Final draft ETSI EN 302 729 V2.1.1 (2016-10)

HARMONISED EUROPEAN STANDARD

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;
Harmonised Standard covering the essential requirements
of article 3.2 of the Directive 2014/53/EU

Reference
REN/ERM-TGUWB-136

Keywords
EHF, harmonised standard, radar, SHF, short
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Foreword

This final draft Harmonised European Standard (EN) has been produced by ETSI Technical Committee Electromagnetic compatibility and Radio spectrum Matters (ERM), and is now submitted for the Vote phase of the ETSI standards EN Approval Procedure.

The present document has been prepared under the Commission's standardisation request C(2015) 5376 final [i.15] to provide one voluntary means of conforming to the essential requirements of Directive 2014/53/EU on the harmonisation of the laws of the Member States relating to the making available on the market of radio equipment and repealing Directive 1999/5/EC [i.12].

Once the present document is cited in the Official Journal of the European Union under that Directive, compliance with the normative clauses of the present document given in table A.1 confers, within the limits of the scope of the present document, a presumption of conformity with the corresponding essential requirements of that Directive, and associated EFTA regulations.

Proposed national transposition dates	
Date of latest announcement of this EN (doa):	3 months after ETSI publication
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Modal verbs terminology

In the present document "**shall**", "**shall not**", "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

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Introduction

- The present document cancels and replaces previous versions of the whole series.

- There have been no significant technical changes incorporated from the previous version of the present document.

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

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

Clause 4 lists all technical requirements specifications. This includes transmitter and receiver conformance requirements as well as requirements for spectrum access, antennas and mitigation techniques.

Clause 5 addresses the conditions for testing. This includes the environmental conditions and product information of the equipment to be tested. It also gives advice on the interpretation of the measurement results and gives the maximum measurement uncertainty values.

Clause 6 provides the information on conformance test suites. This includes test suites for transmitter and receiver parameters as well as test suites for spectrum access, antenna requirements and others.

Annex A explains the relationship between the present document and the essential requirements of Directive 2014/53/EU [i.12].

Annex B provides an application form for facilitating the test preparation.

Annex C lists general requirements on radiated test setups.

Annex D provides information about the requirements of conducted measurements.

Annex E lists the exact locations of radio astronomy sites. The installation of LPR instruments is restricted in the vicinity of these sites.

Annex F gives recommendations on measurement antennas and preamplifiers.

Annex G deals with practically useful approximations of the far field conditions for radiated measurements.

Annex H describes the range of modulation parameters for LPR instruments.

Annex I gives information on the atmospheric absorption of electromagnetic waves as a function of frequency.

Annex J gives practical information on RF measurements, especially in higher frequency bands.

Annex K gives information on radar targets for radiated measurements.

Annex L describes the boundary conditions for the Radar equation.

Annex M (bibliography) lists further related documents.

Annex N contains the change history of the present document.

1   Scope

The present document applies to the following equipment types:

Level Probing Radar (LPR) applications are 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: Level Probing Radar (LPR) permitted frequency bands [i.13]

	LPR assigned frequency bands (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

The present document contains requirements to demonstrate that LPR equipment both effectively uses and supports the efficient use of radio spectrum in order to avoid harmful interference.

Table 1 shows a list of the frequency bands as assigned to Level Probing Radars in the European Commission Decision 2013/752/EU [i.13] on harmonised deployment conditions for industrial Level Probing Radars (LPR) as known at the date of publication of the present document.

Technical and regulatory requirements for LPR are provided in ECC Decision (11)02 [i.20], which are based on ECC Report 139 [i.8].

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.

LPRs always consist of a combined transmitter and receiver and are used with an integral or dedicated antenna. The LPR equipment is for professional applications where 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 (SRD).

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

2   References

2.1   Normative 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 referenced document (including any amendments) applies.

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

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

[1]   ETSI TR 100 028 (all parts) (V1.4.1) (12-2001): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Uncertainties in the measurement of mobile radio equipment characteristics".

[2]   CISPR 16 (part 1-1:2015), (part 1-4:2010+AMD1:2012) and (part 1-5: 2014): "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) (12-2001): "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".

[5]   ETSI EN 303 883 (V1.1.1) (07-2016): "Short Range Devices (SRD) using Ultra Wide Band (UWB); Measurement Techniques".

[6]   ETSI TS 103 361 (V1.1.1) (03-2016):"Short Range Devices (SRD) using Ultra Wide Band technology (UWB); Receiver technical requirements, parameters and measurement procedures to fulfil the requirements of the Directive 2014/53/EU".

2.2   Informative 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 referenced document (including any amendments) applies.

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

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

[i.2]   Recommendation ITU-R SM.1754: "Measurement techniques of Ultra-wideband transmissions".

[i.3]   ERA Report 2006-0713: "Conducted and radiated measurements for low level UWB emissions".

[i.4]   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.5]   Recommendation ITU-R P.526-13 (11/2013): "Propagation by diffraction".

[i.6]   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.7]   Recommendation ITU-R P.676-10 (09/2013): "Attenuation by atmospheric gases".

[i.8]   CEPT ECC Report 139: "Impact of Level Probing Radars Using Ultra-Wideband Technology on Radiocommunications Services", Rottach-Egern, February 2010.

[i.9]   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.10]   European 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.11]   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".

[i.12]   Directive 2014/53/EU of the European Parliament and of the Council of 16 April 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of radio equipment and repealing Directive 1999/5/EC, (OJ L153, 22.5.2014, p62).

[i.13]   European Commission Decision 2013/752/EU amending Decision 2006/771/EC on harmonisation of the radio spectrum for use by short-range devices and repealing Decision 2005/928/EC.

[i.14]   FCC part 15.256: "Operation of level probing radars within the bands 5.925-7.250 GHz, 24.05-29.00 GHz, and 75-85 GHz".

[i.15]   Commission Implementing Decision C(2015) 5376 final of 4.8.2015 on a standardisation request to the European Committee for Electrotechnical Standardisation and to the European Telecommunications Standards Institute as regards radio equipment in support of Directive 2014/53/EU of the European Parliament and of the Council.

[i.16]   ETSI TS 103 051: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Expanded measurement uncertainty for the measurement of radiated electromagnetic fields".

[i.17]   ETSI TR 103 181-2: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD) using Ultra Wide Band (UWB);Transmission characteristics Part 2: UWB mitigation techniques".

[i.18]   Committee on Radio Astronomy Frequencies, European Science Foundation.

NOTE: Available at www.craf.eu.

[i.19]   Void.

[i.20]   ECC/DEC/(11)02: "ECC Decision of 11 March 2011 on industrial Level Probing Radars (LPR) operating in frequency bands 6 - 8.5 GHz, 24.05 - 26.5 GHz, 57 - 64 GHz and 75 - 85 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): Factor which is used to describe different modulation parameters and activity levels of LPR devices and defined as the ratio of active measurement periods t_{meas} (bursts, sweeps, scans) within the overall repetitive measurement cycle T_{meas_cycle}, i.e. t_{meas}/T_{meas_cycle}.

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): product of the pulse repetition frequency (PRF) and the pulse duration

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

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 (PRI), averaged over a sufficiently long time to cover all PRF variations

Pulse Repetition Interval (PRI): time period between two consecutive transmit pulses for example in a pulsed LPR

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

radiation: signals emitted intentionally for level measurements

step response time (of an LPR): time span after a sudden distance change until the output value (distance value) reaches 90 % of the final value for the first time

3.2 Symbols

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

AF	Activity factor
f	Frequency
f_C	Frequency at which the peak power of the emission is at maximum
f_H	Highest frequency of the operating bandwidth
f_L	Lowest frequency of the operating bandwidth
t	Time
t_{meas}	active measurement period
T_{meas_cycle}	overall repetitive measurement cycle
t_G	blanking time
k	Boltzmann constant
c	speed of light
T	Temperature
G	efficient antenna gain of radiating structure or gain of the TLPR antenna in the direction of main radiation (main lobe axis)
G_α :	gain of the TLPR antenna in an angle α off the main lobe axis (see figure 5)
G_t :	gain of the test antenna in the direction of main radiation (main lobe axis)
G_a	declared measurement antenna gain
d	Largest dimension of the antenna aperture of the TLPR or extent of the main lobe in slant distance R_T
d_1	Largest dimension of the TLPR antenna (m)

d_2	Largest dimension of the test antenna (m)
DC	Duty cycle
P_s	Output power of the signal generator measured by power meter
Δf	Bandwidth
BW_{ref}	reference bandwidth
$BW_{measured}$	measurement bandwidth
X	Minimum radial distance (m) between the DUT and the test antenna
λ	wavelength in general or wavelength of the TLPR transmit signal at centre frequency
dB	deciBel
dBi	antenna gain in deciBel relative to an isotropic antenna
ε_r	relative permittivity of the surface material in the real measurement scenario
R_{max}	maximum measurement distance which the individual sensor is still able to reliably measure under the influence of an interferer
Δd	measurement value variation over time during a distance measurement
t_{pulse}	pulse duration in a pulsed system or the duration of an individual frequency step in an SFCW modulation scheme
$P_{r\_real} \left(P_{r\_real}^{dBm} \right)$	received echo power in the real measurement scenario in Watt (in dBm)
$P_t \left(P_t^{dBm} \right)$	maximum value of peak power of the TLPR in Watt (in dBm) in the real measurement scenario
R_{max}	maximum measurement distance of the TLPR under interference conditions
R_T	slant distance between TLPR and target
R	distance between TLPR and test antenna
r	reflection coefficient of the considered surface in the real measurement scenario
r_{sphere}	radius of the conducting sphere
$P_{r\_equivalent} \left(P_{r\_equivalent}^{dBm} \right)$	received echo power in the equivalent measurement scenario in Watt (in dBm)
σ	Radar cross section (RCS) of a target
σ_{sphere}	Radar cross section (RCS) of a conducting sphere
$P_{r\_interferer} \left(P_{r\_interferer}^{dBm} \right)$	received interferer power at the location of the TLPR in Watt (in dBm)
$P_{t\_interferer} \left(P_{t\_interferer}^{dBm} \right)$	transmitted interferer power (generated by the signal generator) in Watt (in dBm)
$\lambda_{interferer}$	wavelength of the interfering signal
$a_{coupler(1-2)}^{dB}$	coupling loss of the directional coupler between ports 1 and 2 in dB
$a_{coupler(1-3)}^{dB}$	coupling loss of the directional coupler between ports 1 and 3 in dB
$a_{cable\_A}^{dB}$	cable loss of coaxial RF-cable A in dB
$a_{cable\_B}^{dB}$	cable loss of coaxial RF-cable B in dB
$a_{attn\_A}^{dB}$	attenuation of the coaxial attenuator A in dB
$a_{attn\_B}^{dB}$	attenuation of the coaxial attenuator B in dB
$\sigma_{square}/\sigma_{triangular}$	Radar cross sections of the square/triangular shaped corner reflector in boresight direction
a	edge length of corner reflector (compare figure M.1)

| r_{ff} | | distance from the TLPR antenna to the inner boundary of the far-field region |
| ϑ_{3dB} : | | half power beamwidth (HPBW) or opening angle of the antenna pattern |

3.3   Abbreviations

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

AC	Alternate Current
AF	Activity Factor
APC	Adaptive Power Control
BW	BandWidth
CISPR	Comité International Spécial des Perturbations Radioélectriques
CW	Continuous Wave
DAA	Detect And Avoid
DC	Duty Cycle
DUT	Device Under Test
e.i.r.p.	equivalent isotropically radiated power
EC	European Commission
ECC	Electronic Communication Committee
EFTA	European Free Trade Union
EIA	Electronic Industries Alliance
EIRP	Equivalent Isotropic Radiated Power
ERA	European Radio Organization
ERC	European Radiocommunication Committee
EU	European Union
EUT	Equipment Under Test
FCC	Federal Communication Commission
FH	Frequency Hopping
FM	Frequency Modulated
FMCW	Frequency Modulated Continuous Wave
FSK	Frequency Shift Keying
FSL	Free Space Loss
HPBW	Half Power BeamWidth
IEC	International Electrotechnical Commission
IF	Intermediate Frequency
ITU-R	International Telecommunication Union - Radio Sector
LBT	Listen Before Talk
LDC	Low Duty Cycle
LNA	Low Noise Amplifier
LO	Local Oscillator
LPR	Level Probing Radar
OATS	Open Area Test Site
OE	Other Emission
PC	Precision Contact
PRF	Pulse Repetition Frequency
PRI	Pulse Repetition Interval
PSD	Power Spectral Density
RBW	Resolution BandWidth
RCS	Radar Cross Section
RCSC	Radio Components Standardization Committee
RF	Radio Frequency
RMS	Root Mean Square
RX	Receiver
SA	Spectrum Analyser
SFCW	Stepped Frequency Continuous Wave
SMA	Sub Miniature type A (connector)
SNR	Signal to Noise Ratio
SRD	Short Range Device
TLPR	Tank Level Probing Radar
TR	TRansmit
TX	Transmitter

UK	United Kingdom
UWB	Ultra-WideBand
VBW	Video BandWidth
VSWR	Voltage Standing Wave Ratio
WG	WaveGuide
WR	Waveguide Rectangular

4   Technical requirements specification

4.1   Environmental conditions

The technical requirements of the present document apply under the environmental profile for operation of the equipment, which shall be declared by the manufacturer. The equipment shall comply with all the technical requirements of the present document at all times when operating within the boundary limits of the declared operational environmental profile.

The normal test conditions are defined in clause 5.2.4.

4.2   General

Level Probing Radar (LPR) applications are 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.

4.3   Transmitter conformance requirements

4.3.1   Permitted frequency range of operation

4.3.1.1   Applicability

This requirement shall apply to all DUT.

4.3.1.2   Description

The permitted frequency ranges of operation are the assigned frequency bands for Level Probing Radar (LPR). They are given in clause 4.3.1.3, table 2.

4.3.1.3   Limits

The permitted frequency range of operation shall be within the limits given in table 2.

Table 2: Permitted frequency ranges of operation [i.13]

6 GHz to 8,5 GHz
24,05 GHz to 26,5 GHz
57 GHz to 64 GHz
75 GHz to 85 GHz

4.3.1.4   Conformance

The permitted frequency ranges(s) of operation used by the EUT shall be declared by the manufacturer. The operating bandwidth will be tested in clause 4.3.2.

4.3.2   Operating bandwidth

4.3.2.1   Applicability

This requirement shall apply to all DUT.

4.3.2.2   Description

The operating bandwidth includes all frequencies on which the equipment is authorized to operate within one or more of the permitted frequency ranges of operation.

f_C is the frequency where the emitted power is at its maximum. The two frequencies below f_C and above f_C where the power decreases by 20 dB are designated as f_L and f_H respectively.

The operating bandwidth is defined as the frequency range between f_L and f_H and is illustrated in figure 1.
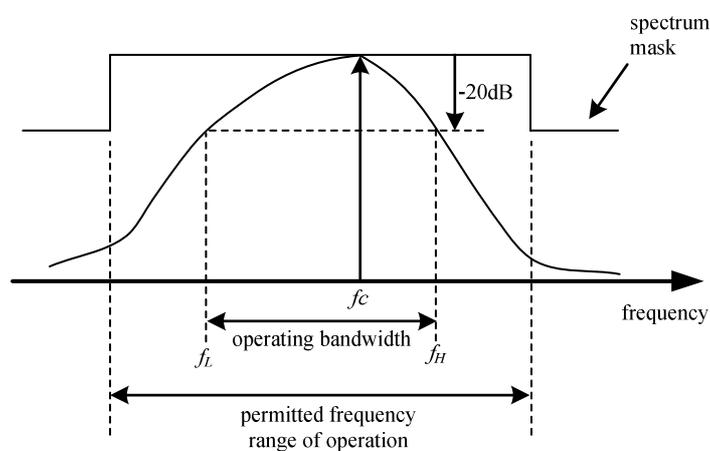
Figure 1: Definition of the operating bandwidth

4.3.2.3   Limits

The operating bandwidth shall comply with the limits of the permitted frequency range(s) of operation given in clause 4.3.1.3, table 2.

4.3.2.4   Conformance

The conformance test suite for the operating bandwidth shall be as defined in clause 6.5.4.

Conformance shall be established under normal test conditions according to clause 5.2.4.

The interpretation of the results for the measurement uncertainty shall be as given in clause 5.3.

4.3.3   Maximum value of mean power spectral density

4.3.3.1   Applicability

This requirement shall apply to all DUT.

4.3.3.2   Description

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

4.3.3.3   Limits

The maximum mean power spectral density shall not exceed the limits stated in table 3.

The tests shall be performed according to the measurement procedure in clause 6.5.5.

Table 3: Limits of LPR emissions in the LPR operating bandwidths [i.13]

Assigned frequency band	Maximum Mean e.i.r.p. spectral density (dBm/MHz) within the LPR operating bandwidths (within main beam)	Maximum mean e.i.r.p. spectral density on half-sphere (dBm/MHz) (see note 1)	Equivalent maximum radiated field strength levels (dBµV/m) at 3 m in case of radiated field strength measurement (within main beam) (see note 2)
6 GHz to 8,5 GHz	-33	-55	62,26
24,05 GHz to 26,5 GHz	-14	-41,3	81,26
57 GHz to 64 GHz	-2	-41,3	93,26
75 GHz to 85 GHz	-3	-41,3	92,26
NOTE 1: The maximum mean e.i.r.p. spectral density limits on half sphere around LPR installation accounts for both the LPR antenna side-lobe emissions and any reflections from the measured material/object. Compliance with these limits is assumed when LPR devices comply with measured maximum mean e.i.r.p. spectral density limits within main beam. Direct measurement of the spectral density on half-sphere is not required. NOTE 2: 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.3] and the FCC Revision of part 15 of the Commission Rules Regarding Ultra- Wideband Systems [i.4]. The preferred test distance for radiated measurements is 3 m provided that far field conditions are achieved, i.e. $d > 2 \times D^2/\lambda$, 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.			

4.3.3.4   Conformance

The conformance test suite for maximum value of mean power spectral density shall be as defined in clause 6.5.5.2 for radiated test setup and in clause 6.5.5.3 for conducted test setup.

The manufacturer shall declare which test setup is used. This shall be stated in the test report.

Conformance shall be established under normal test conditions according to clause 5.2.4.

The interpretation of the results for the measurement uncertainty shall be as given in clause 5.3.

4.3.4   Maximum value of peak power

4.3.4.1   Applicability

This requirement shall apply to all DUT.

4.3.4.2   Description

The maximum peak power specified as e.i.r.p. contained in a 50 MHz bandwidth within the permitted frequency band of operation (clause 4.3.1), radiated in the direction of the maximum level under the specified conditions of measurement.

4.3.4.3   Limits

The maximum peak power limit shall not exceed the limits given in table 4.

The tests shall be performed according to the measurement procedure in clause 6.5.6.

Table 4: Maximum peak power limit EIRP [i.13]

Frequency (GHz)	Maximum peak power (dBm, measured in 50 MHz) (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 < 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.3] and the FCC Revision of part 15 of the Commission Rules Regarding Ultra- Wideband Systems [i.4]. The preferred test distance for radiated measurements is 3 m provided that far field conditions are achieved, i.e. d > 2 × D²/λ, 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.		

4.3.4.4 Conformance

The conformance test suite for the maximum peak power shall be as defined in clause 6.5.6.2 for radiated test setup and in clause 6.5.6.3 for conducted test setup.

The manufacturer shall declare which test setup is used. This shall be stated in the test report.

Conformance shall be established under normal test conditions according to clause 5.2.4.

The interpretation of the results for the measurement uncertainty shall be as given in clause 5.3.

4.3.5 Exterior limits

Not applicable for Level Probing Radar.

4.3.6 Low duty cycle

Not applicable for Level Probing Radar.

4.3.7 Other emissions

4.3.7.1 Applicability

This requirement shall apply to all DUT only if other emissions can be clearly demonstrated.

4.3.7.2 Description

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 a transmitter 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 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 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.

4.3.7.3   Limits

Other narrowband emissions shall not exceed the values in table 5.

Table 5: Other narrowband emission limits [i.1]

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 6.

Table 6: Other wideband emission limits [i.1]

Frequency range	Limit
below 1 GHz	-61,3 dBm (e.r.p.)
above 1 GHz	-51,3 dBm (e.i.r.p.)

4.3.7.4   Conformance

The conformance tests for Other Emissions (OE) shall be as defined in clause 6.5.9 of the present document.

Conformance shall be established under normal test conditions according to clause 5.2.4.

The interpretation of the results for the measurement uncertainty shall be as given in clause 5.3.

4.3.8   Transmitter unwanted emissions

4.3.8.1   Applicability

This requirement shall apply to all DUT.

4.3.8.2   Description

The transmitter unwanted emissions are measured as maximum mean power spectral density (specified as e.i.r.p.) of the radio device under test at all other frequencies except the operating bandwidth (see clause 4.3.2). It is the average power per unit bandwidth (centred on that frequency) radiated in the direction of the main antenna beam under the specified conditions of measurement.

4.3.8.3   Limits

The maximum mean power spectral density shall not exceed the limits stated in tables 7 and 8.

The tests shall be performed according to the measurement procedure in clause 6.5.5.

Table 7: Limits of transmitter unwanted emissions for LPR
operating in the 6 GHz to 8,5 GHz frequency range [i.13]

Frequency (GHz)	Maximum value of mean power spectral density (within main beam) (dBm/MHz)	Maximum mean e.i.r.p. spectral density limit on half-sphere (dBm/MHz) (see note 1)	Equivalent maximum radiated field strength levels (dBµV/m) at 3 m in case of radiated field strength measurement (within main beam) (see note 2)
f ≤ 1,73	-63	-85	32,26
1,73 < f ≤ 2,7	-58	-80	37,26
2,7 < f ≤ 5	-48	-70	47,26
5 < f < 6	-43	-65	52,26
8,5 < f ≤ 10,6	-43	-65	52,26
f > 10,6	-63	-85	32,26
NOTE 1: The maximum mean e.i.r.p. spectral density limits on half sphere around LPR installation accounts for both the LPR antenna side-lobe emissions and any reflections from the measured material/object. Compliance with these limits is assumed when LPR devices comply with measured maximum mean e.i.r.p. spectral density limits within main beam. Direct measurement of the spectral density on half-sphere is not required.			
NOTE 2: 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.3] and the FCC Revision of part 15 of the Commission Rules Regarding Ultra-Wideband Systems [i.4]. The preferred test distance for radiated measurements is 3 m provided that far field conditions are achieved, i.e. $d > 2 \times D^2/\lambda$, where D is the maximum aperture dimension of the measuring antenna and □ 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 8: Limits of transmitter unwanted emissions for LPR
operating outside of the 6 GHz to 8,5 GHz frequency range [i.13]

Assigned frequency band	Frequency (GHz)	Maximum value of mean power spectral density (within main beam) (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 operating bandwidths the maximum value of mean power spectral density (dBm/MHz) shall be 20 dB less than the in-band density specified in table 3. For LPR operating within the 24,05 GHz to 26,5 GHz band, the unwanted emissions in the 23,6 GHz to 24,0 GHz "passive band" shall be at least 30 dB less than the in-band limits specified in table 3.
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	

4.3.8.4   Conformance

The conformance test suite for maximum value of mean power spectral density shall be as defined in clause 6.5.5.

Conformance shall be established under normal test conditions according to clause 5.2.4.

The interpretation of the results for the measurement uncertainty shall be as given in clause 5.3.

4.4   Receiver conformance requirements

4.4.1   General

The receiver conformance requirements defined below are specified according to the framework as set out in ETSI TS 103 361 [6].

4.4.2   Receiver spurious emissions

4.4.2.1   Applicability

Receiver spurious emission testing shall apply only when the equipment can work in a receive-only mode or is a receive-only device.

For collocated TX/RX equipment that does not have a receive-only mode the receiver spurious are considered within the scope of Other Emissions in clause 4.3.7.

4.4.2.2   Description

Receiver spurious emissions are emissions at any frequency when the equipment is in receive-only mode. Consequently, receiver spurious emission testing applies only when the equipment can work in a receive-only mode or is a receive-only device.

4.4.2.3   Limits

The narrowband spurious emissions of the receiver shall not exceed the values in table 9.

Table 9: Narrowband spurious emission limits for receivers [i.1]

Frequency range	Limit
30 MHz to 1 GHz	-57 dBm (e.r.p.)
above 1 GHz to 40 GHz	-47 dBm (e.i.r.p.)

The above limit values apply to narrowband emissions, e.g. as caused by local oscillator leakage.

Wideband spurious emissions shall not exceed the values given in table 10.

Table 10: Wideband spurious emission limits for receivers [i.1]

Frequency range	Limit
30 MHz to 1 GHz	-61,3 dBm (e.r.p.)
above 1 GHz to 40 GHz	-51,3 dBm (e.i.r.p.)

4.4.2.4   Conformance

The conformance test suite for the receiver spurious emissions shall be as defined in clause 6.5.9.

Conformance shall be established under normal test conditions according to clause 5.2.4.

The interpretation of the results for the measurement uncertainty shall be as given in clause 5.3.

4.4.3   Interferer signal handling

4.4.3.1   Applicability

This requirement shall apply to all DUT.

4.4.3.2   Description

Interferer signal handling is defined as the capability of the device to properly operate in presence of interferers in a defined frequency range without exceeding a given degradation due to the presence of an interfering input signal at the receiver.

This quality of the Radar under test ensures a proper operation in an environment where several users share an assigned frequency band and demonstrates the efficient use of radio spectrum by way of an increased resilience against harmful interference in the operating bandwidth of the Radar under test.

The intended use of an LPR device is to measure the distance to a liquid or solid material, for example in a tank, in order to determine its filling level. The performance criterion for interferer signal handling is the distance value variation Δd which is observed during the measurement against a fixed Radar target over a defined period of time under the influence of an interfering signal.

The measurement target in this real scenario (referring to clause 6.6.3.3) is a smooth flat surface consisting of a material with relative permittivity ε_r in a defined distance to the LPR antenna. In this scenario a specular reflection at the surface can be assumed.

The manufacturer states the combination of the minimum relative permittivity ε_r and the maximum approved measurement distance R_{max} which the individual LPR sensor is still able to reliably measure under the influence of an interferer using a specific antenna with gain G.

The values for ε_r, R_{max} and G shall be noted in the user manual and in the "application form for testing". The template of this form can be found in annex B.

The measurement value variation Δd observed under interference conditions over at least 120 seconds or 40 times the step response time of the sensor, whichever is longer, shall not exceed a defined limit.

4.4.3.3   Limits

The maximum allowed measured distance value variation Δd under interference conditions shall not exceed ±50 mm.

EXAMPLE: The manufacturer states for example that for a K-band LPR sensor with an antenna gain of 25 dBi (centre frequency 25 GHz) , the maximum allowed measurement value variation of Δd = ±50 mm is still met under the influence of an interfering signal for a maximum approved measurement distance of 25 m against a material with a relative permittivity $\varepsilon_r = 4,5$.

The performance criterion and the level of performance shall be stated in the user manual and in the "application form for testing" (an example of such a form is given in annex B).

The following text shall be used in the user manual:

"For the receiver test that covers the influence of an interferer signal to the device, the performance criterion has at least the following level of performance according to ETSI TS 103 361 [6].

- Performance criterion: measurement value variation Δd over time during a distance measurement

- Level of performance: Δd ≤ ±50 mm".

4.4.3.4   Conformance

The conformance test suite for interferer signal handling shall be as defined in clause 6.6.3.5 for the radiated equivalent scenario.

The conformance test suite for interferer signal handling shall be as defined in clause 6.6.3.6 for the conducted equivalent scenario.

The conformance test suite for interferer signal handling shall be as defined in clause 6.6.3.9 for the radiated alternative scenario.

The conformance test suite for interferer signal handling shall be as defined in clause 6.6.3.10 for the conducted alternative scenario.

Thus there are altogether four possible test setups, which can be equivalently used in order to demonstrate the conformity of the DUT.

The manufacturer shall declare which test setup is used. This shall be stated in the test report.

Conformance shall be established under normal test conditions according to clause 5.2.4.

The interpretation of the results for the measurement uncertainty shall be as given in clause 5.3.

4.5 Requirements for spectrum access

4.5.1 Detect and avoid (DAA)

Not applicable to Level Probing Radar.

4.5.2 Listen-before-talk (LBT)

Not applicable to Level Probing Radar.

4.5.3 Low duty cycle (LDC)

Not applicable to Level Probing Radar.

4.6 Antenna requirements

4.6.1 Characteristics and orientation

4.6.1.1 Applicability

This requirement shall apply to all DUT.

4.6.1.2 Description

All LPR installations are with downwards installed directional LPR antennas. The wanted emission limits of LPR are measured in this standard in the main beam of the LPR antenna in order to simplify the measurements scenarios. But the following constraints to the LPR antenna are the logical consequence to ensure the protection of other radio users from sidelobe emissions and reflections.

- Strict (stable) downward orientation of LPR antennas under any operating conditions shall be ensured.

- The maximum antenna beamwidth according to table 11: it is defined by -3 dB levels relative to the maximum antenna gain and expressed as HalfPowerBeamWidth (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 main beam 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.8].

4.6.1.3   Limits

The maximum antenna total opening angle (half power beamwidth HPBW) is shown in table 11. In the antenna pattern the side lobe suppression in elevation angles above 60 degrees from the main beam has to fulfil the limits also shown in table 11.

NOTE: The side lobe suppression limits are equal to what is specified in the FCC standard [i.14].

Table 11: Maximum antenna beamwidth and side lobe suppression [i.8]

Assigned frequency band	Maximum antenna beamwidth, in degree (°)	Antenna side lobe suppression relative to the main beam gain in elevation angles above 60 degrees (dB)
6 GHz to 8,5 GHz	12	-22
24,05 GHz to 26,5 GHz	12	-27
57 GHz to 64 GHz	8	-39
75 GHz to 85 GHz	8	-38
NOTE: The side lobe suppression limits are equal to what is specified by FCC [i.14]. Those values are assumed to be equivalent to a maximum antenna gain of -10 dBi above 60 degrees according to ECC/DEC/(11)02 [i.20].		

The LPR antenna shall be installed at a permanent fixed position pointing in downward direction. In addition the antenna positioning, or height from the ground, shall 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 GHz 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 E).

- 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 printing them in the product manual).

4.6.1.4   Conformance

The conformance requirement for antenna characteristics and orientation shall be as defined in clause 6.8.

If the antenna characteristics are measured the conformance shall be established under normal test conditions according to clause 5.2.4 and the interpretation of the results for the measurement uncertainty shall be as given in clause 5.3.

4.7   Other requirements and mitigation techniques

4.7.1   General

The LPR applications covered by the present document shall use one mitigation technique described in this clause in addition to the antenna requirements of clause 4.6. The mitigation techniques described in the following clauses 4.7.2 to 4.7.6 may affect the measured emission values as described in clauses 4.3.3, 4.3.4 and 4.3.8.

The mitigation factors are classified into following categories:

- adaptive power control (APC);

- activity factor and duty cycle;

- frequency domain mitigation;

- shielding effects;

- equivalent mitigation techniques.

Mitigation factors are declared and need sufficiently be demonstrated and documented by the provider

The range of modulation parameters in clause 4.7.7 cannot be used as a mitigation technique.

4.7.2   Adaptive power control (APC)

4.7.2.1   Applicability

This requirement shall apply to all DUT which implemented this mitigation technique. The usage shall be declared by the manufacturer.

4.7.2.2   Description and general requirements

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 shall be at least 20 dB nominal, and shall be controlled with at least 4 steps with nominal 5 dB increments.

> NOTE: SEAMCAT simulations in the ECC Report on LPR [i.8] showed that Adaptive Power Control (APC) with a dynamic range of about 20 dB, as proposed in the ETSI System Reference Document ETSI TR 102 601 [i.9] 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.

4.7.2.3   Limits

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

4.7.2.4   Conformance

The conformance test suite for adaptive power control (APC) shall be as defined in clause 6.9.1.

Conformance shall be established under normal test conditions according to clause 5.2.4.

The interpretation of the results for the measurement uncertainty shall be as given in clause 5.3.

4.7.3   Activity factor and duty cycle

4.7.3.1   Applicability

This requirement shall apply to all DUT which implemented this mitigation technique. The usage shall be declared by the manufacturer. This mitigation technique is an equivalent mitigation technique as mentioned in European Commission Decision 2013/752/EU [i.13].

4.7.3.2   Description

The activity factor (AF) of the LPR device can be taken into account for additional 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 an additional mitigation technique. Further information is given in annex H on LPR modulation schemes. An AF and/or spreading of subsequent pulses on different frequencies of 10 % represent an interference mitigation of 10 dB. Examples are: power on-/off-gating, dithering, etc.

The activity factor (AF) is usually applied with both, FMCW modulation as well as pulse modulation. It is defined as the ratio of active measurement periods t_{meas} (bursts, sweeps, scans) within the overall repetitive measurement cycle T_{meas_cycle}, i.e.

$$AF = \frac{t_{meas}}{T_{meas\_cycle}} \tag{1}$$

For pulse modulation for example, the transmit signal is periodically switched on for a short time (called pulse duration) and switched off during the subsequent reception period until the next pulse is transmitted. The duty cycle (DC) is defined as the product of the pulse repetition frequency (PRF) and the pulse duration.

For FMCW modulation a duty cycle is also applicable if the overall frequency sweep is interrupted for example several times with the transmit signal switched off during this interruption period. This modulation scheme is sometimes called stepped frequency continuous wave (SFCW).

In sources dealing with UWB devices this duty cycle is sometimes called "duty cycle resulting from modulation". Further information about duty cycle can be extracted from annex H.

Duty cycle (DC) is defined as:

$$DC = PRF \cdot t_{pulse} = \frac{t_{pulse}}{PRI} \tag{2}$$

where:

- t_{pulse} is the pulse duration in a pulsed system or the duration of an individual frequency step in an SFCW modulation scheme;

- PRF is the pulse repetition frequency;

- PRI is the pulse repetition interval or pulse period.

The total effective duty cycle is the product of the activity factor (AF) and the duty cycle (DC).

4.7.3.3 Limits

Activity factor and duty cycle, when implemented, shall achieve a reduction of 20 dB. The formulas to achieve the reduction are given in clause 4.7.3.2.

4.7.3.4 Conformance

The activity factor and duty cycle of the LPR are declared by the manufacturer according to clause 6.9.2.

4.7.4 Frequency domain mitigation

4.7.4.1 Applicability

This requirement shall apply to all DUT which implemented this mitigation technique. The usage shall be declared by the manufacturer. This mitigation technique is an equivalent mitigation technique as mentioned in European Commission Decision 2013/752/EU [i.13].

4.7.4.2 Description

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 continuous wave Radar (SFCW) sweeps ca. 1 000 steps, within a period of approximately 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.

4.7.4.3 Limits

Frequency domain mitigation, when implemented, shall achieve a reduction of 20 dB. An example how to achieve the reduction is given in clause 4.7.4.2.

4.7.4.4   Conformance

The frequency domain mitigation of the LPR is declared by the manufacturer according to clause 6.9.3.

4.7.5   Shielding effects

4.7.5.1   Applicability

This requirement shall apply to all DUT which implemented this mitigation technique. The usage shall be declared by the manufacturer. This mitigation technique is an equivalent mitigation technique as mentioned in European Commission Decision 2013/752/EU [i.13].

4.7.5.2   Description and general requirement

Emissions caused by LPR can be reduced by shielding effects due to a special installation environment.

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 Recommendation ITU-R P.526-13 [i.5]. 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 Recommendation ITU-R P.526-13 [i.5]. 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.

4.7.5.3   Limits

Shielding effects, when implemented, shall achieve a reduction of 20 dB.

4.7.5.4   Conformance

The mitigation due to shielding effects of the LPR is declared by the manufacturer. No test needs to be conducted.

4.7.6   Equivalent mitigation techniques

4.7.6.1   Applicability

This requirement shall apply to all DUT which implemented this mitigation technique. The usage shall be declared by the manufacturer.

4.7.6.2   Description and general requirement

Other mitigation techniques and mitigation factors can be taken into account for the calculation of the maximum allowed TX power of an LPR radio device as long as 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.8]. Examples for additional mitigation factors could be the deployment of the radio device in a restricted indoor area with higher wall attenuation or shielding. The additional mitigation factors need to be weighed against the specific services to be protected.

The manufacturer shall provide sufficient information for determining compliance with the LPR emission limits in clauses 4.3.3.3, 4.3.4.3 and 4.3.8.3 when using equivalent mitigation techniques.

> NOTE: Regulations in the EC Decision 2009/343/EC [i.10] 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.

4.7.6.3   Limits

Equivalent mitigation techniques, when implemented, shall achieve a reduction of 20 dB.

4.7.6.4 Conformance

The equivalent mitigation techniques of the LPR is declared by the manufacturer. No test needs to be conducted.

4.7.7 Range of modulation parameters

4.7.7.1 Applicability

This requirement shall apply to all DUT.

4.7.7.2 Description

The description of the modulation parameters can be found in annex H.

4.7.7.3 Limits

There are no limitations for modulation parameters.

4.7.7.4 Conformance

The modulation parameters of the LPR shall be declared by the manufacturer. No test needs to be conducted.

5 Testing for compliance with technical requirements

5.1 Environmental conditions for testing

Tests defined in the present document shall be carried out at representative points within the boundary limits of the declared operational environmental profile.

Where technical performance varies subject to environmental conditions, tests shall be carried out under a sufficient variety of environmental conditions (within the boundary limits of the declared operational environmental profile) to give confidence of compliance for the affected technical requirements.

5.2 General conditions for testing

5.2.1 Product information

The product information required for testing can be found in the "application form for testing" in annex B.

5.2.2 Product information useful to facilitate testing

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 test conditions and for the choice of equipment for testing purposes (clause 5), technical requirements specifications (clause 4) and the conformance test suits (clause 6).

The manufacturer shall offer complete equipment with any auxiliary equipment needed for testing. All necessary set-up information shall accompany the LPR equipment when it is submitted for testing.

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

In order to facilitate testing, the provider should give the following information:

- technical data in the form in annex B;

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

5.2.3   Requirements for the test modulation

Requirements for the test modulation are specified in ETSI EN 303 883 [5], clause 5.3.

5.2.4   Test conditions, power supply and ambient temperatures

Test conditions, power supply- and ambient temperature requirements are specified ETSI EN 303 883 [5], clause 5.4.

5.2.5   Choice of equipment for test suites

The equipment for the test suites shall be chosen according to ETSI EN 303 883 [5], clause 5.5.

If the submitted 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 and activity factor of the transmitter as declared by the provider shall not be exceeded. The actual duty cycle and activity factor 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.

5.2.6   Multiple operating bandwidths and multiband equipment

Where equipment has more than one operating bandwidth (e.g. 500 MHz and 1 300 MHz), a minimum of two operating bandwidths shall be chosen such that the lower and higher limits of the operating range(s) of the equipment are covered (see clause 4.3.2). All operating bandwidths of the equipment shall be declared by the equipment manufacturer.

In case of multiband equipment (i.e. equipment that can operate with an operating bandwidth below 4,8 GHz and above 6,0 GHz), the lowest and highest channel in operation of each band shall be tested.

5.2.7   Testing of host connected equipment and plug-in radio devices

Testing of host connected equipment and plug-in radio devices measurements shall be according to ETSI EN 303 883 [5], clause 5.6.

5.2.8   Radiated measurement arrangements

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 C.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 C.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 4.3, 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 (refer to clause C.2.4), the measured device emissions, the achievable measurement noise floor and the frequency range(s) involved.

> NOTE: This is called "best measurement practice".

5.3   Interpretation of the measurement results

5.3.1   General

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 12, and the interpretation procedure specified in clause 5.3.1 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 ETSI 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 12 is based on such expansion factors.

Table 12: Maximum measurement uncertainties [i.11]

Parameter	Maximum expanded measurement Uncertainty
Radio frequency	$\pm 1 \times 10^{-7}$
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 shall 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.

5.3.2   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 harmonics. 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.

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 analyser 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 analysers can only measure up to around 67 GHz, thus making the use of external mixers unavoidable.

Guidance is provided in ETSI TS 103 051 [i.16] 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.

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

If measurement uncertainty is equal to or less than maximum acceptable uncertainty the interpretation shall be as given in clause 5.7.2 of ETSI EN 303 883 [5].

5.3.4   Measurement uncertainty is greater than maximum acceptable uncertainty

If measurement uncertainty is greater than maximum acceptable uncertainty the interpretation shall be as given in clause 5.7.3 of ETSI EN 303 883 [5].

5.3.5   Emissions

Some of the measured radiated transmitter 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 transmitter emissions used for level probing (e.g. by disabling the device's transmitter) or it can clearly be demonstrated that it is impossible to differentiate between other unwanted emissions and the transmitter emissions that emission or aggregated emissions shall be considered against the other emissions limits (referring to clause 4.3.7).

6   Conformance test suite

6.1   Introduction

Shall be as in ETSI EN 303 883 [5], clause 6.1.

6.2   Initial measurement steps

Shall be as in ETSI EN 303 883 [5], clause 6.2.

6.3   Radiated measurements

6.3.1   General

Shall be as in annex C.

6.3.2   Test sites and general arrangements for measurements involving the use of radiated fields

Shall be as in annexes C, and J. Further description is given in annexes F and G.

6.3.3   Guidance on the use of a radiation test site

The guidance on the use of a radiation test side shall be as in clause C.2.

The range length is described in annex G.

6.3.4   Coupling of signals

Shall be as in clause C.3.

6.3.5   Standard test methods

The calibrated setup shall be as in clause C.4.1 and the substitution method shall be as in clause C.4.2.

6.3.6   Standard calibration method

Shall be as in ETSI EN 303 883 [5], clause 6.3.6.

6.4   Conducted measurements

6.4.1   General Setup

Shall be as in ETSI EN 303 883 [5], clause 6.4.

6.4.2   Specific Setup

Not applicable to Level Probing Radar.

6.5   Conformance test suite for transmitter parameters

6.5.1   General

First the EUT shall be measured for:

- the operating bandwidth(s);

- the maximum mean power spectral density (e.i.r.p.);

- the maximum value of peak power (e.i.r.p.);

- the transmitter unwanted emissions;

- the other emissions (OE).

The following methods of measurement shall apply to the testing of stand-alone units and to the equipment configurations identified in clause 5.2.2.

6.5.2   Method of measurements of the ultra-wideband emissions

Not applicable to Level Probing Radar.

6.5.3   Permitted frequency range of operation

No test necessary.

6.5.4   Operating bandwidth

Measurements for the TLPR/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 down convert 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 down converted 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 (f_C) 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 as explained in annex G.

The radiated method is shown in figure 2.

G_A: Gain of the measurement antenna
G_{LNA}:   Gain of the measurement LNA
g_{LNA}:   Gain of Measurement LNA [dB]
g_A: Gain of Measurement antenna [dBi]
cl1 and cl2:   cable loss [dB]
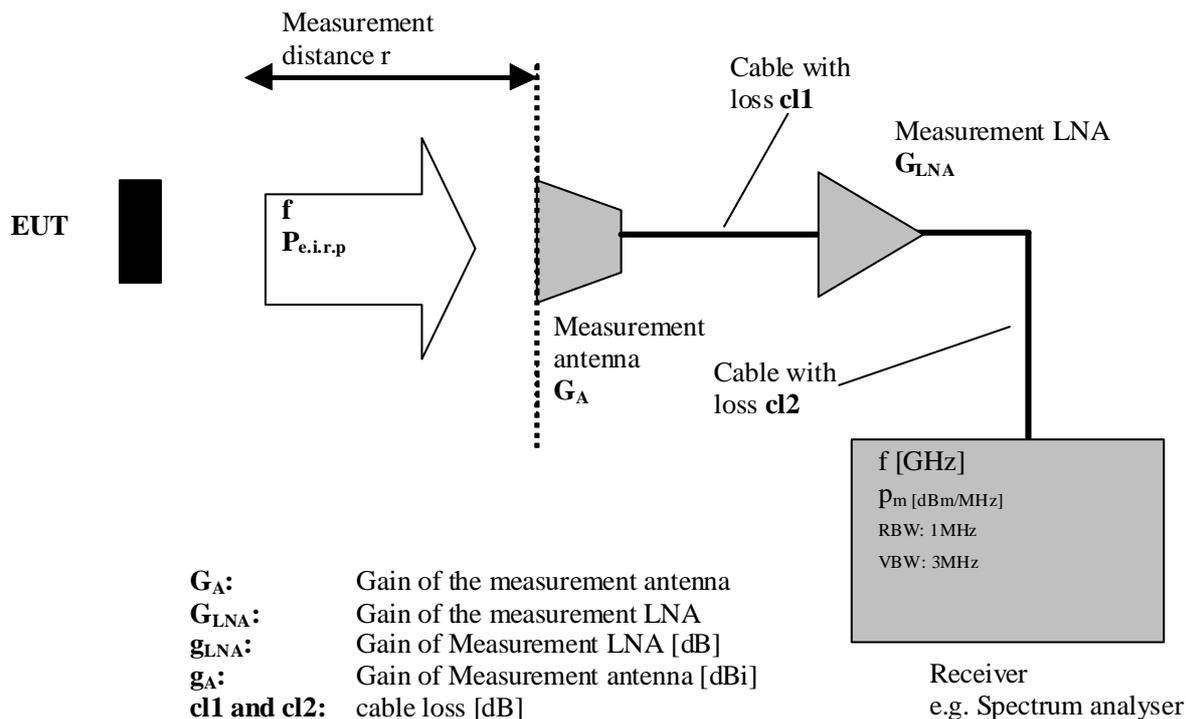
Figure 2: Test set-up for measuring the operating bandwidth

For radiated measurements, a test site selected from annex C 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 lower and upper frequency bounds f_L and f_H are measured as follows:

a)   Set the spectrum analyser detector to positive peak.

b)   Centre the span on the peak of the radiation (f_C) and set the span to a reasonable value larger than the expected operating bandwidth.

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.

d)   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.

e)   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.

6.5.5   Mean power spectral density measurements

6.5.5.1   Description

This measurement method is used for measuring the maximum value of mean power spectral density within the operating bandwidth and the transmitter unwanted emissions outside the operating bandwidth in main beam direction. Measurements of the emissions shall be performed in the frequency ranges given in table 13.

Table 13: Frequency ranges for measurement of emissions

Assigned frequency band	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 CEPT/ERC/REC 74-01 [i.1], 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 13. 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 down convert 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 down converted 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.

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. 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.

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 Recommendation ITU-R SM.1754 [i.2] for details).

Average time (per point on spectrum analyser scan):   1 ms or less for measuring pulsed LPR instrument.

Averaging time of 1 ms per measurement point is not sufficient to measure FMCW or other swept signals as well as pulsed signals with measurement cycles longer than 1 ms as described in clauses H.1 and H.2. The maximum signal repetition time shall be taken into account to set the sweep time of the spectrum analyser properly.

$$sweeptime \geq (t_{meas} + t_G)\frac{total\_measurement\_BW}{RBW} \qquad (3a)$$

To ensure coincidence, the measurement should also be repeated using different analyser sweep times fulfilling the condition stated above. The FMCW period of time for modulation for example used in the formula above is t_{meas} and t_G is the blanking time, defined in clause H.2. For pulse modulated signals please compare clause H.1.

When using spectrum analyser sweep times calculated with the formula above, the frequency domain and activity factor mitigation techniques as well as the duty cycle mitigation factor are included in the measurement results.

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 13.

For LPR operating within the assigned frequency band 6 GHz to 8,5 GHz, this test shall be repeated at the frequencies of the band edges at 1,73 GHz, 2,7 GHz, 5 GHz, 6 GHz, 8,5 GHz and 10,6 GHz as shown in table 14.

For LPR operating within any other assigned frequency band, this test shall be repeated at 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 14.

The measurements at the frequency band edges shall be performed at the frequency offsets as shown in table 14.

Table 14: 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 14 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.

6.5.5.2   Radiated mean power spectral density measurements

For radiated measurements, a test site selected from annex C 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 beam width of the antenna" during this test.

6.5.5.3   Conducted mean power spectral density measurements

Conducted measurements can be performed instead of radiated measurements for the permitted frequency ranges of operation as stated in clause 4.3.1 for the DUT, if it provides an antenna connector.

6.5.6   Peak power measurements

6.5.6.1   Description

The maximum peak power (e.i.r.p.) shall be measured over the whole permitted frequency band of operation (clause 4.3.1).

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 down convert 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 down converted 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.

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 antennae. 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.

When measuring maximum peak power from the device under test, the spectrum analyser used should be configured as follows:

- Frequency: Centre frequency of operating bandwidth. Reasonable frequency span of the spectrum analyser to cover the operating bandwidth.

- 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 a repetition of the measurement under clause 6.5.5 using a peak detector. Proper spectrum analyser settings should be used to ensure coincidence between the measuring receiver and the FMCW modulation.

NOTE 2: For peak power measurements of pulse modulated LPR, the best signal to noise ratio is usually obtained with the widest available resolution bandwidth. On the other hand, spectrum analysers tend to be too slow for higher resolution bandwidths. A suitable resolution bandwidth should be applied (please compare note 4).

- 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.

NOTE 4: 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 peak power measured value should be corrected with a factor of 20 log (50/X) for pulsed LPR. For FMCW or other swept frequency method the correction should not be applied since these signals are narrowband signals with full power within the resolution bandwidth of the SA.

6.5.6.2   Radiated peak power measurements

For radiated measurements, a test site selected from annex C 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.

6.5.6.3   Conducted peak power measurements

Conducted measurements can be performed instead of radiated measurements for the permitted frequency ranges of operation as stated in clause 4.3.1 for the DUT if the equipment provides an antenna connector.

6.5.7   Exterior limit measurement

Not applicable to Level Probing Radar.

6.5.8   Total power

Not applicable to Level Probing Radar.

6.5.9   Other emissions

The transmitter shall be switched on, with normal radar signal and the spectrum analyser 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.

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 C 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 4.3.7.3. Each occurrence shall be recorded.

Measurements shall be performed over the frequency ranges given in table 13 in clause 6.5.5.

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 wideband emissions:

- resolution BW: 100 kHz below 1 GHz; 1 MHz above 1 GHz;

- video BW: not less than the resolution BW;

- detector mode: RMS;

- averaging: off;

- frequency span: Equal to or less than the number of displayed samples multiplied by the resolution bandwidth;

- amplitude: adjust for middle of the instrument's range;

- Average time (per point on spectrum analyser scan): 1 ms or less for measuring pulsed LPR instruments.

An average time of 1 ms per measurement point is not sufficient to measure FMCW or other swept signals as well as pulsed signals with measurement cycles longer than 1 ms as described in clauses H.1 and H.2. The maximum signal time shall be taken into account to set the sweep time of the spectrum analyser properly.

$$sweeptime \geq (t_{meas} + t_G)\frac{total\_measurement\_BW}{RBW} \qquad (3b)$$

To ensure coincidence, the measurement should also be repeated using different analyser sweep times fulfilling the condition stated above. The FMCW period of time for modulation for example used in the formula above is t_{meas} and t_G is the blanking time, see also clause H.2. For pulsed modulated signals please compare clause H.1.

When using spectrum analyser sweep times calculated with the formula above the frequency domain and activity factor mitigation techniques as well as the duty cycle mitigation factor are included in the measurement results.

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 4.3.7.3 in order to prove compliance with the requirements.

6.6 Conformance test suite for receiver parameters

6.6.1 Receiver spurious emissions

The conformance test suite for the receiver spurious emissions shall be used as defined for other emissions in clause 6.5.9.

6.6.2 Receiver sensitivity

Not applicable according to ETSI TS 103 361 [6].

6.6.3 Interferer signal handling

6.6.3.1 Description and general requirement

Interferer signal handling is defined as the capability of the device to properly operate in coexistence with interferers in a defined frequency range without exceeding a given degradation due to the presence of an interfering input signal at the receiver.

The interferer test frequency range, interferers and interferer power levels, test scenario, performance criterion and level of performance shall be recorded in the test report.

6.6.3.2 Interferer frequencies and power levels

The interferer frequencies and power levels which have to be applied to the LPR under test, shall be determined using the procedures described in ETSI TS 103 361 [6].

The determined interferer frequencies and power levels can be found in the "application form for testing" (see annex B).

To simplify and speed-up the test, the highest determined interferer power level may be used for all determined interferer frequencies in the respective "interferer test frequency range".

6.6.3.3   Real scenario

The real measurement scenario against a smooth flat surface consisting of a material with relative permittivity ε_r at the maximum approved measurement distance R_{max} under interference conditions as described in clause 4.4.3.2 is not feasible in practice. This would lead to complex test setups, as there are sensors on the market which are able to measure distances beyond 100 m. Therefore the equivalent scenario (clause 6.6.3.4) and the alternative scenario (clause 6.6.3.8) are proposed which may be conveniently conducted for example in the limited space provided in an anechoic chamber described in clause C.1.

The equivalent and alternative scenarios shall accurately reflect the conditions of the real scenario either in a radiated measurement setup at a shorter distance or in a conducted setup. In order to establish equality to the real scenario two main inputs are necessary:

1)   The received power P_{r_real} which is radiated back in the real scenario from the above defined surface into the receiver. This power can be calculated by means of R_{max}, ε_r and gain G of the LPR antenna.

2)   The power levels and frequencies of the considered interferers (see clause 6.6.3.2).

R_{max}, ε_r and the antenna gain G of the LPR under test can be extracted from the "application form for testing" (see annex B). If the LPR sensor can be equipped with different antennas, a specific set of parameters (R_{max}, ε_r and G) effectively exists for every single antenna resulting in the same received echo power P_{r_real}. Therefore it is sufficient to test the LPR sensor only with one set of parameters for one representative LPR antenna.

It should be noted that R_{max} is not necessarily the maximum measurement distance of the LPR.

The received power P_{r_real} can be calculated according to the following equation, assuming a specular reflection at the surface:

$$P_{r\_real} = \frac{P_t G^2 \lambda^2 |r|^2}{(8\pi R_{max})^2} \qquad (4)$$

Expressed in a logarithmic form leads to the following equation:

$$P_{r\_real}^{dBm} = P_t^{dBm} + 20\,log\,G + 20\,log\,\lambda + 20\,log\,|r| - 20\,log\,R_{max} - 28dB \qquad (5)$$

$P_{r\_real}\left(P_{r\_real}^{dBm}\right):$ received echo power in the real measurement scenario in Watt (in dBm)

$P_t\left(P_t^{dBm}\right):$ maximum value of peak power of the LPR in Watt (in dBm)

$G:$ gain of the LPR antenna in the direction of main radiation (main lobe axis)

$\lambda:$ wavelength of the transmit signal at centre frequency

$R_{max}:$ maximum approved measurement distance of the LPR under interference conditions

$r:$ reflection coefficient of the considered surface

The reflection coefficient of the transition from air to the surface material with relative permittivity ε_r can be approximated by:

$$r \approx \frac{1-\sqrt{\varepsilon_r}}{1+\sqrt{\varepsilon_r}} \qquad (6)$$

$\varepsilon_r:$ relative permittivity of the considered surface material

The conformance test suite for the maximum value of peak power P_t is defined in clause 6.5.6.

EXAMPLE: From the "application form for testing" (see annex B) it can be extracted that the device is able to measure for example against a surface with a relative permittivity $\varepsilon_r = 4,5$ in a measurement distance of 25 m under interference conditions within the maximum measurement value (distance value) variation $\Delta d = \pm 50$ mm. The LPR sensor operates at a centre frequency of 25 GHz ($\lambda = 12$ mm) with an antenna gain of 25 dBi and a peak transmit power of 0 dBm at the antenna connector. With these specifications the received power from the considered surface is $-53,3$ dBm.

6.6.3.4   Equivalent scenario

The aim of the equivalent scenario is to facilitate testing and to enable the possibility to carry out the measurements in the limited space provided by an anechoic chamber (described for example in clause C.1) at a shorter measurement distance R_T ($R_T < R_{max}$).

In order to ensure the same echo signal power at the LPR receiver as in the real scenario, a suitable radar target with a well-defined Radar cross section (RCS) σ is used which is placed at a distance R_T.

The measurement at a smaller distance R_T is valid as the variation of the measured distance value of the LPR is only dependent on the signal-to-noise ratio of the echo signal and generally not on the distance to the Radar target itself.

6.6.3.5   Radiated test setup for the equivalent scenario

Figures 3 and 4 show a possible radiated test setup for the equivalent scenario. There are two signals which have to be provided to the LPR receiver simultaneously:

1)   The echo signal from the radar target which produces the power $P_{r\_equivalent}$ at the LPR receiver. In order to establish equality with the real scenario the following condition shall be met: $P_{r\_real} = P_{r\_equivalent}$.

2)   The interferer signal defined in clause 6.6.3.2.

The interferer signals are generated by means of a microwave signal generator which is connected to a test antenna with gain G_t. The test antenna is placed in a certain distance R from the LPR device, so that both antennas are ideally aligned for their main beam directions and matching polarizations.
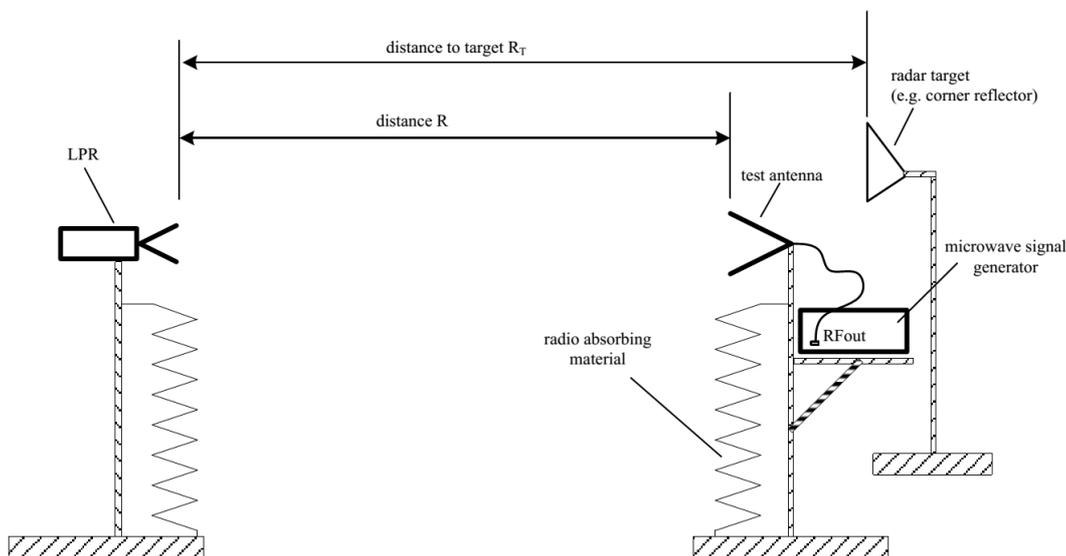
Figure 3: Radiated test setup for the equivalent scenario

It is recommended to use different distances for R_T and R, so that the LPR can separate the desired radar target (see figure 4) from the unwanted echo signal generated by the test antenna support. The LPR sensor has then to be adjusted to measure the distance to the desired radar target. In general there are built in functions and techniques which enable an LPR device to suppress echoes from unwanted reflections, like the unwanted reflections from the instrumentation supports in this measurement scenario.

For LPR antennas with a sufficiently wide main lobe, it is convenient to place both, the test antenna and the radar target, within the half power beamwidth (HPBW) of the main lobe. In this case it is proposed to use the LPR antenna gain G in the direction of main radiation (main lobe axis) instead of the gain G_α in an angle α off the main lobe axis. The error in the echo amplitude will be within 3 dB to the disadvantage of the LPR device under test.

The test should be carried out with the LPR antenna specified in the "application form for testing" (see annex B). If this is not possible, for example due to difficulties in complying with the boundary conditions in annexes K and L, it is possible to conduct the test with any another suitable antenna. The radar target has then to be adapted in size and/or distance in order to result in the same power level of the echo signal $P_{r\_equivalent}$. The interferer power level at the microwave signal generator has to be adapted as well in order to result in the same received interferer power level $P_{r\_interferer}$ at the location of the LPR.
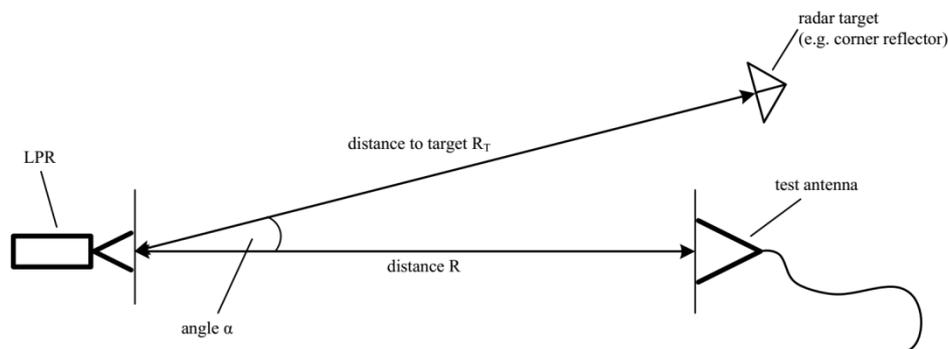
**Figure 4: Radiated test setup for the equivalent scenario
(top view of figure 3 drawn without instrumentation supports)**

Calculation of RCS σ and/or distance R_T:

The power level of the echo signal $P_{r\_equivalent}$ at the receiver during the measurement against the radar target with RCS σ can be calculated according to the following equation, which is well-known in literature as the simple form of the radar equation:

$$\frac{P_{r\_equivalent}}{P_t} = \frac{G_\alpha^2 \lambda^2 \sigma}{(4\pi)^3 R_T^4} \tag{7}$$

Expressed in a logarithmic form leads to the following equation:

$$P_{r\_equivalent}^{dBm} = P_t^{dBm} + 20\,log\,G_\alpha + 20\,log\,\lambda + 10\,log\,\sigma - 40\,log\,R_T - 33dB \tag{8}$$

$P_{r\_equivalent} \left(P_{r\_equivalent}^{dBm} \right)$:	received echo power in the equivalent measurement scenario in Watt (in dBm)
$P_t \left(P_t^{dBm} \right)$:	maximum value of peak power of the LPR in Watt (in dBm)
G_α :	gain of the LPR antenna in an angle α off the main lobe axis (see figure 4)
λ :	wavelength of the LPR transmit signal at centre frequency
R_T :	slant distance between LPR and target
σ :	radar cross section (RCS) of the target

However, the radar equation is only valid within certain boundary conditions which shall be met during the radiated test procedures. These boundary conditions are given in detail in annex L.

With the given echo power level P_{r_real} from the surface in the real scenario (see clause 6.6.3.3) it is possible to calculate the maximum RCS σ of the target at nearly arbitrary distances R_T by setting $P_{r\_real} = P_{r\_equivalent}$ and solving the resulting equation for the radar cross section σ.

The resulting equation in the logarithmic form leads to:

$$10\,log\,\sigma = 20\,log\,G - 20\,log\,G_\alpha - 20\,log\,R_{max} + 20\,log\,|r| + 40\,log\,R_T + 5dB \tag{9}$$

If the test antenna and the radar target are placed within the half power beamwidth (HPBW) of the LPR antenna, the equation can be further simplified to:

$$10 \, log \, \sigma \approx -20 \log R_{max} + 20 \, log \, |r| + 40 \, log \, R_T + 5dB \tag{10}$$

The error in the echo amplitude will thus be within 3 dB to the disadvantage of the LPR device under test.

RCS σ and R_T can be chosen freely to a certain extent (see annex L), because R_{max} and ε_r (and thus $|r|$) are set to constant values and can be extracted from the "application form for testing". However, for all choices of σ and R_T the following condition shall be met during the test:

$$P_{r\_real} \geq P_{r\_equivalent} \tag{11}$$

Suitable radar targets for the radiated test setup depend on the desired RCS σ. Conducting spheres as well as square or triangular shaped corner reflectors of different sizes are most suitable for this purpose. A comprehensive treatise of these three radar targets with their effective boundary conditions, which shall be met during the radiated test procedures, can be found in annex K.

Calculation of the transmitted interferer power:

The exact interferer power level $P_{r\_interferer}$ which shall be applied to the receiver of the LPR device can be determined following the instructions described in ETSI TS 103 361 [6] (refer to clause 6.6.3.2).

The transmitted power level of the interfering signal $P_{t\_interferer}$ which shall be fed into the test antenna in order to generate the wanted interferer power level $P_{r\_interferer}$ at the LPR receiver can be determined using Friis transmission equation:

$$\frac{P_{r\_interferer}}{P_{t\_interferer}} = G_t G \left(\frac{\lambda_{interferer}}{4\pi R} \right)^2 \tag{12}$$

Expressed in a logarithmic form and resolved for the transmitted interferer power leads to the following equation:

$$P^{dBm}_{t\_interferer} = P^{dBm}_{r\_interferer} - 10 \log G_t - 10 \log G - 20 \, log \, \lambda_{interferer} + 20 \, log \, R + 22dB \tag{13}$$

$P_{r\_interferer} \left(P^{dBm}_{r\_interferer} \right)$:	received interferer power at the location of the LPR in Watt (in dBm)
$P_{t\_interferer} \left(P^{dBm}_{t\_interferer} \right)$:	transmitted interferer power (generated by the signal generator) in Watt (in dBm)
G :	gain of the LPR antenna in the direction of main radiation (main lobe axis)
G_t :	gain of the test antenna in the direction of main radiation (main lobe axis)
$\lambda_{interferer}$:	wavelength of the interfering signal
R :	distance between LPR and test antenna

Boundary condition for the Friis transmission equation:

The Friis transmission equation is only valid if far-field conditions are applied in the measurement setups illustrated in figure 3 and figure 4. That means the LPR antenna shall be located in the far-field region of the test antenna and vice versa. From clause C.2.4 one can deduce that the range length (in the test setup illustrated in figures 3 and 4 the range length is identical to the distance R) between the two antennas shall meet the following condition:

$$R \geq \frac{2(d_1 + d_2)^2}{\lambda_{interferer}} \tag{14}$$

$d_1, \, d_2$:   largest dimensions of the physical aperture of the test antenna and the LPR antenna

If this condition cannot be fully met, the uncertainty contributions described in clause G.2 shall be taken into account.

6.6.3.6 Conducted test setup for the equivalent scenario

Figure 5 shows a possible conducted test setup for the equivalent scenario using coaxial components. For higher frequencies an identical setup can be arranged using hollow waveguide components. A profound treatise on these different waveguides can be found in annex J. There are two signals which have to be provided to the LPR receiver simultaneously:

1) The echo signal from the short circuit which produces the power $P_{r\_equivalent}$ at the LPR receiver. In order to establish equality with the real scenario the following condition shall be met: $P_{r\_real} = P_{r_{equivalent}}$.

2) The interferer signal defined in clause 6.6.3.2.

The interferer signals are generated by a microwave signal generator which is connected to the LPR by means of a coaxial RF-cable, a directional coupler and an optional coaxial attenuator.

It is recommended to use different cable lengths, so that the LPR can separate between the desired echo from the short circuited line (see figure 5) and the unwanted reflection from the RF output stage of the microwave signal generator. The LPR sensor has then to be adjusted to measure the distance to the short circuit. In general there are built in functions and techniques which enable LPR devices to suppress echoes from unwanted reflections, like the unwanted reflections from the RF output stage of the microwave signal generator.
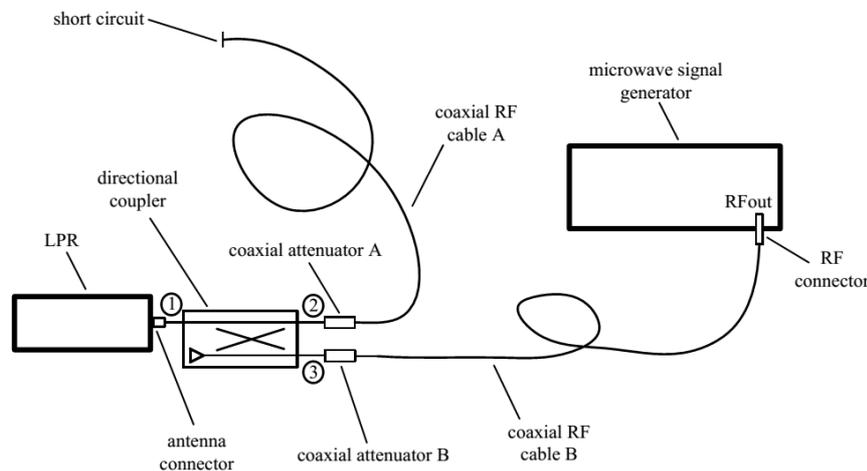
Figure 5: Conducted test setup for the equivalent scenario using coaxial components

Calculation of the required echo attenuation:

The power level of the echo signal $P^{dBm}_{r\_equivalent}$ at the LPR receiver during the measurement against the short circuit can be calculated according to the following equation:

$$P^{dBm}_{r\_equivalent} = P^{dBm}_t - 2\left(a^{dB}_{coupler(1-2)} + a^{dB}_{cable\_A} + a^{dB}_{attn\_A}\right) \tag{15}$$

$P^{dBm}_{r\_equivalent}$:	received echo power in the equivalent measurement scenario in dBm
P^{dBm}_t :	maximum value of peak power of the LPR in dBm
$a^{dB}_{coupler(1-2)}$:	coupling loss of the directional coupler between ports 1 and 2 in dB
$a^{dB}_{cable\_A}$:	cable loss of coaxial RF-cable A in dB
$a^{dB}_{attn\_A}$:	attenuation of the coaxial attenuator A in dB

The three different loss contributions are assumed to be inserted in positive dB-values in the equation above.

With the given echo power level $P^{dBm}_{r\_real}$ from the surface in the real scenario (see clause 6.6.3.3) it is possible to calculate the required attenuation of the coaxial attenuator A by setting $P^{dBm}_{r\_real} = P^{dBm}_{r\_equivalent}$ and solving the resulting equation for the additional attenuation $a^{dB}_{attn\_A}$.

For all choices of the attenuations in the signal path from the LPR to the short circuit, the following condition shall be met during the test:

$$P_{r\_real}^{dBm} \geq P_{r\_equivalent}^{dBm} \qquad (16)$$

Calculation of the transmitted interferer power:

The exact interferer power level $P_{r\_interferer}^{dBm}$ which shall be applied to the receiver of the LPR device can be determined following the instructions described in ETSI TS 103 361 [6] (refer to clause 6.6.3.2).

The transmitted power level of the interfering signal $P_{t\_interferer}^{dBm}$ which shall be fed into coaxial cable B at the RF-connector of the signal generator in order to generate the wanted interferer power level $P_{r\_interferer}^{dBm}$ at the LPR receiver can be determined using the following equation:

$$P_{t_{interferer}}^{dBm} = P_{r\_interferer}^{dBm} + a_{coupler(1-3)}^{dB} + a_{cable_B}^{dB} + a_{attn\_B}^{dB} \qquad (17)$$

$P_{r\_interferer}^{dBm}$:	received interferer power at the LPR receiver in dBm
$P_{t_{interferer}}^{dBm}$:	transmitted interferer power (generated by the signal generator) in dBm
$a_{coupler(1-3)}^{dB}$:	coupling loss of the directional coupler between ports 1 and 3 in dB
$a_{cable\_B}^{dB}$:	cable loss of coaxial RF-cable B in dB
$a_{attn\_B}^{dB}$:	attenuation of the coaxial attenuator B in dB

The different loss contributions are assumed to be inserted in positive dB-values in the equation above.

6.6.3.7   Test procedure for the equivalent scenario

The test for interferer signal handling using the equivalent scenario shall be conducted as follows:

- The interferer frequencies $f_{interferer}$ and power levels $P_{r\_interferer}$ are determined according to clause 6.6.3.2. The transmitted interferer power levels (microwave signal generator output power) $P_{t\_interferer}$ can be determined by means of the methods described in clause 6.6.3.5 for the radiated test setup or clause 6.6.3.6 for the conducted test setup.

- With the specifications of R_{max}, ε_r and antenna gain G of the LPR under test in the "application form for testing", the radar cross section (RCS) σ of the radar target and the distance R_T can be determined according to clause 6.6.3.5 for the radiated setup.

  For the conducted setup in clause 6.6.3.6 first the received echo power $P_{r\_real}^{dBm}$ shall be determined according to clause 6.6.3.3. Then the required attenuation in the signal path of the LPR can be calculated following the instructions in clause 6.6.3.6.

- The measurement setup for the equivalent scenario is arranged according to the figures 3 and 4 in clause 6.6.3.5 with a suitable radar target for the radiated approach. For the conducted approach the measurement setup is arranged according to figure 5 in clause 6.6.3.6.

  The resulting received echo power $P_{r\_equivalent}$ shall be equal or less than the received echo power P_{r_real} in the real scenario.

- The distance measurement is carried out against the radar target in the radiated setup (see figures 3 and 4) or against the short circuit in the conducted setup (see figure 5) with the interferer turned on.

  The test is passed if the measured distance value stays within the maximum measurement value variation Δd (refer to clause 4.4.3.3). The test shall be conducted over at least a time period of 120 seconds or 40 times the step response time of the LPR sensor, whichever is longer.

During this test the LPR sensor shall be configured for the fastest possible step response time. Therefore all averaging functions and echo holding techniques shall be deactivated. If a complete deactivation of these functions is not possible, they shall be set to a state which ensures the fastest possible step response time. The configuration of the device under test in this case shall be noted in the test report.

- If the step response of the LPR sensor is not known, it can be estimated by introducing a sudden change of the distance to the target in the radiated setup or the short circuit in the conducted setup, respectively. The step response time is the time span until the new distance value reaches 90 % of the final value.

- Attention has to be paid that the correct echo is tracked by the LPR device during the test. This shall be verified by switching off the interferer signal. In this case the distance value shall also stay inside the maximum measurement value variation Δd.

- The test shall be repeated for all determined interferers.

6.6.3.8   Alternative scenario

The aim of the alternative scenario (in comparison to the equivalent scenario in clause 6.6.3.4) is to further facilitate testing and to enable the possibility to carry out the measurements in the limited space provided by an anechoic chamber (described for example in clause C.1) without the need for a simultaneous distance measurement. The interfering signal is directly coupled into the receiver and the response of the noise floor of the LPR device is monitored.

For applying this alternative scenario it is mandatory that the LPR provides the possibility to access and monitor its noise level for example in an echo curve graph. If the sensor under test does not provide this feature the equivalent scenario in clause 6.6.3.4 has to be applied for testing.

The LPR signal processing algorithms need a stable echo and a minimum echo signal-to-noise ratio SNR_{min} to ensure a measurement value variation Δd $\leq \pm$50 mm over time during a distance measurement. Echoes with smaller signal-to-noise ratios than SNR_{min} cannot be reliably processed by the LPR with the defined accuracy. This relation can be used to define a further test scenario which is equivalent to the scenario described in clause 6.6.3.4.

The received echo power P_{r_real} can be calculated according to equations (4) and (5), assuming a specular reflection at the surface. The maximum allowed noise level is then determined by the minimum allowed echo signal-to-noise ratio SNR_{min}.

The manufacturer shall supply the relation between the measurement value variation Δd $\leq \pm$50 mm and the minimum required signal-to-noise-ratio SNR_{min} as well as the relation between the measurement value variation Δd $\leq \pm$50 mm and the maximum allowed noise level for the individual LPR under test. This can preferably be achieved by providing recorded measurement data. The minimum required signal-to-noise-ratio SNR_{min} and the maximum allowed noise level shall be noted in the "application form for testing" (see annex B).

The interferer will cause a rise of the noise floor in the receiver of the LPR sensor, no matter what frequency or type of modulation is used in the interfering signal. If the noise floor of the receiver stays below the maximum allowed noise level a measurement variation of Δd $\leq \pm$50 mm can be assured.

6.6.3.9   Radiated test setup for the alternative scenario

Figure 6 shows the radiated measurement setup for the alternative scenario. There is only the interferer signal which has to be provided to the LPR receiver. Therefore a test antenna with gain G_t is placed at a certain distance R from the LPR antenna so that both antennas are ideally aligned for their main beam direction and polarization. The interfering signal is produced by the microwave signal generator which is connected to the test antenna.

The exact interferer power level $P_{r\_interferer}$ which shall be applied to the receiver of the LPR device can be determined following the instructions described in ETSI TS 103 361 [6] (see clause 6.6.3.2).
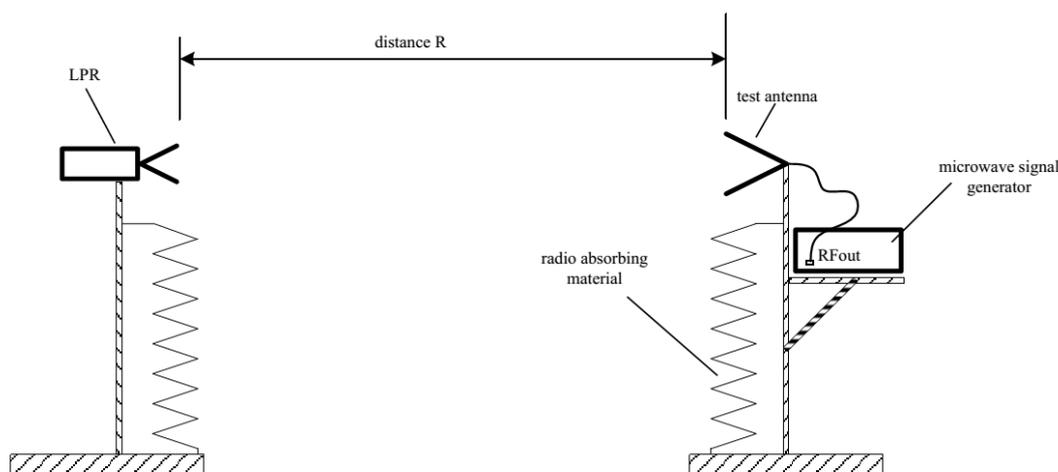
Figure 6: Radiated test setup for the alternative scenario

The transmitted power level of the interfering signal $P_{t\_interferer}$ which shall be fed into the test antenna in order to generate the wanted interferer power level $P_{r\_interferer}$ at the LPR receiver can be determined using Friis transmission equation which is shown in clause 6.6.3.5.

The Friis transmission equation is only valid if far-field conditions are applied in the measurement setup illustrated in figure 6. That means the LPR antenna shall be located in the far-field region of the test antenna and vice versa. Please compare with clause 6.6.3.5 in this context.

During the test in addition to the receiver also the transmitter of the LPR shall be switched on.

6.6.3.10   Conducted test setup for the alternative scenario

Figure 7 shows a possible conducted test setup for the alternative scenario using coaxial components. For higher frequencies an identical setup can be arranged using hollow waveguide components. A comprehensive treatise on these different waveguides can be found in annex J. There is only the interferer signal which has to be provided to the LPR receiver. Therefore the interfering signal is generated by the microwave signal generator and is directly fed into the LPR under test by means of a suitable RF cable or hollow waveguide.

The exact interferer power level $P^{dBm}_{r\_interferer}$ which shall be applied to the receiver of the LPR device can be determined following the instructions described in ETSI TS 103 361 [6] (see clause 6.6.3.2).

The required power level of the interfering signal at the LPR receiver $P^{dBm}_{r\_interferer}$ can easily be adjusted at the signal generator by taking into account all attenuations between the RF connector of the signal generator and the LPR antenna connector. If the dynamic range of the microwave signal generator is too small to provide a signal low enough to the LPR under test, an external attenuator can be connected to the microwave output of the generator as illustrated in the measurement setup in figure 7.

During the test in addition to the receiver also the transmitter of the LPR shall be switched on.
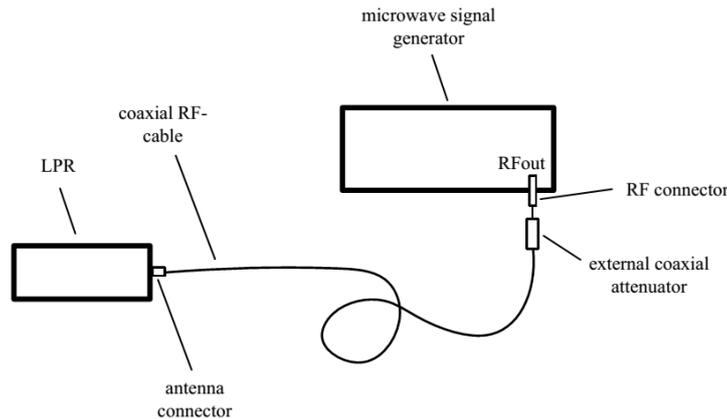
Figure 7: Conducted test setup for the alternative scenario

6.6.3.11   Test procedure for the alternative scenario

The test for interferer signal handling using the alternative scenario shall be conducted as follows:

- The interferer frequencies $f_{interferer}$ and power levels $P_{r\_interferer}$ are determined according to clause 6.6.3.2. The transmitted interferer power levels (microwave signal generator output power) $P_{t\_interferer}$ can be determined by means of the methods indicated in clause 6.6.3.9 for the radiated test setup or clause 6.6.3.10 for the conducted test setup.

- With the specifications of R_{max}, ε_r and antenna gain G of the LPR under test in the "application form for testing", the received echo power $P_{r\_real}^{dBm}$ from the considered surface in the real scenario (see clause 6.6.3.3) is calculated.

- The alternative measurement setup is arranged according to the radiated test procedure in clause 6.6.3.9 (referring to figure 6) or the conducted test procedure in clause 6.6.3.10 (referring to figure 7).

- The interfering signal is turned on and the noise level of the LPR under test is monitored for example in an echo curve graph.

   The test is passed if the noise floor of the LPR under test stays below the maximum allowed noise level. In this case, a measurement value variation smaller than $\Delta d = \pm 50$ mm can be assured over time. The test shall be conducted over at least a time period of 120 seconds or 40 times the step response time of the LPR sensor, whichever is longer.

   The maximum allowed noise level for the individual LPR can be extracted from the "application form for testing" (see annex B).

   During this test the LPR sensor shall be configured for the fastest possible step response time. Therefore all averaging functions and echo holding techniques shall be deactivated. If a complete deactivation of these functions is not possible, they shall be set to a state which ensures the fastest possible step response time. The configuration of the device under test in this case shall be noted in the test report.

- If the step response of the LPR sensor is not known, it can be estimated by introducing a sudden change of the distance to a target in a radiated setup (referring to figures 3 and 4 in clause 6.6.3.5) or to a short circuit in a conducted setup (referring to figure 5 in clause 6.6.3.6), respectively. The step response time is the time span until the new distance value reaches 90 % of the final value.

- The test shall be repeated for all determined interferers.

6.7   Conformance test suites for spectrum access

6.7.1   Detect and avoid mechanisms

Not applicable to Level Probing Radar.

6.7.2   Listen before talk

Not applicable to Level Probing Radar.

6.7.3   Low duty cycle

Not applicable to Level Probing Radar.

6.8   Conformance test suites for antenna requirements

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 8. It is important to assess the maximum antenna gain in the main lobe.

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.8]).

Azimuth Chart: Vertical

Azimuth Chart: Horizontal

Frequency 26000.000 MHz [dB]
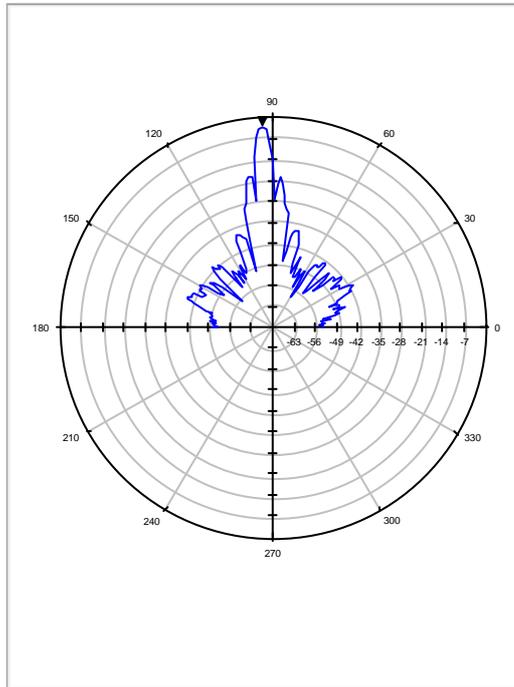
Frequency 26000.000 MHz [dB]

Azimuth Chart: Vertical

Azimuth Chart: Horizontal

Frequency 6300.000 MHz [dB]
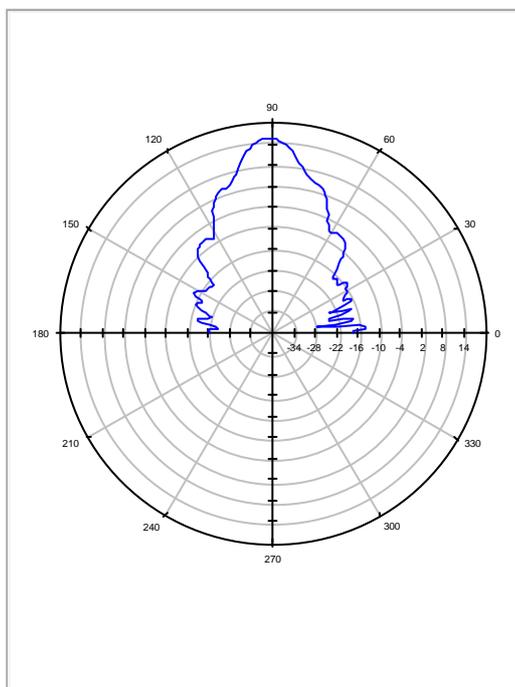
Frequency 6300.000 MHz [dB]

Figure 8: Examples of LPR antenna characteristics

ETSI

6.9   Other test suites

6.9.1   Adaptive/transmit power control (APC/TPC)

If the 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 (steel, iron, copper, or similar with a smooth 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 absorption 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 4.3.3 and 4.3.4.

Figure 9 shows the measurement setup for APC.

0 ,8 meters

Metal plate or absorbing foam

Open ended waveguide equipped with LNA and with measurement receiver, e.g. p ower meter
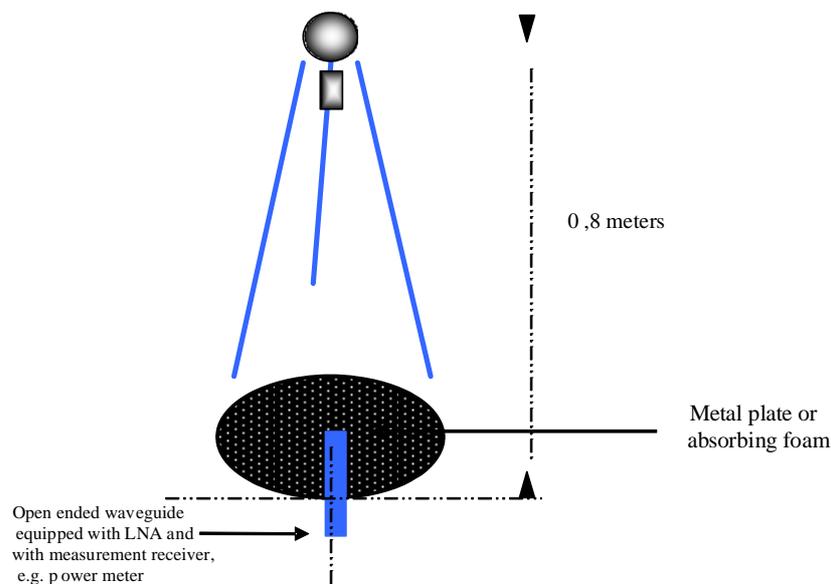
Figure 9: APC measurement setup

For LPRs that emit lower levels of e.i.r.p. of more than 15 dB below the maximum limits as defined in clauses 4.3.3 and 4.3.4 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 gain of the(se) amplifier(s) is recommended to be in the order of 25 dB. The gain of the open ended waveguide cannot 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 ended waveguide caused by the metal reflector plate shall be minimized.

Figures 10 and 11 show examples of open ended waveguides fitted into the absorbing foam and metal plates.
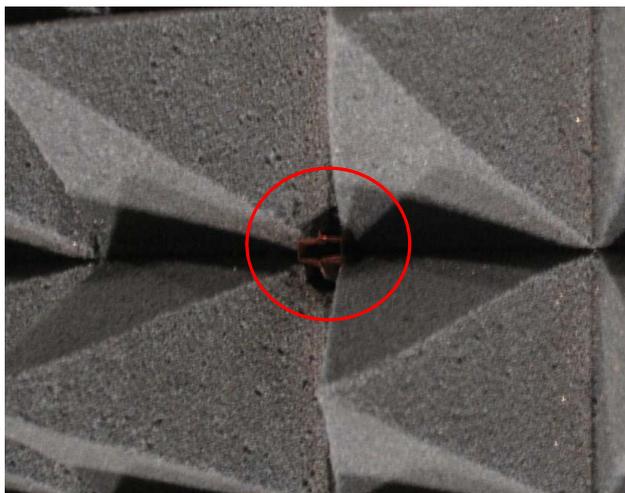
Figure 10: APC measurement setup - open ended waveguide fitted in absorbing foam

Figure 11: APC measurement setup - Details of open ended waveguide through 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 4.3.4 shall not exceed 2 dB.

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

6.9.2   Activity factor and duty cycle

Declared by manufacturer.

6.9.3   Frequency domain mitigation

Declared by manufacturer.

6.9.4   Shielding effects

No test necessary.

6.9.5   Thermal radiations

Not applicable to Level probing Radar.

6.9.6   Site registration

Not applicable to Level Probing Radar.

Annex A (normative):
Relationship between the present document and the essential requirements of Directive 2014/53/EU

The present document has been prepared under the Commission's standardisation request C(2015) 5376 final [i.15] to provide one voluntary means of conforming to the essential requirements of Directive 2014/53/EU on the harmonisation of the laws of the Member States relating to the making available on the market of radio equipment and repealing Directive 1999/5/EC [i.12].

Once the present document is cited in the Official Journal of the European Union under that Directive, compliance with the normative clauses of the present document given in table A.1 confers, within the limits of the scope of the present document, a presumption of conformity with the corresponding essential requirements of that Directive, and associated EFTA regulations.

**Table A.1: Relationship between the present document and
the essential requirements of Directive 2014/53/EU**

Harmonised Standard ETSI EN 302 729 The following requirements are relevant to the presumption of conformity under the article 3.2 of Directive 2014/53/EU [i.12]				
Requirement			**Requirement Conditionality**	
No	**Description**	**Reference: Clause No**	**U/C**	**Condition**
1	Operating bandwidth	4.3.2	U	
2	Maximum value of mean power spectral density	4.3.3	U	
3	Maximum value of peak power	4.3.4	U	
4	Other emissions	4.3.7	C	Applies only if other emissions can be clearly demonstrated.
5	Transmitter unwanted emissions	4.3.8	U	
6	Receiver spurious emissions	4.4.2	C	Applies only to equipment that can be operated in a receive-only mode
7	Interferer Signal handling	4.4.3	U	
8	Antenna requirements	4.6	U	
9	Other requirements and mitigation techniques	4.7.2 - 4.7.6	C	Applies to all DUT which implemented one or more mitigation techniques.
10	Range of modulation parameters	4.7.7	U	

Key to columns:

Requirement:

    No   A unique identifier for one row of the table which may be used to identify a requirement.

    Description   A textual reference to the requirement.

    Clause Number Identification of clause(s) defining the requirement in the present document unless another document is referenced explicitly.

Requirement Conditionality:

    U/C   Indicates whether the requirement shall be unconditionally applicable (U) or is conditional upon the manufacturers claimed functionality of the equipment (C).

    Condition   Explains the conditions when the requirement shall or shall not be applicable for a requirement which is classified "conditional".

Presumption of conformity stays valid only as long as a reference to the present document is maintained in the list published in the Official Journal of the European Union. Users of the present document should consult frequently the latest list published in the Official Journal of the European Union.

Other Union legislation may be applicable to the product(s) falling within the scope of the present document.

Annex B (informative):
Application form for testing

B.1   Introduction

The form contained in this annex may be used by the manufacturer to comply with the requirement contained in clause 5 to provide the necessary information about the equipment to the test laboratory prior to the testing. It contains product information as well as other information which might be required to define which configurations are to be tested, which tests are to be performed as well the test conditions.

This application form should form an integral part of the test report.

B.2   General Information as required by ETSI EN 302 729, clause 5.2

B.2.1   Type of equipment (stand-alone, combined, plug-in radio device, etc.)

☐ Stand-alone

☐ Combined Equipment (Equipment where the radio part is fully integrated within another type of equipment)

☐ Plug-in radio device (Equipment intended for a variety of host systems)

☐ Other ....

B.2.2   The nominal voltages of the stand-alone radio equipment or the nominal voltages of the combined (host) equipment or test jig in case of plug-in devices

Details provided are for the: ☐ stand-alone equipment

☐ combined (or host) equipment

☐ test jig

Supply Voltage   ☐ AC mains   State AC voltage   ……….. V

☐ DC   State DC voltage   ……….. V

In case of DC, indicate the type of power source

☐ Internal Power Supply

☐ External Power Supply or AC/DC adapter

☐ Battery

☐ Other: ....

B.3   Signal related Information as required by ETSI EN 302 729, clause 4.3

B.3.1   Introduction

The following information is provided by the manufacturer.

B.3.2   Operational frequency range(s) of the equipment

- Operational Frequency Range 1:   .... MHz to .... MHz

- Operational Frequency Range 2:   .... MHz to .... MHz

NOTE: Add more lines if more Frequency Ranges are supported.

B.3.3   Nominal channel bandwidth(s)

- Nominal Channel Bandwidth 1: .... MHz

- Nominal Channel Bandwidth 2: .... MHz

NOTE: Add more lines if more channel bandwidths are supported.

B.3.4   The type of modulation used by the equipment

☐ FM

☐ Pulse

☐ Other: ……………

Specify relevant modulation parameters according to the definitions in annex H:

....

B.3.5   Antenna data

- Supply antenna diagram for the EUT according to clause 4.6.

   ....

- Supply details of any antenna switching or electronic or mechanical scanning. Where such features are present, information about whether they can be disabled for testing purposes should also be stated.

   ....

B.3.6   The worst case mode for each of the following tests

NOTE: In this clause specify the Operational mode and not the measured value. E.g. test mode 1 that gives the worst case for the following parameters.

- Operational Frequency Range.

   ....

- Mean Power Spectral Density / Peak Power Spectral Density / Total Power / Other Emissions / Transmitter unwanted emissions.

  ....

B.4 RX test information as required by ETSI EN 302 729, clause 4.4

B.4.1 Worst case mode for RX tests

Declare gauge settings:..………..

B.4.2 Performance criterion and level of performance

- performance criterion : distance value variation Δd over time.

- level of performance: ....(max limit Δd ≤ ±50 mm).

The performance criterion and the level of performance is written in the user manual.

B.4.3 RX test setup

Specify which test setup is used under clause 6.6.3

....

- Declaration of the parameters in the real scenario (clause 6.6.3.3):

  Maximum approved measurement distance under interference conditions R_{max}: ....m

  Surface material with relative permittivity ε_r: ....

  Considered antenna type: .... with gain: ....dBi

- Declaration of the parameters in the alternative scenario (clause 6.6.3.8):

  Minimum required signal-to-noise-ratio SNR_{min}: ....dB and the corresponding maximum allowed noise level:…….dBm.

B.4.4 Definition of interfering signals

The list of the three worst-case interferers is chosen from ETSI TS 103 361 [6].

Frequency [MHz]	Power [dBm]	Type of signal (e.g. CW, CW with DC, other modulation)

B.5 Information on mitigation techniques as required by ETSI EN 302 729, clause 4.7

B.5.1 Mitigation techniques

The manufacturer declare the inclusion and any necessary implementation details of any mitigation or equivalent mitigation techniques. See also ETSI TR 103 181-2 [i.17].

☐ APC

Range of power level variation:...

☐ Activity factor and duty cycle

Specify..

☐ Frequency domain mitigation

Specify..

☐ Shielding effects

Specify..

☐ Equivalent mitigation techniques

Specify..

☐ Others

Specify…………………..

B.6 Additional information provided by the applicant

B.6.1 About the equipment under test

☐ The equipment submitted are representative production models

☐ If not, the equipment submitted are pre-production models?

☐ If pre-production equipment are submitted, the final production equipment will be identical in all radio related respects with the equipment tested

☐ If not, supply full details

....

....

B.6.2 Additional items and/or supporting equipment provided

☐ Spare batteries (e.g. for portable equipment)

☐ Battery charging device

☐ External Power Supply or AC/DC adapter

☐ Test Jig or interface box

☐ RF test fixture (for equipment with integrated antennas)

☐ Host System   Manufacturer: ....

                                Model #:   ....

                                Model name: ....

☐ Combined equipment   Manufacturer: ....

                                Model #:   ....

                                Model name: ....

☐ User Manual

☐ Technical documentation (Handbook and circuit diagrams)

Annex C (normative):
Radiated measurement

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

C.1.0   General

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.

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 ETSI 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.

C.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 C.1.
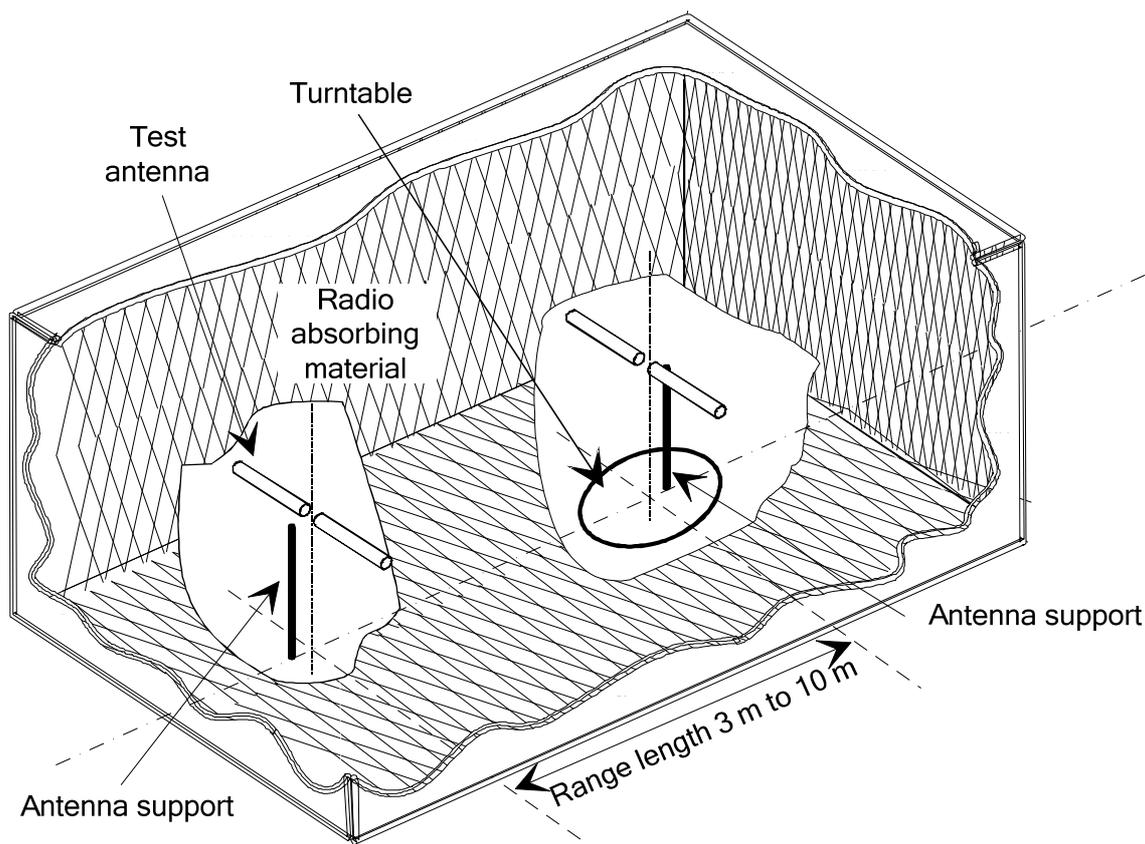
Figure C.1: A typical Anechoic Chamber

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 C.2.4). For further information on measurements at shorter distances see annex G. 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.

C.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 C.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.
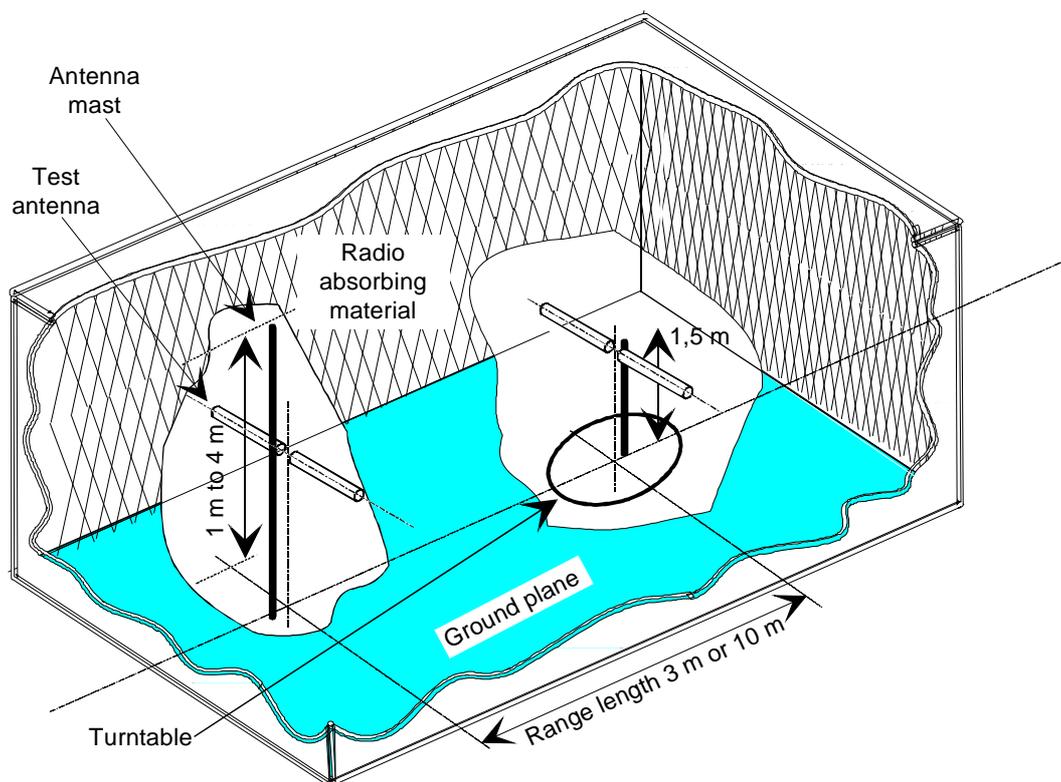

Figure C.2: A typical Anechoic Chamber with a conductive ground plane

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 a 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 C.2.4). For further information on measurements at shorter distances see annex G. 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, and 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.

C.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 C.3.
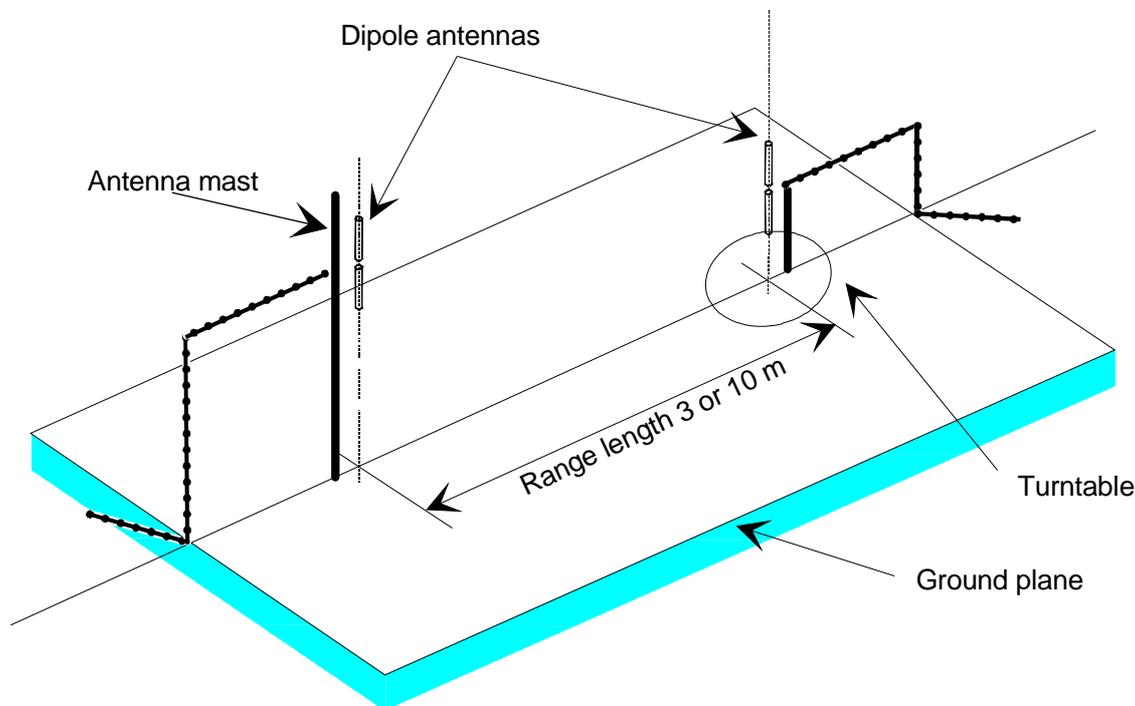
Figure C.3: A typical Open Area Test Site

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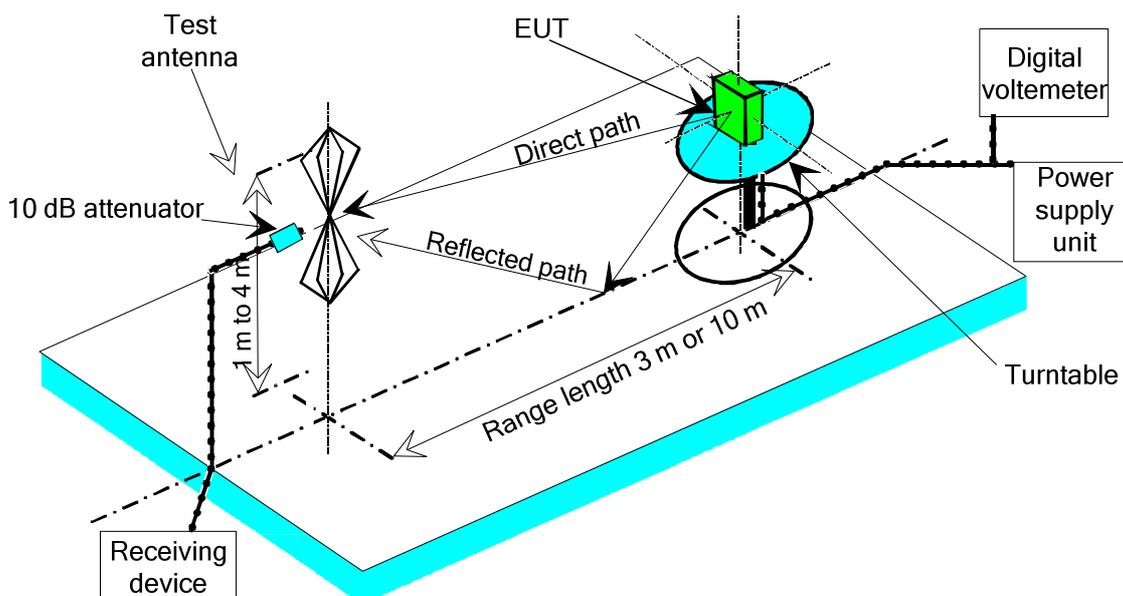
**Figure C.4: Measuring arrangement on ground plane test site
(OATS set-up for spurious emission testing)**

C.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 m.

- Length of 3 m.

- Height of 2 m (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 C.5 shows an example of a test site above 18 GHz with one reflecting surface.
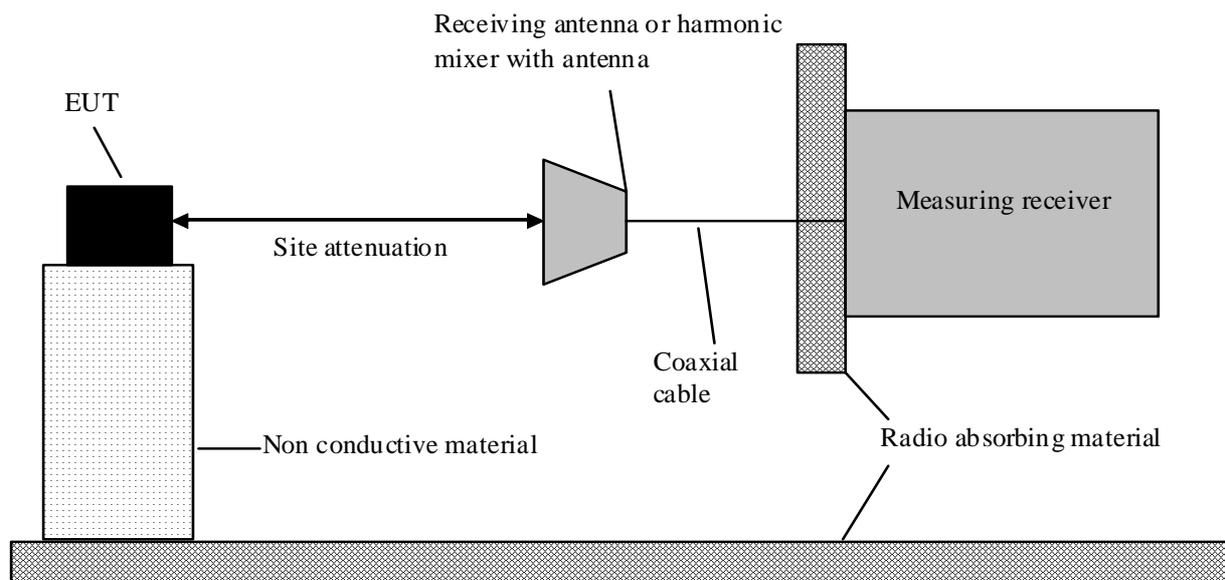
Figure C.5: Example of a test site above 18 GHz with one reflecting surface

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 C.1 to C.3.

Table C.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 C.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 C.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:

$$\lambda = \frac{c}{f} \qquad\qquad (C.1)$$

$$FSL = 20\, log\left(\frac{4\pi r}{\lambda}\right) \qquad\qquad (C.2)$$

C.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 m to 4 m).

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.

C.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.

C.1.7   Measuring antenna

The measuring antenna is used in tests on a EUT in which a receiving parameter (i.e. sensitivity and various immunity tests) is being measured. Its purpose is to enable a measurement of the electric field strength in the vicinity of the EUT. For measurements in the frequency band 30 MHz to 1 000 MHz, the measuring antenna should be a dipole antenna (constructed in accordance with ANSI C63.5 [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.

C.2   Guidance on the use of radiation test sites

C.2.0   General

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.

C.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 ETSI TR 102 273 [3] or equivalent.

C.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 or activity factor (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.

C.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).

C.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:

$$\frac{2(d_1 + d_2)^2}{\lambda} \tag{C.3}$$

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:

$$2\lambda \tag{C.4}$$

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

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

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

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

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

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

C.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.

C.3 Coupling of signals

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).

C.4 Standard test methods

C.4.0 General

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

C.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.

On a test site according to clause C.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.

C.4.2 Substitution method

On a test site, selected from clause C.1, the equipment shall be placed at the specified height on a support, as specified in clause C.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 C.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 C.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 D (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 assigned frequency bands (see clause 4.3.1, table 2).

Annex E (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 E.1: List of radio astronomy sites exclusion zones according to www.craf.eu [i.18]

Country	Name of the station	Geographic Latitude	Geographic Longitude	Frequency Band
Finland	Metsähovi	60°13'04" N	24°23'37" E	A, B and C
	Tuorla	60°24'56" N	22°26'31" E	A and B
France	Plateau de Bure	44°38'01" N	05°54'26" E	B and 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	Badari	51°45'27"N	102°13'16"E	A
	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	A and B
	Svetloe	61°05'00"N	29°46'54"E	A
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	37°03'58" N	03°23'34" W	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	52°55'01" N	06°36'15" E	A
Turkey	Kayseri	38°59'45" N	36°17'58" E	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
Band A: 6 GHz to 8,5 GHz				
Band B: 24,05 GHz to 26,5 GHz				
Band C: 75 GHz to 85 GHz				

NOTE: Table E.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 [i.18].

Annex F (informative):
Measurement antenna and preamplifier specifications

The radiated measurements set-up in annex C 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 F.1 gives examples of minimum recommended data and features for the horn antenna and preamplifier to be used for the test set-up.

Table F.1: Recommended minimum performance data for preamplifier and antenna [i.6]

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 1 dB 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 F.2: Recommended measurement antennas [i.6]

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

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

G.1   Introduction

It may not be possible to measure at the power limits without low-noise amplification to reduce the overall noise figure of the overall measurement system at a separation of approximately 3 m in an RF quiet environment. A move to lower separation distance or reduced measurement bandwidth may be required since the instrumentation noise floor should be below the limit within the instrument bandwidth

The far field condition may imply impossible distances for accurate measurement of power limits or conventional antenna-pattern. 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.

G.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 G.1.

Table G.1: Uncertainty contribution: range length (test methods) [i.11]

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: d1 and d2 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 ETSI TR 102 215 [i.11].

Annex H (informative):
Range of modulation parameters

H.1   Pulse modulation

H.1.1   Definition

For pulse modulation, the transmitter is periodically switched on for a short time (called pulse duration t_{pulse}) and switched off during the subsequent reception period. A typical example is shown in figure H.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 t_{pulse}.

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).
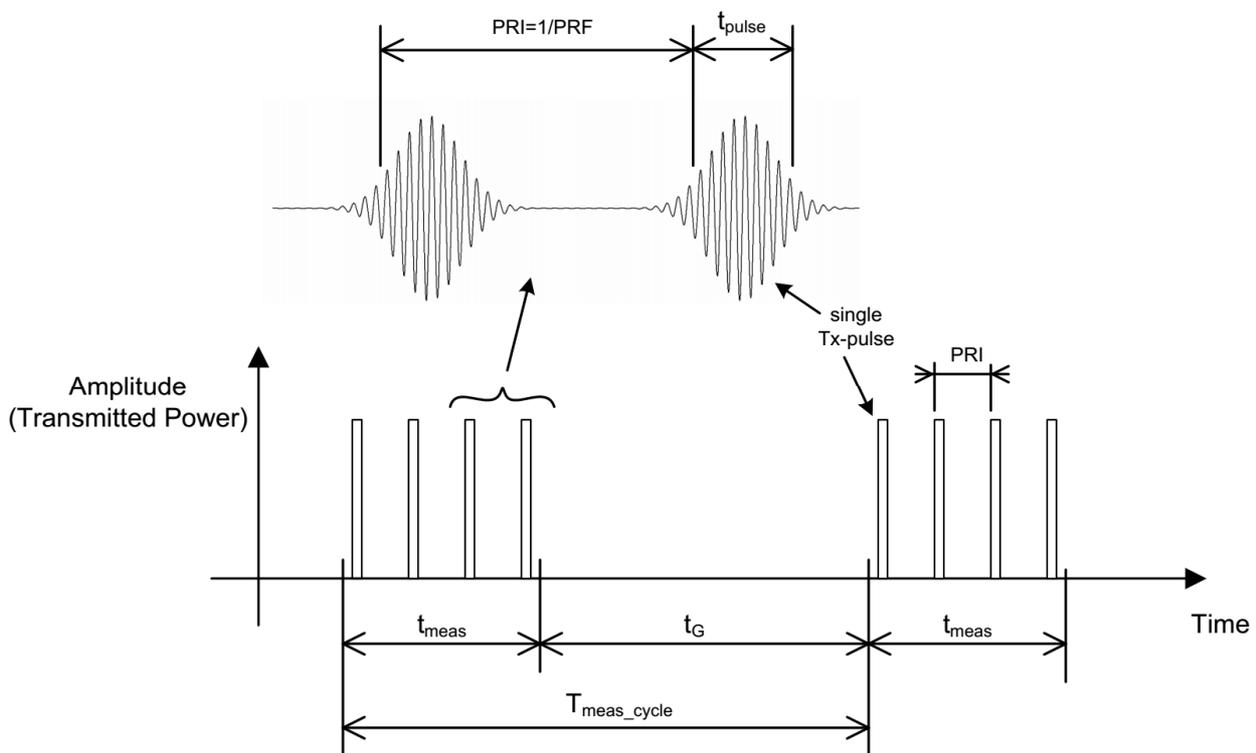

Figure H.1: Typical pulse modulation scheme

Duty cycle (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 considerations on activity factor (AF) are the terms used to completely describe different activity levels of LPR devices. There may be a time t_G (blanking period) where the transmitted waveform is interrupted and adjusted to the requirements of the beginning of the next measurement cycle.

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 t_{meas} (bursts, sweeps, scans) within the overall repetitive measurement cycle T_{meas_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.

H.2 Frequency modulated continuous wave

H.2.1 Definition

For FMCW, FH, FSK, SFCW, 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 t_{meas}. This period of time may be constant, or may be varied. An example of a typical modulation scheme is shown in figure H.2. During the time t_{meas}, 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 (t_{meas}), there may be a time t_G (blanking period) where the transmitted waveform is interrupted and adjusted to the requirements of the beginning of the next period.
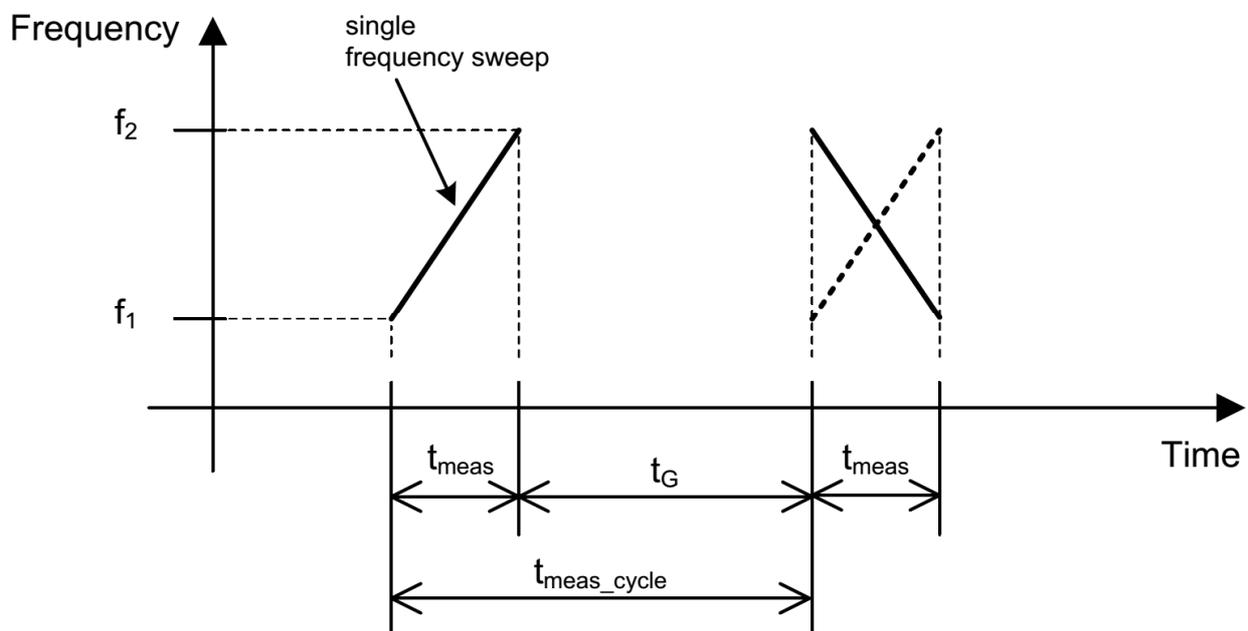

Figure H.2: Typical FMCW modulation scheme

Annex I (informative):
Void

Annex J (normative):
General requirements for RF measurement equipment

J.1   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 J.1 provides some information about connector systems that can be used in connection with the cables.

Table J.1: Connector systems [i.6]

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

J.2   RF waveguides

Wired signal transmission in the millimetre 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 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 J.2 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 J.2: Waveguide bands and associated waveguides [i.6]

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 to 40,0	3-006	WR-28	R320	WG-22	7,11 × 3,56	0,280 × 0,140	54-006 68-002 67B-005	UG-559/U - UG-381/U	Rectangular Rectangular Round
Q	33,0 to 55,0	3-010	WR-22	R400	WG-23	5,69 × 2,84	0,224 × 0,112	67B-006	UG-383/U	Round
U	40,0 to 60,0	3-014	WR-19	R500	WG-24	4,78 × 2,388	0,188 × 0,094	67B-007	UG-383/U-M	Round
V	50,0 to 75,0	3-017	WR-15	R620	WG-25	3,759 × 1,879	0,148 × 0,074	67B-008	UG-385/U	Round
E	60,0 to 90,0	3-020	WR-12	R740	WG-26	3,099 × 1,549	0,122 × 0,061	67B-009	UG-387/U	Round
W	75,0 to 110,0	3-023	WR-10	R900	WG-27	2,540 × 1,270	0,100 × 0,050	67B-010	UG-383/U-M	Round

As waveguides are rigid, it is impractical 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.

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.

J.3   External harmonic mixers

J.3.1   Introduction

Measuring receivers (test receivers or spectrum analysers) with coaxial input are commercially available up to 67 GHz. The frequency range is extended from 26,5 GHz / 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 pre-selectors which are not available. Harmonic mixers are waveguide based and have a frequency range matching the waveguide bands. They shall 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 shall 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 shall 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 analyser, 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 J.1 shows an example where a diplexer is used to convey both, the IF and LO frequencies.
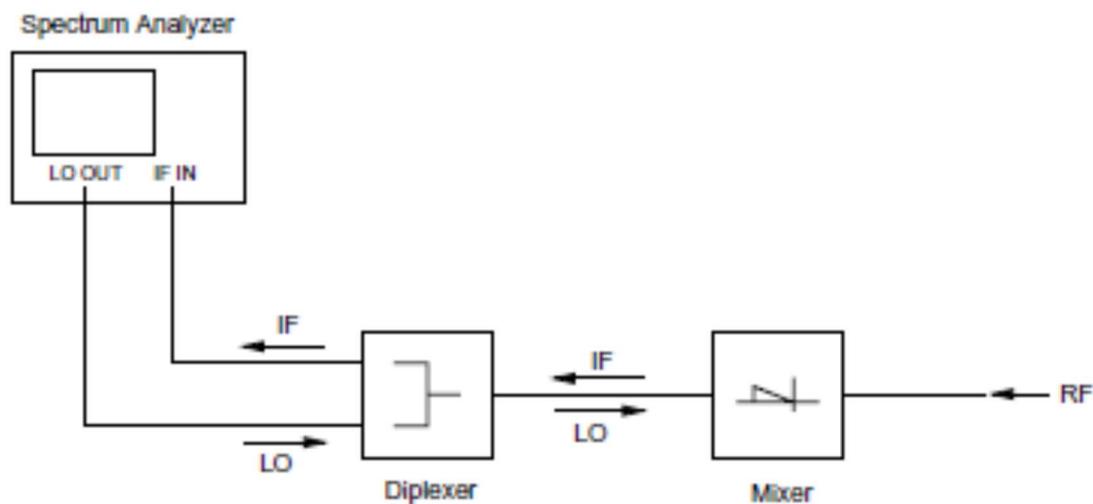
Figure J.1: Set-up of measurement receiver, diplexer and mixer

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.

J.3.2   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 analysed 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 analysers 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 analyser, 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.

J.3.3   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 analyser, 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 analyser.

Additional information on radiated measurements up to 100 GHz is available in ETSI TS 103 052 [i.6].

J.4   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.

J.5   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 16-1 [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 J.3.

Table J.3: Measurement receiver parameters [i.2]

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:

$$B = A + 10 \, log \left(\frac{BW_{ref}}{BW_{measured}} \right)$$ (J.1)

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.)

Annex K (informative):
Radar targets for radiated measurements

K.1   Introduction

Suitable radar targets for the radiated test setup presented in clause 6.6.3.5 depend on the desired radar cross section (RCS) σ. Conducting spheres as well as square or triangular shaped corner reflectors of different sizes are most suitable for this purpose. The equations for the radar cross sections of these different reflectors in boresight direction are simple and can be found throughout the Radar literature. However, the validity of these simple equations is subject to some constraints which are presented in the following clauses.

K.2   Radar cross sections of suitable radar targets

Conducting spheres as well as square or triangular shaped corner reflectors of different sizes are most suitable for conducting radiated measurements with LPR devices.

The radar cross section of a conducting sphere is independent of the wavelength and angle of incidence of the radar signal. It is defined as follows:

$$\sigma_{sphere} = \pi \cdot r_{sphere}^2 \tag{K.1}$$

σ_{sphere} :   Radar cross section (RCS) of the conducting sphere

r_{sphere} :   radius of the conducting sphere

The radar cross sections in boresight direction of the two different trihedral corner reflectors (σ_{square} and $\sigma_{triangular}$) illustrated in figure K.1 can be calculated as follows:

$$\sigma_{square} = 12\frac{\pi a^4}{\lambda^2} \tag{K.2}$$

$$\sigma_{triangular} = \frac{4}{3}\frac{\pi a^4}{\lambda^2} \tag{K.3}$$

$\sigma_{square}/\sigma_{triangular}$:   Radar cross sections of the square/triangular shaped corner reflector in boresight direction

a :   edge length of corner reflector (compare figure K.1)

λ :   wavelength of incident wave

The three above illustrated RCS formulas are subject to constraints. These constraints are treated in detail in clause K.3.
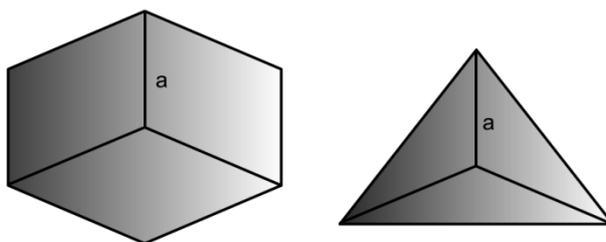

Figure K.1: Different corner reflectors
(left hand side: square shaped, right hand side: triangular shaped)

The correlation between the Radar cross section of the radar target and the physical dimension (sphere radius r_{sphere} or edge length of corner reflector a) in dB(m)²-values is illustrated in figure K.2 for C-band frequencies (42,8 mm wavelength), figure K.3 for K-band frequencies (12 mm wavelength), figure K.4 for V-band frequencies (4,9 mm wavelength) and figure K.5 for W-band frequencies (3,75 mm wavelength).
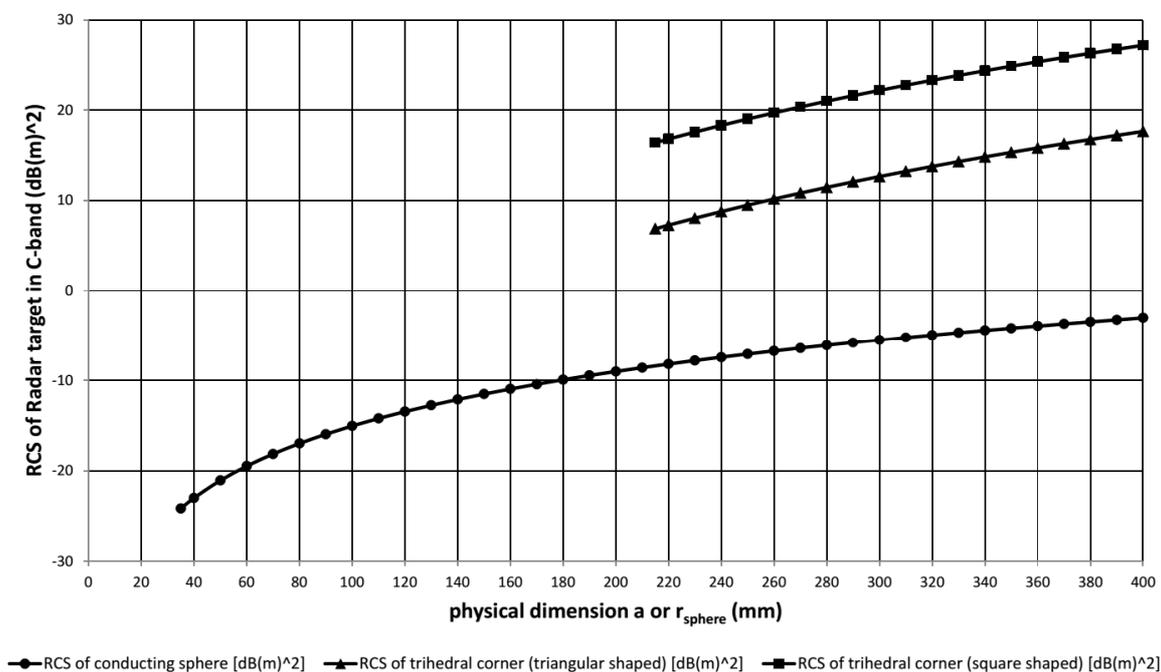

Figure K.2: Radar cross sections as a function of the physical dimensions of different targets for C-band frequencies (wavelength 42,8 mm)
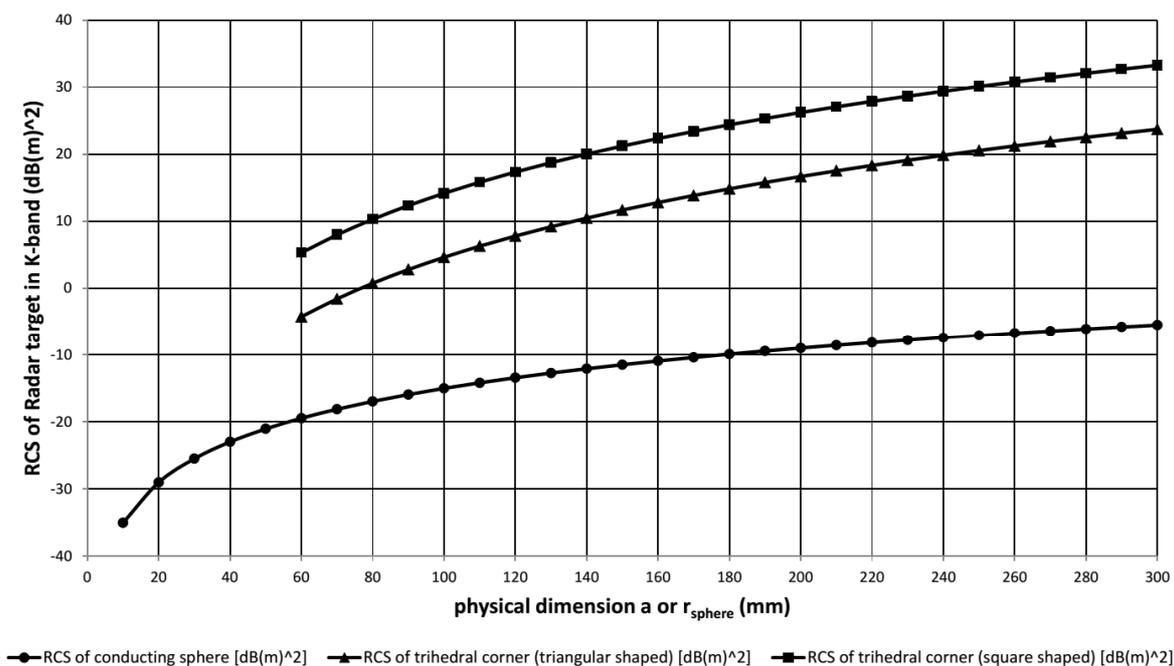

Figure K.3: Radar cross sections as a function of the physical dimensions of different targets for K-band frequencies (wavelength 12 mm)
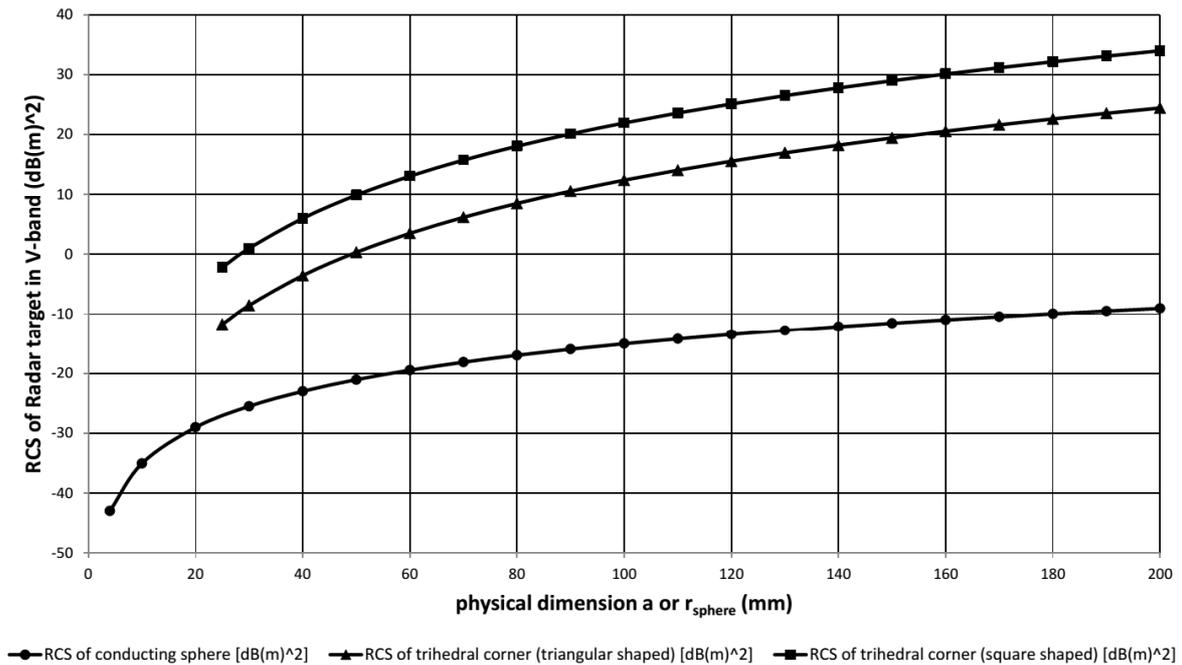
**Figure K.4: Radar cross sections as a function of the physical dimensions
of different targets for V-band frequencies (wavelength 4,9 mm)**
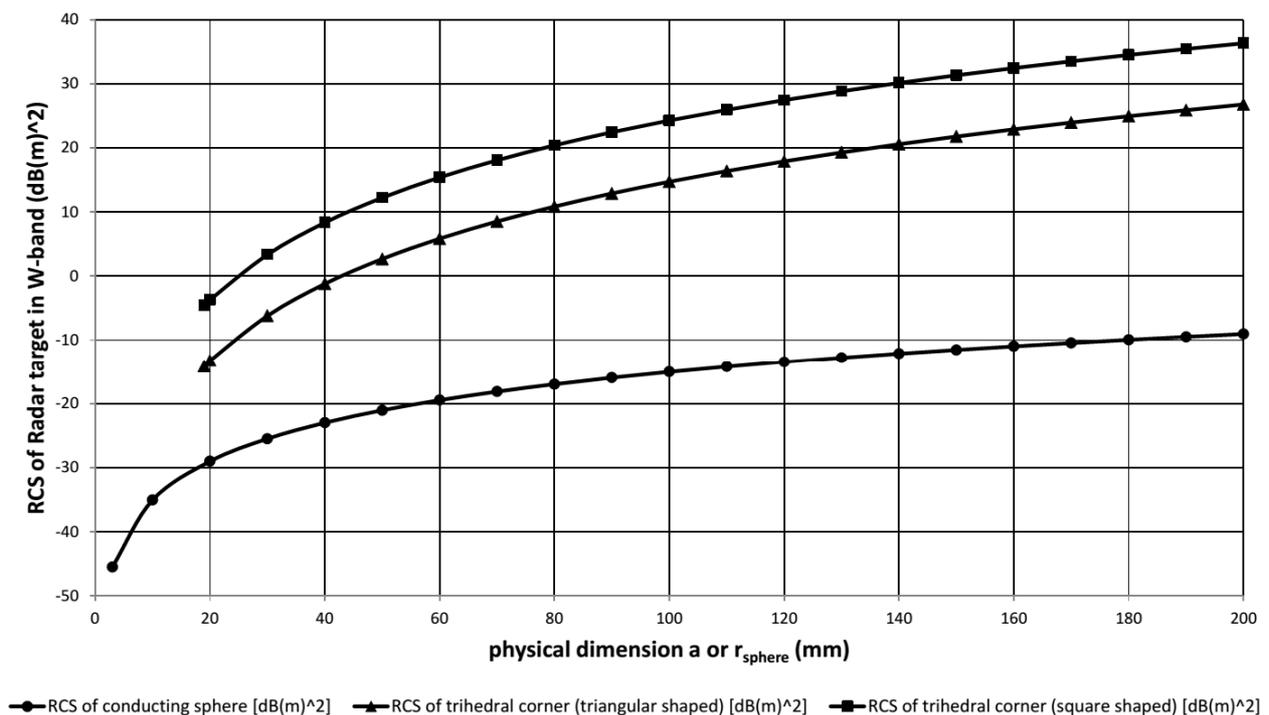

**Figure K.5: Radar cross sections as a function of the physical dimensions
of different targets for W-band frequencies (wavelength 3,75 mm)**

K.3   Boundary conditions of the RCS equations

The basis for the derivation of the RCS equations in clause K.2 is a geometric optics model. This model assumes that the wavelength is small with respect to the physical dimensions of the individual target reflector. Thus the RCS equations depicted in clause K.2 are subject to constraints concerning the relation between the used signal wavelength and the geometric extent of the targets.

The equation used for the Radar cross section of the conducting sphere σ_{sphere} is only valid if the following condition is fulfilled:

$$\frac{2\pi \cdot r_{Sphere}}{\lambda} \geq 5 \qquad (K.4)$$

The equation used for the Radar cross section of the two corner reflectors (σ_{square} and $\sigma_{triangular}$) is only valid if the following condition is fulfilled:

$$\frac{a}{\lambda} \geq 5 \qquad (K.5)$$

These two conditions lead to minimum sphere radius and minimum edge lengths with respect to the frequency of the incident wave. Table K.1 shows these minimum dimensions as a function of frequency for selected frequencies in the assigned LPR frequency bands.

Table K.1: Minimum physical dimensions of the Radar targets as a function of frequency

Frequency of incident wave (GHz)	Minimum sphere radius r_{sphere} (mm)	Minimum corner reflector edge length a (mm)
7	35	215
25	10	60
61	4	25
80	3	19

Annex L (informative):
Boundary conditions for the Radar equation

L.1   Introduction

The validity of the simple form of the Radar equation in the illustrated equivalent test scenario (compare clause 6.6.3.5 figures 3 and 4) is subject to some boundary conditions in order to assure its accuracy. These conditions are presented in the following clauses.

L.2   Far-field condition

The simple form of the radar equation, introduced in clause 6.6.3.5 is only valid if the Radar target is located in the far-field of the LPR antenna. A good measure for the far-field distance of electrically large antennas can be deduced from table G.1 in annex G. It should be noted that in the equivalent scenario illustrated in figures 3 and 4 in clause 6.6.3.5 for the purpose of establishing a desired echo, only the LPR antenna is relevant. Consequently the antenna dimension d_2 in the equations in table G.1 in annex G should be set to zero as the second antenna (test antenna) is not present in this case. This leads to the following equation for the far-field region:

$$r_{ff} = \frac{2d_1^2}{\lambda}$$

(L.1)

r_{ff} :   distance from the LPR antenna to the inner boundary of the far-field region
d_1 :   largest dimension of the physical aperture of the LPR antenna
λ :   wavelength of the transmit signal at centre frequency

That means the following condition ensures far field conditions:

$$R_T \geq r_{ff}$$

(L.2)

R_T :   slant distance between LPR and target

If the condition above cannot be met, for example due to space limitations in the anechoic chamber, the uncertainty contributions from table G.1 in annex G apply.

Figure L.1 shows the correlation between the distance to the inner boundary of the far-field region and the largest antenna aperture dimension for the different LPR frequency bands.
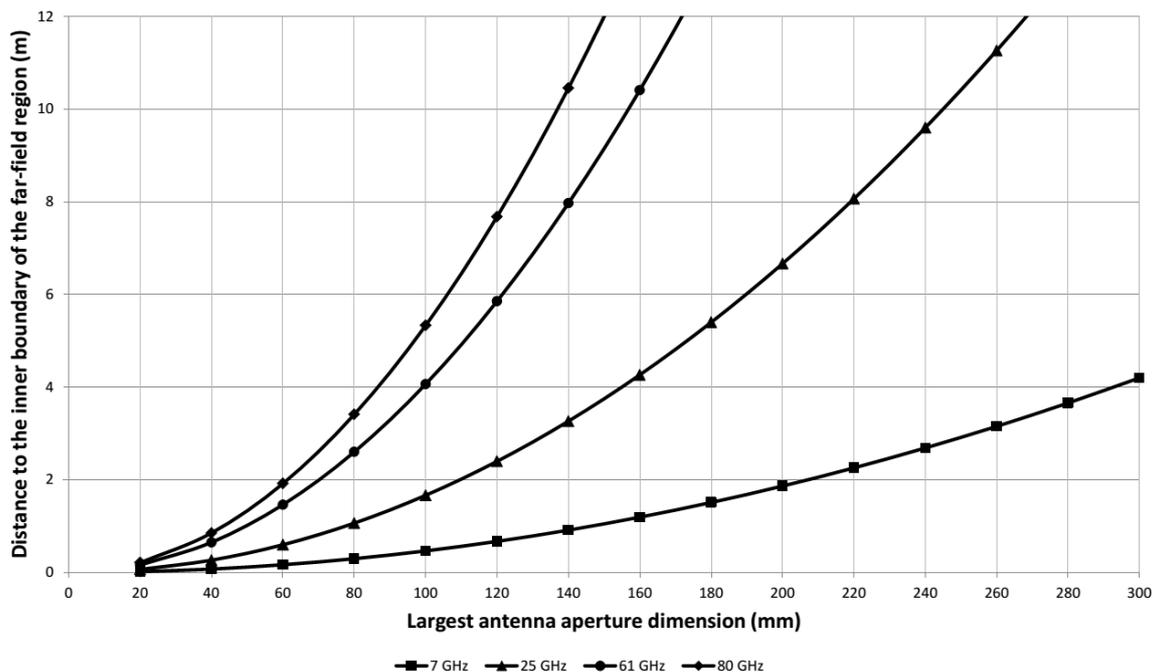
**Figure L.1: Correlation between far-field distance and antenna aperture dimension
for the different LPR frequency bands**

L.3   Point target condition

The simple form of the radar equation, introduced in clause 6.6.3.5, is only valid for point targets. That means the radar target should be either small enough or located far enough from the LPR device in order to behave as a point target compared to the extent of the resolution cell in cross-range at the location of reflection.

Figure L.2 shows a simplified normalized power pattern of a potential LPR antenna in one plane. The extent of the resolution cell in cross-range (angular resolution) is the same as the extent of the main lobe of the antenna pattern at the location of reflection in the slant distance R_T. Thus from the antenna pattern in figure L.2 the angular resolution can be approximately derived as follows:

$$d = 2 \, R_T \, \sin\left(\frac{\vartheta_{3dB}}{2}\right) \tag{L.3}$$

d :   extent of the main lobe in slant distance R_T

ϑ_{3dB} :   half power beamwidth (HPBW) or opening angle of the antenna pattern

R_T :   slant distance between LPR and target

The sphere can be considered as a point target if the following condition is fulfilled:

$$\frac{d}{2 \, r_{sphere}} \geq 5 \tag{L.4}$$
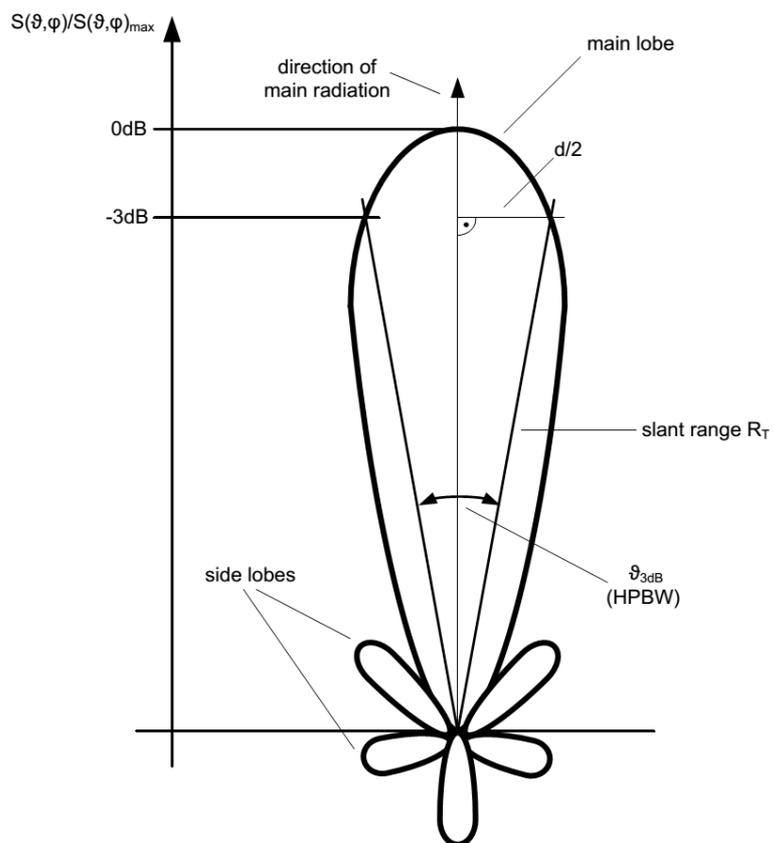
Figure L.2: Simplified Normalized power pattern of a high directive antenna

The two corner reflectors can be considered as point targets if the following condition is fulfilled:

$$\frac{d}{a\sqrt{2}} \geq 5 \qquad \qquad \text{(L.5)}$$

a :   edge length of corner reflector (compare figure K.1)

Annex M (informative):
Bibliography

- ECC/DEC/(11)02: "CEPT ECC Decision of 11 March 2011 on industrial Level Probing Radars (LPR) operating in frequency bands 6 - 8.5 GHz, 24.05 - 26.5 GHz, 57 - 64 GHz and 75 - 85 GHz".

- Recommendation ITU-R SM.1755: "Characteristics of ultra-wideband technology".

Annex N (informative):
Change History

Table to cover paragraph 2 of Article 5 of the Standardisation Request:

Date	Version	Information about changes
May 2011	1.1.2	Last publication as a two part HS under R&TTE
September 2016	2.1.1	• Revision for compliance with Directive 2014/53/EU • Merge of ETSI EN 302 729-1/-2 into a single EN covering the essential requirement of the Directive 2014/53/EU • Out-sourcing of some standard measurement procedures into a separate ETSI EN 303 883 (V1.1.1) • New requirement on receiver interferer signal handling • New Annex B "Application form for testing" • Annex I "Atmospheric absorptions and material dependent attenuations" deleted • New Annex K "Radar targets for radiated measurements" • New Annex L "Boundary conditions for the radar equation"

History

Document history		
V1.1.2	May 2011	Publication as ETSI EN 302 729 part 1 and part 2
V2.1.0	April 2016	EN Approval Procedure AP 20160712: 2016-04-13 to 2016-07-12
V2.1.1	October 2016	Vote V 20161205: 2016-10-06 to 2016-12-05