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European Standard (Telecommunications series)

Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices; Road Transport and Traffic Telematics (RTTT); Short Range Radar equipment operating in the 77 GHz to 81 GHz band; Part 1: Technical requirements and methods of measurement

Reference
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Contents

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Foreword

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

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

Equipment compliant with the present document is intended for fitment into road vehicles, therefore it is subject to automotive EMC type approval and has to comply with Commission Directive 2004/104/EC [i.4]. For use on vehicles outside the scope of Commission Directive 2004/104/EC [i.4] compliance with an EMC directive/standard appropriate for that use is required.

The present document is part 1 of a multi-part deliverable covering Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices; Road Transport and Traffic Telematics (RTTT); Short Range Radar equipment operating in the 77 GHz to 81 GHz band, as identified below:

Part 1: "Technical requirements and methods of measurement";

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

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

1 Scope

The present document specifies the technical requirements and methods of measurement for Short Range Devices (SRD) working as broadband devices with at least 500 MHz occupied bandwidth in the 77 GHz to 81 GHz frequency range, hereinafter referred to as the 79 GHz range, intended for Road Transport and Traffic Telematics (RTTT) applications. Applications include e.g. Short Range Radar (SRR) for obstacle detection, stop&go, blind spot detection, parking aid, backup aid, precrash and other automotive applications. Applications that might interfere with automotive SRR systems, e.g. road infrastructure systems, are explicitly excluded.

The present document covers transmitters intended to operate in the frequency range as defined in the EC decision 2004/545/EC [i.2] and the ECC decision ECC/DEC/(04)03 [i.1].

The document applies to:

a) transmitters in the 79 GHz range operating as broadband devices;

b) receivers operating in the 79 GHz range;

c) integrated transceivers in the 79 GHz range.

The present document:

- contains the technical characteristics and test methods for short range radar equipment fitted with integral antennas operating in the 79 GHz range;
- covers short range radar vehicle applications in the 79 GHz range. It covers integrated transceivers and separate transmit/receive modules.

2 References

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

- For a specific reference, subsequent revisions do not apply.
- Non-specific reference may be made only to a complete document or a part thereof and only in the following cases:
  - if it is accepted that it will be possible to use all future changes of the referenced document for the purposes of the referring document;
  - for informative references.

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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.

2.1 Normative references

The following referenced documents are indispensable for the application of the present document. For dated references, only the edition cited applies. For non-specific references, the latest edition of the referenced document (including any amendments) applies.

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

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

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

2.2 Informative references

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

[i.1] ECC decision ECC/DEC/(04)03 of 19 March 2004 on the frequency band 77 - 81 GHz to be designated for the use of Automotive Short Range Radars.

[i.2] EC decision 2004/545/EC of 8 July 2004 on the harmonization of radio spectrum in the 79 GHz range for the use of automotive short-range radar equipment in the Community.

[i.3] Radio Regulations: "International Telecommunication Union, Edition of 2004".

[i.4] Commission Directive 2004/104/EC of 14 October 2004 adapting to technical progress Council Directive 72/245/EEC relating to the radio interference (electromagnetic compatibility) of vehicles and amending Directive 70/156/EEC on the approximation of the laws of the Member States relating to the type-approval of motor vehicles and their trailers.

[i.5] ETSI EN 302 264-2: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices; Road Transport and Traffic Telematics (RTTT); Short Range Radar equipment operating in the 77 GHz to 81 GHz band; Part 2: Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive".

3 Definitions, symbols and abbreviations

3.1 Definitions

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

activity factor: actual on-the-air time divided by active session time or actual on-the-air emission time within a given time window

associated antenna: antenna and all its associated components which are designed as an indispensable part of the equipment

blanking period: time period where either no waveform or a constant waveform within the 79 GHz range occurs

boresight: axis of the main beam in a directional antenna

channel dwell time: accumulated amount of transmission time of uninterrupted continuous transmission within a single given frequency channel and within one channel repetition interval

duty cycle: ratio of the total on time of the "message" to the total off-time in any one hour period

NOTE: The device may be triggered either automatically or manually and depending on how the device is triggered will also depend on whether the duty cycle is fixed or random. The duty cycle is categorized in 4 different duty cycle classes.

Equipment Under Test (EUT): radar sensor including the integrated antenna together with any external antenna components which affect or influence its performance

equivalent pulse power duration: duration of an ideal rectangular pulse which has the same content of energy compared with the pulse shape of the EUT with pulsed modulation or on-off gating

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

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

on-off gating: methods of transmission with fixed or randomly quiescent period that is much larger than the PRF

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

NOTE: Equipment may be able to operate at more than one operating frequency.

operating frequency range: range of operating frequencies over which the equipment can be adjusted through switching or reprogramming or oscillator tuning

NOTE 1: For pulsed or phase shifting systems without further carrier tuning the operating frequency range is fixed on a single carrier line.

NOTE 2: For analogue or discrete frequency modulated systems (FSK, FMCW) the operating frequency range covers the difference between minimum and maximum of all carrier frequencies on which the equipment can be adjusted.

peak envelope power: mean power (round mean square for sinusoidal carrier wave type) supplied from the antenna during one radio frequency cycle at the crest of the modulation envelope taken under normal operating conditions (see Radio Regulations [i.3])

Power Spectral Density (PSD): ratio of the amount of power to the used radio measurement bandwidth

NOTE: It is expressed in units of dBm/Hz or as a power in unit dBm with respect to the used bandwidth. In case of measurement with a spectrum analyser the measurement bandwidth is equal the RBW.

precrash: time before the crash occurs when safety mechanism is deployed

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

Pulse Repetition Interval (PRI): time between the rising edges of the transmitted (pulsed) output power

quiescent period: time instant where no intentional emission occurs

radome: external protective cover which is independent of the associated antenna, and which may contribute to the overall performance of the antenna (and hence, the EUT)

spatial radiated power density: power per unit area normal to the direction of the electromagnetic wave propagation

NOTE: Spatial radiated power density is expressed in units of W/m^2.

spread spectrum: modulation technique in which the energy of a transmitted signal is spread throughout a larger frequency range

3.2 Symbols

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

λ	Wavelength
ac	alternating current
B	Bandwidth
B_{FH}	Frequency hopping bandwidth
d	largest dimension of the antenna aperture
D_{fb}	distance of ferrite beads
E	Field strength
E_o	Reference field strength
f_c	Carrier frequency
f_{hop}	Hopping frequency
f_h	highest frequency
f_l	lowest frequency
G_a	Antenna gain
P_{rad}	Radiated power
$P_{PK\ 3\ MHz}$	Radiated peak power measured in 3 MHz bandwidth
P_s	Signal generator power
R	Distance
R_o	Reference distance
Rx	Receiver
τ	Pulse width
T_{blk}	Blank time period
T_c	Chip period
T_{dw}	Dwell time
T_{fr}	Frame time
T_{pw}	Pulse power duration
Tx	Transmitter

3.3 Abbreviations

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

ASK	Amplitude Shift Keying
CW	Call Waiting
dB	deciBel
DC	Direct Current
DSB	Dual Side Band
DSS	Direct Sequence Signal
e.i.r.p.	equivalent isotropically radiated power
ECC	Electronic Communications Committee
EMC	Electro Magnetic Compatibility
ERC	European Radiocommunication Committee
EUT	Equipment Under Test
FH	Frequency Hopping
FMCW	Frequency Modulated Continuous Wave
FMICW	Frequency Modulated Interrupted Continuous Wave
FSK	Frequency Shift Keying
IF	Intermediate Frequency
LNA	Low Noise Amplifier
PDCF	Pulse Desensitation Correction Factor
PM	Pulse Modulation
PN	Pseudo Noise
PPM	Pulse Position Modulation (staggered)
PRF	Pulse Repetition Frequency

PRI	Pulse Repetition Interval
PSD	Power Spectral Density
PSK	Phase Shift Keying
R&TTE	Radio and Telecommunications Terminal Equipment
RBW	Resolution BandWidth
RF	Radio Frequency
RMS	Root Mean Square
RTTT	Road Transport and Traffic Telematics
SA	Spectrum Analyser
SPM	Staggered Pulse Position Modulated
SRD	Short Range Device
SRR	Short Range Radar
VBW	Video BandWidth
VSWR	Voltage Standing Wave Ratio

4 Technical requirements specifications

4.1 Presentation of equipment for testing purposes

Each equipment submitted for testing, where applicable, shall fulfil the requirements of the present document on all frequencies over which it is intended to operate. EMC type approval testing to Commission Directive 2004/104/EC [i.4] shall be done on the vehicle.

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

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

The performance of the equipment submitted for testing shall be representative of the performance of the corresponding production model. In order to avoid any ambiguity in that assessment, the present document contains instructions for the presentation of equipment for testing purposes, conditions of testing (clause 5) and the measurement methods (clauses 7 and 8). Instructions for installation of the equipment in a road vehicle are provided in annex D.

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

The EUT will comprise the sensor, antenna and radome if needed and will be tested as a stand alone assembly. The EUTs test fixtures may be supplied by the provider to facilitate the tests (clause 6.1).

These clauses are intended to give confidence that the requirements set out in the document have been met without the necessity of performing measurements on all frequencies.

4.1.1 Choice of model for testing

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

4.2 Mechanical and electrical design

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

Transmitters and receivers may be individual or combination units.

4.3 Auxiliary test equipment

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

5 Test conditions, power sources and ambient temperatures

5.1 Normal and extreme test conditions

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

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

5.2 External test power source

During tests the power source of the equipment shall be an external test power source, capable of producing normal and extreme test voltages as specified in clauses 5.3.2 and 5.4.2. The internal impedance of the external test power source shall be low enough for its effect on the test results to be negligible.

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

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

5.3 Normal test conditions

5.3.1 Normal temperature and humidity

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

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

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

5.3.2 Normal test power source

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

5.3.2.1 Mains voltage

The normal test voltage for equipment shall be the nominal mains voltage. For the purpose of the present document, the nominal voltage shall be the declared voltage, or any of the declared voltages, for which the equipment was designed.

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

5.3.2.2 Other power sources

For operation from other power sources the normal test voltage shall be that declared by the provider. Such values shall be stated in the test report.

5.4 Extreme test conditions

5.4.1 Extreme temperatures

5.4.1.1 Procedure for tests at extreme temperatures

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

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

5.4.1.2 Extreme temperature ranges

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

- temperature: -20 °C to +55 °C.

5.4.2 Extreme test source voltages

5.4.2.1 Mains voltage

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

5.4.2.2 Other power sources

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

6 General conditions

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

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

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. 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, 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, the measured device emissions, the achievable measurement noise floor and the frequency range(s) involved.

6.1 Test fixture

6.1.1 Requirements

The test fixture for radio equipment operating in the 79 GHz range shall enable the EUT to be physically supported, together with a wave guide horn antenna Rx which is used to measure the transmitted energy, in a fixed physical relationship to the EUT or calibration antenna Tx (see figure 1). The test fixture shall be designed for use in an anechoic environment and allow certain measurements to be performed in the far field, i.e. at a distance greater than $2d^2/\lambda$, where d is the largest dimension of the antenna aperture of the EUT.

The test fixture shall incorporate at least one 50 Ω RF connector, a device for electromagnetic coupling to the EUT and a means for repeatable positioning of the EUT. Its compactness shall enable the whole assembly to be accommodated within a test chamber, usually a climatic facility. The circuitry associated with the RF coupling device shall not contain active or non-linear components.

Only after it has been verified that the test fixture does not affect performance of the EUT, the EUT can be confidently tested.

At set-up, the EUT shall be aligned in the test fixture so that the maximum power is detected at the coupled output (see also clause 7.1). Orientation of the horn antenna will take into account the polarization of the EUT.

In addition, the test fixture shall provide a connection to an external power supply.

The test fixture shall be provided by the provider together with a full description, which shall meet the approval of the selected accredited test laboratory.

The performance characteristics of the test fixture shall be measured and shall be approved by the accredited test laboratory. It shall conform to the following basic parameters:

- the gain of the waveguide horn shall not exceed 20 dB;
- the physical distance between the front face of the EUT and the waveguide horn shall be between 50 cm and 1 m;
- the minimum distance between the transmitting and receiving antenna shall guarantee mutual far field conditions (distance greater than $2d^2/\lambda$, where d is the largest dimension of the antenna aperture of the EUT);
- the physical height between the centre of the EUT and the supporting structure of the test fixture shall be between 50 cm and 60 cm;

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

- the Voltage Standing Wave Ratio (VSWR) at the waveguide flange at which measurements are made shall not be greater than 1,5;
- the performance of the test fixture when mounted in the anechoic chamber or in a temperature chamber, shall be unaffected by the proximity of surrounding objects or people inside the chamber. The performance shall be reproducible if the EUT is removed and then replaced;
- the performance of the test fixture shall remain within the defined limits of the calibration report, when the test conditions are varied over the limits described in clauses 5.3 and 5.4.

The characteristics and calibration of the test fixture shall be included in a calibration report.

6.1.2 Calibration

The calibration of the test fixture establishes the relationship between the detected output from the test fixture, and the transmitted power (as sampled at the position of the antenna) from the EUT in the test fixture. This can be achieved by using a calibrated horn with a gain of equal to or less than 20 dB, fed from an external signal source, in place of the EUT to determine the variations in detected power with temperature and over frequency.

The calibration of the test fixture shall be carried out by either the provider of the EUT or the accredited test laboratory. The results shall be approved by the accredited test laboratory.

The calibration should be carried out over the operating frequency band, at least three frequencies, for the declared polarization of the EUT, and over the temperature ranges specified in clause 5.4.1.2.

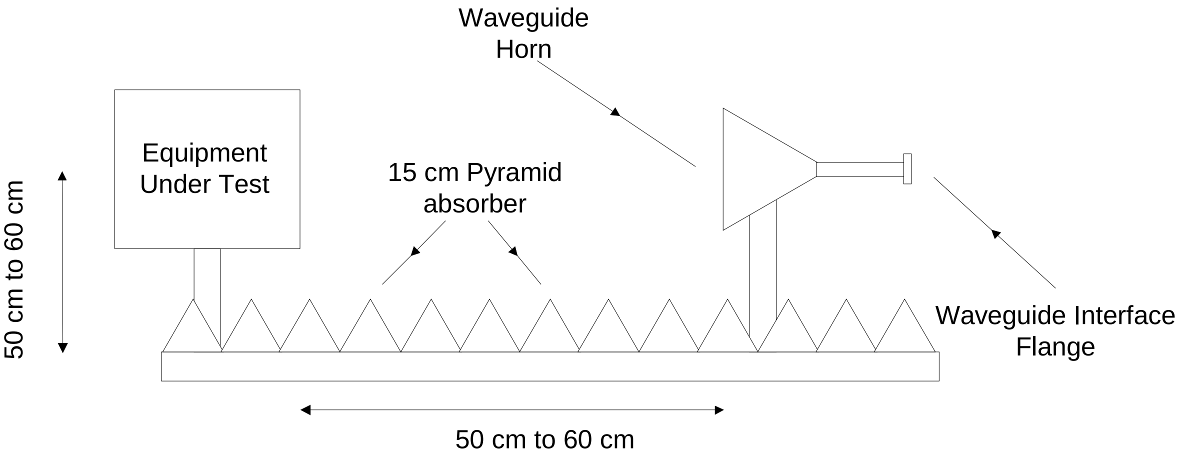

Figure 1: Test fixture

6.1.3 General requirements for RF cables and waveguides

All RF cables or waveguide interconnects, including their connectors at both ends, used within the measurement arrangements and set-ups shall adhere to the following characteristics:

- a nominal characteristic impedance of 50 Ω;
- a VSWR of less than 1,5 at either end;
- a shielding loss in excess of 60 dB.

All RF cables and waveguide interconnects shall be routed suitably in order to reduce impacts on antenna radiation pattern, antenna gain, antenna impedance.

6.1.4 Shielded anechoic chamber

Due to the low power emitted by the EUT, the test site shall be a shielded anechoic chamber.

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

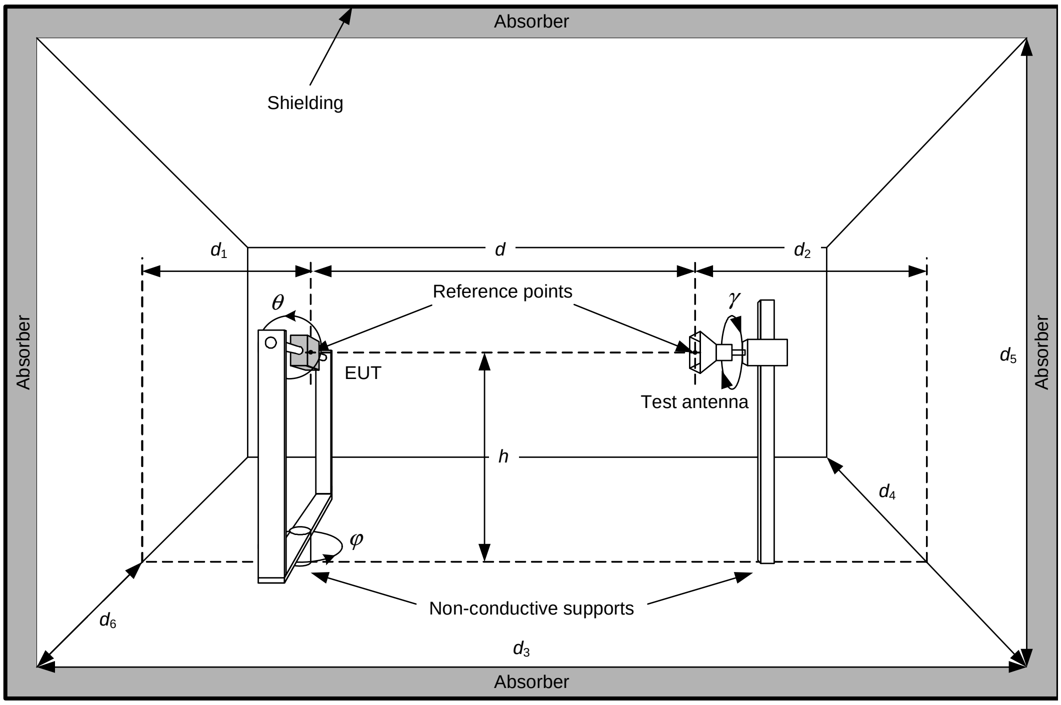

Figure 2: Typical anechoic chamber

The chamber contains suitable antenna supports on both ends.

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

The anechoic chamber shall be shielded. Internal walls, floor and ceiling shall be covered with radio absorbing material. The shielding and return loss for perpendicular wave incidence vs. frequency in the frequency range as of 300 MHz shall meet:

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

Both absolute and relative measurements can be performed in an anechoic chamber. Where absolute measurements are to be carried out the chamber shall be verified.

The shielded anechoic chamber test site shall be calibrated and validated for the frequency range being applicable.

NOTE 1: Information on uncertainty contributions, and verification procedures are detailed in clauses 5 and 6, respectively, of TR 102 273-2 [2].

NOTE 2: Further information on shielded anechoic chambers is given in clause A.3.

7 Methods of measurement and limits for transmitter parameters

The emitted spectrum from SRRs consists of two different emissions:

a) Single carrier emissions in the 77 GHz to 81 GHz.

b) Broadband emissions in the 77 GHz to 81 GHz.

The methods of measurement are different for peak power (over entire bandwidth) and average power (in 1 MHz resolution bandwidth).

7.1 Methods of measurement and limits for transmitters in 77 GHz to 81 GHz band

To meet the requirements for all applications the EUT shall be measured at its maximum peak and mean output power level and maximum antenna gain. Antenna polar diagrams and details of polarization, shall be presented and agreed with the accredited test laboratory if they are necessary to enable the measurements described in clause 7.2.3 to be performed. For systems with antenna beam steering capabilities, the normal scanning operation mode is used (no special test mode with fixed antenna beam is required).

Alternative test methods to those described within the present document may be used with the agreement of the provider, and at the discretion of the accredited test laboratory. Procedures shall comply with CISPR 16 [1].

For 79 GHz range EUTs the type of modulation has to be stated in the test specification.

7.1.1 Permitted range of operating frequencies

7.1.1.1 Definition

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

7.1.1.2 Method of measurement

The occupied bandwidth of the EUT, e.g. the minimum and maximum output frequencies at which the permitted spurious and out-of-band emission levels as specified in clause 7.2 are exceeded due to intentional emission from the radio transmitter shall be measured using the method shown in figure 3. If the Measuring Receiver is capable of measuring the signals directly without any down mixing, the fundamental or harmonic Mixer can be omitted. If more than one modulation scheme can be generated by the EUT, then for each modulation scheme and one typical set of modulation parameters the maximum and minimum frequencies shall be measured and recorded separately.

The measuring receiver may be a spectrum analyser, oscilloscope, selective power meter or any measuring receiver which is appropriate to perform the intended measurement of the EUT.

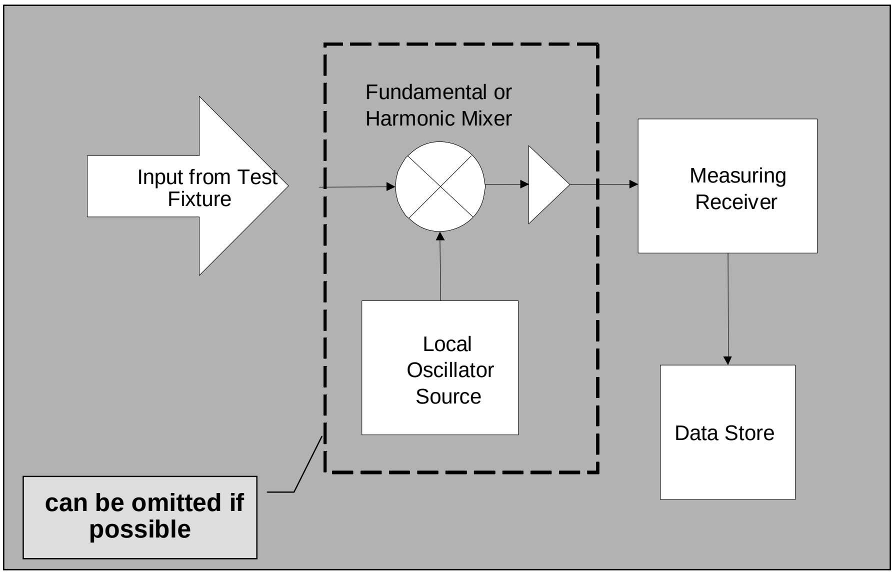

Figure 3: Test equipment for measuring the operating frequency range

This measurement shall be performed at normal and at extreme test conditions (see clauses 5.3 and 5.4).

The method of measurement shall be documented in the test report.

7.1.1.3 Limits

The permitted range of operating frequency for intentional emissions shall be from 77 GHz to 81 GHz. Outside the permitted range of operating frequencies the unintentional emissions shall be reduced to the limits given in clause 7.2.4.

7.1.2 Maximum radiated average power spectral density (e.i.r.p.)

7.1.2.1 Definition

The maximum radiated average power spectral density (e.i.r.p.) is defined as the emitted power spectral density in a one MHz bandwidth of the transmitter including antenna gain according to the procedure given in the following clause. See clause 5 for the test conditions.

7.1.2.2 Method of measurement

Using an applicable measurement procedure e.g. as described in annexes A and B, the power spectral density shall be measured according to figure 4 and recorded in the test report. The method of measurement shall be documented in the test report.

The tests shall be made in an anechoic-shielded chamber, as the measured levels often are lower than the ambient environmental noise.

The test set-up is shown in figure 4.

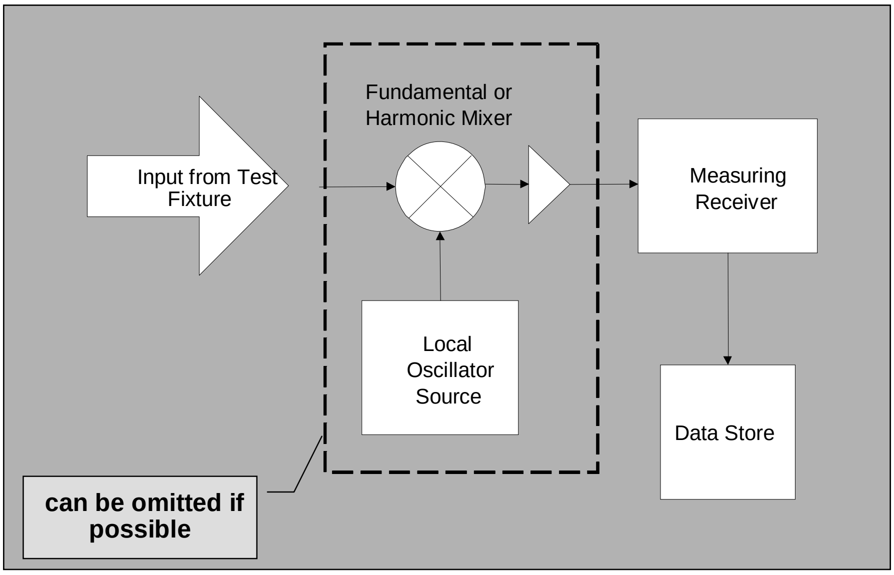

Figure 4: Test set-up for power spectral density measurements of transmitter operating in the 77 GHz to 81 GHz band

The following spectrum analyser settings shall be used:

- Resolution bandwidth ≤ 10 MHz.
- Video bandwidth ≥ 3 MHz.
- Detector mode: r.m.s. with an averaging time of minimum one cycle time per MHz (maximum 50 ms).

The measured spectrum curve at the spectrum analyser is recorded over an amplitude range of approximately 35 dB. Measurements of power densities below -40 dBm/MHz (e.i.r.p.) are not required.

7.1.2.3 Limits

The transmitter maximum radiated average power spectral density (e.i.r.p.) under normal and extreme test conditions shall not exceed the values given in table 1.

Table 1: Limits for broadband maximum radiated average power spectral density (e.i.r.p.) in the frequency band from 77 GHz to 81 GHz

Frequency in GHz	77 GHz to 81 GHz
Maximum radiated average power spectral density (e.i.r.p.) [dBm/MHz] of the EUT	-3 dBm/MHz

7.1.3 Maximum radiated peak power spectral density (e.i.r.p.)

7.1.3.1 Definition

The maximum radiated peak power spectral density is measured in the permitted range of operating frequencies and is an value including antenna gain (e.i.r.p.).

The maximum radiated peak power density including antenna gain (e.i.r.p.) is defined as the peak power measured in a 50 MHz bandwidth. As it is difficult to measure the peak power in a 50 MHz bandwidth with spectrum analysers, the test is measuring the peak power in a resolution bandwidth greater than 1 MHz according to the procedure given in the following clause 7.1.3.2.

7.1.3.2 Method of measurement

The maximum radiated peak power is measured using a spectrum analyser with the detector in max-hold mode.

The peak power measurement is based on a 50 MHz measurement bandwidth. No further correction factor (PDCF) is applied to the readings measured in the 50 MHz RBW. With standard commercial test equipment such large RBW is not feasible. Furthermore the VBW shall be at least as large as the RBW for correct peak measurements. Therefore a resolution bandwidth of 3 MHz shall be used. The measurement shall be centred on the frequency at which the highest radiated emission occurs.

The following spectrum analyser settings shall used:

- Resolution bandwidth = 3 MHz.
- Video bandwidth = 3 MHz.
- Detector mode = Peak with max hold.

According to the modulation scheme, a correction factor needs to be applied. As an example, for a pulse radar using PN PPM modulation (see clause C.1), the pulse bandwidth is much larger than the RBW of the spectrum analyser.

The largest VBW on a spectrum analyser is about 10 MHz, so the widest RBW that could be employed should be 10 MHz. To compensate for the differences in RBW from 50 MHz to 3 MHz, the worst case assumption of a 20 log relationship is used, i.e. reducing the RBW from 50 MHz to 3 MHz results in an attenuation of the peak limit of 20 log (3/50) or -24,44 dB. If peak measurements were to be performed using a 1 MHz RBW, the peak limit would be decreased by 20 log (1/50) or -34 dB.

To illustrate the above mentioned with an example, for a given peak limit of 0 dBm in 50 MHz RBW, the following limits in other RBWs are equivalent:

- 0 dBm in 50 MHz RBW; or
- -24,44 dBm in 3 MHz RBW; or
- -34 dBm in 1 MHz RBW.

The RBW must be centred on the frequency at which the highest radiated emission occurs. Any RBW within 1 MHz and 50 MHz with the peak limit correction following the square of the change in RBW (i.e. 20 log relationship) could be possible.

For equipment under test with fast electronically steerable antennas (antenna dwell time < 1/RBW), the sweep profile has to be taken into account in order to record proper values for peak power.

7.1.3.3 Limits

The transmitter maximum transmitted peak power (e.i.r.p.) under normal and extreme test conditions shall not exceed the values given in table 2.

Table 2: Limits for broadband maximum transmitted peak power (e.i.r.p.) in the 77 GHz to 81 GHz band

Frequency in GHz	77 GHz to 81 GHz
Peak Power (e.i.r.p.) over entire bandwidth in dBm	55

7.2 Maximum radiated spurious and out-of-band emissions

7.2.1 Definition

Spurious emissions: are emissions radiated by the antenna of the EUT or its cabinet on a frequency, or frequencies, outside the permitted range of frequencies occupied by the transmitter. Spurious emissions include harmonic emissions, parasitic emissions, intermodulation products and frequency conversion products, but exclude out-of-band emissions.

Out-of-band emissions: are residual emissions related to the intentional emissions radiated by the antenna of the EUT on the frequencies immediately outside the permitted range of frequencies which results from the modulation process.

Spurious emissions and out-of-band emissions are measured as spectral power density under normal operating conditions.

7.2.2 Measuring receiver

The term "measuring receiver" refers to either a selective voltmeter or spectrum analyser. The bandwidth of the measuring receiver shall, where possible, be according to CISPR 16 [1]. In order to obtain the required sensitivity a narrower bandwidth may be necessary, this shall be stated in the test report form.

A quasi-peak detector is used for spurious emission measurements below 1 GHz, and for frequencies as of 1 GHz and above, peak detection is used unless otherwise stated explicitly in the respective method of measurement.

Table 3: Maximum receiver bandwidths

Frequency being measured (f)	Maximum measuring receiver bandwidth
f < 1 000 MHz	100 kHz to 120 kHz
f ≥ 1 000 MHz	1 MHz

7.2.3 Method of measurement for radiated spurious or out-of-band emissions

A test site such as one selected from annex A, which fulfils the requirements of the specified frequency range of this measurement shall be used. The test method employed should be as described in annex B. For frequencies above 40 GHz a down converter may be used as shown in figure 5. 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 Intermediate Frequency (IF) bandwidth to capture the full spectrum of the signal. The e.i.r.p. of the EUT shall be measured and recorded. For these measurements it is strongly recommended to use a Low Noise Amplifier (LNA) before the SA input to achieve the required sensitivity.

Out-of-band emissions are determined according to the procedure for maximum radiated average power spectral density (see clause 7.1.2).

Spurious emissions are determined according to the procedure for maximum radiated peak power (see clause 7.1.3).

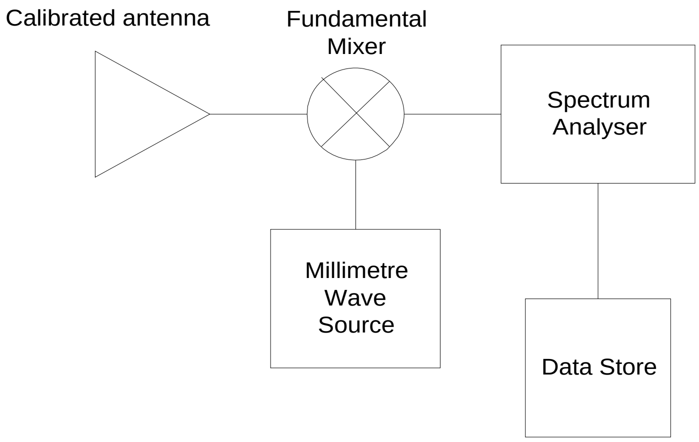

Figure 5: Test equipment for measuring spurious or out-of-band radiation above 40 GHz

7.2.4 Limits

The effective radiated power of any spurious or out-of-band emission shall not exceed the values given in tables 4 and 5.

Table 4: Limits of radiated spurious emissions

Frequency range	Limit values for spurious radiation
47 MHz to 74 MHz	-54 dBm
87,5 MHz to 118 MHz	-54 dBm
174 MHz to 230 MHz	-54 dBm
470 MHz to 862 MHz	-54 dBm
otherwise in band 30 MHz to 1 000 MHz	-36 dBm
1 000 MHz to 170 GHz (see note)	-30 dBm
NOTE: Not applicable within the permitted range of frequencies for the 79 GHz SRR from 77 GHz to 81 GHz.	

Table 5: Limits of radiated out-of-band emissions

Frequency range	Limit values for out of band radiation
25 GHz to 77 GHz	-30 dBm/MHz
81 GHz to 170 GHz	-30 dBm/MHz

8 Methods of measurement and limits for receiver parameters

8.1 Receiver spurious emissions

8.1.1 Definition

Separate radiated spurious measurements need not be made on receivers co-located with transmitters. The definitions from clause 7.2.1 on transmitter spurious and out-of-band emissions apply.

8.1.2 Method of measurement - radiated spurious emissions

This method of measurement applies to receivers having an integral antenna.

a) A test site selected from annex A which fulfils the requirements of the specified frequency range of this measurement shall be used. The test antenna shall be oriented initially for vertical polarization and connected to a measuring receiver. The bandwidth of the measuring receiver shall be adjusted until the sensitivity of the measuring receiver is at least 6 dB below the spurious emission limit given in clause 7.2.4. This bandwidth shall be recorded in the test report.

   The receiver under test shall be placed on the support in its standard position.

b) The frequency of the measuring receiver shall be adjusted over the frequency range from 25 MHz to 100 GHz. The frequency of each spurious component shall be noted. If the test site is disturbed by radiation coming from outside the site, this qualitative search may be performed in a screened room with reduced distance between the transmitter and the test antenna.

c) At each frequency at which a component has been detected, the measuring receiver shall be tuned and the test antenna shall be raised or lowered through the specified height range until the maximum signal level is detected on the measuring receiver.

d) The receiver shall be rotated up to 360 ° about a vertical axis, to maximize the received signal.

e) The test antenna shall be raised or lowered again through the specified height range until a maximum is obtained. This level shall be noted.

f) The substitution antenna (see clause A.2.1) shall replace the receiver antenna in the same position and in vertical polarization. It shall be connected to the signal generator.

g) At each frequency at which a component has been detected, the signal generator, substitution antenna and measuring receiver shall be tuned. The test antenna shall be raised or lowered through the specified height range until the maximum signal level is detected on the measuring receiver. The level of the signal generator giving the same signal level on the measuring receiver as in step e) shall be noted. This level, after correction due to the gain of the substitution antenna and the cable loss, is the radiated spurious component at this frequency.

h) The frequency and level of each spurious emission measured and the bandwidth of the measuring receiver shall be recorded in the test report.

i) Measurements b) to h) shall be repeated with the test antenna oriented in horizontal polarization.

8.1.3 Limit

The maximum equivalent isotropic radiated power (max. e.i.r.p.) of any spurious emission outside the permitted range of frequencies, shall not exceed 2 nW (≈ -57 dBm) in the frequency range 25 MHz $\leq f \leq$ 1 GHz and shall not exceed 20 nW (≈ -47 dBm) on frequencies above 1 GHz.

9 Interpretation of measurement results

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

1) the measured value related to the corresponding limit shall be used to decide whether an equipment meets the requirements of the present document;

2) the measurement uncertainty value for the measurement of each parameter shall be recorded;

3) the recorded value of the measurement uncertainty shall be wherever possible, for each measurement, comply with the figures in table 6, and the interpretation procedure specified in clause 9.1 shall be used.

For the test methods, according to the present document, the measurement uncertainty figures shall be calculated in accordance with the guidance provided in TR 100 028 [3] and shall correspond to an expansion factor (coverage factor) k = 1,96 or k = 2 (which provide confidence levels of respectively 95 % and 95,45 % in the case where the distributions characterizing the actual measurement uncertainties are normal (Gaussian)).

Table 6 is based on such expansion factors.

Table 6: Absolute measurement uncertainty

Parameter	Uncertainty
Radio Frequency (out of band)	$\pm 1 \times 10^{-7}$
Radiated Emission (valid to 100 GHz)	±6 dB
Temperature	±1 K
Humidity	±10 %
DC and low frequency voltages	±3 %
NOTE: For some radiated emissions measurements it may not be possible to reduce measurement uncertainty to the levels specified in table 6 (due to the very low signal level limits and the consequent requirement for high levels of amplification across wide bandwidths). In these cases alone it is acceptable to employ the alternative interpretation procedure specified in clause 7.2.	

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

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

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

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

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

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

9.2 Measurement uncertainty is greater than maximum acceptable uncertainty

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

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

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

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

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

Annex A (normative): Radiated measurements

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

This annex provides information for test sites to be used for SRDs.

For general guidance on the use of radiation test sites refer to CISPR 16 [1].

A.2 Guidance on the use of radiation test sites

For measurements involving the use of radiated fields, use shall be made of a test site in conformity with the requirements of clause A.3. For measurements above 40 GHz care shall be taken to ensure that the selected test site is appropriate. When using such a test site, the following conditions should be observed to ensure consistency of measuring results.

A.2.1 Substitution antenna

The substitution antenna and signal generator is used to replace the EUT in substitution measurements. For measurements below 1 GHz the substitution antenna shall be half wavelength dipole resonant at the frequency under consideration, or a shortened dipole, calibrated to the half wavelength dipole. For measurements between 1 GHz and 4 GHz either a half wavelength dipole or a horn radiator may be used. For measurements above 4 GHz a horn radiator shall be used. The centre of this antenna shall coincide with the reference point of the EUT it has replaced. This reference point shall be the volume centre of the sample when its antenna is mounted inside the cabinet, or the point where an outside antenna is connected to the cabinet. The distance between the lower extremity of the dipole and the ground shall be at least 300 mm.

A.3 Indoor test site using a fully anechoic RF chamber

For radiation measurements when the frequency of the signals being measured is greater than 30 MHz, use shall be made of an indoor site being a well-shielded anechoic chamber simulating free space environment. If such a chamber is used, this shall be recorded in the test report.

In the range between 30 MHz and 100 MHz some additional calibration may be necessary.

An example of a typical measurement site may be an electrically shielded anechoic chamber being 10 m long, 5 m broad and 5 m high. Walls and ceiling should be coated with RF absorbers of 1 m height. The base should be covered with absorbing material 1 m thick, and a wooden floor, able to carry test equipment and operators. A measuring distance of 3 m to 5 m in the long middle axis of the chamber can be used for measurements up to 12,75 GHz. For frequencies above 12,75 GHz the chamber may be used provided it has been calibrated for use at the frequency being measured. The construction of the anechoic chamber is described in the following clauses.

A.3.1 Example of the construction of a shielded anechoic chamber

Free-field measurements can be simulated in a shielded measuring chamber where the walls are coated with RF absorbers. Figure A.3 shows the requirements for shielding loss and wall return loss of such a room. As dimensions and characteristics of usual absorber materials are critical below 100 MHz (height of absorbers < 1 m, reflection attenuation < 20 dB) such a room is preferably suitable for measurements above 100 MHz. Figure A.4 shows the construction of a shielded measuring chamber having a base area of 5 m by 10 m and a height of 5 m.

Ceilings and walls are coated with pyramidal formed RF absorbers approximately 1 m high or equivalent material with the same performance. The base is covered with absorbers which form a non-conducting sub-floor, or with special ground floor absorbers. The available internal dimensions of the room are 3 m × 8 m × 3 m, so that a measuring distance of maximum 5 m length in the middle axis of this room is available.

At 100 MHz the measuring distance can be extended up to a maximum of 2 λ.

The floor absorbers reduce floor reflections so that the antenna height need not be changed and floor reflection influences need not be considered.

All measuring results can therefore be checked with simple calculations and the measurement uncertainties have the smallest possible values due to the simple measuring configuration.

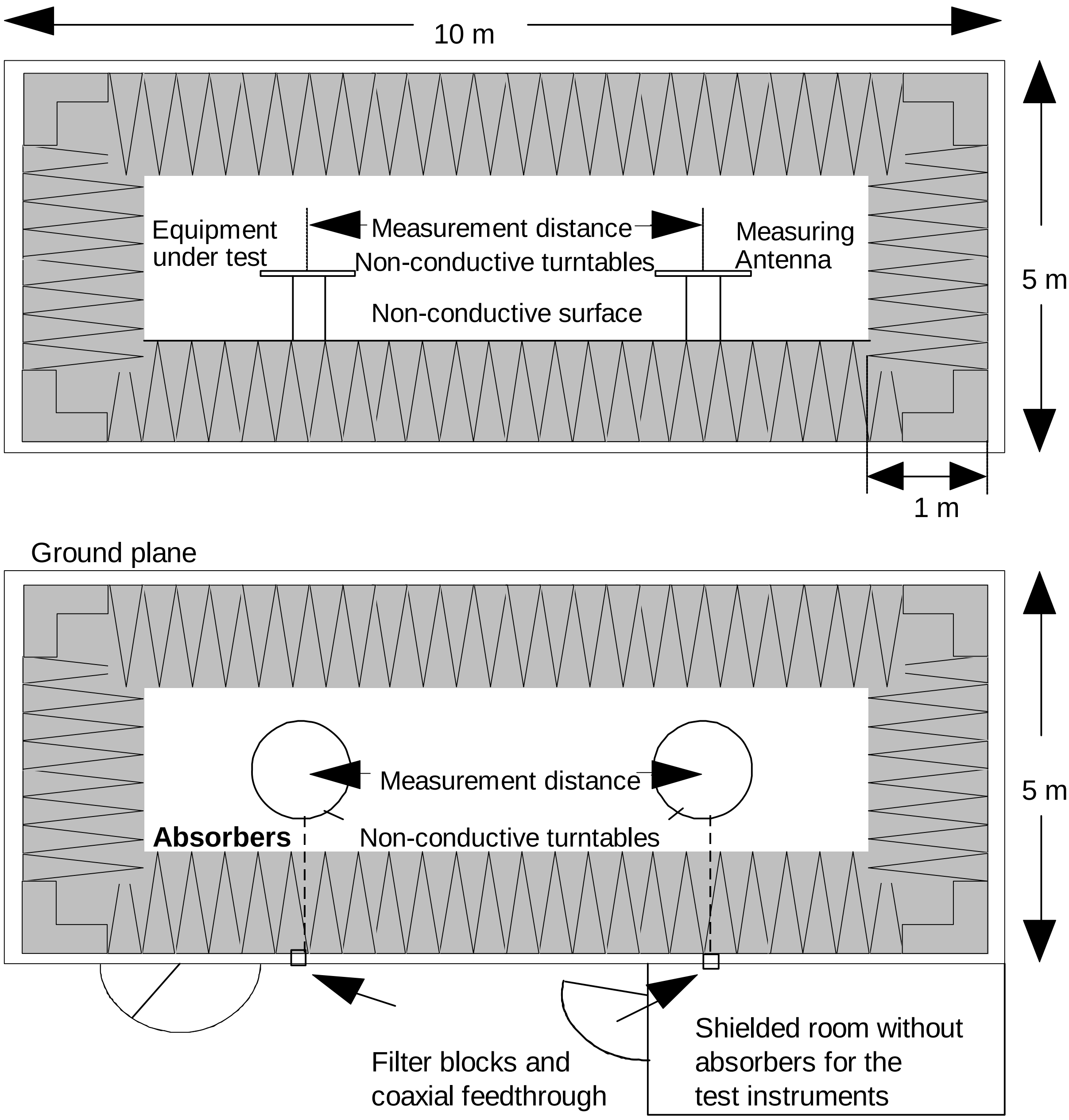

Figure A.1: Example of construction of an anechoic shielded chamber to meet shielding and return loss requirements

A.3.2 Influence of parasitic reflections in anechoic chambers

For free-space propagation in the far field condition the correlation $E = E_o \times (R_o/R)$ is valid for the dependence of the field strength E on the distance R, whereby E_o is the reference field strength in the reference distance R_o.

It is useful to use just this correlation for comparison measurements, as all constants are eliminated with the ratio and neither cable attenuation nor antenna mismatch or antenna dimensions are of importance.

Deviations from the ideal curve can be seen easily if the logarithm of the above equation is used, because the ideal correlation of field strength and distance can then be shown as a straight line and the deviations occurring in practice are clearly visible. This indirect method shows the disturbances due to reflections more readily and is far less problematical than the direct measurement of reflection attenuation.

With an anechoic chamber of the dimensions of clause A.3 at low frequencies up to 100 MHz there are no far field conditions, and therefore reflections are stronger so that careful calibration is necessary. In the medium frequency range from 100 MHz to 1 GHz the dependence of the field strength on the distance meets the expectations very well. In the frequency range of 1 GHz to 100 GHz, because more reflections will occur, the dependence of the field strength on the distance will not correlate so closely.

A.3.3 Calibration of the shielded RF anechoic chamber

Calibration of the chamber shall be performed over the range 30 MHz to 100 GHz.

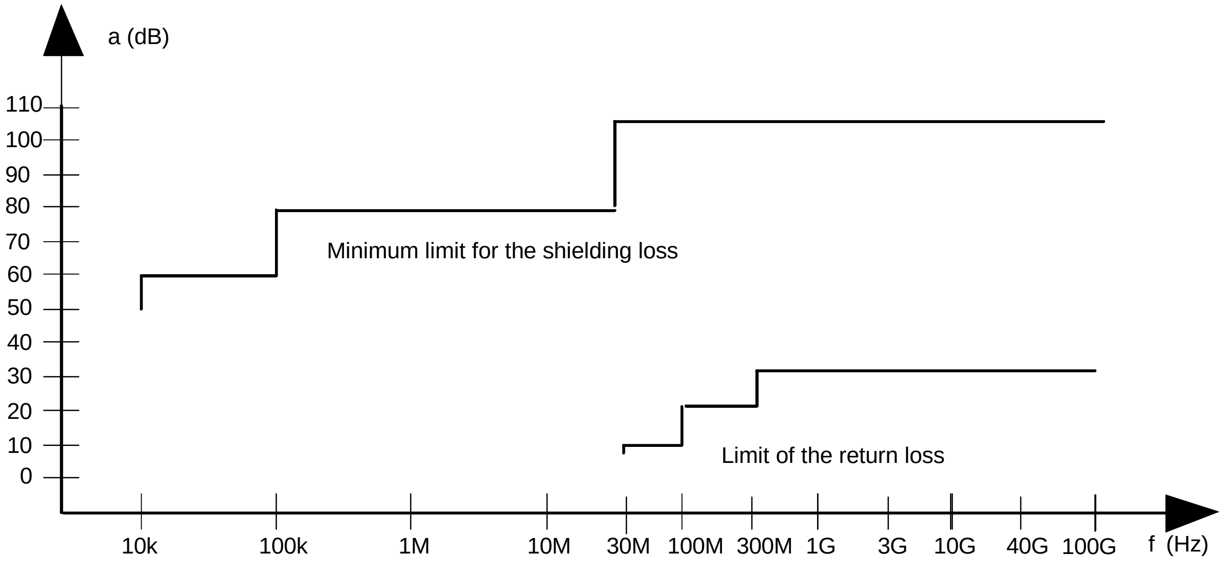

Figure A.2: Specification for shielding and reflections

Annex B (normative):
General description of measurement methods

B.1 Radiated measurements

Radiated measurements shall be performed with the aid of a test antenna and measuring receiver as described in annex A. The test antenna and measurement receiver, spectrum analyser or selective voltmeter (including all cables) shall be calibrated according to the procedure defined in this annex. The EUT and the test antenna shall be oriented to obtain the maximum emitted power level. This position shall be recorded in the measurement report. The frequency range shall be measured in this position.

For equipment with multiple fixed beam antennas, the tests shall be carried out with the test antenna oriented to obtain the maximum emitted power level, and repeated for each beam position. If the equipment transmits more than one beam at a time, then the maximum e.i.r.p. shall be recorded.

If the equipment has an antenna which is either mechanically or electronically scanned, then the scanning shall be inhibited for these tests. With the scanning stopped, the e.i.r.p. for the EUT shall be measured with the antenna in its position of highest gain (i.e. highest output power) as stated by the provider.

Measurements of absolute power levels below 40 GHz shall be carried out at a distance of $2d^2/\lambda$. For measurements of absolute power above 40 GHz an anechoic environment or test site is necessary which should be large enough to allow the erection of a test antenna in the far field (i.e. at a distance of not less than $2d^2/\lambda$).

Radiated measurements shall be performed with the EUT in the approved test fixture in a fully anechoic environment.

All radiated measurements with devices operating in the 77 GHz to 81 GHz band shall be carried out in a fully anechoic environment. For measurements of absolute power the measurement distance shall be large enough to allow the erection of a test antenna in the far field.

For an anechoic chamber the test antenna shall be oriented initially according to the EUT supplier polarization information unless otherwise stated.

Annex C (informative): Example of modulation schemes

C.1 Pseudo Noise Pulse Position Modulation (PN PPM)

C.1.1 Definition

For pulse modulation, the Tx "amplitude" is periodically switched on for a short time (called pulse duration pdt) and switched off during the subsequent reception period. A typical example is shown in figure C.1. Due to finite switch isolation, a residual CW emission does occur.

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.

In case of a pseudo noise variation of the PRI a wideband spectrum with very homogeneous spectral power spectral density and noise like emissions with respect to narrow band receivers can be achieved.

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

The pulse duty cycle is the product of the PRF and the pulse duration. The equivalent pulse power duration has to be applied in case of nonrectangular pulse shapes, which is defined to be the duration of an ideal rectangular pulse which has the same content of energy compared with the nonrectangular pulse shape of the EUT.

The radiated power (RMS) on the crest of the pulse shape is called the peak output power.

The peak output power multiplied by the average pulse duty cycle used to generate the broadband spectrum is called the average output power.

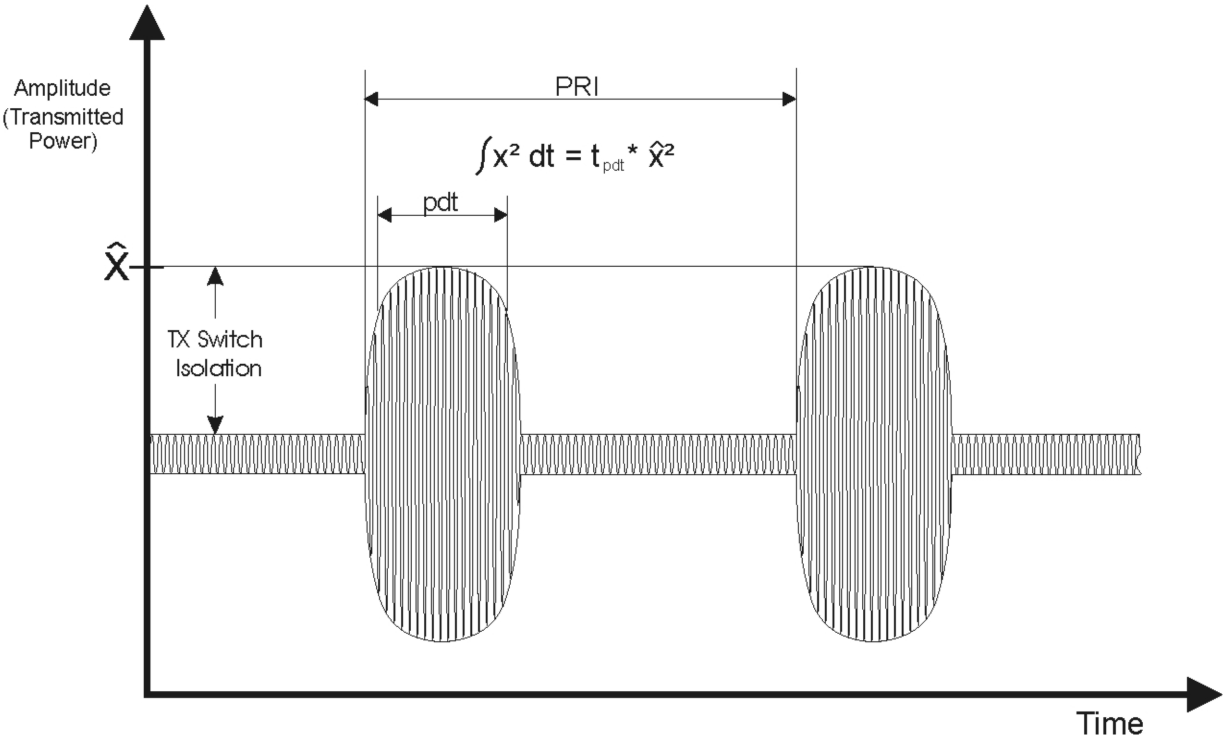

Figure C.1: Typical pulse modulation scheme

C.1.2 Typical operation parameters

The peak and average (RMS) power limits are given in clauses 7.1.3 and 7.1.2. Typical operation parameters are given in table C.1.

Table C.1: Typical operation parameters for pulse modulation

Parameter	Typical value
PRF	2 MHz
Equivalent pulse power duration	500 ps
Activity factor	10 %
Pulse duty cycle	1/1 000
Residual carrier power	< -10 dBm
Occupied Bandwidth ($DSB_{-20\ dB}$)	3,5 GHz

C.2 Pulsed FH (Pulsed Frequency hopping)

C.2.1 Definition

For Frequency Hopping (FH) modulation a frequency carrier is stepped over a given frequency bandwidth B_{FH} within frequency slots that are interleaved by the slot interleave bandwidth Δf_i. The coding of the frequency step pattern can be realized with both randomly and predefined sequences at a given hopping frequency $f_{hop.}$ The granularity of the frequency slots determines the spectral distribution, which in case of a pseudo noise randomized sequence of frequency steps, results in a spectrum similar to white noise.

The continuous emission of the FH can be further time gated with a given pulse width T_{pw}. (e.g. Pulsed FH). If the pulse repetition frequency PRF is varied over time (staggered PRF), the frequency distribution of the pulsed FH is further dithered over the frequency bandwidth B_{FH}.

With a Staggered Pulse Position Modulated Frequency Hopping system (SPM FH) spread spectrum characteristics can be independently tuned by either varying pulse modulation or frequency slot spreading individually.

For a PPM FH system the number of different hopping frequencies n_{slot} and the pulse width T_{pw} can vary from frame to frame.

The accumulated dwell time T_{dw} within a frequency slot depends on the pulse width T_{pw} and the hopping frequency f_{hop} in combination with the number of slots during a complete frame time T_{fr}.

Both pulse width T_{pw} and slot changing frequency f_{hop} can be changed within the frame time T_{fr} as long as the peak and average limits in clauses 7.1.2.3 and 7.1.2 are respected.

A typical PM FH modulation is shown in figure C.2.

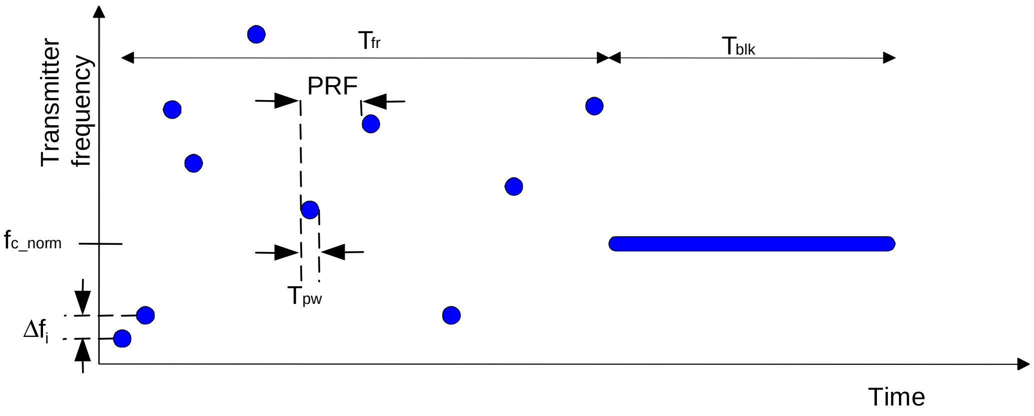

Figure C.2: Typical Pulsed FH Modulation

C.2.2 Typical operation parameters

The peak and average (RMS) power limits are given in clauses 7.1.3 and 7.1.2. Typical operation parameters are given in table C.2.

Table C.2: Typical operation parameters for Pulsed FH modulation

Parameter	Typical value
Number of slots n_{slot} per frame	1 (within SRD band) 2^8 (within B_{FH})
Dwell time per slot T_{dw}	1 µs
Hopping frequency f_{hop}	$1/T_{dw}$
Frame time period T_{fr}	10 ms
Equivalent pulse power duration T_{pw}	100 ns
Duty cycle for pulse train	10 %
Blank Time period T_{blk}	10 ms
Occupied Bandwidth B_{FH} ($DSB_{-10\ dB}$)	1,5 GHz
slot interleave bandwidth Δf_I	15 MHz

C.2.3 Additional requirements for pulsed FH equipment measurement

C.2.3.1 Pulsed FH modulation

Pulsed FH modulation commonly use at least 64 well defined, non-overlapping channels or hopping positions separated by the slot interleave bandwidth. The dwell time per frequency hop is normally 10 µs (the instantaneous bandwidth of a single hop channel is defined by the inverse of the pulse width (i.e. a 50 ns pulse modulation generates an instantaneous occupied bandwidth of 20 MHz). While the equipment is operating (transmitting and/or receiving) each channel of the hopping sequence occupies at least once during the frame period.

The provider usually declares the total number of hops, the dwell time, the -20 dB bandwidth per hop and the maximum frequency separation of the individual hops.

C.2.3.2 Measurement requirements

Measurements should be carried out while the equipment is frequency hopping between the declared occupied bandwidth. The use and the distribution of the individual pulsed frequency hops over the occupied bandwidth should be declared by the provider and measured accordingly.

C.3 PN-ASK (Pseudo noise coded amplitude shift keying)

C.3.1 Definition

With PN-ASK modulation, the transmitted continuous wave radiation is modulated in amplitude by a pseudo noise code, i.e. the direct sequence signal (DSS), that represents the states of the base band signal of a ASK modulation.

A generic binary DSS impulse c(t) and the corresponding transmitted signal s(t) are shown in figure C.4. The DSS impulse c(t) and the transmitted signal s(t) can be expressed as:

$$c(t) = \sum_{i=0}^{L-1} C_i \cdot u(t - i \cdot T_c)\,;$$

$$s(t) = c(t) \cdot \sin(2 \cdot \pi \cdot f_c \cdot t)\,.$$

Where:

C_i defines the states, e.g. {+1, 0} of the elementary signals (chips);

u(t) defines the rectangular signal: $u(t) = \begin{cases} 1 & for\ 0 \le t < T_c \\ 0 & else \end{cases}$;

f_c defines the carrier frequency;

T_c defines the duration of a chip (chip period);

L defines number of chips per PN-sequence.

The bandwidth (B) of the transmitted signal s(t) is defined by the bandwidth of the main lobe and corresponds to twice the inverse of the chip rate, from null to null:

$$B = 2 \times \frac{1}{T_c}$$

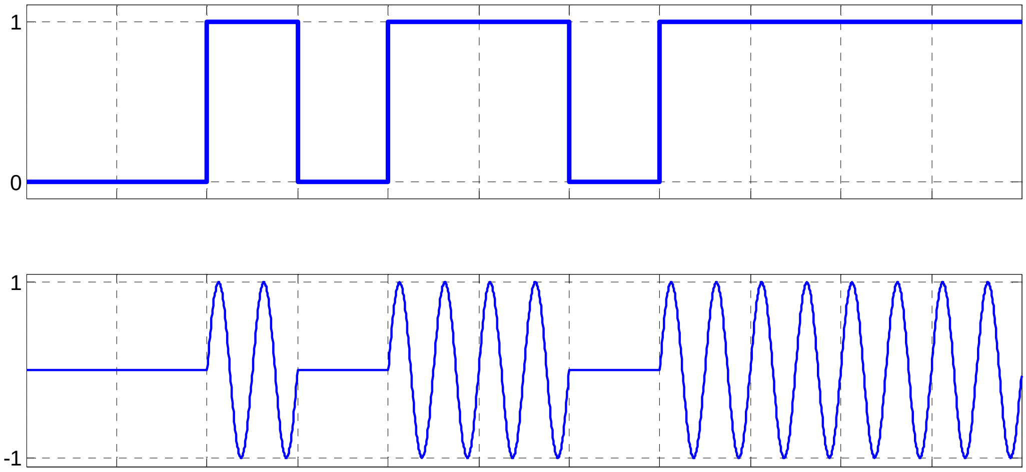

Figure C.3: Typical binary direct sequence impulse c(t) and the transmitted PN-2-ASK signal s(t)

The PN-ASK can furthermore be time-gated or pulsed as described in clause C.2.

C.3.2 Typical operation parameters

The peak and average (RMS) power limits are given in clauses 7.1.3 and 7.1.2. Typical operation parameters are given in table C.3.

Table C.3: Limits for PN-ASK Modulation

Parameter	Typical value
Chip period T_c	500 ps minimum
PN-sequence period ($L \times T_c$)	Defined by ambiguity range
Occupied Bandwidth B	4 GHz maximum

C.4 PN-PSK (Pseudo noise coded phase shift keying)

C.4.1 Definition

With PN-PSK modulation, the transmitted continuous wave radiation is modulated in phase by a pseudo noise code, i.e. the direct sequence signal (DSS), that represents the states of the base band signal of a BPSK modulation.

A generic binary DSS impulse c(t) and the corresponding transmitted signal s(t) are shown in figure C.4. The DSS impulse c(t) and the transmitted signal s(t) can be expressed as:

$$c(t) = \sum_{i=0}^{L-1} C_i \cdot u(t - i \cdot T_c)\,;$$

$$s(t) = c(t) \cdot \sin(2 \cdot \pi \cdot f_c \cdot t)\,.$$

Where:

C_i defines the states, e.g. {+1, -1} of the elementary signals (chips) for BPSK;

u(t) defines the rectangular signal: $u(t) = \begin{cases} 1 \text{ for } 0 \le t < T_c \\ 0 \text{ else} \end{cases}$;

f_c defines the carrier frequency;

T_c defines the duration of a chip (chip period);

L defines number of chips per PN-sequence.

The bandwidth (B) of the transmitted signal s(t) is defined by the bandwidth of the main lobe and corresponds to twice the inverse of the chip rate, from null to null:

$$B = 2 \times \frac{1}{T_c}$$

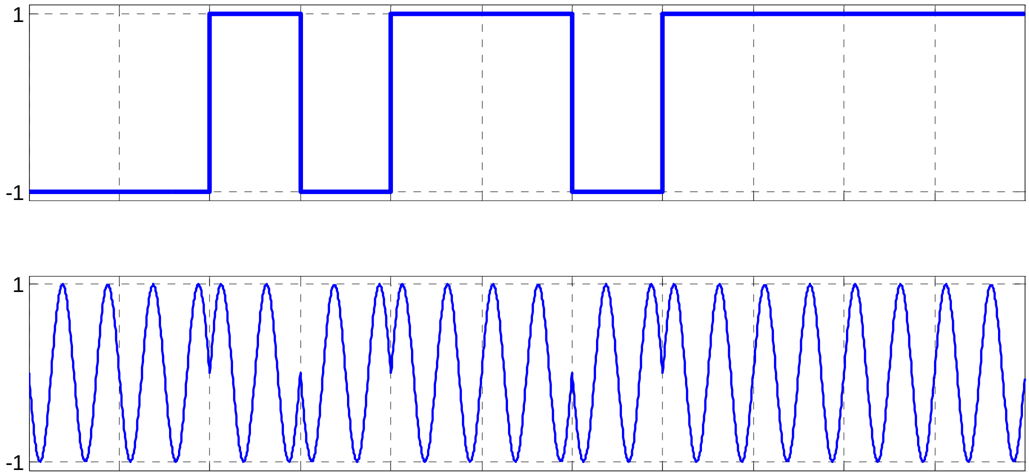

Figure C.4: Typical binary direct sequence impulse c(t) and the transmitted PN-2-PSK signal s(t)

The PN-PSK can furthermore be time-gated or pulsed as described in the clause C.2.

C.4.2 Typical operation parameters

The peak and average (RMS) power limits are given in clauses 7.1.2.3 and 7.1.2. Typical operation parameters are given in table C.4.

Table C.4: Limits for PN-PSK Modulation

Parameter	Typical value
Chip period T_c	500 ps minimum
PN-sequence period ($L \times T_c$)	Defined by ambiguity range
Occupied Bandwidth B	4 GHz maximum

C.5 Frequency modulated continuous wave

C.5.1 Definition

For Frequency Modulated Continuous Wave (FMCW) modulation, the transmitted waveform is frequency modulated over a period of time (P). This period of time may be constant, or may be varied. An example of a typical modulation scheme is shown in figure C.5. During the time (P), the frequency may either increase or decrease. The modulation may assume (but is not limited to) the form of a "sawtooth", "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 (FMICW)). The modulation waveform may be repeated or varied over several periods of time, and at the beginning or end of each period of time (P), there may be a time "G" (the "blanking period") where the transmitted waveform is adjusting to the requirements of the beginning of the next period.

Furthermore several waveforms separated by a suitable frequency offset can be transmitted at the same time.

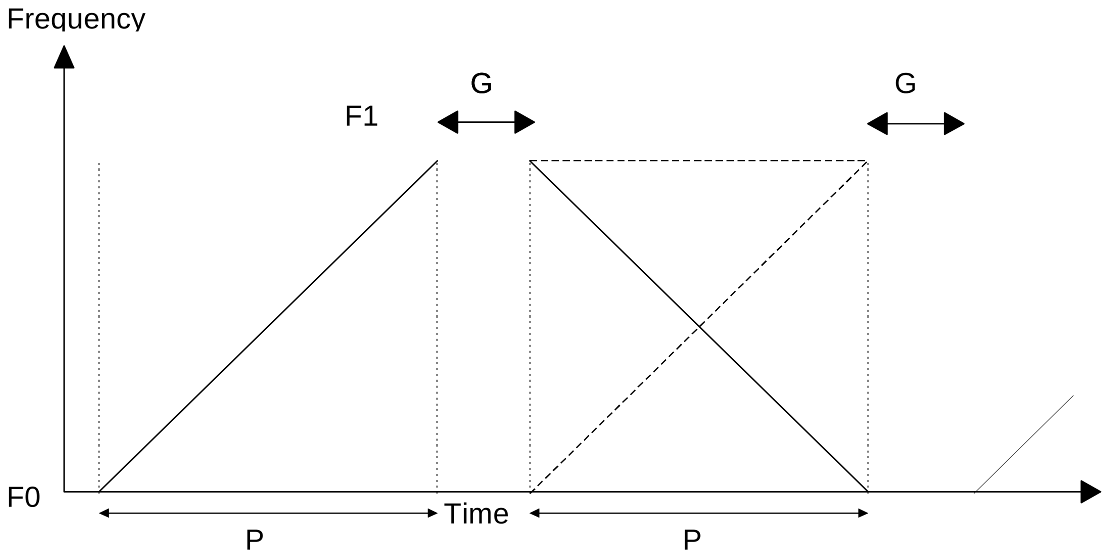

Figure C.5: Typical FMCW modulation scheme

C.5.2 Typical operating parameters

The peak and average (RMS) power limits are given in clauses 7.1.3 and 7.1.2. Typical operating parameters are given in table C.5.

Table C.5: Typical operating parameters for FMCW

Parameter	Typical value
Frequency deviation in one period	4 GHz maximum
Modulation period (P)	10 ms
Blanking period (G)	1 ms

C.6 Combination of modulation types

- Any modulation types may be combined with each other of this annex.

Annex D (normative): Installation requirements of 79 GHz Short Range Radar (SRR) systems

This annex provides the information for 79 GHz SRR equipment manufacturers and installers to design the equipment and the installation in the road vehicle in such a way, that the essential requirement as stated in EN 302 264-2 [i.5], clause 4.2.3, are fulfilled.

The following installation requirements shall be fulfilled:

a) 79 GHz SRR are required to be installed at a permanent fixed position on a terrestrial transportation vehicle;

b) the equipment shall operate only when the vehicle is operating, e.g. the car key is in the ignition position;

c) The maximum mean power spectral density outside a vehicle resulting from the operation of one short-range radar shall not exceed -9 dBm/MHz e.i.r.p.

Annex E (informative): Conversion of power spectral density to e.i.r.p.

This annex offers an example of the conversion from "power/unit area" (power spectral density) to e.i.r.p.

E.1 Assumptions

e.i.r.p. is the product of "power into the antenna" multiplied by the "antenna gain".

e.i.r.p. is the total power transmitted, assuming an isotropic radiator.

Area of a sphere = πd^2.

E.2 Example

For a power spectral density of 200 nW/cm^2 (measured at 3 m):

200 nW/cm^2 (at 3 m) = power measured in a 1 cm^2 area at 3 m distance

e.i.r.p. = total radiated power over the whole area of a sphere

e.i.r.p. = [power measured in a 1cm^2 area at 3 m distance (W)] × [area of sphere at 3 m (in cm^2)]

e.i.r.p. = $[(200 \times 10^{-9}) \times (\pi \times 36 \times 10^{4})]$ W

e.i.r.p. = 226,19 mW

Hence: 200 nW/cm^2 (at 3 m) $\equiv$ 23,54 dBm

Annex F (informative): Bibliography

- ETSI EN 301 489-1: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Electromagnetic Compatibility (EMC) standard for radio equipment and services; Part 1: Common technical requirements".

- ETSI EN 301 489-3: "Electromagnetic compatibility and Radio spectrum Matters (ERM); ElectroMagnetic Compatibility (EMC) standard for radio equipment and services; Part 3: Specific conditions for Short-Range Devices (SRD) operating on frequencies between 9 kHz and 40 GHz".

- Directive 1999/5/EC of the European Parliament and of the Council of 9 March 1999 on radio equipment and telecommunications terminal equipment and the mutual recognition of their conformity.

- Fotis Karamitsos: "The EU approach to Road Safety and Intelligent Transport Systems (ITS)".

NOTE: Available at http://www.cordis.lu.

- Final report of the e-Safety Working Group on Road Safety.

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- EC Mandate, Standardization Mandate Forwarded to CEN/CENELEC,/ETSI in the Field of Information Technology And Telecommunication, M/329, Harmonized Standards, covering Ultra Wideband (UWB) Applications.

NOTE: Available at http://europa.eu.int/comm/enterprise/rtte/harstand.htm.

- EC decision 2004/545/EC of 8 July 2004 on the harmonization of radio spectrum in the 79 GHz range for the use of automotive short-range radar equipment in the Community.

- CEPT/ERC Recommendation 01-06 (1994): "Procedure for mutual recognition of type testing and type approval for radio equipment".

- Council Recommendation 1999/519/EC of 12 July 1999 on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz).

History

Document history		
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