ETSI TR 103 416 V1.1.1 (2016-07)

TECHNICAL REPORT

**System Reference document (SRdoc);
Short Range Devices (SRD) using Ultra Wide Band (UWB);
Technical characteristics and spectrum requirements for UWB based vehicular access systems for operation in the
3,4 GHz to 4,8 GHz and 6 GHz to 8,5 GHz frequency ranges**

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DTR/ERM-558

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Foreword

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

Modal verbs terminology

In the present document "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

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Introduction

The present document includes necessary information to support the co-operation under the MoU between ETSI and the Electronic Communications Committee (ECC) of the European Conference of Post and Telecommunications Administrations (CEPT).

Ultra Wide Band (UWB) technologies enable security-critical vehicular access control applications. The deployment of UWB in the modern automobile will significantly enhance the security of existing Passive Keyless Entry and Start Systems (PKES), also known as Keyless-Go and/or PASE (PAssive Start and Entry).

PKES systems represent the state-of-the-art technology for vehicle access and security systems on its long-term evolution from mechanical locks to electronic access systems and beyond. Highly convenient, the system allows car owners to open and start their vehicle by smart detection of the presence of the key in proximity of the car (less than 2 meters) and also inside the car. The system typically operates when pulling the door handle to open or pushing a START button to start the engine.

UWB technology for PKES

In order to further enhance the security of PKES systems (and access systems in general), UWB technology plays an important role with respect to proximity detection. More precisely, UWB-based PKES will prevent a number of attacks on current PKES systems - namely the so-called "relay attack" - by measuring the true time-of-flight distance between the car and the key and therefore make the cars significantly more secure and safer, without reducing the availability of the access or start function (due to false alarms).

UWB technology enables low-power, precise and secure time-of-flight (ToF) distance measurement between the key fob and the car in order to make a bullet-proof secure open and engine start. Unlike other technologies for distance measurement, UWB can provide a high precision even under Non-Line-Of-Sight (NLOS) conditions, which gives this technique a unique advantage if high reliability is required. Therefore, UWB is appropriate for highest security, system intelligence and convenience.

For car owners, UWB technology brings the highest security and safe operation for a car access system. For automakers, UWB technology enables the highest security grade compliant with existing and future regulations.

Beyond the core access functionality, UWB will support the automakers' effort towards smart cars where centimetre-precise location of the keyfob around and in the car enables new services.

The present document has been created by ERM TGUWB.

1 Scope

The present document provides information on the use of UWB technology in vehicular access control applications, the technical parameters, the relation to the existing spectrum regulation and additional new radio spectrum requirements for UWB equipment for the operation in vehicular access control applications in the band below 10 GHz.

The applications can be divided in 3 different categories:

- **Category A:** Vehicular access systems using triggered UWB transmission for **proximity verification**
- **Category B:** Extended vehicular access systems using triggered UWB transmission for **proximity monitoring**
- **Category C:** Vehicular access systems using periodic UWB beacons for **proximity detection**

The present document includes necessary information to support the **co-operation betwee**n 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).
- Relation to existing spectrum regulation (annex C).

2 References

2.1 Normative references

As informative publications shall not contain normative references this clause shall remain empty.

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

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

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] ECC Report 170, Tallinn, October, 2011: "Specific UWB applications in the bands 3.4 - 4.8 GHz and 6 - 8.5 GHz Location tracking Applications for Emergency Services (LAES), Location Tracking applications type 2 (LT2) and location tracking and sensor applications for automotive and transportation environments (LTA)".

[i.2] ETSI EN 302 065-1 (V2.1.0) (2016-04): "Short Range Devices (SRD) using Ultra Wide Band technology (UWB); Harmonised Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU; Part 1: Requirements for Generic UWB applications".

[i.3] ETSI EN 302 065-3 (V2.1.0) (2016-04): "Short Range Devices (SRD) using Ultra Wide Band technology (UWB); Harmonised Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU; Part 3: Requirements for UWB devices for ground based vehicular applications".

[i.4] Commission Decision 2009/343/EC of 21 April 2009 amending Decision 2007/131/EC on allowing the use of the radio spectrum for equipment using ultra-wideband technology in a harmonised manner in the Community.

[i.5] 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 harmonised manner in the Community.

[i.6] ECC/DEC/(06)04: "UWB technology in bands below 10.6 GHz".

[i.7] IEEE P802.15-08-0576-00-0006, H. Sawada: "Channel Models between body surface and wireless access point for UWB Band".

[i.8] Zhang et. al.: "UWB Systems for Wireless Sensor Networks", March 2009.

[i.9] D. Pozar: "Directivity of omnidirectional antennas", Article in IEEE Antennas and Propagation Magazine vol.35(5), pages 50 - 51 November 1993.

3 Definitions 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 Abbreviations

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

CAN	Controller Area Network
CEPT	Conference Europeenne des Administrations de Postes et des Telecommunications
dBm	deciBel relative to 1 mW
DC	Duty Cycle
ECC	Electronic Communications Committee
EIRP, e.i.r.p.	equivalent isotropically radiated power
EN	European Norm
ERM	Electromagnetic compatibility and Radio spectrum Matters
HPBW	Half Power Beam Width
ID	Identification Device
LDC	Low Duty Cycle
LF	Low-Frequency
LOS	Line Of Sight
LTA	Location and Tracking Applications
NLOS	Non-Line-Of-Sight
PASE	PAssive Start and Entry
PKE	Passive Keyless Entry
PKES	Passive Keyless Entry and Start
PSD	Power Spectral Density
RF	Radio Frequency
RSSI	Receive Signal Strength Indication
RX	Receiver
SRD	Short Range Device
TGUWB	Task Group Ultra-wide Band
ToF	Time-of-Flight
Ton	Transmitter on time
TPC	Transmit Power Control

TRX	Transceiver
TX	Transmitter
UWB	Ultra Wide Band

4 Comments on the System Reference document

Void.

5 Presentation of the system or technology

5.1 Background information: Vehicular Access Functionalities

Today's vehicular access systems appear with different embodiments and functionality:

- The **classic Passive Access System** is triggered by the user pulling the door handle. The car starts the communication and sends a message to wake up the key - typically Low-Frequency (LF) signals (e.g. at 20 kHz or 125 kHz) are used for that. The received LF field strength (RSSI) at the key is also used to locate the key inside or outside the vehicle. The key response is typically transmitted via RF (e.g. 434 MHz) and may include subsequent bidirectional RF communication. The system response times are often enhanced by using capacitive sensors in the door handles to start the communication flow even before the user pulls the handle.

- **Advanced Passive Access Systems** do detect the presence of the user already in advance and at distances up to 5-10 m, in order to realize functions like "Welcome Lighting" or "Approach Unlock". This "presence detection" is realized by the car periodically transmitting an LF wake-up message, in order to trigger a key response. Systems using RF wake-up messages instead of LF are also conceivable.

- The **vehicle Passive Start** is always triggered by the user pushing the START button. The communication for key authentication then follows the classic Passive Access flow (LF Wake-Up, RF Response). Passive Start is a very basic functionality that is being widely introduced in order to replace the mechanical steering lock (enhanced security and comfort). It appears also in vehicles that are not equipped with Passive Access.
The "Passive Start" functionality should not be confused with the " automatic start-stop system" (as described e.g. in https://en.m.wikipedia.org/wiki/Start-stop_system), which is used to reduce fuel consumption. The "automatic start-stop system" does not require additional authentication and thus will be neglected for the purpose of the present document.

- ***Extended functions*** in the context of vehicle access are (re-)using the authentication and localization capabilities to provide or enhance user safety and security:

  - "**Comfort Open**" and "**Comfort Closing**" are used to open or close vehicle windows or convertible tops. The user starts the action with a button press and needs to keep the button pressed to keep it going. The action stops immediately once the user releases the button. Furthermore, the function is only activated if the user is in the vicinity of the car (e.g. 5 m). This supports the intention that the user is monitoring the action and can stop it at any time.

  - The upcoming function "**Remote (Control) Parking**" (also known as "Piloted Parking") enables the user to move the car without being inside, in order to park it into narrow parking lots or garages. The user still is obliged to monitor and start/stop the action by actively operating a remote control, e.g. the key, within a limited range around the vehicle. In particular, this function requires to start the engine from outside the vehicle, which is done by the user pushing a key button (or button combination) instead of the START button inside the car.

  - "**Walk Away Locking**" automatically locks the vehicle once the user leaves the vicinity of the car.

  - "**Door Lock Warning**" is a function that warns the user if he leaves the car unlocked, or an open door or window prevents safe locking of the car. To do this, the vehicle transmits the locking status (e.g. along with other vehicle status information) to the user, as long as the user is in the vicinity of the car.

5.2 Vehicular access systems using UWB

5.2.1 Introduction

In this clause, a set of access control applications using UWB technologies will be presented. The goal of this presentation will be the identification of the key requirements and features of the applications. Furthermore, the operational environment for the specific application will be identified and analysed in order to understand the potential interference behaviour and the corresponding mitigation factors.

For the purpose of the present document, the vehicular access systems are clustered into three categories:

1) **Category A:** Vehicular access systems using triggered UWB transmission for **proximity verification**.
These systems are characterized by short (single) UWB transmissions after a user triggered event.

2) **Category B:** Extended vehicular access systems using triggered UWB transmission for **proximity monitoring**.
These systems are characterized by periodic UWB transmissions for a limited time.
The initialization is a user triggered event. The duration is either based on a user interaction and/or a pre-defined time-out and/or connection loss.

3) **Category C:** Vehicular access systems using periodic UWB beacons for **proximity detection**.
These systems are characterized by periodic UWB transmissions ("beacons"), which are sent by the vehicle in order to trigger an ID device action ("Wake-Up"). Typically, no ID device is in range and thus no response is sent after a vehicle beacon.
Once a response from an ID device is received by the vehicle, the subsequent communication can be viewed as "triggered communication".

5.2.2 Category A: Triggered UWB transmission for proximity verification

5.2.2.1 Introduction

This clause applies to systems where UWB communication is used to **verify the proximity** (or position) of an ID-device carried by the user.
The core characteristic of these systems is that **UWB transmissions are triggered by the system following a user event** and the **communication time is very short** (e.g. just a single or few UWB transmissions).

In general, those systems may still include non-UWB communication links (like LF or RF). For example, the Wake-Up message for the key is still transmitted via an LF-link.

The (triggered) UWB communication will be used to perform:

- distance bounding (to avoid relay attacks); and/or
- all or parts of the data exchange for authentication; and/or
- localization of the key.

The following functions from clause 5.1 can be realized using this category:

- Classic Passive Access;
- Advanced Passive Access (using non-UWB beacons for ID-device wake-up);
- Passive Start;
- Remote Start (e.g. for Piloted Parking).

All functionalities have in common that the UWB communication is triggered only if there has been a successful (uni- or bidirectional) communication on a non-UWB link before and/or there was a specific (intentional) user action.

With respect to the "Advanced Passive Access" function it is pointed out that, in the context of this clause, the **periodic wake-up messages ("beacons") are not using UWB technology**, but conventional LF or RF technology.

The UWB communication may be initiated on either side:

1) Triggered UWB communication, initiated by key: Key is being activated by the car (e.g. LF beacon after user touching the door handle), and is triggering the UWB transmission (see figure 1).

2) Triggered UWB communication, initiated by car: Car system is activated by the key (e.g. user pushing a key button), and is triggering the UWB transmission (see figure 1).

UWB communication ("UWB link") may comprise the exchange of several frames.

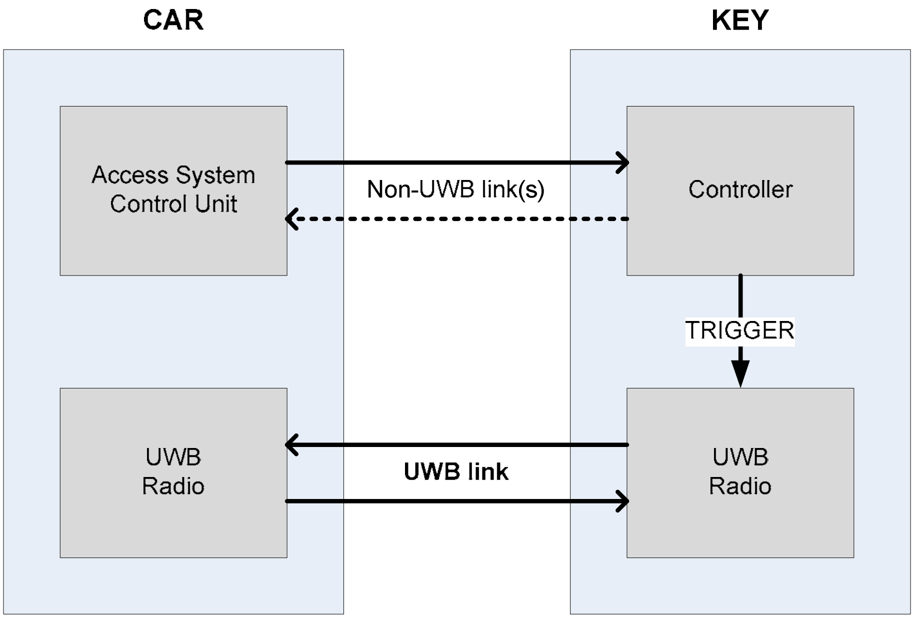

Figure 1: Triggered UWB communication, initiated by key

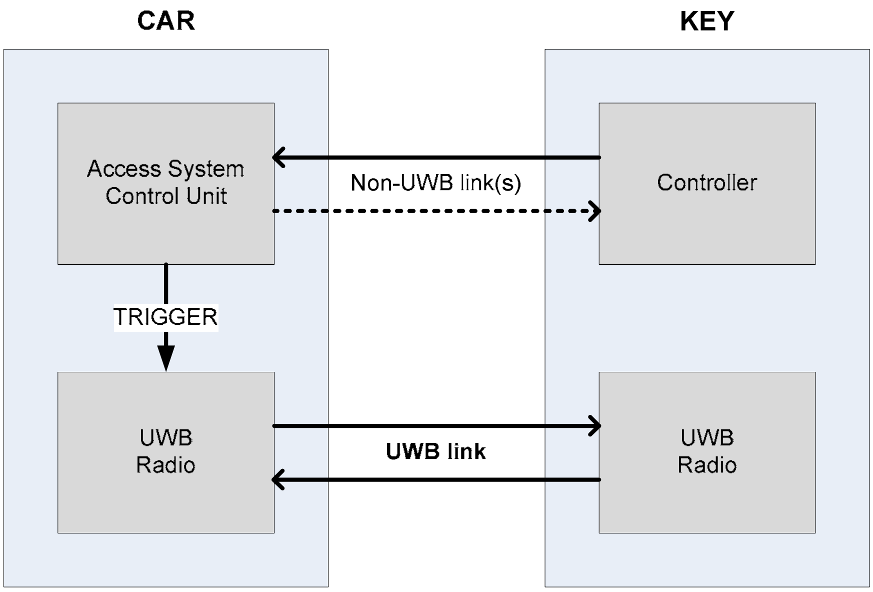

Figure 2: Triggered UWB communication, initiated by car

5.2.2.2 System requirements (UWB)

The basic system requirements for UWB can be summarized as follows:

- Several independent channels.

- Non interruptible operation (short latencies, defined response timings).
- Fast system response, to avoid "wall-effect" (door has not unlocked fast enough).
- Performance: Highest possible link budget due to vehicle and body-shielding effects.
- Space Diversity at vehicle to cope with body shielding effects and metallized windows.

5.2.2.3 Technical description

The target technical parameters of a vehicular access control system for proximity verification.

Table 1: Target technical parameters of a Category A system

System Parameter	Value/Description
Signal Type	UltraWideBand (UWB)
Frequency Range	3,4 GHz to 4,8 GHz and/or 6 GHz to 8,5 GHz
Transmit Power (EIRP)	-41,3 dBm/MHz (Max), without exterior limit
Operational Bandwidth	System dependent, typ. > 500 MHz
Data Rates	System dependent
Tx to Rx Range	typ. 10 m or less
Antenna Diversity	System dependent
Existing mitigation techniques	TPC and/or LDC
Proposed additional mitigation technique	**Trigger-before-talk (see clause 5.2.2.4)**
Duration of bidirectional UWB communication (1 trigger)	typ. 200 msec or less
Cumulative Ton-time (per vehicle device) during bidirectional UWB communication (1 trigger)	typ. 10 msec or less, max. 50 msec LDC requirements (see ETSI EN 302 065-3 [i.3], clause 4.5.3) will be kept in any case: Ton max < 5 msec Toff mean < 38 msec (averaged over 1 sec) ∑Toff > 950 msec per second
NOTE: For more market information see annex A. For detailed technical information, see annex B.	

5.2.2.4 Mitigation factors

In this clause the main identified mitigation factors will be presented. These mitigation factors will be used in conjunction with the potential interference and coexistence investigations.

Mitigation factors for vehicular access control systems using triggered UWB communication for proximity verification:

- Trigger-before-talk:
  - UWB transmission is only initiated when necessary, in particular if the system indicates that UWB devices are in range.
  - Wake-up mechanism for polling is not UWB.
  - Only the physical proximity of a key triggers UWB communication.
- Very low activity factor (typ. < 0,00035 %):
  - Low duty-cycle for the communication due to short packages (small amount of data for command, authentication and/or status transfer).
  - Usage profile of functions is low.
- Once UWB communication is established, TPC can be used as additional mitigation.
- Low risk of aggregate transmissions (uncoordinated networks, ad-hoc communication):
  - Door openings are uncoordinated events. Even in parking lots, door openings are single and sporadic events.

5.2.3 Category B: Triggered UWB transmission for proximity monitoring

5.2.3.1 Introduction

This clause applies to systems, where UWB communication is used to **monitor the proximity** (or position) of an ID-device carried by the user.
The core characteristic of these systems is that **UWB transmissions are triggered by the system following a user event** and the **communication is repeated for a limited time** to check for the user's presence or exact location.

The time limitation for the UWB transmissions is based on:

- a stop trigger by the user (e.g. button release);
- a stop trigger by the UWB ranging (user too far away);
- a time-out (e.g. ID device is not moved for 60 sec);
- loss of connection (e.g. ID device out of range).

In general, these systems may still include non-UWB communication links (like LF or RF). For example, the Wake-Up message for the key is still transmitted via an LF-link.

The (triggered) UWB communication will be used to perform:

- distance bounding (to avoid relay attacks); and/or
- all or parts of the data exchange for authentication; and/or
- localization of the key.

The following functions from clause 5.1 can be realized using this category:

- extended vehicle access functions with user interaction:
    - Comfort-Open, Comfort-Close;
    - Remote (Control) Parking.
- extended vehicle access functions without user interaction:
    - Walk Away Locking;
    - Door Lock Warning.

All functionalities have in common that the UWB communication is triggered only if there has been a successful communication on a non-UWB link before and/or there was a specific user action (e.g. user leaves car).

With respect to functions with user interaction (Comfort-Open, Comfort-Close), it should be pointed out that they typically have a very low activity factor, but are critical concerning response time.

With respect to functions without user interaction (Walk Away Locking, Door Lock Warning) it is pointed out that their usage profile will be similar to the ones for Passive Access. This suggests that, due to the longer activation time, the activity factor might be not very small any more. However, as response time for those functions is not that critical, they can benefit very much from TPC mitigation, e.g. most of the frames can be sent at small power levels, and only for worst-case scenarios (e.g. user is at the edge of the system range) some of the frames are sent at higher power levels.

The UWB communication may be initiated on the key side or the car side.

UWB communication ("UWB link") is repeated for a limited time, until a stop trigger, timeout or connection loss occurs. Figure 3 shows such a scenario for the case that the car system is activated by the key (e.g. user pushes key button) and triggers the UWB communication.

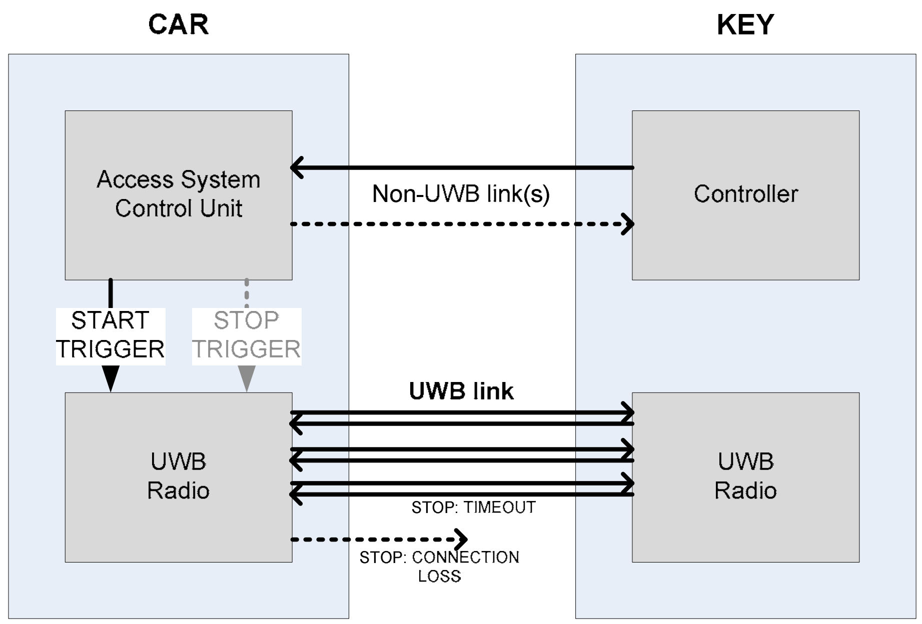

Figure 3: Triggered UWB communication, with limited repetitions

5.2.3.2 System requirements (UWB)

The basic system requirements can be summarized as follows:

- Several independent channels.
- Non interruptible operation (short latencies, defined response timings).
- Fast system response time (< 200 msec) for functions with user interaction.
- Medium system response time (< 500 msec) for functions without user interaction.
- Performance: Highest possible link budget due to vehicle and body-shielding effects.
- Space Diversity at vehicle to cope with body shielding effects and metallized windows.

5.2.3.3 Technical description

The typical technical parameters of a vehicular access control system proximity monitoring.

Table 2: Example technical parameter of a typical UWB based vehicular access control system

System Parameter	Value/Description
Signal Type	UltraWideBand (UWB)
Frequency Range	3,4 GHz to 4,8 GHz and/or 6 GHz to 8,5 GHz
Transmit Power (EIRP)	-41,3 dBm/MHz (Max) without exterior limit
Operational Bandwidth	System dependent, typ. > 500 MHz
Data Rates	System dependent
Tx to Rx Range	typ. 10 m or less
Antenna Diversity	System dependent
Existing Mitigation techniques	TPC and/or LDC
Additional mitigation technique	Trigger-before-talk
Duration of bidirectional UWB communication (1 interval)	typ. 200 msec or less (for 1 UWB communication)
Cumulated Ton-time (per vehicle device) during bidirectional UWB communication (1 interval)	typ. 5 msec or less per interval; max. 50 msec LDC requirements (see ETSI EN 302 065-3 [3], clause 4.5.3) will be kept in any case: Ton max < 5 msec Toff mean < 38 msec (averaged over 1 sec) ∑Toff > 950 msec per second
Duration of UWB communication repetitions (for proximity monitoring)	typ. < 30 sec for functions with user interaction typ. < 60 sec for functions without user interaction
Repetition interval of vehicle transmissions	typ. > 200 msec for functions with user interaction typ. > 500 msec for functions without user interaction
NOTE: For more market information see annex A. For detailed technical information, see annex B.	

5.2.3.4 Mitigation factors

In this clause the main identified mitigation factors will be presented. These mitigation factors will be used in conjunction with the potential interference and coexistence investigations.

Mitigation factors for vehicular access control systems using triggered UWB communication for proximity monitoring:

- Trigger-before-talk:
  - UWB transmission is only initiated when necessary, in particular if the system indicates that UWB devices are in range.
- Very low activity factor (typ. < 0,005 %) (**especially true for functions with user interaction, due to usage profile):**
  - Low duty-cycle for the communication due to short packages (small amount of data for command, authentication and/or status transfer).
  - Usage profile of functions is low.
  - Wake-up mechanism for polling is not UWB.
  - Only the physical proximity of a key triggers UWB communication.
- Once UWB communication established, TPC can be used as a mitigation (**especially true for functions without user interaction, due to lower response time requirements**).
- Low risk of aggregate transmissions (uncoordinated networks, ad-hoc communication).

5.2.4 Category C: Periodic UWB beacons for proximity detection

5.2.4.1 Introduction

This clause applies to systems, where UWB communication is used to **detect the proximity** of an ID-device carried by the user.
The core characteristic of these systems is that **periodic UWB transmissions ("beacons") are sent by the vehicle** in order to trigger an ID device action ("Wake-Up"). Typically, no ID device is in range and thus no response is sent upon a vehicle beacon.

In general, those systems are intended to replace the classical LF- or RF based beacon technology be UWB beacons. In particular, the Wake-Up message and all data communication is done via UWB.

The periodic UWB beacons will be used to perform:

- ID device wake-up; and/or
- parts of the data exchange for authentication.

The following functions from clause 5.1 can be realized using this category:

- Advanced Passive Access (using UWB beacons for wake-up).

Once a response from an ID device is received by the vehicle, the subsequent communication can be viewed as "triggered communication".

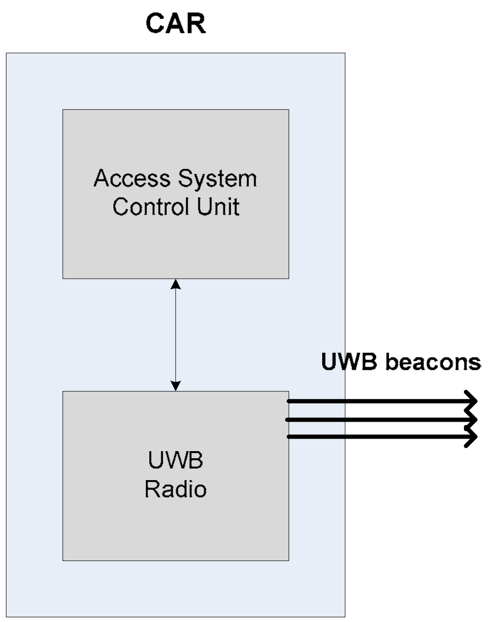

Figure 4: UWB beacons sent by car

5.2.4.2 System requirements (UWB)

The basic system requirements can be summarized as follows:

- Several independent channels.
- Non interruptible operation (short latencies, defined response timings).
- Fast system response, to avoid "wall-effect" (door has not unlocked fast enough).
- Performance: Highest possible link budget due to vehicle and body-shielding effects.
- Space Diversity at vehicle to cope with body shielding effects and metallized windows.

5.2.4.3 Technical description

The typical technical parameter of a vehicular access control system proximity detection.

Table 3: Example technical parameter of a typical UWB based vehicular access control system

System Parameter	Value/Description
Signal Type	UltraWideBand (UWB)
Frequency Range	3,4 GHz to 4,8 GHz and/or 6 GHz to 8,5 GHz
Transmit Power (EIRP)	-41,3 dBm/MHz (Max)
Operational Bandwidth	System dependent, typ. > 500 MHz
Data Rates	System dependent
Tx to Rx Range	typ. 10 m or less
Antenna Diversity	System dependent
Existing mitigation techniques	LDC, TPC
Additional mitigation techniques	none
Duration of bidirectional UWB communication	no communication, just beacons
Cumulated Ton-time (per vehicle device) during bidirectional UWB communication (1 beacon)	typ. 1 msec or less; max. 5 msec LDC requirements (see ETSI EN 302 065-3 [3], clause 4.5.3) will be kept in any case: Ton max < 5 msec Toff mean < 38 msec (averaged over 1 sec) ∑Toff > 950 msec per second ∑Ton < 18 sec per hour
Repetition interval of vehicle transmissions (beacon interval)	typ. > 200 msec

5.2.4.4 Mitigation factors

The main mitigation factor is LDC only.

6 Market information

See annex A.

7 Technical information

7.0 General

Technical information can be found in annexes B and C.

7.1 Differences in the assumptions for compatibility studies

Compared to the LTA applications considered in section 4 of ECC Report 170 [i.1], the new PKES applications have a very low activity factor and often use trigger-before-talk as a mitigation technique. Based on that it will be proposed to not ask PKES application A and B to comply with the exterior limit.

A comparison of the mitigation techniques of PKES applications A, B and C compared to the LTA applications used in ECC Report 170 [i.1] will be provided in this clause.

The assumptions and calculated mitigations for the aggregated compatibility studies for LTA applications can be found in ECC Report 170 [i.1], table 35.

To take into account the trigger-before-talk mitigation, the activity factor calculation is updated based on the usage profiles and the duty-cycle of the protocol of clause B.1.1. The resulting values are shown in table 4.

Table 4: Mitigation for PKES equipment category A, B and C

Mitigations	**Category A: Vehicular access control application for proximity verification**		**Category B: Vehicular access control application for proximity monitoring**		**Category C: Vehicular access control application for proximity detection**
Peak power mitigation	0 dB		0 dB		0 dB
Low Duty Cycle	< 0,5 % / 1 sec		< 0,5 % / 1 sec		< 0,5 % / 1 sec
Trigger-before-talk (UWB transmissions only upon a trigger)	yes		yes		no
Activity factor, including duty-cycle (calculations see clause B.1)	typ. 0,00035 % (54,5 dB)	max. 0,00174 % (47,6 dB)	typ. 0,005 % (43 dB) 0,0067 % (41,7 dB)	max. 0,01 % (39,9 dB) 0,033 % (34,8 dB)	max. 0,5 % (23 dB)
Sum of Mitigations	**More than 47 dB**		**More than 34 dB**		**More than 23 dB**

From table 4 it can be concluded that PKES category A and B (whose are manually triggered by the users) are to be considered with much lower activity factors as assumed in ECC Report 170 [i.1]; the mitigation factors for category A and B are between 34 dB and 47 dB, compared to 13 dB and 23 dB assumed in ECC Report 170 [i.1], and thus for these PKES categories the exterior limit could be removed. PKES category C does not offer that additional mitigation and that application needs to comply with the existing regulation (e.g. exterior limit).

These updated activity factors were also used in the MATLAB® (see note) simulation of ECC Report 170 [i.1] (annex 2), to determine the mitigation factor for vehicular based access control systems. The resulting mitigation due to combination of "Trigger-before-talk" and "Low-Duty-Cycle" is significantly larger than for "Low-Duty-Cycle" itself, and even exceeds the mitigation effect of exterior limits (12 dB), see table 4.

NOTE: "MATLAB®" is the trade name of a product supplied by MathWorks. This information is given for the convenience of users of the present document and does not constitute an endorsement by ETSI of the product named. Equivalent products may be used if they can be shown to lead to the same results."

8 Radio spectrum request and justification

8.1 Technical justification

The ETSI EN 302 065 parts are the harmonised standards for generic, location tracking and vehicular use of UWB. In particular, ETSI EN 302 065-3 [i.3] is the harmonised standard for UWB devices for ground based vehicular applications. This standard accounts for the mitigation techniques defined in the generic regulation [i.2], and adds a 12 dB emission limitation to comply with the exterior limit to -53,3 dBm per MHz in all UWB bands to further protect a limited set of radio services. The additional limitation stems from a study described in [i.1] for applications where the vehicle is on the road moving and communicating with external infrastructure and/or with other cars.

Although ETSI EN 302 065-3 [i.3] is not excluding PKES applications, ECC Report 170 [i.1] however did not cover PKES applications where UWB communication is used between the car key and the car to allow secure open and secure start of the car. In this case, the engine is usually stopped, and in particular the car is not moving on a road and not communicating with an exterior fixed infrastructure. Additionally, typical PKES usage scenarios feature a much lower activity factor than the one considered in ECC Report 170 [i.1], since typical usage profiles assume less than 10 access and start actions per day, see clause B.1.1.

For PKES applications, the exterior limit restriction has a significant impact on the link budget: The system needs to provide margin not only for component tolerances and environmental effects, but also for human body attenuation effects, since the user cannot be expected to operate the ID device in a defined way and may carry it in the pocket or hide it with the hand or body. This means that also for very close distances between the user and the vehicle transceiver the link budget may be at the edge already with the standard -41,3 dBm/MHz limits.

The exterior limit leads to:

- a reduced availability of the access function, as the link budget is not sufficient for all access scenarios; and/or
- the inclusion of more UWB devices (e.g. 8 instead of 4) in the car to compensate for the 12 dB link budget reduction. As a result, the spectrum is used inefficiently by increasing the communication time through retransmissions from more devices at different locations, not to mention the increasing costs to deploy such a multi-node system inside a car.

Both scenarios are not constructive and will essentially reduce the acceptance of UWB technology for access systems.

Further information can be found in clause B.2.

8.2 Business importance

In the last decades vehicle access systems have evolved from simple mechanical keys to secure and smart electronic identification systems. The secure authentication mechanisms are not only used for vehicle access but also for safe operation of vehicle functions in the pre- and post-driving phase (e.g. starting/, parking, closing windows). The introduction of UWB for access systems is vital to further enhance security and safety, and to overcome weaknesses and limitations of the current implementations. UWB technology will support the implementation of secure and safe vehicle access systems and is therefore of public interest.

9 Regulations

9.1 Proposed changes in the regulation

Based on the requirements of the intended applications described in the scope of the present document and the mitigation techniques, the vehicular access control system Category A and Category B are proposed to operate under the automotive European UWB regulation [i.4], [i.5] and [i.6] without the requirements of an additional exterior limit.

Table 5: Proposed regulation for equipment category A

Area of operation/Category	Frequency	Maximum Average power density (EIRP) (dBm/MHz)
Category A: **and** **Category B:**	3,4 GHz to 4,8 GHz	-41,3 dBm/MHz with triggered operation and LDC < 0,5 % (in 1h)
	6,0 GHz to 8,5 GHz	-41,3 dBm/MHz with triggered operation and LDC < 0,5 % (in 1 h) or TPC
Change to current regulation		***No exterior limit requirement for vehicle access systems with user event triggered UWB transmission***

9.2 Expected ECC and ETSI actions

ETSI requests CEPT/ECC to consider the present document, which includes the necessary information to support the co-operation under the MoU between ETSI and the Electronic Communications Committee (ECC) of the European Conference of Post and Telecommunications Administrations (CEPT).

Relevant compatibility studies should be performed for described Category A and B systems to determine whether the proposed changes are appropriate to protect other radio services and to provide practical measures to ensure the protection of other radio services in the anticipated bands for the suggested emission levels.

Category A and B are considered at the moment as prior for implementation and no changes to the regulations are requested yet for category C (systems using periodic UWB beacons). ETSI requests guidance from CEPT/ECC for category C application, which is only deemed feasible without the exterior limit.

It is proposed that CEPT/ECC considers the suggested regulation changes in clause 9.1 and considers amending ECC Decision (06)/04 [i.6] taking into account the requirements and characteristics of future vehicular access systems.

ETSI will be prepared to include the "trigger-before-talk" mitigation technique in one of the next revisions of the relevant ETSI harmonised standards.

Annex A: Market information

A.1 Market size and value

A.1.1 Introduction

In the automotive market, passive keyless entry and start systems are particularly appealing to car owners due to their high security and safety, high convenience and ease of use. The presence of the key fob in the owner's pocket or belongings enables the car to take intelligent actions, e.g. opening car doors when the owner is in its proximity, allowing the engine to start when the owner is inside, and locking the car when the owner is moving away. From a security perspective, UWB systems brings more intelligence and proximity awareness to enable the car to detect several widespread attacks to conventional remote keyless entry systems (e.g. jamming attacks) and therefore to prevent them.

The adoption of passive keyless entry and start systems is increasing with forecasts to reach worldwide 18 million units by 2016 and steady growth in the next 10-year period. In order to realize the expected growth in this market, the system's security and usability has to continue to be improved and further cost reductions need to take place.

A.1.2 Market potential

Passive keyless entry and start systems exhibit stable growth and the forecasts of major market research agencies are that this will continue in the next years with different variations of passive keyless systems penetrating lower-end car models due to the higher value for the end-users and reduced costs. It is forecasted that the adoption levels will reach worldwide 16 to 18 million units in 2016. Broader consumer acceptance in the lower vehicle segments and greater standard fitments by automobile manufacturers (OEMs) will continue.

Kevin Mak, analyst in the Automotive Electronics Service at Strategy Analytics (https://www4.strategyanalytics.com/default.aspx?mod=pressreleaseviewer&a0=5072), said: "*Passive entry and start system offerings abound, including Chinese cars, like the Brilliance 530, the BYD F3 and the Zotye Z200HB. Even Chrysler and Kia, newcomers to this market, offer passive systems. Japanese auto makers expanded their PKE market to cars made in the US and Europe. And BMW offers the simpler Passive Go system as standard on its 2012 1-Series.*"

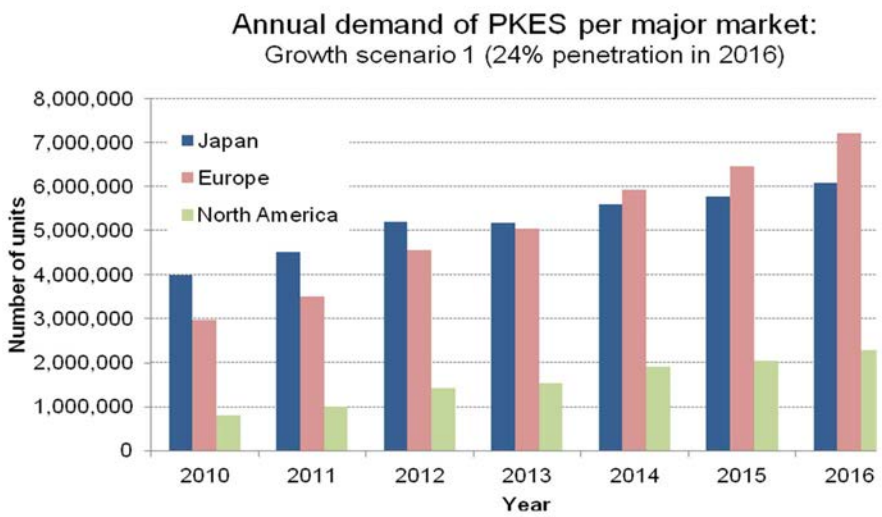

Figure A.1: Projected annual demand of passive keyless systems in 2009 exceed initial expectations as of 2016

It is important to note that European suppliers of passive keyless system are worldwide leaders in this market segment and therefore uniquely position to lead innovation towards more secure, safe and usable vehicle access control.

Annex B: Technical information

B.1 Technical description

B.1.1 Usage Profile, Activity Factor

B.1.1.1 Category A: Systems using triggered UWB transmission for proximity verification

Calculation of the (typical) activity factor for the UWB transmission is based on common usage profiles (manufacturer provided) for the access and start function:

- Passive Access (classic and advanced): typ. 3 500 actions/year:
  - this corresponds to almost 10 vehicle accesses per day (triggered by the user).
- Passive Start (including remote start): typ. 7 500 actions/year:
  - this corresponds to approximately 20 vehicle starts per day (triggered by the user).

The activity factor assumes that one action (= 1 trigger) involves max. 10 msec Ton-time per device.

Ton-time = (3 500 + 7 500) actions/year × 10 msec/action = 110 000 msec/year.

Activity Factor = Ton-time/1 year = 110 000 msec / (365 × 24 × 3 600 × 1 000) msec = $3{,}488 \times 10^{-6} \approx$ **0,00035 %**.

B.1.1.2 Category B: Systems using triggered UWB transmission for proximity monitoring

B.1.1.2.1 Calculation 1 Comfort Open/Close, Remote (Control) Parking

Calculation 1 of the (typical) activity factor for the UWB transmission is based on common usage profiles for the Comfort Open/Close and Remote (Control) Parking:

- Comfort Open/Close: typ. 1 400 actions/year:
  - this corresponds to almost 4 Comfort Open or Close actions per day;
  - duration: typ. 30 sec, with 200 msec interval of vehicle transmissions.
- Remote (Control) Parking: typ. 700 actions/year:
  - this corresponds to almost 2 parking events per day;
  - duration: typ. 30 sec, with 200 msec interval of vehicle transmissions.

During operation, short packages are sent by the key fob to transmit the actual button status and to indicate successful connection and ongoing activation by the user ("dead man switch"). At regular intervals, a bidirectional communication between key and vehicle takes place to acknowledge communication status and to perform ranging or localization. **The interval, in which active vehicle transmissions are occurring, is typically 200 msec**.

The activity factor assumes that one action (= 1 trigger) involves maximum 5 msec Ton-time per interval, and 150 intervals per action (= 30 sec / 200 msec).

Ton-time = (1 400 + 700) actions/year × 150 × 5 msec/action = 1 575 sec/year.

Activity Factor = Ton-time/1 year = 1 575 sec / (365 × 24 × 3 600) sec ≈ **0,005 %**.

B.1.1.2.2 Calculation 2 Leaving vehicle

Calculation 2 of the (typical) activity factor for the UWB transmission is based on common usage profiles for the Walk-Away Locking and Door-Lock Warning features. For the activity factor calculation, the usage profile can be assumed to be similar to the Passive Access usage profile and will be called "Leaving Vehicle":

- Leaving vehicle: typ. 3 500 actions/year:
    - this corresponds to almost 10 vehicle exits per day;
    - duration: typ. < 60 sec, with 500 msec interval of vehicle transmissions.

During the operation of the function the vehicle status is transmitted to the key fob and the position of the key fob is checked in regular intervals. As for calculation 1, a bidirectional communication between key and vehicle takes place to transmit vehicle status and to perform ranging or localization. However, the timing requirements are less critical and the **interval, in which active vehicle transmissions are occurring, is typically 500 msec**.

The activity factor assumes that one action (= 1 trigger) involves max. 5 msec Ton-time per interval, and 120 intervals per action (= 60 sec / 500 msec).

Ton-time = (3 500) actions/year × 120 × 5 msec/action = 2 100 sec/year.

Activity Factor = Ton-time/1 year = 2 100 sec / (365 × 24 × 3 600) sec ≈ **0,0067 %**.

B.1.1.3 Category C: Systems using periodic UWB beacons for proximity detection

The calculation for Category C assumes that the car is parked and is sending UWB beacons. As the percentage of parking time is typically significantly higher than the percentage of driving time, it is set to 100 % (=worst case) for the purpose of the present document, and the few percent of driving time are neglected.

- UWB beacon transmission: 365 days / year:
    - Duration: 24 h, with interval of vehicle transmissions equal to or larger than 200 msec.

The vehicle sends UWB beacons with an interval typically larger than 200 msec. As the only intention of the beacons is to wake up the ID device, they are typically very short and comprise a cumulated Ton-time of less than 5 msec in 1 sec.

The activity factor assumes that one beacon involves max. 1 msec Ton-time, and the repetition interval is 200 msec:

- Duty-Cycle < 1 msec / 200 msec = 0,5 %.
- **Activity Factor** = Ton-time / 1 year = Duty-Cycle < **0,5 %**.

B.1.2 Worst case considerations

B.1.2.1 Category A

B.1.2.1.1 Activity factor with max. Ton and typical usage profile

Assuming a Ton-time of 50 msec per action (limit for Ton max reached):

- Ton-time max = (3 500 + 7 500) actions/year × 50 msec/action = 550 000 msec/year.
- **Activity Factor** max = Ton-time max/1 year = 550 000 msec / (365 × 24 × 3 600 × 1 000) msec ≈ **0,00174 %**.

B.1.2.1.2 Long-term duty-cycle vs. worst-case usage

According to ETSI EN 302 065-3 [i.3] (clause 4.5.3) the sum transmitter on time ("long-term duty-cycle") is less than 18 sec per hour.

With a maximum Ton-time of 50 msec per action, this allows up to 360 actions per hour.

As 1 action corresponds to 1 vehicle access, the user needs to perform more than 360 vehicle accesses in 1 hour, in order to exceed the long-term duty-cycle limit. This can be considered unrealistic, if not impossible (most access systems have implemented some kind of "play protection" that prevents communication trigger in case of frequent - obviously useless or unnecessary - access trials).

B.1.2.2 Category B

B.1.2.2.1 Activity factor with max. Ton and typical usage profile

Assuming a Ton-time of 50 msec per second (limit for Ton max reached) and 30 sec (Calculation 1) respectively 60 sec (Calculation 2) activation (the specific distribution of Ton-time per interval and interval period is not relevant, as the LDC limits are kept):

Calculation 1:

- Ton-time max = (1 400 + 700) actions/year × 30 × 50 msec/action = 3 150 sec/year.
- **Activity Factor** max = Ton-time max/1 year = 3 150 sec / (365 × 24 × 3 600) sec ≈ **0,01 %**.

Calculation 2:

- Ton-time max = (3 500) actions/year × 60 × 50 msec/action = 10 500 sec/year.
- **Activity Factor** max = Ton-time max/1 year = 10 500 sec / (365 × 24 × 3 600) sec ≈ **0,033 %**.

B.1.2.2.2 Long-term duty-cycle vs. worst-case usage

According to ETSI EN 302 065-3 [i.3] (clause 4.5.3) the sum transmitter on time ("long-term duty-cycle") is less than 18 sec per hour.

With a maximum Ton-time of 50 msec per second, this allows up to 360 sec of activation.

This means that a user might exceed the limit if the Comfort Open/Close function is used for more than 6 minutes, or if the user remains more than 6 minutes in the vicinity of the vehicle after leaving the car. While this seems to be feasible, the fact that the values are based on worst-case Ton-times should also be taken into account. Typically - for a couple of reasons, battery life-time alone - the Ton-times for those functions will be just a tenth or less (e.g. 5 msec Ton per second), making it impossible to violate the long-term duty-cycle.

B.1.2.3 Category C

The calculation in clause B.1.1 corresponds already to the allowed worst-case (long-term duty-cycle for not moving vehicle):

- **Activity Factor** max = 18 sec / 1 hour = **0,5 %**.

B.2 Technical justification for spectrum

B.2.1 Introduction

One of the main challenges for UWB based vehicular access systems is to fulfil the requirement of high function availability and reliability with the available UWB link budget.

The link budget needs to provide enough margin to cover path loss, fading effects and human body effects. In particular human body effects may be huge, e.g. if the user is carrying the ID device in his pocket. To cope with that, it is usually necessary to deploy "space diversity", i.e. to install 2 or more UWB transceivers in the vehicle in order to enable communication to at least one in worst-case scenarios.

The exterior limit requirement reduces the available link budget by 12 dB. To compensate for that, even more UWB devices need to be used at the vehicle, assuming that is feasible at all.

The following clause compares the link budget for a system with and without exterior limit.

Furthermore, it shows that it is not possible to do antenna designs that would compensate for the exterior limit (e.g. -12 dB gain reduction for > 0° elevation).

B.2.2 Link budget

B.2.2.1 Path loss and range requirements

Range requirements:

- Absolute minimum range requirement is to cover 2 m around vehicle; this means already a possible (LOS) distance between key and TRX of up to 6-8 m, depending on vehicle size, TRX mounting position and user position.
- It is desirable that UWB communication covers the complete LF-Wake-Up range, which is 5 m to 10 m for advanced Passive Entry systems. This calls for LOS range up to 15 m.

Free Space Loss:

Free Space Loss according to $\mathrm{FSPL} = \left(\frac{4\pi d}{\lambda}\right)^2$:

Free Space Loss	4 GHz	7 GHz
LOS = 2 m	50,5 dB	55,4 dB
LOS = 3 m	54,0 dB	58,9 dB
LOS = 5 m	58,5 dB	63,3 dB
LOS = 10 m	64,5 dB	69,4 dB
LOS = 15 m	68,0 dB	72,9 dB

Thus, free space loss is at least 50,5 dB for 4 GHz, and 55,5 dB for 7 GHz.

Furthermore, a fading margin of 6 dB is necessary.

A human body attenuation of 35 dB needs to be taken into account.

Details can be found in literature:

H. Sawada: "Channel Models between body surface and wireless access point for UWB Band (IEEE P802.15-08-0576-00-0006)," August 2008 [i.7].

B.2.2.2 System budget with exterior limits (Mean PSD ≤ -53,3 dBm/MHz)

TX	Center frequency	**MHz**	**4000**	**7000**
	-10 dB bandwidth	MHz	500	500
	Maximum PSD	dBm/MHz	-53.3	-53.3
	Maximum Tx power (ideal)	dBm	-26.3	-26.3
Tx loss	Tx mask loss	dB	2.3	2.3
	Tx margin (Power amplifier, others)	dB	2	2
	Effective Tx power	**dBm**	**-30.6**	**-30.6**
Link	Path loss 2 meters	dB	50.5	55.4
	Windows screening attenuation	dB	6	6
	Body attenuation	dB	35	35
	Fading		6	6
	Total link loss	**dB**	**97.5**	**102.4**
Rx loss	Tx antenna worst directivity reduction	dB	0	0
	Pre-select filter insertion loss	dB	1.5	1.5
	Total RX Path Loss		99.0	103.9
	Received power	**dBm**	**-129.6**	**-134.5**

Figure B.1: System budget with exterior limits (Mean PSD ≤ -53,3 dBm/MHz)

B.2.2.3 Antenna Design for Exterior Limits

A requirement that appears with outdoor radiation in automotive application is that the mean PSD above the horizon is 12 dB lower than the standard limit, i.e. fixed at -53,3 dBm/MHz instead of -41,3 dBm/MHz. This requirement introduces a constraint on the antenna directivity. The beamwidth needs to be sufficiently narrow to avoid excessive radiation above the horizon while still be able to radiate sufficiently close to the horizon to provide sufficient range for the keyless application.

Assuming a directivity pattern described by |cos(a)|^N (omnidirectional pattern in one plane, narrow beam pattern perpendicular to the omni plane), where a is the angle in the directivity pattern (a=0 is the main radiation direction) and N is the order of the beam pattern (can be non-integer values), the minimum N required to have a 12 dB reduction at a certain angle, which, once the -12 dB beam point is rotated towards the horizon, represents the direction of the maximum directivity is determined. Figure B.2 shows a typical case for N = 3 (half-wavelength dipole), where the -12 dB beamwidth is 102°. This means than the antenna needs to be tilted -61° towards ground to have a radiation pattern that emits at least 12 dB less than the standard above the horizon. This is clearly not in line with applications where energy needs to be radiated relatively far away around the car.

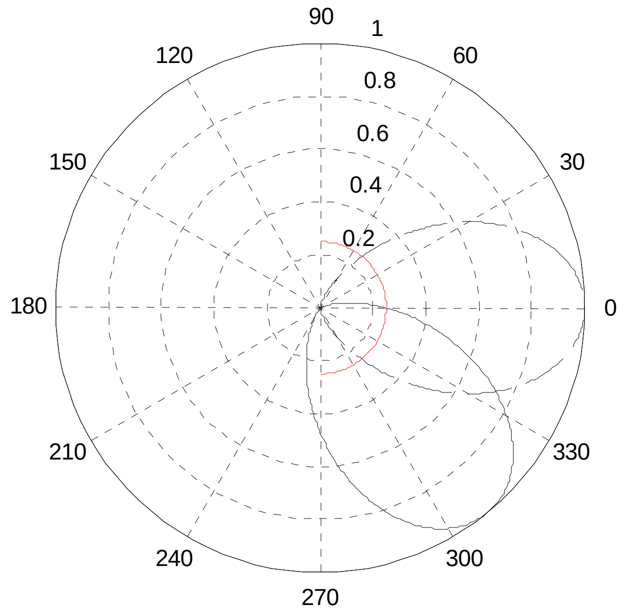

Figure B.2: Directivity pattern described by |cos(a)|^N, for N=3 (half-wavelength dipole)

Assuming the maximum direction of the main beamwidth is not below 22,5° (probably underestimated, smaller angles are to be considered!). Figure B.3 shows that the minimum required order N for an antenna of this type is 17. The corresponding HPBW is 23°.

After Pozar [i.9], the directivity of such an antenna is: D = -172,4 + 191 √(0,818 + 1 / HPBW) = 4,9 = 6,9 dB.

This high directivity (not gain) is only obtainable with antennas with large effective aperture and as a consequence antennas that are large in wavelength and not practical to implement in a car.

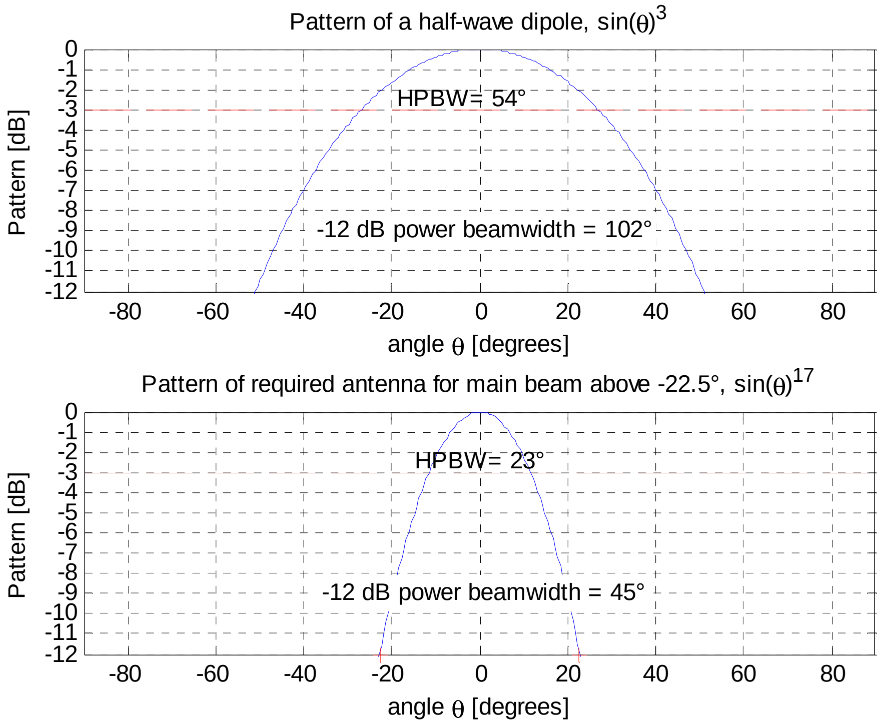

Figure B.3: Beamwidth pattern for half-wave dipole (N=3) compared to antenna designed to meet exterior limit requirements

Conclusion: It is physically very difficult to build an UWB antenna to comply with the current exterior limit definition of -53 dBm/MHz dBm above 0° and +12 dB difference below 0° due to the large difference. Therefore the TX power has to be reduced by 12 dB to safely comply with the currently defined exterior limit regulation.

B.2.2.4 Conclusion for systems complying with exterior limit

Impossibility result: The system budget does not allow practical realization of the vehicle access control application

Given that the UWB system noise floor is -114 dBm/MHz and a typical Receiver Noise Figure of 5 dB and a Max Ton-time of 5 msec, a theoretically coherent UWB chip will not be able to transmit/receive **more than 3 bits** even if the synchronization time is 0 ns.

Calculation justification (theoretical): -114 dBm/MHz (Absolute noise floor) + 12 dBm/MHz (theoretical E_b/N_0 required for coherent demodulation) + 5 dBm (Noise Figure) = -97 dBm for bit rate of 1 Mbit/s = **-127 dBm for bit rate of 1 Kb/s (i.e. only 5 bits in 5 msec maximum allowed Ton-time)**, Zhang et. al [i.8].

Conclusion: If feasible at all, only with a massive deployment of UWB devices around the car (> 8 devices) the system link budget may be improved to meet the worst case scenario and ensure a robustly functional PKES secure and safe system.

B.2.2.5 System budget without exterior limits (Mean PSD ≤ -41,3 dBm/MHz)

By allowing to transmit at -41,3 dBm/MHz, the system link budget improves significantly as follows:

TX	Center frequency	**MHz**	**4000**	**7000**
	-10 dB bandwidth	MHz	500	500
	Maximum PSD	dBm/MHz	-41.3	-41.3
	Maximum Tx power (ideal)	dBm	-14.3	-14.3
Tx loss	Tx mask loss	dB	2.3	2.3
	Tx margin (Power amplifier, others)	dB	2	2
	Effective Tx power	**dBm**	**-18.6**	**-18.6**
Link	Path loss 2 meters	dB	50.5	55.4
	Windows screening attenuation	dB	6	6
	Body attenuation	dB	35	35
	Fading		6	6
	Total link loss	**dB**	**97.5**	**102.4**
Rx loss	Tx antenna worst directivity reduction	dB	0	0
	Pre-select filter insertion loss	dB	1.5	1.5
	Total RX Path Loss		99.0	103.9
	Received power	**dBm**	**-117.6**	**-122.5**

Figure B.4: System budget without exterior limits (Mean PSD ≤ -41,3 dBm/MHz)

Calculation justification (theoretical): -114 dBm/MHz (Absolute noise floor) + 12 dBm/MHz (theoretical E_b/N_0 required for coherent demodulation) + 5 dBm (Noise Figure) = -97 dBm for bit rate of 1 Mbit/s = **-107 dBm for bit rate of 100 Kb/s (i.e. 100 bits in 1 msec packets)**, Zhang et. al [i.8].

Important note: Practical cell-coined powered (key fob compliant) UWB chip implementations would still present much lower RX sensitivity levels compared to theory due to required synchronization time, processing complexity, imprecise clocks processing complexity, implementation losses.

Possibility result: Using -41,3 dBm/MHz, the vehicle access system can be practically realized together with reasonable space diversity (2-4 devices per car, which depend on the car size, metalized windows, etc.) to compensate estimated 20 dB to 25 dB missing system link budget in worst case scenarios.

Annex C: Relation to existing spectrum regulation

C.1 Relation the existing studies

C.1.1 Introduction

ECC Report 170 [i.1] provides detailed studies of the influence of UWB on:

- Fixed Services at 4,4 and 6 GHz (ECC Report 170 [i.1], section 4.3.1);
- Radio-altimeters (ECC Report 170 [i.1], section 4.3.2);
- WiMAX™ (ECC Report 170 [i.1], section 4.3.3);
- Ummanned Ground Systems (ECC Report 170 [i.1], section 4.3.4);
- Fixed Satellite Service (ECC Report 170 [i.1], section 4.3.5); and
- Radio astronomy (ECC Report 170 [i.1], section 4.3.6).

This ECC report can be taken as an entry point to analyze the influence of UWB vehicular access control applications on such services, in order to verify the effectiveness of the "Trigger Before Talk" mitigation technique and to prove the feasibility of the proposed regulation changes in clause 7.

As an example, Radio-Altimeters are expected to be the worst-case concerning aggregation effects (e.g. parking lot at airports) and are investigated in clause C.1.2.

Further studies on other services may be necessary.

C.1.2 Radio-Altimeters

Tables 38 and 39 of ECC Report 170 shows aggregated interferences level compared to the protection level of radio-altimeter. Taking the case with the generic -41,3 dBm/MHz mean PSD per device, without car shielding but with long-term protection of 0,5 %/hour/LTA, it is observed that a maximum of 6 dB is missing for the required protection.

Furthermore, the introduction of an exterior limit provides a protection level of at least -6 dB, see table C.1.

By taking the same activity scenario as in note 1 of table 35 in ECC Report 170 [i.1] (i.e. only 4 devices per car instead of 10), and by multiplying by the number of car per km^2, as assumed in the Report 170, the overall activity rate becomes 5 ppm × 330 × 4/10 = 0,066 %. The level of long-term protection provided by the keyless access is here again nearly one order of magnitude better than the 0,5 % per hour required. The translates into a aggregated interference level 8,7 dB better than the required one for altimeters.

The worst-case aggregation scenario for access systems is based on following assumptions:

- 330 vehicles/km^2 (as in ECC Report 170 [i.1])
- 10 devices/vehicle (as in ECC Report 170 [i.1])
- Max. DC of 5 %/s (as in ECC Report 170 [i.1])
- Worst-case activity factor (as summarized in clause 7)

Table C.1 compares the results of ECC Report 170 with the calculations for Vehicular Access Systems.

Table C.1: Comparison of ECC Report 170 [i.1], table 38 with "Trigger before talk" mitigation for Category A, B and C (without exterior limit)

Aggregated interference level compared to the protection level of radio-altimeters				
Scenario/ Altitude of the aircraft	**100 m**	**500 m**	**1 000 m**	**1 500 m**
Generic LTA applications (from ECC report 170) -41,3 dBm/MHz/LTA - no car shielding ➢ 330 vehicles/km ^{2} ➢ 10 LTA/vehicle ➢ Max DC of 5 %/s LTA ➢ Max DC of 0,5 %/hour/LTA → **18 000 ms/hour**	6 dB	5 dB	4 dB	4 dB
Generic LTA applications (from ECC report 170) -53,3 dBm/MHz/LTA for elevation higher than 0° (i.e. power reduction or car shielding) ➢ 330 vehicles/km ^{2} ➢ 10 LTA/vehicle ➢ Max DC of 5 %/s LTA ➢ Max DC of 0,5 %/hour/LTA → **18 000 ms/hour**	-6 dB	-7 dB	-8 dB	-8 dB
Category A Proximity verification -41,3 dBm/MHz/Vehicle Access - no car shielding ➢ 330 vehicles/km ^{2} ➢ 10 devices/vehicle ➢ Max DC of 5 %/s Proximity verification ➢ Activity Factor (incl. DC) max. 0,00174 % →**62,64 ms/hour**	-18,6 dB	-19,6 dB	-20,6 dB	-20,6 dB
Category B Proximity monitoring -41,3 dBm/MHz/Vehicle Access - no car shielding ➢ 330 vehicles/km ^{2} ➢ **10 devices/vehicle** ➢ Max DC of 5 %/s Proximity monitoring ➢ Activity Factor (incl. DC) max. 0,033 % →**1 188 ms/hour**	-5,8 dB	-6,8 dB	-7,8 dB	-7,8 dB
Category C Proximity detection -41,3 dBm/MHz/Vehicle Access - no car shielding ➢ 330 vehicles/km ^{2} ➢ **10 devices/vehicle** ➢ Max DC of 5 %/s Proximity monitoring ➢ Max DC of 0,5 %/hour/LTA → **18 000 ms/hour**	6 dB	5 dB	4 dB	4 dB

Based on the aggregated scenario in ECC Report 170, it is shown that the "trigger-before-talk" mitigation technique (driven by the end user) for Category A: "Proximity verification" and Category B: "Proximity monitoring applications" provides a high degree of protection to the radio altimeters, even when operating at a maximum mean e.i.r.p. spectral density requirement of -41,3 dBm/MHz outside the vehicle, i.e. without an exterior limit (as defined in ETSI EN 302 065-3 [3]).

Further protection will be achieved by the reduction of number of devices in the vehicle to typically 2-4 depending on the passenger vehicle characteristics instead of 10 devices assumed for LTA applications.

History

Document history		
V1.1.1	July 2016	Publication