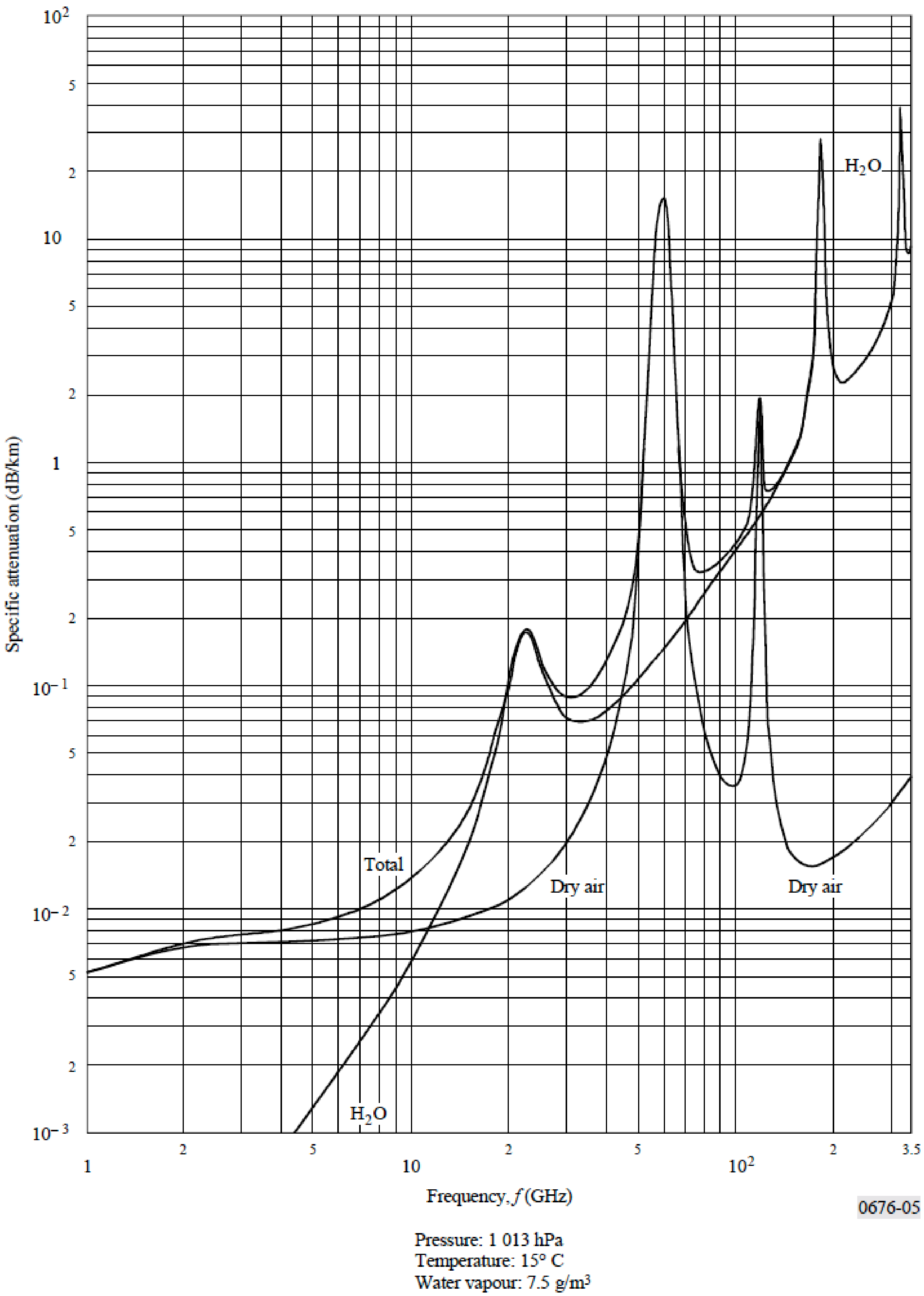


Figure G.1: Specific attenuation due to atmospheric gases in the band 1 GH to 350 GHz in dB/km

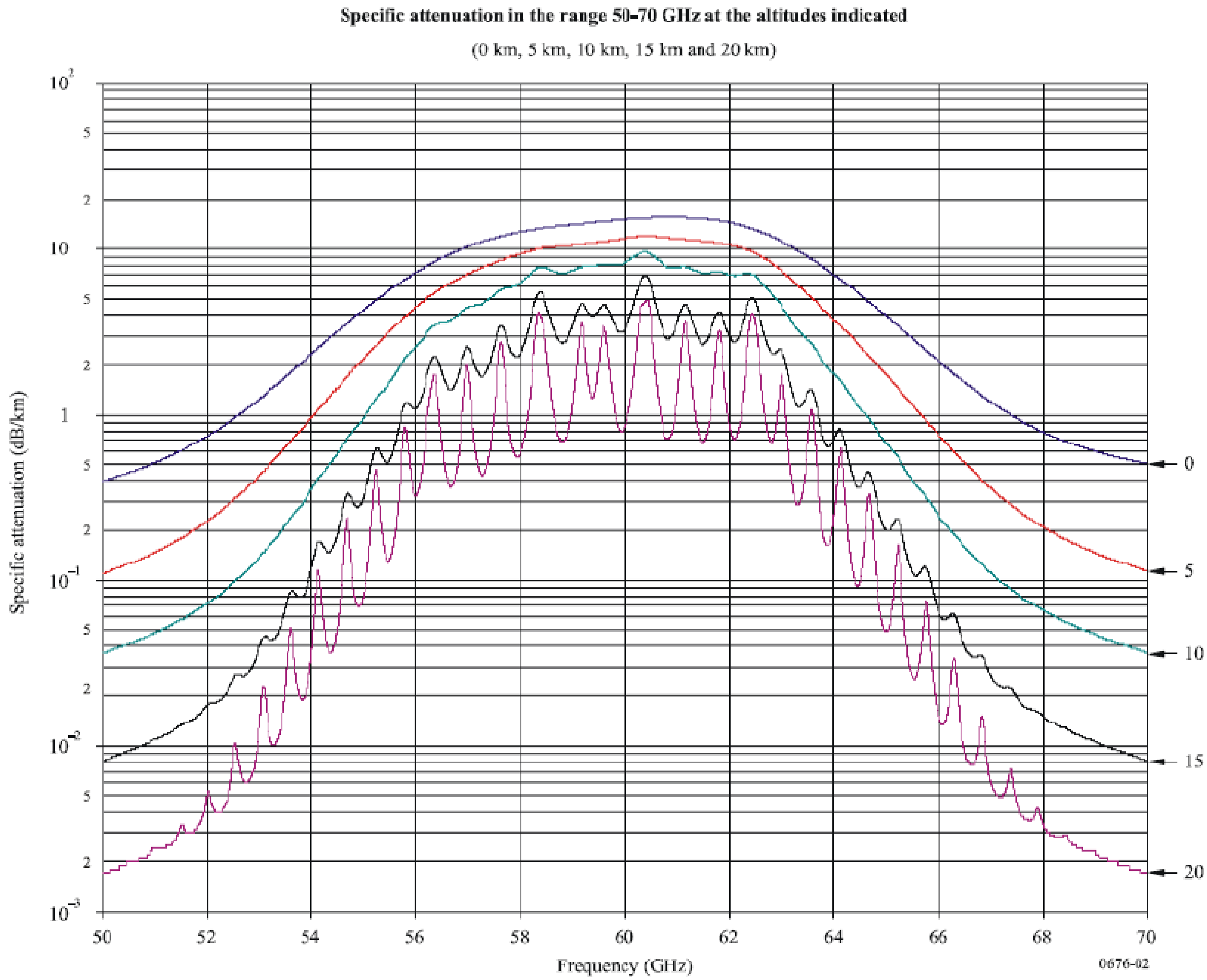


Figure G.2: Specific Atmospheric attenuation in the band 50 GHz to 70 GHz for different altitudes (0 km, 5 km, 10 km, 15 km and 20 km) [i.11]

G.2 Material dependent attenuations

The material dependent attenuation does also increase with the operational frequency. Typical attenuations for different materials are depicted in figure G.3 for the frequency range between 3 GHz and 200 GHz. These effects are important when coexistence scenarios are investigated between indoor and outdoor systems.

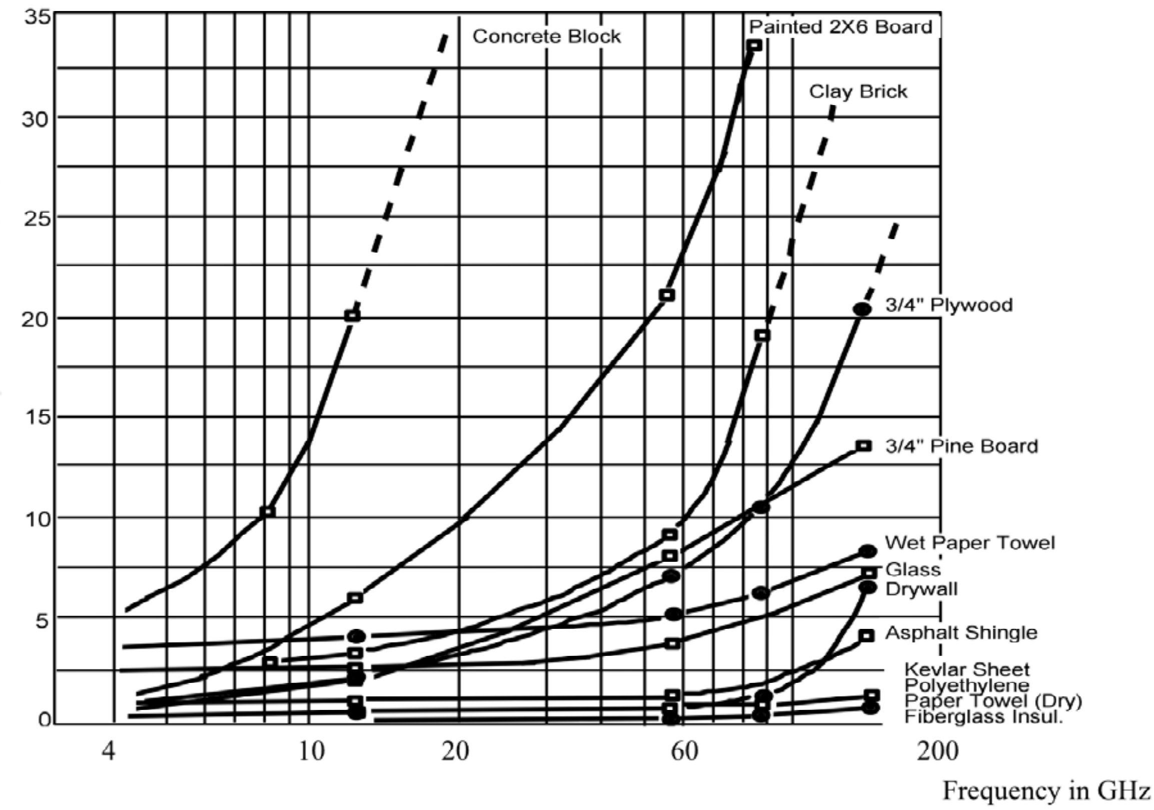


Figure G.3: Material Absorption at High Frequency in the frequency range from 3 GHz to 200 GHz in dB

History

Document history		
V1.1.1	August 2010	Public Enquiry PE 20101204: 2010-06-08 to 2010-06-12