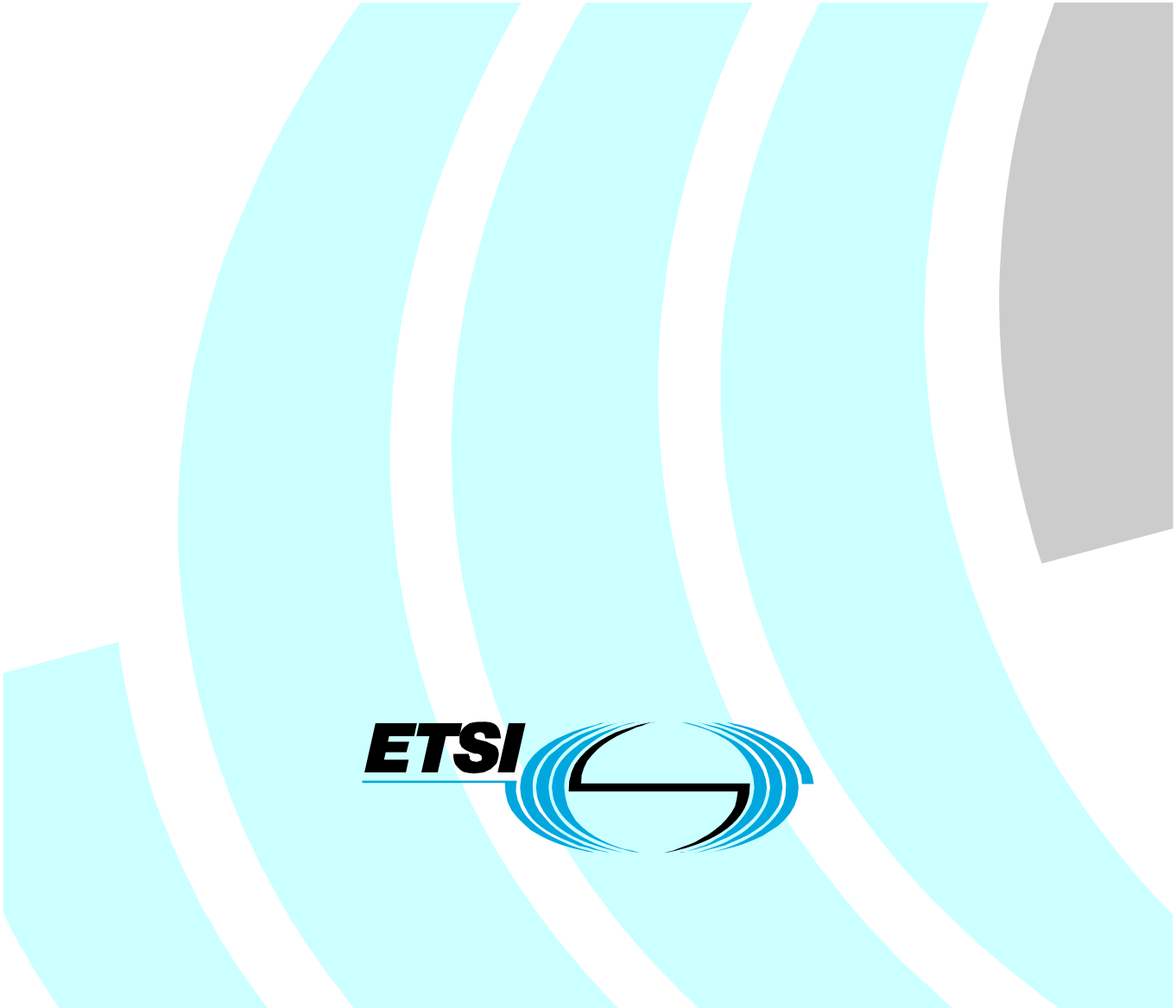
ETSI TR 102 495-3 V1.3.1 (2008-02)

Technical Report

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 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



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Foreword

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

The present document is part 3 of a multi-part deliverable covering Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Technical characteristics for SRD equipment using Ultra Wide Band technology (UWB) as identified below:

Part 1: "Building material analysis and classification applications operating in the frequency band from 2,2 GHz to 8 GHz";

Part 2: "Object Discrimination and Characterization (ODC) applications operating in the frequency band from 2,2 GHz to 8,5 GHz";

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";

Part 4: "Object identification for surveillance applications operating in the frequency band from 2,2 GHz to 8 GHz";

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 personnel tracking and industrial applications;

Part 6: "Object Detection for industrial Mobile, construction, agriculture and other off-road applications operating in the frequency band from 6 GHz to 7,25 GHz (ODM)";

Part 7: "Location tracking and sensor applications for automotive and transportation environments operating in the frequency band from 3.1 GHz to 4.8 GHz and 6 GHz to 9 GHz".

The difference between version 1.1.1 of TR 102 495-3 and version 1.2.1 of TR 102 495-3 is that in version 1.1.1 operation is limited to indoor usage. Version 1.2.1 covers indoor and portable outdoor applications.

The difference between version 1.2.1 of TR 102 495-3 and version 1.3.1 of TR 102 495-3 is that this new version covers indoor and portable or mobile outdoor applications under the conditions of the generic ECC decision as amended in July 2007.

Introduction

Ultra Wide Band (UWB) technology enables a new generation of Location Tracking devices and opens new markets with very different applications. UWB radio location devices with an operating bandwidth of several GHz allow centimetre-level localization and positioning even in the presence of severe multipath effects caused by walls, furniture etc.

It is a viable positioning technology that meets industrial requirements in the following markets:

1) Healthcare.
2) Workplace/Smart Office.
3) Public buildings.
4) Security.
5) Defence training.
6) Entertainment.
7) Logistics, warehouses.
8) Manufacturing assembly lines.
9) Road and rail vehicles.

The purpose of producing the present document is to lay a foundation for industry to quickly bring innovative and useful products to the market while avoiding any harmful interference with other services and equipment.

1 Scope

The present document defines the requirements for radio frequency usage for Ultra Wide Band (UWB) location tracking devices type 1. These devices are operating in the frequency range from 6 GHz to 8,5 GHz. Operation is foreseen for indoor, portable and mobile outdoor applications and the operating distance is limited to a maximum of about 100 metres. It will include applications from all different markets (see list of markets in introduction).

The type 1 equipment complies with the conditions of the amended generic ECC decision [5]. Type 2 is covered in part 5 of TR 102 495 [9] and corresponds to a future generation of the equipment.

The present document covers ultra-wideband location tracking tags which are attached to people or objects and tags are tracked using a fixed receiver infrastructure to only receive the UWB emission emitted by the tags. Equipment covered by the present document is fitted with an integral or dedicated antenna.

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 (annex A).
- Technical information (annex B).
- Expected compatibility issues (annex C).

2 References

References are either specific (identified by date of publication and/or edition number or version number) or non-specific.

- For a specific reference, subsequent revisions do not apply.
- Non-specific reference may be made only to a complete document or a part thereof and only in the following cases:
  - if it is accepted that it will be possible to use all future changes of the referenced document for the purposes of the referring document;
  - for informative references.

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

For online referenced documents, information sufficient to identify and locate the source shall be provided. Preferably, the primary source of the referenced document should be cited, in order to ensure traceability. Furthermore, the reference should, as far as possible, remain valid for the expected life of the document. The reference shall include the method of access to the referenced document and the full network address, with the same punctuation and use of upper case and lower case letters.

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2.1 Informative references

The following referenced documents are indispensable for the application of the present document. For dated references, only the edition cited applies. For non-specific references, the latest edition of the referenced document (including any amendments) applies.

[1] CEPT/ECC Report 64: "The protection requirements of radiocommunications systems below 10,6 GHz from generic UWB applications", Helsinki, February 2005 http://www.ero.dk/doc98/Official/pdf/ECCREP064.pdf.

[2] CEPT/ERC Report 25: "The European table of frequency allocations and utilizations covering the frequency range 9 kHz to 275 GHz" Lisboa January 2002 - Dublin 2003 - Turkey 2004 - Copenhagen 2004.

[3] Document TG3#7-19R0: ("Effects of PSD limits on UWB positioning systems"), submitted to ECC TG3 meeting, Brest, 1-3 March 2005.

[4] FCC 03-33: "Revision of Part 15 of the Commission's Rules Regarding UWB Transmission Systems".

[5] ECC/DEC/(06)04: "ECC Decision of 24 March 2006 amended 6. July 2007 at Constanta on the harmonized conditions for devices using. Ultra-Wideband (UWB) technology in bands below 10.6 GHz.".

[6] Revised Terms of reference for ECC TG3 (July 2006).

[7] Report developed by the European Conference of Postal and Telecommunications Administrations (CEPT) in response to the European Commission (EC) under the Mandate dealing with the harmonized technical conditions for the use in the European Union of the mitigation techniques for UWB applications.

[8] ITU-R, Radio Regulation, Geneva, 2004.

[9] ETSI TR 102 495: " Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Technical characteristics for SRD equipment using Ultra Wide Band Sensor technology (UWB); System Reference Document".

[10] ETSI EN 302 500 (V1.2.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD) using Ultra WideBand (UWB) technology; Location Tracking equipment operating in the frequency range from 6 GHz to 8,5 GHz; Part 1: Technical characteristics and test methods".

[11] ETSI EN 302 500 (V1.1.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD) using Ultra WideBand (UWB) technology; Location Tracking equipment operating in the frequency range from 6 GHz to 8,5 GHz; Part 2: Harmonized EN covering essential requirements of article 3.2 of the R&TTE Directive".

3 Definitions, symbols and abbreviations

3.1 Definitions

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

activity factor: reflects the effective transmission time ratio

light licensing: individual regulatory approval (or notification duty) required for each specific installation based on location and scope

mobile equipment : equipment intended to be used while in motion or during halts at unspecified points

portable equipment: equipment normally used on a stand-alone basis and to be carried around

range resolution: ability to resolve two targets at different ranges

3.2 Symbols

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

c	velocity of light in a vacuum
δR	range resolution or multipath rejection resolution
dBm	deciBel relative to 1 mW
T_P	pulse width

3.3 Abbreviations

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

2D/3D	Two Dimensional/Three Dimensional
CCTV	Closed Circuit TeleVision
CEPT	Conference Europeenne des administrations de Postes et des Telecommunications
ECC	Electronic Communications Committee
ERC	European Radiocommunications Committee
ERM	Electromagnetic compatibility and Radio spectrum Matters
GPS	Global Positioning System
ITU	International Telecommunication Union
LAN	Local Area Network
LORAN	LOng RAnge Navigation
OoB	Out of Band
PRF	Pulse Repetition Frequency
PSD	Power Spectral Density
RF	Radio Frequency
SRD	Short Range Device
ToR	Terms of Reference
UWB	Ultra Wide Band

4 Executive summary

The present document describes devices using Ultra Wide Band Sensor technology for location tracking applications.

In UWB location tracking, small, mobile tags, operating as either transmitters or receivers, or both, are attached to the objects to be located, or are carried by personnel. A network of reference stations around the area to be covered communicate with the tags. By analysing, e.g. the time-of-arrival and/or angle-of-arrival of the radio signal relative to the known reference stations, the 2D/3D position of the tag can be found. Typically, the range between a tag and a reference station might be up to 100 m, depending on the area to be observed.

There is evidence that these devices can address versatile industrial requirements in many different markets and therefore, a socio-economic benefit is given.

It is also possible that such a system will significantly enhance the security and safety of persons monitored in different applications such as health care.

A high precision in range measurement is required. This means that the required signals necessarily demand short pulse length resulting in a high bandwidth to provide the required accuracy.

4.1 Status of the present document

A previous version of the present document has been agreed by TG31C and included several inputs from ECC TG3.

The present document (TR 102 495-3 V1.3.1) is approved by TC-ERM, for publication. It takes into account the recent changes in the draft EN 302 500 [10].

4.2 Market information

For detailed market information, see annex A.

4.3 Technical system description

For a detailed technical information, see annex B.

5 Current regulations

Location tracking devices described in the present document are covered by the amended Generic UWB decision [5].

The FCC has released an UWB regulation which included UWB imaging devices in 04/2002 and revised it in 03/2003 [4].

However, there are neither current regulations permitting the operation of UWB location tracking installed at a fixed outdoor location nor in aircraft and other aviation applications available.

6 Proposed regulations

Based on the needs of the intended applications described in the scope of the present document, the following limits are proposed.

Table 6.1: Proposed regulation for the equipment

Frequency	Area of operation	Maximum Average power density (EIRP) (dBm/MHz)
6 GHz to 8,5 GHz	Indoor, portable or mobile outdoor usage Design requirement: objects or persons being traced must use tags.	-41,3 The PRF shall not be less than 1 MHz according to [5]

The devices permitted under the ECC decision for UWB [5] are exempt from individual licensing and operate on a non-interference, non-protected basis

7 Main conclusions

Ultra wideband technology enables the operation of location tracking devices. The short pulses used by UWB location devices enable accurate signal measurements, allowing centimetre-level positioning even in the presence of severe multipath interference (caused by reflections off doors, windows, walls and furniture).

Devices according to the present document address versatile industrial requirements in many different markets and therefore, a socio-economic benefit is given.

It is also possible that such a system will significantly enhance the security and safety of persons monitored in different applications such as health care.

A high precision in range measurement is required. This means that the required signals necessarily demand short pulse length resulting in a high bandwidth to provide the required accuracy.

8 Expected ECC and ETSI actions

UWB EC Mandate M/407 was received by ETSI, calling for release of Harmonized Standards for UWB.

The present document is fully compliant with the amended ECC decision [5] therefore no further ECC action is required.

The Harmonized European standard (EN 302 500 [11]) for UWB location tracking equipment is under revision at the moment of the publication of the present document.

Annex A:
Detailed market information

A.1 Range of applications

Applications of UWB location tracking technology are many and varied. Within hospitals, equipment, patients and doctors can be located quickly to speed up response to an incident. In the workplace, computers and communications systems can be shared between personnel, and automatically configured for a particular user as they walk up to equipment. In high-security environments, authorized personnel can be tracked, and unauthorized persons quickly identified when passive sensors (e.g. infra-red sensors) detect the presence of a person who is not located by the tracking system. Additionally, in industrial and agricultural environments the system can be used to track products through an assembly line and to monitor animal behaviour (e.g. in the dairy industry).

The list below indicates some of the many applications of UWB Location Tracking technology in each of a number of environments - it is in no way intended to be an exhaustive list:

- Healthcare:
  - Streamlining hospital processes (locating staff, finding wandering patients).
  - Asset tracking and management (finding equipment, evaluating equipment usage).
  - Safety (panic alarms with position-finding capability).
- Industrial & logistics asset tracking:
  - Location tracking of high value assets, pallets or fork-lifts.
  - Tracking is not limited to one building but to every possible location in the whole area., therefore outdoor usage is necessary.
  - Halls are typically very large and installation of infrastructure (network, cabling, and sensors) is very expensive. Therefore an increase of the operating range is very beneficial. People and asset tracking in public places.
  - Security applications. Since September 11th security is a No 1 topic in public places. "Command and Control" systems that know where operational personnel are can raise alarm if they enter critical zones. Integration with camera tracking, resource management for rapid response are examples of applications where mixed indoor/outdoor usage is necessary.
  - Collision avoidance between container wagons.
  - Workflow management and quality control: There are very stringent requirements regarding who is allowed to execute maintenance work at an aircraft. Location tracking enables control of these requirements in real time and the documentation of completed work steps.
- Safety applications in hazardous environments:
  - To know where people are in emergency situations. For example there are rules that in a catastrophic case everybody should leave an oil platform within 20 minutes. Real time location tracking can support this in training situations as well as in a real situation, therefore outdoor usage is necessary.
  - Control the workflow of employees. For example there are rules how long employees are allowed to work in high radiation environments in a nuclear plant. The integration of a tracking system combined with a radio-dosimeter enables accurate and reliable tracking of the workers in radioactive areas gathering dosimeter readings.

As the capability of UWB devices for tracking becomes more well-known, many further applications will be identified.

A.2 Market size and value

As described above, UWB location tracking systems will have a direct impact in a number of markets, such as healthcare, workplace, security, entertainment, defence training, warehousing, and manufacturing. The market size estimates in figure A.2.1 show the projected combined value of hardware, software and professional services for the UWB Location Tracking industry from 2005 to 2012 (with a combined market size estimate of 1 500 million € in 2012). Development of this market will depend on the high accuracy and reliability provided by UWB systems.

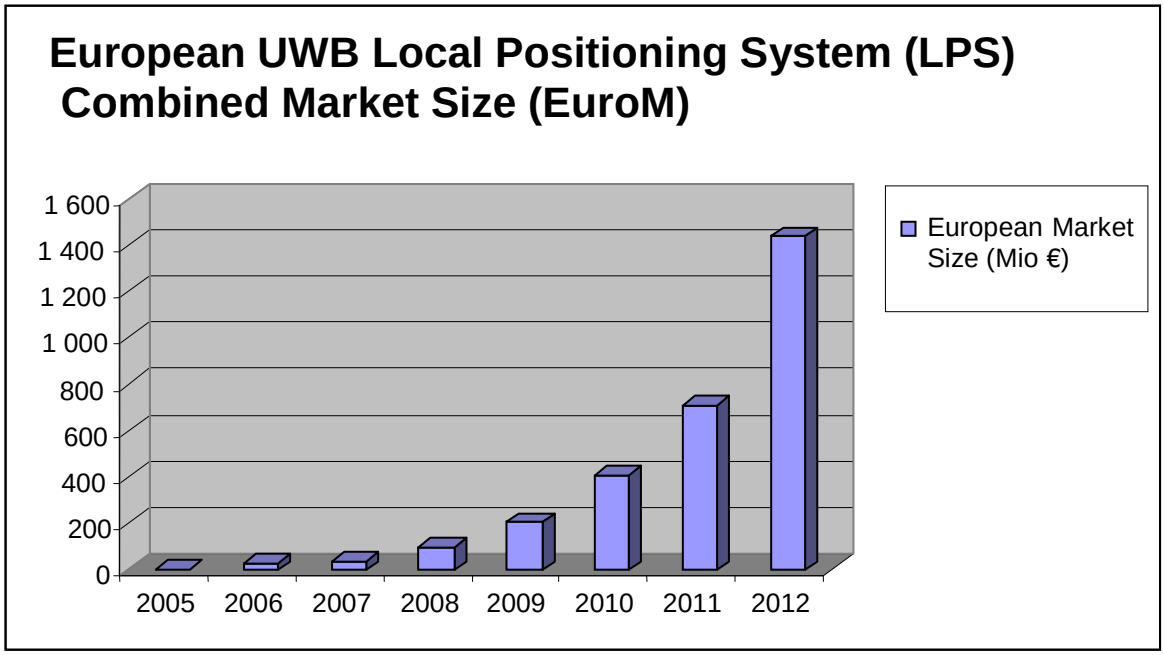

Figure A.2.1: European Location Tracking Systems Combined Market Size per year (2005-2012) in millions of Euros

A.3 Traffic evaluation

The likely modes of deployment and activity factors of UWB Location Tracking systems are discussed below:

- **UWB tracking systems have greatest benefit indoors**. In the outdoor environment, a number of radio technologies have already been developed for locating objects to an accuracy of a few metres (e.g. GPS and Galileo). It seems probable that for most applications the infrastructure-dependent UWB tracking devices will be unable to compete in the outdoor environment, for reasons of cost.

- UWB location tracking systems provide a powerful capability for industry to build automated process management and resource management systems. There is no equivalent technology that can match the accuracy and reliability of UWB for location tracking in a number of key applications.

- These industrial and professional applications will allow the tracking of assets and critical resources.

- Given that the user base of UWB location devices will be limited to certain professional groups, rather than the public at large, the **expected number of location tracking devices will be relatively low**. It is very unlikely that the worst-case numbers of active devices used in previous UWB compatibility studies for UWB communications devices will ever be approached by UWB location systems.

Location system devices are generally required to be very low powered and zero-maintenance (with battery lifetimes of years), and so tend to have **relatively low activity factors.** Assuming a typical pulse train length of 25 milliseconds (used by a representative type 1 device) and a location update frequency of 1 Hz, the resulting activity factor of a device in normal operation is about 2,5 %.

In summary, therefore, UWB location tracking systems are primarily to be used indoors, by professional users, and are likely to have relatively low activity factors.

Annex B:
Technical information

B.1 Detailed technical description

Small UWB transmitter tags are attached to the objects to be located, or are carried by personnel. The signals emitted by these tags are detected by a network of receivers placed at known, fixed points around the area to be instrumented. By detecting the signal at a number of receivers, and analysing the time-of-arrival and/or angle-of-arrival of the radio signal, the 3D position of the tag can be found.

NOTE: Other location system architectures are possible, in which the UWB transmitters are fixed and the receivers are mobile (much like the wide-area GPS system), but the general properties of the systems remain the same. However, mobile UWB transmitters are usually favoured over mobile UWB receivers, because UWB receivers tend to be more power-hungry than UWB transmitters, and power on the mobile units is limited.

A diagram illustrating the components of a typical UWB location tracking system is shown in figure B.1.1.

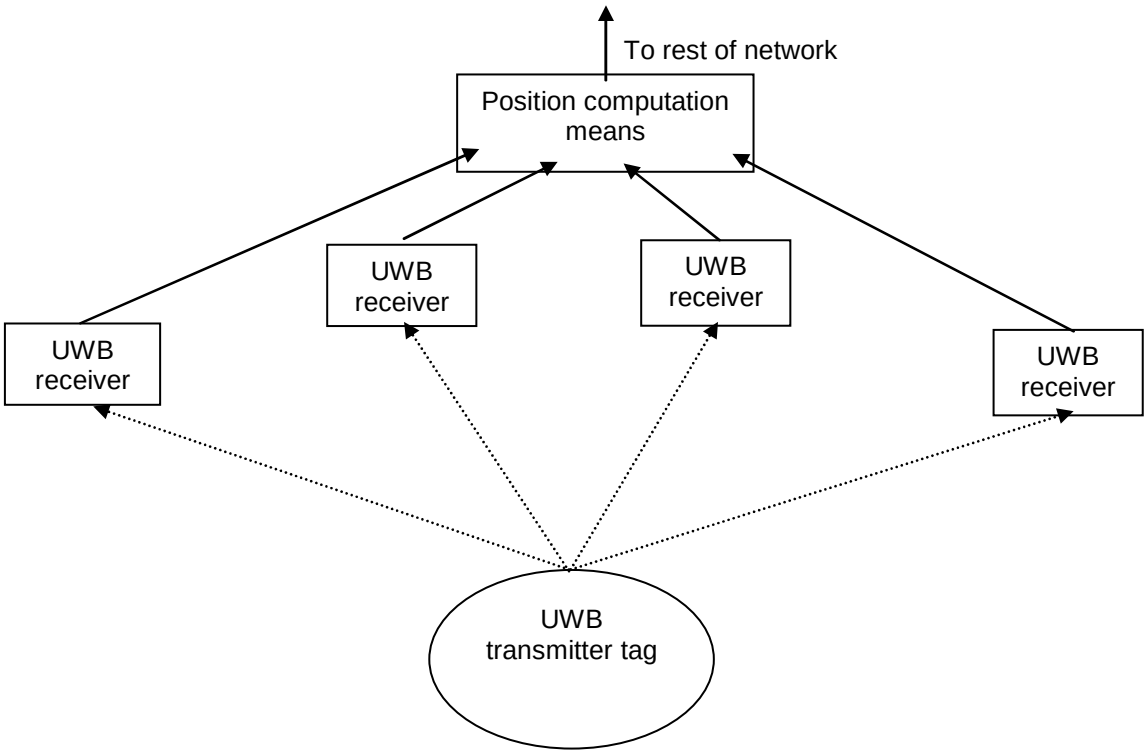

Figure B.1.1: Components of a typical UWB location tracking system

Typically, the range between a tag and a receiver might be between 10 m to 100 m, depending on the level of building obstruction between the two. A large building, such as a hospital, could be covered by a set of receivers placed with roughly the same density as a wireless LAN installation.

It is likely that the range of frequencies and power levels used for UWB tracking systems will be closer to those of communications systems than those of imaging systems. For example, location systems already on the market in the US use spectrum above 5 GHz, whereas UWB imaging systems might operate in the region below 1 GHz. However, user demographics, deployment density, activity factors and modulation schemes will be significantly different for UWB location tracking systems and UWB communications systems.

Since the tracking system devices cannot be located in the absence of supporting surveyed infrastructure, the usefulness of such devices would not be limited if UWB location tracking transmitter activity were tied to particular sites. This step would decrease the risk of uncontrolled proliferation of transmitters and would stop transmitter activity when it was not required (i.e. outside of the operating range of the infrastructure). One way of implementing a system that conformed to this requirement would be to ensure that UWB location tracking transmitters do not transmit if they fail to receive a "heartbeat" signal from the sensor infrastructure. The heartbeat signal could be transmitted in one of a number of ways: over a UWB channel, a conventional RF channel, an infra-red channel, etc. By ensuring (during the installation of the location system infrastructure) that the heartbeat signal was not detectable outside the building in which the system was operating, one could assure that UWB transmitter tags meet the aforementioned requirement.

B.2 Technical justification for spectrum

UWB Location tracking technology present a viable solution because of the reliable operation, precision and functionality for the applications as noted under "Introduction" such as:

- Healthcare.
- Workplace/Smart Office.
- Public buildings.
- Security.
- Defence training.
- Entertainment.
- Logistics, warehouses.
- Manufacturing assembly lines.

and in more detail as listed under clause A.1 "Applications".

A number of radio technologies have been developed for locating objects in the wide area to an accuracy of a few metres (such as GPS, Galileo and LORAN). For a number of reasons, these systems are of little value indoors (and in other high-multipath environments):

- The radio signals used by satellite and ground-based systems do not penetrate the structures of buildings sufficiently.
- Multipath effects within buildings, and the "urban canyon" environments that surround them, substantially degrade the nominal accuracy of present tracking systems.
- At best, in ideal conditions, the accuracy of these existing systems is no better than a few metres. Several applications of in-building tracking technology require knowledge of where a person or object is to the granularity of a room or a floor within a building. Even under ideal conditions, it is questionable whether wide-area systems can provide the required accuracy: if a person stood next to a wall, a location system with an accuracy of a few metres could easily record them as being on the other side of the wall, in another room. Once the nominal accuracy of the wide-area systems is degraded due to attenuation and multipath effects, it becomes clear that they cannot support indoor applications.

In contrast, a UWB location tracking system can position objects within a building to an accuracy of 10 cm to15 cm in 2D/3D - the wide bandwidth of UWB signals significantly improves the system's robustness to in-building multipath effects.

B.2.1 Technical justification for proposed power levels

UWB positioning technologies are very sensitive to the permitted PSD limit because they can only make use of a small fraction of the energy emitted by a UWB transmitter: that portion which reaches a receiver via the direct path.

Calculations based on empirical measurements of type 1 UWB positioning systems deployed in the US [3] show that a PSD limit of -41,3 dBm/MHz will enable a UWB positioning system industry to develop, but that lower PSD limits will increase the amount of required infrastructure to the point where UWB positioning technology will not be adopted.

The out of band emission limits for emissions are defined according to the ECC decision for UWB [5].

Operations under outdoor or harsh environmental conditions require a higher power spectral density than for the location tracking devices of the first generation. Field measurements have verified the proposed PSD limits in clause 6.

The resulting maximum outdoor operating range is up to 150 metres. The indoor operating range is approximately doubled with the proposed PSD limits compared with the first generation devices.

The proposed limits will enable a UWB positioning system industry to develop and have a much wider addressable market. On the contrary, lower PSD limits will increase the amount of required infrastructure to the point where UWB positioning technology will not be adopted.

The Out of Band (OoB) emissions limits for emissions are defined according to the ECC decision for UWB [5].

Table B.2.1.1: OoB emission limits

Frequency Band	Maximum mean e.i.r.p. density (dBm/MHz)
Below 1,6 GHz	-90 dBm/MHz
1,6 GHz to 2,7 GHz	-85 dBm/MHz
2,7 GHz to 6 GHz	-70 dBm/MHz
9 GHz to 10,6 GHz	-65 dBm/MHz
Above 10,6 GHz	-85 dBm/MHz

The out-of-band emission limits given above take into consideration both the requirement for protection of existing services in those regions of the radio spectrum, and the feasibility of taking accurate measurements of very low-level spurious emissions (particularly as the measurement noise floor of test facilities rises with increasing frequency).

B.2.2 Technical justification for bandwidth

UWB location tracking devices operate by radiating a short pulse from a transmitter which is then detected by one or more receivers. By measuring the time-of-arrival (or time-difference-of-arrival) of the signal at one or more receivers, ranges between the transmitter and receiver(s) can be determined, and the position of the transmitter can be found by triangulation.

The accuracy of the location devices and its resistance to multipath effects in indoor environments are determined by the width of the UWB pulse. For example, if the device is to reliably measure different transmitter-receiver ranges when the transmitter is moved from one point to another, the difference in the travel time of the signal from the transmitter to the receiver at the two different positions must be greater than the pulse width. Similarly, a direct path signal and a reflected multipath signal can be separated if the extra time interval required for the signal to travel the reflected path rather than the direct path is greater than the pulse width.

The bandwidth required to generate a pulse with a pulse width T_P is approximately $\left(\frac{1}{T_P}\right)$.

Therefore, for a range resolution or multipath rejection resolution of δR, the bandwidth requirement for the UWB location tracking devices is given by:

$$BW = \frac{c}{(\delta R)}.$$

Where *c* is the velocity of light in a vacuum.

For a range resolution of 10 cm, this gives a bandwidth requirement of around 3 GHz.

Annex C:
Expected compatibility issues

C.1 Coexistence issues

The document is in agreement with the amended generic ECC decision [5].

C.2 Current ITU allocations

There is no current ITU-R allocation corresponding to these devices. The present document assumes operation according to a provision of the Radio Regulations (RR4.4) that does not require any new allocation (i.e. on a non-protected basis and causing no harmful interference).

Due to the broad range of frequencies covered, an excerpt of the European Common Allocation Table [2] is not reproduced here. Please see [2] for further details.

C.3 Sharing issues

Several issues have to be taken into account, which will decrease the probability of interference with the existing radio services.

The following technical aspects (mitigation factors) need to be taken into account as these will decrease the probability of interference with the existing radio services in a suitable manner:

- low usage activity factor;
- low duty cycle of the devices;
- confined usage area;
- no aggregation effect;
- PRF limitation.

History

Document history		
V1.1.1	January 2006	Publication
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V1.3.1	February 2008	Publication