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**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

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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).

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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.

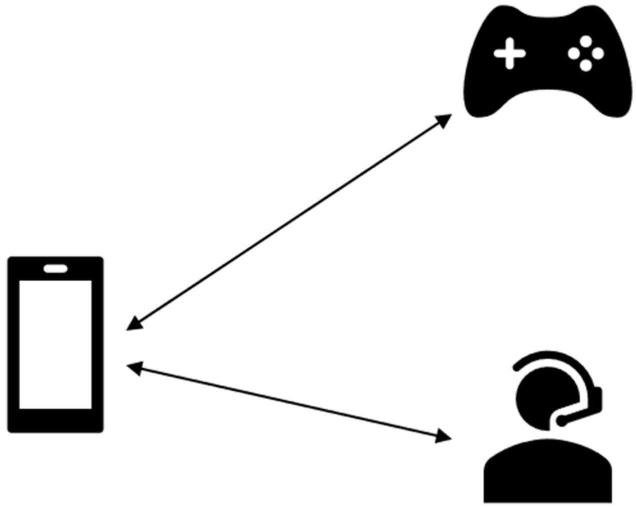

Figure 1: Bidirectional data-transfer

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