ETSI TR 103 862 V1.1.1 (2024-02)

TECHNICAL REPORT

System Reference document (SRdoc);
Short Range Devices (SRD) using Ultra Wide Band (UWB);
Technical characteristics for UWB operation of
fixed infrastructure based indoor localization systems
in the frequency band between 4,2 GHz to 4,8 GHz

Reference

DTR/ERM-612

Keywords

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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 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-wideband technologies enable a very broad set of applications:

- Sensor and imaging applications.
- Communication applications.
- Hybrid application as a combination of sensor and communications.

The present document will provide information on selected fixed installed indoor localization system scenarios, in the 4,2 GHz to 4,8 GHz band, where the main focus is on operation with a 10 dB increased power level in a specific UWB radio channel with the centre frequency at 4 492,8 MHz and an operational bandwidth of 499,2 MHz.

It will also provide an overview over the relevant possible mitigation techniques and system parameters to compensate for the increased power level and protect legacy services in the band of operation of such systems.

The information in the present document will complement and extend the information included in ETSI TR 102 495-7 [i.12] (V1.2.1), ETSI TR 102 495-5 [i.17] (V1.2.1), ETSI TR 102 496 [i.18] (V2.1.1) and ETSI TR 103 314 [i.19] (V1.1.1).

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

1 Scope

The present document provides information on fixed installed indoor localization UWB systems operating between 4 200 and 4 800 MHz with a power level of -31,3 dBm/MHz e.i.r.p. spectral density. The frequency range was selected to allow the use of IEEE Std 802.15.4 [i.13], channel 3, (centre frequency 4 492,8 MHz, operating bandwidth 499,2 MHz).

The present document also provides an overview over the relevant possible mitigation techniques and system parameters to compensate for the increased power level and to protect legacy radio services.

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 (V1.1.1): "Short Range Devices (SRD) using Ultra Wide Band (UWB); Measurement Techniques".

[i.2] ETSI EN 302 065-1 (V2.1.1): "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): "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): "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): "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] CEPT ECC/DEC/(06)04 of 24 March 2006 amended 9 December 2011: "The harmonised conditions for devices using Ultra-Wideband (UWB) technology in bands below 10.6 GHz".

[i.7] ECC Report 170 (October, 2011): "ECC Report on 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.8] 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.9] ETSI EN 302 066 (V2.1.1): "Short Range Devices (SRD); Ground- and Wall- Probing Radar applications (GPR/WPR) imaging systems; Harmonised Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU".

[i.10] ETSI EN 302 372 (V2.1.1): "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.11] ETSI EN 302 729 (V2.1.1): "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.12] ETSI TR 102 495-7 (V1.1.1): "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 operating in the frequency bands from 3,1 GHz to 4,8 GHz and 6 GHz to 8,5 GHz".

[i.13] IEEE Std 802.15.4™: "IEEE Standard for Low-Rate Wireless Network".

[i.14] IEEE Std 802.15.4z™: "IEEE Standard for Low-Rate Wireless Network. Amendment1: Enhanced Ultra-Wideband (UWB) Physical Layers (PHYs) and Associated Ranging Techniques".

[i.15] "Omlox-core-zone-spec-20122-V211-Apr23". Prepared by Profibus International Working Group PG3 "Core Zone" in Committee D "omlox".

[i.16] ETSI TR 102 495-7(V1.2.1): "ETSI TR 102 495-7 (V1.2.1): "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 operating in the frequency bands from 3,1 GHz to 4,8 GHz and 6 GHz to 8,5 GHz".

[i.17] ETSI TR 102 495-5 (V1.2.1): "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 5: Location tracking applications type 2 operating in the frequency bands from 3,4 GHz to 4,8 GHz and from 6 GHz to 8,5 GHz for person and object tracking and industrial applications".

[i.18] ETSI TR 102 496 (V2.1.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); System Reference Document; Short Range Devices (SRD); Technical characteristics for Location tracking Applications for Emergency Services (LAES) in disaster situations operating within the frequency range from 3,4 GHz to 4,8 GHz".

[i.19] ETSI TR 103 314 (V1.1.1): "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.20] ECC Report 64: "The protection requirements of radiocommunications systems below 10,6 GHz from generic UWB applications".

[i.21] ECC Report 278: "Specific UWB applications in the bands 3.4-4.8 GHz and 6.0-8.5 GHz: Location tracking and sensor applications (LTA) for vehicular access systems".

3 Definitions of terms, symbols and abbreviations

3.1 Terms

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

activity factor: reflects the effective transmission time ratio

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

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

range resolution: ability to resolve two targets at different ranges

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 TR 103 181-2 [i.8] apply.

3.3 Abbreviations

For the purposes of the present document, the abbreviations defined in ETSI TR 103 181-2 [i.8] apply.

4 Comments on the System Reference document

4.1 Statements by ETSI Members

No statements or comments have been issued by ETSI members.

5 Presentation of fixed infrastructure based indoor localization application requiring the power level of -31 dBm/MHz

5.1 Background information

In industrial environments, precise localization has been a long-lasting problem. No GPS signal could be picked, while obstructions and reflections made conventional radio helpless.

Since a few years though, precise and reliable positioning solutions have emerged, that leverage the use of Ultra-wideband radio and in particular the possibility to enable ranging algorithms designed for the time domain. Such algorithms have proven to be extremely efficient for the handling of multipath propagation effects in particular. Figure 1 below shows a signal captured in a real-life environment where the direct path, although attenuated, is preferred over stronger energy samples based on their ranking over the time axis.

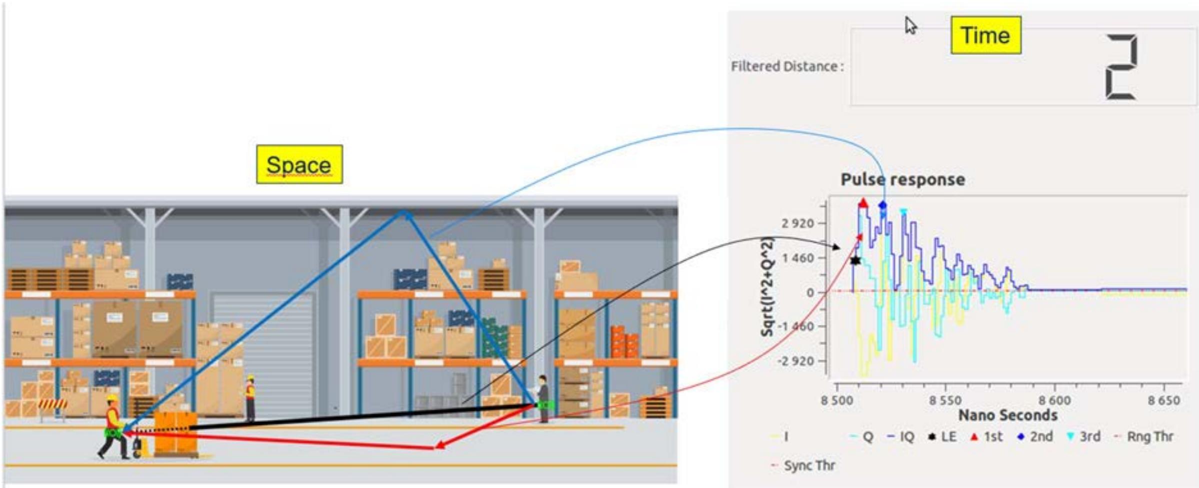

Figure 1: Time domain sampling (Source: STMicroelectronics N.V.)

The wide adoption of UWB radio in industrial settings has given birth to an initiative called *omlox*, gathering a large number of major industrial groups, mostly European. They have defined together a unified way to offer indoors location tracking and issued a first generation of specifications in June 2020. A third revision of the omlox core zone UWB based air interface specification was published in April 2023 [i.15]. This approach is viewed as an important milestone on the road towards Industry 4.0, Digital Twins and Smart Factories in Europe.

When deploying UWB localization solutions indoors, it is necessary to install fixed anchors, sometimes called satellites, quite rightfully as they replicate the main principles of GPS satellites by achieving a certain level of synchronization. Anchors are usually installed in high positions, in order to maximize their range and minimize the direct path obstructions.

Figure 2: Typical industrial hall, height 18 m and width 32 m, with cranes blocking the LoS (Source: Trumpf Tracking Technologies GmbH)

In order to foster the deployment of such solutions, UWB solution providers have tried to maximize the range of their hardware. For this very reason, the omlox initiative has opted for a basic operating frequency at 4,5 GHz, where attenuation is much lower than in other frequencies, like 6,5 GHz or 8 GHz. This choice was submitted to votes within omlox in 2 occasions, and unanimous decision was made twice to adopt this frequency.

An transmission output power of -31,3 dBm/MHz at the 4,5 GHz frequency (IEEE Std 802.15.4 [i.13], UWB channel 3, 500 MHz wide) results in a theoretical total mean transmission output power of as low as -4 dBm. This parameter value is an increase of 10 dB compared to existing regulation, which were released with ultra-low emission limits in a very conservative first regulatory step. Allowing an update of the emission limits to -31 dBm/MHz, which is still extremely low compared to other radio systems, would improve the link budget and allow a significant higher positioning reliability as well as enabling the deployment of indoors localization systems for application areas, where it is not yet possible to deploy due to harsh environment and large scale building geometries constraints. The affordable deployment of standardized indoor localization systems inside European factories would ultimately result in several advantages in terms of Safety at work, Operator productivity, Logistics, and Intralogistics efficiency, to name a few only.

The omlox initiative hosts a requirement working group that has identified around 120 use cases where UWB indoor localization would be a key factor of competitivity for the European Industry.

In the next sections, it will be demonstrated in detail how allowing -31,3 dBm/MHz in UWB channels at 4,5 GHz in European industrial estates will help to save lives, to increase competitiveness and to smoothen logistics operations.

The following applications of indoors localization are just a subset of the use cases and examples of the benefits brought by precise and reliable industrial grade real time UWB indoor localization systems to the European economy.

5.2 Application 1 - Safety: collision prevention

5.2.1 General

Modern warehouses and workshops are operated by a mix of Autonomously Guided Vehicles (AGV), manned forklifts & trucks, as well as pedestrians.

Industrial wards are often noisy, and crowded with racks that obstruct the sight of engine drivers. These conditions lead to a number of casualties that are not in line with the expectations of our modern society. Several options have been explored to reduce accidents, in particular the reduction of vehicle speed, but they are seldomly compatible with the yield expected from a modern factory or logistics environment.

Recent initiatives have focused on tracking engines and people in industrial estates. For engines, laser-based SLAM system (simultaneous location and mapping) can be efficient in static environments, where reliable landmarks can be mapped. This solution has unfortunately several shortcomings:

1) In open places where pallets are temporarily stored, SLAM is inoperant.

2) Laser scanners cannot be fitted on pedestrians, and the most important part of the jigsaw is still missing.

UWB based radio tracking on the other hand allows to overcome those issues and offers an extremely efficient solution both in terms of accurate positioning and real-time collision-avoidance support. The omlox specification, for example, is defining an operation mode where a score of vehicles can be tracked at 8 Hz, while several dozens of pedestrians may be tracked at 4 and 8 Hz with high reliability.

Figure 3 shows an illustrated map of a medium-size logistic centre in the south of France is provided. It is made of open spaces where pallets are stored temporarily, and aisles of racked shelves where they may be stored. The dimensions of such a place are quite significant. In order to achieve safety, the UWB radio has to work reliably over the full area and under all conditions.

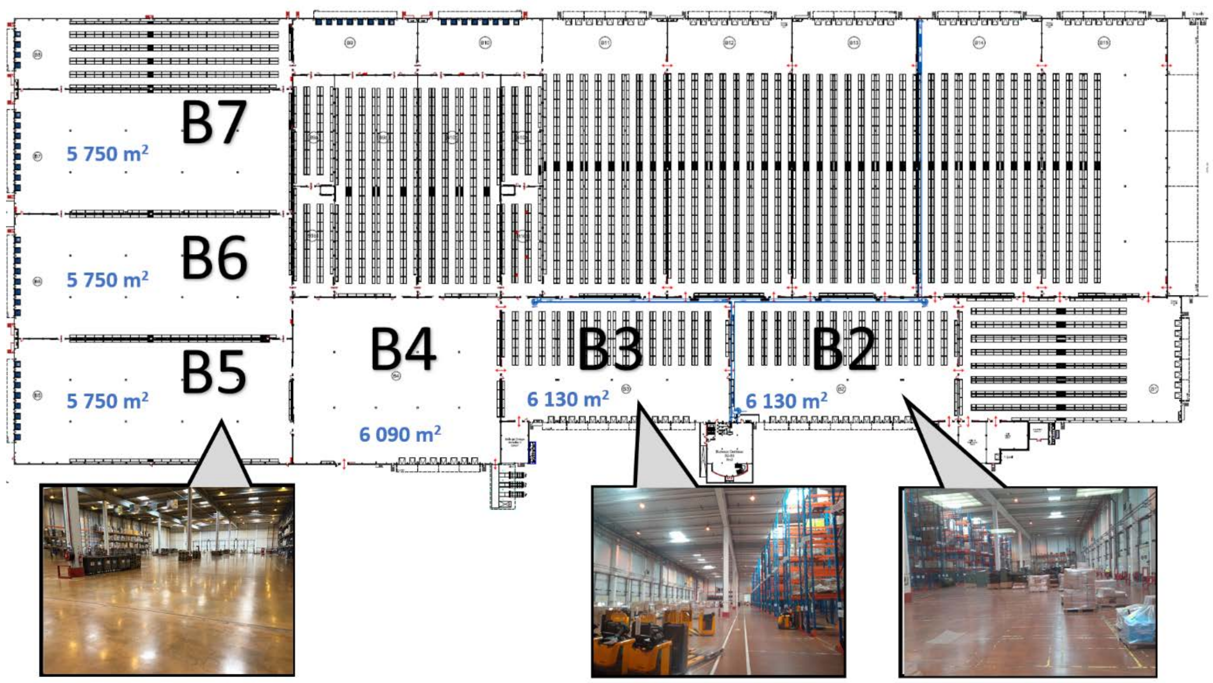

Figure 3: A logistic centre in the south of France (Source: STMicroelectronics N.V.)

5.2.2 System requirements

In warehouses, aisles length may vary from 60 m to 120 m or more. Optimal deployment of a radio tracking system is based on wiring along the walls of the building a daisy chain of anchors that are facing each aisle. This provides ideal conditions in terms of range, allowing Line of Sight or near Line-of-Sight transmissions.

Figure 4: Wall-mounted anchors
(Source: Trumpf Tracking Technologies GmbH)

Walls are a helpful support to wire a series of anchors. On the other hand, hanging an anchor on the ceiling in the middle of an aisle can prove challenging in terms of wiring and setup. As those aisles are typically quite narrow and high there are not many options for installations. Under these conditions anchors can only be installed in a line, which enhances the risk of non-line-of-sight conditions In a free area, anchors can be installed over the full place, allowing them to observe an object from all directions (0° to 360°). In a narrow aisle they can only detect signals from front or back (either 0° or 180°).

There are several critical conditions which are quite likely to happen during these anti-collision use-case:

1) The body of a person may either completely mask or at least strongly attenuate the signal.

2) Objects moved and stored can be composed of unknown material and can completely block the direct path.

3) The situation inside the shelf and floor can change dynamically and generate complex multipath situations.

In order to allow a functional protection of life, one therefore needs to have the best possible conditions for stable location values even under long pathlengths with several reflections. As a result, one needs a system running in the lower frequency range (lower attenuation) and at an improved output power level.

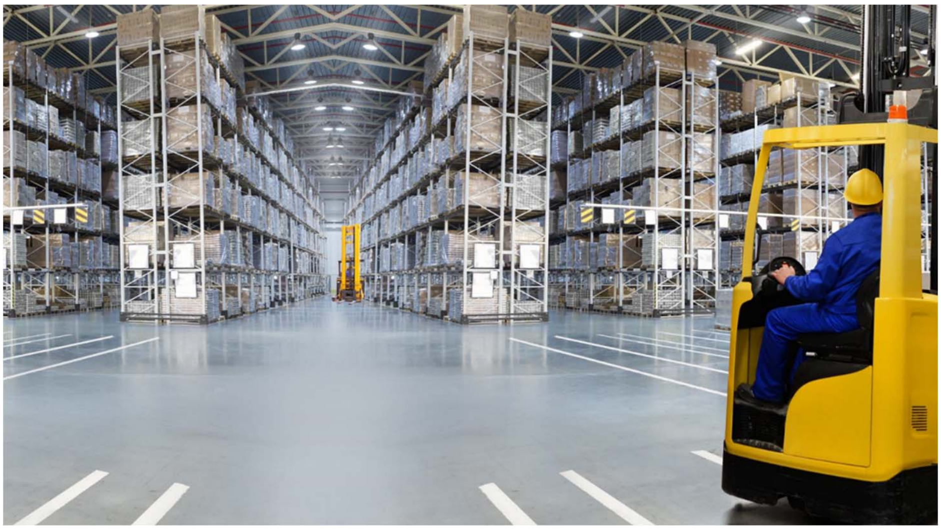

Figure 5: Aisles in warehouses may well exceed 100 m length
(Source: STMicroelectronics N.V.)

5.2.3 Technical description

A +10 dB allowance in the 4,5 GHz band would allow transmit powers up to -31,3 dB/MHz in indoor environments. Given the lower attenuation at 4,5 GHz than in other UWB channels (6,5 GHz and 8 GHz), pathlengths of more than 100 m could be achieved under optimal LoS conditions. This would allow to ensure a stable ranging even in complex Non-Line-of-Sight (NLoS) situations, but in shorter distances for such NLoS cases. For sure the accuracy will be reduced, but the object will not be lost and therefore the accident can be prevented with a much higher reliability.

5.2.4 Mitigation factors

In order to mitigate the extra power requested to implement efficiently UWB-based anti-collision applications, it is suggested:

- To limit this allowance to indoors use only. It is highlighted that walls attenuation are likely to bring the UWB signal at powers much lower than those observed in the vicinity of an UWB-enabled smartphone, for example.
- The fixed installation of the anchors in the indoor scenario with a certain minimum distance to each other and to the potential victim services avoids high spatial densities of UWB transmitters.
- The networked operation mode of such infrastructure-based localization anchor nodes, which avoids usually a synchronous transmission of neighbouring anchor nodes at the same time, avoids adding up of signal levels.
- Low duty cycling mitigation can also be considered as a mitigation technique. This could be defined for the anchor nodes (e.g. 5 % per second) and for the mobile tags (e.g. 1 % per second), which are forming the portable part of the system installation, at a different ratio.
- The omlox system design provides a slotted operation of the anchor nodes as well as the mobile tags, which again is reducing potential aggregation effects to an extremely low level.

5.2.5 Applications specific market information

According to the US Bureau of Labor Statistics (BLS), in 2019, 4,8 % of the workers had been victim of an accident, that is 57 600 people in USA alone.

Out of these, 30 accidents have caused the death of employees.

In France alone, where 850 000 drivers are working every day, a total of 7 500 accidents were recorded in 2018, of which 500 were qualified as serious, and 9 caused death (source: Toyota Material Handling France).

Figure 6: Warehouses can be challenging places for workers safety (Source: STMicroelectronics N.V.)

5.3 Application 2 - Intralogistics: Asset tracking

5.3.1 General

A general trend in the industry is the fine adaptation of production to demand. This result in production lots whose size is constantly decreasing, until it becomes almost normal to have 1 piece of product per lot. The consequence of this trend is the proliferation of lots in the factory, and the huge number of works in progress to be managed at any moment in time.

Complementary to this trend, is the ever-increasing efficiency of processing machines, which are becoming faster and faster with each generation.

The conjunction of these two trends creates an important bottleneck in modern factories: the human operator. Indeed, machines keep on calling for the next production lot, and operators are urged to fetch them, while storing swiftly the job that has just been completed.

Ultimately, misplacements and crowded buffers (see Figure 7) make the life of operators harder.

Figure 7: Buffer at a sheet metal workshop in USA (Source: Trumpf Tracking Technologies GmbH)

As a consequence, the time for searching is rising resulting in millions of unnecessary kilometres of operators, forklifts and other handling equipment. Additionally, a small portion of misplaced materials is not found in time, resulting in an additional second production start. Once the original material is found it will then be directly disposed. These unnecessary movements and disposal are generating waste and inefficiency which is adding up to the overall energy consumption. This kind of unnecessary CO_2 equivalent has to be eliminated in order to support a sustainable economy.

Numerous solutions have been explored, trying to create more discipline. Yet all have failed and the ultimate solution for this problem of intralogistics lies in the deployment of a precise and robust indoor localization solution, which can be enabled based on UWB radio.

5.3.2 System requirements

UWB localization solutions have proven to be a very efficient means to tackle the asset tracking problem. It is even considered that beyond the management of production lots, it would be very helpful to handle tool management, production tracing, digital twins, etc.

However, the possibility of the deployment of such systems has to be proved. Here again, one is facing the problem of the huge size of buildings, which limit the practical usability of such systems. Especially in the production of huge equipment (planes, trains, construction machinery, etc.) the installation is technically not feasible as huge distances and likely multipath conditions add up to a challenging scenario. Here again, a decent increase in output power targeting the still very low -31 dBm/MHz mean transmission power would prove very helpful to foster a wide modernization of European workshops.

5.3.3 Technical description

A decent increase of mean transmission power from the ultra-low -41 dBm/MHz in the 4,5 GHz band would allow transmit power spectral densities of up to -31 dB/MHz. Given the lower attenuation at 4,5 GHz compared to other UWB channels (6,5 GHz and 8 GHz), uniquely here operation ranges of up to 30 m would be achievable even in dominant NLoS environments, which is quite practical and enabling this use case at all.

5.3.4 Mitigation factors

In order to mitigate the extra power requested to implement efficiently UWB-based asset-tracking applications, it is suggested:

- To limit this allowance of the -31 dBm/MHz mean TX power spectral density to indoors use only, ensuring, that the asset tracking tag is communicating with indoor devices, which are mains powered or mounted at indoor locations. It is highlighted that walls attenuation are likely to bring the UWB signal at powers much lower than those observed in the vicinity of an UWB-enable smartphone, for example.
- Low duty cycling mitigation is also to be considered, as asset tracking does not require high frequency tracking typically and a UWB transmission may be activated occasionally only by triggering events, e.g. such as (non)-movement detectors.
- Deployment of complementary low energy, narrow band legacy radio systems is considered as a means to offload UWB radio spectrum from any communication than just the pure ranging process and to support managing time slicing for the UWB messages even for low energy consumption UL-TDoA UWB ranging system elements of the omlox specification.
- The networked operation mode of such infrastructure-based localization anchor nodes, which avoids usually a synchronous transmission of neighbouring anchor nodes at the same time, avoids adding up of signal levels during scheduled synchronization mechanisms between anchor nodes.

The omlox system design provides a slotted operation of the anchor nodes as well as the mobile tags, which again is reducing potential aggregation effects to an extremely low level.

5.3.5 Applications specific market information

The usage probability of asset tracking is with 42 % currently comparatively high to other indoor localization use cases, and is expected to increase up to 71 % until 2025. In order to achieve this growth the systems have to capable of handling the requirements, especially the range under NLOS conditions.

5.4 Application 3 - Automated booking

5.4.1 General

Following the concept of lean production, it is important to reduce non-value-adding labour like manual booking. The booking process in production is time consuming and prone to errors.

Via geo-fencing, orders can be booked automatically. A geo-fence is a virtual zone applied in the omlox hub with a specific position in the building. This position can be assigned to a specific task. If an order enters the geo-fence, this task - in this case automated booking - is executed. As a result, the shipment department of intralogistics can focus on their core tasks.

Besides automated order booking, machines can be started with the right programs automatically and e-Kanban can be updated automatically when an order enters the corresponding geo-fence, so no further human interaction is necessary. HUMI-times and failures are reduced, the process-step is executed faster, and the set-up process is automized.

Additionally, automated booking provides one further step to the paperless production. The operator wants to get displayed only compulsory working instructions on a monitor relevant for the actual job and working station instead of paper instructions. This reduces material waste and leads to faster order adjustments.

Automated booking is therefore an essential element in order to achieve the desired levels of energy reduction requested for modern production and targeting to reduce the CO_2 footprint.

Automated booking is also enabling the upcoming request of a cycle-economy. The need for a sustainable industry is rising. Therefore, modern production sites do care about all material flows, including also waste and byproducts. Those are often not declared correctly as the effort for a complete documentation is just not doable. By allowing an automated booking also for tracked waste and byproducts the recycling of correctly declared material is dramatically enhanced, resulting in drastically reduced CO_2 production and pathing the way towards a sustainable cycle-economy.

5.4.2 System requirements

For automated booking a precise recognition of entering and exiting the geo-fence is necessary. In addition, the geo-fence needs to be added and removed flexible, when the production layout changes. UWB is able to provide both - precise tracking down to 10 cm accuracy and the ability to add, remove or move this zone depending on the production layout. An update rate from 0,2 Hz to 8 Hz is necessary to adapt machine settings immediately to not disturb the process flow. These bookings have to be 100 % failure-safe. If a material is not booked it is lost, as its actual place will be unknown, and the process will be disrupted. Especially in huge buildings and in critical multipath conditions todays UWB systems cannot be deployed due to limited reliability, based on the existing ultra-low generic power levels.

5.4.3 Technical description

A moderate increase of transmission power from the currently allowed ultra-low -41 dBm/MHz in the 4,5 GHz band would allow mean transmit power spectral densities of up to still very low -31 dBm/MHz. Given the lower attenuation at 4,5 GHz compared to other UWB channels (6,5 GHz and 8 GHz), NLOS ranges of up to 30 m would be achievable deploying -31 dBm/MHz mean transmit power spectral density. This would allow a high reliability for the geo-fencing required for this use case, based on the then available link budget.

5.4.4 Mitigation factors

In order to mitigate the extra power requested to implement efficiently UWB-based automated booking applications, it is suggested:

- To limit this allowance to indoors use only. It is highlighted that walls attenuation are likely to bring the UWB signal at powers much lower than those observed in the vicinity of an UWB-enabled smartphone, for example.
- The fixed installation of the anchors in the indoor scenario with a certain minimum distance to each other and to the potential victim services avoids high spatial densities of UWB transmitters.
- The networked operation mode of such infrastructure based localization anchor nodes, which avoids usually a synchronous transmission of neighbouring anchor nodes at the same time, avoids adding up of signal levels.
- Low duty cycling mitigation can also be considered as a mitigation technique, as the automated booking application requires only up to 8 Hz object tracking rate. This could be defined for the anchor nodes (e.g. 5 % per second) and for the mobile tags (e.g. 1 % per second), which are forming the portable part of the system installation, at a different ratio.
- The system design provides a slotted operation of the anchor nodes as well as the mobile tags, which again is reducing potential aggregation effects to an extremely low level.

5.4.5 Applications specific market information

The usage probability of automated booking is expected to increase up to 63 % in production and logistics until 2025.

5.5 Application 4 - Navigation

5.5.1 General

Navigation describes the determination of the position and route from start to target. This use case is divided in the navigation of employees and machines, which both are improved when using indoor localization.

On a specific production site, companies can be enabled to become more flexible by choosing their employees independent, if they are used to work in such site or not. When employees are using indoor navigation systems, it is easier and faster to train them. Using a precise and reliable navigation system, the search times can be reduced. Additionally, equipment handling can be managed more flexible. With a real-time update of equipment and order position, employees know where the next unused equipment is located and get the fastest route displayed. With that, the wasted energy is reduced and the CO_2 footprint of modern industry sited is enhanced while keeping the output on the same level or even increasing it.

Further, also the efficient use of Autonomous Guided Vehicles (AGVs) in dynamic environments is enabled by indoor navigation systems. Tasks like transport, cleaning or lifting can be executed without the supervision of an employee. In today's industry and warehouses logistics workers are a very limited resource. The market demand is rising, but the availability of workers is limited in a demographic aging society.

The essential need of a modern society for a stable logistic was illustrated in Great Britain recently. Due to a shortage of workers many supermarkets run empty and consumer demands of daily goods could not be fulfilled correctly. In order to maintain public life the government had to deputise soldiers for logistic tasks. These kinds of scenarios can also happen inside the European Union. To prevent such critical conditions the logistic supply-chain needs to be stabilized and automated. A reliable automation needs a reliable navigation, which needs a reliable absolute outdoor and indoor location. The reliable outdoor location is supported in Europe with Galileo, whereas the reliable indoor navigation needs still to be implemented. The European driven omlox initiative is allowing such an indoor navigation in an open manner.

5.5.2 System requirements

UWB provides the precision needed for indoor navigation. With an accuracy down to 10 cm and update rate of up to 8 Hz, AGV navigation and anti-collision can be realized at the same time.

For machine navigation, GPS-like tracking, called DL-TDoA in case of UWB based positioning systems, is necessary to provide the AGV with the absolute position in the coordinate system and the opportunity to merge with other sensors for collision-avoidance. Basically AGV/AMR can learn their way already today based on so called Simultaneous Location And Mapping (SLAM) algorithms based on environment sensors like LIDAR, Radar or cameras, but those systems only do allow a relative positioning. Such a kind of relative positioning needs a long training and does not work under dynamically changing environments. An infrastructure based UWB positioning from an open standard like omlox is solving this limitation. In some places UWB absolute indoor location can be implemented already today, but there are several critical conditions under which the usage is critical:

- Huge buildings with high ceilings and moving cranes.
- High warehouses with narrow and tall aisles.
- Dense metallic environment (machinery, metal products) which will hinder line-of-sight and result in multi-reflections with long resulting pathlengths.

For human only navigation, an update rate of 1 Hz to 2 Hz is sufficient for typical scenarios. Additionally anti-collision could be implemented too, but this would need higher update rates of 4 Hz to 8 Hz and could lead to automatically reduced AGV/AMR speeds in the vicinity of a person. Again this would need a highly reliable UWB system, even under critical conditions.

5.5.3 Technical description

As in the previous application examples again an increase of mean transmission power in the 4,5 GHz band from the currently allowed ultra-low -41,3 dBm/MHz to the still very low -31,3 dBm/MHz will be required. Given the lower attenuation at 4,5 GHz compared to other UWB channels (6,5 GHz and 8 GHz), NLOS ranges of up to 30 m would be achievable deploying -31 dBm/MHz mean transmit power spectral density.

5.5.4 Mitigation factors

In order to mitigate the extra power requested to implement efficiently UWB-based high precision navigation applications, it is possible to apply following mitigation factors:

- To limit this allowance to indoors use only. It is highlighted that walls attenuation are likely to bring the UWB signal at powers much lower than those observed in the vicinity of an UWB-enabled smartphone, for example.
- The fixed installation of the anchors in the indoor scenario with a certain minimum distance to each other and to the potential victim services avoids high spatial densities of UWB transmitters.
- The networked operation mode of such infrastructure-based localization anchor nodes, which avoids usually a synchronous transmission of neighbouring anchor nodes at the same time, avoids adding up of signal levels.

- Low duty cycling mitigation can also be considered as a mitigation technique. This could be defined for the anchor nodes (e.g. 5 % per second) and for the mobile tags (e.g. 1 % per second), which are forming the portable part of the system installation, at a different ratio.
- The omlox system design provides a slotted operation of the anchor nodes as well as the mobile tags, which again is reducing potential aggregation effects to an extremely low level.
- Indoor AGV does require update rates of up to 8 Hz in some of the deployment scenarios. The DL-TDoA, mainly deployed for this use case, is a strongly asymmetric operation, where mainly the anchor nodes transmit UWB signals in the downlink while the mobile tags receive the UWB signals only. This limits the density of UWB transmitting devices significantly.

5.5.5 Applications specific market information

According to a survey by MyVoucherCodes.co.uk, 67 % of the respondents under 25 are not able to read maps. Another study, conducted by Ordnance Survey, found that 15 % the surveyed millennials never tried to read a map. Therefore, for the next generation of employees it is important to provide a navigation system if they ought to be taught in fast. Also, the usage of machine navigation is expected to increase about more than 100 % until 2025.

5.6 Application 5 - Logistics: cross dock operations

5.6.1 General

Cross docks are key nodes in the logistics networks. A medium sized operator in France typically run 25 cross docks for a cumulated space of about 100 000 m².

Cross docks are buffers where trucks dock-in, and either offload or load merchandise. In a typical operation, pallets of goods from a given supplier are off-loaded and spread throughout the dock, next to other goods from other suppliers. Then sets of goods are loaded onto the trucks operated by various distribution networks (supermarkets for example).

A cross dock is a very large platform, constantly active to off-load and load, as a multiplexer would do. In this context, efficiency is important as timing is the most important factor in logistics.

Despite excellent organizations, an average operator of docking station spends 40 minutes per day looking for lost pallets, and every night, pallets remain- unloaded, that could not be found in time to be distributed.

To allow smoother operations, various options have been considered and the most promising relies on the deployment of UWB indoor localization systems.

Figure 8: A cross dock in the centre of France (Source: STMicroelectronics N.V.)

5.6.2 System requirements

Deploying an UWB localization network inside a cross dock needs to be optimized in reliability, in order to make sense: once workers start using the system, it has to work with a 99,99 % functionality. Lower reliability would still lead to lost packages. Docks are very large open indoor space with little obstruction, on the other hand, the goods are unknown, and any kind of material can be transferred. As a consequence, the dynamically changing goods buffered somewhere, will lead to unpredictable non-line-of-sight conditions. In order to achieve a high reliability the most critical conditions needs to be considered.

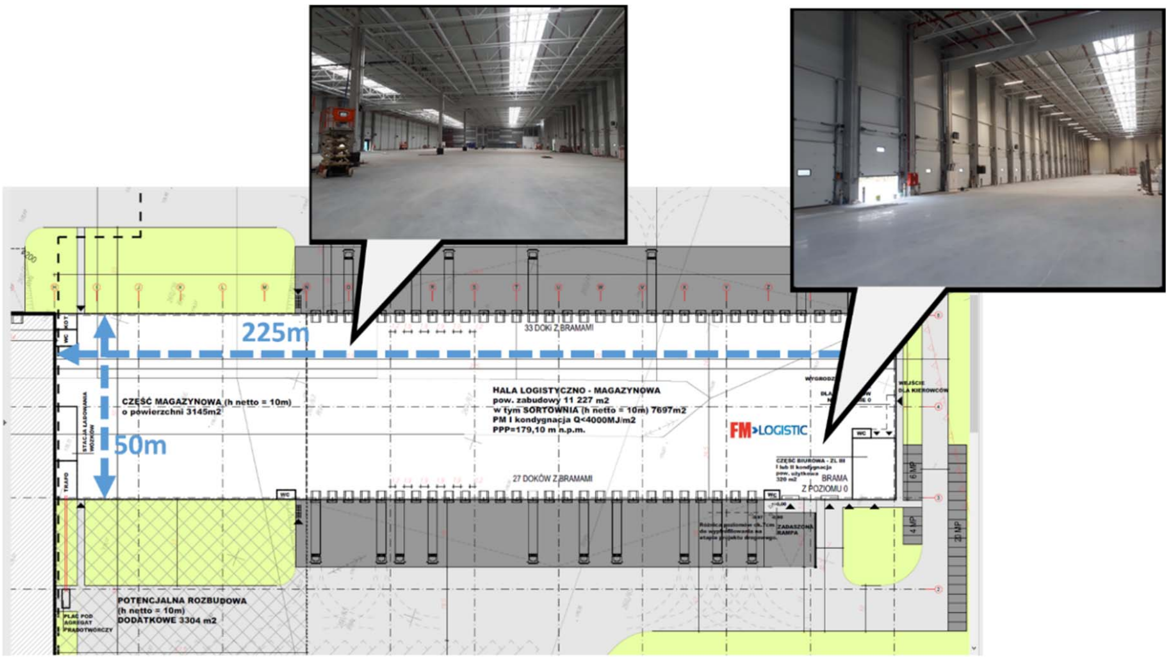

Figure 9: Recently built cross dock in Poland
(Source: STMicroelectronics N.V.)

5.6.3 Technical description

In this use case, Line of Sight or near Line of Sight is reasonably achievable in most cases. But these use-case needs an extremely high reliability and most therefore also run under full load with a lot of goods blocking the way and preventing line-of-sight conditions. As these goods can also be metallic, critical, and long multi-path conditions need to be considered. In such conditions the use of the 4,5 GHz frequency band in combination with the mean transmit power spectral density of -31,4 dB/MHz dBm/MHz will lead to a strong increase of reliability while allowing to cover LoS distances of approximately 100 m and NLoS distances of approximately up to 30 m.

Here a mix of UL-TDoA, DL-TDoA, Two-Way Ranging and Reconstructed ToF ranging methods are deployed for the various participants in this mixed scenario.

5.6.4 Mitigation factors

In order to mitigate the power level requested to implement efficiently UWB-based cross-doc applications, it is suggested:

- To limit this allowance to indoors use only. It is highlighted that walls attenuation are bringing the UWB signal at power levels much lower than those observed in the vicinity of an UWB-enable smartphone, for example.
- The fixed installation of the anchors in the indoor scenario with a certain minimum distance to each other and to the potential victim services avoids high spatial densities of UWB transmitters for the DL-TDoA part of the system.
- The networked operation mode of such infrastructure-based localization anchor nodes, which avoids usually a synchronous transmission of neighbouring anchor nodes at the same time, avoids adding up of signal levels.

- Low duty cycling mitigation can also be considered as a mitigation technique. This could be defined for the anchor nodes (e.g. 5 % per second) and for the mobile tags (e.g. 1 % per second), which are forming the portable part of the system installation, at a different ratio.
- The omlox system design provides a slotted operation of the anchor nodes as well as for the mobile tags also in the UL-TDoA mode of operation, which again is reducing potential aggregation effects to an extremely low level.

5.6.5 Applications specific market information

A regular logistician manages 20 to 30 cross docks per country, for a total space around 100 000 m². Logistics companies are continuously searching for employees. The shortage of workers is sometimes crucial, and the complexity of the job is rising. Due to growing online deliveries, which was even more pushed due to the pandemic situation, these kinds of cross docks are becoming the bottleneck of the supply-chain. Every night several pallets of goods are not delivered or scrapped because they could not be found in time for their dispatch. The stability of logistic supply-chains is getting more and more awareness for national welfare as the pandemic showed how dramatic the effects of a material shortage could be. Many industry segments are suffering from unstable and unpredictable logistics these days and the national effect of the GDP becomes obvious.

6 Market information

The market for indoor localization in industrial context is divided into production and warehouse clusters. Worldwide, the area for possible application is currently 6,5 billion m² and will increase up to 7,3 billion m² until 2028. In Europe, a market of 1,6 billion m² is estimated with a potential growth up to 1,7 billion m², of which 1 billion m² are used in production and 600 million m² are used for warehousing. Applications are listed in Annex A and some example applications are described in clause 5 of the present document.

The majority of UWB enabled localization devices will operate with the typical -41,3 dBm/MHz mean transmit PSD. Only a fraction of about 15 % of the fixed infrastructure UWB localization devices require -31,3 dBm/MHz, e.g. reflecting increased reliability requirements. It can be estimated that the resulting device density would be less than 400 devices/km^2 in urban and less than 40 devices/km^2 in suburban regions, while there might be almost no such devices operating in rural areas.

7 Technical information

7.1 Technical description

The UWB localization system consists of indoor fixed infrastructure anchor nodes, which operate in a synchronized manner and form a TDMA network, where management and control including discovery functionality is performed typically via an out-of-band radio system between such indoor fixed anchor nodes as well as between indoor fixed anchor nodes and portable tag nodes. The UWB transmissions occur basically only for the purpose of the location estimation, enabling a very low duty cycle UWB operation.

Typically, several localization schemes are enabled at the same site. These include two-way-ranging as well as one way ranging schemes, such as Up-Link Time Difference of Arrival (UL-TDoA) and Down-Link Time Difference of Arrival (DL-TDoA).

7.2 Technical parameters and implications on spectrum

7.2.1 Status

7.2.1.1 Current ITU and European Common Allocations

Table 1: European ECA table - 4,2 GHz to 4,8 GHz

Lower Frequency	Upper Frequency	Europe (ECA)
4 200 MHz	4 400 MHz	AERONAUTICAL MOBILE (R)(5.436), AERONAUTICAL RADIONAVIGATION(5.438)
4 400 MHz	4 500 MHz	FIXED, MOBILE
4 500 MHz	4 800 MHz	FIXED, FIXED-SATELLITE (SPACE-TO-EARTH)(5.441), MOBILE

7.2.1.2 Sharing and compatibility studies already available

- **ECC Report 64 [i.20]:** "The protection requirements of radiocommunications systems below 10,6 GHz from generic UWB applications".
- **ECC Report 170 [i.7]:** "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)".
- **ECC Report 278 [i.21]:** "Specific UWB applications in the bands 3,4 - 4,8 GHz and 6,0 - 8,5 GHz: Location Tracking and sensor Applications (LTA) for vehicular access systems".

7.2.1.3 Sharing and compatibility issues still to be considered

It is estimated that the building entry loss will compensate the increased power spectral density in the indoor environment and that the TDMA nature of application of the fixed installation of the systems will have a significantly positive influence on potential aggregation scenarios eliminating such aggregation effects essentially within an installation site.

Therefore, no additional co-existence studies should be needed for these applications in the limited frequency band 4,2 GHz to 4,8 GHz.

7.2.2 Transmitter parameters

- centre frequency: 4 492,8 MHz (according to IEEE Std 802.15.4z [i.14])
- bandwidth: 499,2 MHz (according to IEEE Std 802.15.4z [i.14])
- modulation: impulse radio (according to IEEE Std 802.15.4z [i.14])
- max. mean transmit power spectral density: -31,3 dBm/MHz e.i.r.p.
- max. peak transmit power: 10 dBm/50 MHz e.i.r.p
- antenna pattern for indoor fixed infrastructure: antenna pattern directed downwards
- antenna pattern for mobile tags: omni-directional
- duty cycle of indoor fixed infrastructure: < 1 % per second
- duty cycle of tag: < 0,5 % per second

There is almost no UWB aggregation effect expected because the UWB system operates typically in a TDMA network (e.g. omlox v2 [i.15]). The duty cycle is very low, because management and control signalling, including discovery, is performed typically via an IEEE Std 802.15.4 [i.13] narrow band radio system.

7.3 Information on relevant standard(s)

Table 2: Overview ETSI Standards

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]	Published 11-2016	RED compliant	TG UWB
Location & Tracking	Location Tracking Type 1 (LT1)	6 to 9	ETSI EN 302 065-2 [i.3]	Published 11-2016	RED compliant	TG UWB
	Location Tracking Type 2 (LT2)	3,1 to 4,8	ETSI EN 302 065-2 [i.3]	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]	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]	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]	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.9]	Published 02-2008		
Material sensing devices	Building Material Analysis (BMA)	2,2 to 8,5	ETSI EN 302 065-4 [i.5]	Published 11-2016		
	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 102 495-4	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.10]	Published 02-2009		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.11]	Published 05-2011		Former TG TLPR Now TG UWB
Airborne applications	Aircraft	Under study			Under study	

8 Radio spectrum request and justification

The request is for a mean power spectral density of -31,3 dBm/MHz e.i.r.p. and a peak power of 10 dBm in the band 4,2 GHz to 4,8 GHz for fixed infrastructure based indoor localization UWB systems.

The still extremely low output power of -31,3 dBm/MHz at the 4,5 GHz band considered in the present document brings a significant extension of the reliability and usability of absolute indoor location. 4,5 GHz (channel 3) frequency has a significant lower free space path loss compared to the 8 GHz (channel 9) and is therefore preferred for reliable applications such as industrial location tracking systems. This crucial factor will allow the broad adoption of UWB based indoor location It will foster the deployment of localization in European factories and as consequence, make them Safer, Faster and Smoother, while keeping people at the centre of their operations.

Figure 10: UWB indoor location to become a key enabler in operations management (Source: STMicroelectronics N.V.)

The reliable indoor location based on UWB and ideally supported with the European driven indoor standard omlox will allow the following enhancements which are clearly needed for tomorrows industry and logistics:

1) Increase the safety of workers and reduce accidents, injuries and deaths.
2) Allow an end-to-end traceability and therefore enabling the highly needed circular economy.
3) Enable the continuance of the logistics supply-chain under rising challenges (load & demographic change).
4) Reduce waste and help achieving the goals of the European climate targets.
5) Keep the European economy stable even under rising supply-chain challenges.

As a result, a reliable indoor location based on UWB will be an important factor for the European welfare and stability.

It is estimated that the building entry loss will compensate the increased power spectral density in the indoor environment and that the TDMA nature of application of the fixed installation of the systems will have a significantly positive influence on potential aggregation scenarios.

Therefore, no additional co-existence studies should be needed for these applications in the limited frequency band 4,2 GHz to 4,8 GHz.

9 Regulations

9.1 Current regulations

Currently applications similar to those requested in the present document are allowed based on ECC/DEC(06)04 [i.6] with the restrictions summarized in Figure 11 and Figure 12 below.

A1.1 GENERAL CASE

The technical requirements below are not applicable to:

a) devices and infrastructure used at a fixed outdoor location or connected to a fixed outdoor antenna;
b) devices installed in flying models, aircraft and other aviation;
c) devices installed in road and rail vehicles.

Table 1: Maximum e.i.r.p. limits

Frequency range	Maximum mean e.i.r.p. spectral density	Maximum peak e.i.r.p. (defined in 50 MHz)
Below 1.6 GHz	-90 dBm/MHz	-50 dBm
1.6 to 2.7 GHz	-85 dBm/MHz	-45 dBm
2.7 to 3.4 GHz (Notes 1 and 2)	-70 dBm/MHz	-36 dBm
3.4 to 3.8 GHz (Notes 1 and 2)	-80 dBm/MHz	-40 dBm
3.8 to 4.2 GHz (Notes 1 and 2)	-70 dBm/MHz	-30 dBm
4.2 to 4.8 GHz (Notes 1 and 2)	-70 dBm/MHz	-30 dBm
4.8 to 6 GHz	-70 dBm/MHz	-30 dBm
6 to 8.5 GHz	-41.3 dBm/MHz	0 dBm
8.5 to 10.6 GHz (Note 2)	-65 dBm/MHz	-25 dBm
Above 10.6 GHz	-85 dBm/MHz	-45 dBm
Note 1: within the band 3.1-4.8 GHz, devices implementing **Low Duty Cycle (LDC) mitigation technique** (see Annex 2) are permitted to operate with a maximum mean e.i.r.p. spectral density of -41.3 dBm/MHz and a maximum peak e.i.r.p. of 0 dBm defined in 50 MHz. Note 2: within the bands 3.1-4.8 GHz and 8.5-9 GHz, devices implementing **Detect And Avoid (DAA) mitigation technique** (see Annex 3) are permitted to operate with a maximum mean e.i.r.p. spectral density of -41.3 dBm/MHz and a maximum peak e.i.r.p. of 0 dBm defined in 50 MHz.		

Figure 11: General case in ECC/DEC(06)04 [i.6]

This allows up to -41,3 dBm/MHz e.i.r.p. in the range 3,1 GHz to 4,8 GHz when the LDC and DAA mitigation techniques do apply.

In addition, the ECC/DEC(06)04 [i.6] A1.3.2 provides enhanced indoor regulation rules from 6 GHz to 8,5 GHz, see Figure 12 below.

A1.3.2 Specific applications involving enhanced indoor devices

The technical requirements of Table 6 are applicable to enhanced power devices operating indoor and supporting radiodetermination, location tracking, tracing or data acquisition applications operating in 6-8.5 GHz. The technical requirements applicable to ultra-wideband emissions below 6 GHz and above 8.5 GHz are defined in A.1.1, Table 1.

Table 6: Maximum e.i.r.p. limits

Frequency range	Maximum mean e.i.r.p. spectral density	Maximum peak e.i.r.p. (defined in 50 MHz)
6 < f ≤ 8.5 GHz (Note 1)	-31.3 dBm/MHz	10 dBm
Note 1: Within the band 6-8.5 GHz, the duty cycle is limited to maximum 5% per second. Portable devices can operate with a maximum mean e.i.r.p. spectral density higher than -41.3 dBm/MHz and a maximum peak e.i.r.p. higher than 0 dBm defined in 50 MHz only within an identifiable network and subject to control by an indoor infrastructure.		

Figure 12: Specific enhanced indoor case in ECC/DEC(06)04 [i.6]

9.2 Proposed regulation

Add "4.2-4.8 GHz" in the header paragraph of clause A.1.3.2 of ECC/DEC(06)04 [i.6] (see above, Figure 12).

In Table 6 of ECC/DEC(06)04 [i.6], clause A.1.3.2, add a line for the frequency range of "4,2-4 8 GHz" with the following parameters:

- Frequency range: 4,2-4,8 GHz.
- -31,3 dBm/MHz e.i.r.p. mean power and 10 dBm/50 MHz peak power.
- The same note as for 6-8,5 GHz in Table 6 of ECC/DEC(06)04 [i.6] should apply (duty cycle and indoor only application if higher power is deployed).

Annex A: Market information

The market for indoor localization in industrial context is divided into production and warehouse clusters. Worldwide, the area for possible application is currently 6,5 billion m^2 and will increase up to 7,3 billion m^2 until 2028. In Europe, a market of 1,6 billion m^2 is estimated with a potential growth up to 1,7 billion m^2, of which 1 billion m^2 are used in production and 600 million m^2 are used for warehousing.

The use for indoor localization is shown in the applications listed below:

- Distance information (e.g. distance based behaviour).
- Signalling and Monitoring.
- Safety (e.g. collaborative robotics).
- Location based services.
- Movement analysis (e.g. booking).
- Anti-collision (e.g. internal transports).
- Navigation.
- Access control.
- Asset management (e.g. order fulfilment).
- System support.
- Documentation.

Annex B: Bibliography

- 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".
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- ECC/REC/(11)09: "UWB Location Tracking Systems Type 2 (LT2)", October 2011.
- ECC/REC/(11)10: "Location Tracking Application for Emergency and Disaster Situations", October 2011.
- ECC Report 94: "Technical requirements for UWB LDC devices to ensure the protection of FWA System", Nicosia, December 2006.
- 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).
- ETSI TR 103 416 (V1.1.1): "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 and 6 GHz to 8,5 GHz frequency ranges".
- ETSI TS 103 060 (V1.1.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM);Short Range Devices (SRD); Method for a harmonized definition of Duty Cycle Template (DCT) transmission as a passive mitigation technique used by short range devices and related conformance test methods".
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- ECC Report 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.
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- ERC Recommendation 14-02 (September 2014): "Radio-frequency channel arrangements for high, medium and low capacity digital fixed service systems operating in the band 6425 to 7125 MHz".

- ETSI TS 102 792 (V1.2.1): "Intelligent Transport Systems (ITS); Mitigation techniques to avoid interference between European CEN Dedicated Short Range Communication (CEN DSRC) equipment and Intelligent Transport Systems (ITS) operating in the 5 GHz frequency range".
- Project HIGHTS Deliverable 2.1 (March 2015): "Use cases and Application Requirements".
- Recommendation ITU-R P.526-13 (11/2013): "Propagation by diffraction".
- ETSI TS 103 329 (V1.1.1):" Wireless Industrial Applications (WIA); Radio equipment to be used in the 5,725 GHz to 5,875 GHz frequency range with power level up to 400 mW; Methods and concepts for a WIA system approach to sharing in the 5,725 GHz to 5,875 GHz band".
- ETSI TS 102 800 (V1.1.1):"Electromagnetic compatibility and Radio spectrum Matters (ERM); Cognitive Programme Making and Special Events (C-PMSE); Protocols for spectrum access and sound quality control systems using cognitive interference mitigation techniques", January 2011.
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History

Document history		
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