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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 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

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ETSI

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

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

Siret N° 348 623 562 00017 - NAF 742 C
Association à but non lucratif enregistrée à la
Sous-Préfecture de Grasse (06) N° 7803/88

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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 7 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 for power tool devices operating in the frequency band of 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 (OIS) operating in the frequency band from 2,2 GHz to 8,5 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 person and object tracking and industrial applications";

Part 6: Void.

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".

Introduction

Ultra Wide Band (UWB) radio technology enables a new generation of location tracking and sensor devices and opens new markets with a variety of innovative applications. UWB radio location and sensor devices with an operating bandwidth of several hundreds of MHz up to several GHz allow tens of centimetre-level accuracy, real-time localization and positioning even in the presence of severe multipath effects caused by walls, furniture or any other harsh radio propagation environments.

It is a viable positioning and sensor 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 sensor networks.

10) Public transportation.

The purpose of producing the present document is to lay a foundation for industry to quickly bring innovative and useful products to the market.

Status of pre-approval draft

The present document has been created by ERM TG31C. It has undergone ETSI internal consultation. Final approval for publication as ETSI Technical Report is given at ERM#37 (March 2009).

Target version	Pre-approval date version (see note)				
V1.1.1	**a**	**s**	**m**	**Date**	**Description**
V1.1.1	0.0.7			15th October 2008	Approved by TG31C and sent to ETSI ERM for consultation and subsequent approval.
V1.1.1	0.0.8			4th November 2008	Document updated during ERM#36.
V1.1.1	0.0.9			7 November 2008	ETSI internal enquiry version resulting from ERM#36.
V1.1.1	0.0.10			10 November 2008	Clean version of v1.1.1_0.0.9 for ETSI internal enquiry.
V1.1.1	0.0.11			10 December 2008	Resolution of the internal ETSI consultation at the TG31c#18 meeting.
V1.1.1	0.0.12			5 January 2009	Clean version of V1.1.1_0.0.11 including a few minor editorials.
V1.1.1	0.0.13			16 January 2009	Editorial improvement of version V1.1.1_0.0.12.
V1.1.1	0.0.14			16 January 2009	Clean version of V1.1.1_0.0.13 with a few comments left in.
V1.1.1	0.0.15			21 January 2009	Comments left in from V0.0.14 resolved in this version.
NOTE: See clause A.2 of EG 201 788 [i.12].					

1 Scope

The present document covers a system description and the corresponding spectrum requirements for devices using UWB radio technology operating in the frequency range from 3,1 GHz to 4,8 GHz and from 6 GHz to 8,5 GHz which are in automotive or public transportation environments (e.g. installed in road and rail vehicles).

The operating radio link distance is limited typically to a maximum of about 30 meters, whereby some application scenarios show challenging operating conditions which impose the requirements stated in the present document.

Some applications described in the present document will enhance the safety of the passengers, but these applications are not safety critical.

UWB based applications under the scope of the present document typically rely on small, cost and energy effective, lightweight tags/sensors which are attached *inside or outside the vehicle, to objects or parts of the vehicle* to be monitored, or are explicitly carried by passengers. They may also form an integral part of portable electronic equipment carried by passengers (such as future generation mobile phones equipped with an additional UWB air interface).

They are connected to one or more "reference stations", also in the scope of the present document, placed inside the vehicle, which collect the data and communicate, when needed, via a UWB signal to the tags/sensors.

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:
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  - 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.

NOTE: While any hyperlinks included in this clause were valid at the time of publication ETSI cannot guarantee their long term validity.

2.1 Normative 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.

Not applicable.

2.2 Informative references

The following referenced documents are not essential to the use of the present document but they assist the user with regard to a particular subject area. For non-specific references, the latest version of the referenced document (including any amendments) applies.

[i.1] CEPT/ERC Report 25: "The European table of frequency allocations and utilizations in the frequency range 9 kHz to 3 000 GHz" Lisboa 02- Dublin 03- Kusadasi 04- Copenhagen 04- Nice 07- Baku 08.

[i.2] ECC/DEC/(06)04 of 24 March 2006 on the harmonized conditions for devices using Ultra-Wideband (UWB) technology in bands below 10.6 GHz.

[i.3] ECC/DEC/(06)04 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 (2007/131/EC) amended 6 July 2007.

[i.4] Commission Decision 2007/131/EC of 21 February 2007 on allowing the use of the radio spectrum for equipment using ultra-wideband technology in a harmonized manner in the Community.

[i.5] ECC/DEC/(06)12 (December 2006): Draft update approved by ECC TG3 in October 2008.

[i.6] EC Mandate M/407: "Standardization mandate forwarded to CEN/CENELEC/ETSI for harmonized standards covering ultra-wideband equipment".

[i.7] IEEE 802.15.4a: "Standard for Information Technology - Telecommunications and information exchange between systems - Local and metropolitan area networks - specific requirement Part 15.4: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low-Rate Wireless Personal Area Networks (LR-WPANs)".

[i.8] Standard ECMA-368 (December 2008): "High Rate Ultra Wideband PHY and MAC Standard; 3rd edition".

[i.9] Standard ECMA-369 (December 2008): "MAC-PHY Interface for ECMA-368; 3rd edition".

[i.10] ISO/IEC FCD 14443-1 (Revision): "Identification cards - Contactless integrated circuit(s) cards - Proximity integrated circuit(s) cards - Part 1: Physical characteristics".

NOTE: Available for all parts at: http://wg8.de/sd1.html#14443.

[i.11] Department of Transportation National Highway Traffic Safety Administration, 49 CFR Part 571: (Docket No. NHTSA 2000-8572), RIN 2127-AI3, "Federal Motor Vehicle Safety Standards; Tire Pressure Monitoring Systems; Controls and Displays".

[i.12] ETSI EG 201 788: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Guidance for drafting an ETSI System Reference document (SRdoc)".

[i.13] DfT Research Database Project: Be-In Be-Out Payment Systems for Public transport.

NOTE: Available at: http://www.dft.gov.uk/rmd/project.asp?intProjectID=12490.

[i.14] ETSI TR 102 495-3: "Electromagnetic compatibility and Radio spectrum Matters (ERM); System Reference Document; Short Range Devices (SRD); Technical Characteristics for SRD equipment using Ultra-Wideband Sensor Technology (UWB); Part 3: Location tracking applications type 1 operating in the frequency band from 6 GHz to 8,5 GHz for indoor, portable and mobile outdoor applications".

[i.15] ETSI TR 102 495-4: "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 4: Object Identification for Surveillance applications (OIS) operating in the frequency band from 2,2 GHz to 8,5 GHz".

[i.16] ETSI TR 102 495-5: "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.17] ITU-R Radio Regulations Edition of 2008.

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:

dBm	deciBel relative to 1 mW
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
BIBO	Be-In-Be-Out person/tag positioning system
CAN	Controller Area Network
CEPT	Conference Europeenne des Administrations de Postes et des Telecommunications
DAA	Detect and Avoid
ECC	Electronic Communications Committee
ECU	Electronic Control Unit
EFM	Electronic Fare Management
ERC	European Radiocommunications Committee
ERM	Electromagnetic compatibility and Radio spectrum Matters
ETSC	European Transport Safety Council's
GPS	Global Positioning System
HDR-LT	High Data Rate Location Tracking
ITU	International Telecommunication Union
LAN	Local Area Network
LDC	Low Duty Cycle
LDR	Low Data Rate
LDR-LT	Low Data Rate - Location Tracking
LIN	Local Interconnect Network
MB-OFDM	MultiBand OFDM
NHTSA	National Highway Traffic Safety Administration
OFDM	Orthogonal Frequency Division Multiplexing
PAN	Personal Area Network
PRF	Pulse Repetition Frequency
PSD	Power Spectral Density
RF	Radio Frequency
RKE	Remote Keyless Entry

SRD	Short Range Device
TPC	Transmit Power Control
TPMS	Tire Pressure Monitoring Systems
UWB	Ultra Wide Band
UWB-RT	Ultra Wide Band Radio Technology

4 Comments on the System Reference Document

Void.

5 Executive summary

5.1 Background information

The growing demand for UWB based applications installed in road and rail vehicles covered in the present document are grouped into three categories according to the commonalities in the spectral usage requirements resulting from specific application scenarios. All three categories belong to the automotive or public transportation environments. They are listed in table 1 and shortly summarized in clause 5.2.

Table 1: Overview of location tracking and sensor applications for automotive and public transportation environments

category	application	short description	frequency
A	Location Tracking in a public transportation environment	Location positioning datagrams are exchanged through one or more of the reference stations mounted inside the vehicle at convenient locations, with mobile tags carried by passengers and/or luggage. The typical range of radio operation is 1 m to 30 m. Environmental conditions can be challenging in selected cases. All cases need to be covered with high reliability.	3,1 GHz to 4,8 GHz, 6,0 GHz to 8,5 GHz
B	Location Tracking in the automotive environment	Location tracking datagrams are exchanged between a base station located inside the vehicle and corresponding mobile tags and/or the vehicle key.	3,1 GHz to 4,8 GHz, 6,0 GHz to 8,5 GHz
C	Sensing in the automotive environment	Telemetry datagrams are exchanged in a vehicle mounted sensor network.	3,1 GHz to 4,8 GHz, 6,0 GHz to 8,5 GHz

5.2 Application technical summary and market information

The implementation of new UWB applications in transportation environments requires new spectrum for the defined categories as further described in the following clauses.

5.2.1 Category A: Location tracking in public transportation (road and rail vehicles)

In various European countries public transportation network operators are currently looking for Electronic Fare Management (EFM) systems based on the Be-In-Be-Out (BIBO) principle. Be-In-Be-Out systems determine automatically if a person is inside a transportation means and are more accepted than any check-in-check-out technology in public transportation. It is a basic element of future Electronic Fare Management Systems.

BIBO systems can be realized in an optimal way applying UWB radio-based, accurate, real-time, automatic positioning.

Small mobile tags operating as transceivers are attached to the objects to be monitored or are carried by humans in clothing or inside luggage. *A network of reference stations is inside the vehicle and suitably covers the internal* area. The network communicates with the tags. Typically, the range between a tag and a reference station will be from 1 m to 30 m, depending on the public transportation vehicle size and geometry.

By analysing tag-related radio link parameter(s), 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(s) can be found. Data can be transmitted containing information derived by the tags.

The main application, EFM systems based on the BIBO principle, needs to exchange data telegrams and identify the location of mobile tag(s) in or around the public transportation vehicles. The base stations (or so called anchor nodes) are placed inside the vehicle. The system is basically communicating to exchange location datagrams with some minor additional information for example about tag identity.

Two UWB specific technological options are still being considered: LDR-LT based on pulsed transmissions (similar to standardized IEEE 802.15.4a [i.7]) as well as HDR-LT based on MB-OFDM (similar to standardized ECMA-368 [i.8] and ECMA-369 [i.9]). The communication is controlled by a cluster head and thus will happen subsequently with the tag devices (usually up to several tens of devices per cluster head coverage area). However, this happens only in certain time intervals and at different geographic positions as the transportation system operates mainly if customers occupy/leave the transportation vehicle.

Selected European experimental activities have illustrated the strong demand for EFM systems, for example see [i.13]; however it is hardly possible at the moment to provide exact figures on the market share of BIBO-based systems.

In Germany BIBO is already part of the German EFM standard "VDV-Kernapplikation". In the UK the British Department for Transport has contracted a desk study on the applicability of BIBO for the UK's public transport market in 2007. In Switzerland the Swiss Federal Railways has requested proposals from suppliers of BIBO technologies using mobile phones in 2007. From public transportation network operators in other EU countries, such as Portugal, a general demand for BIBO solutions is known from the CALYPSO project.

It can be extrapolated from the active EU countries, that in general BIBO systems are of highest interest for public transportation network operators in the European landscape characterized by a high coverage of public transport. The application of BIBO systems increases quality of life for the passengers and provides significant economic advantages for the public transportation network operators. Furthermore the application of BIBO systems saves natural resources such as energy and reduces pollution like CO_2.

Experiments and trials have shown that the BIBO systems need to function fully automatically in order to reach sufficient user acceptance level and therefore standardized low power short range radio with inherent high accuracy and real-time location positioning features are required. UWB is the only radio technology known currently fulfilling those requirements. Therefore it can be expected that in the far future all BIBO systems will be completely realized by applying UWB radio technology.

The number of BIBO systems in operation in the future can be extrapolated to the total number of public transportation systems in a given geographic area. Other technological alternatives have clearly shown weaknesses in user acceptance (end user as well as public transport network operator), which will lead in the long term to their disappearance from the market resulting in a 100 % coverage of UWB-based BIBO EFM systems.

For more market information concerning category A systems, see annex A. For detailed technical information of category A, see annex B.

5.2.2 Category B: Location tracking and positioning in the automotive environment

In the automotive environment, the radio link range is typically on the order of the size of the vehicle and the base station(s) is(are) typically inside the vehicle, while the tag could be inside or outside the vehicle. One example application is the door open function with the ability to locate a mobile tag based on ranging. The system mainly exchanges short data telegrams being used for processing ranging when the tag is arriving at the vehicle zone or is leaving the vehicle zone.

Based on the typical application and range, it is expected that there will be one category B system per car implemented in the future. So the market is enormous in terms of relative share, which is expected to become 100 %, as well as absolute numbers, which can be directly derived from the annual sales of new cars in the European countries. In addition there will be possibilities to add those systems to used cars, but the market share there is expected to be negligible compared to the primary market.

There is a ramp up period foreseen, where first more luxury cars will be equipped with category B systems, while it then will be expanded to the mid-size and even down to the economy cars over time due to the potential for very cost efficient mass production and ultra low energy consumption.