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TECHNICAL SPECIFICATION

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

Reference
DTS/ERM-TGUWB-140

Keywords
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Contents

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Foreword

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

Modal verbs terminology

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Introduction

In June 2016, the Directive 2014/53/EU [i.1] will replace the R&TTE Directive [i.2]. One of the main differences is that article 3.2 of the new Directive requires not only transmitters/transceivers, but also receivers to use spectrum efficiently and effectively and protect against harmful interference.

ETSI has published ETSI EG 203 336 [i.3] covering receiver parameters to be considered when updating harmonised standards. However, the parameter selection in that guide suggests that it was written with narrowband systems operating in licensed, channelized bands in mind.

The present document contains the results of the specialist task force (STF) 494 dealing with receiver parameters for ultra-wideband (UWB) applications.

1 Scope

The present document specifies receiver technical requirements, parameters and measurement procedures for UWB technologies.

It is a reference document for drafting new or revised UWB harmonised standards to fulfil the requirements of the Directive 2014/53/EU [i.1].

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.

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

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

[1] ETSI EN 303 883: "Short Range Devices (SRD) using Ultra Wide Band (UWB); Measurement Techniques".

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] 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.

[i.2] 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.

[i.3] ETSI EG 203 336: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Guide for the selection of technical parameters for the production of Harmonised Standards covering article 3.1(b) and article 3.2 of Directive 2014/53/EU".

[i.4] IEEE 802.15.4™-2011: "Part 15.4: Low-rate wireless personal area networks (LR-WPANs)", September 2011.

[i.5] ETSI EN 302 510-1 (V1.1.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Radio equipment in the frequency range 30 MHz to 37,5 MHz for Ultra Low Power Active Medical Membrane Implants and Accessories; Part 1: Technical characteristics and test methods".

[i.6] ETSI TR 102 309 (V1.1.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Ultra Low Power Active Medical Implants (ULP-AMI); "Membrane Implant" devices operating in the 30 MHz to 37,5 MHz band; System Reference Document".

[i.7] ETSI EN 300 220-1 (V2.4.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Radio equipment to be used in the 25 MHz to 1 000 MHz frequency range with power levels ranging up to 500 mW; Part 1: Technical characteristics and test methods".

[i.8] ETSI EN 300 224-1 (V1.3.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); On-site paging service; Part 1: Technical and functional characteristics, including test methods".

[i.9] ETSI EN 302 077-1 (V1.1.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Transmitting equipment for the Terrestrial - Digital Audio Broadcasting (T-DAB) service; Part 1: Technical characteristics and test methods".

[i.10] ETSI EN 302 054-1 (V1.2.1): "Meteorological Aids (Met Aids); Radiosondes to be used in the 400,15 MHz to 406 MHz frequency range with power levels ranging up to 200 mW; Part 1: Technical characteristics and test methods".

[i.11] ETSI EN 302 152-1 (V1.1.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Satellite Personal Locator Beacons (PLBs) operating in the 406,0 MHz to 406,1 MHz frequency band; Part 1: Technical characteristics and methods of measurement".

[i.12] ETSI EN 301 502 (V12.1.6): "Global System for Mobile communications (GSM); Base Station (BS) equipment; Harmonised Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU".

[i.13] ETSI TS 145 005 (V12.5.0): "Digital cellular telecommunications system (Phase 2+); Radio transmission and reception (3GPP TS 45.005 version 12.5.0 Release 12)".

[i.14] ETSI EN 301 511 (V12.1.1): "Global System for Mobile communications (GSM); Harmonized EN for mobile stations in the GSM 900 and GSM 1800 bands covering essential requirements under article 3.2 of the R&TTE directive (1999/5/EC)".

[i.15] ETSI EN 302 208-1 (V2.1.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Radio Frequency Identification Equipment operating in the band 865 MHz to 868 MHz with power levels up to 2 W and in the band 915 MHz to 921 MHz with power levels up to 4 W; Part 1: Technical requirements and methods of measurement".

[i.16] ETSI EN 302 018-1 (V1.2.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Transmitting equipment for the Frequency Modulated (FM) sound broadcasting service; Part 1: Technical characteristics and test methods".

[i.17] ETSI EN 300 422-2 (V1.4.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Wireless microphones in the 25 MHz to 3 GHz frequency range; Part 2: Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive".

[i.18] ETSI EN 301 908-13 (V11.0.1 draft): "IMT cellular networks; Harmonised EN covering the essential requirements of article 3.2 of the R&TTE Directive; Part 13: Evolved Universal Terrestrial Radio Access (E-UTRA) User Equipment (UE)".

[i.19] ETSI EN 301 908-3 (V7.1.1): "IMT cellular networks; Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive; Part 3: CDMA Direct Spread (UTRA FDD) Base Stations (BS)".

[i.20] ETSI EN 301 908-2 (V11.0.1 draft): "IMT cellular networks; Harmonised Standard covering the essential requirements of article 3.2 of the Radio Equipment Directive 2014/53/EU; Part 2: CDMA Direct Spread (UTRA FDD) User Equipment (UE)".

[i.21] ETSI EN 301 908-4 (V6.2.1): "IMT cellular networks; Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive; Part 4: CDMA Multi-Carrier (cdma2000) User Equipment (UE)".

[i.22] ETSI EN 301 908-5 (V5.2.1): "IMT cellular networks; Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive; Part 5: CDMA Multi-Carrier (cdma2000) Base Stations (BS)".

[i.23] ETSI EN 300 422-1 (V1.5.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Wireless microphones in the 25 MHz to 3 GHz frequency range; Part 1: Technical characteristics and methods of measurement".

[i.24] ETSI EN 301 166-1 (V1.3.2): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Land Mobile Service; Radio equipment for analogue and/or digital communication (speech and/or data) and operating on narrow band channels and having an antenna connector; Part 1: Technical characteristics and methods of measurement".

[i.25] ETSI TS 100 910 (V8.20.0): "Digital cellular telecommunications system (Phase 2+); Radio Transmission and Reception (3GPP TS 05.05 version 8.20.0 Release 1999)".

[i.26] ETSI TS 136 104 (V12.9.0): "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) radio transmission and reception (3GPP TS 36.104 version 12.9.0 Release 12)".

[i.27] ETSI TS 136 101 (V12.7.0): "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception (3GPP TS 36.101 version 12.7.0 Release 12)".

[i.28] ETSI TS 125 101 (V12.6.0): "Universal Mobile Telecommunications System (UMTS); User Equipment (UE) radio transmission and reception (FDD) (3GPP TS 25.101 version 12.7.0 Release 12)".

[i.29] ETSI EN 301 908-10 (V4.2.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Base Stations (BS), Repeaters and User Equipment (UE) for IMT-2000 Third-Generation cellular networks; Part 10: Harmonised Standard for IMT-2000, FDMA/TDMA (DECT) covering the essential requirements of article 3.2 of the Directive 2014/53/EU".

[i.30] ETSI EN 300 175-2 (V2.6.1): "Digital Enhanced Cordless Telecommunications (DECT); Common Interface (CI); Part 2: Physical Layer (PHL)".

[i.31] 3GPP2 C.S0002-E (V3.0): "Physical Layer Standard for cdma2000 Spread 2 Spectrum Systems".

[i.32] ETSI EN 301 908-6 (V5.2.1): "IMT cellular networks; Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive; Part 6: CDMA TDD (UTRA TDD) User Equipment (UE)".

[i.33] ETSI TS 125 102: "Universal Mobile Telecommunications System (UMTS); User Equipment (UE) radio transmission and reception (TDD) (3GPP TS 25.102)".

[i.34] ETSI EN 301 908-7 (V5.2.1): "IMT cellular networks; Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive; Part 7: CDMA TDD (UTRA TDD) Base Stations (BS)".

[i.35] ETSI TS 125 104: "Universal Mobile Telecommunications System (UMTS); Base Station (BS) radio transmission and reception (FDD) (3GPP TS 25.104)".

[i.36] ETSI EN 301 908-14: "IMT cellular networks; Harmonised EN covering the essential requirements of article 3.2 of the R&TTE Directive; Part 14: Evolved Universal Terrestrial Radio Access (E-UTRA) Base Stations (BS)".

[i.37] ETSI EN 302 064 (2.1.0): "Wireless Video Links operating in the 1,3 GHz to 50 GHz frequency band; Harmonised Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU".

[i.38] 3GPP2 C.S0010-D (V1.0): "Recommended Minimum Performance Standards for cdma2000 Spread Spectrum Base Stations".

[i.39] ETSI EN 301 908-19: "IMT cellular networks; Harmonised Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU; Part 19: OFDMA TDD WMAN (Mobile WiMAX™) TDD User Equipment (UE)".

[i.40] ETSI EN 301 908-20: "IMT cellular networks; Harmonised Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU; Part 20: OFDMA TDD WMAN (Mobile WiMAXTM) TDD Base Stations (BS)".

[i.41] ETSI EN 300 440: "Short Range Devices (SRD); Radio equipment to be used in the 1 GHz to 40 GHz frequency range; Harmonized Standard covering the essential requirements of article 3.2 of the Directive for 2014/53/EU".

[i.42] ETSI EN 300 328: "Wideband transmission systems; Data transmission equipment operating in the 2,4 GHz ISM band and using wide band modulation techniques; Harmonised Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU".

[i.43] ETSI EN 303 203 (V2.1.1): "Short Range Devices (SRD); Medical Body Area Network Systems (MBANSs) operating in the 2 483,5 MHz to 2 500 MHz range; Harmonised Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU".

[i.44] ETSI EN 301 559: "Low Power Active Medical Implants (LP-AMI) operating in the frequency range 2 483,5 MHz to 2 500 MHz Harmonised Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU".

[i.45] ETSI EN 301 908-16 (V4.2.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Base Stations (BS), Repeaters and User Equipment (UE) for IMT-2000 Third-Generation cellular networks; Part 16: Harmonized EN for IMT-2000, Evolved CDMA Multi-Carrier Ultra Mobile Broadband (UMB) (UE) covering the essential requirements of article 3.2 of the R&TTE Directive".

[i.46] ETSI EN 301 908-17 (V4.2.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Base Stations (BS), Repeaters and User Equipment (UE) for IMT-2000 Third-Generation cellular networks; Part 17: Harmonized EN for IMT-2000, Evolved CDMA Multi-Carrier Ultra Mobile Broadband (UMB) (BS) covering the essential requirements of article 3.2 of the R&TTE Directive".

[i.47] ECC Report 174: "Compatibility between the mobile service in the band 2500-2690 MHz and the radiodetermination service in the band 2700-2900 MHz".

[i.48] ECC Report 219: "Characteristics of PMSE digital video links to be used in compatibility and sharing studies".

[i.49] ETSI EN 302 625 (V1.1.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); 5 GHz BroadBand Disaster Relief applications (BBDR); Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive".

[i.50] ETSI EN 301 893 (V1.8.1): "Broadband Radio Access Networks (BRAN); 5 GHz high performance RLAN; Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive".

[i.51] ETSI EN 302 502 (V1.2.1): "Broadband Radio Access Networks (BRAN); 5,8 GHz fixed broadband data transmitting systems; Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive".

[i.52] ETSI EN 300 674-1 (V1.2.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Road Transport and Traffic Telematics (RTTT); Dedicated Short Range Communication (DSRC) transmission equipment (500 kbit/s / 250 kbit/s) operating in the 5,8 GHz Industrial, Scientific and Medical (ISM) band; Part 1: General characteristics and test methods for Road Side Units (RSU) and On-Board Units (OBU)".

[i.53] ETSI EN 302 217 (All parts): "Fixed Radio Systems; Characteristics and requirements for point-to-point equipment and antennas".

[i.54] ETSI EN 302 217-3 (V2.2.1), annex UBa.2: "Fixed Radio Systems; Characteristics and requirements for point-to-point equipment and antennas; Part 3: Equipment operating in frequency bands where both frequency coordinated or uncoordinated deployment might be applied; Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive".

[i.55] ETSI EN 302 729: "Short Range Devices (SRD); Equipment for Detection and Movement; 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 essential requirements of article 3.2 of the Directive 2014/53/EU".

[i.56] ETSI EN 303 135 (V1.1.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Coastal Surveillance, Vessel Traffic Services and Harbour Radars (CS/VTS/HR); Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive".

[i.57] ETSI EN 302 372: "Short Range Devices (SRD); Equipment for Detection and Movement; Tank Level Probing Radar (TLPR) operating in the frequency bands 5,8 GHz, 10 GHz, 25 GHz, 61 GHz and 77 GHz; Harmonised Standard covering essential requirements of article 3.2 of the Directive 2014/53/EU".

[i.58] ETSI EN 302 326: "Fixed Radio Systems; Multipoint Equipment and Antennas".

[i.59] ERC/REC 25-10: "Frequency ranges for the use of temporary terrestrial audio and video sap/sab links (incl. ENG/OB)".

[i.60] ETSI EN 302 288: "Short Range Devices; Transport and Traffic Telematics (TTT); Short Range Radar equipment operating in the 24GHz range; Harmonized Standard covering essential requirements of article 3.2 of the Directive 2014/53/EU".

[i.61] ERC/REC 70-03: "Relating to the use of Short Range Devices (SRD)".

[i.62] ECC/REC/(09)01: "Use of the 57 - 64 GHz frequency band for point-to-point fixed wireless systems".

[i.63] ETSI EN 305 550: "Short Range Devices (SRD); Radio equipment to be used in the 40 GHz to 246 GHz frequency range; Harmonized Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU".

[i.64] ETSI EN 302 567: "WAS/RLAN systems; Multiple-Gigabit WAS/RLAN equipment operating in the 60 GHz band; Harmonised Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU".

[i.65] ETSI EN 302 686: "Intelligent Transport Systems (ITS); Radiocommunications equipment operating in the 63 GHz to 64 GHz frequency band; Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive".

[i.66] ETSI EN 301 091: "ElectroMagnetic Compatibility and Radio Spectrum Matters (ERM); Road Transport and Traffic Telematics (RTTT); Technical characteristics and test methods for radar equipment operating in the 76 GHz to 77 GHz band".

[i.67] ETSI EN 302 264: "Short Range Devices; Transport and Traffic Telematics (TTT); Short Range Radar equipment operating in the 77 GHz to 81 GHz band; Harmonized Standard covering essential requirements of article 3.2 of the Directive 2014/53/EU".

[i.68] ECC Decision (15)05: " The harmonised frequency range 446.0-446.2 MHz, technical characteristics, exemption from individual licensing and free carriage and use of analogue and digital PMR 446 applications".

[i.69] Recommendation ITU-R SM.332-4: "Selectivity of receivers".

[i.70] Merill I. Skolnik, "Introduction to radar systems", McGraw-Hill Edition, 2001.

[i.71] ISO/IEC 7498-1: "Information technology - Open Systems Interconnection - Basic Reference Model: The Basic Model".

[i.72] 2008/477/EC: "Commission Decision of 13 June 2008 on the harmonisation of the 2500 - 2690 MHz frequency band for terrestrial systems capable of providing electronic communications services in the Community (notified under document number C(2008) 2625) (Text with EEA relevance)".

[i.73] ERC report 38: "Handbook on Radio Equipment and Systems. Video links for ENG/OB use".

[i.74] ECC Report 204: "Spectrum use and future requirements for PMSE".

[i.75] ECC Report 172: "Broadband Wireless Systems Usage in 2300-2400 MHz".

[i.76] ECC Report 110: "Compatibility studies between Broad-Band Disaster Relief (BBDR) and other systems".

[i.77] ECC Report 101: "Compatibility studies in the band 5855– 5925 MHz between Intelligent Transport Systems (ITS) and other systems".

[i.78] ECC Report 173: "Fixed Service in Europe".

[i.79] ERC REC (14)01: "Radio-frequency channel arrangements for high capacity analogue and digital radio-relay systems operating in the band 5925 to 6425 MHz ".

[i.80] ECC REC (02)06: "Preferred channel arrangements for digital Fixed Service Systems operating in the frequency range 7125-8500 MHz".

[i.81] ITU-R Radio Regulation.

[i.82] ETSI ES 202 131: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Wideband Transmission systems; Data transmission equipment operating in the 2,4 GHz ISM band using spread spectrum modulation techniques and 5 GHz high performance RLAN equipment; Specification of Reference Receiver Performance Parameters for Spectrum Planning".

[i.83] ETSI EN 302 065 (All parts): "Short Range Devices (SRD) using Ultra Wide Band technology (UWB); Harmonised Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU".

[i.84] ETSI EN 300 086: "Land Mobile Service; Radio equipment with an internal or external RF connector intended primarily for analogue speech; Harmonised Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU".

[i.85] IEEE 802.11™: "IEEE Standard for Information technology--Telecommunications and information exchange between systems Local and metropolitan area networks--Specific requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications".

[i.86] IEC 61000-4-3: "Electromagnetic compatibility (EMC) - Part 4-3: Testing and measurement techniques - Radiated, radio-frequency, electromagnetic field immunity test".

[i.87] ERC REC (14)02: "Radio-frequency channel arrangements for high, medium and low capacity digital fixed service systems operating in the band 6425 to 7125 MHz".

3 Definitions, symbols and abbreviations

3.1 Definitions

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

applicable interferers: interferers to be tested for interferer signal handling

interferer signal handling: capability of the receiver to operate as intended in coexistence with interferers

performance criterion: metric used to evaluate the performance of the device

receiver parameter: characteristic of the receiver that is tested

user manual: end user documentation to be included with the device

3.2 Symbols

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

A_{lin}	attenuation (linear)
B_{chan}	bandwidth of the radio service
B_{CW}	bandwidth of CW signal
dB	decibel
Hz	Hertz
m	metre
P_{CW}	power of the CW signal
PSD(f)	power spectral density of signals for that radio service
P_{tx}	power of the radio service

3.3 Abbreviations

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

ALD	Assistive Listening Devices
AWG	Arbitrary Waveform Generator
AWGN	Additive White Gaussian Noise
BBDR	Broad Band Disaster Relief
BER	Bit Error Rate
BFWA	Broadband Fixed Wireless Access
BMA	Building Material Analysis
BPSK	Binary Phase Shift Keying
BS	Base Station
CDMA	Code Division Multiple Access
CEPT	Conférence des administrations Européennes des Postes et Telecommunications
CW	Continuous Wave
DAA	Detect And Avoid
DAB	Digital Audio Broadcast
DAC	Digital to Analog Converter
DCS	Digital Cellular System
DECT	Digital Enhanced Cordless Telecommunication
DUT	Device Under Test
ECC	Electronic Communications Committee
E-GSM	Extended GSM
EIRP	Effective Isotropic Radiated Power
EMC	ElectroMagnetic Compatibility
ER-GSM	Extended Railway GSM
ERM	Electromagnetic compatibility and Radio spectrum Matters
E-UTRA	Enhanced Universal Terrestrial Radio Access
FDD	Frequency Division Duplex
FIR	Finite Impulse Response
FM	Frequency Modulation
GPR	Ground Probing Radar
GSM	General System for Mobile communication
IEEE	Institute of Electrical and Electronics Engineers
IMT	International Mobile Telecommunications
ISM	Industrial, Scientific and Medical
ISO	International Organization for Standardization
ITS	Intelligent Transport Systems
ITU	International Telecommunications Union
LAN	Local Area Network
LBT	Listen Before Talk
LLC	Logical Link Control
LPR	Level Probing Radar
LTE	Long Term Evolution
MAC	Medium Access Control
MBANS	Medical Body Area Network System
MOB	Man Over-Board

ND	Noise and Distortion
NLOS	Non Line-Of-Sight
OSI	Open System Interconnect
PAN	Personal Area Network
PCS	Personal Communications Service
PCS	Physical Coding Sublayer
PER	Packet Error Rate
P-GSM	Primary GSM
PHR	PHY HeadeR
PHY	PHYsical layer
PMA	Physical Medium Attachment sublayer
PMD	Physical Medium Dependent sublayer
PMR	Private Mobile Radio
PMSE	Program Making and Special Events
PPDR	Public Protection and Disaster Relief
PSD	Power Spectral Density
R&TTE	Radio and Telecommunications Terminal Equipment
RCS	Radar Cross Section
RED	Radio Equipment Directive
RF	Radio Frequency
RFID	Radio Frequency Identification
R-GSM	Railway GSM
RRC	Root Raised Cosine
SECDED	Single Error Correction Double Error Detection
SND	Signal, Noise and Distortion
SNR	Signal to Noise Ratio
SRD	Short Range Device
SRR	Short Range Radar
STF	Special Task Force
T-DAB	Terrestrial DAB
TDD	Time Division Duplex
TLPR	Tank Level Probing Radar
TTT	Transport and Traffic Telematics
UE	User Equipment
UMTS	Universal Mobile Telecommunication System
UTRA	Universal Terrestrial Radio Access
UWB	Ultra-WideBand
WiMAX	Worldwide Interoperability for Microwave ACCess
WLAN	Wireless Local Area Network
WPR	Wall Probing Radar

4 Purpose of receiver parameters

The intention of article 3.2 of Directive 2014/53/EU [i.1] in relation to a receiver is explained in recitals 10 and 11 of the Directive which state:

"...in the case of a receiver, it [receiving device] has a level of performance that allows it to ***operate as intended and protects it against the risk of harmful interference, in particular from shared or adjacent channels****, and, in so doing, supports improvements in the efficient use of shared or adjacent channels."*

ETSI EG 203 336 [i.3] translates these high level essential requirements into technical specifications by defining a number of receiver parameters in clause 5.3 of ETSI EG 203 336 [i.3].

In order to specify performance of the receiving device, ETSI EG 203 336 [i.3] uses terms like 'level of performance' and 'a given degradation'. Therefore, quantified performance criteria are required. Clause 5 of the present document discusses these performance criteria in the context of UWB applications. Clause 6 then considers the receiver parameters in ETSI EG 203 336 [i.3] and proposes more suitable receiver parameters for UWB applications.

As a result, the definition of receiver parameters should ensure the proper operation of receiving devices in an environment co-located with other radio equipment.

5 Receiver performance criteria and level of performance

A way to quantify, evaluate and specify the level of performance of the receiving device is required. A performance criterion is defined as the metric used to evaluate the performance of the device. The performance criterion reflects a certain performance of the receiving device, e.g. bit error ratio (BER) versus received signal power for communication systems or detection depth for a wall scanner.

For communications applications, standards usually specify a minimum receiver sensitivity level to ensure interoperability. However, it is interesting to note that no receiver sensitivity level is mandated by the IEEE 802.15.4 UWB PHY [i.4] specification. In practice, most UWB communication devices available are proprietary systems developed for specific applications. Rather than mandating a common performance level, it is therefore more appropriate to let the manufacturer specify an "intended level of performance".

For non-communication devices, e.g. sensors, radars, and so on, the transmitter and the receiver are generally designed by the same manufacturer, who can design the system in such a way that it performs "as intended". There is no need of interoperability among sensor or radar devices provided by different manufacturers. Non-communication devices may be considered "custom applications", with performance requirements best determined by the manufacturer.

While a common performance criterion would be more desirable, these examples and the discussion above demonstrate that due to the wide variety of UWB applications, the performance criterion needs to be application dependent. The manufacturers, with their knowledge of the application, are best placed to define and specify the performance criterion such that the device "*has a level of performance that allows it to operate as intended*", as clearly required by Article 3.2 of the RED [i.1].

Further information on performance criteria for communication devices is provided in clause A.1 and for sensor devices in clause A.2. Recommended performance criteria and tests for common applications are listed in clause 9.4. Where the indicated performance criteria are not suitable, the performance criterion used to determine the performance of the receiver shall be declared and published by the manufacturer.

The performance criterion and the level of performance shall be stated in the user manual (see clause 9.2.1).

6 Receiver parameters

6.1 Introduction

ETSI EG 203 336 [i.3] lists receiver parameters that need to be evaluated and considered as possible candidates to be included in the harmonised standards.

These receiver parameters are very much tailored for narrow band channelized communication systems. For each of these systems an application specific standard exists.

Looking at ultra-wideband systems where the bandwidth is much higher, there's a huge variety of different applications covered by one standard and in most cases no clearly defined channels can be found.

Hence, the classical receiver parameters used in ETSI EG 203 336 [i.3] cannot be used for ultra-wideband systems. Instead, other meaningful receiver parameters should be used that meet the requirement to ensure proper device operation in a shared environment.

In addition to the above general considerations the parameters from ETSI EG 203 336 [i.3] are discussed in clause 6.2.

6.2 Receiver parameters in ETSI EG 203 336

6.2.1 Receiver sensitivity

Receiver sensitivity is the ability to receive a wanted signal at low input signal levels while providing a pre-determined level of performance. In general increased sensitivity converts into an improved link budget. However, as suggested in ETSI EG 203 336 [i.3], given the wide range of UWB applications, it is more appropriate to let the manufacturer decide the right balance between receiver sensitivity and interference immunity.

For many UWB sensor systems a good link budget does however not convert into improved performance since the link budget requirements may be very relaxed. In such situations, overdesigning the receiver at the cost of increased power consumption is not beneficial.

As a consequence receiver sensitivity is not considered relevant as receiver parameter for ultra-wideband equipment.

6.2.2 Receiver co-channel rejection

Receiver co-channel rejection is a measure of the capability of a receiver to receive a wanted signal, without exceeding a given degradation, due to the presence of an unwanted signal, both signals being at the nominal frequency of the receiver.

The regulated frequency bands for ultra-wideband systems are intended for non-protected license exempt use without a defined channelization. The direct implication is that the nominal frequency of the receiver will vary between systems. This means that an interferer at a fixed frequency may be co-channel for some systems and out-of-band for other systems operating under the same harmonised standard. The uncoordinated use of UWB devices also undermines the aim of spatial reuse cited in ETSI EG 203 336 [i.3].

Still the ability to operate as intended in presence of an interferer within the receiver bandwidth is considered fundamental and in line with the intentions of the radio directive. The suggestion is therefore to implement this parameter but slightly redefined reflecting the fact that the channel may be very wide and specific for different equipment. The actual implementation has to be considered also in the context of Receiver Selectivity/Blocking since an interferer at a given frequency may appear co-channel or as a blocker depending on the actual UWB equipment.

This parameter will be considered in the newly defined parameter "Interferer signal handling".

6.2.3 Receiver Selectivity and Blocking

Receiver selectivity is described in Recommendation ITU-R SM.332-4 [i.69] identifying the capability to receive a wanted signal, without exceeding a given degradation, due to the presence of an unwanted signal, which differs in frequency from the wanted signal by a specified amount. Receiver Blocking is similar, but is not limited to signals with a specific distance in frequency from the receiver bandwidth but rather at "any other frequency". Since this term is obviously unbound such a definition will not be practically implementable during conformance tests. Instead a minimum offset from the receiver bandwidth is suggested.

Where relevant, Technical Bodies should also consider receiver blocking as a measure of the capability of the receiver to receive a wanted signal without exceeding a given degradation due to the presence of an unwanted input signal at any frequency other than those of the spurious responses or of the adjacent channels. Furthermore Technical Bodies should consider practical measurement methods as testing at "any frequency" is clearly an unbounded requirement.

This parameter will be considered in the newly defined parameter "Interferer signal handling".

6.2.4 Receiver dynamic range

Receiver "dynamic range" is a generic term broadly defined as the range of input signal levels over which a receiver functions at a specified performance level. For the same reasons as described under Receiver Sensitivity, dynamic range is not a good metric for ultra-wideband systems and is therefore suggested not to consider.

6.2.5 Reciprocal mixing

Reciprocal mixing is an important degrading effect in all receivers. Noise sidebands of the Local Oscillator (LO) mix with unwanted signals producing unwanted noise at the frequency of the receiver which may result in degraded receiver sensitivity.

The influence of reciprocal mixing on system performance will be very dependent on the actual system and the receiver structure. The cost of mitigating this effect may be increased power consumption in the receiver, which will have no significant benefit for the performance and level of co-existence for many sensor systems.

ETSI EG 203 336 [i.3] describes the motivation for measuring this parameter thus: *"Noise sidebands of the Local Oscillator (LO) mix with unwanted signals producing unwanted noise at the frequency of the receiver which may result in degraded receiver sensitivity."* However, in the case of UWB systems there is no single "frequency of the receiver", and a receiver which uses heterodyne techniques will already capture (and mix its LO with) signals over a very large (perhaps >1 GHz) bandwidth. LO phase noise will not result in a significant effective increase in the range of frequencies captured by the receiver. Furthermore, the LO signal in a heterodyne UWB receiver may be deliberately designed to have a wide bandwidth itself.

As a result this parameter is not considered.

6.2.6 Desensitisation

Desensitisation is a degradation of receiver sensitivity caused by the presence of a large unwanted signal. This situation is likely to occur when a strong interferer is located close to the receiver and may degrade system performance significantly. The suggested approach for ultra-wideband systems is to not measure this effect directly, but rather evaluate the eventual consequence of desensitisation through evaluating system performance in the terms of performance criteria under influence of interferers.

6.3 Receiver parameter for ultra-wideband applications: Interferer signal handling

From the above considerations the device operation in the presence of interferers is the key to ensure coexistence and spectrum efficiency. The receiver parameter proposed for UWB applications is therefore "interferer signal handling", defined as the capability of the receiving device to operate as intended in coexistence with interferers in a defined frequency range called "interferer test frequency range" (see clause 9.1.2).

The requirements for Co-Channel Signal Handling and interferer signal handling inside the operating frequency range measure the ability of the receiving device to process wanted and unwanted signals together. As such, they are analogous to the "classical" tests for co-channel rejection and adjacent channel selectivity.

The requirement for interferer signal handling outside the operating frequency range measures the ability to operate in the presence of a strong interfering signal. As such, it is analogous to the "classical" test for blocking.

Therefore these Rx parameters fulfil the original aim for the definition of receiver parameters to improve the coexistence of different devices.

The rationale for limiting the actual interferer test frequency range is to enable practical conformance tests and the fact that most receivers will be less sensitive to interferers present at frequencies far below or above the actual system bandwidth.

7 Potential interferers

7.1 Introduction

This clause contains potential interferers in the frequency ranges 30 MHz to 10,8 GHz, 23,9 GHz to 26,7 GHz, 56,8 GHz to 64,2 GHz, and 74,8 GHz to 85,2 GHz.

The following services have not been considered: UWB, satellite, military, maritime, airborne, amateur radio, services with duty cycle < 2 %

Clause 7.2 contains the complete list of interferers. The application specific interferers can be found in clauses 7.4 - 7.8. For the application specific interferer lists only those interferers are considered, which are marked as relevant in the rightmost column in table 1.

7.2 Complete list of interferers

Table 1: Complete list of interferers

Radio Service	Freq. Min [MHz]	Freq. Max [MHz]	Center Freq. [MHz]	max. EIRP [dBm]	Ch. BW [MHz]	Duty cycle	Reference	Remarks	relevant
Active Medical Membrane Implants	30	37,5	33,75	0	0,55	6 min of 60 min	[i.5], [i.6]	Antenna gain 0dBi assumed. In a period of 1 hour the duty cycle shall not exceed 10 %. Typical duty cycle <1 %.	x
SRD	34,995	35,225	35,11	20			[i.7]	Antenna gain 0dBi assumed.	x
On-site paging systems / Base station	40	40,25	40,125	37	0,006		[i.8]	Base Station.	x
On-site paging systems / Pocket device	40	40,25	40,125	17	0,006		[i.8]	Pocket device.	x
SRD/Model control	40,665	40,675	40,67	20	0,01	100 %	[i.7], [i.61]		x
Generic SRD	40,66	40,7	40,68	10			[i.7], [i.61]	Antenna gain 0dBi assumed.	x
SRD/Model control	40,685	40,695	40,69	20	0,01	100 %	[i.7], [i.61]		x
T-DAB	47	68	57,5	60	1,536		[i.9]		x
FM radio	68,0	108,0	88	Unspecified (>50dBW)	0,2		[i.16]	Max. EIRP not defined, thus omit service.	
Generic SRD	138,2	138,45	138,325	10			[i.7], [i.61]		x
SRD/Meter reading	169,4	169,475	169,4375	27	0,05		[i.7], [i.61]		x
SRD/Radio microphone applications	169,4875	169,5875	169,5375	27	0,05		[i.23], [i.61]		x
Public hearing aids	169,4	169,8125	169,60625	27	0,2		[i.17]		x
SRD/Radio microphone applications	169,4	174	171,7	10	0,05		[i.23], [i.61]		x

Radio Service	Freq. Min [MHz]	Freq. Max [MHz]	Center Freq. [MHz]	max. EIRP [dBm]	Ch. BW [MHz]	Duty cycle	Reference	Remarks	relevant
T-DAB	174	240	207	60	1,536		[i.9]		x
Meteorological Aids (radiosondes)	400,15	406	403,075	23	0,3		[i.10]		x
Personal locator beacons	406	406,1	406,05	20			[i.11]		x
Generic SRD/Non specific use	433,05	434,79	433,915	10			[i.7], [i.61]		x
PMR446	446	446,2	446,1	27	0,013		[i.24], [i.68]		x
GSM450 UE	450,4	457,6	454	39	0,2		[i.13]		x
On-site paging systems / Base station	440	470	455	37	0,006		[i.8]		x
On-site paging systems / Pocket device	440	470	455	17	0,006		[i.8]		x
GSM450 BS	460,4	467,6	464	58	0,2		[i.12]		x
GSM480 UE	478,8	486	482,4	39	0,2		[i.13]		x
GSM480 BS	488,8	496	492,4	58	0,2		[i.12]		x
LTE E-UTRA#28 UE	703,0	748,0	725,5	23	1,4		[i.18]		x
LTE E-UTRA#28 BS	758,0	803,0	780,5	55	1,5		[i.19]	Mobile transmit, Base receive, Medium range BS 38 dBm with 17 dBi. BW 1,5 MHz to 20 MHz.	x
LTE E-UTRA#20 BS	791,0	821,0	806	55	1,5		[i.19], [i.20]	Mobile receive, Base transmit, Medium range BS 38 dBm with 17 dBi. BW 1,5 MHz to 20 MHz.	x
Wireless Microphones	823	832	827,5	20	0,2		[i.23], [i.61]		x
LTE-E-UTRA#20 UE	832	862	847	23	1,5		[i.19], [i.20]	BW 1,5 MHz to 20 MHz.	x
Assistive Listening Devices (ALD)	863	865	864	10	0,2		[i.23]		x
Generic SRD/Wireless Audio Applications	863	865	864	10			[i.7], [i.61]		x
Generic SRD/Wireless Audio Applications	864,8	865	864,9	10	0,05		[i.7], [i.61]		x
Generic SRD/RFID	865,6	867,6	866,6	33	0,2		[i.15], [i.61]		x
Generic SRD/Non specific use	869,4	869,65	869,525	27	0,025		[i.7], [i.61]		x
Generic SRD/Alarms	869,65	869,7	869,675	14	0,025		[i.7], [i.61]		x
Generic SRD/Non specific use	869,7	870	869,85	7			[i.7], [i.61]		x
ER-GSM 900 UE	873	915	894	39	0,2		[i.14]		x
R-GSM 900 UE	876	915	895,5	39	0,2		[i.14]		x
E-GSM 900 UE (Multistandard)	880	915	897,5	39	0,2		[i.13]	Mobile transmit, base receiver.	x
P-GSM 900 UE	890	915	902,5	39	0,2		[i.14]		x
Generic SRD/RFID	915	921	918	36	0,4		[i.15], [i.61]		x
ER-GSM 900 BS	918	960	939	58	0,2		[i.12]		x
R-GSM 900 BS	921	960	940,5	58	0,2		[i.12]		x
E-GSM 900 BS (Multistandard)	925	960	942,5	58	0,2		[i.21], [i.22]	Mobile receiver, base transmit.	x

Radio Service	Freq. Min [MHz]	Freq. Max [MHz]	Center Freq. [MHz]	max. EIRP [dBm]	Ch. BW [MHz]	Duty cycle	Reference	Remarks	relevant
P-GSM 900 BS	935	960	947,5	58	0,2		[i.12]		x
T-DAB	1 452	1 492	1 472	60	1,536		[i.9]		x
PMR	30	3 000	1 515	27	0,01		[i.24], [i.68]	Services have not been implemented in CEPT countries, thus disregard service.	
DCS 1800 UE	1 710	1 785	1 747,5	36	1,4		[i.25], [i.26]		x
LTE (E-UTRA) (UE)	1 710	1 785	1 747,5	23	1,4		[i.27]		x
Wireless Microphones	1 785	1 804,8	1 794,9	17	0,6		[i.23], [i.61]		x
DCS 1800 BS	1 805	1 880	1 842,5	63	0,2		[i.25]	Max output power (40 W = 46 dBm) including antenna gain 17 dBi, see 4.1.2.1 in [i.25].	x
LTE (E-UTRA) (BS)	1 805	1 880	1 842,5	55	1,4		[i.26]	Medium range BS 38 dBm with 17 dBi.	x
PCS 1900 UE	1 850	1 910	1 880	33	0,2		[i.25]		x
UMTS UE	1 850	1 910	1 880	24	5		[i.28]	Reference only contains limits for UE.	x
IMT (DECT)	1 900	1 980	1 940	24	1,73	0,42 ms of 10 ms	[i.29], [i.30]		x
IMT (UTRA FDD Band I UE)	1 920	1 980	1 950	24	3,84		[i.20], [i.28]		x
IMT (CDMA2000 Band 6 UE)	1 920	1 980	1 950	33	3,69		[i.21], [i.31]		x
IMT (E-UTRA Band 1 UE)	1 920	1 980	1 950	23	1,4		[i.18], [i.27]	E-UTRA channel BW 1,4 MHz up to 20 MHz.	x
PCS 1900 BS	1 930	1 990	1 960	63	0,2		[i.25]	Max output power (40 W = 46 dBm) including antenna gain 17 dBi, see 4.1.2.1 in [i.25].	x
IMT (UTRA FDD Band XVI UE)	2 010	2 025	2 017,5	24	3,84		[i.20], [i.28]		x
IMT (UTRA TDD Band a UE)	2 010	2 025	2 017,5	24	1,28		[i.32], [i.33]	UTRA TDD 1,28 Mcps, 3,84 Mcps and 7,68 Mcps possible.	x
IMT (UTRA TDD Band a BS)	2 010	2 025	2 017,5	55	1,28		[i.34], [i.35]	UTRA TDD 1,28 Mcps, 3,84 Mcps and 7,68 Mcps possible. Medium range BS 38 dBm with 17 dBi.	x
IMT (E-UTRA Band 34 UE)	2 010	2 025	2 017,5	23	1,4		[i.18], [i.27]	E-UTRA channel BW 1,4 MHz up to 20 MHz.	x
IMT (E-UTRA Band 34 BS)	2 010	2 025	2 017,5	55	1,4		[i.36], [i.26]	E-UTRA channel BW 1,4 MHz up to 20 MHz. Medium range BS 38 dBm with 17 dBi.	x
IMT (DECT)	2 010	2 025	2 017,5	24	1,73	0,42 ms of 10 ms	[i.29], [i.30]		x
PMSE	2 015	2 110	2 062,5	23	10		[i.37]	ECC Report 219 [i.48] no temporary or mobile link considered, 20 dBm + 3 dBi. See also ERC report 38 [i.73], ECC Report 204 [i.74].	x
IMT (UTRA FDD Band I BS)	2 110	2 170	2 140	55	3,84		[i.19], [i.35]	Medium range BS 38 dBm with 17 dBi.	x
IMT (E-UTRA Band 1 BS)	2 110	2 170	2 140	55	1,4		[i.36], [i.26]	E-UTRA channel BW 1,4 MHz up to 20 MHz. Medium range BS 38 dBm with 17 dBi.	x
IMT (CDMA2000 Band 6 BS)	2 110	2 170	2 140		4,6		[i.22], [i.38], [i.31]	Power level not defined. Proposal to omit service as relevant information not found and other IMT services in same band.	

Radio Service	Freq. Min [MHz]	Freq. Max [MHz]	Center Freq. [MHz]	max. EIRP [dBm]	Ch. BW [MHz]	Duty cycle	Reference	Remarks	relevant
PMSE	2 200	2 290	2 245	23	10		[i.37]	ECC Report 219 no temporary or mobile link considered, 20 dBm + 3 dBi. See also ERC report 38 [i.73], ECC Report 204.	x
PMSE	2 300	2 400	2 350	23	10		[i.37]	ECC Report 219 no temporary or mobile link considered, 20 dBm + 3 dBi. See also ERC report 38, ECC Report 204.	x
IMT (E-UTRA Band 40 UE)	2 300	2 400	2 350	23	1,4		[i.18], [i.27]	E-UTRA channel BW 1,4 MHz up to 20 MHz.	x
IMT (E-UTRA Band 40 BS)	2 300	2 400	2 350	55	1,4		[i.36], [i.26]	Medium range BS 38 dBm with 17 dBi. E-UTRA channel BW 1,4 MHz up to 20 MHz. See also ECC Report 172 [i.75], ECC Report 174 [i.47].	x
IMT (Mobile WiMAX TDD 1B UE)	2 300	2 400	2 350	26	10		[i.39]		x
IMT (Mobile WiMAX TDD 1B BS)	2 300	2 400	2 350	53	10		[i.40]	Typical 36 dBm (ECC Report 172), 17 dBi. UE has always higher power@device, thus omit service.	
SRD, Radiodetermination	2 400	2 483,5	2 441,75	14			[i.41]		x
Wideband data transmission	2 400	2 483,5	2 441,75	20	5	5 ms of 10 ms	[i.42]	For frequency hopping system. For other wideband modulation 20 MHz, duty cycle 10 ms of 20 ms max.	x
RFID	2 446	2 454	2 450	27		100 %	[i.41]		x
RFID (in building only)	2 446	2 454	2 450	36		30 ms of 200 ms	[i.41]		x
PMSE	2 483,5	2 500	2 491,75	23	10		[i.37]	ECC Report 219 no temporary or mobile link considered, 20 dBm + 3 dBi. See also ERC report 38, ECC Report 204.	x
MBANS	2 483,5	2 500	2 491,75	0	3	6 min of 60 min	[i.43]		x
MBANS	2 483,5	2 500	2 491,75	10	3	1,2 min of 60 min	[i.43]	Higher power level for reduced duty cycle from 10 % to 2 %.	x
Medical implants	2 483,5	2 500	2 491,75	10	2	6 min of 60 min	[i.44]		x
IMT (UTRA FDD Band VII UE)	2 500	2 570	2 535	24	3,84		[i.20], [i.28]		x
IMT (E-UTRA Band 7 UE)	2 500	2 570	2 535	23	1,4		[i.18], [i.27]	E-UTRA channel BW 1,4 MHz up to 20 MHz	x
IMT (UMB Band 13 UE)	2 500	2 570	2 535	22,5			[i.45]		x
IMT (UTRA FDD Band XVI BS)	2 585	2 600	2 592,5	55	3,84		[i.19], [i.35]	Medium range BS 38 dBm with 17 dBi. max. 43 /46 dBm according to ECC Report 174, ECC DEC 2008/477/EC [i.72].	x
IMT (Mobile WiMAX TDD 3A UE)	2 500	2 690	2 595	26	10		[i.39]		x

Radio Service	Freq. Min [MHz]	Freq. Max [MHz]	Center Freq. [MHz]	max. EIRP [dBm]	Ch. BW [MHz]	Duty cycle	Reference	Remarks	relevant
IMT (Mobile WiMAX TDD 3A BS)	2 500	2 690	2 595	53	10		[i.40]	Typical 36 dBm (ECC Report 172), 17 dBi. See also ECC Report 174, EC dec 2008/477/EC [i.72]. UE has always higher power@device, thus omit service.	
IMT (E-UTRA Band 38 UE)	2 570	2 620	2 595	23	1,4		[i.18], [i.27]	E-UTRA channel BW 1,4 MHz up to 20 MHz.	x
IMT (E-UTRA Band 38 BS)	2 570	2 620	2 595	55	1,4		[i.36], [i.26]	Medium range BS 38 dBm with 17 dBi. E-UTRA channel BW 1,4 MHz up to 20 MHz.	x
IMT (UTRA TDD Band d UE)	2 570	2 620	2 595	24	1,28		[i.28], [i.33]	UTRA TDD 1,28 Mcps, 3,84 Mcps and 7,68 Mcps possible.	x
IMT (UTRA TDD Band d BS)	2 570	2 620	2 595	55	1,28		[i.34], [i.35]	Medium range BS 38 dBm with 17 dBi. max. 43 /46 dBm according to ECC Report 174, ECC DEC 2008/477/EC [i.72], UTRA TDD 1,28 Mcps, 3,84 Mcps and 7,68 Mcps possible.	x
PMSE	2 520	2 670	2 595	23	10		[i.37]	ECC Report 219 no temporary or mobile link considered, 20 dBm + 3 dBi. See also ERC report 38, ECC Report 204.	x
IMT (UTRA FDD Band XV BS)	2 600	2 620	2 610	55	3,84		[i.19], [i.35]	Medium range BS 38 dBm with 17 dBi. max. 43 /46 dBm according to ECC Report 174, ECC DEC 2008/477/EC [i.72].	x
IMT (UTRA FDD Band VII BS)	2 620	2 690	2 655	55	3,84		[i.19], [i.34]	Medium range BS 38 dBm with 17 dBi. max. 43 /46 dBm according to ECC Report 174, ECC DEC 2008/477/EC [i.72].	x
IMT (E-UTRA Band 7 BS)	2 620	2 690	2 655	55	1,4		[i.36], [i.26]	Medium range BS 38 dBm with 17 dBi. max. 43 /46 dBm according to ECC Report 174, ECC DEC 2008/477/EC [i.72], E-UTRA channel BW 1,4 MHz up to 20 MHz.	x
IMT (UMB Band 13 BS)	2 620	2 690	2 655	manufacturer defined			[i.46]	Proposal to omit service, as not many info found and other IMT service in same band. max. 43 /46 dBm according to ECC Report 174, ECC DEC 2008/477/EC [i.72].	
Radiolocation	2 700	3 300	3 000	75	25	44 ms each 4 seconds	[i.47]	Less than 2 % duty cycle. 500 uV/m. 25 MHz largest value in ECC Report 174.	
PMSE	3 400	3 600	3 500	23	10		[i.48]	Man. Def. (20 dBm +3 dBi based on ECC Report 219).	x
WiMAX Base Station	3 400	3 800	3 600	43	10	3 ms per 5 ms	[i.47]	Duty cycle: http://www.comreg.ie/_fileupload/publications/ComReg0851R2.pdf p 88.	x
WiMAX Terminal Outdoor Antenna	3 400	3 800	3 600	20					x
WiMAX Terminal Indoor Antenna	3 400	3 800	3 600	12	10		[i.47]		x
PMSE	4 400	5 000	4 700	23	10		[i.48]	Man. Def. (20 dBm +3 dBi based on ECC Report 219).	x
BBDR-PPDR Base Station	4 800	4 990	4 895	39	20	100 %	[i.49]		x
BBDR-PPDR Terminal	4 800	4 990	4 895	26	20		[i.49]		x

Radio Service	Freq. Min [MHz]	Freq. Max [MHz]	Center Freq. [MHz]	max. EIRP [dBm]	Ch. BW [MHz]	Duty cycle	Reference	Remarks	relevant
BBDR-PPDR Base Station	5 150	5 250	5 200	39	20	100 %	[i.49]		x
BBDR-PPDR Terminal	5 150	5 250	5 200	26	20		[i.49]		x
WLAN	5 150	5 875	5 512,5	27	20		[i.50], [i.51]		x
Radiodetermination applications	4 500	7 000	5 725	24	2 500		[i.57]	Bandwidth up to 2,5 GHz.	x
SRD	5 725	5 875	5 800	14	100	100 %	[i.61]	ECC Report 110 [i.76] page 29, up to 100 MHz bandwidth.	x
TTT (Tolling)	5 795	5 815	5 805	39	28	100 %	[i.52]		x
ITS	5 855	5 925	5 890	33	10	5 ms per 55 ms	[i.52]	Indoor: 100 m distance, Outdoor: 10m distance.	x
Fixed links	5 925	8 500	7 212,5	85	29,65		[i.53]	ECC Report 101 [i.77], ECC Report 173 [i.78]: Antenna gain 45 dBi, additional side lobe attenuation of 50 dB added to 1 km path loss and wall/shielding attenuation. F; ECC REC 02/06 [i.80], ITU-R Radio Regulation [i.81] article 21.	x
Radiodetermination applications	6 000	8 500	7 250	7	2 500	100 %	[i.55]	Bandwidth up to 2,5 GHz.	x
Fixed (point-to-point)	8 400	8 500	8 450	85			[i.53]	ECC Reports 101, 173: Antenna gain 45 dBi, additional side lobe attenuation of 50 dB added to 1 km path loss and wall/shielding attenuation. ERC REC 14-1 [i.79] / ERC REC 14-2 [i.87]; ECC REC 02/06, ITU-R Radio Regulation article 21.	x
Radiolocation (civil) (CS/VTS/HR)	8 500	10 000	9 250	80			[i.56]	Duty cycle <2 %: Service not relevant.	
Radiodetermination applications	8 500	10 600	9 550	30	2 100		[i.57]	Bandwidth up to 2,1 GHz.	x
BFWA	10 150	10 300	10 225	85			[i.58]	EIRP values: ITU-R Radio Regulation article 21.	x
Fixed	10 150	10 300	10 225	85			[i.53]	ECC Reports 101, 173: Antenna gain 45 dBi, additional side lobe attenuation of 50 dB added to 1km path loss and wall/shielding attenuation. ERC REC 14-1 [i.79] / ERC REC 14-2 [i.87]; ECC REC02/06, ITU-R Radio Regulation article 21.	x
PMSE	10 000	10 650	10 325	67			[i.59]	ECC Report 219 table 8, point-to-point system with 33 dBm +34 dBi.	x
Radiolocation (civil)	10 150	10 500	10 325	80			[i.56]		x
Fixed	10 450	10 650	10 550	85			[i.53]	ECC Reports 101, 173: Antenna gain 45 dBi, additional side lobe attenuation of 50 dB added to 1 km path loss and wall/shielding attenuation. ERC REC 14-1 [i.79] / ERC REC 14-2 [i.87]; ECC REC 02/06, ITU-R Radio Regulation article 21.	x
BFWA	10 500	10 650	10 575	85			[i.58]	EIRP values: ITU-R Radio Regulation article 21.	x

Radio Service	Freq. Min [MHz]	Freq. Max [MHz]	Center Freq. [MHz]	max. EIRP [dBm]	Ch. BW [MHz]	Duty cycle	Reference	Remarks	relevant
ISM	24 000	24 250	24 125	20			[i.53]		x
Non-specific SRDs	24 000	24 250	24 125	20			[i.53]	Reference to ISM.	x
SRR	22 650	25 650	24 150	-24,44			[i.60]		x
SRR (only carrier)	24 050	24 250	24 150	20	20		[i.60]		x
PMSE	24 000	24 500	24 250	67			[i.59]	ECC Report 219 table 8, point-to-point system with 33 dBm +34 dBi.	x
TTT	24 050	24 500	24 275	20			[i.61]		x
Fixed	24 250	26 500	25 375	55			[i.58]		x
Radiodetermination applications	24 050	26 500	25 275	43	2 450	100 %	[i.55]	Bandwidth up to 2,45 GHz.	x
BFWA	24 500	26 500	25 500	55			[i.58]		x
Radiodetermination applications	24 050	27 000	25 525	26	2 950		[i.57]	Bandwidth up to 2,95 GHz.	x
Fixed	57 000	64 000	60 500	55	2 000		[i.54], [i.62]	Bandwidth up to 2 GHz.	x
Radiodetermination applications	57 000	64 000	60 500	43	7 000	100 %	[i.57]	Bandwidth up to 7 GHz.	x
Radiodetermination applications	57 000	64 000	60 500	35	7 000		[i.55]	Bandwidth up to 7 GHz.	x
Non-specific SRDs	57 000	64 000	60 500	20			[i.63]		x
ISM	61 000	61 500	61 250	20			[i.63]		x
Wideband data transmission systems (indoor)	57 000	66 000	61 500	40			[i.64]		x
ITS	63 000	64 000	63 500	40			[i.65]		x
Fixed	64 000	66 000	65 000	85	2 000		[i.54], [i.62]	Bandwidth up to 2 GHz.	x
Fixed	71 000	76 000	73 500	85	250		[i.54]	Bandwidth between 250 MHz and 5 GHz.	x
Railway applications	76 000	77 000	76 500	55	1 000		[i.66]		x
TTT	76 000	77 000	76 500	55	1 000		[i.54]		x
SRR	76 000	81 000	78 500	55			[i.67]		x
Radiodetermination applications	75 000	85 000	80 000	43	10 000	100 %	[i.57]	Bandwidth up to 10 GHz.	x
Radiodetermination applications	75 000	85 000	80 000	34	10 000		[i.55]	Bandwidth up to 10 GHz.	x
Fixed	81 000	86 000	83 500	85	250		[i.54]	Bandwidth between 250 MHz and 5 GHz.	x

7.3 The concept of service groups and interferer power levels

To calculate the interferer power at the position of the ultra-wideband device under test, the interferers are grouped into service groups. A service group defines the attenuation of the interferer signal on its way to the ultra-wideband device. To calculate this attenuation, a distance between interferer and ultra-wideband device and other attenuations like wall attenuation and NLOS attenuation are defined (see annex C).

The definition of the service groups is dependent on the UWB application. The service groups of the different applications are listed in tables 2, 4, 6, 8, 10, 12 and 14.

For special interferer cases that do not fall into one of the service groups, the total attenuation is directly put into the column "total attenuation" of the application specific interferer tables 3, 5, 7, 9, 11, 13, and 15.

In the application-specific interferer tables the power@device is calculated as follows (equation (1)):

$$\text{Power@device [dBm]} = \text{max. EIRP [dBm]} - \text{Total attenuation [dB]} \qquad (1)$$

Figure 1: Generation of a certain power@device

A certain power@device with a transmit antenna with gain g and a distance d between antenna and DUT can be achieved by setting the signal generator to the power p (see figure 1) according to equation (2).

$$p \text{ [dBm]} = \text{power@device [dBm]} + 20 \cdot \log10(4 \cdot \pi \cdot d \cdot fc/c) - g \text{ [dBi]} \qquad (2)$$

where fc is the centre frequency of the interferer and c the velocity of light.

If there are additional losses, e.g. cable losses, this shall also be accounted for.

7.4 Interferers for indoor applications

This clause contains potential interferers for UWB indoor applications in the frequency range 30 MHz to 10,8 GHz.

Table 2: Service groups for indoor applications

Service group (interferer)	Distance [m]	Wall loss [dB]	Additional loss NLOS [dB]
1. Mobile	2	0	10
2. (Fixed) outdoor	100	12	10
3. Fixed indoor	10	0	10
4. Fixed outdoor long range	1 000	12	10

Table 3: List of interferers for indoor applications

Radio Service	Center Freq. [MHz]	max. EIRP [dBm]	Service group	Total attenuation [dB]	Power @ device [dBm]	Ch. BW [MHz]	Duty cycle
Active Medical Membrane Implants	33,75	0	1	19	-19	0,55	6 min of 60 min
SRD	35,11	20	1	19	1		
On-site paging systems / Base station	40,125	37	4	87	-50	0,006	
On-site paging systems / Pocket device	40,125	17	1	21	-4	0,006	
SRD/Model control	40,67	20	1	21	-1	0,01	1
Generic SRD	40,68	10	1	21	-11		
SRD/Model control	40,69	20	1	21	-1	0,01	1
T-DAB	57,5	60	4	90	-30	1,536	

Radio Service	Center Freq. [MHz]	max. EIRP [dBm]	Service group	Total attenuation [dB]	Power @ device [dBm]	Ch. BW [MHz]	Duty cycle
Generic SRD	138,325	10	1	31	-21		
SRD/Meter reading	169,4375	27	1	33	-6	0,05	
SRD/Radio microphone applications	169,5375	27	1	33	-6	0,05	
Public hearing aids	169,60625	27	1	33	-6	0,2	
SRD/Radio microphone applications	171,7	10	1	33	-23	0,05	
T-DAB	207	60	4	101	-41	1,536	
Meteorological Aids (radiosondes)	403,075	23	1	41	-18	0,3	
Personal locator beacons	406,05	20	1	41	-21		
Generic SRD/Non specific use	433,92	10	1	41	-31		
PMR446	446,1	27	1	41	-14	0,013	
GSM450 UE	454	39	1	42	-3	0,2	
On-site paging systems / Base station	455	37	4	108	-71	0,006	
On-site paging systems / Pocket device	455	17	1	42	-25	0,006	
GSM450 BS	464	58	4	108	-50	0,2	
GSM480 UE	482,4	39	1	42	-3	0,2	
GSM480 BS	492,4	58	4	108	-50	0,2	
LTE E-UTRA#28 UE	725,5	23	1	46	-23	1,4	
LTE E-UTRA#28 BS	780,5	55	4	112	-57	1,5	
LTE E-UTRA#20 BS	806	55	4	113	-58	1,5	
Wireless Microphones	827,5	20	1	47	-27	0,2	
LTE-E-UTRA#20 UE	847	23	1	47	-24	1,5	
Assistive Listening Devices (ALD)	864	10	1	47	-37	0,2	
Generic SRD/Wireless Audio Applications	864	10	1	47	-37		
Generic SRD/Wireless Audio Applications	864,9	10	1	47	-37	0,05	
Generic SRD/RFID	866,6	33	1	47	-14	0,2	
Generic SRD/Non specific use	869,525	27	1	47	-20	0,025	
Generic SRD/Alarms	869,675	14	3	61	-47	0,025	
Generic SRD/Non specific use	869,85	7	1	47	-40		
ER-GSM 900 UE	894	39	1	47	-8	0,2	
R-GSM 900 UE	895,5	39	1	48	-9	0,2	
E-GSM 900 UE (Multistandard)	897,5	39	1	48	-9	0,2	
P-GSM 900 UE	902,5	39	1	48	-9	0,2	
Generic SRD/RFID	918	36	1	48	-12	0,4	
ER-GSM 900 BS	939	58	4	114	-56	0,2	
R-GSM 900 BS	940,5	58	4	114	-56	0,2	
E-GSM 900 BS (Multistandard)	942,5	58	4	114	-56	0,2	
P-GSM 900 BS	947,5	58	4	114	-56	0,2	
T-DAB	1 472	60	4	118	-58	1,536	
DCS 1800 UE	1 747,5	36	1	53	-17	1,4	
LTE (E-UTRA) (UE)	1 747,5	23	1	53	-30	1,4	
Wireless Microphones	1 794,9	17	1	54	-37	0,6	
DCS 1800 BS	1 842,5	63	4	120	-57	0,2	
LTE (E-UTRA) (BS)	1 842,5	55	4	120	-65	1,4	
PCS 1900 UE	1 880	33	1	54	-21	0,2	
UMTS UE	1 880	24	1	54	-30	5	
IMT (DECT)	1 940	24	1	54	-30	1,73	0,42 ms of 10 ms
IMT (UTRA FDD Band I UE)	1 950	24	1	54	-30	3,84	

Radio Service	Center Freq. [MHz]	max. EIRP [dBm]	Service group	Total attenuation [dB]	Power @ device [dBm]	Ch. BW [MHz]	Duty cycle
IMT (CDMA2000 Band 6 UE)	1 950	33	1	54	-21	3,69	
IMT (E-UTRA Band 1 UE)	1 950	23	1	54	-31	1,4	
PCS 1900 BS	1 960	63	4	120	-57	0,2	
IMT (UTRA FDD Band XVI UE)	2 017,5	24	1	55	-31	3,84	
IMT (UTRA TDD Band a UE)	2 017,5	24	1	55	-31	1,28	
IMT (UTRA TDD Band a BS)	2 017,5	55	4	121	-66	1,28	
IMT (E-UTRA Band 34 UE)	2 017,5	23	1	55	-32	1,4	
IMT (E-UTRA Band 34 BS)	2 017,5	55	4	121	-66	1,4	
IMT (DECT)	2 017,5	24	1	55	-31	1,73	0,42 ms of 10 ms
PMSE	2 062,5	23	3	69	-46	10	
IMT (UTRA FDD Band I BS)	2 140	55	4	121	-66	3,84	
IMT (E-UTRA Band 1 BS)	2 140	55	4	121	-66	1,4	
PMSE	2 245	23	3	69	-46	10	
PMSE	2 350	23	3	70	-47	10	
IMT (E-UTRA Band 40 UE)	2 350	23	1	56	-33	1,4	
IMT (E-UTRA Band 40 BS)	2 350	55	4	122	-67	1,4	
IMT (Mobile WiMAX TDD 1B UE)	2 350	26	1	56	-30	10	
SRD, Radiodetermination	2 441,75	14	1	56	-42		
Wideband data transmission	2 441,75	20	1	56	-36	5	5 ms of 10 ms
RFID	2 450	27	3	70	-43		1
RFID (in building only)	2 450	36	3	70	-34		30 ms of 200 ms
PMSE	2 491,75	23	3	70	-47	10	
MBANS	2 491,75	0	1	56	-56	3	6 min of 60 min
MBANS	2 491,75	10	1	56	-46	3	1,2 min of 60 min
Medical implants	2 491,75	10	1	56	-46	2	6 min of 60 min
IMT (UTRA FDD Band VII UE)	2 535	24	1	57	-33	3,84	
IMT (E-UTRA Band 7 UE)	2 535	23	1	57	-34	1,4	
IMT (UMB Band 13 UE)	2 535	22,5	1	57	-34		
IMT (UTRA FDD Band XVI BS)	2 592,5	55	4	123	-68	3,84	
IMT (Mobile WiMAX TDD 3A UE)	2 595	26	1	57	-31	10	
IMT (E-UTRA Band 38 UE)	2 595	23	1	57	-34	1,4	
IMT (E-UTRA Band 38 BS)	2 595	55	4	123	-68	1,4	
IMT (UTRA TDD Band d UE)	2 595	24	1	57	-33	1,28	
IMT (UTRA TDD Band d BS)	2 595	55	4	123	-68	1,28	
PMSE	2 595	23	3	71	-48	10	
IMT (UTRA FDD Band XV BS)	2 610	55	4	123	-68	3,84	
IMT (UTRA FDD Band VII BS)	2 655	55	4	123	-68	3,84	
IMT (E-UTRA Band 7 BS)	2 655	55	4	123	-68	1,4	
PMSE	3 500	23	3	73	-50	10	
WiMAX Base Station	3 600	43	4	126	-83	10	3 ms per 5 ms
WiMAX Terminal Outdoor Antenna	3 600	20	2	106	-86		
WiMAX Terminal Indoor Antenna	3 600	12	3	74	-62	10	
PMSE	4 700	23	3	76	-53	10	
BBDR-PPDR Base Station	4 895	39	4	128	-89	20	1
BBDR-PPDR Terminal	4 895	26	2	108	-82	20	

Radio Service	Center Freq. [MHz]	max. EIRP [dBm]	Service group	Total attenuation [dB]	Power @ device [dBm]	Ch. BW [MHz]	Duty cycle
BBDR-PPDR Base Station	5 200	39	4	129	-90	20	1
BBDR-PPDR Terminal	5 200	26	2	109	-83	20	
WLAN	5 512,5	27	1	63	-36	20	
Radiodetermination applications	5 750	24	4	130	-106	2 500	
SRD	5 800	14	1	64	-50	100	1
TTT (Tolling)	5 805	39	4	130	-91	28	1
ITS	5 890	33	2	110	-77	10	5 ms per 55 ms
Fixed links	7 212,5	85		172	-87	29,65	
Radiodetermination applications	7 250	7	4	132	-125	2 500	1
Fixed (point-to-point)	8 450	85		173	-88		
Radiodetermination applications	9 550	30	4	134	-104	2 100	
BFWA	10 225	85	4	135	-50		
Fixed	10 225	85		175	-90		
PMSE	10 325	67	4	135	-68		
Fixed	10 550	85		175	-90		
BFWA	10 575	85	4	135	-50		

7.5 Interferers for outdoor applications

This clause contains potential interferers for UWB outdoor applications in the frequency range 30 MHz to 10,8 GHz.

Table 4: Service groups for outdoor applications

Service group (interferer)	Distance [m]	Wall loss [dB]	Additional loss NLOS [dB]
1. Mobile	2	0	10
2. (Fixed) outdoor	100	0	10
3. Fixed indoor	100	12	10
4. Fixed outdoor long range	1 000	0	10

Table 5: List of interferers for outdoor applications

Radio Service	Center Freq. [MHz]	max. EIRP [dBm]	Service group	Total attenuation [dB]	Power @ device [dBm]	Ch. BW [MHz]	Duty cycle
Active Medical Membrane Implants	33,75	0	1	19	-19	0,55	6 min of 60 min
SRD	35,11	20	1	19	1		
On-site paging systems / Base station	40,125	37	4	75	-38	0,006	
On-site paging systems / Pocket device	40,125	17	1	21	-4	0,006	
SRD/Model control	40,67	20	1	21	-1	0,01	1
Generic SRD	40,68	10	1	21	-11		
SRD/Model control	40,69	20	1	21	-1	0,01	1
T-DAB	57,5	60	4	78	-18	1,536	
Generic SRD	138,325	10	1	31	-21		
SRD/Meter reading	169,4375	27	1	33	-6	0,05	
SRD/Radio microphone applications	169,5375	27	1	33	-6	0,05	
Public hearing aids	169,60625	27	1	33	-6	0,2	
SRD/Radio microphone applications	171,7	10	1	33	-23	0,05	
T-DAB	207	60	4	89	-29	1,536	

Radio Service	Center Freq. [MHz]	max. EIRP [dBm]	Service group	Total attenuation [dB]	Power @ device [dBm]	Ch. BW [MHz]	Duty cycle
Meteorological Aids (radiosondes)	403,075	23	1	41	-18	0,3	
Personal locator beacons	406,05	20	1	41	-21		
Generic SRD/Non specific use	433,92	10	1	41	-31		
PMR446	446,1	27	1	41	-14	0,013	
GSM450 UE	454	39	1	42	-3	0,2	
On-site paging systems / Base station	455	37	4	96	-59	0,006	
On-site paging systems / Pocket device	455	17	1	42	-25	0,006	
GSM450 BS	464	58	4	96	-38	0,2	
GSM480 UE	482,4	39	1	42	-3	0,2	
GSM480 BS	492,4	58	4	96	-38	0,2	
LTE E-UTRA#28 UE	725,5	23	1	46	-23	1,4	
LTE E-UTRA#28 BS	780,5	55	4	100	-45	1,5	
LTE E-UTRA#20 BS	806	55	4	101	-46	1,5	
Wireless Microphones	827,5	20	1	47	-27	0,2	
LTE-E-UTRA#20 UE	847	23	1	47	-24	1,5	
Assistive Listening Devices (ALD)	864	10	1	47	-37	0,2	
Generic SRD/Wireless Audio Applications	864	10	1	47	-37		
Generic SRD/Wireless Audio Applications	864,9	10	1	47	-37	0,05	
Generic SRD/RFID	866,6	33	1	47	-14	0,2	
Generic SRD/Non specific use	869,525	27	1	47	-20	0,025	
Generic SRD/Alarms	869,675	14	3	93	-79	0,025	
Generic SRD/Non specific use	869,85	7	1	47	-40		
ER-GSM 900 UE	894	39	1	47	-8	0,2	
R-GSM 900 UE	895,5	39	1	48	-9	0,2	
E-GSM 900 UE (Multistandard)	897,5	39	1	48	-9	0,2	
P-GSM 900 UE	902,5	39	1	48	-9	0,2	
Generic SRD/RFID	918	36	1	48	-12	0,4	
ER-GSM 900 BS	939	58	4	102	-44	0,2	
R-GSM 900 BS	940,5	58	4	102	-44	0,2	
E-GSM 900 BS (Multistandard)	942,5	58	4	102	-44	0,2	
P-GSM 900 BS	947,5	58	4	102	-44	0,2	
T-DAB	1 472	60	4	106	-46	1,536	
DCS 1800 UE	1 747,5	36	1	53	-17	1,4	
LTE (E-UTRA) (UE)	1 747,5	23	1	53	-30	1,4	
Wireless Microphones	1 794,9	17	1	54	-37	0,6	
DCS 1800 BS	1 842,5	63	4	108	-45	0,2	
LTE (E-UTRA) (BS)	1 842,5	55	4	108	-53	1,4	
PCS 1900 UE	1 880	33	1	54	-21	0,2	
UMTS UE	1 880	24	1	54	-30	5	
IMT (DECT)	1 940	24	1	54	-30	1,73	0,42 ms of 10 ms
IMT (UTRA FDD Band I UE)	1 950	24	1	54	-30	3,84	
IMT (CDMA2000 Band 6 UE)	1 950	33	1	54	-21	3,69	

Radio Service	Center Freq. [MHz]	max. EIRP [dBm]	Service group	Total attenuation [dB]	Power @ device [dBm]	Ch. BW [MHz]	Duty cycle
IMT (E-UTRA Band 1 UE)	1 950	23	1	54	-31	1,4	
PCS 1900 BS	1 960	63	4	108	-45	0,2	
IMT (UTRA FDD Band XVI UE)	2 017,5	24	1	55	-31	3,84	
IMT (UTRA TDD Band a UE)	2 017,5	24	1	55	-31	1,28	
IMT (UTRA TDD Band a BS)	2 017,5	55	4	109	-54	1,28	
IMT (E-UTRA Band 34 UE)	2 017,5	23	1	55	-32	1,4	
IMT (E-UTRA Band 34 BS)	2 017,5	55	4	109	-54	1,4	
IMT (DECT)	2 017,5	24	1	55	-31	1,73	0,42 ms of 10 ms
PMSE	2 062,5	23	2	89	-66	10	
IMT (UTRA FDD Band I BS)	2 140	55	4	109	-54	3,84	
IMT (E-UTRA Band 1 BS)	2 140	55	4	109	-54	1,4	
PMSE	2 245	23	2	89	-66	10	
PMSE	2 350	23	2	90	-67	10	
IMT (E-UTRA Band 40 UE)	2 350	23	1	56	-33	1,4	
IMT (E-UTRA Band 40 BS)	2 350	55	2	90	-35	1,4	
IMT (Mobile WiMAX TDD 1B UE)	2 350	26	1	56	-30	10	
SRD, Radiodetermination	2 441,75	14	1	56	-42		
Wideband data transmission	2 441,75	20	1	56	-36	5	5 ms of 10 ms
RFID	2 450	27	3	102	-75		1
RFID (in building only)	2 450	36	3	102	-66		30 ms of 200 ms
PMSE	2 491,75	23	2	90	-67	10	
MBANS	2 491,75	0	1	56	-56	3	6 min of 60 min
MBANS	2 491,75	10	1	56	-46	3	1,2 min of 60 min
Medical implants	2 491,75	10	1	56	-46	2	6 min of 60 min
IMT (UTRA FDD Band VII UE)	2 535	24	1	57	-33	3,84	
IMT (E-UTRA Band 7 UE)	2 535	23	1	57	-34	1,4	
IMT (UMB Band 13 UE)	2 535	22,5	1	57	-34		
IMT (UTRA FDD Band XVI BS)	2 592,5	55	4	111	-56	3,84	
IMT (Mobile WiMAX TDD 3A UE)	2 595	26	1	57	-31	10	
IMT (E-UTRA Band 38 UE)	2 595	23	1	57	-34	1,4	
IMT (E-UTRA Band 38 BS)	2 595	55	4	111	-56	1,4	
IMT (UTRA TDD Band d UE)	2 595	24	1	57	-33	1,28	
IMT (UTRA TDD Band d BS)	2 595	55	4	111	-56	1,28	
PMSE	2 595	23	2	91	-68	10	
IMT (UTRA FDD Band XV BS)	2 610	55	4	111	-56	3,84	
IMT (UTRA FDD Band VII BS)	2 655	55	4	111	-56	3,84	
IMT (E-UTRA Band 7 BS)	2 655	55	4	111	-56	1,4	
PMSE	3 500	23	2	93	-70	10	
WiMAX Base Station	3 600	43	4	114	-71	10	3 ms per 5 ms
WiMAX Terminal Outdoor Antenna	3 600	20	2	94	-74		
WiMAX Terminal Indoor Antenna	3 600	12	3	106	-94	10	
PMSE	4 700	23	2	96	-73	10	
BBDR-PPDR Base Station	4 895	39	4	116	-77	20	1
BBDR-PPDR Terminal	4 895	26	2	96	-70	20	
BBDR-PPDR Base Station	5 200	39	4	117	-78	20	1
BBDR-PPDR Terminal	5 200	26	2	97	-71	20	
WLAN	5 512,5	27	1	63	-36	20	
Radiodetermination applications	5 750	24	4	118	-94	2 500	
SRD	5 800	14	1	64	-50	100	1
TTT (Tolling)	5 805	39	4	118	-79	28	1

Radio Service	Center Freq. [MHz]	max. EIRP [dBm]	Service group	Total attenuation [dB]	Power @ device [dBm]	Ch. BW [MHz]	Duty cycle
ITS	5 890	33		78	-45	10	5 ms per 55 ms
Fixed links	7 212,5	85		160	-75	29,65	
Radiodetermination applications	7 250	7	4	120	-113	2 500	1
Fixed (point-to-point)	8 450	85		161	-76		
Radiodetermination applications	9 550	30	4	122	-92	2 100	
BFWA	10 225	85	4	123	-38		
Fixed	10 225	85		163	-78		
PMSE	10 325	67	4	123	-56		
Fixed	10 550	85		163	-78		
BFWA	10 575	85	4	123	-38		

7.6 Interferers for mobile (indoor and outdoor) applications

This clause contains potential interferers for mobile UWB applications that are used indoors and outdoors in the frequency range 30 MHz to 10,8 GHz.

Table 6: Service groups for mobile (indoor and outdoor) applications

Service group (interferer)	Distance [m]	Wall loss [dB]	Additional loss NLOS [dB]
1. Mobile	2	0	10
2. (Fixed) outdoor	100	0	10
3. Fixed indoor	10	0	10
4. Fixed outdoor long range	1 000	0	10

Table 7: List of interferers for mobile (indoor and outdoor) applications

Radio Service	Center Freq. [MHz]	max. EIRP [dBm]	Service group	Total attenuation [dB]	Power @ device [dBm]	Ch. BW [MHz]	Duty cycle
Active Medical Membrane Implants	33,75	0	1	19	-19	0,55	6 min of 60 min
SRD	35,11	20	1	19	1		
On-site paging systems / Base station	40,125	37	4	75	-38	0,006	
On-site paging systems / Pocket device	40,125	17	1	21	-4	0,006	
SRD/Model control	40,67	20	1	21	-1	0,01	1
Generic SRD	40,68	10	1	21	-11		
SRD/Model control	40,69	20	1	21	-1	0,01	1
T-DAB	57,5	60	4	78	-18	1,536	
Generic SRD	138,325	10	1	31	-21		
SRD/Meter reading	169,4375	27	1	33	-6	0,05	
SRD/Radio microphone applications	169,5375	27	1	33	-6	0,05	
Public hearing aids	169,60625	27	1	33	-6	0,2	
SRD/Radio microphone applications	171,7	10	1	33	-23	0,05	
T-DAB	207	60	4	89	-29	1,536	
Meteorological Aids (radiosondes)	403,075	23	1	41	-18	0,3	
Personal locator beacons	406,05	20	1	41	-21		
Generic SRD/Non specific use	433,92	10	1	41	-31		
PMR446	446,1	27	1	41	-14	0,013	
GSM450 UE	454	39	1	42	-3	0,2	

Radio Service	Center Freq. [MHz]	max. EIRP [dBm]	Service group	Total attenuation [dB]	Power @ device [dBm]	Ch. BW [MHz]	Duty cycle
On-site paging systems / Base station	455	37	4	96	-59	0,006	
On-site paging systems / Pocket device	455	17	1	42	-25	0,006	
GSM450 BS	464	58	4	96	-38	0,2	
GSM480 UE	482,4	39	1	42	-3	0,2	
GSM480 BS	492,4	58	4	96	-38	0,2	
LTE E-UTRA#28 UE	725,5	23	1	46	-23	1,4	
LTE E-UTRA#28 BS	780,5	55	4	100	-45	1,5	
LTE E-UTRA#20 BS	806	55	4	101	-46	1,5	
Wireless Microphones	827,5	20	1	47	-27	0,2	
LTE-E-UTRA#20 UE	847	23	1	47	-24	1,5	
Assistive Listening Devices (ALD)	864	10	1	47	-37	0,2	
Generic SRD/Wireless Audio Applications	864	10	1	47	-37		
Generic SRD/Wireless Audio Applications	864,9	10	1	47	-37	0,05	
Generic SRD/RFID	866,6	33	1	47	-14	0,2	
Generic SRD/Non specific use	869,525	27	1	47	-20	0,025	
Generic SRD/Alarms	869,675	14	3	61	-47	0,025	
Generic SRD/Non specific use	869,85	7	1	47	-40		
ER-GSM 900 UE	894	39	1	47	-8	0,2	
R-GSM 900 UE	895,5	39	1	48	-9	0,2	
E-GSM 900 UE (Multistandard)	897,5	39	1	48	-9	0,2	
P-GSM 900 UE	902,5	39	1	48	-9	0,2	
Generic SRD/RFID	918	36	1	48	-12	0,4	
ER-GSM 900 BS	939	58	4	102	-44	0,2	
R-GSM 900 BS	940,5	58	4	102	-44	0,2	
E-GSM 900 BS (Multistandard)	942,5	58	4	102	-44	0,2	
P-GSM 900 BS	947,5	58	4	102	-44	0,2	
T-DAB	1 472	60	4	106	-46	1,536	
DCS 1800 UE	1 747,5	36	1	53	-17	1,4	
LTE (E-UTRA) (UE)	1 747,5	23	1	53	-30	1,4	
Wireless Microphones	1 794,9	17	1	54	-37	0,6	
DCS 1800 BS	1 842,5	63	4	108	-45	0,2	
LTE (E-UTRA) (BS)	1 842,5	55	4	108	-53	1,4	
PCS 1900 UE	1 880	33	1	54	-21	0,2	
UMTS UE	1 880	24	1	54	-30	5	
IMT (DECT)	1 940	24	1	54	-30	1,73	0,42 ms of 10 ms
IMT (UTRA FDD Band I UE)	1 950	24	1	54	-30	3,84	
IMT (CDMA2000 Band 6 UE)	1 950	33	1	54	-21	3,69	
IMT (E-UTRA Band 1 UE)	1 950	23	1	54	-31	1,4	
PCS 1900 BS	1 960	63	4	108	-45	0,2	
IMT (UTRA FDD Band XVI UE)	2 017,5	24	1	55	-31	3,84	
IMT (UTRA TDD Band a UE)	2 017,5	24	1	55	-31	1,28	
IMT (UTRA TDD Band a BS)	2 017,5	55	4	109	-54	1,28	
IMT (E-UTRA Band 34 UE)	2 017,5	23	1	55	-32	1,4	
IMT (E-UTRA Band 34 BS)	2 017,5	55	4	109	-54	1,4	
IMT (DECT)	2 017,5	24	1	55	-31	1,73	0,42 ms of 10 ms
PMSE	2 062,5	23	2	89	-66	10	
IMT (UTRA FDD Band I BS)	2 140	55	4	109	-54	3,84	
IMT (E-UTRA Band 1 BS)	2 140	55	4	109	-54	1,4	
PMSE	2 245	23	2	89	-66	10	
PMSE	2 350	23	2	90	-67	10	
IMT (E-UTRA Band 40 UE)	2 350	23	1	56	-33	1,4	
IMT (E-UTRA Band 40 BS)	2 350	55	2	90	-35	1,4	

Radio Service	Center Freq. [MHz]	max. EIRP [dBm]	Service group	Total attenuation [dB]	Power @ device [dBm]	Ch. BW [MHz]	Duty cycle
IMT (Mobile WiMAX TDD 1B UE)	2 350	26	1	56	-30	10	
SRD, Radiodetermination	2 441,75	14	1	56	-42		
Wideband data transmission	2 441,75	20	1	56	-36	5	5 ms of 10 ms
RFID	2 450	27	3	70	-43		1
RFID (in building only)	2 450	36	3	70	-34		30 ms of 200 ms
PMSE	2 491,75	23	2	90	-67	10	
MBANS	2 491,75	0	1	56	-56	3	6 min of 60 min
MBANS	2 491,75	10	1	56	-46	3	1,2 min of 60 min
Medical implants	2 491,75	10	1	56	-46	2	6 min of 60 min
IMT (UTRA FDD Band VII UE)	2 535	24	1	57	-33	3,84	
IMT (E-UTRA Band 7 UE)	2 535	23	1	57	-34	1,4	
IMT (UMB Band 13 UE)	2 535	22,5	1	57	-34		
IMT (UTRA FDD Band XVI BS)	2 592,5	55	4	111	-56	3,84	
IMT (Mobile WiMAX TDD 3A UE)	2 595	26	1	57	-31	10	
IMT (E-UTRA Band 38 UE)	2 595	23	1	57	-34	1,4	
IMT (E-UTRA Band 38 BS)	2 595	55	4	111	-56	1,4	
IMT (UTRA TDD Band d UE)	2 595	24	1	57	-33	1,28	
IMT (UTRA TDD Band d BS)	2 595	55	4	111	-56	1,28	
PMSE	2 595	23	2	91	-68	10	
IMT (UTRA FDD Band XV BS)	2 610	55	4	111	-56	3,84	
IMT (UTRA FDD Band VII BS)	2 655	55	4	111	-56	3,84	
IMT (E-UTRA Band 7 BS)	2 655	55	4	111	-56	1,4	
PMSE	3 500	23	2	93	-70	10	
WiMAX Base Station	3 600	43	4	114	-71	10	3 ms per 5 ms
WiMAX Terminal Outdoor Antenna	3 600	20	2	94	-74		
WiMAX Terminal Indoor Antenna	3 600	12	3	74	-62	10	
PMSE	4 700	23	2	96	-73	10	
BBDR-PPDR Base Station	4 895	39	4	116	-77	20	1
BBDR-PPDR Terminal	4 895	26	2	96	-70	20	
BBDR-PPDR Base Station	5 200	39	4	117	-78	20	1
BBDR-PPDR Terminal	5 200	26	2	97	-71	20	
WLAN	5 512,5	27	1	63	-36	20	
Radiodetermination applications	5 750	24	4	118	-94	2 500	
SRD	5 800	14	1	64	-50	100	1
TTT (Tolling)	5 805	39	4	118	-79	28	1
ITS	5 890	33		78	-45	10	5 ms per 55 ms
Fixed links	7 212,5	85		160	-75	29,65	
Radiodetermination applications	7 250	7	4	120	-113	2 500	1
Fixed (point-to-point)	8 450	85		161	-76		
Radiodetermination applications	9 550	30	4	122	-92	2 100	
BFWA	10 225	85	4	123	-38		
Fixed	10 225	85		163	-78		
PMSE	10 325	67	4	123	-56		
Fixed	10 550	85		163	-78		
BFWA	10 575	85	4	123	-38		

7.7 Interferers for level probing and tank level probing applications

This clause contains potential interferers for UWB level probing applications in the frequency ranges 5,8 GHz to 8,7 GHz, 23,9 to 26,7 GHz, 56,8 to 64,2 GHz, and 74,8 to 85,2 GHz and for UWB tank level probing applications in the frequency ranges 4,3 GHz to 7,2 GHz, 8,3 GHz to 10,8 GHz, 23,9 to 26,7 GHz, 56,8 to 64,2 GHz, and 74,8 to 85,2 GHz.

General

(Tank) Level probing radars operate in a controlled industrial environment and the operators have to be professionally trained persons [i.55] Itis in the responsibility of the operator to ensure that for his application the interferer level is low enough for safe operation.

What cannot be controlled by the operator is the potential interference coming from outside of the plant. Here the minimum distance is set to 100 m.

Service groups of interferers

For (T)LPR the interferers are categorized into the following four service groups:

1) Mobile handheld applications like phones, industrial communication systems, radio modems connected to sensors or control elements. These equipment may come close to the installed (T)LPR device as itis assumed to be used also within the plant.

   Minimum distance is 10 m.

   The radiation direction of this kind of equipment is not controllable as either it radiates in more or less all directions, or, as it is hand carried, it can be turned in all directions.

   So the maximum EIRP is directed to the (T)LPR device in worst case. No NLOS attenuation can be introduced in this case.

   The duty cycle of this equipment will be taken into account.

2) Car radar, TTT - Transport and Traffic Telematics, other fixed broadcast transmitters.

   This interference will come from outside of the plant.

   The minimum distance is thus set to 100 m.

   The radiation is not directed or controllable, so the maximum EIRP is directed to the (T)LPR device in worst case. Also in this case no NLOS attenuation can be introduced.

   Even car radar and TTT equipment may also be used within the plant with shorter distances, but the operator can control and avoid disturbing interference levels depending on the required (T)LPR system availability. If a car radar interferes with a (T)LPR device it will only occur short term i.e. a few seconds when the car is passing by.

3) Point-to-point radio connection like mobile backhaul, etc.

   This interference will come from outside of the plant.

   The minimum distance is thus set to 100 m.

   The radiation is directed to the dedicated receive antenna with LOS connection. The (T)LPR application will certainly not be located in the main beam of the directional antenna of the point-to-point transmitter. Therefore the interfering radiation is coming from the side lobes of the interferer's directional antenna. For high power applications also high gain antennas shall be used .for example 50 dBi antenna gain for the frequency band 71 to 86 GHz. The resulting side lobe suppression for class 3 is 41 dB@ 10 deg. offset and 49 dB @ 20 deg. offset [i.53].

   A side lobe suppression of 40 dB is taken into account as NLOS attenuation on the interferer side.

4) Radio determination devices within the plant, for example other (T)LPR devices.

Further (T)LPR devices can be placed on neighbouring tanks or in LPR applications within 10m distance to each other.

Both types of devices, LPR and TLPR, have the NLOS attenuation described under service group 3 when they act as interferers. Thus for this service group also 40 dB additional attenuation is taken into account on the interferer side.

Non line of sight (NLOS) attenuation due to (T)LPR

Both TLPR and LPR devices provide additional NLOS attenuation due to their installation requirements.

TLPR:

Tank level probing radars (TLPR) are installed in closed metallic tanks or reinforced concrete tanks or similar structures which shield the outside world from emissions from the installed radar (please compare ETSI EN 302 372 [i.57], annex G) Of course the tank also protects the TLPR device from harmful radiation caused by interferers outside the tank.

The attenuation of such a tank is at least 40 dB which is taken into account as NLOS loss at the TLPR side.

LPR:

Level probing radars (LPR) shall be installed with the antenna main beam pointing vertically downwards onto the material whose distance to the radar device is to be measured [i.55]. The interferer from outside the industrial plant will radiate towards the LPR from somewhere in the horizontal plane.

The reception of this interferer will occur due to LPR antenna side lobes around 90 degrees offset from the main beam axis.

Antennas for LPR devices have a minimum antenna gain in the range of 25 dBi. This is the case as a maximum half power beamwidth of 8 to 12 degrees is required and a minimum the side lobe suppression has to be fulfilled. For the frequency band 75 GHz to 85 GHz for example a minimum side lobe attenuation of -38 dB is required in elevation angles above 60 degrees (see ETSI EN 302 729 [i.55] clause 4.6). Finally a maximum antenna gain of -13 dBi in elevation angles above 60 degrees can be assumed.

The side lobes at 90 degree elevation angle are assumed to be further attenuated by at least 10 dB.

Thus the resulting total attenuation is assumed to be 20 dB which is taken into account as NLOS loss at the LPR side.

Resulting total attenuation

For the transmission path between the interferer and the (T)LPR victim receiver input the total attenuation is the sum of the free space loss, the NLOS loss of the interferer and the NLOS loss of the radar device. See tables 6 to 9 below.

The free space loss can be calculated according to the well-known equation (3).

$$a_{free\ space}^{dB} = 20\ log\left(\frac{4\pi r f_c}{c}\right) \quad (3)$$

$a_{free\ space}^{dB}$: free space attenuation expressed in positive dB values

c : speed of light, $3 \cdot 10^8 m/s$

f_c : interferer center frequency

r : distance between the interferer and the victim receiver

The actual interferer level at the (T)LPR receiver input port is then calculated with the known interferer EIRP level reduced by the total attenuation.

Table 8: Service groups for level probing applications

Service group (interferer)	Distance [m]	NLOS loss from interferer [dB]	Additional NLOS loss for LPR [dB]
1. Mobile, handhelds, etc.	10	0	20
2. Car, TTT, fixed broadcast	100	0	20
3. Point-to-point	100	40	20
4. Radio determination	10	40	20

NOTE: For tank level probing applications see tables 10 and 11.

Table 9: List of interferers for level probing applications

Radio Service	Center Freq. [MHz]	max. EIRP [dBm]	Service group	Total attenuation [dB]	Power @ device [dBm]	Ch. BW [MHz]	Duty cycle
SRD	5 800	14	1	88	-74	100	1
TTT (Tolling)	5 805	39	2	108	-69	28	1
ITS	5 890	33	2	108	-75	10	5 ms per 55 ms
Fixed links	7 212,5	85	3	150	-65	29,65	
Radiodetermination applications	7 250	7	4	130	-123	2 500	1
Fixed (point to point)	8 450	85	3	151	-66		
ISM	24 125	20	2	120	-100		
Non-specific SRDs	24 125	20	2	120	-100		
SRR	24 150	-24,44	2	120	-145		
SRR (only carrier)	24 150	20	2	120	-100	max. 10 %	
PMSE	24 250	67	3	160	-93		
TTT	24 275	20	2	120	-100		
Fixed	25 375	55	3	161	-106		
Radiodetermination applications	25 275	43	4	140	-97	2 450	1
BFWA	25 500	55	3	161	-106		
Radiodetermination applications	25 525	26	4	141	-115	2 950	
Fixed	60 500	55	3	168	-113	2 000	
Radiodetermination applications	60 500	43	4	148	-105	7 000	1
Radiodetermination applications	60 500	35	4	148	-113	7 000	
Non-specific SRDs	60 500	20	2	128	-108		
ISM	61 250	20	2	128	-108		
Wideband data transmission systems (indoor)	61 500	40	2	128	-88		
ITS	63 500	40	2	128	-88		
Railway applications	76 500	55	3	170	-115	1 000	
TTT	76 500	55	2	130	-75	1 000	
SRR	78 500	55	2	130	-75		
Radiodetermination applications	80 000	43	4	151	-108	10 000	1
Radiodetermination applications	80 000	34	4	151	-117	10 000	
Fixed	83 500	85	3	171	-86	250	

Table 10: Service groups for tank level probing applications

Service group (interferer)	Distance [m]	NLOS loss from interferer [dB]	Additional NLOS loss for TLPR [dB]
1. Mobile, handhelds, etc.	10	0	40
2. Car, TTT, fixed broadcast	100	0	40
3. Point-to-point	100	40	40
4. Radio determination	10	40	40

Table 11: List of interferers for tank level probing applications

Radio Service	Center Freq. [MHz]	max. EIRP [dBm]	Servic e group	Total attenuatio n [dB]	Power @ device [dBm]	Ch. BW [MHz]	Duty cycle
PMSE	4 700	23	2	126	-103	10	
BBDR-PPDR Base Station	4 895	39	2	126	-87	20	1
BBDR-PPDR Terminal	4 895	26	2	126	-100	20	
BBDR-PPDR Base Station	5 200	39	2	127	-88	20	1
BBDR-PPDR Terminal	5 200	26	2	127	-101	20	
WLAN	5 512,5	27	2	127	-100	20	
Radiodetermination applications	5 750	24	4	148	-124	2 500	
SRD	5 800	14	2	128	-114	100	1
TTT (Tolling)	5 805	39	2	128	-89	28	1
ITS	5 890	33	2	128	-95	10	5 ms per 55 ms
Fixed (point-to-point)	8 450	85	3	171	-86		
Radiodetermination applications	9 550	30	4	152	-122	2 100	
BFWA	10 225	85	3	173	-88		
Fixed	10 225	85	3	173	-88		
PMSE	10 325	67	3	173	-106		
Fixed	10 550	85	3	173	-88		
BFWA	10 575	85	3	173	-88		
ISM	24 125	20	2	140	-120		
Non-specific SRDs	24 125	20	2	140	-120		
SRR	24 150	-24,44	2	140	-165		
SRR (only carrier)	24 150	20	2	140	-120	max. 10 %	
PMSE	24 250	67	3	180	-113		
TTT	24 275	20	2	140	-120		
Fixed	25 375	55	3	181	-126		
Radiodetermination applications	25 275	43	4	160	-117	2 450	1
BFWA	25 500	55	3	181	-126		
Radiodetermination applications	25 525	26	4	161	-135	2 950	
Fixed	60 500	55	3	188	-133	2 000	
Radiodetermination applications	60 500	43	4	168	-125	7 000	1
Radiodetermination applications	60 500	35	4	168	-133	7 00	
Non-specific SRDs	60 500	20	2	148	-128		
ISM	61 250	20	2	148	-128		
Wideband data transmission systems (indoor)	61 500	40	2	148	-108		
ITS	63 500	40	2	148	-108		
Fixed	73 500	85	3	190	-105	250	
Railway applications	76 500	55	3	190	-135	1 000	
TTT	76 500	55	2	150	-95	1 000	
SRR	78 500	55	2	150	-95		
Radiodetermination applications	80 000	43	4	171	-128	10 000	1
Radiodetermination applications	80 000	34	4	171	-137	10 000	
Fixed	83 500	85	3	191	-106	250	

7.8 Interferers for automotive applications

For automotive applications, given the fact that a car is typically moving (or parked) in the same environment as outdoor application (i.e. an urban or rural area), the same set of interferers have been considered, limited to the frequency range applicable to automotive. However, due to the different characteristics of the car with respect to buildings (e.g. metal shielding instead of wall shielding, the fact that the car may move, etc.), some modifications in the service group parameters. - i.e. distances, NLOS loss and additional NLOS losses - are required.

For automotive applications, two different areas in the car where the device may be installed are considered:

- Devices inside the surface and not in the passenger area: these devices may be typically installed in the bonnet, the trunk, etc. This means that a very strong attenuation, due to car metal surface, are to be considered as car shielding from interferer.

- Devices outside the surface or in the passenger area: these devices may be installed in the passenger area or in other parts of the car not shielded by the car metallic surface (e.g. tyres, mirrors, etc.). For such devices the shielding effects comes from rubber, tissues, glasses, or even attenuation by diffraction against external car metallic surface. There is a large spread of value of the additional NLOS attenuation due to such materials

NLOS contribution due to interferer characteristics

With respect to outdoor application, a car may move at high speeds. This causes the car to be subjected to the LOS of potential fixed interferer for very short times. Furthermore, as in the case of LPR and TLPR, it may be considered that radiation of fixed interferers is directed to the dedicated receive antenna with LOS connection, not to the victim car. Hence, the automotive application will not be located in the main beam of the directional antenna, except for very short time intervals. Therefore, the interfering radiation is mainly coming from the side lobes of the interferers' directional antenna.

For this reasons, the NLOS contribution from interferers is considered for all fixed applications, assuming 12 dB, a typical medium-level side lobe attenuation for a directional antenna.

Additional NLOS contribution due to installation

Shielding properties of car, when due to metallic surfaces, are strong and are comparable with shielding effects of TLPR. Therefore, in this case the NLOS additional contribution is increased to 40 dB.

7.8.1 Devices inside the surface and not in the passenger area

This clause contains potential interferers for automotive UWB applications inside the surface and not in the passenger area in the frequency ranges 3 GHz to 4,9 GHz and 5,8 GHz to 9,2 GHz.

Table 12: Service groups for automotive applications inside the car surface

Service group (interferer)	Distance [m]	NLOS loss from interferer [dB]	Additional NLOS loss due to car shielding [dB]
1. Mobile	2	0	40
2. (Fixed) outdoor	100	12	40
3. Fixed indoor	100	12	40
4. Fixed outdoor long range	1 000	12	40

Table 13: List of interferers for automotive applications inside the car surface

Radio Service	Center Freq. [MHz]	max. EIRP [dBm]	Service group	Total attenuation [dB]	Power @ device [dBm]	Ch. BW [MHz]	Duty cycle
PMSE	3 500	23	3	135	-112	10	
WiMAX Base Station	3 600	43	4	156	-113	10	3 ms per 5 ms
WiMAX Terminal Outdoor Antenna	3 600	20	2	136	-116		
WiMAX Terminal Indoor Antenna	3 600	12	3	136	-124	10	
PMSE	4 700	23	3	138	-115	10	
BBDR-PPDR Base Station	4 895	39	4	158	-119	20	1
BBDR-PPDR Terminal	4 895	26	2	138	-112	20	
SRD	5 800	14	1	94	-80	100	1
TTT (Tolling)	5 805	39	4	160	-121	28	1
ITS	5 890	33	2	140	-107	10	5 ms per 55 ms
Fixed links	7 212,5	85		200	-115	29,65	
Radiodetermination applications	7 250	7	4	162	-155	2 500	1
Fixed (point-to-point)	8 450	85		201	-116		

7.8.2 Devices outside the surface or within the passenger area

This clause contains potential interferers for automotive UWB applications outside the surface or within the passenger area in the frequency ranges 3 GHz to 4,9 GHz and 5,8 GHz to 9,2 GHz.

Table 14: Service groups for automotive applications outside the car surface

Service group (interferer)	Distance [m]	NLOS loss from interferer [dB]	Additional NLOS loss due to car shielding [dB]
1. Mobile	2	0	10
2. (Fixed) outdoor	100	12	10
3. Fixed indoor	100	12	10
4. Fixed outdoor long range	1 000	12	10

Table 15: List of interferers for automotive applications outside the car surface

Radio Service	Center Freq. [MHz]	max. EIRP [dBm]	Service group	Total attenuation [dB]	Power @ device [dBm]	Ch. BW [MHz]	Duty cycle
PMSE	3 500	23	3	105	-82	10	
WiMAX Base Station	3 600	43	4	126	-83	10	3 ms per 5 ms
WiMAX Terminal Outdoor Antenna	3 600	20	2	106	-86		
WiMAX Terminal Indoor Antenna	3 600	12	3	106	-94	10	
PMSE	4 700	23	3	108	-85	10	
BBDR-PPDR Base Station	4 895	39	4	128	-89	20	1
BBDR-PPDR Terminal	4 895	26	2	108	-82	20	
SRD	5 800	14	1	64	-50	100	1
TTT (Tolling)	5 805	39	4	130	-91	28	1
ITS	5 890	33	2	110	-77	10	5 ms per 55 ms
Fixed links	7 212,5	85		170	-85	29,65	
Radiodetermination applications	7 250	7	4	132	-125	2 500	1
Fixed (point-to-point)	8 450	85		171	-86		

8 Test signal

The test signal generation procedure should be as easy as possible, but the signal shall be realistic enough to enable mechanisms of the device under test that make use of the real signal characteristics.

In order to combine these requirements 4 options are given.

Option 1: CW

The test signal may be a continuous wave signal, provided its whole integrated power equates the power of the intended interferer, as from table 1. See annex C.

Signal: Continuous wave sinusoidal signal.

Frequency: Center frequency of interferer.

Power: The integrated power equals to the max. EIRP from the relevant interferer table. See annex C.

Option 2: Wideband test signal (more realistic test)

More realistic wideband signals may be employed. For such signals, the bandwidth is increased up to the true channel bandwidth. This kind of signal shall be built as follows:

Signal: Gaussian, any kind of Gaussian modulation directly available by commercial test equipment: FSK, ASK, BSK, AWG, etc., plus Gaussian filtering. See annex C.

Bandwidth: between 0 and the channel bandwidth of the real interferer. The channel bandwidth can be found in the interferer table. If no channel bandwidth is specified there, either option 2 cannot be used or a reference specifying the channel bandwidth shall be provided. Accepted references are EN, TS, EC decision, ECC DECision, ECC Report, ETSI standard, or official ITU document.

The modulation and the Gaussian filter shape shall be set such that at least 90 % of the total signal power is within the selected interferer channel bandwidth.

Frequency: Center frequency of interferer.

Power: The integrated power equals to the max. EIRP from the relevant interferer table. See annex C.

Option 3: Signals with duty cycle

A duty cycle may be applied both in case of option 1 or option 2 in order to provide a realistic pattern of activity of the interferer.

Signal: CW or Gaussian, according to Option 1 or Option 2.

Frequency: Center frequency of interferer.

Power: see option 1 or option 2. The power level of the signal shall be set at 100 % duty cycle, then duty cycle is applied. See Annex C.

Duty cycle: The duty cycle can be found in the interferer table. If "100 %" or "1" is explicitly indicated, no duty cycle may be applied. If no duty cycle is specified there, either option 3 cannot be used or a reference specifying the duty cycle shall be provided. Accepted references are EN, TS, EC decision, ECC DECision, ECC Report, ETSI standard, or official ITU document. The duty cycle shall be defined in the form of a timing (e.g. 5 ms per 100 ms) and not in the form of a percentage (e.g. 5 %).

Option 4: Real interferer signal

Signal: Real signal as defined in the appropriate standard.

Frequency: Center frequency of interferer.

Power: The integrated power equals to the max. EIRP from the relevant interferer table. See annex C.

NOTE: For the goal of building the test interferer, the real centre frequency of the interferer channel nearest to the centre frequency from the table can also be taken instead of the centre frequency from interferer tables. This ensures that interferer detection mechanisms, that rely on the real channel frequencies of the interferer work.

9 Test procedure

9.1 Definitions

9.1.1 Receiver operating frequency range

From a test-procedure point-of-view it is very difficult to measure the receiver frequency range. Therefore, the Operating Bandwidth [1] is taken as the Receiver operating frequency range (see Figure 2). If the Operating Bandwidth consists of several segments, the sum of the segments is relevant.

Receiver-only device with corresponding transmitter device
Receiver operating frequency range is equal to the Operating Bandwidth of the transmitter device.

Receiver-only device without corresponding transmitter device
Manufacturer declares the receiver operating frequency range.

Figure 2: Receiver operating frequency range

9.1.2 Interferer test frequency range

The interferer test frequency range is defined as the receiver operating frequency range exceeded by a frequency offset of 5 % of the BW (max. 200 MHz; lower end >= 30 MHz) at the lower and upper end (see figure 3). If the receiver operating frequency range consist of several segments, the frequency offsets shall be added to each segment.

Figure 3: Interferer test frequency range

9.2 Test setup

9.2.1 Definition of the scenario, performance criterion and level of performance

The tests shall be performed in a scenario representative of a typical usage scenario denoted as "real scenario".

For the test an appropriate scenario, performance criterion and level of performance from the recommended scenarios listed in clause 9.4 shall be used.

If no suitable scenario can be found in clause 9.4 or a relevant harmonised standard, the manufacturer needs to define a specific scenario, performance criterion and level of performance that represents typical usage conditions.

Alternatively to the real scenario an equivalent scenario or a conducted measurement can be used. Care has to be taken that the transmit and interference levels at the receiver are equivalent to the ones of the typical usage scenario.

The performance criterion and the level of performance shall be stated in the user manual (see clause 9.2.2).

9.2.2 Required text for the user manual

For stating the performance criterion and the level of performance in the user manual the following text shall be used:

For the receiver test, that tests the influence of an interferer signal to the device, the following performance criterion has at least the following level of performance (ETSI TS 103 361, the present document).
Performance criterion: <*performance criterion*>
Level of performance: <*level of performance*>

9.2.3 DUT orientations and polarization directions

The test shall be performed in the direction of the maximum mean transmit power. If this is not feasible the test shall be repeated with the test antenna facing each side of the DUT (six sides: front, rear, right, left, top, bottom). However, if technical justifications are presented, less sides of the DUT can be tested.

The test shall be repeated with vertical and horizontal polarization of the test antenna. If the most sensitive polarization direction of the DUT is known, it is sufficient to only test for this polarization direction.

9.2.4 Environmental conditions

The test shall be conducted under normal test conditions as defined in clause 5.4.3 of ETSI EN 303 883 [1], if not specified differently in the respective harmonised standard.

9.3 Test for interferer signal handling

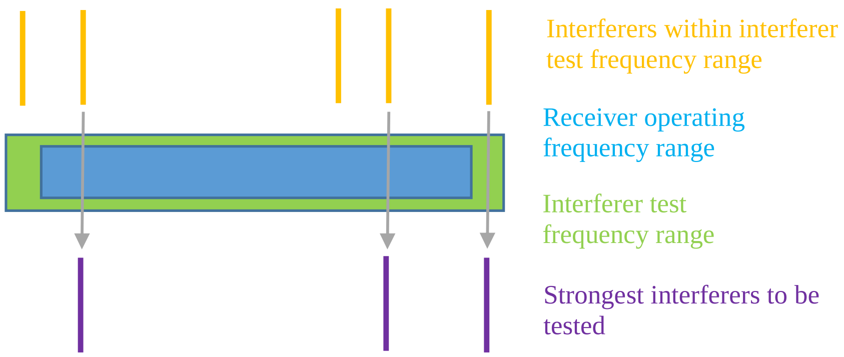


Figure 4: Applicable interferers

Procedure:

1) Find the potential interferers inside the interferer test frequency range (interferer **centre** frequency inside interferer test frequency range) using the appropriate interferer table for the application in clause 7 (tables 3, 5, 7, 9, 11, 13, 15).

2) If there are more than 3 interferers, only use the 3 strongest ones (strongest power @ device; see clause 7).

3) The interferers found after step 1 and 2 are the applicable interferers (see figure 4).

4) Choose one of the options for the test signal defined in clause 8.

5) Set the interferer power such that the power at the position of the device is equal to the power mentioned in the interferer list as "power@device".
If the test is performed in a scenario and the attenuation of the scenario is not already considered in the interferer power, the interferer power shall be set such that the power at the scenario equals the power mentioned in the interferer list as "power@device".

EXAMPLE:

- BMA: Power at the wall surface.
- TLPR: Power at the device as the power has already been adjusted for the attenuation of the tank.

6) Check for each applicable interferer, if the device behaves as intended.

7) The test is passed, if the device behaves as intended for all applicable interferers.

If there are no applicable interferers within the interferer test frequency range the test is passed.

The device behaves as intended, if:

- the performance criterion is met (the device continues working as intended); or
- the device switches off as intended (LBT); or
- the device changes the frequency as intended (DAA); or
- the device detects that it does not work correctly and manages the condition as intended; or
- the device shows an "interferer detected" message.

If the device crashes this is regarded as an EMC immunity issue and not as receiver failure. Therefore this is not relevant for the receiver test. It shall be shown that the same issue occurs, if the receiver is switched off.

If not stated in the relevant standard, the test for each interferer should last for at least 0,5 seconds or the reaction time of the device, whichever is the largest.

9.4 Recommended tests

9.4.1 Building material sensor

Performance criterion Detection of rebar rod of diameter 12 mm at a depth of d.

Level of performance Object detected, if object is present. No detection, if object is not present.

Real scenario Test wall made of two plaster boards (thickness 12 mm) in a distance of e. The iron rebar rod is placed between the boards in a depth d measured from the front surface of the first board (see figure 5).

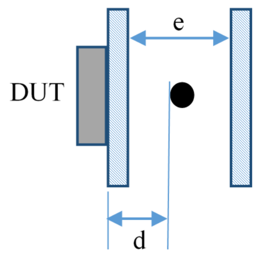


Figure 5: Scenario for building material sensors

If the device under test (DUT) requires movement to detect the object, the DUT shall be moved on a path perpendicular to the iron rod orientation for the test.

Depending on the DUT direction of maximum sensitivity to an interferer, the antenna emitting the interferer shall be placed. Typically, the interferer antenna is placed on the opposite side of the test wall with respect to the DUT facing the DUT.

Equivalent scenario -

Conducted measurement -

Manufacturer definitions Object depth d (12 mm ≤ d ≤ e)

Distance between plaster boards e (typically 80 mm)

9.4.2 Respiration sensor

Performance criterion Remote detection of respiration on a person standing at a distance d from the sensor.

Level of performance Chest movement caused by respiration activity detected if a person is present. No detection if no person is present within the range d of the sensor.

Real scenario Adult person at d meters distance from the sensor.

Equivalent scenario The person may be replaced by a reflecting object (phantom) with the same radar cross-section as the chest of an adult person. The object should be moved in a cyclic pattern with amplitude of a meters directly towards the sensor.

Conducted measurement -

Manufacturer definitions Distance between sensor and person (phantom) d [m]

Chest moving amplitude a [m]

Radar cross-section of chest/phantom RCS [m2]

9.4.3 Presence sensor

Performance criterion Detecting the presence of a human person within a defined detection area with a certain width and depth.

Level of performance If a person is present, the sensor should detect the person with a failure rate below r (i.e. the person should be detected x out of y times where r=1-x/y).

Real scenario An adult human is present in a room and makes slight movements within the detection area.

Equivalent scenario The person may be replaced by a reflecting object (phantom) with the same radar cross-section (RCS) as the body of an adult person. The object should be moved in a cyclic pattern with an amplitude of a meters directly towards the sensor.

Conducted measurement -

Manufacturer definitions Detection area (width, depth) [m^2]

Cross-section of eventual phantom RCS [m^2]

Maximum failure rate r [%]

9.4.4 Distance measurement system

Performance criterion Distance (d) to a static object with a given radar cross-section (RCS) within a defined maximum range (r).

Level of performance If the object is present within the range, the sensor should report the distance to the object with a certain accuracy (x).

Real scenario Static object with a radar cross-section of RCS m2 at d meters distance (LOS). The object should be placed in an anechoic chamber to eliminate ambiguities.

Equivalent scenario If the real scenario maximum range r is above what is practically possible to measure in the test-lab, a shorter range may be used as long as object radar cross-section is reduced accordingly maintaining the same power level of the echo signal at the DUT.

Conducted measurement -

Manufacturer definitions RCS of object [m^2]

Maximum detection range r [m]

Distance d [m]

Accuracy x [%]

9.4.5 On-body pulse rate sensor

Performance criterion Detecting the pulse rate of a human/animal with a sensor placed onto the body.

Level of performance When the sensor is placed onto the body of a living human/animal, the pulse rate should be detected and reported.

Real scenario For humans the sensor should be placed on top of the chest with the device radiating into the body. For animals the sensor should be placed in a collar around the neck. The device should report heart/pulse rate.

Equivalent scenario A phantom could replace the human/animal. An oscillating object modelling the heart or arteries should be located inside the volume of the phantom. The object should have a radar cross section (RCS) equal to that of the moving parts of the heart and with a similar amplitude.

Conducted measurement -

Manufacturer definitions -

9.4.6 Communications device

Performance criterion Sensitivity, i.e. receiver minimum power level required to achieve a maximum of P_o PER for N bytes payload. P_0 and N should be defined in a specific communication standard, covering all relevant ISO OSI layers [1]). The minimum layers that such standard should define in order to make this definition applicable, are the PHY and the MAC layers (Layers 1 and 2 of the ISO-OSI stack, see clause A.1).

Level of performance Minimum power level P_{rx} at which the performance criterion is met. P_{rx} should be defined in a specific communication standard, covering all relevant ISO OSI layers [1]).

Real scenario Transmitter and receiver with distance d facing towards each other (radiated measurements). The distance d shall be chosen such that the power level P_{rx} is realized at the receiver. The distance d shall be evaluated:

- By calculation: assuming a LOS propagation model at UWB signal centre frequency, including the contribution of the RX and TX best antenna gains (main lobes peaks).

- By equivalence: measuring the received power at RX antenna output, by means of a test instrument (Spectrum Analyser) and using the same RX antenna used for the UWB device, along the direction of peaks of antennas main lobes (RX and TX best antenna gain)

Equivalent scenario -

Conducted measurement

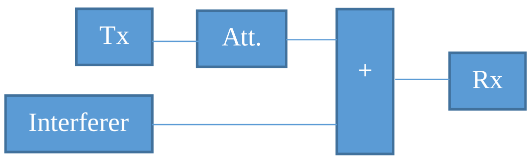


Figure 6: Conducted measurement for communication device

Manufacturer definitions Manufacturer defined performance criteria apply whether no specific communication standard exists, covering all related ISO-OSI layers and specifying the related sensitivity parameters. Namely the manufacturer shall specify in the user manual:

Expected maximum PER P_0

Packet size N for the expected PER P_0

Minimum required power level P_{rx} [dBm] for PER ≤ P_0 and packet length N

At the moment, such telecommunication standards do not exist for UWB communication, therefore values for performance level shall be provided by the manufacturer, according to the implemented proprietary protocol.

9.4.7 (T)LPR Method

Performance criterion Measurement value variation (due to the interferer) of a distance measurement with the (T)LPR sensor against a known surface at a defined measurement distance.

Level of performance The (T)LPR sensor shall be able to measure against a large flat surface consisting of a material with relative permittivity ε_r in the maximum approved measurement distance R_{max} according to the manufacturer specification which still meets a measured distance value variation of ±50 mm over time under interference conditions.

Real scenario Measurement against the large flat surface consisting of a material with relative permittivity ε_r in maximum approved measurement distance R_{max} which still meets the declared distance value variation.

The power which is radiated back from the respective surface into the receiver can be approximated according to equation (4) assuming a specular reflection.

$$P_r^{dBm} = P_t^{dBm} + 20 \cdot log\ G + 20 \cdot log\ \lambda - 20 \cdot log\ R_{max} + 20 \cdot log\ |r| - 28dB \quad (4)$$

P_r^{dBm} : received power in dBm
P_t^{dBm} : transmitted power in dBm
G : gain of the LPR antenna
λ : wavelength of the transmit signal
R_{max} : maximum approved measurement distance under interference conditions
r : reflection coefficient of the considered surface

The reflection coefficient of the transition from air to the surface material with the relative permittivity ε_r can be approximated by the simplified equation (5).

$$r \approx \frac{1 - \sqrt{\varepsilon_r}}{1 + \sqrt{\varepsilon_r}} \quad (5)$$

ε_r : relative permittivity of the considered surface material

Equivalent scenario In practice the measurement against a liquid or a bulk material surface at larger distances is not feasible and leads to expensive test setups. (There are LPR sensors on the market which can measure distances beyond 100 m.)

In order to facilitate testing and to keep the effort (and thus costs) manageable, an equivalent radar target at a smaller distance R with RCS σ is used which produces the same (or less) echo signal power at the receiver as the above introduced flat surface at the defined measurement distance.

The measurement at the smaller distance R is allowed as the performance criterion (variation of the measurement value) is in general only dependent on the signal-to-noise ratio of the echo signal and not on the distance to the target.

The power level of the echo signal P_r^{dBm} at the receiver during the measurement against the target with RCS σ can be calculated according to equation (6).

$$P_r^{dBm} = P_t^{dBm} + 20 \cdot log\ G + 20 \cdot log\ \lambda + 10 \cdot log\ \sigma - 40 \cdot log\ R - 33dB \quad (6)$$

R : distance between LPR and target
σ : radar cross section (RCS) of the target

With the given echo power level from the above introduced surface it is possible to calculate the RCS σ of the target at nearly arbitrary distances R. This is necessary as some test houses may not have the possibility to conduct measurements at longer distances due to the very limited space in their anechoic chamber.

The test scenario includes an interferer signal with well-defined power and frequency.

Suitable radar targets for a radiated test setup depend on the desired RCS. The conducting sphere as well as square or triangular shaped corner reflectors are most suitable for this purpose.

The test is passed if the (T)LPR sensor is still able to detect the radar target and measure the distance to the target within a maximum measured distance value variation of $\leq \pm 50$ mm over time.

Alternative (equivalent) scenario

The (T)LPR signal processing algorithms need a stable echo and a minimum echo signal-to-noise ratio (SNR) of y dB (declared and proven by manufacturer) to ensure a distance value variation smaller than ± 50 mm over time during a distance measurement.

Unstable echoes or echoes with signal-to-noise ratios smaller than y dB cannot be reliably processed by the (T)LPR-sensor with the declared accuracy. This circumstance can be taken into account to define the following equivalent test scenario.

The interferer will provoke a rise of the noise floor in the receiver of the (T)LPR sensor and thus degrade the SNR of an echo signal. If the noise floor of the receiver stays y dB below the power level of the above defined echo signal in the real scenario (produced by the flat material surface with relative permittivity ε_r), a measurement value variation of $\leq \pm 50$ mm can be assured over time.

Thus a simultaneous distance measurement is no longer needed. The interferer signal is directly fed into the receiver of the (T)LPR sensor either in a conducted or radiated setup. The system noise level is observed in an echo curve graph for example.

The test is passed if the resulting system noise level stays at least y dB below the echo power level produced by the above defined flat surface.

Conducted measurement

Both presented equivalent scenarios can also be carried out in a conducted test setup, assumed that a suitable antenna connector is present.

In the equivalent scenario above the required echo signal is generated for example by means of a short circuited RF-cable or a hollow waveguide. The necessary attenuation to provide the required echo power at the receiver can be introduced by a coaxial attenuator or a waveguide attenuator, respectively. The interfering signal is also fed into the receiver by means of a suitable waveguide. Of course an appropriate coupler is necessary in the test setup in order to provide both signals (echo and interferer) to the receiver simultaneously.

In the alternative scenario a simultaneous distance measurement is no longer needed as only the noise level of the sensor is observed. So the interferer is directly fed into the receiver by means of an appropriate waveguide (e.g. RF-cable or hollow waveguide). The required interferer power level can be adjusted by using the internal attenuator in the RF signal generator or by using an external attenuator in the waveguide.

Manufacturer definitions

- Maximum approved measurement distance R_{max} under interference conditions used in the real scenario. (This is not necessarily the maximum measurement distance capability of the (T)LPR sensor).
- Maximum measured distance value variation of ±50 mm under interference conditions.

- Relative permittivity ε_r of the considered surface material in the real scenario
- Relation between the measured distance value variation and the signal-to-noise ratio of the respective echo signal (only required if the alternative scenario above is used).

The first three manufacturer definitions determine the level of performance of the individual (T)LPR device under interference conditions and shall therefore be declared in the user manual.

For further information see annex D.

9.4.8 GPR/WPR device

Performance criterion	The difference D between the Rx signal noise (increased by an interferer) and the maximum input signal for the Rx in the linear region of operation.
Level of performance	The difference D shall be larger than Dmin (in dB).
Real scenario	GPR/WPR device placed on a sandpit with antenna facing downwards.
Equivalent scenario	-
Conducted measurement	-
Manufacturer definitions	Dmin (in dB), see performance criterion.

Annex A (informative): Information on Performance Criteria

A.1 Communication devices

For the application group of communication devices, BER or PER might be possible to be used commonly for all applications. However, imposing the same predefined BER or PER level as performance criteria in a non-specific application standard seems somehow forcing the same hard requirement to whichever application, independently on how each specific application "intend to operate".

To overcome this issue, different solutions were adopted in other ETSI standard, namely:

- In ETSI ES 202 131 [i.82], a performance criteria suitable for the needs of the application itself is adopted ("wanted criteria", derived by specific-application standards, like e.g. IEEE 802.11™ [i.85] or Bluetooth™). The test procedure is defined, but its goal is testing the performance against the "wanted criteria", not against a single predefined level imposed by the standard itself to all applications.

- In in ETS EN 300 086 [i.84], the used performance criterion is the ratio SND/ND, i.e. the ratio between the power of sum of the wanted signal, the noise, and the distortion due to the unwanted signal - and the power of sum the noise and distortion. This criterion is more suitable for a standard approaching only specific electromagnetic compatibility characteristics and not dealing with any protocol definition, as the ETSI EN 302 065 [i.83] does.

As it will be seen in the next paragraph, for communication applications, an analysis of the ISO-OSI model provides a straightforward insight about the fact that sensitivity, or any associated parameter like BER/PER, may be a suitable performance criterion to be specified in a standard. In short words:

- Whereas an application-specific standard covers all the OSI layers determining the BER or PER performance - i.e. the MAC and the PCS sublayers, down to the PMD sublayer - the standard should consider sensitivity as an applicable receiver parameter, and BER or PER as applicable performance criteria. A standard defining all these layers is e.g. the IEEE 802.15.4-2011 [i.4] (although no sensitivity requirement is stated for the PHY layer based on UWB).

- On the contrary, in case the standard does not cover these sublayers, sensitivity and BER/PER should be disregarder by the standard. Related specifications should be provided by manufacturer declarations (who designed the protocol). In this case, the BER or PER corresponding to the minimum sensitivity level as declared by the manufacturer may be adopted as an appropriate performance criterion in the test procedure of other the receiver parameters. This is the case of ETSI EN 302 065.

Applicability of BER/PER as performance criteria: the ETSI UWB standards and the ISO-OSI model

The ISO OSI model [i.71] and [i.70] is widely adopted by standardization bodies. Typically, the layers interested in UWB standardization/specification are the lowest, the PHY and MAC. An example is the IEEE 802.15.4-2011 [i.4] standard, which belongs to the IEEE 802 family (LAN/PAN).

In IEEE 802.15.4-2011 [i.4], clause 14 defines a complete MAC+PHY stack for an UWB communication application, intended to enhance the traditional ZigBEE MAC+PHY. This architecture is shown in Figure A.1.

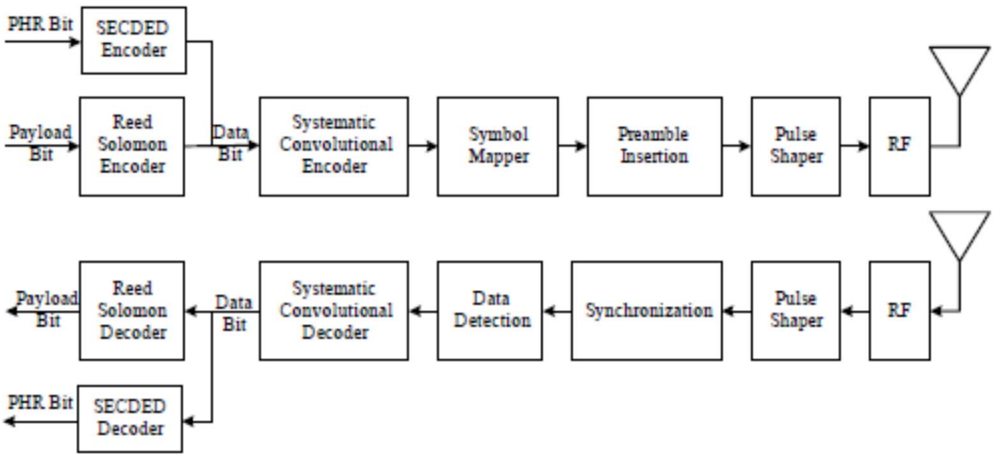


Figure A.1: UWB PHY signal flow from IEEE 802.15.4-2011 [i.4]

According to ISO-OSI definitions, the PHY layer - (Layer 1 of the ISO-OSI model) performs the following functionalities:

- Establishment and termination of a connection to a communications medium.
- Participation in the process whereby the communication resources are effectively shared among multiple users, e.g. contention resolution and flow control.
- Conversion between the representation of digital data in user equipment and the corresponding signals transmitted over a communications channel.

Adopting the LAN terminology, the Physical Layer is in its turn subdivided in three sublayers:

- PCS (Physical Coding Sublayer) - This sublayer determines when a functional link has been established, provides rate difference compensation, and performs bit coding, scrambling/descrambling, etc. Moreover, it provides interface to Layer 2 (at the MAC layer).
- PMA (Physical Medium Attachment Sublayer) - This sublayer performs framing, octet synchronization/detection, additional scrambling/descrambling, etc.
- PMD (Physical Medium Dependent Sublayer) - This sublayer consists of the transceiver adapting the final data stream to the physical medium (i.e. the pulser or the DAC for the UWB case).

Following previous definitions, the UWB PHY sublayers may be identified in the IEEE 802.15.4-2011 [i.4] signal flow, as shown in figure A.2.

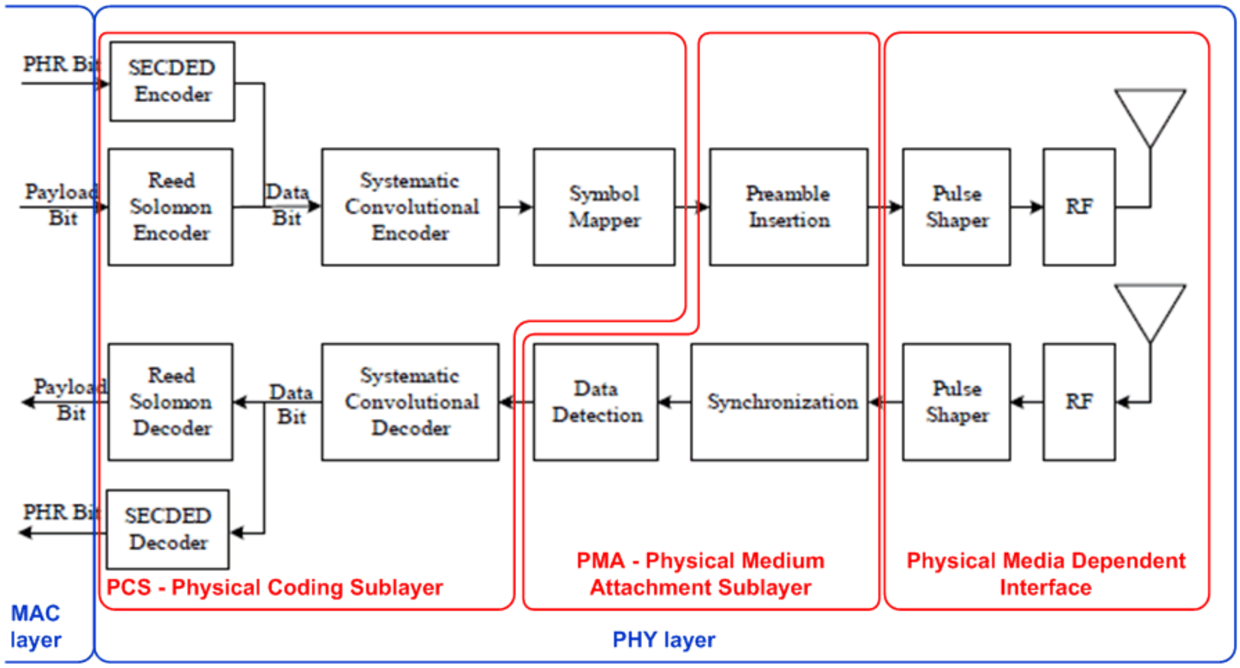


Figure A.2: Mapping of PHY sublayers on the IEEE 802.15.4-2011 UWB PHY protocol

The corresponding architectural mapping is shown in figure A.3. It is straightforward that there exists a difference between a standard like IEEE 802.15.4-2011 [i.4] and the ETSI EN 302 065 [i.83], parts 1, 2 and 3:

- IEEE 802.15.4-2011 is a vertical standard, providing a complete and vertical specification of the MAC layer and the PHY layer, covering the whole signal flow, from the PER lever (the MAC layer) to the BER lever (the PHY layer, and namely the PCS sublayer), and finally down to the RF signal level (the PHY layer, and namely the PMD sublayer).

- ETSI EN 302 065 [i.83] is a horizontal standard, expanding the definition of the technical requirements at the lowest PMD layer of the PHY layer, i.e. the medium interface layer. ETSI EN 302 065 [i.83] does only consider technical requirements in no way related to higher layers, from which specifications for BER or PER may be derived.

It is worth to recall now that sensitivity is often formally defined as the minimum RF power level at the receiver antenna input required to get a predefined BER or PER. Therefore, sensitivity is an appropriate requirement in IEEE 802.15.4-2011 [i.4], given the fact that this standard specifies the whole vertical signal flow, from the PER level (i.e. the MAC layer) down to the layer specifying technical characteristics for the TX/RX RF signals (i.e. the PMD layer).

However, it should be highlighted that in the last version of ZigBee™ standard, IEEE 802.15.4™-2011, all PHYs layers – including the UWB PHY – are fully specified in terms of bit coding, from PMD layer to the MAC layer. On the contrary, sensitivity is defined for all PHYs, except the UWB, even if the information included in the standard would allow the definition of a sensitivity limit.

On the other hand, sensitivity appears not an appropriate requirement in ETSI EN 302 065 [i.83], due to the "horizontal" nature of this standard, that limits its scope only to the lowest PMD layer (i.e. the RF transceiver layer), not considering any higher-level information, necessary to provide a clear specification of BER or PER performances. Therefore, due to the lack of relevant information, sensitivity specification should be avoided in ETSI EN 302 065 [i.83].

On the other hand, sensitivity could be specified by a standard covering all aspects impacting on PER and BER, i.e. a standard specifying MAC and PHY layer, as the IEEE 802.15.4-2011 [i.4] does.

Such a standard, at the moment, does not exist in the ETSI UWB family of standards.

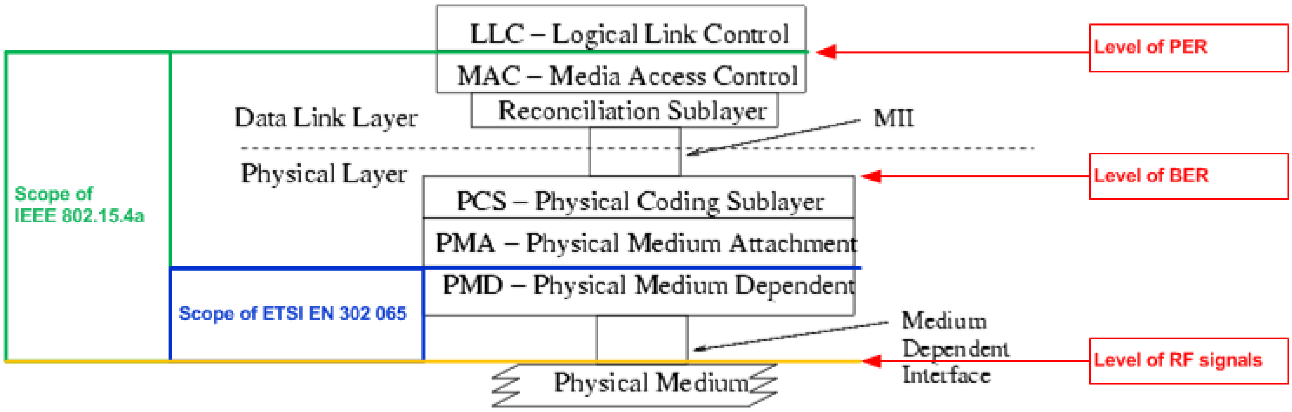


Figure A.3: Mapping the ISO-OSI architecture on IEEE 802.15.4-2011 [i.4] and ETSI EN 302 065 [i.83]

As a final remark, it may be noted that ETSI EN 302 065 [i.83] includes specification of technical parameters related to the transmission medium, i.e. the radio spectrum. Therefore, a performance criterion based on the SND/ND ratio - as the one used in ETSI EN 300 086 [i.84] - appears in case more suitable to the scope of these standards rather than a criterion based on BER or PER, which are parameters out of the scope of ETSI EN 302 065 [i.83].

In conclusion, from these analyses, the following points should be considered:

- A sensitivity specification should not be included in the ETSI EN 302 065 [i.83] standards, given their nature of "generic standard", not approaching any aspect related to protocol design and therefore not impacting the sensitivity.
- For custom communication application, a receiver minimum sensitivity should be specified by the manufacturer. Related parameters specified by the manufacturer - including BER and/or PER - may be adopted as performance criteria.
- In case a new UWB ETSI standard would in future be developed, and this will cover the MAC layer and the PCS sublayer, sensitivity specification should be included in such standard.

A.2 Sensor devices

While the performance of communication devices in most cases may be defined by a Bit Error Rate (BER) for a given range/protocol, most sensor devices are proprietary since they typically do not need to comply with certain standards / protocols. In addition the main purpose of a sensor is to sense certain physical parameters and to process the physical data into some form of application related parameter like distance, position, breath rate, fluid level, etc. The performance of a sensor device is thus a combination of the electrical/physical quality of the sensor and the signal processing required extracting the required information. As a consequence it is very hard to specify a well-defined performance criterion covering all sensor devices.

Therefore it is suggested using a manufacturer defined performance level. A similar approach is used for example in IEC 61000-4-3 [i.86] (EMC immunity).

Examples for manufacturer defined performance levels:

- BMA: The device detects a certain object in a defined depth within a specific wall.
- TLPR: The device measures a certain surface in a defined distance with a specific accuracy.

Annex B (informative): Text blocks for harmonised standards

B.1 Receiver Conformance Requirements (4.4)

The following text blocks are proposals for the text that can be included in the relevant ETSI UWB standards in the sections dealing with receiver parameters.

Receiver requirements (4.4.1)

Not part of the present document

Receiver spurious emissions (4.4.2)

Not part of the present document

Interferer signal handling (4.4.3)

Applicability (4.4.3.1)

This requirement applies to all devices under test.

Description (4.4.3.2)

Interferer signal handling, defined as the capability of the device to operate as intended in coexistence with interferers, is the receiver parameter for UWB applications.

Operation as intended is evaluated using a performance criterion. For common applications, recommended performance criteria and test cases are defined in clause 9.4 of *<ETSI TS 103 361>*. For other applications the manufacturer shall choose an appropriate performance criterion according to clause 9.2.1 of *<ETSI TS 103 361>*. The performance criterion shall be stated in the user manual (see clause 9.2.2 of *<ETSI TS 103 361>*).*(define "user manual" under definitions in HS).*

Limits (4.4.3.3)

The limits are met, if the requirements in clause 9 of *<ETSI TS 103 361>* are met.

Conformance (4.4.3.4)

The conformance tests for Interference Signal Handling shall be as defined in clause 6.6.2 of the present document.

The tests for the interferer signal handling shall be done under normal test conditions as defined in the related clause *<of the harmonised standard>*.

B.2 Conformance methods of measurement for receiver (6.6)

The following text blocks are proposals for the text that can be included in the relevant standards in the sections dealing with receiver parameters.

Receiver spurious emissions (6.6.1)

Not part of the present document

Interferer signal handling (6.6.2)

Interference signal handling measurements shall be as given in *<ETSI TS 103 361>*, clause 9.

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

Annex C (informative): Test signal generation

Calculation of the power level

When performing the test, the interferer signal should be built according to table 1 and related Service Group characteristics. The attenuation to be applied for building the test interferer (identified by Service Group characteristics) has been split into four contributions; hence, in order to calculate the average power of the test signal, say P_{test}, equation (C1) is applied.

$$P_{test} = P_{ref} - 20*\log10(4*pi* L_{SG} *fc/c) - A_{SG, NLOS, fix, dB} - A_{SG, ADD, dB} \quad \text{(C1)}$$

In this formula:

- P_{ref} is the transmitted average power level for the selected interferer, defined in column 3 (max. EIRP) of tables 3, 5, 7, 9, 11, 13 and 15.
- L_{SG} is the applicable line of-sight distance, defined in column 2 of the relevant Service Group table.
- fc is the interferer centre frequency reported in column 2 of tables 3, 5, 7, 9, 11, 13 and 15. Instead of the centre frequency from table 1 also the real centre frequency of the interferer channel nearest to the centre frequency from the table can be taken (see note in clause 8).
- c is the light speed, i.e. 3×10^8 m/s.
- $A_{SG, NLOS, fix, dB}$ is a fixed non-line-of-sight contribution defined in column 3 of Service Group table (expressed in dB).
- $A_{SG, ADD, dB}$ is an additional non-line of sight attenuation, defined in column 4 of Service Group Tables.

In the case of (T)LPR, $A_{SG, NLOS, fix, dB}$ and $A_{SG, ADD, dB}$ are exchanged by the following:

- $A_{SG, NLOS, Int, dB}$: is a fixed non-line-of-sight contribution defined in column 3 of Service Group table (expressed in dB) caused by attenuation at the interferers side, i.e. shielding of the interferer due to walls or metal housings or side lope suppression due to the fact that the interferer is not radiating in direction of our victim receiver.

  $A_{SG, NLOS, DUT, dB}$: is a fixed non-line-of-sight contribution defined in column 4 of Service Group table (expressed in dB) caused by attenuation of the DUT side, i.e. shielding of the interferer due to walls or metal housings or side lope suppression due to the fact that the DUT antenna is not receiving in direction of the interferer.

The test signal should be set such to provide a power level equal to the calculated P_{test}:

$$P_{test} = \int_{B_{chan}} PSD_{test}(f)df$$

(C2)

Continuous wave test signals

For a CW signal, equation (C2) becomes (C3).

$$P_{test} = \int_{B_{chan}} PSD_{test}(f)df = \int_{B_{CW}} PSD_{CW}(f)df$$

(C3)

In this equation B_{chan} is the bandwidth of the channel interferer and B_{CW} is the finite bandwidth of the CW signal, having considered that pure CW signals do not exist, therefore a finite bandwidth B_{CW}, and the finite power spectral density PSD_{CW} have been introduced for the (almost) CW signal. Moreover, it has been considered that in general $B_{chan} \geq B_{CW}$, therefore $PSD_{CW}(f)$ vanishes outside B_{CW}.

In theory, B_{CW} may be chosen as low as possible, and PSD_{CW} may be chosen as high as possible, such that the integration results is P_{test}. In practice, the limit of the minimum detectable B_{CW} is imposed by the used resolution bandwidth of the spectrum analyser, say B_{res}. Hence, taking into account also that the PSD_{CW} may be considered almost constant within B_{CW}, previous equation becomes (C4).

$$P_{test} = \int_{B_{res}} PSD_{CW}(f)df \approx PSD_0 * B_{res} \Rightarrow PSD_0 = \frac{P_{test}}{B_{res}} \qquad \text{(C4)}$$

where the assumption $B_{CW} \leq B_{res}$ has been done.

In this equation the quantity P_{test} is the power measured by the spectrum analyser or, equivalently, the power of the CW signal. This measured power, being $B_{CW} \leq B_{res}$, will be seen by the SA as "peak power", i.e. the power integrated in a single spectral bin equal to B_{res}. On the other hand, PSD_0 is the power spectral density measured by the SA when the channel bandwidth is set equal to the resolution bandwidth.

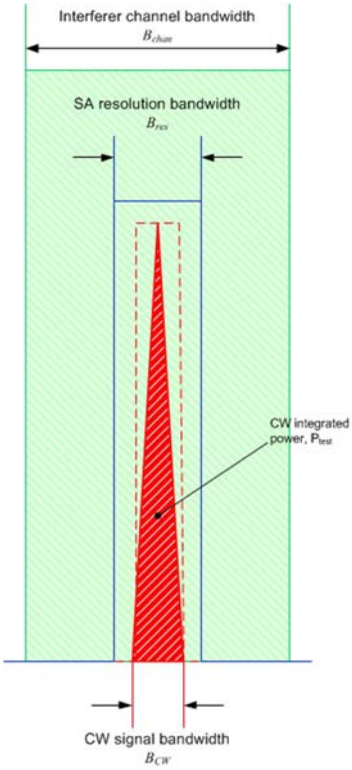
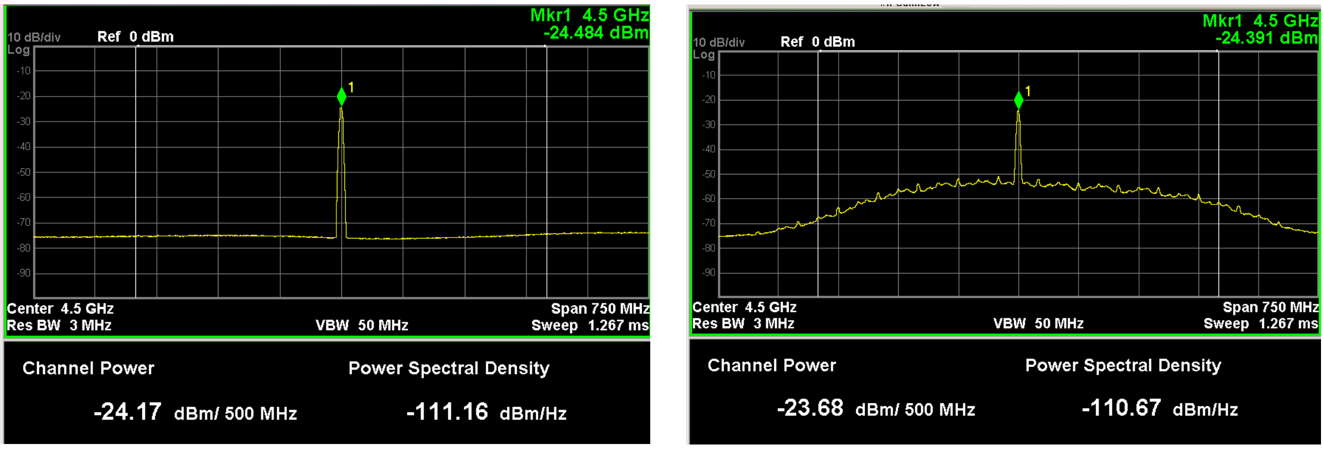


Figure C.1: Relationship between interferer channel bandwidth, SA resolution bandwidth, and CW bandwidth

From the above considerations, it is seen that the signal level for the CW interferer test signal may be set at the measured peak level of test signal, provided that $B_{chan} \geq B_{res}$. An example of a test CW interferer is shown in figure C.1.



(a) **(b)**

Figure C.2: Continuous wave interferer, centered at 4,5 MHz and added to a 500 MHz bandwidth UWB signal: (a) CW without UWB signal, (b) CW added to UWB signal

In this example the CW interferer was centered at 4,5 GHz, i.e. the same carrier than the UWB signal (theoretically this should be the worst case). The resolution bandwidth of the SA was 3 MHz.

In figure C.2 (a) the CW signal is stand alone; its power level was set at -24,5 dBm. The peak level was -24,5 dBm, the integrated channel power over the whole 500 MHz bandwidth was -24,2 dBm. The difference, about 0,3 dB, was the contribution of the noise floor on the whole 500 MHz bandwidth, and this shows that for CW signals the peak power and the integrated channel power are the same. Reducing the integration bandwidth below 500 MHz has low impact on the whole integrated bandwidth (maximum 0,3 dB). This is true because of the high SNR ratio, i.e. 50 dB in the presented example. If the SNR were lower, integrating the CW signal power over large bandwidth may lead to wrong integrated power estimation, due to the increased contribution of the noise floor.

In figure C.2 (b) the UWB signal was added. The peak power is increased by 0,1 dB, meaning that a minimum negligible contribution of the UWB signal is added to the CW signal after the addition of the UWB signal.

Wideband test signals (more realistic test)

A wideband test signal may be considered for the interferer test, to get more realistic results. Such signal may be generated by a generic modulation followed by a Gaussian filter. This is defined in Option 2.

A general scheme for generating such kind of interferers is shown in figure C.3: a random generator is modulated accordingly to any generic signal modulation, then the signal is filtered by a Gaussian filter, having a predefined bandwidth. This kind of processing is generally available in commercial test equipment and does not require addition of external HW.

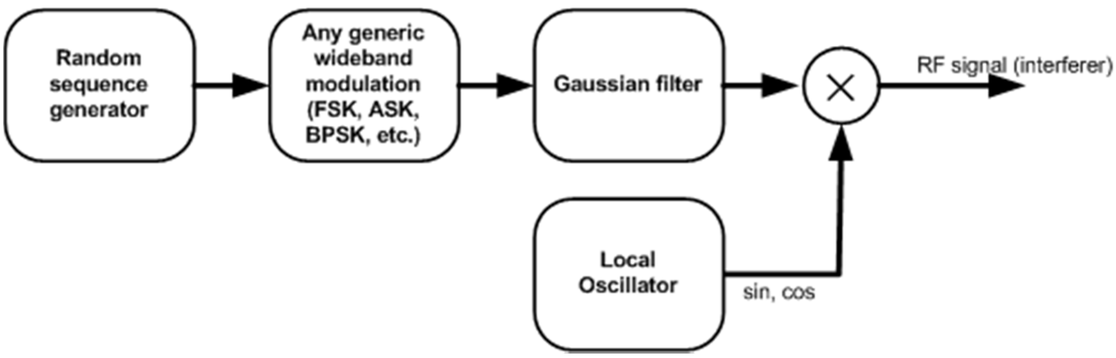


Figure C.3: Interferer generation for Option 2 (More realistic signals)

An example of signal generated according to figure C.3 and the related spectrum, is shown in figure C.4: the Gaussian interferer has been generated by a commercial Vector Signal Generator (PSG). The used test equipment, or other equivalent ones, are commonplace and they may be purchased at middle cost. In the example case, the setting of the equipment where: FSK modulation having a frequency deviation of 10 MHz and a centre frequency of 4,5 MHz, plus Gaussian filter. All these settings were directly available on the instrument.

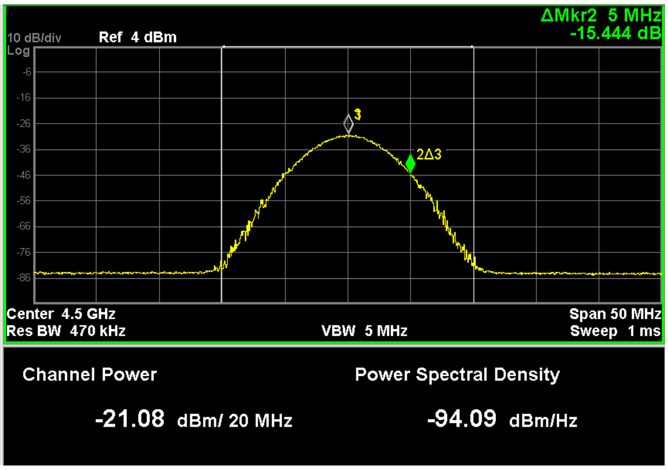
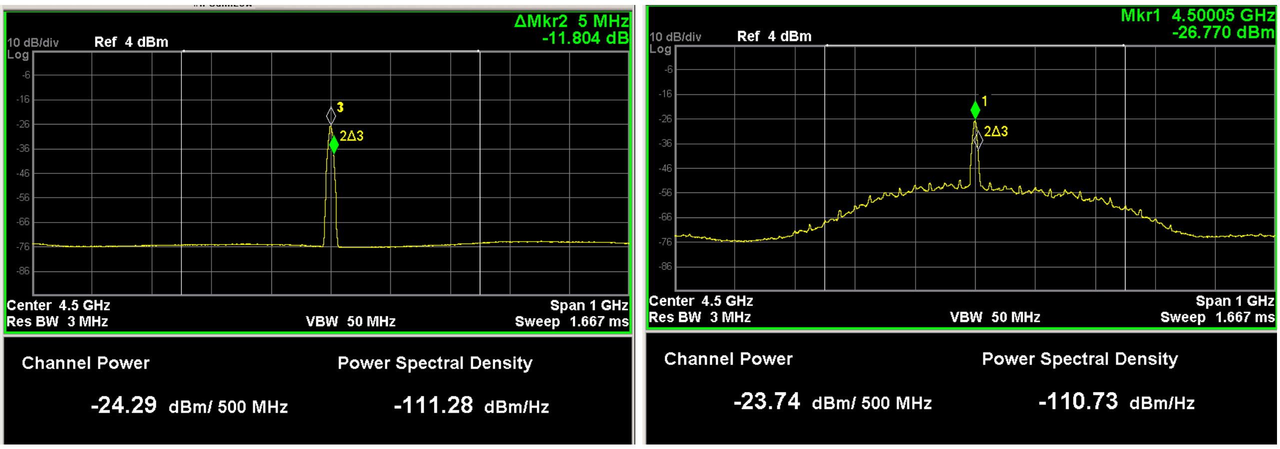


Figure C.4: Wideband test interferer generated with a commercial PSG: FSK modulation + Gaussian filter

In this case the signal has been generated over a BW_{chan}= 20 MHz. Hence, almost all the integrated power were comprised within this channel bandwidth. Differently than in the case of the CW, there is a difference of 10 dB between the peak power and the channel power, due to the Gaussian spectral shaping of the signal and on the fact that in this case $BW_{chan} > B_{res}$.



(a) **(b)**

Figure C.5: Wideband test interferer, centered at 4,5 MHz and added to a 500 MHz bandwidth UWB signal: (a) test interfere without UWB signal, (b) test interferer added to UWB signal

Signals with duty cycles

The formula (1) for the calculation of P_{test} defines the power of level of the interferer test signal according to its modulation, irrespectively by the adopted duty cycle (option 3). In fact, the duty cycle defined for different "Service Groups" is intended as the activity factor of a user application, irrespectively of the power level of the signal. Hence the P_{test} level is referred to 100 % duty cycle. This means that when the duty cycle is applied the value P_{test} is decreased by an amount directly proportional to the duty cycle. The signal level including the duty cycle, say $P_{test, DC}$, is therefore given by equation (C5).

$$P_{test, DC} = P_{ref} - 20*\log10(4*pi*L_{SG} *fc/c) - A_{SG, NLOS, fix, dB} - A_{SG, ADD, dB} + 10*\log10(DC) =$$

$$= P_{test} + 10*\log10(DC) \qquad (C5)$$

being DC the duty cycle expressed as fraction of activity with respect to the whole transmission interval (or the whole test interval). Due to the fact that DC ≤ 1, it is clear that $P_{test, DC} \leq P_{test}$.

The signal peak level, however is not affected by the duty cycle and should be unchanged.

Annex D (informative): Derivation of the Equations for (T)LPR

Simple Form of the Radar Equation (Point Target).

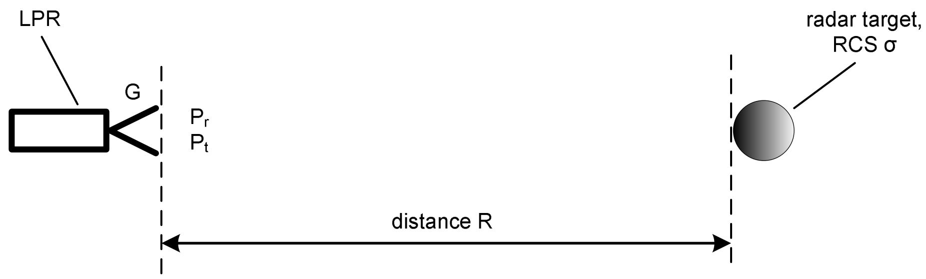


Figure D.1: LPR device with radar target

The power level of the echo signal P_r at the receiver during the measurement against the target with RCS σ can be calculated according to equation (D1).

$$a = \frac{P_r}{P_t} = \frac{G^2\lambda^2\sigma}{(4\pi)^3R^4}$$

(D1)

a : attenuation

P_r :received power

P_t :transmitted power

G :gain of the LPR antenna

λ : wavelength of the transmit/receive signal

σ : radar cross section (RCS) of the target

R : distance between LPR and target

This formula is known to be the simple form of the radar equation. The derivation of this equation can be found in [i.70] for example.

Expressed in dB in equations (D2) and (D3).

$$a_{dB} = 10 \cdot \log\left(\frac{P_r}{P_t}\right) = 20 \cdot \log G + 20 \cdot \log \lambda + 10 \cdot \log \sigma - 40 \cdot \log R - 30 \cdot \log(4\pi)$$

(D2)

$$P_r^{dBm} = P_t^{dBm} + 2 \cdot g + 20 \cdot \log \lambda + 10 \cdot \log \sigma - 40 \cdot \log R - 33dB$$

(D3)

a_{dB} : attenuation expressed in dB

P_r^{dBm} :received power expressed in dBm

P_t^{dBm} :transmitted power expressed in dBm

g : gain of the LPR antenna expressed in dBi, $g = 10 \cdot \log G$

Radar Equation (Volume Target in the Form of an infinite surface)

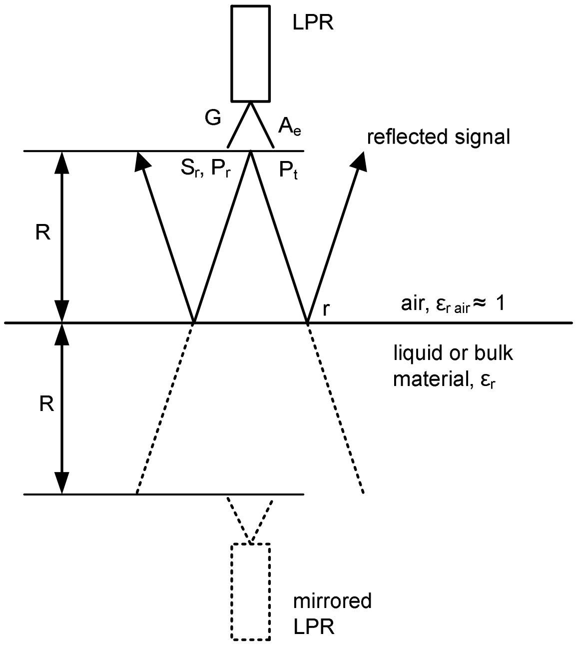


Figure D.2: Reflected signal from LPR device

The power which is radiated back from a surface into the receiver of a (T)LPR device can be approximated using figure D.2 assuming a specular reflexion.

The power density S_r at the location of the LPR receiver is the transmit power P_t divided by the surface area $4\pi(2R)^2$ of an imaginary sphere of radius 2R. Please consider the concept of the mirrored LPR device in the picture above. In this consideration should not be forgotten the antenna gain which takes effect the first time during transmission of the Radar signal and a second time during reception with the same (LPR) antenna. This leads to end up with equation (D4).

$$S_r = \frac{P_t \cdot G}{4\pi(2R)^2}$$

(D4)

S_r : power density at the location of the LPR receiver

The received power of the LPR P_r (equation (D5)) is then the power density at the location of the LPR receiver S_r multiplied by the effective aperture of the LPR antenna A_e.

$$P_r = S_r \cdot A_e$$

(D5)

The effective antenna aperture A_e is calculated according to equation (D6) [i.71].

$$A_e = \frac{G \cdot \lambda^2}{4\pi}$$

(D6)

A_e : effective antenna aperture of the LPR

Equation (D7) is attained:

$$P_r = \frac{P_t \cdot G^2 \cdot \lambda^2}{(8\pi R)^2}$$

(D7)

Additionally the attenuation due to the reflection at the transition from air to the liquid or bulk material has to be taken into account. The reflection coefficient r is calculated for an electromagnetic wave with normal incidence according to equation (D8).

$$r = \frac{Z_{material} - Z_{air}}{Z_{material} + Z_{air}} \approx \frac{1 - \sqrt{\varepsilon_r}}{1 + \sqrt{\varepsilon_r}}$$

(D8)

r : reflection coefficient of the transition from air to the considered surface material with relative permittivity ε_r.

ε_r: relative permittivity of the considered surface material.

In the above derived formula it is assumed that the magnetic permeability of the liquid or bulk material and air is close to one and thus cancels out. In addition to that the relative permittivity of air is also set to one. The reflection coefficient has to be inserted squared into the equation as power levels are considered.

This leads to the final equation (D9).

$$P_r = \frac{P_t \cdot G^2 \cdot \lambda^2 \cdot |r|^2}{(8\pi R)^2}$$

(D9)

Expressed in dB in equations (D10) and (D11).

$$10 \cdot \log P_r = 10 \cdot \log P_t + 20 \cdot \log G + 20 \cdot \log \lambda - 20 \cdot log\ R + 20 \cdot \log\ |r| - 20 \cdot \log(8\pi)$$

(D10)

$$P_r^{dBm} = P_t^{dBm} + 2 \cdot g + 20 \cdot \log \lambda - 20 \cdot log\ R + 20 \cdot \log\ |r| - 28dB$$

(D11)

Annex E (informative): Change History

Date	Version	Information about changes
January 2016	0.1.1	First publication of the stable draft TS for approval by ERM TG UWB TGUWB#31 (1-3 February 2016; Cambridge)
January 2016	0.1.2	- interferer lists updated - additional application: mobile (indoor and outdoor) - added recommended test case for GPR/WPR - editorial work
February 2016	1.0.0	- editorial work - small changes in interferer tables - change of recommended test in clause 9.4.3
February 2016	1.0.1	- editorial work

History

Document history		
V1.1.1	March 2016	Publication