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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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Contents

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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:
  - 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.

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.

For detailed market information concerning category B systems, see annex A, and for detailed technical application descriptions, see annex B.

5.2.3 Category C: Sensing in the automotive environment

The vision of accident-free traffic is one of the most challenging visions in today's and the future automotive market. The improvement of traffic safety is a strong motivation for many important innovations in the automotive industry. In the automotive environment, a number of different sensor applications are considered to support the realization of this vision. Some of those sensor applications are active while the car is moving only and provide thus an inherent mitigation to fixed/portable legacy radio services. Others operate inside different compartments of the car and experience a high shielding attenuation towards the outside world. Some are active inside the shielding if the car electronic is switched on and remain active until switched off. They are used mainly for cable replacement or as a cable break fallback solution in order to reduce weight, manufacturing and maintenance costs and increase reliability of telemetric command and control communications and thus enhance the safety of the car passengers.

An example covered by the present document is an intelligent tire system providing information on the tire and the tire-road contact. It is an important element of the electronic car management system, which can provide much additional information to a wide range of vehicle control sub-systems and various vehicle control as well as comfort and safety applications. The first products that have been introduced in the field of intelligent tires are as pure Tire Pressure Monitoring Systems (TPMS). More sophisticated tire sensor systems, that are still in the process of research or pre-development, show the high interest in this field. Basic sensor technologies which enhance the realization potential for innovative monitoring of tire and tire-road contact are under investigation. UWB radio communication is a technology that allows low-power transmission at relatively high throughput, and guarantees a good immunity to multipath and therefore is the logical choice for such applications, where information has to be transferred from a rotating tire towards the car networking elements places in the car chassis, see annex B for a more detailed technical explanation.

Since November 2003 all new car sales in the USA are forced by NHTSA by law to be equipped with TPMS. The European Commission has proposed as well a law, which mandates that from 2012 all cars sold in Europe are equipped with intelligent TPMS systems [i.11]. The target is to reduce fuel consumption (alone in Europe 10 million tons of CO_2 emission can be reduced by TPMS) and to increase passengers' safety. TPMS are only the first step into the direction of smart sensing of tire and tire-road contact and increasing in an evolutionary way the absolute safety of passengers and therefore avoiding extremely harmful accidents and in turn costs for the European society at the same time.

Therefore it is expected that the next step of the policy makers will be to go further in this direction and to force by law that intelligent tire systems are employed. Those systems cannot operate with traditional radio and therefore a 100 % market share of UWB-driven, smart tire systems can be expected.

For detailed market information concerning category C systems, see annex A; for more detailed technical information about category C systems see annex B.

5.3 Radio spectrum requirements and justification

Table 2: Overview of radio spectrum requirements per application

Category	Application	Radio spectrum required	Justification
A	Positioning in public transportation environment	3,1 GHz to 4,8 GHz, and 6,0 GHz to 8,5 GHz	According to update of ECC/DEC/(06)04 [i.3] and draft update of ECC/DEC/(06)12 [i.5] with additional power to cover rare cases with high reliability.
B	Positioning in the automotive environment	3,1 GHz to 4,8 GHz, and 6,0 GHz to 8,5 GHz	According to update of ECC/DEC/(06)04 [i.3] and draft update of ECC/DEC/(06)12 [i.5].
C	Sensing in the automotive environment	3,1 GHz to 4,8 GHz, and 6,0 GHz to 8,5 GHz	According to update of ECC/DEC/(06)04 [i.3] and draft update of ECC/DEC/(06)12 [i.5].

6 Current regulations

Location tracking devices which are only for indoor operation are covered by the Generic UWB decision [i.2] in Europe. However, there were no regulations permitting the operation of UWB location tracking and sensing applications in mixed and outdoor scenarios or of UWB devices installed in "road and rail vehicles".

However, in [i.3] it is recommended to extend the application of UWB devices to installations in road and rail vehicles and it is expected, that the EC will update the legally binding rulemaking [i.4] according to [i.6] by the beginning of 2009.

7 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.

Table 3: Proposed regulation for equipment

Frequency	Area of operation/Category	Maximum Average power density (EIRP) (dBm/MHz)
	Category A	
3,1 GHz to 4,8 GHz	public transportation EFM systems	-41 dBm/MHz, TPC+DAA, if MB-OFDM (see notes 1 and 2)
6,0 GHz to 8,5 GHz	public transportation EFM systems	-31 dBm/MHz This proposed limit is 10 dB above the current generic rules to compensate for higher path loss and technology losses (but offers additional mitigation in terms of TPC, if MB-OFDM). An extra +6 dB Tx power dynamic is requested to cover rare "difficult" cases in terms of radio propagation/blocking (up to 1 % of cases). An additional mitigation is to limit the activity factor to approximately < 10 %.
	Category B	
3,1 GHz to 4,8 GHz, 6,0 GHz to 8,5 GHz	road vehicles location systems	-41,3 dBm/MHz, LDC
	Category C Road and rail vehicles wireless sensor data communications	
3,1 GHz to 4,8 GHz, 6,0 GHz to 8,5 GHz	Smart tire: Devices attached to chassis - transmission towards chassis, transmission only during movement of vehicles (minimum speed 20 km/h), tire shielding attenuation (15 dB to 20 dB)	-41,3 dBm/MHz, duty cycle/activity factor max. 5 %
	Telemetry network inside vehicles	-41,3 dBm/MHz, LDC or TPC
	Passenger alarm systems	-41,3 dBm/MHz, LDC
NOTE 1: +6 dB Tx power dynamic is requested to cover rare "difficult" cases in terms of radio propagation/blocking (for up to 1 % of cases). NOTE 2: Additional mitigation is to limit the activity factor to be approximately < 10 %.		

The LDC definition used in the present document is: 5 % TX activity over 1s, 0,5 % TX activity over 1 h, 5 ms max burst duration, 38 ms min off-time between bursts.

Devices permitted under ECC and EC decisions for UWB [i.2], [i.3] and [i.4] are for indoor usage, exempt from individual licensing and operate on a non-interference, non-protected basis. For usage in road and rail vehicle the same rules as for indoors usage should apply with an additional requirement for a 12 dB range Transmit Power Control in certain subbands (according to update of ECC/DEC/(06)12 [i.5]) if there is no LDC rule applied.

8 Requested ECC and EC actions

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

Relevant compatibility studies should be performed 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.

The requested EC action is a revision of the existing EC rulemaking [i.4].

Table 4: Status with respect to current regulations

category	Frequency	relation to current regulation	requested modifications to current regulation
A	3,1 GHz to 4,8 GHz	ECC/DEC/(06)04 [i.3] in combination with ECC/DEC/(06)12 [i.5] for DAA is applied	Additional provision for TPC with increased PSD of up to 6 dB compared with the existing TPC regulation, i.e. range from -35,3 dBm/MHz to -53,3 dBm/MHz. In order to offset the increased PSD, a maximum activity factor restriction of 10 % is proposed.
	6,0 GHz to 8,5 GHz		An increase of 10 dB for PSD is proposed combined with an 18 dB TPC range from -25,3 dBm/MHz to -43,3 dBm/MHz. Furthermore, a maximum activity factor restriction of 10 % is proposed. This frequency band can be implemented as stand-alone or in combination with the lower frequency band.
B	3,1 GHz to 4,8 GHz	ECC/DEC/(06)04 [i.3] in combination with ECC/DEC/(06)12 [i.5] for LDC is applied	ECC is requested to confirm the interpretation of conformance to the existing regulation and to confirm that the proposed application is conform to the rules laid out in EC decision 2007/131/EC [i.4].
	6,0 GHz to 8,5 GHz		An LDC provision is proposed instead of TPC. ECC is requested to confirm that LDC can be applied instead of TPC in this band as well (according to the ECC-TG3 approved proposal for update of ECC/DEC/(06)12 [i.5]).
C	3,1 GHz to 4,8 GHz	ECC/DEC/(06)04 [i.3] in combination with ECC/DEC/(06)12 [i.5] for LDC or DAA+TPC is applied	ECC is requested to confirm the interpretation of conformance to the existing regulation taking into account the condition of equivalent protection laid out in EC Decision 2007/131/EC [i.4].
	6,0 GHz to 8,5 GHz	ECC/DEC/(06)04 [i.3] is applied	An LDC provision is proposed instead of TPC. ECC is requested to confirm that LDC can be applied instead of TPC in this band as well (according to the ECC-TG3 approved proposal for update of ECC/DEC/(06)12 [i.5]).

9 Expected ETSI actions

Mandate M/407 [i.6] was received by ETSI, calling for establishment of Harmonized Standards for UWB.

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 and sensor communication technology described in the present document form an important subset complementing the ones described in parts 3 [i.14], 4 [i.15] and 5 [i.16] of this multi-part deliverable. Within automotive environments and transportation scenarios, in general the application of UWB will enable higher efficiency of systems configuration and maintenance, less weight of vehicles and increased safety and security. Besides these objective parameters, the quality of life and convenience for the customer will be significantly increased. Important benefits for public transportation operators are expected in terms of route optimization which saves resources as well as significant contributions to the global CO_2 reduction which has recently been defined as a major political requirement.

The list below indicates the UWB Location Tracking and sensor technology in each of a number of the most urgent environments; it is in no way intended to be an exhaustive list and is just meant to illustrate some representative examples to enable better understanding of the principles:

- Location tracking and sensing in/around cars:
  - Differentiation in/out-car
  - Intention
  - Distance
  - Parameter check
- Location tracking and sensing inside public transportation vehicles:
  - Be-In-Be-Out systems (BIBO) EFM systems for road and rail vehicles: This application is part of a global fully automatic e-ticketing system requiring a high reliability of precise positioning in various public transportation means. In particular, the local and rural area transportation will be covered, where there is a relatively high effort compared to the ticket price to maintain a paper/card ticket service. Therefore local trains, trams and bus lines are primarily addressed.

A.2 Market size and value

UWB location tracking and sensor systems will have a direct impact in a number of markets, such as healthcare, workplace, security, entertainment, defence training, warehousing, and manufacturing.

A.2.1 Market potential for BIBO based EFM as envisaged under category A

In many countries transport operators operating public transport networks are looking for BIBO systems. Some significant activities may illustrate the strong demand; however it is impossible at the moment to provide exact figures on the BIBO market in public transport.

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

A rough estimation for an example area (state of Saxony), assuming 100 % coverage of all passengers, is 400 000 users in total and approximately 100 000 users today already using some kind of discount system including flat rates for certain traffic zones. The market potential is close to about 400 000 users as one can expect. With a fully automatic system, not only the zone flat rates but in addition specific usage can be charged accordingly, and users who use the public transportation not very frequently will benefit as well. However, it is expected that a minor amount of technology-agnostic people (about 2 % to 3 % of the users) will be reluctant to change to the new system. Once the success of a BIBO system will be demonstrated in an example area, other states/areas will soon follow the example as the economic gain for the transport operator is significant. Extrapolating the derived usage pattern to Germany one may consider a market potential of approximately 97 % to 98 % of all local (national) public transportation users.

A.2.2 Market potential for Automotive Positioning Systems as envisaged under category B

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 a keying 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 new sold 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. During ramp-up the market share is expected to vary from 10 % to 80 % of annual new car sales.

A.2.3 Market potential for Automotive Sensor Systems as envisaged under category C

The European Transport Safety Council's (ETSC) general reports on EU fatalities illustrate that each year 42 000 EU citizens are killed and over 3,5 million are injured in transport crashes. These accidents cost over 166 billion Euros and are the leading cause of death and hospital admission for citizens under 45 years. Finnish accident analysis shows that defective tires were either a contributing factor or a main cause in about 16 % of all fatal accidents. According to a report from German Traffic Safety Committee, more than half of the accidents with personal injury are caused by slippery tracks due to rain, ice and snow.

Accident analysis reveals that detecting adverse road conditions is of great interest from a traffic safety point of view and shows the great benefit of the envisaged system to improve traffic safety. UWB-RT is a possible technical means enabling implementation of applications helping to solve that challenge. Also hybrid radio systems promise to be viable candidates to serve for specific applications under this category.

As an example, in the field of intelligent tire systems Tire Pressure Monitoring Systems (TPMS) have been the first products introduced in the market. This development was mainly driven by vehicle manufacturers. The basic functionality of a TPMS is to monitor tire inflation pressure and temperature. The range of available solutions and products comprises various indirect and direct systems as well as simple or sophisticated means for the relevant driver information.

Another trend is to develop sophisticated sensors which can provide additional information for vehicle applications. These activities are more or less driven by automotive electronic suppliers or research organizations.

UWB radio is the right wireless technology for transmitting digital data over a wide spectrum of frequency bands with very low power. The required peak data rate and energy efficiency can only be provided by UWB radio as of today. These features are becoming significant taking into account the absence of traditional energy sources in the rotating tire.

Therefore it is expected that 100 % of smart tire systems, which extend the relatively simple TPMS towards more sophisticated sensor systems, will be enabled by UWB short range radio links to connect the tire sensor network with the car chassis command and control and safety network.

A.3 Traffic evaluation

The likely modes of deployment and activity factors of UWB Location Tracking and Sensing systems in automotive and in public transportation environments are discussed below:

- **Category A: Location positioning tracking in public transportation**. It is estimated, that the local activity factor will be on the order of less than 10 %. The system basically communicates to transmit the location datagrams with some minor additional information about the tag identity. Both options are still considered: LDR-LT based on pulsed transmissions (similar to IEEE 802.15.4a [i.7]) as well as HDR-LT based on MB-OFDM (according to ECMA-368 [i.8] and ECMA-369 [i.9]). The communication is controlled by a cluster head and thus will happen subsequently with many 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 only if customers occupy the transportation or if the interior of the transportation has been reconfigured.

- **Category B: Location positioning in an automotive environment.** These systems have a very low activity factor on average, and is compliant to ECC/DEC/(06)04 [i.3] and ECC/DEC/(06)12 [i.5] activity factor levels of 5 % in one second and 0,5 % in one hour.

- **Category C: UWB sensor systems in an automotive environment**. In the automotive environment, a number of different applications are considered. Some are active only while the car is moving. Others are inside different compartments of the car and are active if the electronic is switched on and is used for certain cable replacement or a cable break fallback solution. It is about 5 % activity factor for the smart tire system, while it is about 0,5 % for telemetry network and passenger alarm systems. For the smart tire, the system is in operation only at a certain time in each vehicle (5 %), and in addition the vehicle may be moving to a different location and "disappearing" from the potential victims' horizon rapidly.

Location and sensor system devices are generally required to be very low powered and zero-maintenance (with battery lifetimes of years), and so tend to have inherently **relatively low activity factors.**

In summary, UWB location tracking and sensor systems are primarily to be used on moving platforms, which have indoor like parameters, by nomadic users, and are likely to have relatively low activity factors and duty cycle.

Annex B: Detailed Technical information

B.1 Detailed technical description

B.1.1 Public Transportation Systems

B.1.1.1 Status of development of electronic fare management systems based on automatic detection of user media

Background

Proximity based contactless smart cards (ISO/IEC 14443-1 [i.10]) have widely been rolled out over the past years in Electronic Fare Management (EFM) for public transport. Meanwhile on the application level national standards or industrial de-facto standards have been defined by several organizations (e.g. ITSO in the UK, VDV-Kernapplikation in Germany, CALYPSO etc.) in order to facilitate the implementation of interoperable EFM schemes in public transport.

Successful roll-outs of proximity smart cards are well known either from closed systems that have fare gates at the stations, or from systems using pre-specified fare products (as an electronic equivalent to today's paper tickets): e.g. Octopus in Hong Kong, Navigo in Paris, Oyster in London.

However, many cities and regions that do not have gated systems (i.e. open systems) and that have high proportions of season pass holders are concerned about a massive loss of convenience by implementing proximity smart cards and have therefore not yet implemented smart cards at all. If season pass holders were obliged to validate their tickets on the smart card at least at the beginning of each journey, the user acceptance gets lost. In Germany and other central European countries about 70 % to 85 % of the passenger journeys are by season pass holders. This is an important reason that there are no significant proximity smart card schemes in public transport in Germany and Switzerland.

Moreover implementing smart cards does not focus only on replacing a paper or magstripe ticket by a smart card as a new fare media, but it goes further beyond by opening new opportunities for the migration of the fare structure and fare products. In particular EMF schemes could offer distance related fares ("pay-as-you-go") if in addition to the entrance validation the exit data of the journey were recorded. Furthermore exact journey data from users (precise recording of entrance and exit) provide a database for optimizing operation costs and operation planning in a completely new quality level.

Apart from some very limited implementations, the applicability of payment smart cards (e.g. electronic purse cards from credit institutes) failed due to technical restrictions and commercial conditions in using those cards in multi-application environments for public transport. Even latest developments in proximity technology for credit cards such as PayWave by VISA or PayPass by Mastercard do not meet the requirements of advanced future public transport ticketing as described here.

Functional requirements of an automatic detection

Due to the described background situation, future EFM systems have to meet the following basic functional requirements:

- convenient handling for users in open environments (no fare gates);
- handling of complex fare structures in integrated transport systems (multi-operator schemes);
- handling for season pass holders at least as convenient as today's paper tickets are;
- exact recording of journey data (begin and end).

Proximity smart cards are not able to meet all these requirements. Therefore transport operators have a strong demand in developing new technologies for EFM that enable a fully automatic detection of smart cards during the journey. Only a fully automatic detection is able to meet all the requirements mentioned above.

State-of-the art in automatic detection of smart cards

First concepts for an automatic detection have been developed and tested since the mid 1990s. E.g. in the ICARE project and later in the CALYPSO project, see figure B.1, RATP Paris has developed and tested a hands free antenna in cooperation with operators and partners in Lisbon using a passive proximity card in a vicinity environment. However the development was stopped in 2000 because the detection reliability achieved was not sufficient to handle (financially relevant) ticketing transactions with a high quantity of transactions per day. Even other concepts using passive smart cards such as the walk-in walk-out approach tested in Geneva during the EasyRide trial of Swiss Federal Railways in 2000, see figure B.2, failed due to limited detection reliability.

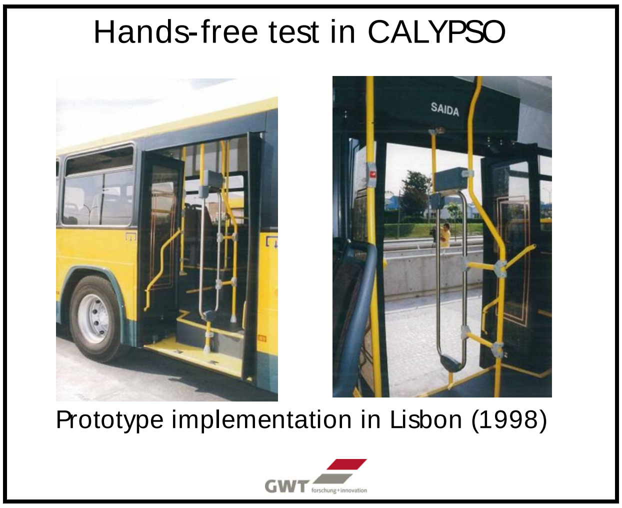

Figure B.1: Prototype implementation of hands free antennas in Lisbon in 1998

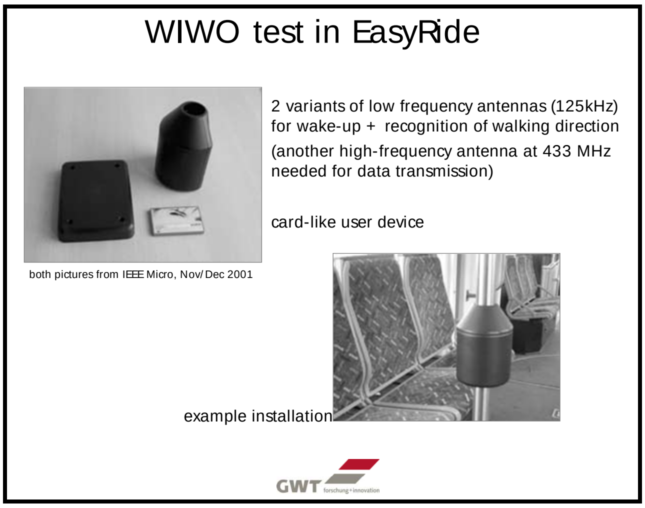

Figure B.2: Prototype installation of a walk-in walk-out approach in Geneva in 2000

However, these approaches and trials prove that public transport operators have a strong need for an automatic detection or registration of electronic tickets.

Therefore concepts and solutions have been developed for EFM based on active smart cards or active devices (RF-tags). For the first time Swiss Federal Railways has successfully tested an active smart card with automatic presence detection during the EasyRide trial in Basle in 2000 using a Be-In Be-Out (BIBO) approach. This technical approach was further developed and tested in a complete EFM environment during the ALLFA-Ticket pilot testing in Dresden in 2005. It was the first project in which the functional feasibility and the user acceptance of a BIBO approach that meets the functional requirements for future EFM has been successfully demonstrated in real operation.

The ALLFA-Ticket uses a two step detection approach, as described in figure B.3, in order to meet the BIBO requirements:

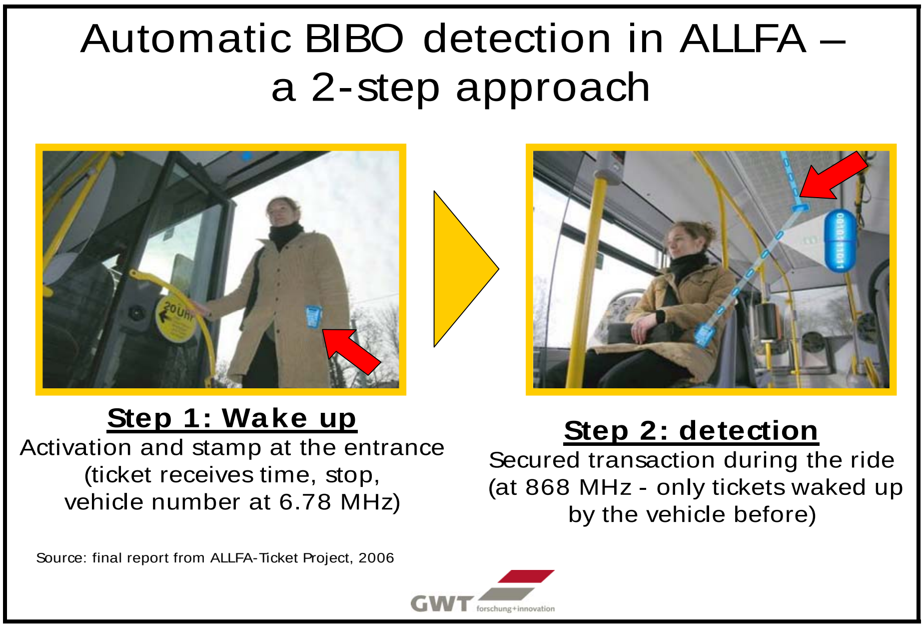

Figure B.3: The two step detection approach of BIBO in the ALLFA-Ticket system

Further concepts using active RFID technology based upon CALYPSO and 868 MHz are known from Technopuce (France). However information on practical experimentation is not available.

Basic requirements for automatic detection of user devices

The BIBO approach defines rather sophisticated requirements in terms of localization, security and communication speed:

- Coverage of various public transport vehicles (vehicle length up to 50 m).
- Precise localization of the user device (clear distinction between inside or outside of a vehicle with a tolerance of < 0,3 m only).
- Highly reliable detection of user devices (detection rate > 99 %) under public transport environment (vibration, moisture, interferences).
- Fast bidirectional communication: Detection of about 200 user devices between two stops within 10 s maximum (> 500 kbit/s or even higher).
- Secured messaging (currently 3DES, in future even asymmetric cryptography).

No standard communication technologies such as WLAN, USB, NFC, UMTS are available so far that meet these requirements of a BIBO approach. Therefore BIBO systems had to apply specific and proprietary communication systems. For that reason BIBO systems are more expensive in terms of user devices compared to proximity-based EFM systems and to standard communication systems.

Mobile phones as user device for public transport ticketing

Since the breakthrough of the mobile phone, transport operators consider mobile phones as a possible user device for EMF in public transport. The mobile phone provides two significant advantages for public transport operators:

- The operator has not to cover the costs for the user device (as for smart cards issued by him).
- The mobile phone provides power supply and a user interface enabling user interaction and feedback on system function.

Therefore more and more concepts have been developed focusing on an exploitation of the mobile phone for EFM in public transport. However the communication interfaces of current mobile phones including USB and the Near Field Communication (NFC) interface do not meet the BIBO requirements.

In the ALLFA trial, see figure B.4, both an active smart card and a mobile phone with an additional BIBO communication interface have been used. About 50 % of the trial participants voted for a mobile phone as a user device in BIBO schemes.

Demand for development

The description of the functional and technical requirements above and the state-of-the-art in available technologies shows a gap that defines the need for further developments.

After the functional feasibility and the user acceptance of a BIBO approach has been successfully demonstrated in the ALLFA pilot scheme, commercial exploitation of BIBO is the next step on the way to a roll-out.

UWB is considered as a possible approach for commercial exploitation of BIBO, because it has the potential to meet the defined requirements. Moreover UWB has the potential for a cost-effective solution due to its standardization and due to the expected quantities of UWB devices for several applications in the market.

Conclusions

Public transport operators require EFM systems beyond the implemented proximity smart cards providing the ability of an automatic detection of user devices.

Several conceptual approaches, samples and trials known from various countries prove this demand.

While concepts using passive smart cards failed completely, systems based on active devices are able to meet the BIBO requirements for ticketing transactions. A first BIBO system has been tested successfully and has to be commercialized for exploitation. However, commercial exploitation requires a massive reduction of costs for both the user devices and for the antennas/readers including wiring in the vehicles.

Using UWB as a basic communication scheme in EFM seems to be a promising way for a cost effective BIBO approach using a future standard technology available in user devices such as mobile phones in a completely automatic way while still providing the required accuracy.

B.1.1.2 Summary description

The system concept serves a wide range of positioning/logistics and very low data rate communications processes. LDR communications and navigation capabilities are addressed with priority on exact real time localization features. The system enables operation in the presence of many uncoordinated applications (from other potential radios) using either an impulsive or an ODFM based PHY. Its main advantage is the wide application using a standardized air interface solution for short range and being capable of exact location tracking available in almost any portable devices in the near future, even if originally planned only as communications devices. The BIBO decision requires sub 30 cm resolution, data transmission between the node and the anchor nodes in a bi-directional way and this data transfer can be used at the same time for exact location tracking. The system is required to be very robust and reliable as the positioning and the data transfer can be related to payment operations. This system builds on the wide availability of BT v3.0 PHY (OFDM based UWB above 6 GHz) or wireless USB (OFDM based UWB below 5 GHz) in almost any cellular phone in the future as well as supports dedicated chip card based solutions operating with impulsive UWB below 5 GHz and above 6 GHz respectively.

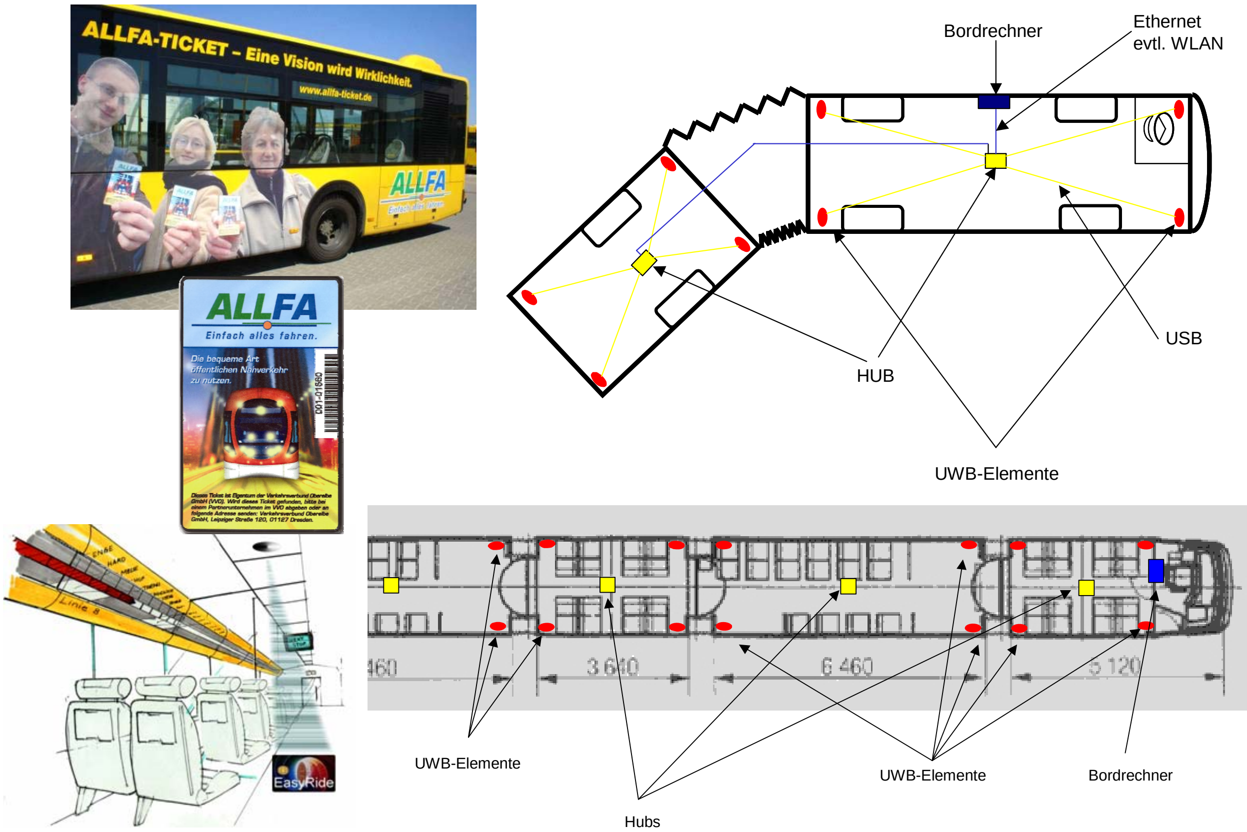

Figure B.4: Transportation Scenarios

B.1.2 Category B: Automotive Location Positioning Systems

B.1.2.1 "Keying Application"

The location tracking function for the following applications is described in this clause: RKE - Remote Keyless Entry (with additional functions), Keyless/Passive Entry, Passive Start/Stop functions.

A future vehicle key is shown in figure B.5.

Figure B.5: Future vehicle key

The applications for the automotive location systems have a low activity factor. The applications in this category cover comfort and security as well as safety related features for keying applications.

For the realization of the following applications a combination of SRD-Technology in the UHF Frequency range and UWB is possible and can be necessary to fulfil the customers' requirements in the future.

The different applications in this category can be split in the following groups:

- **Remote Keyless Entry (RKE):** This application allows the driver to manually open the vehicle with a radio controlled key. An extension of this application is the keyless or passive entry.

- **Keyless or Passive Entry:** This more convenient application is based on bidirectional communication between the vehicle and the driver. The UWB Location Tracking sensors detect the approaching driver. A signal is sent from the vehicle to the driver's key, which responds with an identification signal. The same identification signal plus the localization (on which seat) allows the driver to start the engine by simply pushing a button without putting the key into the ignition lock.

Two additional functions for the keying functions are:

- **The passive start application.** This means that starting the engine without any identification signal is impossible, which enhances the antitheft protection. The car can only be started when the driver (the key/tag) is in the car.

- The second additional function is **Remote Key,** for opening and closing of windows, sunroof, retractable hardtops, etc. Doors may automatically lock when the driver exceeds a certain distance from the vehicle.

In addition to the UWB signal, a Command and Control Signal Channel can be realized in the ISM or SRD frequency range to activate the tracking system or combine with other automotive applications (e.g. switch on car heating or personal car Communication).

B.1.2.2 Personal Car Communication System

This system allows the driver to receive information at greater distances from the vehicle, telling him e.g. that the lights or radio are left on or that the car is not locked.

An additional function is e.g. to start the fuel fired heater or other car functions. An important aspect is the enhanced safety function of this application e.g. detecting persons left in a car.

B.1.2.3 UWB tracking function for a car finding application (e.g. in a parking area)

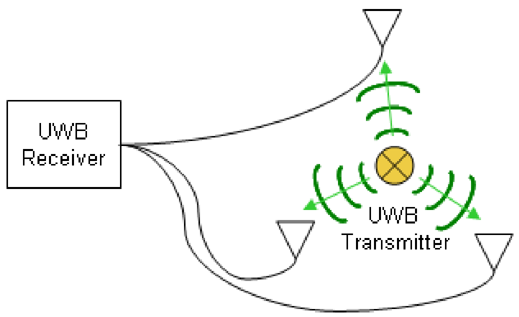

Figure B.6: Typical location tracking system setup

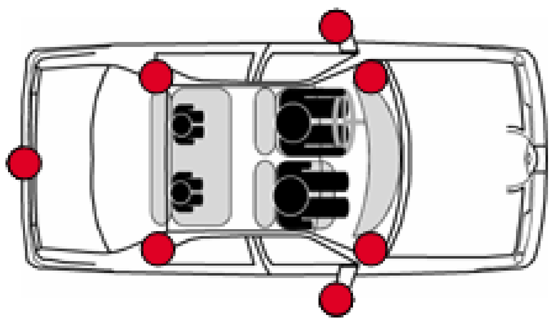

Figure B.7: Example of one possible antenna placement

Figure B.6 is a typical location tracking system setup. Figure B.7 is an example of one possible antenna placement in a car.

- Car Finder and Parking Application:

  This application can be realized in parking areas and in combination with the car and car communicator to find the car in large parking lots. To increase the "finding distance", a combination of the car systems (key + car) in an Ad-hoc network is also possible.

- UWB imaging system also as an intrusion/interior monitoring function for vehicle alarm:

  The same UWB radio system applied for the keyless entry system and all of its advanced versions can be easily used for a second functionality related to theft and intrusion detection/protection.

The system can be turned into a sensing network to monitor non-cooperative objects entering the passenger compartment. Therefore the same antenna and RF units but a slightly changed baseband processing inside the UWB tags will be applied. The double use of the devices saves resources as well as costs.

The silent detection can be used to monitor activities of persons inside the passenger compartment in order to detect presence, position/size and physical conditions at the same time.

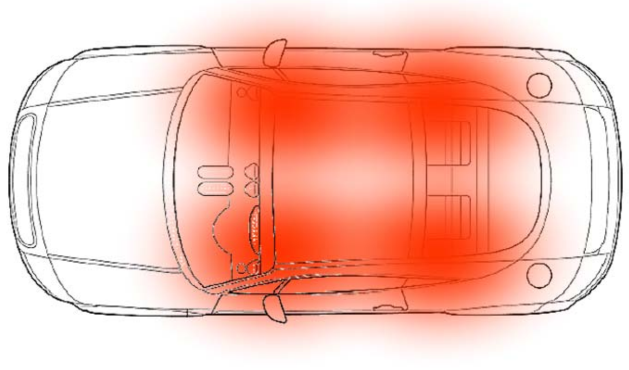

Figure B.8: Simplified field distribution inside a car, when the antennas sit in the A and C pillars

B.1.3 Category C: Automotive Sensor Systems

For this application it is also possible to have, in addition to the UWB signal, a Command and Control signal channel which can be realized in ISM or SRD frequency ranges.

This can lead to telemetry network communication, e.g.: communication between truck and trailer.

B.1.3.1 Communication between truck and trailer

The transmitted information enables the driver to monitor the status of important points on the trailer, such as brakes, lighting, individual pressure of all tires, etc.

To provide drivers with an image of the whole surrounding of a vehicle, camera sensors can be used. These cameras are mounted outside of the vehicle. For very long vehicles (e.g. trucks with trailers) two cameras are mounted on the truck and two on the trailer to cover the vehicle surroundings (see figure B.9). The data rate of two trailer cameras is about 200 Mbits/s. To avoid additional cables and interconnection efforts between the vehicle and the trailer, a wireless transmission of the trailer cameras' data to an Electronic Control Unit (ECU) are considered. The wireless transmission is outside of the vehicle.

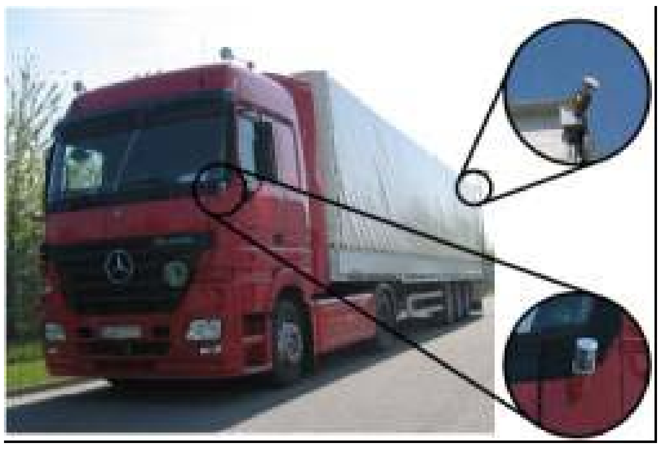

Figure B.9: Truck equipped with four cameras

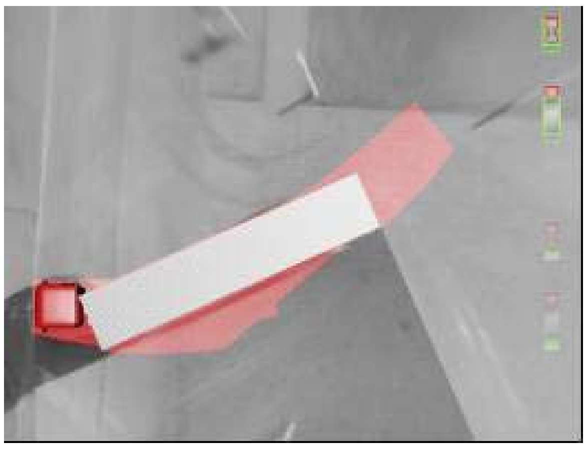

Figure B.10: The bird's-eye-view image shows the whole surrounding area of a truck-trailer combination

Narrowband wireless systems, such as conventional wireless LANs, suffer from multi-path fading in highly reflective environments and thus need a significant amount of fading margin. The Ultra Wide Band (UWB) technology is considered as a promising system to transmit the camera sensor data of the trailer, due to its robustness against the influence of multi-path fading, resistance to interference, reliable high data throughput, and low complexity in the transceiver architecture. Additionally the UWB technology enables a relative distance measurement between the transmitter in the camera sensor and the receiver. This information can be used to find the exact position of the cameras (e.g. when the trailer is moving) relative to the vehicle.

A wireless camera sensor data transmission system needs to be able to offer reliable high speed data rates in the vehicle propagation environment. To obtain a top-view image, a view of the whole surrounding area of the vehicle from above (see figure B.10), four cameras are combined. Such a blind spot free image is shown to the driver on a single display mounted on the dashboard. Since the combined top-view image is displayed in real time, the trailer cameras require a low latency transmission. Low latency can be achieved by transmitting high speed video data with low latency video compression yielding higher data rates than compression algorithms where latency is not an issue. The UWB technology is able to transmit these high data rates in a specific vehicle scenario.

A first estimation shows that every year about 10 000 new Mercedes trucks can be equipped with such a system. The number for the after sales market can be much greater.

B.1.3.2 Inside Vehicle Command and Control Communications

In a modern car, a large number of knobs and controls are available. A typical car entertainment and climate control centre hosts a large number of push buttons and control wheels. Other examples are the window opener buttons for side doors, or a back seat climate control centre. As each user interface element needs to be connected to a control unit or body computer, typically located in the dashboard, a large cable harness is required, providing a pair of wires to each element.

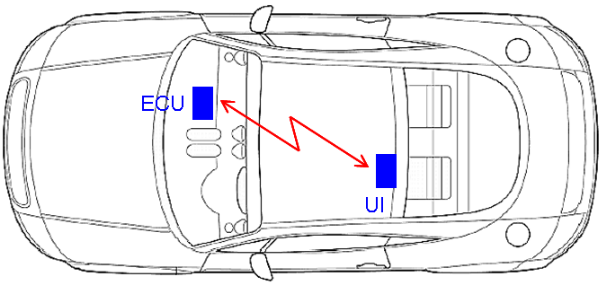

Figure B.11: Communication inside the passenger cabin

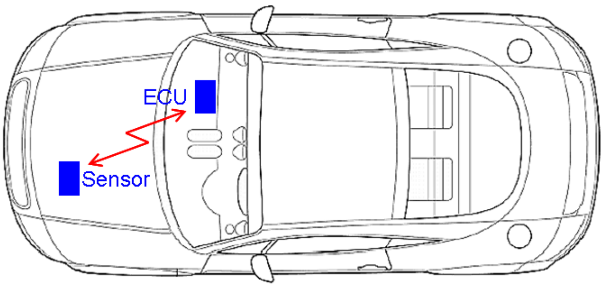

Figure B.12: Communication inside the motor compartment

Wireless communication between the remotely mounted user interface elements, scattered everywhere in the passenger cabin and the corresponding control unit located in the dashboard (see figure B.11) leads to a reduced cabling effort. Also customization of car models is much simpler and retrofit equipment can be easily installed.

A power supply for the components of the remote user interface is still needed; however alternative supply means such as common supply cabling or energy harvesting are possible. User interaction will only occur very sparsely, and the information volume to be passed to the control unit will be extremely small.

Although most of the user interface consists of such very simple components such as push-buttons, others might have more elaborate elements such as display to provide additional information. Therefore two-way communication is necessary to achieve a satisfying remote control solution.

B.1.3.3 Engine compartment

Transmission of wireless datagrams for telemetry information saves copper cabling costs and weight as well as set-up and maintenance costs.

There is a lot of data communication inside the motor compartment between different sensors and their corresponding ECU. In order to reduce the cabling effort, achieve higher flexibility in mounting positions and installation of after-market devices, wireless data communication is desired.

Two applications are of interest specifically at the moment. The first application is a simple communication between the car battery and an ECU, providing the car battery charge state to the electronic control unit, see figure B.12. This type of data communication is typically realized using a wired LIN bus. The second application will address a CAN bus type communication.

Figure B.13 shows a typical electrical field distribution of a high frequency signal at 433 MHz in the engine department. Because of the metallic surroundings and the complex geometry of the compartment, a number of arbitrarily shaped field minima and maxima can be observed.

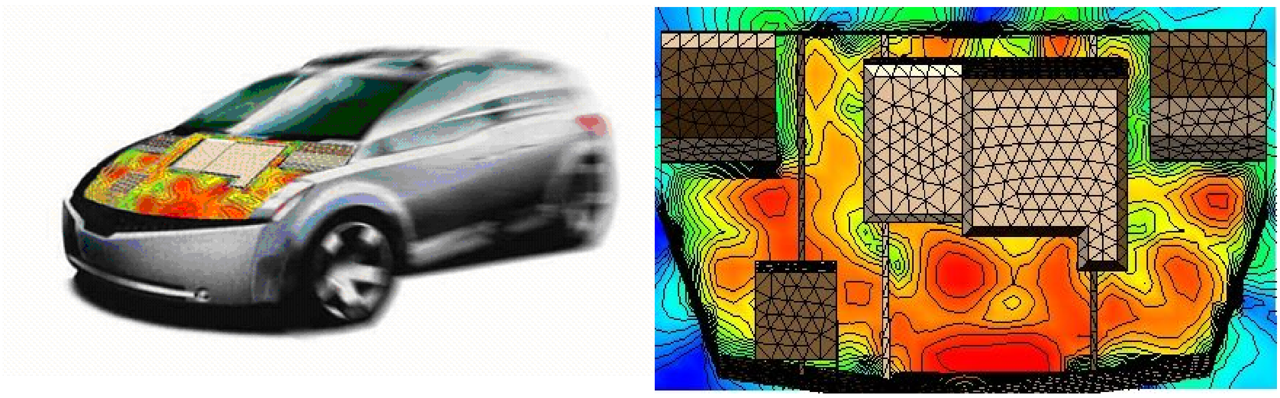

Figure B.13: The UWB propagation channel - reliable in the harsh automotive environment

B.1.3.4 Tire Pressure Monitoring System (TPMS)

TPMS is considered an integral part of additional measures as required by the European Commission in order to achieve the EU CO_2 policy target of 120 g/km.

Background: The EU has set out a strategy to achieve a fleet average target for new vehicles sold in 2012 to 120 g CO_2/km. To achieve this target, the Commission is proposing to require mandatory CO_2 emission targets for manufacturers that equate to average CO_2 emissions of 130 g/km. To compensate for the gap of 10 g/km, additional measures have still to be defined. Current proposals include low rolling resistance tires, low friction oils, more efficient air-conditioners, TPMS, etc.

The role of TPMS is to eliminate the statistically proven incidents of low tire pressure that lead to increased rolling resistance and consequent higher fuel consumption.

The safety aspects of TPMS need to be also not overlooked. An unreliable system may lead either to failure to warn of low tire pressures or to false alarms.

A further enhanced approach of this concept is the "Intelligent Tire".

Smart Tire: reliable transmission of sensor data accumulated in a smart tire network inside a tire towards the car backbone network inside the chassis.

The *Intelligent Tire* basically is a sensor network having the goal of acquiring signals from a cluster of sensors located in the tire and of transmitting data to a receiver located in the car chassis.

The main components of the system are the following:

- Sensor Node: The Sensor Node is the in-tire device. It is mainly responsible for data acquisition, processing and transmission to the in-vehicle equipment. Typically there are two to three sensor nodes in each tire.

  PAN Coordinator: This device is a microprocessor-based unit basically responsible for the communication management and Sensor Nodes control. In order to simplify the wireless PAN architecture and management, the preferred choice is to have more than one PAN Coordinator in a single car and namely one coordinator in each wheel well. In this way, the number of Sensor Nodes to be controlled by each PAN Coordinator is limited, and each Sensor Cluster Node in a tire may be managed as an independent PAN, disregarding other clusters. Hence the network is build by 4 PAN Coordinators.

- System Control Host: The system control host is a microprocessor-based unit having the goal of collecting data from the different PANs that are on the car and providing the highest layer of control to the system.

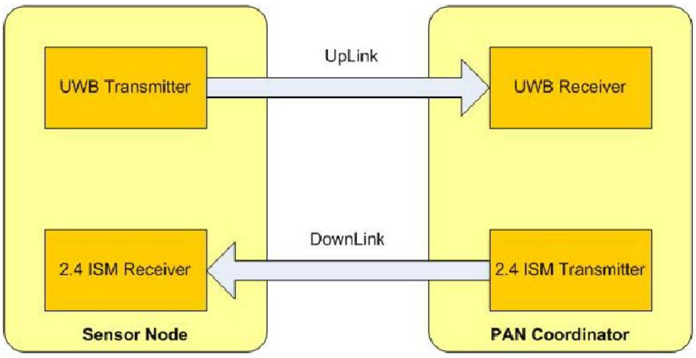

Figure B.14: Automotive Sensor Example

The RF section architecture is schematically depicted in figure B.14. The main functions of the RF section are low energy TX, high speed, short data telegram transmission from the node to the PAN coordinator (here Up-Link, requiring more energy for reception) and low-speed data reception from the PAN coordinator (Down-Link, requiring only very little energy for reception).

The power supply subsystem will be battery-less. The hypothesis considered is scavenging technologies, and so the main constraint for both transmitter and receiver of the Sensor Node is ultra low power consumption. It has to be considered that a scavenger provides a time-dependent power, since power generation and coupling is strictly related to the wheel motion and position.

Due to presence of severe multipath, wideband transmissions are preferred to narrowband transmission, and the benefits of UWB radio are that it allows low-power transmission at relatively high throughput, and that it guarantees a good immunity to multipath.

The channel is from the tire on a car up to a receiver in the wheel-well. Hence, the channel model has been built by taking a UWB model, available from technical literature, taking measurements from a car environment, and adapting consequently the model parameters in such a way to fit channel true measurements with modelled data.

A typical, small car was selected as the "host" for the measurements, and the right, rear quarter of the car was cut off, preserving all machinery and components connected to the wheel-well. This piece was mounted on a platform as shown in figure B.15. This allowed measurements to be made from the UWB channel in a true environment very similar to the final operating environment in which the system will be operating.

Figure B.15: Smart tire measurement set-up

The data collected from the described setup have been compared to the Saleh-Valenzuela model (SV model) adopted by the IEEE 802.15.4a [i.7] working group, and the overall shape of the data shows results very close to the SV model.

An estimation of the RF channel (including also car chassis, etc.) at the radio link operating frequency has been made in order to take into account free space losses, losses in propagation through the tire, multi-path effects due to the harsh environment and other lossy propagation effects.

A set of measurements on tire-induced attenuation have been performed; the measurements consider a range of frequency from 2,4 GHz to 10 GHz and have been performed in an outdoor environment.

The attenuation range is very wide and differs with tire type, angle between antennas and also antenna type.

It can be noticed that the total tire structure (not only rubber but also metallic structures into the tire) affects high frequency RF propagation. Every particular tire with its own structure underlines particular critical frequencies depending also on the propagation angle between the two antennas.

An evaluation of the dependency of tire attenuation on transmission angle has been performed, see figure B.16: up to 4 GHz, a degradation of about 6 dB (one quarter power) for 90° with respect to 0° is shown.

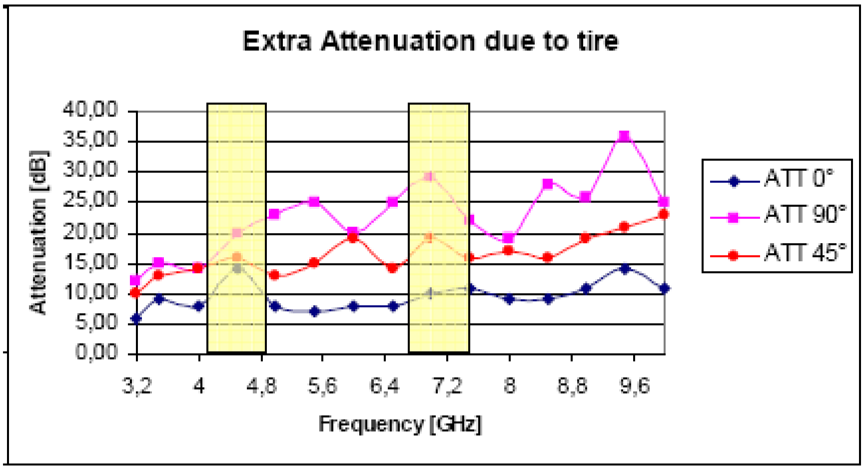

Figure B.16: Smart tire attenuation measurement results

Looking to the current mitigation techniques, we can observe that our solution is in line with the requirement [i.4] relative to the sum of all transmitted signals less than 5 % of the time each second (1st requirement), in line with the requirement that each transmitted signal does not exceed 5 ms (3rd requirement); and if we consider that the system turns on if the speed is higher than 30 km/h, it is also matched that the sum of all transmitted signals is less than 0,5 % of the time each hour (2nd requirement).

The protocol actually under development is compliant to 1st, 2nd and 3rd requirements:

- 5 ns of pulse length each 80 ns, for ½ wheel round, means about 3,13 % of time each second: 1st requirement is matched.
- Each transmitted signal (frame) will be long 40 bytes. Given the channel coding characteristics, this means a duration < 1 ms: 3rd requirement is matched.
- As for the 2nd requirement, it is matched if we assume that the percentage of 0,5 % of time each hour for the sum of all transmitted signals is computed by averaging over a whole day, the averaged hours per day in which the car is continuously utilized is lower than 6 h and 15 minutes.

  Alternatively one can argue, that at a certain place the UWB device is not transmitting longer than a few seconds (due to transmission during movement only) and therefore only the short term duty cycle definition can be applied to this application case and thus the long term duty cycle limitation is fulfilled anyway.

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

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:

- it makes use of a directive antenna toward the wheel-well;
- it is active only when car is on and moving faster than 20 km/h.

B.2 Technical justification for spectrum

B.2.1 Technical justification for proposed power levels

In the majority of the cases, the required spectrum and the associated transmit power spectral density are covered by the most recent ECC Decisions and EC Decisions, which are released and which are expected to be updated shortly [i.2], [i.3] and [i.4]. In category A and C there are a few exceptions with slight deviations from the valid/proposed rulemaking. However in order to be in line with the policy of adequate protection described in [i.4] additional mitigation factors are applied, and it is assumed by the authors that through these additional mitigation the equivalent protection of known potential victim systems is provided.

In the following clauses, for each category a short description and the proposed power levels are provided.

B.2.1.1 Category A: Location tracking in public transportation (road and rail vehicles)

For category A applications, there is a demand of medium range and increased reliability at an application level (up to 30 m, more than 99,75 % transaction reliability at application level) usage under difficult operating conditions and environments for a certain (even low) percentage of the application scenarios. Therefore a higher maximum power level (to be switched to by the UWB location tracking devices only in some of those rarely occurring exceptional "bad" radio propagation condition cases) is proposed in combination with specific mitigation factors.

There is evidence that these devices can address versatile industrial and security requirements in many different markets and therefore a strong socio-economic benefit is given as well as safety of life is increased. It is possible that such a system will significantly enhance the security and safety of transportation systems, and it will enable to contribute significantly to the challenging goals of saving the environment in terms of CO_2 reduction while maintaining people's mobility.

A relatively high precision in tag location as well as a high reliability of detecting devices is required for category A. High location precision in time-variant environments means that the required signals necessarily demand short signal length resulting in a high bandwidth to provide the required accuracy. The demand for high reliability means that also the *"difficult"* cases in the application scenarios (for example where the radio propagation environment is challenging due to several humans caused radio link blocking) need to be covered. This can be translated into either a total higher transmit power or to a more sophisticated solution such as in a higher dynamic range assuming an extended range of transmit power control.

Table B.1 gives a technical justification for the proposed power levels for category A.

Table B.1: Technical justification for proposed power level for category A (public ground transportation)

Category	frequency	justification
A	3,1 GHz to 4,8 GHz	In order to realize the challenging reliability demand for the financial transactions (clause A.3), which are based on the localization decisions, the SNR for the localization is required to be relatively high, which can be observed in the majority of the cases (due to the short range between Tx and Rx devices). However in a few rare cases there is multiple blocking due to the fact that public transportation is very crowded at certain times and not all passengers will have a LOS or a single blocker radio link. In order to compensate for this, an additional 6 dB of Tx power is requested. To compensate for that and still to provide an equivalent protection of potential victim services an additional mitigation in terms of 10 % duty cycle restriction is proposed in addition to the existing mitigation technique.
	6,0 GHz to 8,5 GHz	An increase of 10 dB for PSD is proposed in order to compensate for the higher attenuation in the higher frequency band and the higher losses in the technology in this frequency band. Further the same justification as in the frequency band from 3,1 GHz to 4,8 GHz applies.

B.2.1.2 Category B/C: Location tracking, positioning, and sensing in the automotive environment

The existing scheduled update of the existing ECC and EC Decisions [i.2] and [i.3] provides the required bandwidth and power levels for a majority of applications. This holds for category B and for a subset of category C (namely the *telemetry network inside vehicles* and the *passenger alarm* systems). For those applications the mean maximum PSD of -41,3 dBm/MHz is considered appropriate along with the corresponding 0 dBm/50 MHz peak power limitation. These values are corresponding to the currently valid rules specified in updated ECC/DEC/(06)04 [i.3].

UWB short range localization and sensing technologies are very sensitive to the permitted PSD limit because the transmitted power is a design driver. Increasing it has key benefits such as the capability of transferring data (via faster protocol usage and via reduced BER), increasing reliability to transmission errors due to noise floor and augmenting the maximum coverage range.

A PSD limit of -41,3 dBm/MHz will enable industry to develop and deploy UWB sensing systems technology as proposed in the present document. In table B.2 a link budget calculation example is provided.

Table B.2: Link budget calculation for category C (automotive sensor, smart tire)

Geometric frequency	4,50E+09	Hz
Light Speed (c)	300000000	m/sec
Payload Bit Rate	1,00E+06	Hz
Tbit	1,00E-06	sec
Average Noise Power per bit (N=-174+10*log(Br))	-114	dBm
RX Noise Figure (ESTIMATED)	8	dB
Average Noise Power per bit included RX (PN=N+NF)	-106	dBm
Average Output Power	-20	dBm
(Ppeak=-13dBm on 100OOhm,200mVpp)		
TX antenna Loss	6	dBi
PathLoss at 1 m	45,501618	AWGN
d	1	m
PathLoss at d m	0	
Total Path Loss (PL=PL1+PL2)	45,501618	AWGN
RX antenna Loss	1	dBi
Received Power (PR=Pout-Txant-PL-Rxant)	**-72,501618**	
Minimum Eb/N0 at fixed BER/PER	15	dB
Implementation Loss	3	dB
LinkMargin (Margin=PR-PN-EB/N0-Loss)	**15,498382**	
Proposed Sensitivity of the Receiver	**-88**	dBm

B.2.2 Technical justification for bandwidth

UWB location tracking and sensor devices operate by radiating a short signal (pulse) or a wideband OFDM signal 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 time-width of the UWB signal. For example, if the device is supposed 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 needs to be greater than the signal 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 signal width.

The bandwidth required to generate a signal with a signal width *Ts* is approximately 1/Ts. Therefore, for a range resolution or multipath rejection resolution of R, 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. For a range resolution of 30 cm, an approximate BW of 1 GHz would be needed following this approach.

For robust sensor communications a bandwidth higher than the channel coherence bandwidth is required. At short distances the channel delay spread is relatively small and therefore the coherence bandwidth is relatively large. In representative automotive environment the coherence bandwidth is several hundreds of MHz and therefore only UWB systems can achieve a frequency diversity providing a more reliable and robust wireless communication link.

B.2.2.1 Category A

Table B.3 gives the technical justification for proposed bandwidth for category A.

Table B.3: Technical justification for proposed bandwidth for category A (public transportation)

Category	frequency	Justification
A	3,1 GHz to 4,8 GHz	Due to the attenuation of free space as well as objects, the lower frequency bands are more suited than higher ones. Therefore the lower band is one target band. The bandwidth should be at least 500 MHz to 1 000 MHz for reliable real time ranging with an accuracy of about 30 cm. For systems according to ECMA-368 [i.8]/ WiMedia, this lower band allows to operate three bands ensuring sufficient number of channels to build up small networks as envisaged in public transportation means.
	6,0 GHz to 8,5 GHz	The higher band is foreseen for BT v3.0 (or later versions) implementations. Therefore the spread of mobile devices applying this technology will be very high, assuming that in any mobile phone such a device will be present. They can be activated on request. The timely economic success and the potential export to other regions of the world will lead to lower costs due to the economy of scale.

B.2.2.2 Category B

Table B.4 gives a technical justification for proposed bandwidth for category B (tracking and positioning in the automotive environment).

Table B.4: Technical justification for proposed bandwidth for category B (tracking and positioning in the automotive environment)

category	frequency	justification
B	3,1 GHz to 4,8 GHz	Due to the attenuation of free space as well as objects, the lower frequency bands are more suited than higher ones. Therefore the lower band is one target band. The bandwidth should be at least 500 MHz to 1 000 MHz for reliable real time ranging with an accuracy of about 30 cm. For systems according to ECMA 368 [i.8]/ WiMedia, this lower band allows to operate three bands ensuring sufficient number of channels to build up small networks as envisaged in the public transportation means.
	6,0 GHz to 8,5 GHz	The higher band is foreseen for BT v3.0 (or later versions) implementations. Therefore the spread of mobile devices applying this technology will be very high, assuming that in any mobile phone such device will be present. They can be activated on request. The timely economic success and the potential export to other regions of the world will lead to lower costs due to the economy of scale. Using equipment such as mobile phones by just updating the application level on such equipment will save the environment by avoiding double/triple portable equipment and will ensure increased usability of the application.

B.2.2.3 Category C

Table B.5 gives a technical justification for proposed bandwidth for category C (UWB sensor systems in automotive environment.

Table B.5: Technical justification for proposed bandwidth for category C (UWB sensor systems in automotive environment

category	frequency	justification
C	3,1 GHz to 4,8 GHz	Due to the attenuation of free space as well as objects, the lower frequency bands are more suited than higher ones. Therefore the lower band is one target band. The bandwidth should be at least 500 MHz to 1 000 MHz for reliable link establishment over a relatively short time (e.g. certain angle of tire circulation). The high bandwidth at relatively low centre frequency enables economic mass market product introduction for a very wide range of vehicles increasing safety significantly. Not only luxury cars, but also middle class and economy cars can be equipped with this life-saving technology this way.
	6,0 GHz to 8,5 GHz	The higher band is foreseen for this application for certain devices, which are expected to be more complex and to be able to make a decision based on cognitive principles if the upper band can be used (allowed for by link propagation), and thus the lower band can be protected by default from unnecessary radio interference. Having this band allowed equals an additional mitigation for the lower band reducing activity in the lower band as well as enhancing directivity and thus reducing unwanted emissions in other directions as well.

Annex C: Expected compatibility issues

C.1 Coexistence issues

Possible coexistence problems need to be investigated. Work reported in ECC-TG3, although focussing mainly 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) [i.17] 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 [i.1] is not reproduced here. Please see [i.1] for further details.

C.3 Sharing issues

LDC, DAA and TPC mitigation techniques, as qualified in the draft update of ECC/DEC/(06)12 [i.5], approved on October 1st 2008 by ECC TG3, and in the July 2007 update of ECC/DEC/(06)04 [i.3] are applied to the systems proposed in the present document. In addition extra mitigation techniques are applied providing an extra protection or compensating an extra requested transmits power respectively. A spectrum underlay system design based on non-protection basis and ensuring not to cause any harmful interference to other radio systems is applied. Therefore a band sharing of those systems allowing coexistence with all legacy radio systems is ensured.

Details for each system in each category can be found in clauses C.3.1, C.3.2 and C.3.3.

C.3.1 Sharing issues for Public Transportation Systems

Table C.1 summarizes requested modifications to the current regulations.

Table C.1: Sharing issues and proposed additional mitigation for category A (public ground transportation)

category	frequency	relation to current regulation	requested modifications to current regulation
A	3,1 GHz to 4,8 GHz	ECC/DEC/(06)04 [i.3] in combination with ECC/DEC/(06)12 [i.5] for DAA is applied	Additional provision for TPC with increased PSD of up to 6 dB compared with existing TPC regulation, i.e. range from -35,3 dBm/MHz to -53,3 dBm/MHz. In order to offset the increased PSD, a maximum activity factor restriction of 10 % is proposed.
	6,0 GHz to 8,5 GHz		An increase of 10 dB for PSD is proposed combined with an 18 dB TPC range from -25,3 dBm/MHz to -43,3 dBm/MHz. Furthermore, a maximum activity factor restriction of 10 % is proposed. This frequency band can be implemented as stand-alone or in combination with the lower frequency band.

C.3.2 Sharing issues for Automotive Location Systems

Automotive Location Systems have a very low activity factor on average, and are compliant to the ECC/DEC/(06)04 [i.3] and ECC/DEC/(06)12 [i.5] activity factor levels of 5 % in one second and 0,5 % in one hour. No sharing issues behind the compatibility and coexistence investigations performed in CEPT/ECC-TG3 are expected.

C.3.3 Sharing issues for Automotive Sensor Systems

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

C.3.3.1 Smart tire system

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:

- it makes use of a directive antenna toward the wheel-well;
- it is active only when car is on and moving faster than 20 km/h.

There are interference mitigation effects to be mentioned and considered for coexistence investigations. The following examples in table C.2 explain the assumed effects.

Table C.2: Smart tire system

Generic UWB emission limit in 3,8 GHz to 4,8 GHz range (automotive usage)	-41,3 dBm/MHz
Low usage duty cycle per second	< 5 %, as allowed in ECC/DEC/(06)12 [i.5] and EC decision 2007/131/EC [i.4]
Low usage duty cycle per hour	< 5 %, compared to 0,5 % allowed in ECC/DEC/(06)12 [i.5] and EC decision 2007/131/EC [i.4]
Several additional mitigation	movement dependent (no stationary operation, starts radio operation only at approx more than 20 km/h speed of vehicle) directional antenna (> 2 dBi antenna gain) reduced aggregation due to limited usage time of car par day/week reduced bandwidth compared to generic rule, e.g. operation starts above WiMAX frequencies to protect potential mobile WiMAX terminals on board the vehicle no indoor operation (not in home, not in office) and therefore absolutely protect fixed WiMAX terminal installations
TPC	No (for complexity/energy consumption reasons)

Annex D: Bibliography

CEPT/ECC Report 64: "The protection requirements of radiocommunications systems below 10,6 GHz from generic UWB applications", Helsinki, February 2005.

NOTE: Available at: http://www.ero.dk/doc98/Official/pdf/ECCREP064.pdf.

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

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

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

EC Mandate: "Final and adopted Mandate to CEPT to identify the conditions relating to the harmonized introduction in the EU of radio applications based on ultra-wideband (UWB) technology (Mandate 4)".

History

Document history		
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