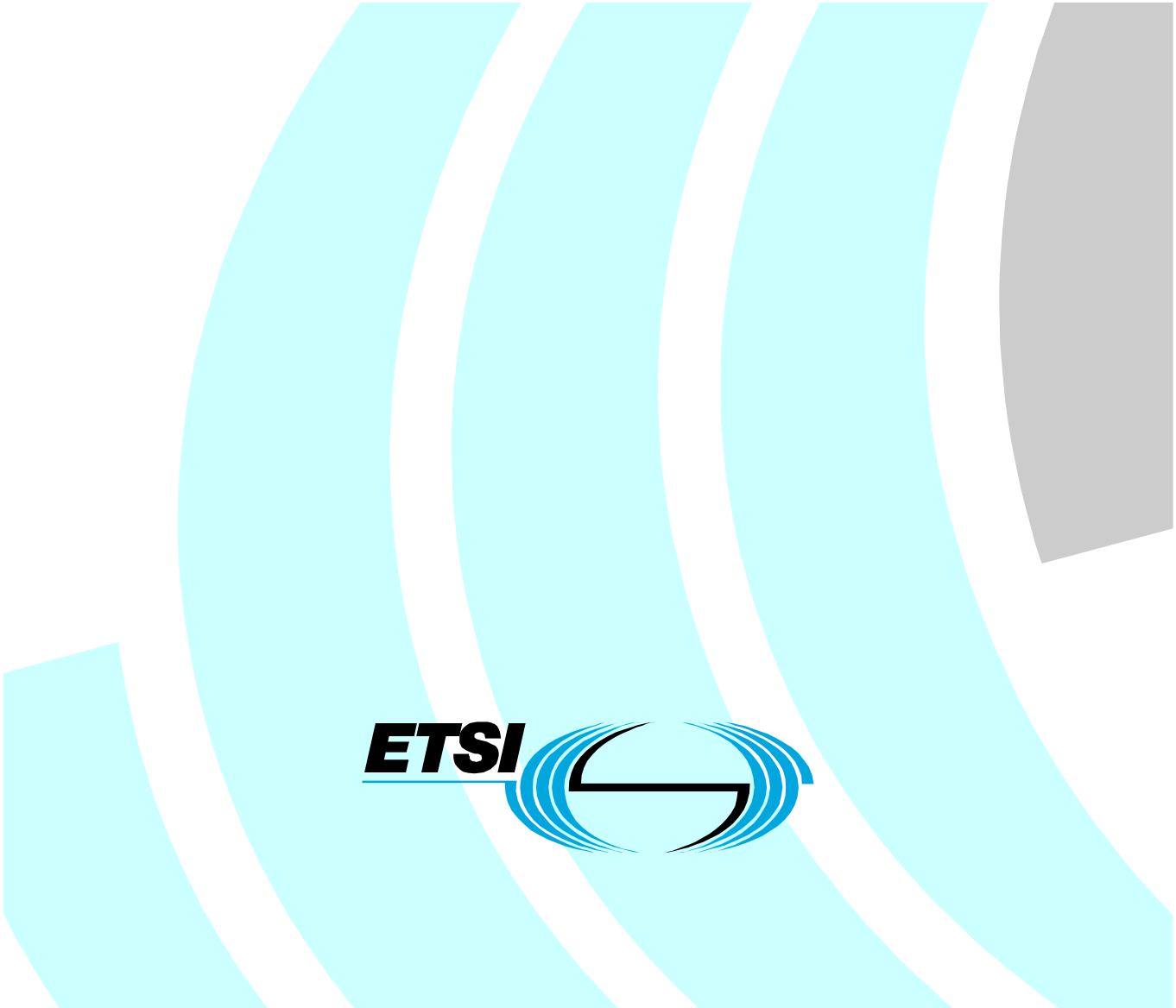
ETSI TR 102 495-3 V1.1.1 (2006-01)

Technical Report

Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Technical characteristics for SRD equipment using Ultra Wide Band Sensor technology (UWB); System Reference Document Part 3: Location tracking applications operating in the frequency band from 6 GHz to 9 GHz



Reference
DTR/ERM-RM-044-3

Keywords
radar, radio, short range, SRDoc, testing, UWB

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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 applications";

Part 3: "Location tracking applications operating in the frequency band from 6 GHz to 9 GHz";

Part 4: "Object identification for surveillance applications".

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

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. These devices are operating in the frequency range from 6 GHz to 9 GHz and using a fixed infrastructure. Operation is limited to indoor only 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).

UWB based location tracking applications, under the scope of the present document, require small, lightweight tags are attached to the objects to be located, or being carried by personnel. These applications will not allow operation at a fixed outdoor location.

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

For the purposes of this Technical Report (TR) the following references apply:

[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 utilisations 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] Document TG3#11-55-A4R0: "Draft ECC Decision of xx 2006 on the harmonized conditions for the use of UWB devices below 10,6 GHz".

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

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
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
dBm	deciBel relative to 1 mW
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
UWB	Ultra Wide Band

4 Executive summary

The present document describes a new generation of 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

The present document has included several inputs from ECC TG3. These were received after submitting a preliminary version of the TR 102 495-3.

Therefore the present document has undergone significant re-write in light of the developments of the ECC TG3 meeting in September, where location tracking should now be considered under the same radio regulations as other UWB SRDs.

4.1.1 Limits proposed in clause 6

It should be noted that the limits proposed in clause 6 have so far not been unanimously agreed within ETSI.

4.1.2 Statement of TC SES

"TC SES welcomes SRDocs providing full description of technical characteristics of UWB equipments, in order to provide proper input to compatibility issues. However, it is TC SES's understanding that compatibility issues between UWB and other systems are the sole responsibility of ECC TG3. As a matter of fact, such compatibility studies are currently debated within the ECC TG3 group, with technical analysis due to be completed during September 2005. Approval by ECC TG3 of a final report on this matter can reasonably be expected at the end of 2005.

Pending the outcome of ECC TG3 compatibility studies, TC SES can not approve any UWB SRDocs requesting frequencies within satellite bands where the proposed regulation of emission limits contained in those SRDocs exceed the provisional limits proposed by ECC TG3 in ECC Report 64 (Feb 2005) [1].

After approval of ECC TG3 final report on compatibility studies between UWB and other equipments, TC SES will be ready to reconsider UWB SRDocs in the light of ECC TG3's recommendations. Before that, aforementioned documents can not be endorsed by TC SES."

4.1.3 Statement from France Telecom

France Telecom suggests that ETSI UWB task groups fully take the work carried out by ECC-TG3 into consideration. At this stage, France Telecom expresses its reservations concerning certain emission powers levels, proposed frequency ranges and potential of interference of systems operating in other bands.

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

There are no current regulations permitting the operation of the applications covered by the present document in Europe.

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

6 Proposed regulations

Based on the needs of the intended applications described in the scope of the present document, the following limits are proposed as input values for the ongoing discussions and considerations in ECC TG3.

Table 6.1: Proposed regulation for equipment

Frequency	Area of operation	Maximum Average power density (EIRP) (dBm/MHz)
6 GHz to 9 GHz	Indoor only 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 a new generation 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).

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.

8 Expected ECC and ETSI actions

Mandate M/329 was received by ETSI, calling for release of Harmonized Standards for UWB.

ECC-TG3 continues the work under revised ToR conditions. This work includes work for UWB tracking devices such as UWB sensors.

ETSI requests ECC to consider the present document, which includes necessary information under the MoU between ETSI and the ECC issuing regulations for the proposed location tracking device types..

ETSI asks CEPT-ECC to perform the relevant compatibility studies to determine whether the emissions described in the present document are appropriate to protect other radio services and to provide the practical measures to ensure the protection of other radio services in the anticipated bands and emission levels.

A draft harmonized European standard for the equipment covered by the present document is under development in ETSI ERM TG31C.

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).
- Workplace:
  - Improved communications between distributed sites (better visibility of remote sites);
  - Sharing space more effectively (low-overhead personalization, measurement of space utilization);
  - Recording activity (automatic generation of a "corporate memory").
- Security:
  - Enhancing CCTV coverage (activity-based video stream selection);
  - Daytime intruder detection (correlate data from active tracking and passive IR sensors);
  - Visitor management (enforcing restricted zones and escort policies);
  - Asset tracking;
  - Automatic "man-down" and "lone-worker" detection.
- Retail environments:
  - Personalized retail experience;
  - Footfall analysis;
  - Locating friends and family in malls.
- Hazardous training:
  - After-action review for urban combat training;
  - "Man-down" detection in fire-fighter training simulators.

- Non-emergency applications in limited areas:
  - Localization of human objects:
    - Medical staff, patients, nurses;
    - Service staff;
    - Tracking of endangered persons or persons in high-security areas.
  - Localization of other objects:
    - Organ transports;
    - Valuable goods & hazardous materials;
    - Surveillance of cattle out at feed.

As the capability of UWB devices for indoor tracking becomes more well-known, it seems likely that 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 Mio € in 2012). Development of this market will depend on the high accuracy and reliability provided by UWB systems.

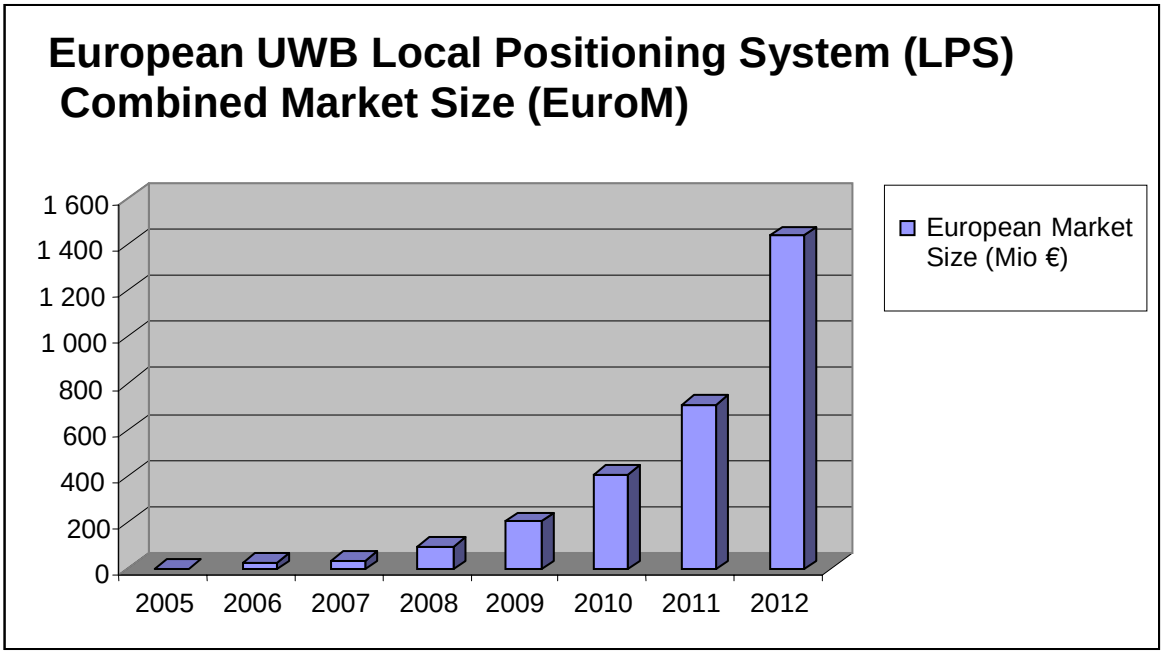

Figure A.2.1: European Location Tracking Systems Combined Market Size per year (2005-2012) in millions of Euros

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 utility 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.

- 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.

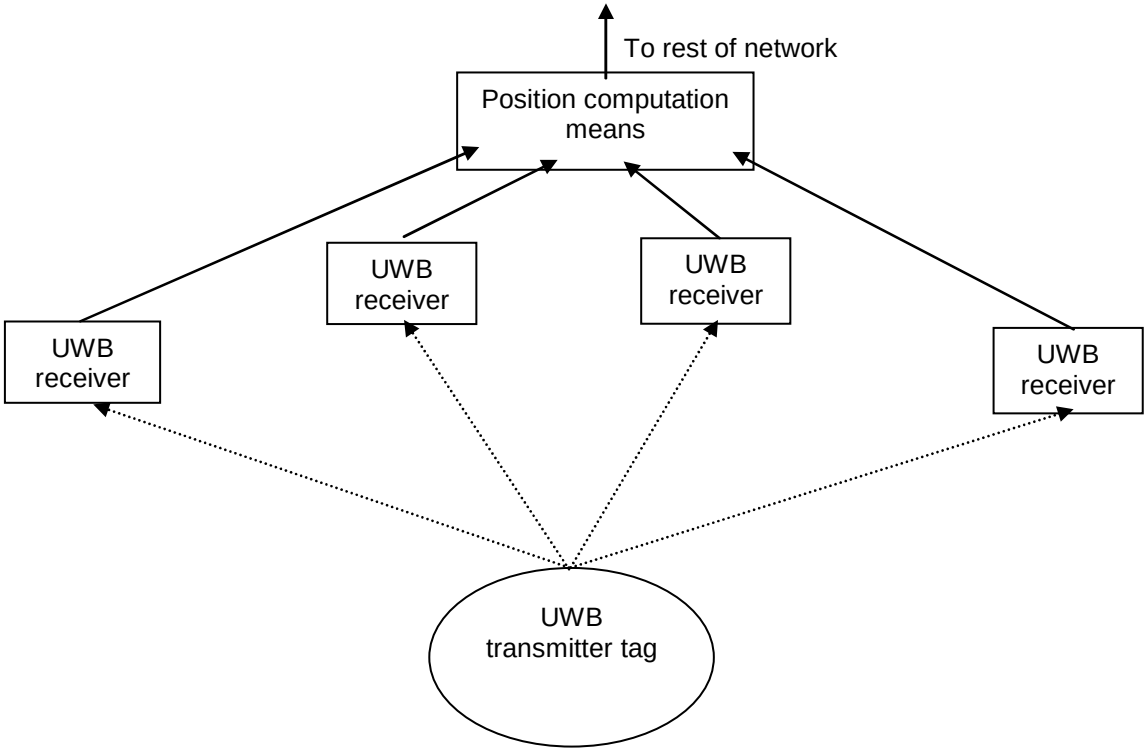

Figure B.1.1: Components of a typical UWB location tracking system

Typically, the range between a tag and a receiver might be between 10m to 100m, 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 emissions limits for emissions are defined according to the ECC decision for UWB [5].

Table B.2.1: 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

Possible coexistence problems need to be investigated in ECC-TG3. ECC Report 64 [1], although focussing on UWB for communications equipment, should be considered as a source of information for the purpose of new compatibility studies for UWB sensors.

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;
- confined usage area;
- no aggregation effect;
- indoor usage restriction;
- PRF limitation.

History

Document history		
V1.1.1	January 2006	Publication