ETSI TR 103 750 V1.1.1 (2023-04)

TECHNICAL REPORT

System Reference document (SRdoc);
Short Range Devices (SRD) using Ultra Wide Band (UWB);
Technical characteristics for UWB operation in the frequency band between 8,5 GHz to 10,6 GHz

Reference
DTR/ERM-600

Keywords
SRDoc, UWB

ETSI

650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - APE 7112B
Association à but non lucratif enregistrée à la
Sous-Préfecture de Grasse (06) N° w061004871

Contents

Intellectual Property Rights 5
Foreword 5
Modal verbs terminology 5
Introduction 5
1 Scope 7
2 References 7
2.1 Normative references 7
2.2 Informative references 7
3 Definition of terms, symbols and abbreviations 10
3.1 Terms 10
3.2 Symbols 10
3.3 Abbreviations 11
4 Comments on the System Reference document 11
5 Presentation of the system or technology 11
5.1 Introduction 11
5.2 Body worn radiodetermination 11
5.2.1 General 11
5.2.2 Functional System requirements 11
5.2.3 Technical description 12
5.2.4 Mitigation factors 12
5.2.5 Applications specific market information 12
5.3 Indoor UWB low-latency wireless communication for gaming, HMI and audio applications 13
5.3.1 General 13
5.3.2 System requirements 13
5.3.3 Technical description 13
5.3.4 Mitigation factors 14
5.3.5 Applications specific market information 14
5.4 In-vehicle monostatic radiodetermination 15
5.4.1 General 15
5.4.2 System requirements 15
5.4.3 Technical description 16
5.4.4 Mitigation factors 17
5.4.5 Applications specific market information 18
5.5 Indoor and outdoor fixed movement sensor and surveillance radar 18
5.5.1 General 18
5.5.2 Technical description 19
5.5.3 Mitigation factors 21
5.5.4 Applications specific market information 21
5.6 Radiodetermination for high precision location tracking applications 22
5.6.1 General 22
5.6.2 System requirements 22
5.6.3 Technical description 23
5.6.3.1 Professional Location tracking 23
5.6.3.2 End user and Vehicular Location Tracking 24
5.6.4 Mitigation factors 24
5.6.4.1 Professional Location tracking 24
5.6.4.2 End user and Vehicular Location Tracking 25
5.6.5 Application specific market information 26
5.6.5.1 Professional Location tracking 26
5.6.5.2 End user and Vehicular Location Tracking 27
5.6.5.3 Market parameters 28
5.7 Summary 29

6 Allocations in the band 8,5 GHz to 10,6 GHz and related compatibility topics 30
6.1 Introduction 30
6.2 Current European Common Allocations 31
6.3 Available sharing and compatibility studies 33
6.4 Sharing and compatibility issues still to be considered 33
6.5 Ongoing research activities for IMT 33

7 Radio spectrum request and justification 34
7.1 Introduction 34
7.2 Indoor radiodetermination and communication 34
7.2.1 Generic Indoor radiodetermination applications 34
7.2.2 Body Worn Indoor radiodetermination applications 35
7.2.3 Indoor communication applications 36
7.2.4 Comparison with existing regulation 36
7.3 Fixed outdoor 37
7.3.1 Generic fixed outdoor radio determination applications 37
7.3.2 Infrastructure fixed outdoor radiodetermination applications 37
7.3.3 Comparison with existing regulation 38
7.4 In-vehicle applications 38
7.4.1 New in-vehicle applications 38
7.4.2 Comparison with existing regulation 39

Annex A: *TRP* and TRP_{sd} considerations 40

A.1 Introduction 40

A.2 Definition Total Radiated Power (*TRP*) 40

A.3 TRP assessment based on radiated (e.i.r.p.) measurement 42

A.4 TRP spectral density 44

A.5 Summary and conclusions 45

Annex B: Overview UWB regulations and standards 46

Annex C: Bibliography 50

History 52

Intellectual Property Rights

Essential patents

IPRs essential or potentially essential to normative deliverables may have been declared to ETSI. The declarations pertaining to these essential IPRs, if any, are publicly available for **ETSI members and non-members**, and can be found in ETSI SR 000 314: *"Intellectual Property Rights (IPRs); Essential, or potentially Essential, IPRs notified to ETSI in respect of ETSI standards"*, which is available from the ETSI Secretariat. Latest updates are available on the ETSI Web server (https://ipr.etsi.org/).

Pursuant to the ETSI Directives including the ETSI IPR Policy, no investigation regarding the essentiality of IPRs, including IPR searches, has been carried out by ETSI. No guarantee can be given as to the existence of other IPRs not referenced in ETSI SR 000 314 (or the updates on the ETSI Web server) which are, or may be, or may become, essential to the present document.

Trademarks

The present document may include trademarks and/or tradenames which are asserted and/or registered by their owners. ETSI claims no ownership of these except for any which are indicated as being the property of ETSI, and conveys no right to use or reproduce any trademark and/or tradename. Mention of those trademarks in the present document does not constitute an endorsement by ETSI of products, services or organizations associated with those trademarks.

DECT™, **PLUGTESTS™**, **UMTS™** and the ETSI logo are trademarks of ETSI registered for the benefit of its Members. **3GPP™** and **LTE™** are trademarks of ETSI registered for the benefit of its Members and of the 3GPP Organizational Partners. **oneM2M™** logo is a trademark of ETSI registered for the benefit of its Members and of the oneM2M Partners. **GSM**® and the GSM logo are trademarks registered and owned by the GSM Association.

BLUETOOTH® is a trademark registered and owned by Bluetooth SIG, Inc.

Foreword

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

Modal verbs terminology

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

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

Introduction

The present document includes the necessary information to support the co-operation under the MoU between ETSI and the Electronic Communications Committee (ECC) of the European Conference of Post and Telecommunications Administrations (CEPT).

Ultra-Wide Band (UWB) technologies enable a very broad set of applications:

- Active and passive radiodetermination applications including sensor, imaging and location/tracking applications.
- Communication applications.
- Hybrid application as a combination of sensor and communications

The present document will provide information on the existing and future intended UWB applications in the operational band up to 10,6 GHz with the focus on the 8,5 GHz to 10,6 GHz band extension. Most of these new applications will require significantly broader operational frequency ranges not covered by the available UWB regulations. The present document will also provide an overview of the relevant possible mitigation techniques and factors to protect existing and future services in the band 8,5 GHz to 10,6 GHz. The information in the present document will complement and extend the information included in ETSI TR 103 314 [i.34].

WRC-23 AI 1.2 asks to study and potentially identify the frequency band 6 425 - 7 125 MHz for IMT. This has already been reflected in the most recent revision of ECC DEC (06)04 [i.9] by adding a consideration pointing out the pending additional use of that frequency band. It, therefore, creates considerable uncertainty for future use of that frequency range for UWB.

The new applications in the band could significantly reduce the performance of existing and future UWB applications. The new interference scenario may lead to a complete loss of up to three available UWB channels for some current UWB applications in this frequency range. The present document also serves as a basis to study the range 8,5 - 10,6 GHz for the use of additional UWB radiodetermination applications to facilitate the adequate deployment of these applications with the same level of performance.

It also needs to be mentioned that the band below 7 125 MHz is being considered for WAS/RLAN.

A specific emphasis will be put on the X-band radionavigation and radiolocation systems in the band above 8,5 GHz.

The present document has been created by ETSI TC ERM TGUWB.

In addition, work for WRC-27 has started and first proposals for agenda items are received. Amongst one of them, a proposal by GSA that asks to study frequency bands from within the range of 7 - 24 GHz for IMT. This overlaps significantly with the existing UWB use below 8,5 GHz and the bands covered by the present document above 8,5 GHz. This may change the future environment for UWB operations significantly.

1 Scope

The present document will provide information on the existing and future intended UWB applications in the operational band up to 10,6 GHz with the focus onto the 8,5 GHz to 10,6 GHz band extension. It will also provide an overview over the relevant possible mitigation techniques and factors to protect existing and future services in the band 8,5 GHz to 10,6 GHz. The information in the present document will complement and extend the information included in ETSI TR 103 314 [i.34].

A specific emphasis will be put onto the investigations of X-band radionavigation and radiolocation systems in the band above 8,5 GHz.

The present document includes necessary information to support the co-operation between ETSI and the Electronic Communications Committee (ECC) of the European Conference of Post and Telecommunications Administrations (CEPT), including:

- Detailed market information
- Technical information
- Expected compatibility issues

2 References

2.1 Normative references

Normative references are not applicable in the present document.

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] ETSI EN 303 883-1 (V1.2.1) (02-2021): "Short Range Devices (SRD) and Ultra Wide Band (UWB); Part 1: Measurement techniques for transmitter requirements".

[i.2] ETSI EN 302 065-1 (V2.1.1) (11-2016): "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; Part 1: Requirements for Generic UWB applications".

[i.3] ETSI EN 302 065-2 (V2.1.1) (11-2016): "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; Part 2: Requirements for UWB location tracking".

[i.4] ETSI EN 302 065-3 (V2.1.1) (11-2016): "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; Part 3: Requirements for UWB devices for ground based vehicular applications".

[i.5] ETSI EN 302 065-4 (V1.1.1) (11-2016): "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; Part 4: Material Sensing devices using UWB technology below 10,6 GHz".

[i.6] ETSI EN 302 066 (V2.2.1) (06-2020):" Short Range Devices (SRD); Ground- and Wall- Probing Radio determination (GPR/WPR) devices; Harmonised Standard for access to radio spectrum".

[i.7] ETSI EN 302 372 (V2.1.1)(12-2016):" Short Range Devices (SRD); Tank Level Probing Radar (TLPR) equipment operating in the frequency ranges 4,5 GHz to 7 GHz, 8,5 GHz to 10,6 GHz, 24,05 GHz to 27 GHz, 57 GHz to 64 GHz, 75 GHz to 85 GHz; Harmonised Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU".

[i.8] ETSI EN 302 729 (V2.1.1)(12-2016):" Short Range Devices (SRD); Level Probing Radar (LPR) equipment operating in the frequency ranges 6 GHz to 8,5 GHz, 24,05 GHz to 26,5 GHz, 57 GHz to 64 GHz, 75 GHz to 85 GHz; Harmonised Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU".

[i.9] CEPT ECC/DEC/(06)04 of 24 March 2006 amended 18 November 2022: " The harmonised use, exemption from individual licensing and free circulation of devices using Ultra-Wideband (UWB) technology in bands below 10.6 GHz".

[i.10] ECC Report 120 (March 2008): "ECC Report on Technical requirements for UWB DAA (Detect and avoid) devices to ensure the protection of radiolocation in the bands 3.1-3.4 GHz and 8,5-9 GHz and BWA terminals in the band 3.4-4.2 GHz".

[i.11] ECC/DEC/(07)01: "ECC Decision of 30 March 2007 on specific Material Sensing devices using Ultra-Wideband (UWB) technology (amended 26 June 2009)".

[i.12] ECC Report 170 (October, 2011): "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.13] Commission Decision 2014/702/EU of 7 October 2014 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 (notified under document C(2014) 7083).

[i.14] ETSI TR 103 181-2 (V1.1.1) (06-2014): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD) using Ultra Wide Band (UWB);Transmission characteristics Part 2: UWB mitigation techniques".

[i.15] ETSI TR 103 181-1 (V1.1.1) (07-2015): "Short Range Devices (SRD) using Ultra Wide Band (UWB); Technical Report Part 1: UWB signal characteristics and overview CEPT/ECC and EC regulation".

[i.16] ETSI TR 102 495-3: "Electromagnetic compatibility and Radio spectrum Matters (ERM); System Reference Document; Short Range Devices (SRD); Technical Characteristics for SRD equipment using Ultra-Wideband Sensor Technology (UWB); Part 3: Location tracking applications type 1 operating in the frequency band from 6 GHz to 8,5 GHz for indoor, portable and mobile outdoor applications".

[i.17] Frank Leong, Wolfgang Küchler, Riku Pirhonen (NXP Semiconductors): "UWB sensing in 802-15", IEEE 802.15.4ab™ contribution, IEEE 802 Plenary, July 2021.

[i.18] XR and its potential for Europe, Ecorys, April 2021.

[i.19] Draft ECC Report on WI71: "UWB radiodetermination applications in the frequency range 116-260 GHz".

[i.20] Request for Waiver of Section 15.255(c)(3) of the Commission's rules for Short Range Interactive Motion Sensing Devices, Tesla Inc., July 2020.

[i.21] F. Berens et al.: "UWB car attenuation measurements," 2007 16th IST Mobile and Wireless Communications Summit, 2007, pp. 1-5, doi: 10.1109/ISTMWC.2007.4299240.

[i.22] J. Fortuny-Guasch: "UWB Screening Attenuation Measurements of Cars".

[i.23] Antenna Pattern Measurement: Concepts and Techniques, Michael D. Foegelle, Compliance Engineering, Annual Reference Guide 2002.

[i.24] Total Radiated Power Measurement above 1 GHz with Partially-Spherical Scanning of a Probe, EMC'09 / Kyoto.

[i.25] "UWB Secure Ranging in FiRa", FiRa Consortium, August 2022: (Link date 12.12.2022).

[i.26] "How could UWB transform transport ticketing experiences?", Infineon, Stefan Rüping, May 6, 2021, (Link date 12.12.2022).

[i.27] "Better Together: How 5G, Wi-Fi 6, UWB and NFC Are Creating Tomorrow's Wireless Railways", NXP blog Lars Reger, December 11, 2020, (Link date 12.12.2022).

[i.28] "NXP Collaborates with ING and Samsung to Pilot Industry's First UWB-Based Peer-to-Peer Payment Application", NXP Semiconductors, July 7, 2022, , (Link date 12.12.2022).

[i.29] Video: "What's new in Nearby Interaction, Apple WWDC22" (Link date 12.12.2022).

[i.30] "UwbClient API", Google Play services, last updated July 8, 2022, (Link date 12.12.2022).

[i.31] IEEE 802.15 WSN™ Task Group 4ab (TG4ab) 802.15.4 UWB Next Generation, IEEE, last updated Nov 25, 2022.

[i.32] GSA: "IMT towards 2030 and beyond (6G)", (Link date 12.12.2022).

[i.33] "Use cases and societal values - including aspects of sustainability, security and spectrum", (Link date 12.12.2022).

[i.34] ETSI TR 103 314: "System Reference document (SRdoc); Short Range Devices (SRD) using Ultra Wide Band (UWB); Technical characteristics for SRD equipment using Ultra Wide Band Sensor technology (UWB) based on amended mitigation techniques for UWB".

[i.35] ECC Report 327: "Technical studies for the update of the Ultra Wide Band (UWB) regulatory framework in the band 6.0 GHz to 8.5 GHz.

[i.36] 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 Text with EEA relevance.

[i.37] ECC Report 64: "The protection requirements of radiocommunications systems below 10.6 GHz from generic UWB applications".

[i.38] CEPT Report 9: "Report from CEPT to the European Commission in response to the Mandate to Harmonise radio spectrum use for Ultra-Wideband systems in the European Union", 2005.

[i.39] ECC Report 302: " Sharing and compatibility studies related to Wireless Access Systems including Radio Local Area Networks (WAS/RLAN) in the frequency band 5925-6425 MHz".

[i.40] ERC Recommendation 70-03: "Relating to the use of Short Range Devices (SRD)".

[i.41] IEEE 802.15.4z™: " IEEE Standard for Low-Rate Wireless Networks--Amendment 1: Enhanced Ultra Wideband (UWB) Physical Layers (PHYs) and Associated Ranging Techniques".

[i.42] 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 Directive 2014/53/EU".

[i.43] List of European Union cities proper by population density - Wikipedia.

[i.44] Ecorys, XR and its potential for Europe, April 2021.

[i.45] Joaquim Fortuny-Guasch: "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 0,85GHz and 11GHz, IPSC, October 2006.20.

3 Definition of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the terms given in ETSI EN 303 883 -1 [i.1] and the following apply:

activity factor: reflects the effective transmission time ratio over a longer time period depending on the user behaviour

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

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 %).

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

movement sensor: device to determine the position and the dynamic behaviour of an object of interest

object discrimination: operation to determine specific characteristics of an object of interest like material density, humidity or structure

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

radar: monostatic radiodetermination application

radiodetermination: determination of the position, velocity and/or other characteristics of an object, or the obtaining of information relating to these parameters, by means of the propagation properties of *radio waves*

NOTE: In monostatic radiodetermination applications the transmitter and the receiver is located at the same position. The determination of the object characteristics is done by passive sensing. Typical example for a monostatic radiodetermination application is a monostatic radar.

radionavigation: Radiodetermination used for the purposes of navigation, including obstruction warning.

radiolocation: Radiodetermination used for purposes other than those of radionavigation

range resolution: ability to resolve two targets at different ranges

sensor application: radiodetermination application used for object and material identification, characterization and classification.

transmitter off time (T_{off}): time interval between two consecutive bursts when the UWB emission is kept idle

transmitter on time (T_{on}): duration of a burst irrespective of the number of pulses contained

3.2 Symbols

For the purposes of the present document, the symbols defined in ETSI EN 303 883-1 [i.1] and the following apply.

TRP	Total radiated power

TRP_{sd}	Total radiated power spectral density
T_{on}	transmitter on time
T_{off}	transmitter off time

3.3 Abbreviations

For the purposes of the present document, the abbreviations defined in ETSI EN 303 883-1 [i.1] and the following apply:

LIAT	Location and Industrial Asset Tracking

4 Comments on the System Reference document

Void.

5 Presentation of the system or technology

5.1 Introduction

In this clause a set of proposed applications are presented that rely on the availability of a broader spectrum band for the operation with UWB devices. These applications include sensing and tracking applications that will only be feasible when very broadband UWB signals are deployed in order to reach the required sensing and/or tracking precision, and communications applications that require the availability of more channels to facilitate intra-device and inter-devices RF coexistence.

5.2 Body worn radiodetermination

5.2.1 General

Virtual Reality (VR) is a representative body worn application. Virtual Reality (VR) headsets fully immerse people in 3D virtual environments. VR brings the sense of presence to our remote communications. VR has enormous potential to transform how people play, work, learn, communicate, and experience the world around them. It is already positively impacting the way companies do business and changing the face of education and professional training in healthcare and beyond.

VR applications require high speed data transfer between headsets and controllers.

UWB is an ideal technology to achieve this function, in particular taking into account the requirement to use very low power.

5.2.2 Functional System requirements

- Burst rates of up to 125 Mbps to accommodate the required raw and processed data transfer between headsets and controllers
- 500 MHz bandwidths
- Very short range, 2 m
- Spectrum from 7,125 GHz to 10,6 GHz to provide sufficient channels for intra-device and inter-devices RF coexistence

In particular, UWB is already allowed and operating up to 10,6 GHz in the USA. Opening close to 2 GHz of spectrum with similar characteristics would be required to respond to the projected increased market size expected to leverage the technology.

5.2.3 Technical description

The VR headset communicates to one or more controllers transferring user input and raw and processed data necessary for the positioning, tracking and location applications. The radio link between the VR headset and the controller(s) could have line-of-sight or be heavily attenuated by the user's body.

- Bandwidth: 500 MHz
- Data rate: 125 Mbps
- Spectrum band: 7,125 GHz to 10,6 GHz
- Maximum Duty Cycle: 25 % per 500 MHz band
- Typical Duty Cycle: 2 % per 500 MHz
- Typical antenna gain: 3 dBi to 5 dBi
- Maximum mean e.i.r.p. spectral density: -31,3 dBm/MHz (indoor only)
- TRP_{sd}: -34 dBm/MHz (indoor with absorption by body and other materials)
- Installed in 25 % of the apartments
- Activity factor AF: 0,666 % typical.

5.2.4 Mitigation factors

- Specific shielding factors: limited to indoor usage only
- Duty cycle restrictions per second: 25 % max per 500 MHz band with a typical value of 2 %
- Specific absorption factors: indoor installations and tissue
- Low TRP_{sd}: limit of -34 dBm/MHz
- Specific application: VR limits the number of devices (maximum = population density)
- Sensitive band protection: no emissions in 10,6 - 10,7 GHz

5.2.5 Applications specific market information

As discussed in [i.44], "*virtual, augmented and mixed reality technology will fundamentally change how we connect, communicate, collaborate and learn*" and "*research and development in Europe [in virtual, augmented and mixed reality technology] has been incredibly broad, ranging from hardware components (i.e. sensors) to advanced manufacturing techniques including AI and ML. In terms of thematic areas, developments can be seen in all sectors, from healthcare to manufacturing and education.*" It is also stated in [i.44] that "the total market value of the European VR and AR industry is expected to increase to between € 35 billion and € 65 billion by 2025, representing a gross added value of between € 20 billion and € 40 billion, and directly creating employment for some 440 000 to 860 000 people".

Each user can only use one VR device at a time. Assuming a very aggressive 50 % market penetration (one habitant out of 2 owns a VR device), the device density would not exceed 50 % of the population density. The average population density in the European Union is 112 habitants/km^2.

Given the definition of rural, urban and urban centre areas in Europe, and the population density of the largest EU cities [i.43], the population density for rural, suburban and urban can be assumed to correspond to 90, 900 and 9 000 hab/km^2, corresponding to 45, 450 and 4 500 devices/km^2, with an average of 66 devices/km^2, see Table 1.

Table 1: Assumed device densities for VR use case, indoor only

Average (devices/km2)	Rural (devices/km²)	Suburban (devices/km²)	Dense Urban (devices/km²)
66	45	450	4 500

The activity factor (assuming 8 hours of use per day with a 2 % average duty cycle during use) is 0,66 % which would further reduce the number of active devices compared to the overall number of devices, see Table 2.

Table 2: Assumed active device densities for VR use case

Average (active devices/km2)	Rural (active devices/km²)	Suburban (active devices/km²)	Dense Urban (devices/km²)
0,44	0,3	3	30

5.3 Indoor UWB low-latency wireless communication for gaming, HMI and audio applications

5.3.1 General

High responsiveness is key in Human-Machine Interfaces (HMI) and gaming applications, requiring low-latency, high fidelity data transfer. UWB enables low-power, ultra-low latency communication compared to other incumbent short-range wireless technologies. Although Bluetooth® technology provides nearly universal compatibility with a wide range of devices, the latency can be very high, in the order of a few hundred ms. Wi-Fi® has a lower latency, ~10 to 20 ms, which increases significantly with the number of devices, especially in poor link conditions, due to contention. UWB on the other hand, offers very low latency down to a couple of milliseconds which makes it the ideal choice of technology for low-latency applications. The short pulses offer the additional advantage of low air-time and a high bandwidth consequently resulting in robustness to jamming and coexistence with other radios.

5.3.2 System requirements

- Bandwidth: ≥ 1 GHz
- Latency: 2 - 10 ms
- Data Rate: Few hundred kbps to few Mbps
- Max. duty cycle: 10 %
- Typ. duty cycle: < 1 %
- Maximum mean e.i.r.p. spectral density: -41,3 dBm/MHz
- Mainly indoor operation
- Antenna gain

5.3.3 Technical description

HMI device is generally portable device (may be used indoor and outdoor) and wirelessly communicating with an associated controller. Antennas are generally omnidirectional to cover a 360 degree FoV. Operational when the consumer is using actively (up to 10 hours a day?). Communication distance: typically short range up to a few meters. A typical scenario is depicted in Figure 1.

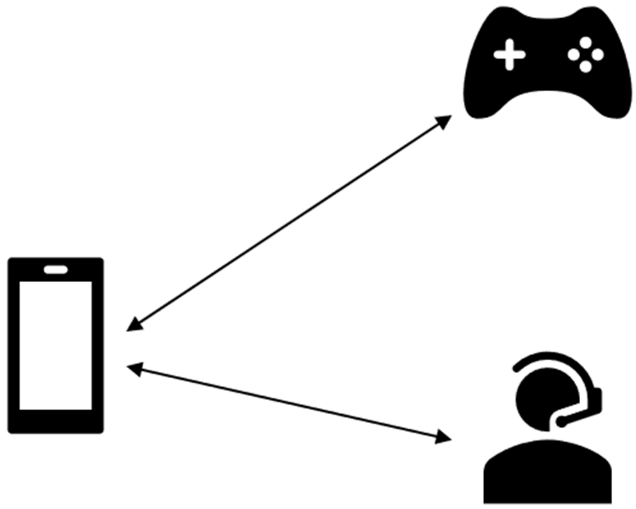


Figure 1: Bidirectional data-transfer

5.3.4 Mitigation factors

- Maximum Duty Cycle: 10 %
- Typical duty cycle: < 1 %
- Maximum mean e.i.r.p. spectral density: -41,3 dBm/MHz
- Mainly indoor operation
- Antennas: gain 3 dBi
- Body loss: 3 dB
- TRP_{sd}: -47,3 dBm/MHz
- Activity factors: 2 h per day
- AF: 0,0833 %

5.3.5 Applications specific market information

Similar to Table 1 and Table 2 the assumed device density for low-latency wireless communication is provided in Table 3 and the resulting active device density is provided in Table 4.

Table 3: Assumed device densities for low-latency wireless communication

	Rural (devices/km²)	Suburban (devices/km²)	Dense Urban (devices/km²)
Total Device density (100 %)	**50**	**500**	**5 000**
Indoor (90 %)	45	450	4 500
Outdoor (10 %)	5	50	500

Table 4: Assumed active device densities for low-latency wireless communication

Low-latency wireless communication (clause 5.3), AF = 0,083 %			
Total active device density per km² (100 %)	**0,0416**	**0,416**	**4,16**
Indoor (90 %)	0,03735	0,3735	3,735
Outdoor (10 %)	0,00416	0,0416	0,416

5.4 In-vehicle monostatic radiodetermination

5.4.1 General

High resolution in-vehicle sensors can provide a broad range of information to the vehicular control systems. This information can be used for different purposes:

- UWB broad band sensors will provide vehicle security benefits. It can be used to enhance theft prevention systems by detecting a broken window or vehicle intrusion [i.20].
- One safety issue, which in-vehicle radar sensing is well-suited to address, is the risk of heatstroke in children inadvertently left in hot cars [i.20].
- Advanced airbag and breaking control for seat which are not used [i.20].
- Heart stroke detection of driver and other passengers like children.
- Vehicular dynamic control by using passenger recognition, identification and classification.
- Haptic control of multimedia systems and other vehicular applications.

In order to be able to generate an accurate set of sensing samples a high spatial resolution down to some mm will be required. This high resolution will support the static and dynamic detection process. Static detection processes can lead to a detailed identification and classification of passengers (size, weight and position). The dynamic detection can be used for control functionality (haptic control), vital signs (e.g. heartbeat, movement) and dynamic safety features (adaptive airbag and break control).

In order to reach this high spatial resolution of the sensing signals a very high bandwidth is required. Potential solution here are based on 60 GHz radar system of mmWave radar systems. Due to the operational frequency of these systems higher TX power levels are required to overcome the additional attenuation of the signals. UWB signal up to 10,6 GHz have a much better free-space attenuation behaviour (at least 15 dB better) than the 60 GHz or 80 GHz system. This will significantly reduce the overall power consumption of the system and RF exposure levels. For human body vital sign analyses operation lower frequencies give much better body penetration capabilities.

The lower operational frequency will also provide a better material penetration behaviour of the signals which is beneficial for the vital signs detection and identification process.

5.4.2 System requirements

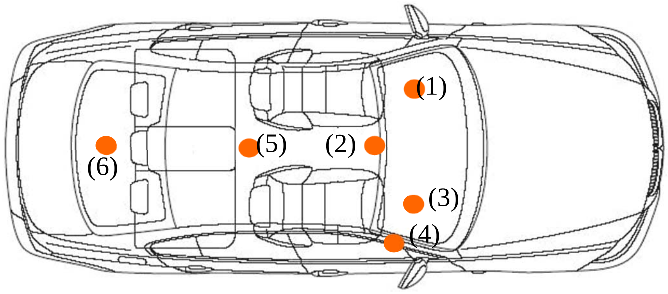
In order to be able to identify and monitor the detailed behaviour of the vehicular passengers a very high resolution is required. The required bandwidth of the UWB signal has to be much higher than in the typical communication and tracking applications.

- Bandwidth: ≥ 4 GHz bandwidth
- Data rate: Not applicable here
- Location precision/accuracy: ≤ 10 mm
- Spectrum band: 6,0 GHz to 10,6 GHz
- Maximum Duty Cycle: 20 % per minute (mainly for health monitoring)
- Maximum duty cycle per 50 MHz frequency bin: ≤ 2,5 %
- Typical duty cycle: < 1 % per minute
- Typical duty cycle per 50 MHz frequency bin: ≤ 0,02 % taking into account FMCW or FH modulation
- Maximum mean e.i.r.p. spectral density: -41,3 dBm/MHz
- Installed in 25 % of vehicle fleet

- Modulation scheme: Pulsed, FMCW or Frequency Hopping Modulation
- Activity factor AF: 1h per vehicle per day, 1 % DC → AF = 0,042 %
- Antenna: typical gain of 3 dBi to 5 dBi

5.4.3 Technical description

The proposed object sensor installed in the car will in general be a fixed installed system at one or more positions in a vehicle like a car or a train. The antennas for will be directed mainly towards the passenger seating in the car or waggon. Only a limited part of the emission will be directed to the outside of the vehicle.



Top View – car with antenna positions

Figure 2: Typical antenna position for in vehicle object discrimination use case (Source [i.45])

Some typical positions for the in-vehicle sensors are given in Figure 2 and in the list below:

(1) Steering wheel/combi Instrument (radiation towards seat)

(2) Central Console/Radio shaft (vertical radiating into car interior)

(3) Glove box (above, radiating half sphere above)

(4) A-Pillar

(5) Ceiling

(6) Storage Font

The figure and position have been taken from the 2006 JTC, Ispra UWB car attenuation measurements [i.45] and [i.22].

Figure 3: Installation of antenna for position 5 in Figure 2 (Source [i.45])

5.4.4 Mitigation factors

- Specific shielding factors:
  - Mainly in-vehicle use with antennas directed towards the passenger
  - Car shielding effects, see [i.21] and [i.22]
- Duty cycle restrictions: < 1 % typical, 20 % max
- Specific absorption factors:
  - In-vehicle installations and tissue
  - Total radiated power spectral density (TRP_{sd}): significant decrease of power above 6 GHz [i.21] and [i.22]
- Operation conditions:
  - Very low activity factor (AF) with a maximum of 1h operation per day and car with a duty cycle of 1 %, AF < 0,042 % over vehicle population
- Environmental mitigation factors: Operation on street level only
- Possible reduced power levels in the band 4,8 GHz to 6 GHz and above 10,6 GHz and below 3,1 GHz
- Antenna gain: Use a limitation of the Total Radiated power in conjunction with the maximum mean e.i.r.p.:
  - Maximum mean e.i.r.p. spectral density: -41,3 dBm/MHz

- TRP_{sd}: -46,3 dBm/MHz or below when including additional effects

5.4.5 Applications specific market information

In can be assumed that 25 % of the sold cars will be equipped with an in-vehicle sensor system using UWB. With a market size of around 18 Mio vehicles sold in 2019 (ACEA) this would mean 4,5 Mio equipped vehicles per year in Europe.

In final stage 80 Mio equipped vehicles could be on the road after full roll-out 2035.

This would lead to a assumed device density for radiodetermination device for object discrimination inside vehicles, see Table 5 and the related active device density in Table 6.

Table 5: Assumed device densities for in-vehicle radiodetermination applications

	Rural (devices/km²)	Suburban (devices/km²)	Dense Urban (devices/km²)
Total Device density (100 %)	**15**	**150**	**1 500**
NOTE: 25 % equipment rate assumed over the car population.			

Table 6: Assumed active device densities for in-vehicle radiodetermination applications

In-vehicle use case (clause 5.4), AF = 0,042 %			
Total active device density per km2 (100 %)	**0,0063**	**0,063**	**0,63**
NOTE: 25 % equipment rate assumed over the car population.			

5.5 Indoor and outdoor fixed movement sensor and surveillance radar

5.5.1 General

The categories of UWB radars (passive radiodetermination application, no active device at the target object or material), the frequency range 6,0 GHz to 10,6 GHz enables applications with high resolution. This is especially interesting for several major application categories:

- Indoor mobile and handheld/portable applications, like surveillance radars for robots and autonomous household devices (e.g. dust cleaners) or short-range interaction movement detection (e.g. gesture or object recognition).
- Ambient assisted living applications like fall detection, present detection and movement detection, vital sign detection
- Fixed indoor and outdoor surveillance radars, e.g. for intrusion detection.

Given the inherent need for detecting motion and presence of individual persons, objects, limbs or fingers, the bandwidth of the detection signal is essential. Lower frequency components are required for the detection of vital signs.

For all these applications, the privacy-preserving nature of the radar sensing is a fundamental property. Such sensors are used to assess the situation in a volumetric space. The situation is assessed by detecting the overall presence of an object (e.g. human) or parts of, e.g. micro-motion caused by heartbeat, breathing, or assessing the physical characteristics - the contour or the movement - of the objects. Some use cases may also encompass the differentiation of creatures or objects, like between animals and objects or even between different animals.

Indoor applications are plentiful in the context of smart home, smart building, smart factory, and e-health. In these "verticals", there is a huge requirement for contactless monitoring of people, including people detection, tracking, counting and activity recognition or to provide functions to devices which work together with humans. This can be achieved by either illuminating a room with one or several radars depending on the room size and geometry or putting the function into a cooperative device (e.g. a robot). In the e-health vertical, monitoring the vital signs of persons in rooms, at their desk or workplace is gradually becoming a key technology to improve the well-being of people.

In hospital or old people's homes, this is also useful for the vital signs monitoring of patients being alone in their room or in bed.

Overview on some planned common applications:

- Vital sign tracking (heartbeat/breathing): for example, assessment of the physical well-being - e.g. in a hospital setting - of one or several persons in the scene. The presence and evolution of vital signs are detected by assessing micro-motion caused by heartbeat and/or breathing.
- Exit and/or entry monitoring: for example, determining the contour of persons in an access corridor (e.g. a door), and assessing whether the contour corresponds to an allowed entry and/or exit policy.
- Person identification and tracking: for example, by using the contour of the occupant(s), an accurate tracking in a scene can be performed, even with occupants in close proximity.
- Object protection purposes: for example, detection of forgotten objects (e.g. mobile phones) or detection of unwanted intrusion into the scene (e.g. protection of valuable items).

The fixed indoor operation is shielded by the building envelope for industrial and consumer applications. Typically, the direction of main radiation of the sensor is horizontal or tilted downwards below the horizontal direction. Only for the handheld/mobile applications it could be the case that there are emissions above the horizon, but for such applications there are lower power levels possible.

For any kind of outdoor installations the radiation of the sensor will be down tilted with a limited emission above the horizon.

5.5.2 Technical description

- Building with mounted detector installed indoor or outdoor.
- Mounting height 2 - 3 m over ground (outdoor) or floor level if indoor.
- Antenna tilted by 12 degrees down from horizon.
- Angle of detection is 90 degrees in horizontal plane and vertical plane.
- Detected distance: up to 30 m.
- Operational 24/7 (max).

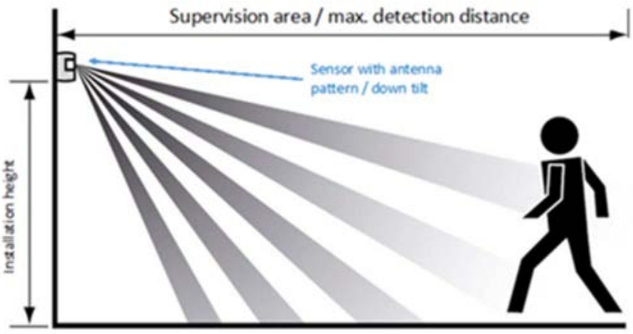


Figure 7: Motion and presents sensor for home applications

Figure 4: Motion and presents sensor for home applications (Source: Robert Bosch GmbH)

In Figure 5 and Figure 6 some typical examples for the antenna pattern coverage for these applications are given.

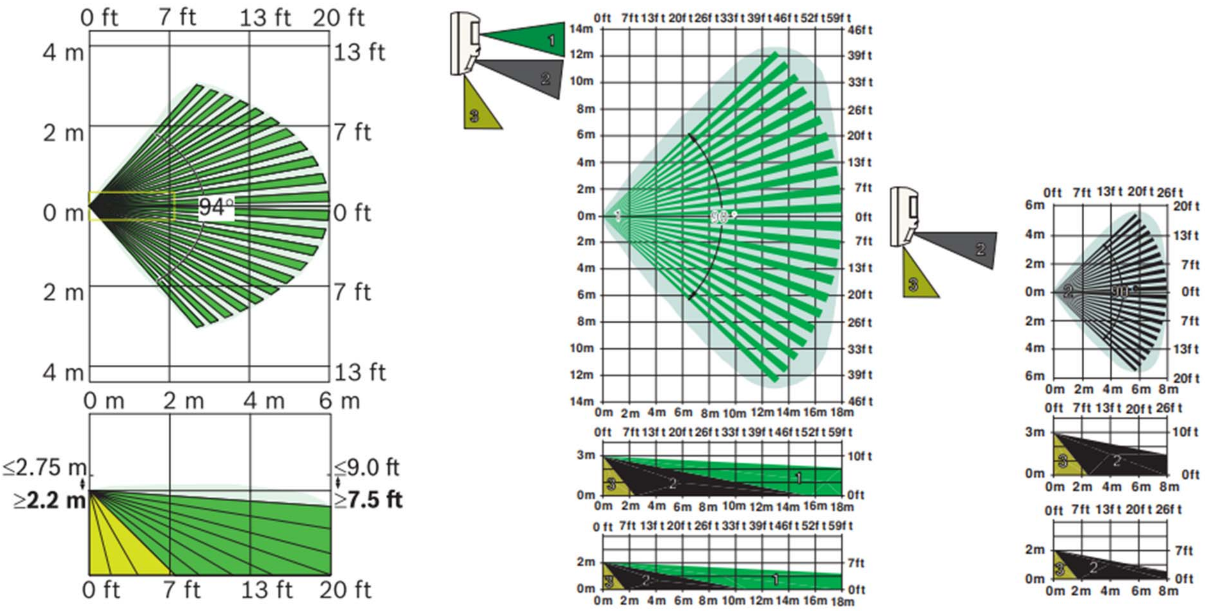


Figure 5: Coverage examples for sensors (Source: Robert Bosch GmbH)

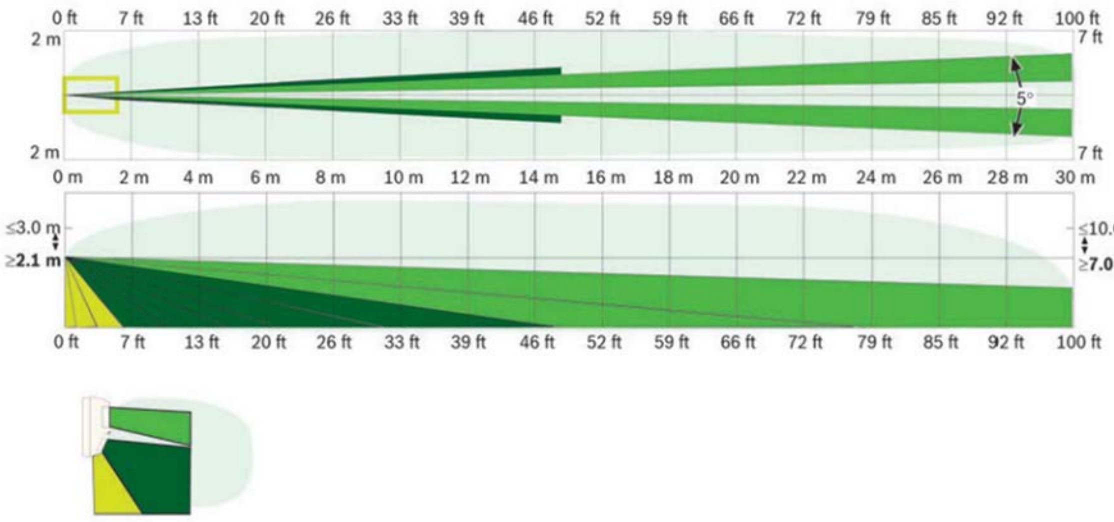


Figure 6: Coverage examples for sensors for long range (Source: Robert Bosch GmbH)

- Bandwidth: up to 5 GHz bandwidth
- Data rate: Not applicable here
- Location precision/accuracy: ≤ 10 mm
- Spectrum band: 6,0 GHz to 10,6 GHz, for some application lower frequency components might be required
- Maximum Duty Cycle: ≤ 20 % per minute in operational bandwidth
- Typical duty cycle: ≤ 2 % in operational bandwidth
- Maximum mean e.i.r.p. spectral density: -41,3 dBm/MHz
- Installed in 25 % of the apartments
- Modulation scheme: Pulsed, FMCW or Frequency Hopping Modulation

- Activity factor AF: 8 h day, 2 % DC → AF = 0,666 %
- Activity factor in a 50 MHz frequency bin: ≤ 0,333 %
- For fixed installation: minimum antenna gain 10 dBi → TRP_{sd} limit for fixed installations: -51,3 dBm/MHz

5.5.3 Mitigation factors

- Specific shielding factors: in-door usage for some application, limited outdoor usage with down tilt antennas (see Table 7)
- Duty cycle restrictions per minute: < 2 % typical, < 20 % max
- Specific absorption factors: indoor installations, tissue absorption and installation on walls, could be considered as part of a TRP_{sd} limitation
- For fixed installed antenna: down tilt antenna with a minimum antenna gain of 10 dBi
- For fixed installed antenna: TRP_{sd} limit of -51,3 dBm/MHz
- For portable and body worn devices: TRP_{sd} limit of -46,3 dBm/MHz
- Possible reduced power levels in the band above 10,7 GHz

5.5.4 Applications specific market information

The situation inside buildings is difficult to estimate. The number of devices depends on the success of IoT and home automation applications and the temporal deployment. Such indoor surveillance sensors will be part of a building automation or security system. For a worst-case estimation one sensor per room (living room, entrance hall, etc.) could be assumed. This could lead up to 5 sensors per house or up to 3 sensors per flat.

The market size in EU for Dual motion detectors (PIR/MW) with narrowband radars at 10 and 24 GHz is roughly 60 million EUR for indoor detectors and roughly 40 million EUR for outdoor detectors.

A UWB regulation would lead to a replacement of existing sensors and new sensors based on the new possible functions. Based on typical lifetime of existing equipment, other regulations for radiodetermination (for some use cases) it could be expected that such numbers could be reached within 10 - 15 years.

The following device densities were considered for the studies for generic object discrimination radar applications, see Table 7. These densities could be used as the bases for the market estimation and further compatibility studies.

The given densities are based on the overall device densities, see Table 7. When more than one signal channels are used these density have to be apportioned to the available and used channels.

Table 7: Assumed device densities object discrimination use case [i.19]

	Rural (devices/km²)	Suburban (devices/km²)	Dense Urban (devices/km²)
Total Device density (100 %)	**50**	**500**	**5 000**
Handheld/mobile (50 %)	25	250	2 500
Consumer fixed indoor (30 %)	15	150	1 500
Professional fixed indoor (10 %)	5	50	500
Fixed outdoor (10 %)	5	50	500

The assumed device density and the usage factor would lead to a total number of active devices, see Table 8.

Table 8: Assumed active device densities object discrimination use case

Indoor object discrimination use case (clause 5.5), 8h per day, DC = 2 % (AF = 0,666 %)			
Total active device density per km2 (100 %)	**0,33**	**3,3**	**33**
Handheld/mobile indoor (50 %)	0,166	1,66	16,6
Consumer fixed indoor (40 %)	0,133	1,33	13,3
Professional fixed indoor (10 %)	0,033	0,33	3,3

5.6 Radiodetermination for high precision location tracking applications

5.6.1 General

Open standardized infrastructure for seamless, reliable and precise positioning is enabling various use cases in professional, private and public environments. An existing commodity in terms of an open standardized infrastructure for radio positioning of objects and subjects, relative and absolute to a certain environment, is enabling multiple scenarios, were several participants are in spatial relation to each other partly or as a group. This could happen even quasi-parallel in the same environment. Providing such widespread radio positioning commodity will allow to leverage the economy of scale and lower significantly the barriers to deploy radio positioning as a key enabling factor for the introduction of highly innovative and efficient services in a majority of industrial and public sectors as well as private scenarios.

Such standardized infrastructure needs to support a wide variety of technical requirements from various applications, such as e.g. precise AR/VR/XR, energy efficient object tracking and identification, virtual fencing, keyless entry, access control for public and private infrastructure transactions in public and private settings, highly accurate automotive positioning applications, precise machine and robotic steering and vehicular tracking.

Supporting as much as possible from the available frequency bands is key in order to allow smart and efficient local spectrum sharing and co-existence with several other radio systems depending on the actual deployment scenario boundary conditions.

In addition, a key issue is the alignment on a spectrum band for end user applications (specifically those involving personal devices and devices participating in services associated with personal devices: mobile phones or tags or other devices that are used for tracking moving objects or persons) that has been aligned worldwide. The band above 8,3 GHz is deemed most suitable for the extension and this purpose. In particular given the impact of the changes to the interference environment below 7,2 GHz.

5.6.2 System requirements

- Bandwidth: up to 5 GHz (min 1,5 GHz), with channelization options of 500 MHz.
- Location precision/accuracy: < 10 mm …< 30 cm depending on the actual deployments.
- Spectrum band: 6,0 GHz to 10,6 GHz, end user emphasis on additional capacity above 8,25 GHz.
- Maximum Duty Cycle:
    - Infrastructure < 5 % (limited number of anchors)

NOTE 1: In specific locations, e.g. public transport or other mass access/payment applications, higher duty cycles are required – up to 30 %. In such situation professional oversight for the installation would be appropriate.

- Mobile Devices < 2 % (higher number)

NOTE 2: Up to 10 % duty cycle may be necessary in locations where the link budget is critical due to high path loss and/or interference received given that UWB is not the primary user of the spectrum.

- Typical duty cycle:
    - 2 % Infrastructure (limited number of anchors); and

- 0,001 %...0,5 % UL-TDoA (higher number of mobile tags/devices).

- Maximum mean e.i.r.p. spectral density: -41,3 dBm outdoor and -31,3 dBm/MHz indoor.
- TRP_{sd} outdoor: -46,3 dBm/MHz or -51,3 dBm/MHz.
- TRP_{sd} indoor: -36,3 dBm/MHz or -41,3 dBm/MHz.
- for deployment in industrial sites see Figure 7.
- Modulation scheme: pulse.
- Duty cycle DC and activity factor AF:
  - private: up to 2 h/day;
  - professional: 8 h/day;
  - major industrial: up to 24 h/day;
  - road and rail environment: up to 24 h/day;
  - typ. 0,1 % DC … 2 % DC;
  - →AF = 0,01 % …. 2 %.
- Antenna: Infrastructure with mounted antennas/devices, mobile devices with integrated antennas.

5.6.3 Technical description

5.6.3.1 Professional Location tracking

The standardized infrastructure is in charge of organizing the use of the spectrum so that mobile units can access it in a deterministic way. The onboarding of the mobile may be performed out of band in order to avoid any contention. The overall spectrum is divided into multiple frequency channels that are in turn sliced in time slots.

The use of the infrastructure downlink is synchronized and managed on the infrastructure side. Synchronization messages are transmitted periodically in order to keep mobile units in synch. Time slots and frequency channels are allocated to the mobile units based on the requested transmission frequency. The latter varies depending on the use case and nature of the mobile unit. For example, a real-time, low-latency transmission can be implemented thanks to a perfectly synchronous transmission recurrence. Another example is the transmission of short burst for location tracking, where the recurrence of the transmission is linked to the speed of the mobile unit.

The fine level of synchronization achieved with very short pulses enables a fine slicing of time and guarantees that no collision may take place. This offers an enhance reliability to applications and avoid the aggregation of transmitters even in dense environments.

Allocating alternatively different time slot on different frequency channels, i.e. mixing FDMA and TDMA offers an enhanced immunity to the communication and synchronization system, see Figure 7. The use of different frequency channels will increase the sensing bandwidth and thus can facilitate higher accuracy of the ranging and positioning operation where needed.

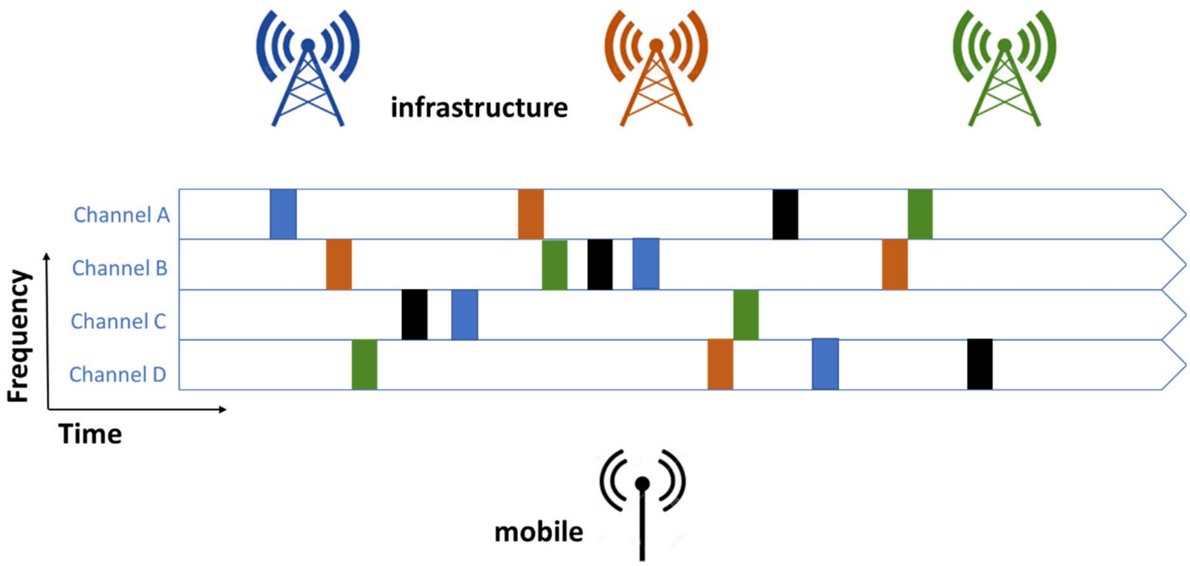


Figure 7: Mixing FDMA and TDMA

5.6.3.2 End user and Vehicular Location Tracking

These protocol characteristics are similar to those described in the previous clause with deviations on time synchronization. Depending on the application at hand not only downlink but also active mobile systems (uplink) location systems are deployed.

Any uplink system will apply some form of identification, session or authentication protocol to determine which UWB devices are to participate in location tracking. Mostly out of band using technologies such as BTLE.

Ranging is the fastest growing application segment of the UWB market. Mobile personal devices are used to track location or persons securely and are used to authenticate transactions (from opening a car door, entering a local train or football station) and track personal items.

Protocols deployed are those that are based on IEEE 802.15.4z standard [i.41], with improved versions assumed to be entering the market, see [i.25]. Ranging sessions will be triggered by an out of band protocol (BLE or other) and will only be performed by devices intended and capable to interact. Applications may adopt features of the forthcoming IEEE 802.15.4ab standard [i.31].

5.6.4 Mitigation factors

5.6.4.1 Professional Location tracking

Infrastructure based radio positioning is inherently radio co-existence friendly as there is typically a synchronisation mechanism between the so called anchor nodes performed, which is either performed based on wired backbone signalling or alternatively in a slotted wireless mode avoiding inherently interference aggregation effects.

Furthermore by allowing synchronous DL-TDoA operation a very high number of mobile participants of the scenario can operate in "receive only mode" and only a few anchor nodes transmit (typically directed downwards from a higher wall mounting position) in a sequential way allowing to minimize temporal interference aggregation significantly compared to infrastructure less operational scenarios.

Duty cycle of anchor nodes are typically below 5 % per second while duty cycle of portable devices can vary from receive only mode operation (like in GPS systems) over transmit by trigger event (e.g. stop of movement detected, or nearby door lock observed) up to scheduled transmission, which again can range from a single frame per day up to 20 frames per second.

Due to the static nature of the fixed infrastructure typically the operator/installer will be able to harmonize frequency bands deployed with other surrounding radio services (e.g. complementary quasi simultaneous operation of 5G, Wi-Fi® and UWB in the same area while protecting other radio services such as FSS, radio altimeters, or any other radio service.

5.6.4.2 End user and Vehicular Location Tracking

End user deployment of Location tracking will typically be limited to indoor locations and selected public spaces, mostly indoor.

End user deployment of vehicular location tracking will be limited to specific situations where such location tracking is part of an application creating significant benefit, e.g. in public car parking, valet parking.

Uplink TDoA, downlink TDoA as well as TOF are deployed depending on the setting and equipment availability and dependency. Each has favourable mitigation properties in some part of the application space.

Duty cycle of all applications is low. TDoA downlink is similar to professional application parameters. TDoA uplink and TOF (ranging) applications would be used in case of fewer tracked items. The duty cycle per anchor and mobile device is typically 2 % or lower. However, 10 % duty cycle may be necessary in locations where the link budget is critical due to high path loss and/or interference received given that UWB is not the primary user of the spectrum

Activity factors are quite application dependent. For specific TDoA downlink systems the activity factor is typically constant, actual activity depending on the required time resolution of the application (20x per second down to 1x per hour) For systems using TDoA uplink or ranging the activity is layered at typically 10x per second for distance measurement frequency plus an additional activity level at a longer timescale as and when tracked devices enter and exit the tracking space. Typical parameters are 1 - 2 devices in a tracking space for 4 hours per 24 hours. Deployment density of potentially tracked devices is not the most relevant measure, deployed infrastructure and the recognition or participating mobile devices is defining the higher layer of activity.

Antenna positions and patterns: for mobile stations typically omnidirectional (with a bias towards vertical orientation, i.e. modest attenuation towards the zenith), for anchors omnidirectional for indoor, and omnidirectional with vertical orientation for lower placed outdoor anchors. For anchors mounted on elevated positions (higher than 2,5 m above pedestrian surface) special precautions are not preferred. Average antenna gain is low and can be modelled using the TRP_{sd} concept.

All ranging actions are triggered by a higher layer protocol matching the mobile node to their counterparts not using the here considered section of the UWB band.

Practical applications are dimensioned to very low airtime to support ultra-low power mobile nodes (like tags, wearables).

Locations of interaction between mobile nodes and fixed infrastructure with high utilization will be linked to well considered locations (in public or quasi-public locations) where professional interference mitigation techniques can be deployed in case of a known victim service deployment.

Indoor ranging with fixed infrastructure may be used for various location aware applications. Handsfree payment, location aware smart building applications are examples. Also smart building application. parking access control, EV charging locations, etc.

Antenna properties are the same as for End user and Vehicular Location Tracking applications.

5.6.5 Application specific market information

5.6.5.1 Professional Location tracking

Based on profound market research and member interrogation in the omlox© working-group use case a full list of 115 different use cases for industrial usage were collected and described. Besides industry there are also benefits of open location infrastructure in other segments, like e.g. Healthcare or Retail. Still the most thorough investigations took place for the industrial usage in the application fields of manufacturing and warehousing.

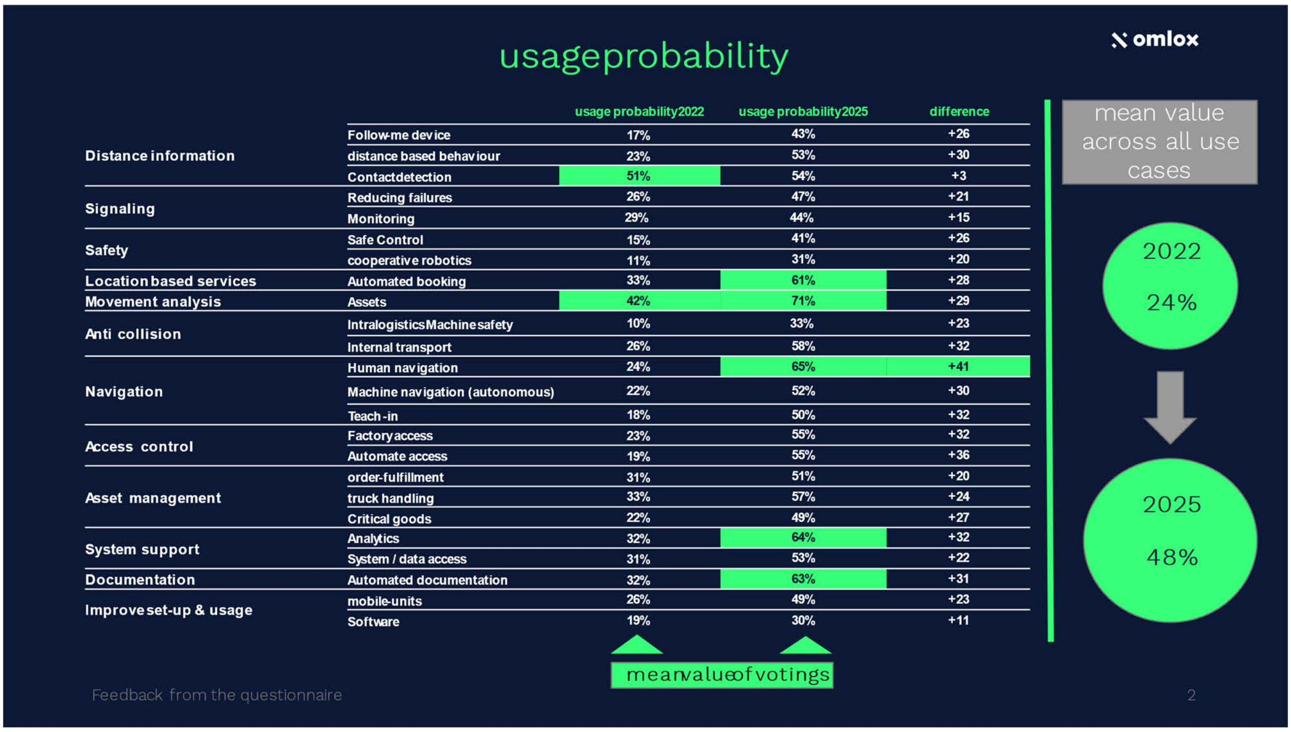


Figure 8: Overview of expected parallel usages of location infrastructure in industry (Source: omlox©)

Figure 8 shows the expected evolution of the parallel usage of an location infrastructure over time. The adoption rate is expected to increase over time, leading to an universal usage of such a wireless locating infrastructure. Such adoption rates are very typical for multi-purpose infrastructure installation. Driven by the vulnerability of supply-chains the demand for real-time location is dramatically increasing. This can be compared to the evolution of the standardized Wi-Fi-Network as shown in Figure 9.

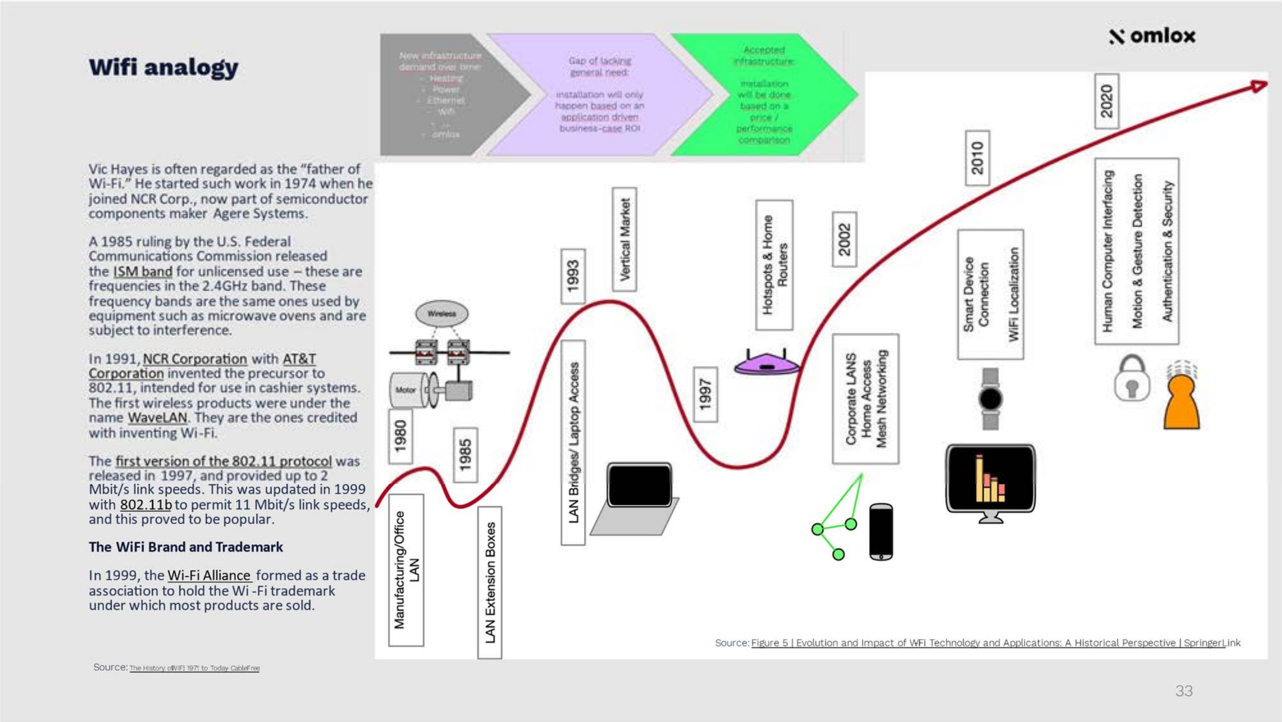


Figure 9: Wi-Fi® analogy for the evolution of standardized infrastructure (Source: omlox©)

Such standardized infrastructures prepared for multi-purpose usages can dramatically increase the adoption rate by reducing the load in wireless emission: By using one standardized infrastructure many different applications share the same resource. Some necessary tasks like e.g. time synchronisation will only be needed once and the concurring problems of independent wireless systems running in parallel and provoking interference are solved before they appear. In this respect one multi-purpose infrastructure can be seen as a mitigation factor to reduce air-traffic in upcoming industrial usage. This is especially true if the infrastructure is providing means for a self-location of mobile devices by just listening to the infrastructure. In such an environment the amount of participants can become infinite without increasing the overall air-traffic. With omlox© there is already such a standard defined with an increasing amount of supporters globally.

A strong growth of such standardized infrastructures is expected first before they will be adopted in healthcare, retail and many other commercial fields. Finally, this will lead to a similar widespread adoption as Wi-Fi®. In TDMA based systems like omlox© this will ensure that the load will never excess allowed limits and different applications will not result in exponential air-traffic caused by interference problems.

5.6.5.2 End user and Vehicular Location Tracking

Market parameters of end user and vehicular applications are similar to those for professional location tracking. Deployment densities are expected to scale with the deployment of mobile phones incorporating UWB, tracking tags, wearables and vehicles, and scale (in the case of a per person deployment) to a penetration of up to 3 (devices per person) and up to 50 % active use in the forthcoming decade.

This band is needed to support a variety of applications in both Android and iOS offer API support for UWB ranging applications as part of their mobile application development frameworks [i.29] and [i.30], unleashing creativity for new applications to be developed in conjunction with UWB enabled smartphones, typically targeting indoor applications. Specifically in ranging "hotspots" significant spectrum, requirements are anticipated and high aggregate UWB spectrum utilization may occur. Payment and quasi payment applications are being developed. See e.g. [i.28].

Also a wide range of vehicular application use cases is now emerging. See Figure 10 and e.g. [i.26] and [i.27].

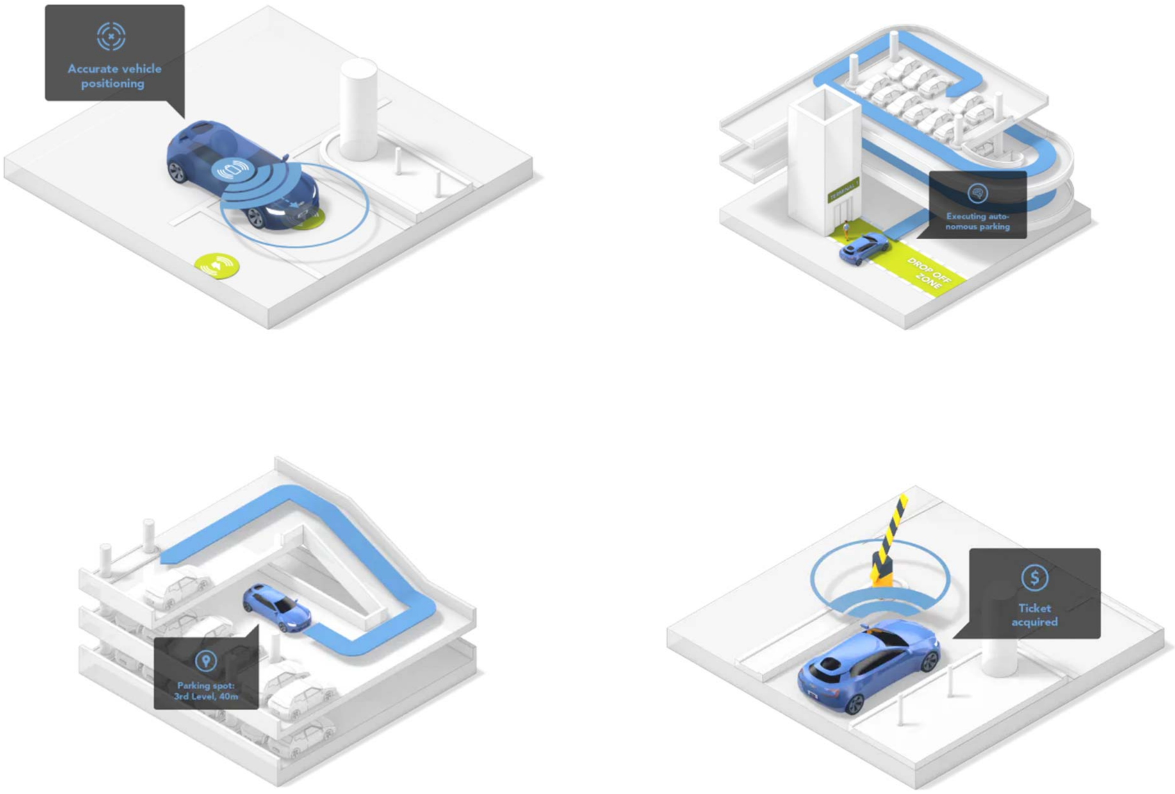


Figure 10: Automotive use cases (copy pictures courtesy of NXP Semiconductors)

5.6.5.3 Market parameters

Similar to Table 1 and Table 2 the assumed device density for open infrastructure for location tracking is provided in Table 9 and the resulting active device density is provided in Table 10.

Table 9: Assumed device densities for open infrastructure for location tracking (see note 2)

	Rural (devices/km²)	**Suburban (devices/km²)**	**Dense Urban (devices/km²)**
Total Device density professional location (100 %)	**50**	**500**	**5 000**
Indoor professional location (90 %)	45	450	4 500
Outdoor professional location (10 %)	5	50	500
Total Device density end user and vehicular location (100 %) (see note 1)	**75**	**745**	**7 450**
Indoor end user	50	500	5 000
Outdoor end user and vehicular location	25	245	2 450
NOTE 1: There is substantial overlap in the tracked end user devices: cellphones, tag, other wearables and vehicle based nodes, etc. between location tracking and end user, assumed at 75 %. Activation of the tracking and ranging may be very selective. Deployment density of potentially tracked devices is not the most relevant measure. Deployed infrastructure and the recognition or participating mobile devices is defining the higher layer of activity.			
NOTE 2: It is assumed that professional and end user usage is mutually exclusive. In places where professional use takes place, the use of radio devices tends to be restricted.			

Table 10: Assumed device densities for open infrastructure for location tracking

Open infrastructure for location tracking (clause 5.6), AF = 2,0 %			
Total active device density per km^2 (100 %)	**1**	**10**	**100**
Indoor (90 %)	0,9	9	90
Outdoor (10 %)	0,1	1	10
End user location tracking (clause 5.6), AF indoor = 1 %, AF outdoor as in ECC Report 327 [i.35]			
Total active device density per km^2 (100 %)	**0,8**	**8,1**	**80,67**
Indoor	0,5	5	50
Outdoor	0,3	3,1	30,67

5.7 Summary

Table 11: Overview: Assumed device densities for band extension

	Rural (devices/km²)	Suburban (devices/km²)	Dense Urban (devices/km²)
Radiodetermination applications			
Body worn radiodetermination, Virtual Reality use case (clause 5.2)			
Total Device density (100 %)	**50**	**500**	**5 000**
Indoor (90 %)	45	450	4 500
Outdoor (10 %)	5	50	500
Indoor object discrimination use case (clause 5.5)			
Total Device density (100 %)	**50**	**500**	**5 000**
Handheld/mobile indoor (50 %)	25	250	2 500
Consumer fixed indoor (40 %)	20	200	2 000
Professional fixed indoor (10 %)	5	50	500
In-vehicle use case (clause 5.4)			
Total Device density (100 %)	**15**	**150**	**1 500**
NOTE: 25 % equipment rate assumed over the car population			
Open infrastructure for location tracking (clause 5.6)			
Total Device density (100 %)	**245**	**2 450**	**24 500**
Indoor (90 %)	45	450	4 500
Outdoor (10 %)	5	50	500
Communication applications			
Low-latency wireless communication (clause 5.3)			
Total Device density (100 %)	**50**	**500**	**5 000**
Indoor ([90 %])	45	450	4 500
Outdoor ([10 %])	5	50	500

Table 12: Overview: Assumed active device densities for band extension including DC and AF

	Rural (devices/km²)	Suburban (devices/km²)	Dense Urban (devices/km²)
Radiodetermination application			
VR use case(clause 5.2), DC = 10 %, 2,4h per day, AF = 1 %			
Total active device density per km2 (100 %)	**50 × 10 % × 10 % = 0,5**	**500 × 10 % × 10 % = 5**	**5 000 × 10 % × 10 % = 50**
Indoor ([90 %])	0,45	4,50	45,00
Outdoor ([10 %])	0,05	0,50	5,00
Indoor object discrimination use case (clause 5.5), 8h per day, DC = 2 % (AF = 0,666 %)			
Total active device density per km2 (100 %)	**0,33**	**3,3**	**33**
Handheld/mobile indoor (50 %)	0,166	1,66	16,6
Consumer fixed indoor (40 %)	0,133	1,33	13,3
Professional fixed indoor (10 %)	0,033	0,33	3,3
In-vehicle use case (clause 5.4), AF = 0,042 %, DC = 100 %			
Total active device density per km2 (100 %)	0,0063	0,063	0,63
NOTE 1: 25 % equipment rate assumed over the car population			
Open infrastructure for location tracking (clause 5.6), AF = 2 %			
Total active device density per km2 (100 %)	**1**	**10**	**100**
Indoor (90 %)	0,9	9	90
Outdoor (10 %)	0,1	1	10
End user location tracking (clause 5.6), AF indoor = 1 %, AF outdoor as in ECC Report 327 [i.35] typical DC = 2 %, max DC 10 % (see note 2)			
Total active device density per km2 (100 %)	**0,8**	**8,1**	80,67
Indoor	0,5	5	50
Outdoor	0,3	3,1	30,67
NOTE 2: 10 % duty cycle may be necessary in locations where the link budget is critical due to high path loss and/or interference received given that UWB is not the primary user of the spectrum.			
Communication applications			
Low-latency wireless communication (clause 5.3), AF = 0,083 %			
Total active device density per km2 (100 %)	**0,0416**	**0,416**	**4,16**
Indoor (90 %)	0,03735	0,3735	3,735
Outdoor (10 %)	0,00416	0,0416	0,416

6 Allocations in the band 8,5 GHz to 10,6 GHz and related compatibility topics

6.1 Introduction

In the frequency band between 8 - 5 GHz and 10,6 GHz several services and applications are allocated. The main identified victim services are radio location and navigation services and the passive EESS services. It is assumed in the present document that the presented application and use cases can avoid the passive bands and thus provide the required protection. For the radio location and navigation services different mitigation factors and techniques can be used. A more detailed analysis of the interference behaviour has to be performed in the scope of the CEPT work.

6.2 Current European Common Allocations

Table 13: Allocation table ECA for the band 8,5 GHz to 10,6 GHz

Frequency band	Allocations	Applications
8 500 MHz - 8 550 MHz (5.469) (ECA24) (ECA36)	• RADIOLOCATION	• UWB applications • Radiodetermination applications • Aeronautical navigation • Aeronautical military systems • Radiolocation (military) • Radiolocation (civil)
8 550 MHz - 8 650 MHz (5.469) (5.469A) (ECA24) (ECA36)	• EARTH EXPLORATION-SATELLITE (ACTIVE) • RADIOLOCATION • SPACE RESEARCH (ACTIVE)	• Radiolocation (civil) • Active sensors (satellite) • Radiolocation (military) • Aeronautical military systems • Aeronautical navigation • Radiodetermination applications • UWB applications
8 650 MHz - 8 750 MHz (5.469) (ECA24) (ECA36)	• RADIOLOCATION	• UWB applications • Radiodetermination applications • Aeronautical navigation • Aeronautical military systems • Radiolocation (military) • Radiolocation (civil)
8 750 MHz - 8 850 MHz (ECA24) (ECA36)	• AERONAUTICAL RADIONAVIGATION (5.470) • RADIOLOCATION • Space Research	• Radiolocation (civil) • Radiolocation (military) • Aeronautical military systems • Aeronautical navigation • Radiodetermination applications • UWB applications
8 850 MHz - 9 000 MHz (5.473) (ECA24) (ECA36)	• MARITIME RADIONAVIGATION (5.472) • RADIOLOCATION • Space Research	• UWB applications • Radiodetermination applications • Aeronautical navigation • Aeronautical military systems • Radiolocation (military) • Radiolocation (civil)
9 000 MHz - 9 200 MHz (5.471) (5.473A) (ECA24) (ECA36)	• AERONAUTICAL RADIONAVIGATION (5.337) • RADIOLOCATION Space Research	• Radiolocation (civil) • Radiolocation (military) • Aeronautical military systems • Aeronautical navigation • Radiodetermination applications
9 200 MHz - 9 300 MHz (5.473) (5.474) (5.474D) (ECA24) (ECA36)	• MARITIME RADIONAVIGATION (5.472) • RADIOLOCATION • Space Research EARTH EXPLORATION-SATELLITE (ACTIVE) (5.474A) (5.474B) (5.474C)	• Radiodetermination applications • Aeronautical navigation • Aeronautical military systems • Radiolocation (military) • Radiolocation (civil) • Synthetic aperture radar
9 300 MHz - 9 500 MHz (5.427) (5.474) (5.475) (5.475A) (5.475B) (5.476A) (ECA24) (ECA36)	• EARTH EXPLORATION-SATELLITE (ACTIVE) • SPACE RESEARCH (ACTIVE) • RADIONAVIGATION (5.476A) • RADIOLOCATION	• Radiolocation (civil) • Radiolocation (military) • Satellite systems (military) • Weather radar • Aeronautical military systems • Aeronautical navigation • Radiodetermination applications
9 500 MHz - 9 800 MHz (5.476A) (ECA24) (ECA36)	• EARTH EXPLORATION-SATELLITE (ACTIVE) • RADIOLOCATION • SPACE RESEARCH (ACTIVE)	• Radiodetermination applications • Aeronautical navigation • Aeronautical military systems • Radiolocation (military) • Satellite systems (military) • Radiolocation (civil) • Active sensors (satellite)

Frequency band	Allocations	Applications
9 800 MHz - 9 900 MHz (5.478A) (5.478B) (ECA24) (ECA36)	• RADIOLOCATION • Space Research (active) • Earth Exploration-Satellite (active)	• Radiolocation (civil) • Satellite systems (military) • Radiolocation (military) • Aeronautical military systems • Aeronautical navigation • Radiodetermination applications
9 900 MHz - 10 000 MHz (5.477) (5.478) (5.479)	• RADIOLOCATION • Fixed • EARTH EXPLORATION-SATELLITE (ACTIVE) (5.474A) (5.474B) (5.474C)	• Radiodetermination applications • Aeronautical navigation • Aeronautical military systems • Radiolocation (military) • Satellite systems (military) • Radiolocation (civil) • Synthetic aperture radar
10 000 MHz - 10 400 MHz (5.474D) (5.479) (ECA17A) (ECA36)	• FIXED • MOBILE • RADIOLOCATION • Amateur • EARTH EXPLORATION-SATELLITE (ACTIVE) (5.474A) (5.474B) (5.474C)	• Synthetic aperture radar • Amateur • Radiolocation (civil) • Land military systems • Maritime military systems • Radiolocation (military) • Aeronautical military systems • Radiodetermination applications • PMSE • FWA • Fixed
10 400 MHz - 10 450 MHz (ECA17) (ECA17A) (ECA36)	• FIXED • RADIOLOCATION • Amateur • Mobile	• PMSE • Radiodetermination applications • Aeronautical military systems • Maritime military systems • Radiolocation (military) • Land military systems • Amateur • Radiolocation (civil)
10 450 MHz - 10,5 GHz (5.481) (ECA17) (ECA17A) (ECA23) (ECA36)	• FIXED • MOBILE • RADIOLOCATION • Amateur • Amateur-Satellite	• Amateur • Radiolocation (civil) • Amateur-satellite • Land military systems • Maritime military systems • Radiolocation (military) • Aeronautical military systems • Radiodetermination applications • PMSE
10,5 GHz - 10,55 GHz (ECA17A)	• FIXED • MOBILE • Radiolocation	• PMSE • Fixed • Radiodetermination applications
10,55 GHz - 10,6 GHz (ECA17A)	• FIXED • MOBILE EXCEPT AERONAUTICAL MOBILE • Radiolocation	• Radiodetermination applications • Fixed • PMSE
10,6 GHz - 10,68 GHz (5.149) (5.482) (5.482A) (ECA17)	• EARTH EXPLORATION-SATELLITE (PASSIVE) • FIXED • Mobile except aeronautical mobile • RADIO ASTRONOMY • SPACE RESEARCH (PASSIVE) • Radiolocation	• PMSE • Fixed • Radio astronomy • Passive sensors (satellite)
10,68 GHz - 10,7 GHz (5.340)	• EARTH EXPLORATION-SATELLITE (PASSIVE) • RADIO ASTRONOMY • SPACE RESEARCH (PASSIVE)	• Passive sensors (satellite) • Radio astronomy

6.3 Available sharing and compatibility studies

- ECC Report 64 [i.37]
- ECC CEPT Report 9 [i.38]
- ECC Report 120 [i.10]
- ECC Report 170 [i.12]
- ECC Report 327 [i.35]

The following considerations of ECC/DEC(06)04 [i.9] are well describing the coexistence assumptions that lead to the current regulation in ECC/DEC(06)04 [i.9]:

l) that a maximum mean e.i.r.p. spectral density of -65 dBm/MHz in the band 8,5 - 9 GHz is based on single interference analyses with radar systems assuming a minimum separation distance of 25 m;

o) that complementary technical studies presented in CEPT Report 9 [i.38] (using different propagation models and assuming 100 % of UWB devices operating indoor with an average 1 % activity factor) provide some level of confidence regarding the protection of outdoor stations from the Fixed Service and the Fixed-Satellite Service with a maximum mean e.i.r.p. spectral density level of -41,3 dBm/MHz;

v) that technical requirements for DAA UWB 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 are presented in ECC Report 120 [i.10];

w) that DAA technical requirements in the band 8,5 - 9 GHz are based on characteristics of monostatic radiolocation systems and may be revised subject to reported risk of interference to other classes of X-band radars considered to be deployed in the future, in particular passive radars;

x) that DAA technical requirements given in Annex 3 of this ECC Decision need to be supplemented by adequate guidance on DAA measurement procedures and test patterns as defined in relevant standards (e.g. relevant versions of ETSI EN 302 065-1 [i.2] including Harmonised European Standards adopted under RE Directive 2014/53/EU [i.36]).

6.4 Sharing and compatibility issues still to be considered

Table 14: Critical radio services/application and potential mitigation technique/factors

Frequency band	Critical spectrum users and applications	Mitigation factors and techniques
8,5 GHz to 9,0 GHz	X-Band military	Reference limit for radars from existing studies is -65 dBm/MHz 20 - 30 dB mitigation required for the requested new applications 17 dB mitigation by indoor restriction For the protection of radars DAA or LBT? Low Duty Cycle others
9,0 GHz to 10,6 GHz	X-Band military and civil radar	Reference limit for radars from existing studies is -65 dBm/MHz 20 - 30 dB mitigation required for the requested new applications 17 dB mitigation by indoor restriction For the protection of radars DAA or LBT? Low Duty Cycle others
10,6 GHz to 10,7 GHz	Passive	reference level of -85 dBm/MHz will be used No change to existing regulation

6.5 Ongoing research activities for IMT

Since the SRdoc also provides an overview of the relevant possible mitigation techniques and factors to protect existing and future services in the band 8,5 GHz to 10,6 GHz, in this clause an overview of the ongoing research activities targeting the 7 - 24 GHz range for possible future IMT usage are provided.

There is a global research effort addressing future IMT developments towards 2030 (IMT-2030). Within this effort, the 7,125 - 24 GHz range is considered by mobile industry as an essential component for future candidate bands [i.32]. Similar view is supported by the European research project Hexa-X [i.33], which was launched in 2021 as part of the European Union's Horizon 2020 research and innovation initiative.

7 Radio spectrum request and justification

7.1 Introduction

Several of the radio-determination applications considered in the present document are targeting high precision positioning or sensing. These applications require significantly higher bandwidths than the commonly used 500 MHz to achieve the desired performance. At the high end, these bandwidths are not even available under the current regulations.

For other applications, a higher number of channels is needed to manage channels according to local interference situations and to still distribute UWB's aggregation effects over broader bandwidths. This will both reduce UWB's interference potential towards other services and other UWB-based spectrum users.

ECC Report 302 [i.39] shows interference potential to UWB from RLANs operating in 5 945 - 6 425 MHz. Existing users of the 6 GHz UWB spectrum are starting to move higher in frequency to avoid interference from RLAN.

Further work is currently ongoing in CEPT to potentially allocate the 6 425 - 7 125 MHz band to new mobile radio services. This spectrum is also no longer at the edge of the 6,0 - 8,5 GHz UWB range and is therefore likely to affect multiple UWB channels.

These conditions will significantly reduce the usability of this part of the spectrum for UWB applications. To counterbalance this, an increase of the spectrum available to UWB will restore the current channel management capabilities.

7.2 Indoor radiodetermination and communication

7.2.1 Generic Indoor radiodetermination applications

This set of regulatory rules should cover generic indoor radio sensing and radiolocation applications including "location and tracking" and material sensing and characterisation applications and passive radiodetermination (radar). The TRP value could contain effects of the antenna gain and scenario related effects like absorption of a body and other materials. Passive radiodetermination applications will rather need higher band widths than 500 MHz.

The proposal is to develop a new regulation (in ECC/DEC(06)04 [i.9]) for generic indoor radiodetermination applications with the details in Table 15. A comparison with the existing limits is provided in clause 7.2.4.

Table 15: Proposed UWB regulation in the bands 8,5 GHz to 10,6 GHz, generic indoor radiodetermination

Frequency band	Total radiated power spectral density (TRP_{sd})	Maximum mean e.i.r.p.	Maximum peak e.i.r.p.	Minimum operational bandwidth	Duty Cycle per 50 MHz frequency bin per minute
8,5 GHz to 10,6 GHz	-46,3 dBm/MHz	-41,3 dBm/MHz	0 dBm/50 MHz	0,5 GHz	≤ 5 % ≤ 1 %
	-36,3 dBm/MHz	-31,3 dBm/MHz	10 dBm/50 MHz	0,5 GHz	≤ 1 %

The spectrum between 7,7 GHz and 9,3 GHz is actually foreseen for the worldwide aligned deployment for these systems with an midterm perspective to extend the upper frequency bound up to 10,6 GHz.

7.2.2 Body Worn Indoor radiodetermination applications

This set of regulatory rules should cover indoor radio sensing and radio location applications including "location and tracking", transferring data necessary to support "location and tracking", and incidental data transfer for tracking and location applications were devices are body worn, or in near proximity to a body. For example, the VR use case. The TRP_{sd} value contain effects of the antenna gain and scenario related to tissue absorption of the body.

The proposal is to develop a new regulation (in ECC/DEC(06)04 [i.9]) for body worn indoor radiodetermination applications with the details in Table 16. A comparison with the existing limits is provided in clause 7.2.4.

Table 16: Proposed UWB regulation in the bands 7,125 GHz to 10,6 GHz, body worn indoor radiodetermination applications

Frequency band	Total radiated power spectral density (TRP_{sd})	Maximum mean e.i.r.p.	Maximum peak e.i.r.p.	Minimum operational bandwidth	Duty Cycle per 500 MHz frequency bin per minute
7,125 GHz to 10,6 GHz	-34 dBm/MHz	-31,3 dBm/MHz	+10 dBm/50 MHz	500 MHz	≤ 25 %
NOTE 1: TRP_{sd} measured taking into account absorption of tissue and other materials inherent in use case. NOTE 2: Body worn includes devices that by design are operated in close proximity to the body.					

As demonstrated by Figure 11, higher, -31,3 dBm/MHz. EIRP is required to overcome the large path losses that occur between body worn devices. Figure 12 defines the configurations measured in Figure 11. Path losses of 90 dB are possible.

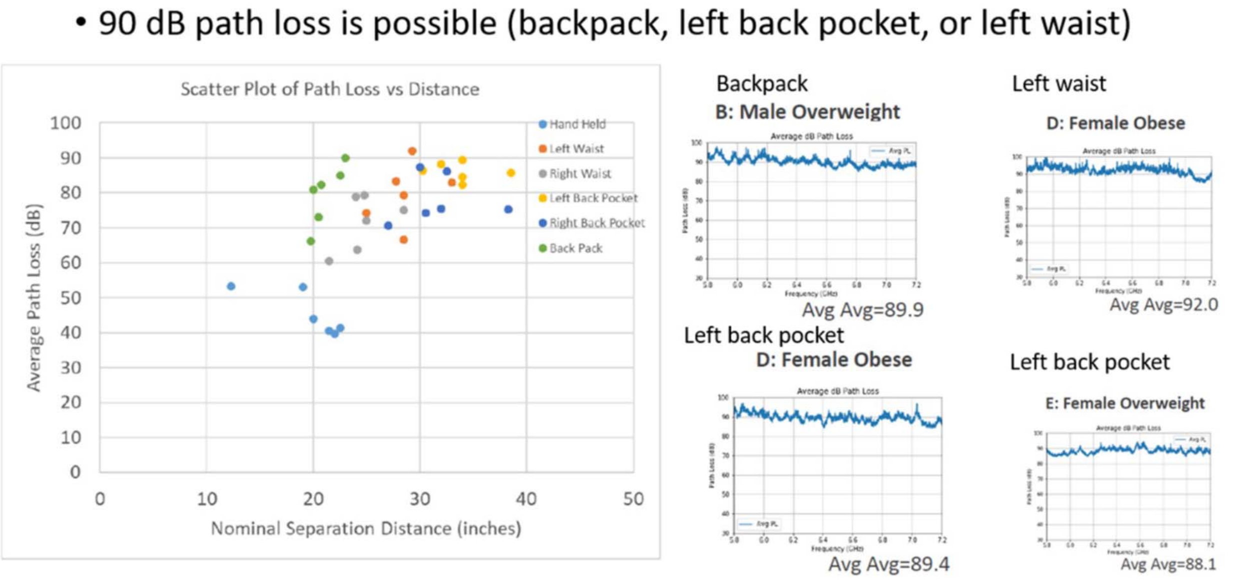


Figure 11: Body worn path loss measurements (Source: Meta)

Case No	Position	DUT1 Orientation	Antenna Position	Path Type
1	Hand Held	Vertical	Top	LOS
2	Left Waist	Horizontal	Bottom	NLOS
3	Right Waist	Horizontal	Top	PLOS
4	Left Back Pocket	Vertical	Top	NLOS
5	Right Back Pocket	Vertical	Top	PLOS
6	Back Pack	Horizontal	Bottom	NLOS

LOS	Line of Sight
NLOS	Non Line of Sight
PLOS	Partial Line of Sight

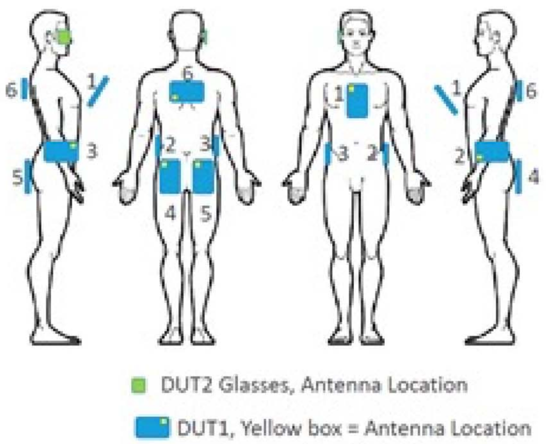


Figure 12: Body worn path loss measurement paths (Source: Meta)

The 500 MHz minimum channel bandwidth is required to support the 125 Mbps typical data rate in this challenging environment while maintaining a low EIRP density. In a typical use case, body worn devices require two channels to asynchronously interact. To support multiple users in the same household and allow for other uses of the band, and taking account of the maximum 25 % duty cycle, a minimum of six 500 MHz channels are required to mitigate channel blocking (impacting the user experience).

7.2.3 Indoor communication applications

The proposal is to develop a new regulation (in ECC/DEC(06)04 [i.9]) for indoor communication applications with the details in Table 17. A comparison with the existing limits is provided in clause 7..4.

Table 17: Proposed UWB regulation in the bands 8,5 GHz to 10,6 GHz for indoor communication applications

Frequency band	Total radiated power spectral density (TRP_{sd})	Maximum mean e.i.r.p.	Maximum peak e.i.r.p.	Minimum/typical operational bandwidth	Duty Cycle per 50 MHz frequency bin per minute
8,5 GHz to 10,6 GHz	-41,3 dBm/MHz	-31,3 dBm/MHz	10 dBm/50 MHz	500 MHz/1 GHz	≤ 1 %
NOTE: UWB devices operating under this rule should be capable of operating at least in the complete frequency band 6 GHz to 10,6 GHz in order to reduce the overall device density per 500 MHZ frequency bin.					

NOTE: This would cover the communication only use case.

7.2.4 Comparison with existing regulation

Table 18: Proposed UWB regulation in the bands 7,125 GHz to 10,6 GHz, indoor applications, comparison with existing regulation

Frequency band	Existing limits: maximum mean e.i.r.p.	Proposed limits in SRDoc: maximum mean e.i.r.p. Generic indoor	Proposed limits in SRDoc: maximum mean e.i.r.p. Body worn	Proposed limits in SRDoc: maximum mean e.i.r.p. Indoor communication
6,0 GHz to 7,125 GHz	-31,3 dBm/MHz (indoor only)	No change	No change	No change
7,125 GHz to 8,5 GHz	-31,3 dBm/MHz (indoor only)	No change	No change	No change
8,5 GHz to 9,0 GHz	-65 dBm/MHz -41,3 dBm/MHz with DAA	-41,3 dBm/MHz TRP_{sd} ≤ -46,3 dBm/MHz Indoor only DC ≤ 5 %	-31,3 dBm/MHz TRP_{sd} ≤ -34 dBm/MHz Indoor only/body worn DC ≤ 25 %	-31,3 dBm/MHz TRP_{sd} ≤ -36,3 dBm/MHz Indoor only DC ≤ 1 %

Frequency band	Existing limits: maximum mean e.i.r.p.	Proposed limits in SRDoc: maximum mean e.i.r.p. Generic indoor	Proposed limits in SRDoc: maximum mean e.i.r.p. Body worn	Proposed limits in SRDoc: maximum mean e.i.r.p. Indoor communication
		-31,3 dBm/MHz TRP_{sd} ≤ -36,3 dBm/MHz Indoor only DC ≤ 1 %		
9,0 GHz to 10,6 GHz	-65 dBm/MHz and 9,2 - 9,5 GHz and 9,5 - 9,975 GHz with 25mW each (ERC/REC 70-03, bands h and i of Annex 6) 10,5 GHz to 10,6 GHz with 500 mW (ERC/REC 70-03, bands j of Annex 6) for Radiodetermination	-41,3 dBm/MHz TRP_{sd} ≤ -46,3 dBm/MHz Indoor only DC ≤ 5 % -31,3 dBm/MHz TRP_{sd} ≤ -36,3 dBm/MHz Indoor only DC ≤ 1 %	-31,3 dBm/MHz TRP_{sd} ≤ -34 dBm/MHz Indoor only/body worn DC ≤ 25 %	-31,3 dBm/MHz TRP_{sd} ≤ -36,3 dBm/MHz Indoor only DC ≤ 1 %

7.3 Fixed outdoor

7.3.1 Generic fixed outdoor radio determination applications

This set of regulatory rules should cover the all radio sensing and radio location applications including "location and tracking" and material sensing and characterisation applications and monostatic radio determination (radar). The TRP_{sd} value could contain effects of the antenna gain and scenario related effects like absorption of a body and other materials. Monostatic radio determination applications will in general need higher band widths than 500 MHz.

The proposal is to develop a new regulation (in ECC/DEC(06)04 [i.9]) for fixed outdoor radio determination applications with the details in Table 19. A comparison with the existing limits is provided in clause 7.2.3.

Table 19: Proposed UWB regulation in the bands 8,5 GHz to 10,6 GHz, fixed outdoor radio determination

Frequency band	Total radiated power spectral density (TRP_{sd})	Maximum mean e.i.r.p.	Maximum peak e.i.r.p.	Minimum/typical operational bandwidth	Duty Cycle per 50 MHz frequency bin per minute
8,5 GHz to 10,6 GHz	-51,3 dBm/MHz	-41,3 dBm/MHz	0 dBm/50 MHz	0,5 GHz/1,5 GHz	≤ 5 %

The spectrum between 7,7 GHz and 9,3 GHz is actually foreseen for the worldwide aligned deployment for this systems with an midterm perspective to extend the upper frequency bound up to 10,6 GHz.

7.3.2 Infrastructure fixed outdoor radiodetermination applications

This set of regulatory rules should cover the radio location applications "location and tracking" under the control of a professional operator.

The proposal is to develop a new regulation (in ECC/DEC(06)04 [i.9]) for infrastructure fixed outdoor radio determination applications with the details in Table 20. A comparison with the existing limits is provided in clause 7.3.3.

Table 20: Proposed UWB regulation in the bands 8,5 GHz to 10,6 GHz, infrastructure fixed outdoor radiodetermination

Frequency band	Total radiated power spectral density (TRP_{sd})	Maximum mean e.i.r.p.	Maximum peak e.i.r.p.	Minimum/typical operational bandwidth	Duty Cycle per 50 MHz frequency bin per minute
8,5 GHz to 10,6 GHz	-51,3 dBm/MHz	-41,3 dBm/MHz	0 dBm/50 MHz	500 MHz/500 MHz	≤ 5 %
NOTE 1: UWB devices operating under this rule should be capable of operating at least in the complete frequency band 6 GHz to 10,6 GHz in order to reduce the overall device density per 500 MHz frequency bin. NOTE 2: Fixed outdoor UWB device operating under this rule should be under the control of professional operators.					

The spectrum between 7,7 GHz and 9,3 GHz is actually foreseen for the worldwide aligned deployment for this systems with an midterm perspective to extend the upper frequency bound up to 10,6 GHz.

7.3.3 Comparison with existing regulation

Table 21: Proposed UWB regulation in the bands 7,125 GHz to 10,6 GHz, fixed outdoor applications, comparison with existing regulation

Frequency band	Existing limits: maximum mean e.i.r.p.	Proposed limits in SRDoc: maximum mean e.i.r.p. Generic fixed outdoor	Proposed limits in SRDoc: maximum mean e.i.r.p. Infrastructure fixed outdoor
6,0 GHz to 7,125 GHz	-41,3 dBm/MHz (additional TRP_{sd} limit of -46,3 dBm/MHz)	No change	No change
7,125 GHz to 8,5 GHz	-41,3 dBm/MHz (additional TRP_{sd} limit of -46,3 dBm/MHz)	No change	No change
8,5 GHz to 9,0 GHz	N/A	-41,3 dBm/MHz TRP_{sd} ≤ -51,3 dBm/MHz DC ≤ 5 % Bandwidth ≥ 0,5 GHz	-41,3 dBm/MHz TRP_{sd} ≤ -51,3 dBm/MHz DC ≤ 5 %
9,0 GHz to 10,6 GHz	9,2 - 9,5 GHz and 9,5 - 9,975 GHz with 25 mW each (ERC/REC 70-03 [i.40], bands h and i of Annex 6) 10,5 GHz to 10,6 GHz with 500 mW (ERC/REC 70-03, bands j of Annex 6) for Radiodetermination	-41,3 dBm/MHz TRP_{sd} ≤ -51,3 dBm/MHz DC ≤ 5 % Bandwidth ≥ 0,5 GHz	-41,3 dBm/MHz TRP_{sd} ≤ -51,3 dBm/MHz DC ≤ 5 %

7.4 In-vehicle applications

7.4.1 New in-vehicle applications

This set of regulatory rules should material sensing and characterisation applications and passive radio determination (radar) applications installed internally of a vehicular. The TRP_{sd} value contains effects of the antenna gain and scenario related effects like absorption of materials and passengers. Passive radio determination applications will rather need higher band widths than 500 MHz.

The proposal is to develop a new regulation (in ECC/DEC(06)04 [i.9]) for in-vehicle radiodetermination applications with the details in Table 22. A comparison with the existing limits is provided in clause 7.4.2.

Table 22: Proposed UWB regulation in the bands 8,5 GHz to 10,6 GHz, in-vehicle applications

Frequency band	Total radiated power spectral density (TRP_{sd})	Maximum mean e.i.r.p.	Maximum peak e.i.r.p.	Minimum/typical operational bandwidth	Duty Cycle per 50 MHz frequency bin per minute
8,5 GHz to 10,6 GHz	-51,3 dBm/MHz	-41,3 dBm/MHz	0 dBm/50 MHz	500 MHz/1 GHz	≤ 5 %

7.4.2 Comparison with existing regulation

Table 23: Proposed UWB regulation in the bands 7,125 GHz to 10,6 GHz, in-vehicle applications, comparison with existing regulation

Frequency band	Existing limits: maximum mean e.i.r.p.	Proposed limits in SRDoc: maximum mean e.i.r.p. In-vehicle application
6,0 GHz to 7,125 GHz	-41,3 dBm/MHz DC ≤ 1 % max antenna heights ≤ 4 m	No change
7,125 GHz to 8,5 GHz	-41,3 dBm/MHz DC ≤ 1 % max antenna heights ≤ 4 m	No change
8,5 GHz to 9,0 GHz	N/A	-41,3 dBm/MHz TRP_{sd} ≤ -51,3 dBm/MHz DC ≤ 5 %
9,0 GHz to 10,6 GHz	9,2 - 9,5 GHz and 9,5 - 9,975 GHz with 25 mW each (ERC/REC 70-03 [i.40], bands h and i of Annex 6) 10,5 GHz to 10,6 GHz with 500 mW (ERC/REC 70-03 [i.40], bands j of Annex 6) for Radiodetermination	-41,3 dBm/MHz TRP_{sd} ≤ -51,3 dBm/MHz DC ≤ 5 %

Annex A: *TRP* and *TRP*sd considerations

A.1 Introduction

UWB devices are mainly highly integrated and therefore UWB devices does not provide an antenna connector and therefore the emissions could only be measured radiated.

The highly integration as several reason, e.g.:

- size of the device based on the intended use (handheld/mobile)
- or the integration into another device (combined device/hitting mounting)
- to reach a good antenna matching over the large OFR

But from the regulatory perspective a limitation of the transmitter output power would be welcome.

Therefore, there is a need to specify a requirement to limit the TX-output power on the one side but this requirement is assessable via radiated test. This real radiated power is also the power which could cause interference to other radio devices.

For those reasons a limitation of the Total Radiated Power (TRP) or better the Total Radiated Power Spectral Density (TRP_{sd}) could the requirement for UWB devices.

A.2 Definition Total Radiated Power (*TRP*)

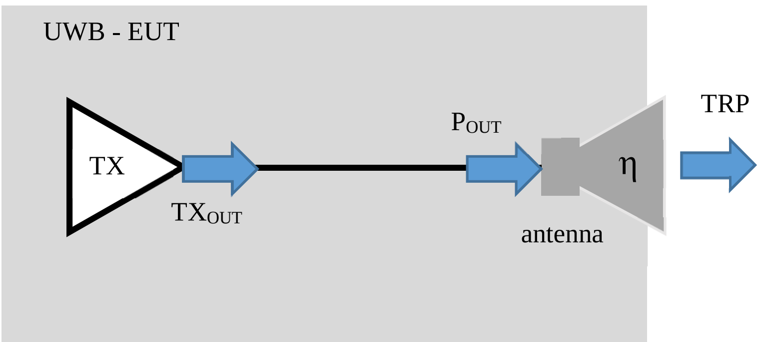
Total Radiated Power (TRP) is a Radio Frequency (RF) engineering term used to describe the sum of all power radiated by an antenna connected to a transmitter. Total Radiated Power is closely related to the efficiency of the antenna, and is in fact tied to the definition of efficiency.

In Figure A.1 below the relation between TX output power (P_{TX}) and TRP is shown:

- TRP is the radiated Output Power, or P_{out}.
- TX_{out} is the transmitter output power.
- Antenna efficiency (η) of the antenna, is the ratio of output power to input power.

With:

- TRP is expressed in terms of power: Watts (W), milliwatts (mW), or the logarithmic terms for W and mW (dBW and dBm).
- Antenna efficiency is expressed either in percentage or dB.



$$\eta = \frac{TRP}{P_{OUT}} \qquad (A.1)$$

Figure A.1: Relation TRP with Transmitter output power (TXout)

In reality there will be some losses between the transmitter output and the radiated power, and therefore the transmitter output is higher than the real radiation. These losses are expressed by the antenna efficiency η. For simplification (worst case) these losses will be set to zero and it is assumed that the antenna has an efficiency of 100 %, η = 1. This leads to the following simplified relation, see equation (A.2):

$$TRP = P_{OUT} = TX_{OUT} \qquad \text{(A.2)}$$

An additional relation of the TRP could also be given with the antenna directivity/antenna gain. This would also allow to specify/regulate a minimum antenna gain in the regulation.

In case the directivity D of the transmit antenna including all surrounding parts is known, the TRP derives from the radiation e.i.r.p. the following way, see equation (A.3):

$$TRP = \frac{e.i.r.p}{D} \qquad \text{(A.3)}$$

Where e.i.r.p. means the complete radiated power in all directions.

As an example in Figure A.2 the directivity is 9,3 dBi and the 0 dBi circle represents the TRP. As an example for an e.i.r.p. of -55,7 dBm/MHz the TRP derives to -65 dBm/MHz. For a lossless antenna the gain G equals the directivity D. This example is taken from ETSI TR 103 181-2 [i.14].

For real antennas the gain equals, see equation (A.4)

$$G = \eta \cdot D \qquad \text{(A.4)}$$

where η is the efficiency of the antenna.

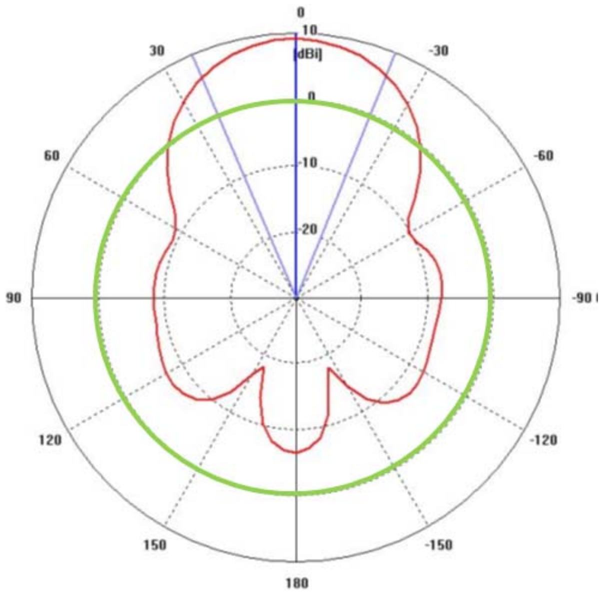
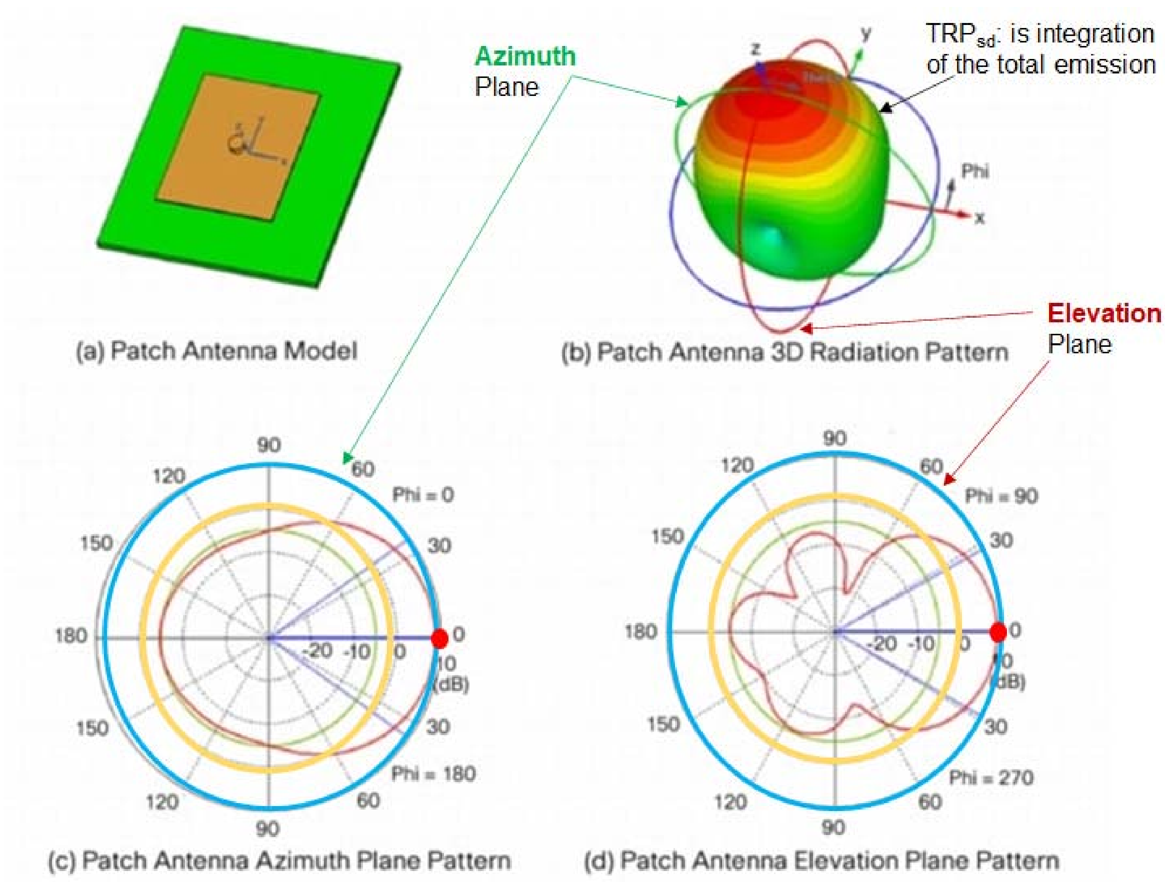


Figure A.2: Example radiation pattern of an antenna in free-space with a directivity of D = 9,3 dBi

An additional example is shown in Figure A.3 which is for an 10 dBi patch antenna.



Blue circle: max regulated limit: mean power spectral density of -41,3 dBm/MHz (+ 0 dBm/50 MHz peak)
Red curve: max real emission of the device: mean power spectral density of:
- 41,3 dBm/MHz + 0 dBm/50 MHz peak
Red dot: point where the device reaches the max regulated limit (worst case assumption)
Orange line: calculated TRP_{SD} value → 10 dB below the max emission → -51,3 dBm/MHz

Figure A.3: Connection between Total Radiated Power Spectral Density (TRP_{SD}) and Antenna Gain of 10 dBi

A.3 TRP assessment based on radiated (e.i.r.p.) measurement

The Total Radiated Power of the EUT is the integration of the time-averaged power flux density S of the EUT emissions across the entire spherical surface enclosing the EUT. The result of this measurement is the effective radiated TX power taking into account the antenna efficiency

Measuring the electric field strength, the average power flux density is given by equation (A.5):

$$S = \frac{|E_{RMS}|^2}{Z_{F0}} \quad \text{(A.5)}$$

Where:

$Z_{F0} = 120\pi\Omega$ **represents the wave impedance of free space.**

The RMS value of the field strength can be obtained using equation (A.6):

$$E_{RMS} = \frac{|E|^2}{\sqrt{2}} \quad \text{(A.6)}$$

Where:

$|E|$ **is the amplitude of the electric field.**

Using a spectrum analyser, the power flux density is given by equation (A.7):

$$S = \frac{P_r}{A_r} \quad \text{(A.7)}$$

Where:

P_r **is the radiated power of the EUT in a certain direction; and**

A_r **is the effective area of the receiving antenna.**

The Total Power is then given by equation (A.8), see Figure A.4:

$$\mathrm{TRP} = \int_{\Theta=0}^{\pi} \int_{\Phi=0}^{2\pi} \mathrm{S} \times \mathrm{r}^2 \times \sin(\Theta)\, \mathrm{d}\Theta\, \mathrm{d}\Phi \quad \text{(A.8)}$$

Where:

- r is the radius of the sphere
- Θ is the elevation angle
- Φ is the azimuth angle

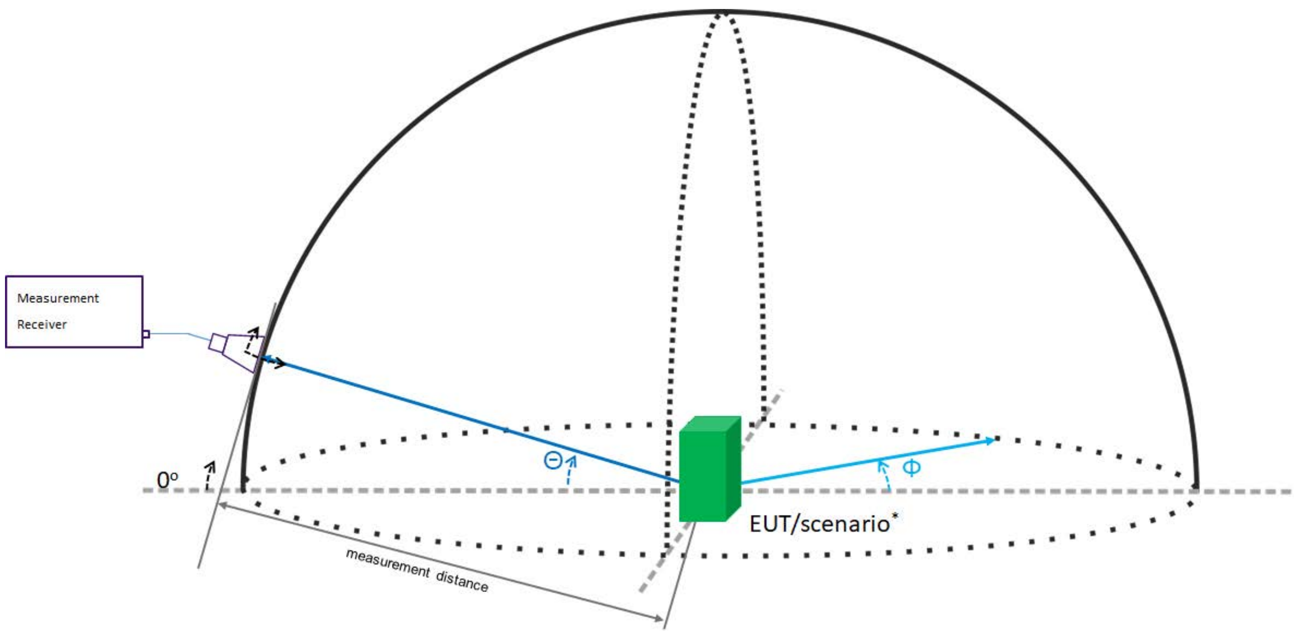
and with the measured radiated emissions (e.i.r.p.) see equation (A.9)

$$\mathrm{TRP} = \int_{\Theta=0}^{\pi} \int_{\Phi=0}^{2\pi} \frac{P_{\Theta,\Phi}}{A_r} \times \mathrm{r}^2 \times \sin(\Theta)\, \mathrm{d}\Theta\, \mathrm{d}\Phi \quad \text{(A.9)}$$

Where:

- Radiated emission $P_{\Theta,\Phi}$ measurement (recorded) one point of the sphere depending Θ and Φ
- r is the radius of the sphere/measurement distance
- Θ is the elevation angle
- Φ is the azimuth angle
- A_r is the effective area of the receiving antenna (measurement antenna)

A more detailed assessment procedure is described in ETSI EN 303 883-1, clause 5.6.2 [i.1].



* EUT/scenario: could be a single device or a complex scenario (e.g. indirect emissions, see ETSI EN 303 883 -1 [i.1], clause 5.7).

Figure A.4: Azimuth and Elevation angle definition

More details on TRP measurement and background information are provided in [i.23] and [i.24].

A.4 TRP spectral density

Based on the huge bandwidth of an UWB signal (OFR) the emission limits given in the UWB decisions and recommendation are specified as maximum mean e.i.r.p. spectral density limits in 1 MHz. This represent the maximally allowed radiated spectral density at any frequency in one direction. This value is given in dBm/MHz. In order to have an equivalent limitation of the overall radiated power in 1 MHz a TRP spectral density value, TRP_{sd}, is defined as:

$$\mathrm{TRP}sd = \int_{\Theta=0}^{\pi} \int_{\Phi=0}^{2\pi} \frac{P_{\mathrm{psd},\Theta,\Phi}}{A_r} \times \mathrm{r}^2 \times \sin(\Theta)\, \mathrm{d}\Theta\, \mathrm{d}\Phi \qquad \text{(A.10)}$$

Where:

- Radiated mean power spectral density $P_{\mathrm{psd},\Theta,\Phi}$ measurement in 1 MHz (recorded) one point of the sphere depending Θ and Φ and frequency
- r is the radius of the sphere/measurement distance
- Θ is the elevation angle
- Φ is the azimuth angle
- A_r is the effective area of the receiving antenna (measurement antenna)

Based on that the $\boldsymbol{P_{\mathrm{psd},\Theta,\Phi}}$ is specified to be measured with angular steps delta Θ and delta Φ a value of 15 degrees, see [i.9] and [i.11] the $\boldsymbol{TRP_{\mathrm{sd}}}$ can be calculated:

$$\boldsymbol{TRP_{sd}} = \sum_{\Theta=0}^{\pi} \sum_{\Phi=0}^{2\pi} \boldsymbol{PSD}\ \Delta\Theta\Delta\Phi \qquad \text{(A.11)}$$

Where:

- PSD is the measured and recorded mean power spectral density $P_{\mathrm{psd},\Theta,\Phi}$ (e.i.r.p.) at the sphere around the EUT (on the angular steps delta Θ and delta Φ).

To assess the *TRP* value of the emission there is the option to integration the TRP_{sd} over the OFR of the TX-signal.

The specification of an TRP_{sd} requirement is more realistic and efficient. For an UWB device it is impossible to specify an antenna gain over the complete OFR. The antenna gain could vary over the OFR and therefore it is based on the technical point of view and the interference assessment better to consider the *TRP* in smaller ranges (1 MHz). With this TRP_{sd} requirements a minimum antenna gain over the OFR could be guaranteed.

A.5 Summary and conclusions

A *TRP* requirement is in comparison with the TX output power a more stringent requirement to limit the total radiated emission. In addition the *TRP* and the *TRP* spectral density requirements offer the possibility to specify a minimum antenna gain/directivity of the EUT and is easy to measure. Furthermore, the TRP spectral density can be used in SEAMCAT simulations to model the effect of different radiations directions in a aggregated interference scenario.

A UWB device could be regulated as follows:

1) Max mean and peak power spectral density:

   a) Max e.i.r.p. mean power spectral density of: - XX dBm/MHz

   b) Max e.i.r.p. power density of: - YY dBm/50 MHz

and

2) limit the TRP_{sd} mean spectral density and thus implicitly request a minimum antenna gain:

   - TRP_{sd} of ZZ dBm per bandwidth (either based on peak with 50 MHz or mean density with 1 MHz measurement)

   - TRP_{sd} = max density (e.i.r.p.) - minimum antenna gain requirement

Annex B: Overview UWB regulations and standards

Ultra-wide Band 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 summarised in ETSI TR 103 181-1 [i.15].

Table B.1: Overview of UWB applications, as resulting from ETSI standards and current EU regulations

Type of application	Description	Remark/ Application classification
Generic	Non-specific, generic consumer applications.	
Location & Tracking	• Localization of object in a range gate. • Tracking of target movements within the detection range. • Sensor tracking technology for end user applications. • Indoor tracking applications covered by FCC regulation and ECC UWB decision. • Localization of persons and objects in emergency areas.	Radiodetermination: Radio Location applications
Automotive & railway	• Sensing or communication application, intended for usage related to road and rail vehicles, and namely: – stand-alone radio equipment with or without its own control provisions, mounted in road or rail vehicles. – plug-in radio devices intended for use with, or within, a variety of host systems, e.g. personal computers, etc. – plug-in radio devices intended for use within combined equipment, e.g. modems, access points, etc. – equipment for the communication inside and outside of road and rail vehicles. • Equipment for the localization of devices inside and outside of road and rail vehicles, e.g. hand-held devices.	Radiodetermination: Sensing application communication applications
Concrete inspections & imaging	• Imaging systems based on field disturbance sensors, designed to operate only in close proximity or even in contact with the ground or wall or other concrete structures, for the purpose of detecting or obtaining images of buried objects or determining the physical properties within the structure. The energy from these sensors is intentionally directed into the material to be analysed, as such the majority of the signal transmitted by the sensor is absorbed.	Radiodetermination: Sensing application

Type of application	Description	Remark/ Application classification
Material sensing devices, fixed or mobile	• Devices enabling radiodetermination applications designed to detect the location of objects within a structure or to determine the physical properties of a material. This may include localization of hidden targets in construction e.g. pipes, holes, wires for increased safety while e.g. drilling, construction testing, or characterization of material, e.g. metal, plastic, or humidity, sensors which could be attached/integrated in tooling equipment and, and namely: – Building Material Analysis (BMA), i.e. devices designed to detect the location of objects within a building structure or to determine the physical properties of a building material. – Object Discrimination and Characterization (ODC) devices, allowing the identification and classification of objects (including human tissue) in addition to detecting their presence and position. The operation is contactless and works over a short distance of less than 40 cm, even if the object is hidden by an obstacle. – Ground Probing Radars (GPR) radiating directly downwards into the ground, such that any horizontal radiation from this equipment is considered as undesired emission. • Wall Probing Radars (WPR) radiating directly into a "wall", where the "wall" is a building material structure, the side of a bridge, the wall of a mine or another physical structure that absorbs a significant part of the signal transmitted by the radar.	Radiodetermination: Sensing application
Level probing radars	• Level probing sensors, that may radiate in free space (LPR), concerned with process control, to measure the amount of various substances (mostly liquids or granulates) having the main purposes of: – to increase reliability by preventing accidents; – to increase industrial efficiency, quality and process control; – to improve environmental conditions in production processes. • Level probing sensors installed in closed tanks made of strong attenuating RF material (TLPR), holding a substance, liquid or powder, that cannot radiate outside of their container.	Radiodetermination: Sensing application
Airborne applications	• Cabin Management System (CMS) application field. • Passenger communication and in-flight entertainment. • Mobile devices (also by passengers) which will become part of the future cabin equipment. • Communication headsets for pilots in the cockpit and for the flight crew.	Communication Applications

These applications are defined in official documents delivered by ETSI and CEPT. A more detailed overview of the published UWB standards, as well as related ETSI framework and status in the standards process, are listed in Table B.2. Table B.3 gives an overview over the ETSI Harmonized Standards in preparation at the time of preparation of the present document.

Table B.2: Overview ETSI Standards, published

Type	Application	Frequency Ranges [GHz]	ETSI Standard	Status	Remark	Responsible ETSI TC ERM
Generic	Non-specific consumer or professional applications	3,1 to 4,8 6 to 9	ETSI EN 302 065-1 [i.2]	ETSI Published 11-2016	RED compliant	TG UWB
Location & Tracking	Location Tracking Type 1 (LT1)	6 to 9	ETSI EN 302 065-2 [i.3]	ETSI Published 11-2016	RED compliant	TG UWB
	Location Tracking Type 2 (LT2)	3,1 to 4,8	ETSI EN 302 065-2 [i.3]	ETSI Published 11-2016	RED compliant	TG UWB
	Location Application for emergency Services (LAES)	3,1 to 4,8	ETSI EN 302 065-2 [i.3]	ETSI Published 11-2016	RED compliant	TG UWB
Automotive & railway	Automotive and railway	3,1 to 4,8 6 to 9	ETSI EN 302 065-3 [i.4]	ETSI Published 11-2016	RED compliant	TG UWB
	Location Tracking for automotive & transportation environment (LTT)	3,1 to 4,8 6 to 8,5	ETSI EN 302 065-3 [i.4]	ETSI Published 11-2016	RED compliant	TG UWB
Concrete inspections & imaging	Professional Ground and Wall Probing Radars (GPR-WPR)	0,030 to 12,4	ETSI EN 302 066 [i.6]	Published 06-2020		
Material sensing devices	Building Material Analysis (BMA)	2,2 to 8,5	ETSI EN 302 065-4 [i.5]	ETSI published 11-2016	New version	
	Object Discrimination and Characterization (ODC)	2,2 to 8,5	ETSI EN 302 065-4 [i.5]	Published 06-2010		
	Object Identification for Surveillance Applications (OIS)	2,2 to 8	ETSI TR 102 495-3 [i.16]	Stopped		
Level probing radars	Tank Level Probing Radar (TLPR)	4,5 to 7 8,5 to 10,6 24,05 to 27 57 to 64 75 to 85	ETSI EN 302 372 [i.7]	Published 12-2016		Former TG TLPR Now TG UWB
	Level Probing Radars (LPR)	6,0 to 8,5 24,05 to 26,5 57 to 64 75 to 85	ETSI EN 302 729 [i.8]	Published 05-2011		Former TG TLPR Now TG UWB
Onboard aircraft	Devices using UWB technology onboard aircraft	6,0 to 6,650 6,6752 to 8,5	ETSI EN 302 065-5 [i.42]	Published 09-2017		

Table B.3: Overview ETSI Standards, in preparation as of April 2022

Type	Application	Frequency Ranges [GHz]	ETSI Standard	Status	Remark	Responsible ETSI TC ERM
Generic	Generic UWB Communication	3,1 to 4,8 6 to 9	ETSI EN 302 065-1-1 [i.42]	Early Draft		TG UWB
	Generic UWB presence detection applications	3,1 to 4,8 6 to 9	ETSI EN 302 065-1-2 [i.42]	Early Draft		TG UWB
	Generic UWB through-air non-contact vital signs	3,1 to 4,8 6 to 9	ETSI EN 302 065-1-3 [i.42]	Start of work		TG UWB
Location & Tracking	UWB tracking 6 - 8,5 GHz	6 to 8,5	ETSI EN 302 065-2-1 [i.42]	Early Draft		TG UWB
	UWB tracking 3,1- 4,8 GHz	3,1 to 4,8	ETSI EN 302 065-2-2 [i.42]	Start of work		TG UWB
	UWB DAA tracking 3,1 - 4,8 GHz	3,1 to 4,8	ETSI EN 302 065-2-3 [i.42]	TB adoption of WI		
Automotive & railway	UWB keyless entry	3,1 to 4,8 6 to 8,5	ETSI EN 302 065-3-1 [i.42]	Draft Review after PE		TG UWB
	Requirements for location tracking devices installed in rail and road vehicles	3,1 to 4,8 6 to 8,5	ETSI EN 302 065-3-2 [i.42]	TB adoption of WI		TG UWB
	Requirements for location tracking devices installed in rail and road vehicles	3,1 to 4,8 6 to 8,5	ETSI EN 302 065-3-3 [i.42]	TB adoption of WI		TG UWB
Material sensing devices	Building Material Analysis (BMA)	2,2 to 8,5	ETSI EN 302 065-4-1 [i.42]	Draft Review after PE		TG UWB
	UWB Material Sensing devices for Security Scanning		ETSI EN 302 065-4-2 [i.42]	Start of work		TG UWB
	ground humidity and condition sensor		ETSI EN 302 065-4-3 [i.42]	Early Draft		TG UWB
	UWB external vehicular sensors		ETSI EN 302 065-4-4 [i.42]	In ENAP		TG UWB
	parking lot sensor		ETSI EN 302 065-4-5 [i.42]	Start of work		TG UWB

Annex C: Bibliography

- ETSI TR 103 086 (V1.1.1) (03-2013): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Conformance test procedure for the exterior limit tests in ETSI EN 302065-3 UWB applications in the ground based vehicle environment".
- ECC Report 167 (May, 2011): "The Practical Implementation of Registration/Coordination Mechanism for UWB LT2 (Location Tracking Type 2) Systems".
- CEPT/ECC Report 64: "The protection requirements of radiocommunications systems below 10,6 GHz from generic UWB applications", Helsinki, February 2005.
- CEPT Report 34: "Report B from CEPT to European Commission in response to the Mandate 4 on Ultra-Wideband (UWB); Final Report on 30 October 2009 by the Electronic Communications Committee (ECC) within the European Conference of Postal and Telecommunications Administrations (CEPT)".
- Commission Decision 2007/131/EC of 21 February 2007 on allowing the use of the radio spectrum for equipment using ultra-Wide Band technology in a harmonised manner in the Community (notified under document number C(2007) 522).
- ETSI TS 102 754 (V1.3.1) (03-2013): "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".
- ERC Recommendation 74-03 (2011): "Unwanted Emissions in the Spurious Domain", Cardiff.
- ECC Report 235 (May 2015): "Assessment of the feasibility of the possible joint use, on a long term basis, of the adjacent bands 5925-6425 MHz and 6425-7125 MHz for P-P links".
- ETSI TR 103 181-3 (V1.1.1) (08-2016): "Short Range Devices (SRD) using Ultra Wide Band (UWB); Part 3: Worldwide UWB regulations between 3,1 and 10,6 GHz".
- 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"; Report approved on 21 June 2013 by the ECC. .
- Commission Decision 2009/343/EC of 21 April 2009 amending Decision 2007/131/EC on allowing the use of the radio spectrum for equipment using ultra-wideband technology in a harmonized manner in the Community (notified under document number C(2009) 2787) (Text with EEA relevance).
- ECC Recommendation (11)09 on UWB Location Tracking Systems Type 2 (LT2), October 2011.
- ECC Recommendation (11)10 on Location Tracking Application for Emergency and Disaster Situations, October 2011.
- ECC Reports 94: "Technical requirements for UWB LDC devices to ensure the protection of FWA System", Nicosia, December 2006.
- ETSI TR 103 416 (V1.1.1) (07-2016): "System Reference document (SRdoc); Short Range Devices (SRD) using Ultra Wide Band (UWB); Technical characteristics and spectrum requirements for UWB based vehicular access systems for operation in the 3,4 GHz to 4,8 GHz
- ETSI TS 103 060 (V1.1.1) (09-2013): "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".
- ECC Reports 175 (March 2012): "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".

- CEPT report 17 (30 March 2007): "Report from CEPT to the European Commission in response to the Mandate to: identify the conditions relating to the harmonised introduction in the European Union of radio applications based on ultra-wideband (UWB) technology".
- ECC Reports 139 (February 2010): "Impact of level probing radars using Ultra-Wideband technology on radiocommunications services", Rottach-Egern.
- ECC Report 123 (September 2008): "The impact of object discrimination and characterization (ODC) applications using ultra-wideband (UWB) technology on radio services", Vilnius.
- ETSI TR 102 495-7 (V1.1.1) (03-2010): "Electromagnetic compatibility and Radio spectrum Matters (ERM); System Reference Document; Short Range Devices (SRD); Technical characteristics for SRD equipment using Ultra Wide Band Sensor technology (UWB); Part 7: Location tracking and sensor applications for automotive and transportation environments
- ETSI EN 301 091-3: "Short Range Devices; Transport and Traffic Telematics (TTT); Radar equipment operating in the 76 GHz to 77 GHz range; Harmonised Standard covering the essential requirements of article 3.2 of Directive 2014/53/EU; Part 3: Railway/Road Crossings obstacle detection system applications".
- IEEE 802.15.4-2011™: "IEEE Standard for Local and metropolitan area networks -- Part 15.4: Low-Rate Wireless Personal Area Networks (LR-WPANs)".
- Michal M. Pietrzyk, Thomas von der Grün: "Ultra-wideband Technology-based Ranging Platform with Real-time Signal Processing", Proceedings of 4th ICSPCS, 2010.
- Michael Tüchler, Volker Schwarz, Alexander Huber: "Accuracy of an UWB localization system based on a CMOS chip", Proceedings of the 2nd WPNC, 2005; pp. 211 .
- Duje Čoko, Zoran Blažević and Ivan Marinović: "Effects of Bandwidth on Estimation of UWB Channel Parameters" Novel Trends - Antennas and Propagation, August 2011, InTech Pub., Chapter 5, pp. 97-116.
- "The Future of the Automotive Experience with UWB", NXP blog from Markus Staeblein, December 3, 2020, (Link date 12.12.2022).

History

Document history		
V1.1.1	April 2023	Publication