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Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD) using Ultra Wide Band (UWB); Transmission characteristics Part 2: UWB mitigation techniques

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Foreword

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

The present document is part 2 of a multi-part deliverable covering Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD) using Ultra Wide Band (UWB); Transmission characteristics, as identified below:

Part 1: "Signal characteristics";

Part 2: "UWB mitigation techniques".

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Modal verbs terminology

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"**must**" and "**must not**" are **NOT** allowed in ETSI deliverables except when used in direct citation.

Introduction

Ultra Wideband technology (UWB) provides a very flexible technology for many fields of applications, like sensors, radars, short range telecommunications, etc.

The main characteristic of an UWB transmission is its very high bandwidth (greater than 50 MHz in ECC countries), combined with the capability to generating signals with reduced power consumption at the transmitter. This enables a variety of new applications, such that low power is required with very high bandwidth.

Due to its very large bandwidth, an UWB application should limit emissions in other bands, which may interfere with other applications. Therefore trade-offs between the transmitter power levels required by the intended UWB application and the low level of emissions that may be received by potential victim applications, without jeopardizing them, needs to be carefully assessed.

A way for increasing flexibility in designing UWB application, allowing higher power level of transmitted power and preventing at the same time harmful interference on other bands, are the so called mitigation techniques.

A mitigation technique is a limitation imposed over specific transmissions characteristics (e.g. duty cycle, special rules for accessing the medium, limitation of the radiated pattern within specific angular sectors, etc.), under which adoption the transmission may be enabled or the transmitted power levels may be increased.

There are two different kinds of usage of mitigation techniques in EU standards: a mitigation may be imposed as a mandatory requirement or it may be allowed as an optional requirement. When a mitigation is used as a mandatory requirement, a device is allowed to operate only if it adopts that mitigation; when a mitigation is used as an optional requirement, devices using the mitigation are allowed to increase the emitted power limits with respect to devices not using any mitigation. In UWB standards there are examples of both these usage.

In the present document a summary of the mitigation techniques allowed for UWB, classified by kinds of application and range of frequency, is presented.

The present document presents a summary of the different UWB applications covered by current ETSI standards. Then, starting from this summary, the different mitigation techniques are described and for each of the listed applications, the related technical parameters implemented in ETSI standards or EC and ECC regulations are reported.

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1 Scope

The present document summarizes the requirements for different mitigation techniques adopted by Ultra Wide Band (UWB) applications.

Covered mitigation techniques are Listen Before Talk (LBT), Detect and Avoid (DAA), Transmitter Power Control (TPC), Low Duty Cycle (LDC), Radiation Power Limitation like Total Radiated Power limits (TRP), Exterior Limit, restrictions on e.i.r.p. over predefined angular sectors and shielding.

Additional information is given in the following annexes:

- Quantitative analysis for the technique of trading LDC against transmitted power (Annex A).
- Details on the mathematical models used for the evaluation of trading LDC against transmitted power (Annex B).

2 References

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

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2.1 Normative references

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

Not applicable.

2.2 Informative references

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

[i.1] EU Commission Decision 2009/343/EC 21 April 2009 amending Decision 2007/131/EC on allowing the use of the radio spectrum for equipment using ultra-wideband technology in a harmonised manner in the Community.

[i.2] EU Commission Decision 2007/131/EC of 21 February 2007 on allowing the use of the radio spectrum for equipment using ultra-wideband technology in a harmonized manner in the Community.

[i.3] ECC Decision of 24 March 2006 on the harmonized conditions for devices using Ultra-Wideband (UWB) technology in bands below 10.6 GHz, amended 9 December 2011 (ECC/DEC/(06)04).

[i.4] ECC Decision of 30 March 2007 on Building Material Analysis (BMA) devices using UWB technology (ECC/DEC/(07)01).

[i.5] ECC Report 064: "The protection requirements of radiocommunications systems below 10.6 GHz from generic UWB applications", Helsinki, February 2005.

[i.6] ECC Report 120: "Technical requirements for UWB DAA (Detect and Avoid) devices to ensure the protection of radiolocation services in the bands 3.1 - 3.4 GHz and 8.5 - 9 GHz and BWA terminals in the band 3.4 - 4.2 GHz", Kristiansand, June 2008.

[i.7] ECC Report 123: "The impact of object discrimination and characterization (ODC) applications using ultra-wideband (UWB) technology on radio services", Vilnius, September 2008.

[i.8] ECC Report 170: "Specific UWB applications in the bands 3.4 - 4.8 GHz and 6 - 8.5 GHz Location Tracking Applications for Emergency Services (LAES), location tracking applications type 2 (LT2) and location tracking and sensor Applications for automotive and transportation environments (LTA)", Tallinn, October, 2011.

[i.9] CEPT Report 010: Report from CEPT to the European Commission in response to the Mandate on UWB Specific Applications, Final Report on July 2006.

[i.10] CEPT Report 009: Report from CEPT to the European Commission in response to the Mandate on Harmonise radio spectrum use for Ultra-Wideband Systems in the European Union, Final Report on 28 October 2005.

[i.11] CEPT Report 45: Report from CEPT to the European Commission in response to the Fifth Mandate to CEPT on ultra-wideband technology to clarify the technical parameters in view of a potential update of Commission Decision 2007/131/EC, Final Report on 28 October 2005.

[i.12] ETSI TS 102 883 (V1.1.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD) using Ultra Wide Band (UWB); Measurement Techniques".

[i.13] ETSI TS 103 060 (V1.1.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM);Short Range Devices (SRD);Method for a harmonized definition of Duty Cycle Template (DCT) transmission as a passive mitigation technique used by short range devices and related conformance test methods".

[i.14] ETSI TS 102 754 (V1.3.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Technical characteristics of Detect And Avoid (DAA) mitigation techniques for SRD equipment using Ultra Wideband (UWB) technology".

[i.15] ETSI TR 103 181-1 (V1.1.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD) using Ultra Wide Band (UWB);Transmission characteristics Part 1: Signal characteristics".

[i.16] ETSI TR 103 086 (V1.1.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Conformance test procedure for the exterior limit tests in EN 302 065-3 UWB applications in the ground based vehicle environment".

[i.17] ETSI TR 102 495-1 (V1.1.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Technical characteristics for SRD equipment using Ultra Wide Band Sensor technology (UWB); System Reference Document Part 1: Building material analysis and classification applications operating in the frequency band from 2,2 GHz to 8 GHz".

[i.18] ETSI TR 102 495-2 (V1.2.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Technical characteristics for SRD equipment using Ultra Wide Band Sensor technology (UWB); System Reference Document; Part 2: Object Discrimination and Characterization (ODC) applications for power tool devices operating in the frequency band of 2,2 GHz to 8,5 GHz".

[i.19] ETSI EN 302 435 (parts 1 and 2) (V.1.3.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Technical characteristics for SRD equipment using Ultra WideBand technology (UWB); Building Material Analysis and Classification equipment applications operating in the frequency band from 2,2 GHz to 8,5 GHz".

[i.20] ETSI EN 302 066 (parts 1 and 2) (V.1.3.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Ground- and Wall- Probing Radar applications (GPR/WPR) imaging systems".

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[i.21] ETSI EN 302 498 (parts 1 and 2) (V.1.1.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Technical characteristics for SRD equipment using Ultra WideBand technology (UWB); Object Discrimination and Characterization Applications for power tool devices operating in the requency band from 2,2 GHz to 8,5 GHz".

[i.22] ETSI EN 300 328 (V.1.8.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Wideband transmission systems; Data transmission equipment operating in the 2,4 GHz ISM band and using wide band modulation techniques; Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive".

[i.23] ETSI EN 302 065-1 (V.1.3.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD) using Ultra Wide Band technology (UWB); Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive; Part 1: Requirements for Generic UWB applications".

[i.24] ETSI EN 302 065-2 (V.1.1.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD) using Ultra Wide Band technology (UWB); Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive; Part 2: Requirements for UWB location tracking".

[i.25] ETSI EN 302 065-3 (V.1.1.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD) using Ultra Wide Band technology (UWB); Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive; Part 3: Requirements for UWB devices for road and rail vehicles".

[i.26] ETSI EN 302 729 (all parts) (V1.1.2): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Level Probing Radar (LPR) equipment operating in the frequency ranges 6 GHz to 8,5 GHz, 24,05 GHz to 26,5 GHz, 57 GHz to 64 GHz, 75 GHz to 85 GHz".

[i.27] ETSI EN 302 372 (all parts) (V1.2.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Equipment for Detection and Movement; Tanks Level Probing Radar (TLPR) operating in the frequency bands 5,8 GHz, 10 GHz, 25 GHz, 61 GHz and 77 GHz".

[i.28] Recommendation ITU-R P.526-10: "Propagation by diffraction".

[i.29] Recommendation ITU-R P 679-1: "Propagation data required for the design of broadcasting-satellite systems".

[i.30] Recommendation ITU-R RA 769-2: "Protection criteria used for radio astronomical measurements".

[i.31] ECC TG3#18-18R0: "Flexible DAA mechanism based on "isolation criteria" between victim service and UWB devices", ECC TG3 Meeting 18, Mainz, March 2007.

[i.32] "Report on Radio Frequency Compatibility Measurements between UWB LDC Devices and Mobile WiMAX (IEEE 802.16e-2005) BWA Systems", JRC, Ispra, July 26-27, 2010.

[i.33] "Mobile WiMAX - Part I: A Technical Overview and Performance Evaluation", August 2006, The WiMAX Forum.

[i.34] "Assessment of compatibility between Ultra WideBand devices and selected federal systems", NTIA special publication, L. K. Brunson et Alt., January 2001.

[i.35] "Propagation of Ultra Wideband Signals in Automotive Environment", Ching-Ping Wang and Wen-Jiao Liao, National Taiwan University of Science and Technology, Taiwan.

[i.36] "UWB screening attenuation measurements of cars", study by IPSC of JRC and ETSI TG31C on the measurements of the screening attenuation of cars in the frequency range between 0,85 GHz and 11 GHz, Joaquim Fortuny-Guasch, IPSC, October 2006.

[i.37] ETSI EN 302 500, Parts 1 and 2 (V.2.1.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD) using Ultra WideBand (UWB) technology; Location Tracking equipment operating in the frequency range from 6 GHz to 9 GHz.

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[i.38] ECC Reports 094: "Technical requirements for UWB LDC devices to ensure the protection of FWA System", Nicosia, December 2006.

[i.39] ECC Reports 175: "Co-existence study considering UWB applications inside aircraft and existing radio services in the frequency bands from 3.1 GHz to 4.8 GHz and from 6.0 GHz to 8.5 GHz", March 2012.

[i.40] ECC Reports 139: "Impact of level probing radars using Ultra-Wideband technology on radiocommunications services", Rottach-Egern, February 2010.

[i.41] CEPT report 17: "Report from CEPT to the European Commission in response to the Mandate to: identify the conditions relating to the ha rmonised introduction in the European Union of radio applications based on ultra-wideband (UWB) technology", 30 March 2007.

[i.42] R&TTE Directive: 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.43] ISO/IEC 7498-1: "Information technology -- Open Systems Interconnection -- Basic Reference Model: The Basic Model".

3 Definitions, symbols and abbreviations

3.1 Definitions

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

absolute transmission availability ratio (Q_{aa})**:** for a victim link, this is the ratio between the sum of all time window where the aggregated interference level is below a predefined threshold, and a predefined observation time, irrespectively of the windows duration

active mitigation technique: mitigation technique based on some measurement or feedback from the channel or the operating environment where the transmitting device is operating

detect and avoid: active mitigation technique consisting in listening potential victim service in the transmission channel and, if any potential victim is detected, reducing the transmitted power accordingly

equivalent isotropically radiated power (e.i.r.p.): product of the power supplied to the antenna and the antenna gain in a given direction relative to an isotropic antenna (absolute or isotropic gain) (RR 1.161)

interferer or interfering link: link or service affected from interference coming from the device intended to be subjected to mitigation

jammer or jamming link: device intended to be subjected to mitigation, potentially affecting any victim link

linear trading (of e.i.r.p. levels versus LDC limits): passive mitigation technique consisting in limiting the product of duty cycle and e.i.r.p. power levels, provided that e.i.r.p. and LDC are within certain defined boundaries

listen before talk: active mitigation technique consisting in listening potential victim service in the transmission channel before initiating a transmission and, if any potential victim is detected, avoid the transmission until the channel is free

(low) duty cycle: ratio of T_{on} and T_{period}: (L)DC = T_{on} / T_{period} = T_{on} /(T_{on} + T_{off})

NOTE: The duty cycle is conventionally referred as "low" duty cycle in case of small values (typically lower than 10 %).

maximum mean e.i.r.p. spectral density: average power per unit bandwidth (centred on that frequency) radiated in the direction of the maximum level under the specified conditions of measurement

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

mitigation technique: technique of controlling radiated power of a transmitting device, having the goal to reduce harmful interferences against potential victim services or applications operating in the same bandwidth of the transmitting device

minimum guard distance: distance between a jammer and a victim link such that the signal to interference ratio is sufficiently high to guarantee a reliable quality of link for victim transmission

passive mitigation technique: mitigation technique based on some a priori knowledge of the channel, the interferer transmitter, and the potential victim service or application to be protected

Quality of Service (QoS): objective indication of the quality of a communication link, based on the measurement of different parameters relevant to the connection performances

EXAMPLES: Service response time, signal-to-noise ratio, crosstalk, echo, interrupts, frequency response, loudness levels, packet error rate, etc.

quality of service management: adaptive policy implemented by a link management layer, having the goal to maximize the quality of service depending on the communication link status

EXAMPLES: Increasing coding and reducing throughput when transmission occurs in noisy channels, etc.

pulse: transmitted signal having the minimum duration (T_{pulse}) such to occupying the intended UWB bandwidth

NOTE: In case of non-pulsed UWB transmission, this definition does not apply.

pulse repetition time: for a pulsed transmission, this is the time interval between two consecutive pulses

relative transmission availability ratio (**Q_{ar}**)**:** for a victim link, this is the ratio between the sum of all time window where the aggregated interference level is below a predefined threshold, and a predefined observation time, such that selected windows must have a duration not lower than a minimum required time equal to T_{guard}

signal to interferer ratio: ratio between the average power of a frame to be received by the victim link and the power of jamming transmission, computed at victim receiver side

transmitter power control: active mitigation technique consisting in determining, by means of some feedbacks from the environment where the device is operating, whether the application requires transmitting its maximum power or transmitter power may be reduced

trading linearl(ly) in dB (of e.i.r.p. levels versus LDC limits): See linear trading.

victim link (or service): See interferer link.

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3.2 Symbols

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

D_U the duty cycle due to the application
D_X duty cycle due to the modulation
LDC_J duty cycle of the jamming link
LDC_V duty cycle of the victim link
PLPC probability of losing a colliding packets

EXAMPLE: The probability that a single packet from a possible victim service, colliding against an interferer or jamming packet, gets lost at the victim receiver side.

PoC Probability of Collision between signals of a victim service and signals of an interfering or jamming transmitter
P_{tx} transmitter power by an intended device
T_{IFS} inter-frame spacing between two consecutive frames of the victim communication service
T_{DD} sum of Tframe and T_{IFS}: $T_{DD} = T_{frame} + T_{IFS}$

T_{frame} frame duration of the victim communication service
T_{guard} minimum interval seen by the victim receiver such that the interferer signal stay below Vguard, and a satisfactory quality of transmission for the victim service is guaranteed
T_{obs} any predefined observation time for an intended phenomenon
T_{off} silent period between two consecutive UWB Ton periods. In case of pulsed UWB devices, in general T_{off} >> PRT
T_{period} sum of T_{on} and T_{off} : $T_{period} = T_{on} + T_{off}$
T_{pulse} UWB pulse duration. For an UWB pulsed transmission, this is the duration of a single UWB pulse

NOTE: In case of non-pulsed UWB transmission, this parameter does not applyT_{on} duration of an UWB frame. In case of pulsed UWB devices, in general T_{on} >> T_{pulse}. For UWB applications other than communication links, T_{on} is the uninterrupted transmission time required by the UWB application to radiate into the air a meaningful uninterrupted information slot.

Q_a any parameter between Q_{aa} or Q_{ar}
Q_{aa} absolute transmission availability ratio
Q_{ar} relative transmission availability ratio
$V_{aggregate}$ aggregate level of many interferer signals
V_{guard} interferer signal level threshold at victim receiver to be complied in order to guarantee satisfactory quality of transmission for the victim service

3.3 Abbreviations

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

AF Activity Factor
APC Adaptive Power Control or Automatic Power Control
BER Bit Error Rate
BMA Building Material Analysis
BW BandWidth
BWA Broadband Wireless Access
CEPT European Conference of Postal and Telecommunications Administrations
CMS Cabin Management System
DAA Detect And Avoid
dc direct current
DC Duty Cycle
DCT Duty Cycle Template
DEC Decision of Electronics Comminications Committee
DUT Device Under Test
e.i.r.p. equivalent isotropically radiated power
ECC Electronic Communications Committee
FCC Federal Communications Commission
GPR Ground Probing Radar
ISM Industrial Scientific and Medical band
JRC Joint Research Centre
LAES Location tracking Application for Emergency and disaster Situations
LBT Listen Before Talk
LDC Low Duty Cycle
LoS Line of Sight
LPR Level Probing Radar
LT1 Location Tracking type 1
LT2 Location Tracking type 2
LTT Location Tracking for automotive & Transportation environment
MSS Mobile Satellite Services
MU Medium Utilization
NIM Non Interference Mode
NTIA National Telecommunications and Information Administration
ODC Object Discrimination and Characterization
OIS Object Identification and Surveillance
PER Performance
PHY Physical Layer, as described in Open Systems Interconnection (OSI) model

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NOTE: ISO/IEC 7498-1 [i.43].

PLPC	probability of losing a colliding packets
PRF	Pulse Repetition Frequency
PRI	Pulse Repetition Interval
PRT	Pulse Repetition Time
PSD	Power Spectral Density
QoS	Quality of Service
R&TTE	Radio and Telecommunications Terminal Equipment
RAM	Random Access Memory
RAS	Radio Astronomy Service
RF	Radio Frequency
RSSI	Received Signal Strength Indication
Rx	Receiver or received
SIR	Signal to Interfere Ratio
SRD	Short Range Device
TCP	Transmission Control Protocol
TGUWB	Task Grooup Ultra-WideBand
TLPR	Tank Level Probing Radar
TPC	Transmit Power Control or Total Power Control
TPR	Tanks Probing Radars
TRP	Total Radiated Power
Tx	Transmitter or Transmitted
UDP	User Datagram Protocol
UE	User Equipment
UMTS	Universal Mobile Telecommunication System
UWB	Ultra WideBand
WPR	Wall Probing Radar
WRC	World Radiocommunication Conference

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4 Overview of UWB Applications and Regulation in ECC/EC

4.1 Summary of UWB application defined in Europe

Ultra-wideBand technology is mainly related to sensor applications, specifically functions such as radars, ranging and location tracking devices, and/or their related communications. Applications using UWB in Europe, described in ETSI and ECC documents, are summarized in Table 1.