



CEPT Report 45

Report from CEPT to the European Commission in response to the Fifth Mandate to CEPT on ultra-wideband technology to clarify the technical parameters in view of a potential update of Commission Decision 2007/131/EC

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0 EXECUTIVE SUMMARY

This Report describes Ultra-WideBand (UWB) technology used by Short Range Devices (SRD) and has been developed in 2012-2013 by the European Conference of Postal and Telecommunications Administrations (CEPT) in response to the Fifth Mandate to CEPT on ultra-wideband technology to clarify the technical parameters in view of a potential update of Commission Decision 2007/131/EC [1].

The Report addresses the following aspects of UWB technology and regulation and aims to:

- Maximise the efficient use of spectrum and safeguard economies of scale for emerging equipment using UWB technology, taking into account ECC/DEC/(06)04 [2], as amended in December 2011, and standardisation activities within ETSI (general task);
- Ensure internal market benefits for new UWB equipment, including but not limited to equipment used in road and rail vehicle applications, a coherent and consistent regulatory environment is warranted (general task);
- Clarify the technical parameters as defined in the recently amended ECC/DEC/(06)04 [2] (task1);
- Differentiate transparently between those parameters essential for inclusion in a further amendment of Commission Decision 2007/131/EC [1] (as amended by Commission Decision 2009/343/EC [4]) on ultra-wideband (UWB) technology and the technical parameters to be taken into account in the development of Harmonised European Standards (task 3);
- Clarify of the difference, if any, between the “exterior limit” for road and rail vehicle applications and the generic limits for maximum e.i.r.p. densities radiated into the air, in particular in regard to relationship between the required mitigation techniques for specific applications and the permitted limits for maximum e.i.r.p. densities (task 2);
- Provide information about the definition of the technical parameters for the Low Duty Cycle (LDC) mitigation technique and other mitigation techniques (task 1);
- Provide information on other types of devices using UWB technology which are under Commission Decision 2006/771/EC [3] or elsewhere (task 3). The present Report includes a proposal for harmonisation of UWB devices on-board aircraft.

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LIST OF ABBREVIATIONS

Abbreviation	Explanation
BER	Bit Error Rate
BWA	Broadband Wireless Access
CEPT	European Conference of Postal and Telecommunications Administrations
DAA	Detect and Avoid
dBi	dB relative to an isotropic radiator
DC	Duty Cycle
ECC	Electronic Communications Committee
EC	European Commission
e.i.r.p	effective isotropically radiated power
ETSI	European Telecommunications Standards Institute
FCC	Federal Commission for Communications
FMSC	Frequency Modulated Stepped Carrier
FSS	Fixed Satellite Service
FWA	Fixed Wireless Access
GBSAR	Ground Based Synthetic Aperture Radar
JRC	Joint Research Centre
LAES	Location Tracking Application for Emergency Services
LBT	Listen Before Talk
LDC	Low Duty Cycle
LPR	Level Probing Radar
LRR	Long Range Radar
LT2	Location Tracking Application at fixed industrial sites using ultra-wideband technology
LTA	Location Tracking and sensor applications
PER	Packet Error Rate
PSD	Power Spectrum Density
RAS	Radio Astronomy Service
RTL	Real Time Location Tracking
Rx	The telegraph abbreviation for reception
SIR	Signal to Interferer Ratio
SFCW	Stepped Frequency Continuous Wave
SRD	Short Range Device
SRR	Short Range Radar
TLPR	Tank Level Probing Radar
Toff	Transmit off
Ton	Transmit on
TPC	Transmit Power Control
Tx	The telegraph abbreviation for transmission
UWB	Ultra Wide Band
WIMAX	Worldwide Interoperability for Microwave Access

1 INTRODUCTION

CEPT Report 27 [16] (March 2009) had provided an overview of the CEPT investigations on the generic UWB regulation completed with the amendment of Decision ECC/DEC/(06)12 [5] in October 2008.

Some further amendments of Decisions ECC/DEC/(06)04 [2] and ECC/DEC/(06)12 [5] were proposed within the frame of a new review of the generic UWB regulation in 2010/2011. They aimed to provide additional clarification on the regulatory framework in Europe and to reflect the outcome of latest further studies on UWB. CEPT agreed to merge the two Decisions, resulting in the amended ECC/DEC/(06)04 [2], in order to facilitate possible future updates.

The generic regulation for UWB devices in Europe given in Decision ECC/DEC/(06)04 [2] was developed to respond primarily to the core market demand for communication applications and cable replacement. It enables also various types of radio determination applications using UWB technology in bands below 10.6 GHz such as location-tracking and sensor technologies.

CEPT Report 34 [17] made clear that in the past CEPT had decided that fixed outdoor UWB emitters should not be permitted. Any interference to fixed service receivers from such fixed UWB emitters would (given the short ranges involved) be almost constant in level, unlike that from mobile or nomadic UWB terminals. However, as the only service receivers for which this argument is relevant are also fixed, coordination is possible to avoid interference. Most UWB devices operate under a general authorisation ("licence-exempt"), which makes any coordination unenforceable as well as impractical. However, for a large industrial site a form of authorisation or registration is appropriate, and would enable enforcement.

Such an authorisation/registration regime has been studied in ECC Report 167 [6] which concluded that there should be no problems to authorise well defined sites, such as workplace/offices, public buildings, security and manufacturing assembly lines, where the applicant is able to demonstrate that potential victim stations can be protected. This led to ECC/REC/(11)09 [12] in response to a demand for fixed outdoor Location Tracking Applications on large scale at industrial sites using Ultra-Wideband (UWB) technology (known as LT2). The ECC Recommendation should ensure that frequency bands are available on a harmonised basis to enable the introduction of UWB devices in a timely manner and ensuring economies of scale while ensuring protection of existing applications or services.

There is a huge interest from the industry to use UWB technology in 3.1 to 4.8 GHz and 6 to 8.5 GHz for different location tracking applications. For that reason in ECC Report 170 [9] the establishment of exclusion zones for the most sensitive victims and specific LDC requirements for automotive applications (LTA) were defined to allow in addition to the 6 to 8.5 GHz range efficient location tracking application in the frequency range 3.4 to 4.8 GHz. Based on ECC/REC/(11)09 [12] the industry has now the required possibility to realise fixed outdoor tracking applications.

Another request from industry was for future Location Tracking Application for Emergency Services (LAES) in disaster situations. The scope of initial compatibility studies performed by CEPT was already presented in CEPT Report 34 [17]. The intended users of the equipment are services or agencies, recognised and defined as such by the national administration, responsible for public safety. A questionnaire was also developed within CEPT so as to better assess and confirm the needs for such application. The questionnaire helped clarifying the intended market for this equipment. The main conclusion was that there is a clear need for equipment such as LAES for fire and rescue services. Based on the answers provided, 86% of the organisations have a clear need for such system and 72% of the organisations are ready to buy such a system, depending on the cost. The results of studies on the impact of LAES systems on radio services operating in the band 3.4 to 4.8 GHz are presented in ECC Report 170 [9]. This led to ECC/REC/(11)10 [10] in response to a demand for UWB LAES Application. The ECC Recommendation should ensure that frequency bands are available on a harmonised basis to enable the introduction of UWB devices in a timely manner and ensuring economies of scale while ensuring protection of existing applications or services.

Both, LT2 and LAES are non-consumer like applications which may need in future a specific regulation. The ECC Recommendation (11)09 describes registration/coordination requirements to ensure compatibility with primary service protection requirements for LT2. The ECC Recommendation (11)10 describes technical and

coordination requirements to ensure compatibility with primary services for LAES systems. The present Report does not propose to include these applications in the next update of Commission Decision 2006/771/EC.

CEPT also received a request from industry for the use of UWB applications on-board aircraft and conducted a co-existence study considering UWB applications on-board aircraft and existing radio services in the frequency bands from 3.1 GHz to 4.8 GHz and from 6.0 GHz to 8.5 GHz as in ECC Report 175 [33]. ECC/DEC/(12)03 [11] for UWB applications on-board aircraft operating in the frequency range from 6 GHz to 8.5 GHz has been developed.

An agreed regulatory approach is required to ensure that the spectrum utilised by UWB applications on-board aircraft in identified frequency bands can be used in any national airspace that the aircraft is crossing, provided that the system conforms to agreed radio specification limits in order to prevent harmful interference. Therefore, it is proposed to also include a regulation in the amendment of Commission Decision 2007/131/EC [1] for UWB applications on-board aircraft.

The current trends in UWB technologies shows very promising capabilities in a broad range of location tracking applications such as industrial, logistics, assisted living applications.. For high precision location and tracking no alternative exists. Future developments towards hybrid systems combining communication, sensor and tracking application will open up new fields of deployment.

2 DELIVERABLES DEVELOPED BY CEPT SINCE THE LAST AMENDMENT OF COMMISSION DECISION 2007/131/EC

The following Table 1 provides a list of the ECC Deliverables developed since the last amendment of the Commission Decision 2007/131/EC [1] and related ETSI standards.

Table 1: Overview ECC deliverables

Document	Applications	Mitigation techniques	ETSI Standard
Decisions ECC/DEC/(06)04 and ECC/DEC/(06)12 were merged as part of the review of the generic UWB regulation in 2010/2011 resulting in the amended ECC/DEC/(06)04	Communications, measurement, imaging, surveillance and medical systems	DAA, LDC, TPC	EN 302 065-1 in future
	Location tracking in the range 6 to 9 GHz (former Type LT1)	DAA	EN 302 065-2 in future
	Applications in ground based vehicle (automotive)	TPC, DAA, specific LDC Exterior Limit can be interpreted as a kind of mitigation	EN 302 065-3 in future
ECC/REC/(11)09 LT2	Location tracking Type 2 applications incl. fixed outdoor installations using UWB technology	DC, DAA (between 3.1 and 3.4 GHz) and also implementation of registration/coordination mechanisms	EN 302 065-2 in future
ECC/REC/(11)10 LAES	Location application for emergency services using UWB technology	DC, DAA (between 3.1 and 3.4 GHz) and also implementation of registration/coordination mechanisms for training centers. Limited deployment/ use by emergency services only allows higher emission limits	EN 302 065-2 in future
New ECC Decision (12)03 for UWB onboard aircraft operating in the frequency range 6 to 8.5 GHz	UWB radio links for intra-aircraft communications purposes onboard an aircraft	Emission limit reduction; Alternative mitigation techniques offering equivalent protection such as the use of shielded portholes	No ETSI work item for a Harmonised European Standard, however use of ETSI TS 102 883 and ETSI TS 103 360 possible
ECC Report 175 co-existence study considering UWB applications inside aircraft and existing radio	All short-haul aircraft such as A320 and B737 as well as all long range aircraft such as A330/340/350 or A380 and	Emission limit reduction The study report considered two UWB	No ETSI work item for a Harmonised European

Document	Applications	Mitigation techniques	ETSI Standard
services in 3.1 to 4.8 GHz/6.0 to 8.5 GHz	B747, B777 or B787	devices transmitting <u>simultaneously</u> operating on the same frequencies (500 MHz) onboard an aircraft. In addition, ECC Report 175 did not consider mitigation techniques.	Standard, however use of ETSI TS 102 883 and ETSI TS 103 360 possible. Precise Implementations are specific to the type of aircraft
ECC Report 170 on specific UWB applications in the bands 3.4 to 4.8 GHz and 6 to 8.5 GHz LAES, LT2 and LTA	Automotive applications, LT2 and LAES	Automotive applications, relates to new LDC options and exterior limits concept. Does not work for all described applications, i.e. not each LDC option works for all UWB applications	EN 302 065-2 in future for LT2 and LAES EN 302 065-3 in future for LTA
ECC Report 167 on practical implementation of registration/coordination mechanism for UWB LT2 systems	LT2	Describes registration/coordination requirements to ensure compatibility with primary service protection requirements	EN 302 065-2 in future
ECC Report 139 Impact of LPR, using Ultra-Wideband Technology on radiocommunications services	Level Probing Radars (LPR) is a radio determination application targeting mainly a wide range of industrial applications LPR are using UWB technology. This category covers Level Probing Radars (LPR) and mainly targets a wide range of industrial applications TLPR and LPR are both covered by the EC Decision for SRD. It is proposed to keep all SRD radio determination applications in one place	Usage restrictions related to their installation as well as TPC and specific antenna pointing and antenna pattern requirements also covered by the applicable Harmonised European Standard Note that three of the four LPR operating frequency ranges are above 10.6 GHz	EN 302 729 for LPR RAS site protection information included in the Harmonised Standard

3 CONSISTENCY AMONGST UWB LIMITS

3.1 MITIGATION TECHNIQUES

3.1.1 Low Duty Cycle (LDC) Mitigation Technique

Limitations on the duty cycle of UWB devices can improve the coexistence with other radiocommunication systems. The technical requirements for LDC UWB devices to protect FWA terminals are presented in ECC Report 094 [7].

Based on studies and measurement campaigns on the impact of LDC UWB devices on radars in the band 3.1 to 3.4 GHz, it was concluded in 2008 that the probability of a single LDC UWB device to radiate into the main beam of the radar was low and hence the risk of harmful interference was considered to be small. One study showed that aggregation effects from LDC UWB devices on radars could cause unacceptable probability of interference in the band 3.1 to 3.4 GHz. However, the various regulatory provisions aiming to minimise outdoor use could be sufficient to reduce the aggregate interference.

ECC Report 170 [9] provides compatibility studies in the bands 3.4 to 4.8 GHz and 6 to 8.5 GHz on the impact of LDC UWB devices installed inside road and rail vehicles.

As a result of ECC Report 170 [9], a specific LDC mitigation (vehicle speed dependent) was defined and implemented into the amended ECC/DEC/(06)04 [2].

During the on-going ECC WGSE Project Team SE24 work item (SE24_37) on LDC as mitigation for UWB application, an assessment on the combination UWB emission limits and the LDC transmitting time has been made.

It is important to understand that a linear trade-off between UWB emission limits and the use of LDC as a mitigation technique, i.e.: increasing LDC and decreasing emitted power accordingly as shown in Table 2, - is not straightforward. In order to assess the impact of the proposed limits on the affected radio services, some studies are based on ECC Report 170 [9]. Additional studies were also performed on request of industry on the possibility to increase for automotive UWB applications the LDC limit when reducing the Tx emission power by means of a linear trade-off. The following points are essential for understanding the trade-off considerations:

For pure aggregated scenarios, the linear trade-off of LDC and power limit should always give an equivalent effect as the original limit proposal;

This also assumes the geographical distribution of transmitting devices to be so that the peak to average ratio of the interference received by the victim is within the borders of the original compatibility consideration. An unbounded trade-off of power and Duty Cycle cannot be made, because a law for trading Duty Cycle and transmitted power, giving the same effects at the victim side, is not linear. It means that this trade-off between LDC and the transmitter power is only possible in a linear way within certain boundaries. If the bias effect of interference in the time domain, which is mainly defined by the demodulation system of the victim, i.e. the bias effect of interference in the amplitude domain and the sensitivity of the victim receiver, is known, a defined trade-off range may be established where it is considered as linear.

Table 2: is the result of such an exercise assuming a known aggregate of ground based non fixed installed devices. The applicability of Table 2: is therefore limited to applications conforming to this scenario.

For single entry scenarios one should also consider the sensitivity of the victim service with respect to short term interference, e.g. in case of Wimax. Here the impact may be different. However, the issue has been raised of limiting T_{on} to values below 5ms based on a study provided by the JRC. The results of those measurements showed that the impact on Wimax was increasing with smaller T_{on} values below 5 ms (remaining overall activity limit of 5% is or constant, equalling 50 ms/second) whilst the PER even decreased

for Ton values up to 50ms (see ECC Report 170 Annex 5 [9]). This was the rationale in the past to establish a work item for further investigations into the LDC mitigation technique. Studies are on-going in the CEPT and there is a possibility that the exact technical parameters of the LDC limits will be subject to re-consideration with the aim of ensuring protection of the radio services from UWB applications using LDC mitigation techniques. This will however not delay the current update of the EC Decision since it is proposed to provide these detailed parameters in the updated ECC/DEC/(06)04 [2] and the Harmonised European Standards but not to describe them in detail in the EC Decision itself.

Moreover, also for single entry scenario, a linear trading of LDC against transmit power may provide a protection criteria equivalent or even wider than the baseline LDC limits. This is reflected in ECC Report 170 [9] when analysing a single UWB interferer against a WiMAX receiver located at 3.6m of distance (see Figure 4): in this case, decreasing by 4dB the Signal to Interference Ratio (or equivalently decreasing by 4dB the UWB transmit power level) completely vanishes the PER, whichever duty cycle would be adopted.

The main conclusion is that the effectiveness of LDC mitigation in the single entry case is dependent on the susceptibility to transmission time patterns of the interferer and the sensitivity of the receiver for the pulsed signal and therefore victim application dependent.

The combinations of LDC limits and the transmitter emission limits as shown in Table 2 may give an equivalent protection as the current baseline LDC limits in ECC/DEC(06)04 [2] and as shown in Table 1 below: a more deep technical background related to this subject, based on official information available in EC and ECC, may be retrieved in Annex 2.

Table 2: Combination of LDC limits and the transmitter emission limit

PSD limit	External limit Elevation >0°	Long Term Duty Cycle	Short Term Duty Cycle	Max (Ton)	Mean (Toff)	Max [Σ Ton]	Min [Σ Toff]
dBm/Mhz	dBm/Mhz	seconds in 1 hour	% in 1 second	milliseconds	milliseconds	milliseconds	milliseconds
-41,3	-53,3	18-180	5,0%	5,0	38,0	50,0	950,0
-44,3	-56,3	36-360	10,0%	10,0	38,0	100,0	900,0
-47,3	-59,3	72-720	20,0%	20,0	38,0	200,0	800,0
-50,3	-62,3	144-1440	40,0%	40,0	38,0	400,0	600,0
-51,3	-63,3	180-1800	50,0%	50,0	38,0	500,0	500,0

In Table 2, the row in green background represents currently allowed baseline limits in ECC/DEC/(06)04 [2], and the other rows represent proposed trading ranges.

As can be seen from Table 2, there are ranges given for the long term duty cycle limit. The reason is that in case of UWB devices installed in road and rail vehicles, within the band 3.4 to 4.8 GHz, this long term duty cycle requirement does not apply for operation with vehicle speed above 40 km/h (see EC DEC(06)04 [2]). For vehicle speeds between 20 km/h and 40 km/h a gradual implementation of the long term duty cycle limit from 18 seconds to 180 seconds per hour would be required as shown in Figure 1.

Based on the results in CEPT ECC WGSE (on-going work item SE24_37) so far, linear trading of LDC against transmitted power as shown in Table 2 and within these boundaries only is considered to provide equivalent protection to the LDC limits stated in EC DEC(06)04 [2] as amended in 2011.

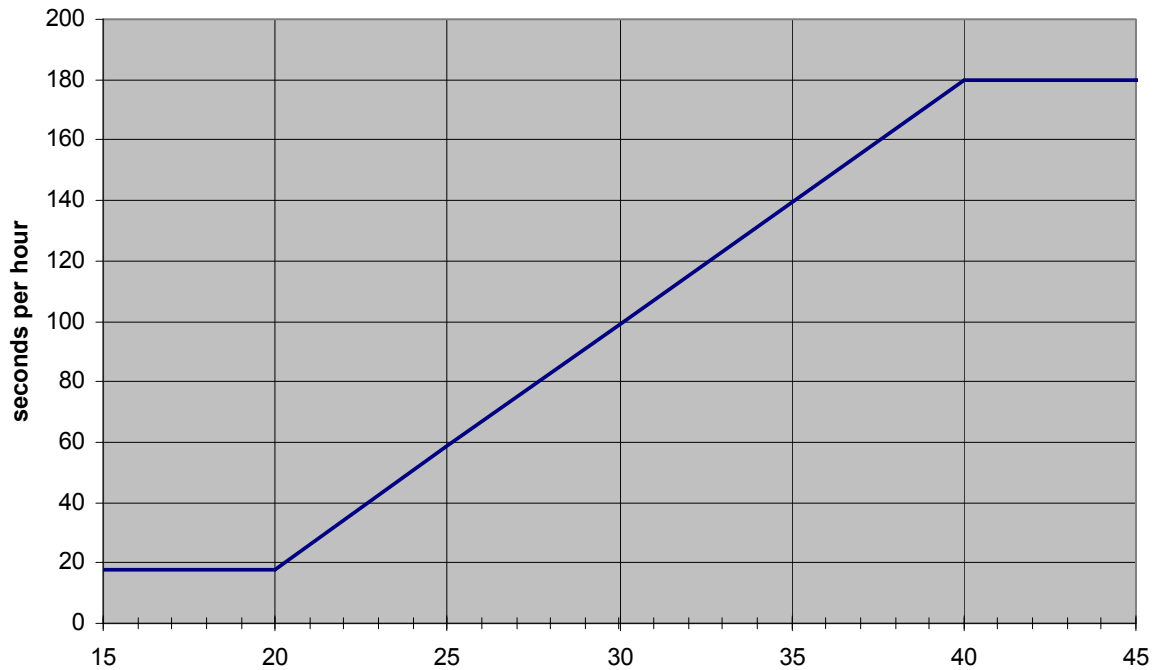


Figure 1: Long term duty cycle for different speeds of vehicle in km/h for the baseline PSD limit of -41.3 dBm/MHz

The current baseline LDC limits for single UWB devices are included in ECC/DEC/(06)04 [2]:

Ton max = 5 ms
Toff mean \geq 38 ms (averaged over 1 sec)
 Σ Toff > 950 ms per second
 Σ Ton < 18 s per hour

These LDC precise parameters can change in the future.

For the EC Decision, it is proposed to include in future only the LDC definitions necessary but not to include the precise technical parameters which may be subject to changes, if needed and based on new technical study results.

This approach is considered in line with the paragraph in the Commission Decision 2007/131/EC [1] and the approach to streamline the regulatory environment:

<< Appropriate mitigation techniques (including detect-and avoid or low-duty-cycle approaches) studied and specified by CEPT and ETSI under the respective EC Mandates, should be included in Harmonised Standards under the R&TTE Directive once stable and proven to provide equivalent protection to the emission levels identified in this Decision.>>

The alternative approach would be an unstable regulatory framework which requires more frequent updates of the EC Decision, also to be synchronised with technical studies in CEPT and updating of ECC deliverables as well as the creation or revision of Harmonised European Standards for UWB equipment.

In case of UWB devices for **location tracking applications (LT2)** in the range 3.4 to 4.8 GHz, additional specific LDC parameters were defined in ECC/REC/(11)09 [12].

These parameters are for fixed in- and outdoor transmitter and mobile equipment for tracking applications / systems:

Ton max = 25 ms
Toff mean \geq 38 ms (averaged over 1 sec)
 Σ Toff > 950 ms per second

In addition for fixed indoor and mobile terminals the transition per minute is restricted too:
 Σ Ton < 900ms per minute (Note 1,5%/minute)

Note: for fixed outdoor terminals a "radiation pattern" is combined to the LDC to reach the necessary equivalent mitigation

For the EC Decision, it is proposed to include in future only the LDC definitions necessary but not to include the detailed technical parameters and combinations which may be subject to changes, if needed and based on new technical study results.

A revision of ECC/DEC/(04)04 is planned to include the results on the on-going studies on LDC.

3.1.2 Detect And Avoid (DAA)

The implementation of Detect and Avoid (DAA) mechanism can improve the coexistence with other radiocommunication systems.

The technical requirements for DAA UWB devices to ensure the protection of radiolocation services in the bands 3.1 - 3.4 GHz and 8.5 - 9 GHz and BWA terminals in the band 3.4 - 4.2 GHz are presented in ECC Report 120 [35].

DAA technical requirements in the band 8.5 - 9 GHz are based on characteristics of active radiolocation systems and may be revised in the future subject to reported risk of interference to other classes of X-band radars considered to be deployed in the future. In particular for future passive radars, a DAA mechanism is not going to help. Based on the concept of passive radar to detect objects in a known electromagnetic field, which is generated by other sources than the radar itself the influence of UWB needs to be studied. The "noise like" constant emissions of UWB devices could help the co-existence with passive radars.

DAA technical requirements provided in Annex 3 of ECC/DEC/(06)04 [2] need to be supplemented by adequate guidance on DAA measurement procedures and test patterns as defined in relevant ETSI Harmonised European Standards adopted under Directive 1999/5/EC [13].

DAA technical requirements should safeguard the protection of BWA terminal stations for more than 99.75% of the time.

DAA technical requirements will need to be reviewed as existing systems are subject to technological change and other systems may be deployed or developed in the future.

The requirement of UWB DAA devices operating in the band 3.1 to 4.8 GHz to be capable of selecting an operating channel anywhere within the band 3.1 to 4.8 GHz band will provide additional mitigation to radio service.

The flexible DAA concept is based on the definition of different zones for which an appropriate UWB emission power level (maximum mean e.i.r.p. spectral density) is authorised. A zone is defined by a range of isolation between a device/system of a victim radio service and the UWB device. These zones and associated range of isolation correspond to the maximum mean e.i.r.p. spectral density levels specified in Table 3:.

In the first zone, the UWB device shall operate at an emission level applied in the avoidance bandwidth as defined in Table 2:.. In the last zone, the UWB device can operate without restriction up to the maximum permitted power level of -41.3 dBm/MHz or as defined in a future DAA regulation for the corresponding operational frequency range except in road and rail vehicles where additional restrictions apply. Between these extreme zones, a transition zone is defined for the band 3.4 to 4.8 GHz.

Before initiating UWB communications, the UWB device shall perform a monitoring of the RF environment during a minimum time to detect any actively operating victim signal (minimum initial channel availability check time value given in Table 3). Based on the result of this detection process, the UWB device has to determine the corresponding zone it occupies and react accordingly.

This function shall be able to detect victim systems signals and measure if this power level in a given bandwidth is above or below a detection threshold in any of the frequency bands denoted here after. This detection threshold is specified at the antenna connector assuming a 0dBi antenna gain for each detection operation and may be based on multiple levels. This detection threshold can alternatively be expressed as a field strength limit.

The DAA UWB devices shall be able to continuously detect any change of the RF configuration (e.g. modification of operating zone) and switch to corresponding emission level within a maximum detect and avoid time according to the victim service and procedural tests defined in relevant standards.

This context is meant to be duly taken into account by ETSI in the development of Harmonised Standards (see Table 1: in section 3).

Consequently, because the mitigation techniques are defined with all relevant parameters in the Harmonised European Standards and in line with the ECC relevant study reports and deliverables, there is no need to include the detailed DAA parameters also the Commission Decision. This is seen as part of streamlining the regulatory environment.

Table 3: Technical parameters to be used by UWB DAA devices

	Operational frequency	3.1 to 3.4 GHz	3.4 to 3.8 GHz ¹	3.8 to 4.8 GHz ¹	8.5 to 9 GHz
	Minimum initial channel availability check time	14s	5.1s		14s
Zone 1 for Signal detection level S > A	Maximum mean e.i.r.p. spectral density	-70 dBm/MHz	-80 dBm/MHz	-70 dBm/MHz	-65 dBm/MHz
	Default Avoidance bandwidth	300 MHz	200 MHz		500 MHz
Signal Detection threshold A		-38 dBm	-38 dBm		-61 dBm
Zone 2 for Signal detection level A > S > B	Maximum mean e.i.r.p. spectral density	-41.3 dBm/MHz	-65 dBm/MHz		-41.3 dBm/MHz
	Default Avoidance bandwidth	-	200 MHz		-
Signal Detection threshold B			-61 dBm		
Zone 3 for Signal detection level S < B	Maximum mean e.i.r.p. spectral density	-	-41.3 dBm/MHz		-

Definitions of the parameters in Table 3 can be found in ECC Report 120 [35].
¹ Detection mechanism needs to be validated to protect existing operation of victim stations of radio services such as BWA terminals

UWB DAA devices shall be capable of selecting an operating channel anywhere within the band 3.1 to 4.8 GHz.

3.1.3 Transmit Power Control

CEPT Report 17 [18] recommended for UWB devices **installed inside road and rail vehicles** the implementation of Transmit Power Control (TPC) for devices which do not implement Low Duty Cycle (LDC) mitigation technique in view of reducing the aggregate interference on outdoor stations of radio services.

Within the bands 3.1 to 4.8 GHz and 8.5 to 9 GHz, devices implementing Detect And Avoid (DAA) mitigation technique are permitted to operate with a maximum mean e.i.r.p. spectral density of -41.3 dBm/MHz and a maximum peak e.i.r.p. of 0 dBm defined in 50MHz. Operation is in addition subject to the implementation of Transmit Power Control (TPC) mitigation technique and an exterior limit of -53.3 dBm/MHz for UWB devices installed inside road and rail vehicles.

Within the band 6 to 8.5 GHz devices implementing Transmit Power Control (TPC) mitigation technique and an exterior limit of -53.3 dBm/MHz are permitted to operate with a maximum mean e.i.r.p. spectral density of -41.3 dBm/MHz and a maximum peak e.i.r.p. of 0 dBm defined in 50 MHz for UWB devices installed inside road and rail vehicles.

Devices implementing Transmit Power Control (TPC) should fulfil at least a dynamic range of 12 dB (mean e.i.r.p. range of -41.3 to -53.3 dBm/MHz).

This mitigation technique is taken into account by ETSI in the development of Harmonised Standard EN 302 065-3 [22]. Consequently, because the mitigation technique are defined with all detailed relevant parameters in the Harmonised European Standards and in line with the ECC relevant study reports and deliverables,

there is no need to include these detailed parameters also the Commission Decision. This is seen as part of streamlining the regulatory environment.

3.2 EXTERIOR LIMITS

The regulations defined in ECC/DEC/(06)04 [2] allow, besides general cases, the usage of Ultra Wideband (UWB) devices installed in road and rail vehicles, where special limits apply for the bands 3.1 to 4.8 GHz, 6 to 8.5 GHz and 8.5 to 9 GHz if mitigation techniques are implemented.

Operation is permitted with a maximum mean e.i.r.p. spectral density (PSD_{mean}) of -41.3 dBm/MHz and a maximum peak e.i.r.p. (PSD_{peak}) of 0 dBm defined in 50MHz if:

- within the bands 3.1 to 4.8 GHz and 6 to 8.5 GHz Low Duty Cycle (LDC) and an exterior limit (PSD_{ext}) of -53.3 dBm/MHz are implemented or
- within the bands 3.1 to 4.8 GHz and 8.5 to 9.0 GHz Detect And Avoid (DAA), Transmit Power Control (TPC) and an exterior limit of -53.3 dBm/MHz are implemented or
- within the band 6 to 8.5 GHz Transmit Power Control (TPC) and an exterior limit of -53.3 dBm/MHz are implemented.

The exterior limit is defined, for each UWB device installed in a road or rail vehicle, as the maximum mean e.i.r.p spectral density for the emissions outside the vehicle at elevation angles higher than 0 degree.

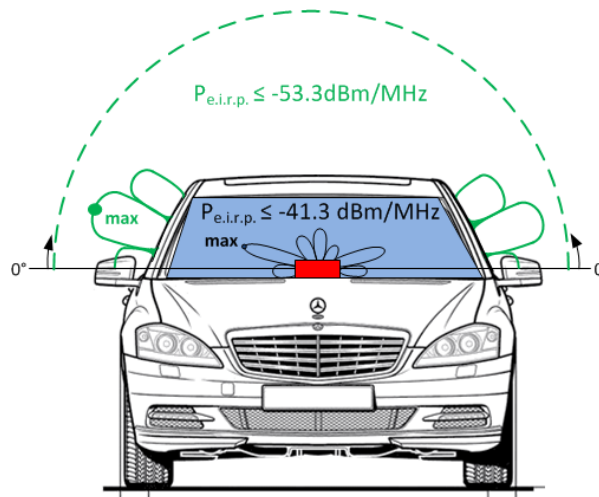


Figure 2: Principle of the regulations

Note: The exterior limit refers to the maximum mean e.i.r.p. spectral density measured outside the vehicle and every local maximum shall be below the limits.

ECC Report 170 [9] identified some exceptional cases, where the UWB antennas were placed directly behind the car windows pointing through the window to the outside, There was a low attenuation reported (2dB).

A summary based on all available studies for the spread of car screening attenuation shows the following attenuation levels:

Lower range 3.4 to 4.8 GHz: 2 - 37dB

Upper Range 6 to 8.5 GHz: 4 - 37dB.

This big spread of the car screening attenuation was the motivation to add an exterior limit for UWB devices installed in road and rail vehicles.

The reference points for the limits shown in Figure 2 are 1) the single UWB device aperture limit of a maximum mean e.i.r.p. spectral density (PSD_{mean}) of -41.3 dBm/MHz inside the vehicle and 2) the exterior limit outside the vehicle. It should be emphasized here that all other UWB limits in the UWB generic regulations than this exterior limit outside of vehicles are expressed as single UWB device aperture limits and based on the definition in Decision 2007/131/EC [1] in Article 2 under 11: "radiated into the air" which means those parts of the signal emitted by specific applications of ultra-wideband technology which are not absorbed by their shielding. This is also important because many UWB sensors are embedded in a material which provides some attenuation. If this attenuation is high enough and in accordance with the concept of providing adequate mitigation, an installation can be considered as indoor-like.

ECC Report 170 [9] provides compatibility studies in the bands 3.4 to 4.8 GHz and 6 to 8.5 GHz on the impact of LDC UWB devices installed inside road and rail vehicles assuming a penetration rate of 50%, 10 devices per vehicle (6 in 3.1 to 4.8 GHz and 4 devices per vehicle in 6 to 8.5 GHz) and their intended emissions directed towards the inside. ECC Report 170 [9] concludes that an exterior limit of -53.3 dBm/MHz for emissions outside road and rail vehicles would provide a high level of confidence on the protection of most affected radio services.

The advantage of the exterior limit is that it allows no limitation of the UWB device number simultaneously transmitting in a vehicle while at the same time to ensure compatibility with defense applications such as unmanned ground vehicles. Without exterior limits and having a deployment of UWB in millions of vehicles in the future, the exclusion of fixed outdoor UWB installations from the generic UWB would be de-facto contradicted.

The precise definition of exterior limits also needs to be complemented by a measurement concept for exterior limits at and around vehicles. ETSI has created TR 103 086 [28] on conformance test procedure for the exterior limit tests in the Harmonised European Standard EN 302 065-3 [22] UWB applications in the ground based vehicle environment. This Technical Report on UWB vehicle measurements provides the information how exterior limits for vehicular application can be measured.

Consequently, because the exterior limit with all relevant parameters is going to be included in the Harmonised European Standard EN 302 065-3 [22] for UWB applications in the ground based vehicles case and in line with the ECC relevant study reports in ECC Report 170 [9] and the amended ECC/DEC/(06)04 [2], there is no need to include detailed technical parameters for the exterior limit in the Commission Decision.

The current Decision 2007/131/EC defines in Article 2 under 11: "radiated into the air" which means those parts of the signal emitted by specific applications of ultra-wideband technology which are not absorbed by their shielding or by the material under investigation. This is understood to cover the exterior limit and therefore, it is not considered to be necessary to provide an additional definition for the exterior limit in the EC Decision.

3.3 UWB ONBOARD AIRCRAFT LIMITS

ECC/DEC/(06)04 [2] for UWB technology below 10.6 GHz excludes devices installed in flying models, aircraft and other aviation. Use of radio links for intra-aircraft communications purposes on-board an aircraft is an emerging field. Motivated by the ever increasing demand for lighter and more efficient aircraft as well as the demand for the introduction of wireless communications capabilities for passengers and crew, the use of ultra-wideband (UWB) radio technology on-board commercial passenger aircraft is seen as a promising technological option for replacing wires and creating new and innovative applications. In particular applications such as enhanced wireless passenger communications and entertainment, non-safety wireless crew communications as well as non-safety wireless control and monitoring functions are candidates for the initial use of UWB technology.

CEPT received ETSI TR 102 834 [29] describing the use of UWB applications on-board aircraft and conducted a co-existence study considering UWB applications on-board aircraft and existing radio services in the frequency bands from 3.1 GHz to 4.8 GHz and from 6.0 GHz to 8.5 GHz. The results of these studies are in ECC Report 175 [33] and the related regulatory approach was developed and agreed as in ECC/DEC/(12)03 [11]. This ECC Decision defines general harmonised conditions for the use of devices using UWB technology on-board aircraft operating in the frequency band from 6 GHz to 8.5 GHz

An agreed pan-European regulatory approach is required to ensure that the spectrum utilised by UWB applications on-board aircraft in identified frequency bands can be used in any national airspace that the aircraft is crossing, provided that the system conforms to agreed radio specification limits in order to prevent harmful interference. The allocation or designation of frequency bands under specified conditions in EU member countries is recommended to be laid down by law, regulation or administrative action. An EC Decision is required to deal with the carriage and use of equipment throughout Europe. It is also recognised that for UWB applications on-board aircraft to be introduced successfully throughout Europe, confidence must be given on the one hand to manufacturers to make the necessary investments and on the other hand to users of existing services that their protection will be ensured.

At the time of writing this Report, no work item for the creation of a Harmonised European Standard for UWB devices on-board aircraft existed in ETSI. However, the use of ETSI TS 102 883 [30] and ETSI TS 103 360 [24] is possible.

It is proposed to include the limits in Table 4 below in the EC Decision together with the notes provided in the Table 4 below. It is to note that Note 1 in the Table 4 below gives the necessary flexibility for aircraft specific type implementations.

It can be argued that due to the limited number of aircraft manufacturers and the need for implementations specific to the type of aircraft, this is not a subject to be covered in a Harmonised European Standard but rather specific implementation construction files provided by the manufacturer to the certification process. The UWB on-board equipment will also be subject to several certification processes, i.e. the one under R&TTE Directive but also the airworthiness type approval process.

The following limits are included in ECC/DEC/(12)03 [11]. Equipment using ultra-wideband technology on-board aircraft are proposed to use the radio spectrum with the e.i.r.p. limits given in section 1.1 of Commission Decision 2009/343/EC [4] provided that for the bands from 6.650 GHz to 8.50 GHz the following parameters are applied as shown in the table below.

Table 4: Technical parameters to be used by UWB devices onboard aircraft

Frequency range	Maximum mean e.i.r.p. spectral density	Maximum peak e.i.r.p. (defined in 50 MHz)	Requirements for mitigation techniques
Below 1.6 GHz	-90 dBm/MHz	-50 dBm	
1.6 to 2.7 GHz	-85 dBm/MHz	-45 dBm	
2.7 to 3.4 GHz	-70 dBm/MHz	-36 dBm	
3.4 to 3.8 GHz	-80 dBm/MHz	-40 dBm	
3.8 to 4.2 GHz	-70 dBm/MHz	-30 dBm	
4.2 to 4.8 GHz	-70 dBm/MHz	-30 dBm	
4.8 to 6 GHz	-70 dBm/MHz	-30 dBm	
6.0 to 6.650 GHz	-41.3 dBm/MHz	0 dBm	
6.650 to 6.6752 GHz	-62.3 dBm/MHz	-21 dBm	notch of 21 dB should be implemented to meet a level -62.3 dBm/MHz ¹
6.6752 to 8.5 GHz	-41.3 dBm/MHz	0 dBm	7.25 to 7.75 GHz (FSS and MetSat (7.45 to 7.55 GHz) protection) ^{1,2} 7.75 to 7.9 GHz (MetSat protection) ^{1,3}
8.5 to 10.6 GHz	-65 dBm/MHz	-25 dBm	
Above 10.6 GHz	-85 dBm/MHz	-45 dBm	

¹Alternative mitigation techniques offering equivalent protection such as the use of shielded portholes

Frequency range	Maximum mean e.i.r.p. spectral density	Maximum peak e.i.r.p. (defined in 50 MHz)	Requirements for mitigation techniques
could be a solution.			
² 7.25 to 7.75 GHz (Fixed Satellite Service) and 7.45 to 7.55 GHz (Meteorological Satellite) protection: - 51.3 - $20 \cdot \log_{10}(10[\text{km}]/x[\text{km}])(\text{dBm}/\text{MHz})$ for heights above ground above 1000 m, where x is the aircraft height above ground in kilometres, -71.3 dBm/MHz for heights above ground of 1000m and below.			
³ 7.75 to 7.9 GHz (Meteorological Satellite) protection: -44.3 - $20 \cdot \log_{10}(10 [\text{km}] / x [\text{km}]) (\text{dBm}/\text{MHz})$ for heights above ground above 1000 m, where x is the aircraft height above ground in kilometres, and -64.3 dBm/MHz for heights above ground of 1000 m and below.			

ECC Report 175 [33] assumed that not more than two UWB devices would be transmitting at any time within an aircraft within the same frequency range. In case the active number of UWB devices installed or deployed onboard an aircraft significantly exceeds this assumptions used in ECC Report 175 [33] then this regulation will have to be reviewed in the future.

ECC Report 175 [33] did not consider mitigation techniques and the limits expressed in Table 4 are all single device limits, i.e. the reference point is the limit is at the single UWB device transmitter aperture inside the aircraft cabin.

Based on Note 1 in Table 4, aircraft manufacturers are expected to find solutions to apply alternative mitigation techniques offering equivalent protection to primary radio services. Since the number of airline manufacturers is limited and the application of such techniques may depend on the aircraft type, it is considered that this is a flexible solution to apply mitigation techniques.

Concerning Note 1 in Table 4, based on the consideration with two UWB devices simultaneously transmitting at any time on-board an aircraft and an aircraft fuselage attenuation of 15 dB, the limits in Table 4 are consistent with the exterior limit for the road and rail vehicle case when assuming operation of UWB onboard aircraft with the aircraft being on the ground.

With regard to Notes 2 and 3 in Table 4, it needs to be noted that the limits are more stringent when the aircraft is in the air at heights above ground because the FSS and MetSat victims are on the ground, whereas on the ground, it is precisely the same limit as for other UWB applications (-41.3 dBm/MHz).

3.4 OTHER TYPES OF EQUIPMENT USING UWB TECHNOLOGY

Part of task 3 is to investigate how the generic limits for maximum e.i.r.p. densities radiated into the air relate to attenuation factors that apply to the usage of specific UWB equipment or the use of UWB technology in other applications. This includes also those types of UWB equipment for which frequency access is harmonised through other Commission Decisions such as, but not limited to, those in Commission Decision 2006/771/EC [3].

There are several applications covered by Commission Decision 2006/771/EC [3] (as amended), other EC Decisions (e.g. for SRRs) or in ERC Recommendation 70-03 [34] which use UWB technology. These include:

- Tank Level Probing Radars (TLPR) (already included in 2006/771/EC) [3];
- 57 to 64 GHz SRD (candidate for inclusion in 2006/771/EC [3]);
- 57 to 66 GHz Wideband Communication Systems (already included in 2006/771/EC [3]);
- 76 to 77 GHz automotive LRR (used for e.g. cruise control applications), the technology is also used for other ground-based applications (e.g. airplanes during taxiing, train level crossings, fixed installations along road sites) (already included in 2006/771/EC [3]);
- 24 GHz automotive short range radar applications (already included in 2005/50/EC as amended by 2011/485/EU [41]);
- 79 GHz automotive short range radar applications (already included in 2004/545/EC [37]);

- LPR (same sensors as TLPR but installation is different) (candidate for inclusion in 2006/771/EC);
- Ground- and Wall- Probing Radar (decided in the past in RSCOM that this professional application does not need a legally binding harmonisation measure);
- RTLT (Real time Location Tracking applications in 2.4 GHz (use the 2.4 to 2.4835 GHz existing regulations);
- GBSAR – Ground Based Synthetic Aperture Radars (already included in 2006/771/EC [3])
- ECC/DEC/(07)01 [15] and ETSI EN 300 435 [19] for building material analysis (this is part of the present EC Decision [1]) but in ECC Decision also devices for object discrimination in critical situation are defined, see ETSI EN 300 498 [20].

The LPR application is an interesting case. Industrial Level Probing Radar is based on the same technology as Tank Level Probing Radar (TLPR). The inclusion of the LPR entries in the EC Decision for SRD would roughly double the addressable market for this technology. The technology exists since years and is ready for the market. Timely inclusion is therefore beneficial. Compatibility studies in ECC have led to an ECC decision (11)02 [39] describing technical requirements such as TPC and a minimum requirement for the used antenna pattern (this includes half-sphere limits around the LPR mainbeam which is always pointed downwards, i.e. a very specific deployment situation is specified). In addition, exclusion zones around RAS sites are for some LPR operating frequencies necessary. The relevant standard is ETSI EN 302 729-2 [21]. LPR have been proposed to be included in the EC decision for SRD. The technical requirements, in particular the transmit power control and specific antenna requirements, as well as exclusion zones are also reflected in the Harmonised European Standard.

Since TLPR is in the SRD framework, it is advised to not decide otherwise for LPR. In addition, The FCC in the USA indicated to handle the TLPR and LPR application regulation precisely the same way as has been agreed in Europe so far, i.e. under the SRD framework. It should also be noted that three of the four operating frequency ranges are above 10.6 GHz, i.e. the frequency range under consideration in 2007/131/EC [1] (as amended): 6.0 to 8.5 GHz, 24.05 to 26.5 GHz, 57 to 64 GHz and 75 to 85 GHz.

Background information on LPR is also available in ETSI TR 102 601 [38]. The LPR antenna is specifically designed in a manner that is installed at a permanent fixed position pointing in downward direction.

The same sensors as for TLPR and LPR are also used in an even more specific case, i.e. in still pipes. This usage is described in ETSI TS 102 692 [25] and the very specific mitigations resulting from using such level gauging sensors in metal pipes with holes are described in the technical specification and how results of conformity assessment measurements can be compared to Commission Decision 2007/131/EC [1]. Still pipes level gauges operate in 9 to 10.6 GHz since many years without problems, i.e. they were already in existence before the UWB regulation. The still pipe radar level gauges intended for the use in the above mentioned frequency range do not use the time domain UWB short pulses. Instead the radar level gauges use the frequency domain FMCW and/or SFCW. Thus the frequency band generated by the FMCW and/or SFCW radars is strictly controlled. There is the ISO standard ISO 4266-1 [40] that describes the use of still pipes used in petroleum and liquid petroleum product tanks.

The still pipes case can be seen as a successful example and precedence case where the principle stipulated in the Annex of the Commission Decision 2007/131/EC [1] under appropriate mitigation techniques was applied in the field:

Equipment using ultra-wideband technology may also be allowed to use the radio spectrum with e.i.r.p. limits other than those set out in the table in point 1 provided that appropriate mitigation techniques other than those set out in the first sub-paragraph are applied with the result that the equipment achieves at least an equivalent level of protection to that provided by the limits in the table set out in point 1.

Examples of such application not considered for inclusion in the EC Decision for UWB may be found in industrial machine installations operating equipment with UWB devices or other areas with very limited traffic from people, and/or narrow field of emission resulting from use of directional antennas.

Efforts to investigate such a specific scenario, such as the still pipes case, and to describe it in regulations are very ineffective, especially in cases where the application existed even before a generic regulation came into force. Additional technical studies on very specific deployment scenarios would require considerable resources of the proponents as well as of administrations in the ECC in such very specific cases and are

therefore recommended to be treated in the same way as the still pipes case, i.e. with reference to the generic regulation and outlining which specific mitigation, antenna and installation requirements are applied which ensure equivalent protection of the primary radio services in the same frequency range.

For location tracking applications in the railway environment, a combination of ETSI TR 101 538 [26] and ETSI TS 103 085 [27] (published) can be used. This kind of application uses a combination of requirements. For the necessary fixed terminals, the LT2 requirements could be used and for the mobile devices (trains) dependent on the application and environment, the LT2 indoor mobile terminal or vehicular requirements could be used.

For GBSAR for example, only very low density static ground-based deployment was assumed in compatibility studies and there are detailed technical requirements for the antenna pattern and LBT mechanism to be used.

For applications about 60 GHz, the relative bandwidth as a percentage of the fundamental bandwidth is comparable to the relative bandwidth of other radio applications, and such applications are therefore considered rather wideband devices than UWB devices.

The SRR applications also show a specific deployment, specific mitigation techniques and even installation requirements.

Based on the considerations above, it can be concluded that only applications operating below 10.6 GHz and without very specific combination of deployment assumptions, mitigation techniques, antenna and installation requirements should be considered for inclusion in the EC Decision for UWB.

Additional studies in the 76-77 GHz range are under preparation in CEPT (with the support of ETSI) for safety-related application during the landing approach at low altitude above the ground to avoid obstructions, e.g. used by helicopters as well as the need to investigate the situation with different types of radar applications (fixed infrastructure, surveillance and vehicular radars) in the 76-77 GHz range to ensure that fixed installed outdoor radar applications do not harmfully interfere with the road-safety related vehicular radar applications.

4 ON-GOING ETSI AND CEPT ACTIVITIES FOR UWB APPLICATIONS

In November 2012, ETSI ERM approved the following deliverables for publication:

1. ETSI TR 103 086 [28]: Conformance test procedure for the exterior limit tests in ETSI EN 302 065-3 [22] UWB applications in the ground based vehicle environment. This Technical Report on UWB vehicle measurements provides the information how exterior limits for vehicular application can be measured and a developed measurement procedure which will be part of the new ETSI EN 302 065-3 [22];
2. ETSI TS 102 754 [23]: Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Technical characteristics of Detect-And-Avoid (DAA) mitigation techniques for SRD equipment using Ultra Wideband (UWB) technology;
3. ETSI TS 103 360 [24]: Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Method for a harmonized definition of Duty Cycle Template (DCT) transmission as a passive mitigation technique used by short range devices and related conformance test methods. The new ETSI LDC definitions are called DCT (Duty Cycle Template). An identified problem in related to LDC is measurements at very low emission values.

ETSI is developing the following technical specifications:

1. Revision of TS 102 883 [30]. This document is used as a normative annex in all future ETSI HENs on UWB. This document describes a harmonized measurement setup and procedure for different UWB signals and a solution (all emissions, UWB emissions and other emissions) to fulfil the requirement to measure the very low regulated radiated emissions;
2. ETSI TR 103 181-1 [31]: Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD) using Ultra Wide Band (UWB); Transmission characteristics Part 1: Signal characteristics (The purpose of the document is to summarize the available information about the main types of transmission characteristics used by UWB devices (signal and modulation);
3. ETSI TR 103 181-2 [32]: Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD) using Ultra Wide Band (UWB); Transmission characteristics Part 2: UWB mitigation techniques (The purpose of the document is to summarize the available information of possible mitigation techniques and principles and evaluate their effectiveness).

In the present versions of the Harmonised European Standards (EN 302 065-1 to -3 [22]) is the LDC mitigation requirement as manufacturer declaration included. This is the actual state of the art in all Harmonised European Standards for UWB equipment below 10 GHz. A possible conformance test procedure is under development and testing. During the work, the main problem identified is that a conducted emission measurement is not every time possible for UWB devices and therefore the low level of UWB in combination with LDC is difficult to measure which leads to high and very expensive test equipment. The developed LDC measurement procedure are going to be defined in a revised version of ETSI TS 102 883 [30].

In parallel, there are still technical studies on-going in ECC WGSE Project Team SE24 with regard to the LDC mitigation technique (work item SE24_37) and these studies will be finalised in 2013. The summary of the time plan can be seen in Figure 3. This time plan foresees the finalisation of the LDC studies in the ECC by end of 2013 and also a subsequent amendment of ECC/DEC/(06)04 [2].

There is no work item in ETSI for the creation of a Harmonised European Standard for on-board aircraft UWB devices. However, the use of ETSI TS 102 883 [30] and ETSI TS 103 360 [24] is possible. This Report points out that this is a specific situation and real implementation depends heavily on the precise aircraft model. Shielded portholes are just one solution to provide additional attenuation needed for spectrum compatibility on some frequencies. There are other implementation possibilities achieving equivalent mitigation. This can be reflected in a technical construction file of the aircraft manufacturer describing the

precise solution. Due to the specifics of aircraft models and the fact that there are only a limited number of manufacturers, it is not obvious that this is a matter for a Harmonised European Standard.

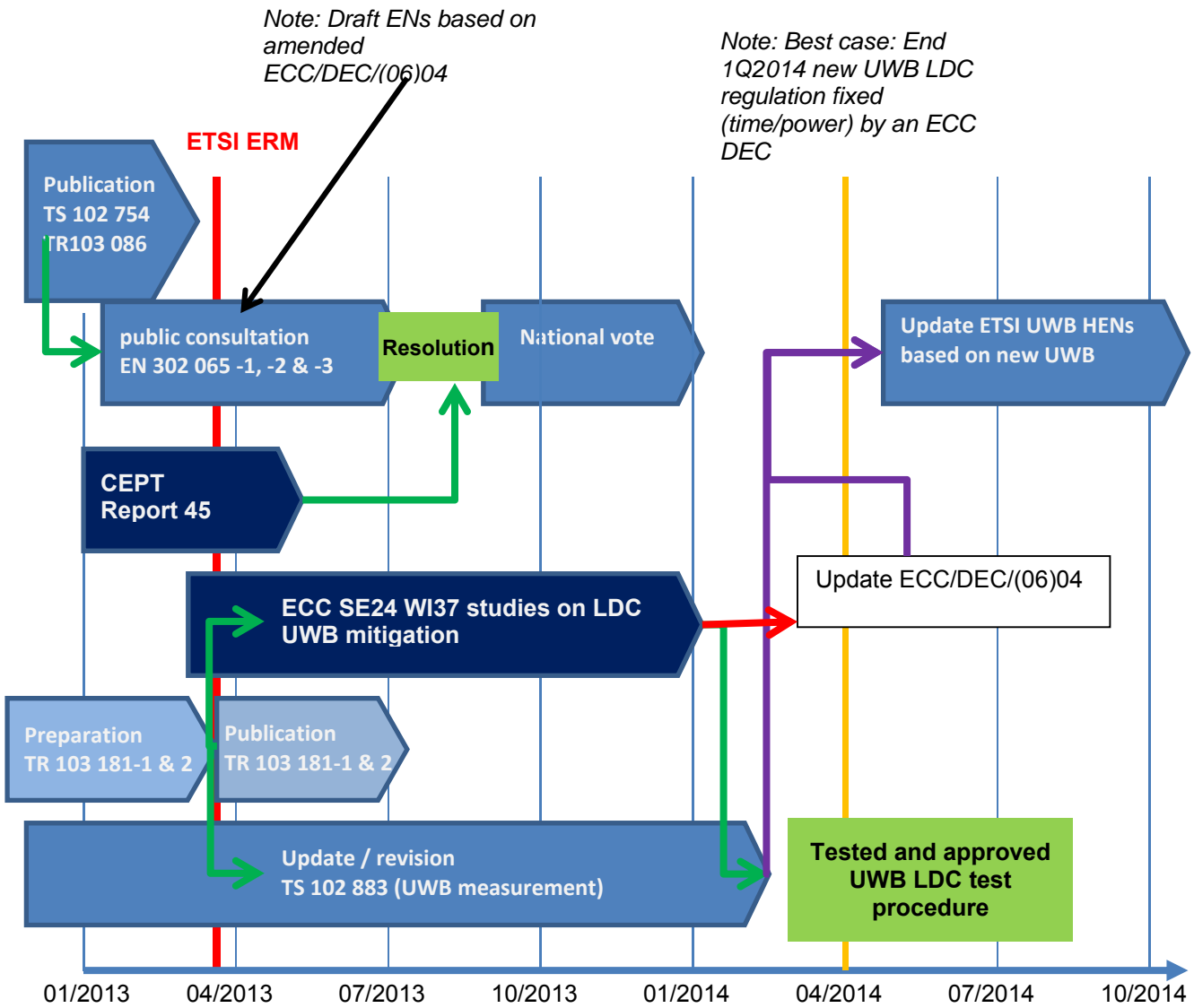


Figure 3: ETSI standardisation plan

5 CONCLUSIONS AND PROPOSALS FOR INCLUSION OF RELEVANT PARAMETERS IN THE COMMISSION DECISION

5.1 ARTICLE 2 OF 2007/131/EC

In Article 2 of 2007/131/EC [1], the following point is proposed to be added:

- “onboard aircraft” means the use of radio links for intra-aircraft communications purposes onboard an aircraft.

5.2 APPROPRIATE MITIGATION TECHNIQUES

Equipment using ultra-wideband technology shall also be allowed to use the radio spectrum with higher e.i.r.p. limits than mentioned in the table in section 1.1 of the annex of the Commission Decision 2007/131/EC [1] when applying additional mitigation techniques as described in the relevant Harmonised standards adopted under Directive 1999/5/EC [13] or other mitigation techniques on condition that it achieves at least an equivalent level of protection as provided by the limits in the table in section 1.1 of the annex of the Commission Decision 2007/131/EC [1].

It is important to link the technical details of the mitigation techniques to the Harmonised European Standards (or equivalent technical specifications). These mitigation techniques are taken into account by ETSI in the development of Harmonised European Standards. Consequently, because the mitigation technique are defined with all relevant detailed parameters in the Harmonised European Standards and in line with the ECC relevant study reports and ECC/DEC/(06)04 [2] deliverables, there is no need to include these detailed technical parameters also the Commission Decision. This is seen as part of streamlining the regulatory environment.

Chapters 1.2 and 1.3 of the annex of the Commission Decision are proposed to only list the appropriate mitigation techniques but without the technical details which are or are going to be all be included in the ETSI Harmonised European Standards and the ECC(DEC/(06)04 [2]:

1. LDC mitigation within the band 3.1 to 4.8 GHz;
2. LDC within the band 3.1 to 4.8 GHz and 6 to 8.5 GHz, for devices implemented in ground based vehicles and subject to the implementation of an exterior limit;
3. DAA within the bands 3.1 to 4.8 GHz and 8.5 to 9 GHz;
4. DAA within the bands 3.1 to 4.8 GHz and 8.5 to 9 GHz, for devices implemented in ground based vehicles and subject to the implementation of Transmit Power Control (TPC) mitigation technique and an exterior limit;
5. TPC within the band 6 to 8.5 GHz for devices implemented in ground based vehicles and subject to the implementation of an exterior limit.

Combinations of reduced emission limits (including exterior limit for devices installed in road and rail vehicles) and increased low duty cycle limits within the boundaries accepted by technical studies in the CEPT can also be applied provided that this mitigation technique is described in the relevant Harmonised European Standards adopted under Directive 1999/5/EC [13].

5.3 SPECIFIC APPLICATIONS

Based on the considerations in the present Report, it can be concluded that only applications operating below 10.6 GHz and without very specific combination of deployment assumptions, mitigation techniques, antenna and installation requirements should be considered for inclusion in the EC Decision for UWB.

5.4 UWB ON-BOARD AIRCRAFT

It is proposed to add a new annex in the Commission Decision 2007/131/EC [1] for UWB on-board aircraft as outlined in section 3.3 with the technical requirements as in Table 4: of section 3.3 of the present Report.

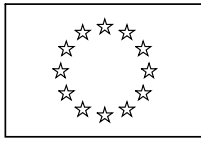
5.5 FUTURE INVESTIGATIONS

Future investigations for inclusions/ amendments of 2007/131/EC [1] can include:

- LT2 considerations: important for a lot of industrial location tracking applications;
- LAES considerations for emergency services,

after first experiences will have been gained within the national implementation of the necessary registration and coordination mechanisms as outlined by the ECC/REC/(11)09 [12] and ECC/REC/(11)10 [10].

ANNEX 1: CEPT MANDATE



EUROPEAN COMMISSION

Information Society and Media Directorate-General

Electronic Communications Policy

Radio Spectrum Policy

Brussels, 23 March 2012

DG INFSO/B4

RSCOM12-04

ADOPTED

RADIO SPECTRUM COMMITTEE

**Opinion of the RSC
pursuant to Advisory Procedure under Article 4 of Regulation
182/2011/EU and Article 4.2 of Radio Spectrum Decision
676/2002/EC**

**Subject: Fifth Mandate to CEPT on ultra-wideband technology to clarify the
technical parameters in view of a potential update of Commission Decision
2007/131/EC**

This is a Committee working document which does not necessarily reflect the official position of the Commission. No inferences should be drawn from this document as to the precise form or content of future measures to be submitted by the Commission. The Commission accepts no responsibility or liability whatsoever with regard to any information or data referred to in this document

**Fifth Mandate to CEPT
on ultra-wideband technology to clarify the technical parameters
in view of a potential update of Commission Decision 2007/131/EC**

1. Purpose

The objective of this mandate is to ensure a consistent application of technical parameters related to ultra-wide band (UWB) technology within the internal market. Any resulting decision should maximise the efficient use of spectrum and safeguard economies of scale for emerging equipment using UWB technology, taking into account ECC Decision (06)04, as amended in December 2011, and standardisation activities within ETSI.

In order to ensure internal market benefits for new UWB equipment, including but not limited to equipment used in road and rail vehicle applications, a coherent and consistent regulatory environment is warranted. In this regard, it is necessary to clarify the technical parameters as defined in the recently amended ECC Decision (06)04 and to differentiate transparently between those parameters essential for inclusion in a further amendment of Commission Decision 2007/131/EC¹ on ultra-wideband (UWB) technology and the technical parameters to be taken into account in the development of Harmonised Standards.

2. Justification

Pursuant to Article 4 of the Radio Spectrum Decision the Commission may issue mandates to the CEPT for the development of technical implementing measures with a view to ensuring harmonised conditions for the availability and efficient use of radio spectrum; such mandates shall set the task to be performed and the timetable therefore.

Since the last Mandate on UWB (Mandate 4 of 2 October 2008) new opportunities to implement UWB technology, in particular for road, rail and airborne applications, have emerged and corresponding technical requirements have been developed by CEPT. In order to ensure a coherent and consistent regulatory environment with regard to the technical parameters and requirements on ultra-wideband usage within the internal market, it is necessary that any update of Commission Decision 2007/131/EC be based on clarity and transparency with regard to the technical parameters and ensure that appropriate information on mitigation techniques is available for inclusion in an appropriate manner into the ETSI Harmonised Standards.

Ensuring consistency in particular requires a clarification of the difference, if any, between "exterior limit" for road and rail vehicle applications and the generic limits for maximum e.i.r.p. densities radiated into the air, in particular in regard to relationship between the required mitigation techniques for specific applications and the permitted limits for maximum e.i.r.p. densities.

In addition more information is needed in regard to the inclusion of this and other technical parameters as the Low Duty Cycle (LDC) mitigation technique and other mitigation techniques.

3. Main EU policy objectives

With this mandate the Commission seeks to obtain relevant technical information with the objective of contributing to the improvement of efficient use of spectrum, resulting in positive economic and social benefits in the internal market. The EU policy objectives include:

- To establish transparent regulatory conditions for the benefit of industry;
- To create an open and competitive internal market under harmonised technical conditions, which provides opportunities for using new technologies and applications;
- To create an effective internal market for applications using ultra-wideband technology with a view to enable the benefits of economies of scale and socio-economic benefits for citizen and business.

4. Task order and schedule

Through this mandate, the CEPT is requested:

- 1) To validate the technical requirements as collated in the tables attached in annex and to provide clear definition for the mitigation techniques referenced in the footnotes, in view of ensuring an appropriate inclusion of such techniques in the relevant Harmonised Standards.

¹ Commission Decision 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, as amended by Commission Decision 2009/343/EC of 21 April 2009.

- 2) To clarify the definition of the term "exterior limit" in particular in regard to the difference if any between "exterior limit" for road and rail vehicle applications and applicable generic limits for maximum e.i.r.p. densities radiated into the air, as harmonised in Commission Decision 2007/131/EC as amended.
- 3) To ensure a streamlined and transparent internal market framework for ultra-wideband technology, by clarifying:
 - Which mitigation techniques in each frequency range lead to what deviation from the generally applicable technical conditions for generic UWB usage;
 - How the generic limits for maximum e.i.r.p. densities radiated into the air relate to attenuation factors that apply to the usage of specific UWB equipment or the use of UWB technology in other applications. This includes also those types of UWB equipment for which frequency access is harmonised through other Commission Decisions such as -but not limited to- those in Commission Decision 2006/771/EC [3].
 - Which, if any, further technical conditions need to be included in the annex of the Commission Decision on UWB and to provide justifications why the inclusion of relevant technical parameters in Harmonised Standards is not sufficient.

CEPT is mandated to provide deliverables according to the following schedule:

Delivery date	Deliverable
March 2013	For RSC#43 Draft final report, subject to public consultation
July 2013	Final report delivery

In implementing this mandate, the CEPT shall, where relevant, take the utmost account of Community law applicable and support the principles of technological neutrality, non-discrimination and proportionality insofar as technically possible.

The Commission, with the assistance of the Radio Spectrum Committee pursuant to the Radio Spectrum Decision, may consider applying the results of this mandate in the EU, pursuant to Article 4 of the Radio Spectrum Decision.

Annex

GENERAL CASE

frequency range	technical requirements		comments
	Maximum mean e.i.r.p. Spectral density	Maximum peak e.i.r.p (defined in 50 MHz)	
Below 1.6 GHz	-90 dBm/MHz	-50 dBm	
1.6 to 2.7 GHz	-85 dBm/MHz	-45 dBm	
2.7 to 3.1 GHz	-70 dBm/MHz	-36 dBm	
3.1 to 3.4 GHz	-70 dBm/MHz or -41.3 dBm/MHz using LDC ¹ or -41.3 dBm/MHz using DAA ²	-36 dBm or 0 dBm or 0 dBm	
3.4 to 3.8 GHz	-80 dBm/MHz or -41.3 dBm/MHz using LDC ¹ or -41.3 dBm/MHz using DAA ²	-40 dBm or 0 dBm or 0 dBm	
3.8 to 4.8 GHz	-70 dBm/MHz or -41.3 dBm/MHz using LDC ¹ or -41.3 dBm/MHz using DAA ²	-30 dBm or 0 dBm or 0 dBm	
4.8 to 6 GHz	-70 dBm/MHz	-30 dBm	
6 to 8.5 GHz	-41.3 dBm/MHz	0 dBm	
8.5 to 9 GHz	-65 dBm/MHz or -41.3 dBm/MHz using DAA ²	-25 dBm or 0 dBm	
9 to 10.6 GHz	-65 dBm/MHz	-25 dBm	
Above 10.6 GHz	-85 dBm/MHz	-45 dBm	

¹ [to be included: definition of the mitigation technique]

² [to be included: definition of the mitigation technique]

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frequency range	technical requirements		comments
	Maximum mean e.i.r.p. Spectral density	Maximum peak e.i.r.p (defined in 50 MHz)	
Below 1.6 GHz	-90 dBm/MHz	-50 dBm	
1.6 to 2.7 GHz	-85 dBm/MHz	-45 dBm	
2.7 to 3.1 GHz	-70 dBm/MHz	-36 dBm	
3.1 to 3.4 GHz	-70 dBm/MHz	-36 dBm	

	<p>or</p> <p>-41.3 dBm/MHz using LDC¹ + e.l.⁴</p> <p>or</p> <p>-41.3 dBm/MHz using TPC³ + e.l.⁴ +DAA²</p>	<p>or</p> <p>0 dBm</p> <p>or</p> <p>0 dBm</p>	
3.4 to 3.8 GHz	<p>-80 dBm/MHz</p> <p>or</p> <p>-41.3 dBm/MHz using LDC¹+e.l.⁴</p> <p>or</p> <p>-41.3 dBm/MHz using TPC³ + e.l.⁴+DAA²</p>	<p>-40 dBm</p> <p>or</p> <p>0 dBm</p> <p>or</p> <p>0 dBm</p>	
3.8 to 4.8 GHz	<p>-70 dBm/MHz</p> <p>or</p> <p>-41.3 dBm/MHz using LDC¹+e.l.⁴</p> <p>or</p> <p>-41.3 dBm/MHz using TPC³ + e.l.⁴+DAA²</p>	<p>-30 dBm</p> <p>or</p> <p>0 dBm</p> <p>or</p> <p>0 dBm</p>	
4.8 to 6 GHz	<p>-70 dBm/MHz</p>	<p>-30 dBm</p>	
6 to 8.5 GHz	<p>-53.3 dBm/MHz</p> <p>or</p> <p>-41.3 dBm/MHz using LDC¹+e.l.⁴</p> <p>or</p> <p>-41.3 dBm/MHz using TPC³+e.l.⁴</p>	<p>-13.3 dBm</p> <p>or</p> <p>0 dBm</p> <p>or</p> <p>0 dBm</p>	
8.5 to 9 GHz	<p>-65 dBm/MHz</p> <p>or</p> <p>-41.3 dBm/MHz using TPC³ + e.l.⁴+DAA²</p>	<p>-25 dBm</p> <p>or</p> <p>0 dBm</p>	
9 to 10.6 GHz	<p>-65 dBm/MHz</p>	<p>-25 dBm</p>	
Above 10.6 GHz	<p>-85 dBm/MHz</p>	<p>-45 dBm</p>	

¹ [to be included: definition of the mitigation technique]

² [to be included: definition of the mitigation technique]

³ [to be included: definition of the mitigation technique]

⁴[to be included: definition on "exterior limit", if necessary]

ANNEX 2: TRADING LDC LIMITS AGAINST TRANSMITTED POWER LIMITS

A2.1 INTRODUCTION

The annex illustrates that in a plurality of cases trading of PSD against LDC, even linearly in dB, does not jeopardize a victim receiver. In order to achieve more insights about this kind of trading, there is the need to summarise two main points considered in official documents adopted in EC and even outside, regarding the different scenarios where interferer effects should be taken into account. One may basically distinguish a scenario based on a single interferer, and a scenario where a lot of interferer affects the victim receiver. These may be described as follows:

- Single interferer scenario: in this case, a single jammer affects the victim receiver. Typically, the degradation of performance is estimated using parameters such as per cent of packet lost (for services such as UDP), increase of transfer data time (for services such as ftp), degradation of audio or video quality (for video streaming or VoIP).

Due to the fact that these services produce packets having a typical length (e.g.: 5msec for WiMAX), adopting duty cycle mitigation and consequently imposing the interferer a T_{off} time to be higher than a predefined minimum or average value, guarantees the victim radio service a safe transmission time allocation, lowering the probability that packets would collide with jammer packets.

- Aggregated interferers scenario: in this case, a set of interferers produces an aggregate field affecting a victim receiver. It is realistic and commonly adopted the hypothesis of uncorrelated interferers, thus the aggregated interfering field received by the victim is seen as increased noise floor level. Therefore, the parameter of interest in this case are mainly the Interferer whole power to noise floor ratio, namely I/N, or the Signal to Interferer Ratio, namely SIR.

Due to the fact that the interfering field is seen as extra noise, adopting the criterion to limit the I/N ratio or the SIR ratio (in predefined typical scenarios) guarantees the victim receiver to achieve satisfactory packets error rates at predefined sensitivity levels.

In the following paragraphs, general conclusions are provided for both cases. The assumptions are valid for UWB versus a narrower band victim and within a defined power range. In addition, the time dependency of the victim in the single interferer scenario needs to be highlighted.

A2.2 SINGLE INTERFERER SCENARIO

The aim of this section is to analyse some results reported in the JRC Report [6], "*Report on Radio Frequency Compatibility Measurements between UWB LDC Devices and Mobile WiMAX (IEEE 802.16e-2005) BWA Systems*", and included "as is" in ECC Report 170 [9]. Basing only on these official data, one can demonstrate several benefits that may be achieved by linearly trading TX power against LDC, and by increasing T_{on} and T_{off} , given a predefined LDC.

In the following, there is consideration of Figure 4: and Figure 5:, taken from [6] (even replicated in [9]). These figure refers to PER degradation of a WiMAX link jammed by a single UWB transmitter, according to a test setting which details may be found in [6]. Specifically, the figures present different cases of T_{on} when LDC=5%. Moreover, the case at LDC=100% also is presented, i.e. the highest dotted curve: and it is clear that, for any other case having LDC<100% even not represented in the Figure below, the related PER curve will be lying below the PER curve corresponding to 100% duty cycle.

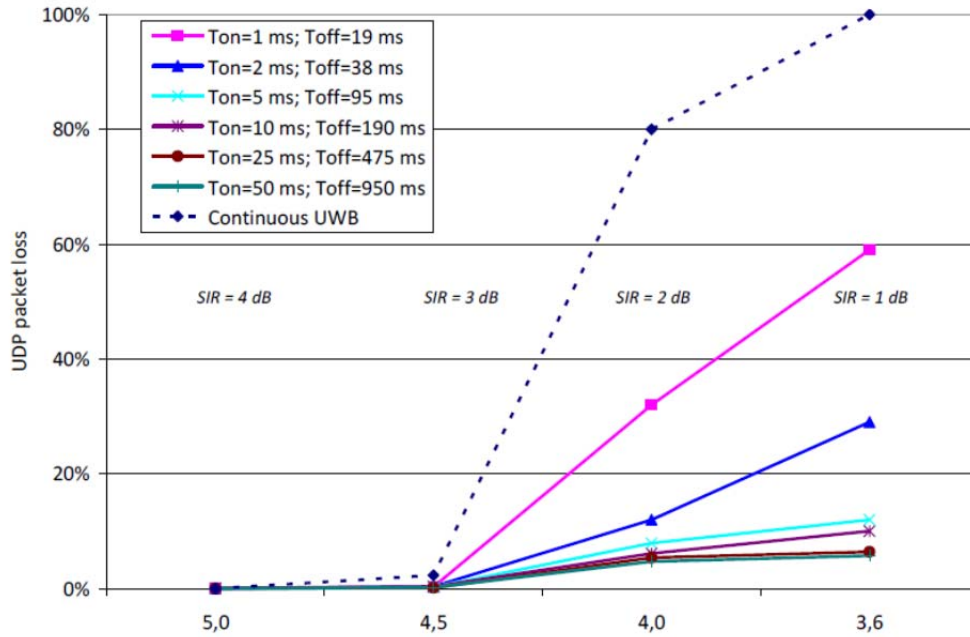


Figure 4: UDP packet loss vs. equivalent distance to interferer (LOS), victim RSSI = -84.6 dBm(from[6])

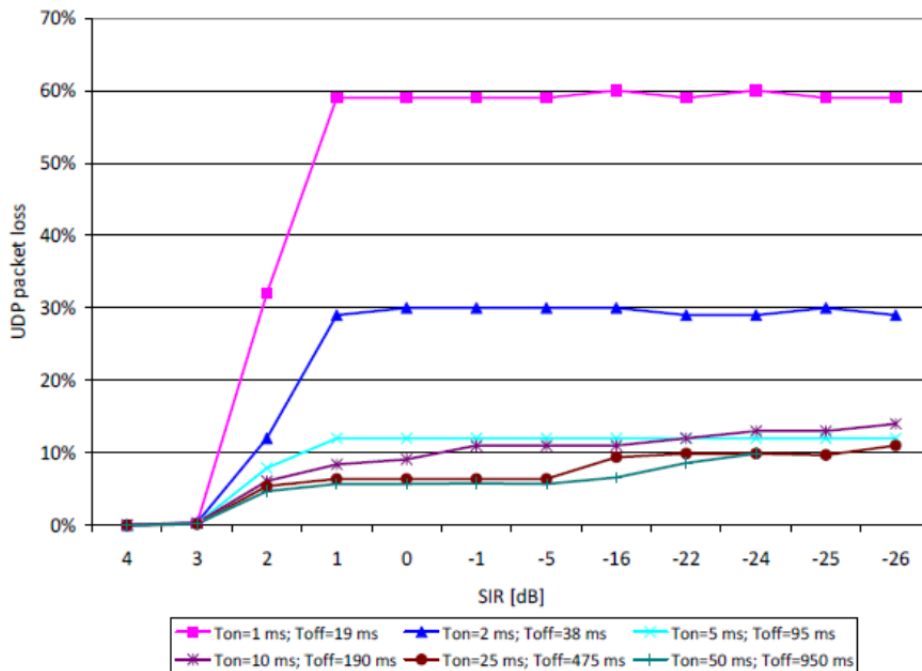


Figure 5: UDP packet loss rates vs. WiMAX Signal to Interference Ratio (SIR) for various pulses, RSSI = 84.6 dBm (from[6])

An analysis of these figures provides deep insight on LDC, discovering three kinds of benefits we may achieve by linearly trading TX power against LDC, as reported in the following paragraphs.

A2.2.1 Benefits of trading TX power against LDC linearly in dB over PER

From both figures it may be observed that:

When duty cycle is 5% (all lines except the dotted one), for any value of T_{on} and T_{off} :

- worst case PER is achieved at $SIR \leq 1.0\text{dB}$
- $PER < 5\%$ may be achieved when $SIR > 3.0\text{dB}$
- $PER \approx 0\%$ is achieved when $SIR > 4.0\text{dB}$

When duty cycle is $\leq 100\%$, for any LDC value such that $5\% < LDC < 100\%$, and for any value of T_{on} and T_{off} , the case $LDC=100\%$ represents an upper boundary. Hence:

- worst case PER is 100%, and it is achieved at $SIR \leq 1.0\text{dB}$ when $LDC=100\%$
- $PER < 5\%$ may be achieved when $SIR > 3.0\text{dB}$, for any value of LDC, T_{on} and T_{off}
- $PER \approx 0\%$ is achieved when $SIR > 4.0\text{dB}$, for any value of LDC, T_{on} and T_{off}

An immediate conclusion we get from these figures is that, under the tested conditions, **the percent of lost packets by a WiMAX victim receiver decreases from its worst case value down to 0% as SIR increases by few dB, from 1dB to 4dB.** Being this gap in dB very short, this means that **one may achieve benefits over PER at victim receiver side by reducing the transmitted power even by few dB.**

As a matter of example demonstrating this last sentence, one needs to consider the following case: TX and RX at 3.6m, $LDC=5\%$, $T_{on}=25\text{ms}$, $SIR=2.0$, such that we get $PER \approx 5\%$. In case we double the LDC from 5% to 10% (equivalent to +3dB) and we reduce the transmitted power by 3dB, SIR is increased up to 5dB: this means $PER \approx 0\%$, whichever T_{on} and T_{off} would be used. This example confirms that we may get benefits from applying linear trading of LDC and PSD, even when TX and victim RX are within relatively short distances.

Please note that the described benefit underlies on the fact that the PER curve is very sharp and it decreases from best values (almost 0%) to worst values (almost 100%) within few dB. This is a general conclusion, common to almost all communications protocol, due to the fact that the PER curves vary exponentially with respect to BER, hence they are normally very sharp, falling from lowest PER to highest PER within very few dB: **therefore the described kind of benefit on PER holds in general for all communication protocols and not only for WiMAX.**

A2.2.2 Benefits of trading TX power against LDC linearly in dB on the minimum safe distance

Relate now the SIR to the distance between jammer transmitter and victim receiver. Due to the fact that $SIR=4.0\text{dB}$ – i.e.: the SIR such that $PER \approx 0\%$ - corresponds to a distance about 5 meters (see figures), first one may conclude that **the effect of a single UWB interferer is not meaningful against a WiMAX receiver when the UWB transmitter is located at distance greater than 5 meters from the victim receiver.**

This does not mean that one may disregard “any” mitigation technique when the distance increases above 5m. The correct interpretation is that the single interferer scenario does not apply when the distance between the UWB interferer and the WiMAX victim is greater than 5 meters: hence, when such a distance increases above 5 meters the correct mitigation scenario to be considered is related to the aggregate scenario, not the single interferer scenario in this case.

This fact reflects a general principle, and namely the fact that the minimum distance such that the link is immune from interferer may be decreased according to a PSD reduction. The law of variation of this minimum distance may be computed by considering that the transmitted power decreases according to the square of distance. Hence, given an UWB node transmitting a certain power spectral density, say PSD_0 , and given a minimum distance immune from interferer effects, say $L_{min}(PSD_0)$, should this transmitter change its power spectral density from PSD_0 to PSD_1 , a new minimum distance immune from interference, say

$L_{\min}(PSD_1)$, would be given, which variation in dB is same and opposite dB amount. As a matter of example, let's consider that the performances depicted in Figure 4: has been computed at $PSD_0 = -41.3 \text{ dBm/MHz}$, measured when transmitter is continuously on: by reducing this power spectral density e.g. at $PSD_1 = -47.3 \text{ dBm/MHz}$, the minimum immune distance is halved from 5m to 2.5m.

Table 5: Decreasing of safe distance for PER<5% when trading PSD against LDC linearly in dB

LDC	Variation of LDC (dB)	PSD dBm/MHz	Safe distance for PER<5%	Variation of safe distance for PER<5% (dB)
5%	0	-41,3	4.50m	0
10%	+3	-44,3	3.18m	-3
20%	+6	-47,3	2.25m	-6
40%	+9	-50,3	1.59m	-9
50%	+10	-51,3	1.42m	-10
100%	+13	-54.3	1.01m	-13

This fact is reflected in Table 5; where a safe distance of 4.5m is assumed for PER<5% at $PSD = -41.3 \text{ dBm/MHz}$: it is seen that this safe distance decreases as LDC is increased and the PSD is traded according to LDC linearly in dB, such to keep SIR=3.0dB and consequently PER<5%.

Please note how this means that in case we increase the duty cycle and reduce accordingly the PSD by adopting a linear trading in dB, we get benefits on the minimum safe distance: each time the duty cycle is doubled – and the PSD is reduced by 3dB accordingly – the minimum safe distance is reduced by a factor $\sqrt{2} = 1.41$

Finally we note that in this case also, for same reason addressed when discussing benefit over PER of linear trading, the described benefit on minimum safe distance holds in general for all communication protocols and not only for WiMAX.

A2.2.3 Benefits of increasing T_{on} and T_{off}

Another important conclusion coming out from Figure 4: and Figure 5: is that by increasing T_{on} and T_{off} and keeping same duty cycle, PER would be reduced. Hence **we do not need to limit T_{on} and T_{off} : on the contrary, given a predefined LDC, better PER are achieved as T_{on} and T_{off} increase**, as it may be seen straightforward either from Figure 4: and Figure 5:.

It is very easy to explain this behaviour: with reference to Figure 6:, consider a repetition time for the interferer transmission, say T_{period} , and a repetition time for the victim transmission, say T_{DD} , and assume to increase T_{period} , without changing the duty cycle, such that $T_{period} \gg T_{DD}$: it is clear that at a certain point we will get $T_{on}, T_{off} \gg T_{frame}$: therefore in this limit case there will exist a lot of victim frames within T_{on} , and these will be likely lost (in case of low SIR); on the other hand they will exist a lot of victim frames within T_{off} , and these will be certainly received: therefore lost and received frames will be distributed proportionally to T_{on} and T_{off} respectively, as long as T_{period} increases with respect T_{DD} .

On the other hand, as long as T_{period} , decreases with respect to T_{DD} , the probability of collision increases, and it becomes 100% when $T_{period} \leq T_{DD}$, and $T_{on}, T_{off} \leq T_{frame}$ accordingly: this is the worst case for the PER, since no victim frame is free of collisions anymore.

Hence, given a predefined duty cycle LDC , the PER tends from 100% to LDC as T_{period} increases from values lower or comparable to T_{DD} to values much higher than T_{DD} . Finally, assuming each frame get lost after a collision, we get:

$$\min(PER) \propto 100\% , \quad \frac{T_{DD}}{T_{period}} \geq 1$$

$$\min(PER) \propto \frac{T_{on}}{T_{period}} = LDC_J , \quad \frac{T_{DD}}{T_{period}} \ll 1$$

(1)

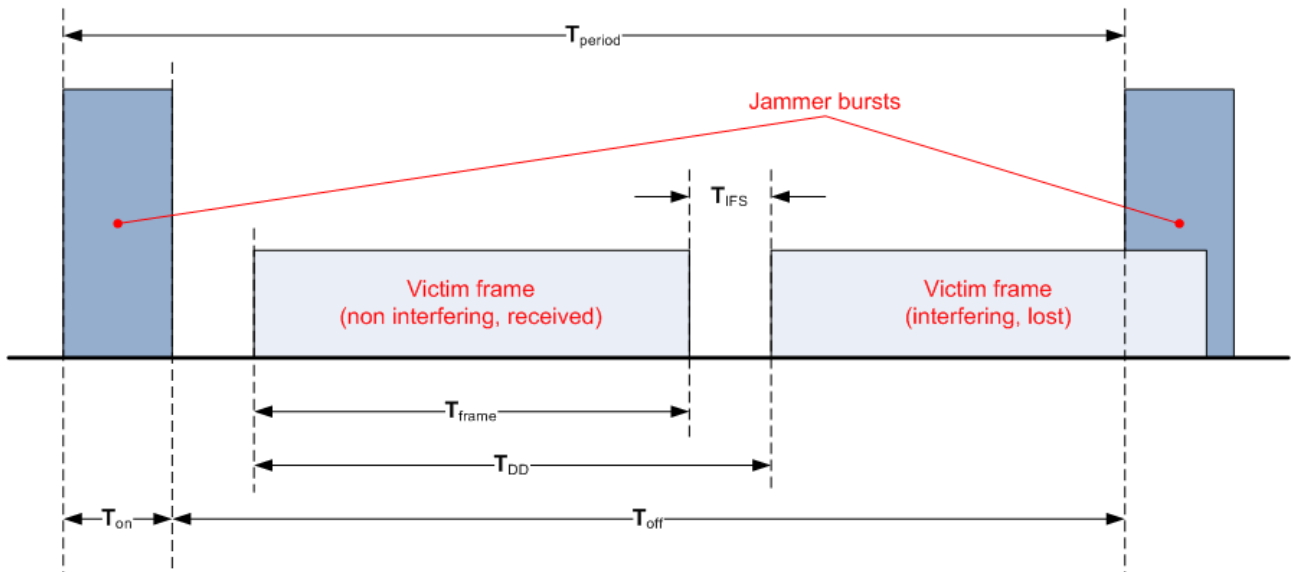


Figure 6: Exemplary case of interference between a jamming service and a victim service

However in general, once a collision occur, the probability to lose the colliding victim packet is not 100% but it is a function of SIR, i.e. $PER(SIR)$. Therefore, taking into account this finite probability, it is needed to correct previous equation as follows:

$$\min(PER) \propto PER(SIR) , \quad \frac{T_{DD}}{T_{period}} \geq 1$$

$$\min(PER) \propto \frac{T_{on}}{T_{period}} * PER(SIR) = LDC_J * PER(SIR) , \quad \frac{T_{DD}}{T_{period}} \ll 1$$

(2)

It's worth noting how the very simple arguments leading to (2) provide a very good qualitative explanation of the curves depicted in Figure 4: in fact, as long as T_{period} (i.e.: $T_{on} + T_{off}$) decreases, the PER increases towards a maximum boundary, the dotted line, representing the PER vs SIR curve (reached when $LDC_J=100\%$); on the other hand, as long as T_{period} increases, all curves tends to reach same value, only depending on SIR (and selected LDC).

Finally it should be noted that the conclusions reported in this paragraph are based only on the generic behaviour of two periodic links interfering each other. Therefore it is straightforward to understand that arguments exposed herein hold for almost any couple of interferer/victim services based on periodic transmissions, and they are not only limited to WiMAX and UWB.

A2.3 AGGREGATED SCENARIO

In the aggregated scenario, a plurality of emitters is affecting a single victim receiver.

At a first level of approximation, the effect of duty cycle mitigation results in an average PSD reduction pro rata: in fact, it is straightforward that, under the assumption of a “perfect” average of many transmitters, each transmitting a predefined maximum power level, say $P_{tx}(n)$, and adopting a predefined duty cycle limit, say $LDC(n)$, the average power is a weighted sum of all transmitted powers, i.e.:

$$P_{txavg} = \sum_{n=1}^N LDC(n)P_{tx}(n) \quad (3)$$

This equation only requires assuming the transmitters to be *uncorrelated each other*, thus each transmitted signal is statistically independent from any other transmitted signal. This assumption is commonly adopted in spectrum analyses documents currently available. In this case the T_{off} time inserted by each single interferer disappears, causing a relevant reduction of whole average PSD.

Therefore in this scenario the meaningful parameter related to the interferer aggregated field is the whole averaged PSD, being LDC included in this figure. Hence, the meaningful limitation to impose over each single interferer is the limitation of maximum and averaged PSD, and NOT duty cycle limitations: **should any LDC limitations be imposed, they can be converted in dB attenuation, decreasing whole averaged interferer PSD**; moreover, according to this principle, **should the PSD limit of each jamming device be decreased, the LDC limit might be indeed increased accordingly, without any additional impact over the aggregate PSD and the global link quality**.

A clear example of this point and related protection criteria applicable to an aggregated scenario are provided in [8] and [14], related to Radio Astronomy Services (RAS): in fact, in [14] protection criteria for RAS is stated as minimum interference power threshold, without any mentioning of Duty Cycle mitigations. Moreover, in [8], Duty Cycle mitigation is mentioned but it is transformed in attenuation dB, lowering the maximum interference level, as reported in Table 7.

Table 6: protection criteria for radio Astronomy Services stated in Recommendation ITU-R RA.769-2 [8]

Threshold levels of interference detrimental to radio astronomy continuum observations

Centre frequency ⁽¹⁾ f_c (MHz)	Assumed bandwidth Δf (MHz)	Minimum antenna noise temperature T_A (K)	Receiver noise temperature T_R (K)	System sensitivity ⁽²⁾ (noise fluctuations)		Threshold interference level ⁽³⁾		
				Temperature ΔT (mK)	Power spectral density ΔP (dB(W/Hz))	Input power ΔP_H (dBW)	pdf $S_H \Delta f$ (dB(W/m ²))	Spectral pdf S_H (dB(W/m ² · Hz))
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
13.385	0.05	50 000	60	5 000	-222	-185	-201	-248
25.610	0.12	15 000	60	972	-229	-188	-199	-249
73.8	1.6	750	60	14.3	-247	-195	-196	-258
151.525	2.95	150	60	2.73	-254	-199	-194	-259
325.3	6.6	40	60	0.87	-259	-201	-189	-258
408.05	3.9	25	60	0.96	-259	-203	-189	-255
611	6.0	20	60	0.73	-260	-202	-185	-253
1 413.5	27	12	10	0.095	-269	-205	-180	-255
1 665	10	12	10	0.16	-267	-207	-181	-251
2 695	10	12	10	0.16	-267	-207	-177	-247
4 995	10	12	10	0.16	-267	-207	-171	-241
10 650	100	12	10	0.049	-272	-202	-160	-240
15 375	50	15	15	0.095	-269	-202	-156	-233
22 355	290	35	30	0.085	-269	-195	-146	-231
23 800	400	15	30	0.050	-271	-195	-147	-233
31 550	500	18	65	0.083	-269	-192	-141	-228
43 000	1 000	25	65	0.064	-271	-191	-137	-227
89 000	8 000	12	30	0.011	-278	-189	-129	-228
150 000	8 000	14	30	0.011	-278	-189	-124	-223
224 000	8 000	20	43	0.016	-277	-188	-119	-218
270 000	8 000	25	50	0.019	-276	-187	-117	-216

Rec. ITU-R RA.769-2

⁽¹⁾ Calculation of interference levels is based on the centre frequency shown in this column although not all regions have the same allocations.
⁽²⁾ An integration time of 2 000 s has been assumed; if integration times of 15 min, 1 h, 2 h, 5 h or 10 h are used, the relevant values in the Table should be adjusted by +1.7, -1.3, -2.8, -4.8 or -6.3 dB respectively.
⁽³⁾ The interference levels given are those which apply for measurements of the total power received by a single antenna. Less stringent levels may be appropriate for other types of measurements, as discussed in § 2.2. For transmitters in the GSO, it is desirable that the levels be adjusted by -15 dB, as explained in § 2.1.

Table 7: Mitigations for RAS single entry scenario (a) and aggregated scenario (b) in ECC Report 123 [8]

Mitigations	Application B: non fixed	Application A: fixed
Additional wall attenuation	0 dB	0 dB
Duty Cycle 10%	10 dB	0 dB
TPC (not always activated)	0 dB	1.1 dB
ODC Elevation pattern from -20 to +30°	0dB	20 dB
sum of mitigations	10 dB	21.1 dB

(a)

Mitigations	Application B: non fixed	Application A: fixed
Additional TRP limitation	10 dB	0 dB
Additional wall attenuation	7.4 dB	7.4 dB
TPC	0 dB	1.1 dB
Duty Cycle 10%	10 dB	0 dB
ODC Elevation pattern from -10 to +30°	0dB	20 dB
sum of mitigations	27.4 dB	28.5 dB

(b)

A2.4 CONCLUSIONS

In previous paragraphs, data has been analysed from ECC Report 170 [9] and Recommendation ITU-R RA 769-2 [14], in order to understand whether a linear trading of LDC against transmit power would provide equivalent protection criteria than the ones stated by ECC/DEC/(06)04 [2] amended in 2011.

Clear and short conclusions may be achieved from the discussion exposed in the previous pages, namely:

For single interferer scenario: given the limits described in ECC/DEC/(06)04 [2], a linear trading of PSD against LDC may provide benefits in terms of reduction of PER and reduction of minimum guard distance.

Moreover, benefits are even achieved by increasing both T_{on} and T_{off} , once LDC has been established.

For an aggregate interferer scenario: it is well consolidated the hypothesis to consider all interferers as uncorrelated emitters. Under this hypothesis any LDC variation may be converted by same variation of average TX power. This point of view is widely adopted within regulatory bodies. Concerning the case of RAS protection criteria stated by Recommendation ITU-R RA 769-2 [14] and ECC Report 170 [9]: in both cases LDC only transmit power is relevant, whilst in ECC Report 170 [9] LDC is transformed linearly in dB in equivalent attenuation.

These conclusions provide the possibility under predefined assumptions to interpret the LDC rules stated in ECC/DEC/(06)04 [2] as a baseline of LDC regulations, without excluding the possibility to trade them with transmitted power limits in a more flexible way, such increasing the capability of deployment of new industrial UWB applications.

A2.5 REFERENCES IN ANNEX 2

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- [14] “*Assessment of compatibility between Ultra WideBand devices and selected federal systems*”, NTIA special publication, L. K. Brunson et Alt., January 2001.

ANNEX 3: LIST OF REFERENCE

- [1] Commission 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
- [2] ECC Decision (06)04 on the harmonised conditions for devices using UWB technology in bands below 10.6 GHz
- [3] Commission Decision 2006/771/EC on the harmonisation of the radio spectrum for use by short-range devices
- [4] Commission Decision 2009/343/EC on ultra-wideband (UWB) technology and the technical parameters to be taken into account in the development of Harmonised European Standards (task 3);
- [5] ECC Decision (06)12 on supplementary regulatory provisions to Decision ECC/DEC/(06)04 for UWB devices using mitigation techniques
- [6] ECC Report 167 Practical implementation of registration/coordination mechanism for UWB LT2 systems
- [7] ECC Report 094 Technical requirements for UWB LDC devices to ensure the protection of FWA systems
- [8] ECC Report 123 The impact of Object Discrimination and Characterization (ODC) applications using Ultra-Wideband (UWB) technology on radio services
- [9] ECC Report 170 Specific UWB applications in the bands 3.4 to 4.8 GHz and 6 to 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)
- [10] ECC Recommendation (11)10 Location tracking application for emergency and disaster situations
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- [17] CEPT Report 34 Report B from CEPT to European Commission in response to the Mandate 4 on Ultra-Wideband (UWB)
- [18] CEPT Report 17 Report from CEPT to the European Commission in response to the Mandate to: identify the conditions relating to the harmonised introduction in the European Union of radio applications based on Ultra-WideBand (UWB) technology
- [19] ETSI EN 300 435 Base standard including interworking to connectionless networks
- [20] ETSI EN 300 498 ODA communication services
- [21] ETSI EN 302 729-2 Level Probing Radar (LPR) equipment operating in the frequency ranges 6 GHz to 8,5 GHz, 24,05 GHz to 26,5 GHz, 57 GHz to 64 GHz, 75 GHz to 85 GHz
- [22] ETSI EN 302 065-1 to -3 Short Range Devices (SRD) using Ultra Wide Band technology (UWB) for communications purposes
- [23] ETSI TS 102 754: Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Technical characteristics of Detect-And-Avoid (DAA) mitigation techniques for SRD equipment using Ultra Wideband (UWB) technology
- [24] ETSI TS 103 360: Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Method for a harmonized definition of Duty Cycle Template (DCT) transmission as a passive mitigation technique used by short range devices and related conformance test methods.
- [25] ETSI TS 102 692 RF conformance testing of radar level gauging applications in still pipes
- [26] ETSI TR 101 538: Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); UWB location tracking devices in the railroad environment
- [27] ETSI TS 103 085 Short Range Devices (SRD) using Ultra Wide Band (UWB) for Location and Tracking railroad applications
- [28] ETSI TR 103 086: Conformance test procedure for the exterior limit tests in ETSI EN 302 065-3 [22] UWB applications in the ground based vehicle environment.
- [29] ETSI TR 102 834 Technical Characteristics for airborne Ultra-WideBand (UWB) applications operating in the frequency bands from 3,1
- [30] ETSI TS 102 883 Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD) using Ultra Wide Band (UWB); Measurement Techniques
- [31] ETSI TR 103 181-1 Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD) using Ultra Wide Band (UWB); Transmission characteristics Part 1: Signal characteristics

(The purpose of the document is to summarize the available information about the main types of transmission characteristics used by UWB devices (signal and modulation)

- [32] ETSI TR 103 181-2: Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD) using Ultra Wide Band (UWB); Transmission characteristics Part 2: UWB mitigation techniques (The purpose of the document is to summarize the available information of possible mitigation techniques and principles and evaluate their effectiveness)
- [33] ECC Report 175 Co-existence study considering UWB applications inside aircraft and existing radio services in the frequency bands from 3.1 GHz to 4.8 GHz and from 6.0 GHz to 8.5 GHz
- [34] ERC Recommendation 70-03 Relating to the use of Short Range Devices (SRD)
- [35] ECC Report 120: Technical requirements for UWB DAA (Detect and Avoid) devices to ensure the protection of radiolocation services in the bands 3.1 to 3.4 GHz and 8.5 to 9 GHz and BWA terminals in the band 3.4 - 4.2 GHz
- [36] 2005/50/EC: Commission Decision of 17 January 2005 on the harmonisation of the 24 GHz range radio spectrum band for the time-limited use by automotive short-range radar equipment in the Community (as amended)
- [37] Commission Decision of 8 July 2004 on the harmonisation of radio spectrum in the 79 GHz range for the use of automotive short-range radar equipment in the Community
- [38] [38] ETSI TR 102 601: Electromagnetic compatibility and Radio spectrum Matters (ERM); System reference document; Short Range Devices (SRD); Equipment for Detecting Movement using Ultra Wide Band (UWB) radar sensing technology; Level Probing Radar (LPR)-sensor equipment operating in the frequency bands 6 GHz to 8,5 GHz; 24,05 GHz to 26,5 GHz
- [39] ECC Decision (11)02 on industrial Level Probing Radars (LPR) operating in frequency bands 6 to 8.5 GHz, 24.05 to 26.5 GHz, 57 to 64 GHz and 75 to 85 GHz
- [40] ISO 4266-1 (2002): "Petroleum and liquid petroleum products -- Measurement of level and temperature in storage tanks by automatic methods -- Part 1: Measurement of level in atmospheric tanks"
- [41] Commission Implementing Decision of 29 July 2011 amending Decision 2005/50/EC on the harmonisation of the 24 GHz range radio spectrum band for the time-limited use by automotive short-range radar equipment in the Community