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Regulatory framework for the introduction of UWB technology and its compatibility with radio-communication services

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Abstract: The paper presents the basics for implementation of devices using UWB (Ultra-Wideband) technology describing its performances and potential problems as these devices operate over large part of the frequency spectrum that is shared with many radio-communication services. Two elements are considered in particular; the regulatory framework and the question of compatibility or impact that UWB technology may have on radio-communication systems. The European approach to introduction of devices using UWB technology is very cautious and so is also evolution of the European regulatory framework. However, significant progress was made recently and there are promising perspectives for 2009 and beyond.

Keywords: ITU, CEPT, UWB, SRR, PSD, BW, PPM, BPM

Regulatorni okvir za uvedbo tehnologije UWB in njena kompatibilnost z radijskimi komunikacijskimi storitvami

Povzetek. Članek opisuje uporabo naprav, ki delujejo na podlagi tehnologije UWB (Ultra-Wideband), pred-stavi njihove lastnosti in potencialne probleme, ker te naprave zasedajo velik del frekvenčnega spektra, ki si ga delijo s številnimi drugimi radiokomunikacijskimi storitvami. Članek obravnava predvsem problem ustrez-nega regulatornega okvira in vprašanje kompatibilnosti tehnologije UWB oziroma njenega morebitnega vpliva na radiokomunikacijske sisteme. Poseben poudarek je na regulatornem pristopu za uvedbo opreme UWB v državah članicah Evropske unije in njeni viziji o nadaljnjem razvoju te obetavne tehnologije.

Ključne besede:
ITU, CEPT, UWB, SRR, PSD, BW, PPM, BPM

1 Introduction

ITU launched the studies on Ultra Wideband (UWB) technology[1] in 2003 with special attention to the spectrum management framework and compatibility consideration (impact) between UWB devices and radiocommunication services (ITU-R Questions 226/1 and 227/1).

An important number of administrations of Member States and representative of industry, scientific organisations, regulators and operators of radiocommunication services contributed to the successful outcome. Four (4) Recommendations and one (1) Report were developed, the text of which was considered harmonized to maximum extent possible. The results of the study were influenced by the status of national UWB rules, by industry advancement and by the concern of current spectrum occupation by existing radiocommunication services.

Although some administrations expressed their hesitations relative to certain UWB features, it was noted that some others already operate UWB devices for various applications since 2002 (USA) on successful ground and with promising perspectives. While the Member States in Region 3 (Asia) were also favourable to early introduction of new technology, some CEPT countries remained concerned with respect to the compatibility and regulatory considerations.

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[1] *The UWB technology mean technology for short range radio-communication, involving the intentional generation and transmission of energy over a very large frequency range which may overlap several frequency bands, allocated to radiocommunication services. With the bandwidth significantly wider than 50 MHz, the devices have intentional radiation from the antena with either a* -10 dB *bandwidth of at least* 500 MHz *or a* -10 dB *fractional bandwidth greater than* 0.2. *The* -10 dB *bandwidth* B_{-10} *and* -10 dB *fractional bandwidth* μ_{-10} *are calculated as follows*:

$B_{-10} = f_H - f_L$ *and* $\mu_{-10} = B_{-10} / f_C$ *where:*

f_H: *highest frequency at which the power spectral density of the UWB transmission is* -10 dB *relative to the maximum frequency of UWB transmission* f_M

f_L: *lowest frequency at which the power spectral density of the UWB transmission is* -10 dB *relative to* f_M

$f_C = (f_H + f_L)/2$: *centre frequency of the* -10 dB *bandwidth. The fractional bandwidth may be expressed as a percentage.*

UWB technology can potentially be integrated into many applications, e.g. the vehicular radar devices for collision avoidance, airbag activation and road sensors, short-range high data-rate communication devices, tagging devices, liquid level detectors and sensors, surveillance devices, location determination devices, and as a replacement for wired high data-rate connections over short distances.

These devices operate at very low power levels and can support applications involving multiple users at high data rates (e.g. short-range Wireless Personal Area Networks (WPANs)) which may be greater than 100 Mbit/s. UWB signals are potentially harder to detect than other radio-communication signals. This is because UWB signals occupy large bandwidth and may communicate with a unique randomizing timing code at millions of bits/s. Each bit is typically represented by a large number of pulses of very low amplitude, typically below the noise level. These features result in secure transmissions with low probability of detection (LPD) and low probability of interception (LPI).

The theoretical system capacity of any UWB communication system may be calculated from the Shannon relation:

$$C = B \log_2 \left(1 + \frac{\int_B P_d(f)\,\mathrm{d}f}{\int_B N_0\,\mathrm{d}f} \right) \qquad (1)$$

C: channel capacity (bits/s)
B: channel bandwidth (Hz)
$P_d(f)$: signal PSD (W/Hz or dBm/Hz)
N_0: noise PSD (W/Hz or dBm/Hz)

The channel capacity is very large because of its bandwidth, even though its power spectral density (PSD) is very low and restricted in amplitude. UWB signals, generated by basic PPM (pulse position modulation), have numerous spectral peaks and randomization is used to make the signal more noise-like. The shape of the power spectrum density of the signal is controlled by an appropriate choice of the pulse shape. Pulse shaping enables control of the frequency content of UWB transmission which can reduce interference into radio-communication systems.

Appropriate hybrid modulation (PPM, BPM, etc.) and randomization of a signal makes UWB spectrum appear like the white Gaussian noise. The choice of UWB modulation scheme impacts the signal PSD and consequently its impact on radio-communication services. The impact of the discrete components of the PSD can be mitigated or they can be eliminated. A wide transmission bandwidth (BW) is needed to overcome multipath fading in an indoor environment. The delay spread between different multipath reflections will be small, and the coherence bandwidth of the channel will therefore be large.

2 Regulatory framework[2] and compatibility considerations for the introduction of UWB

Administrations have a sovereign right to regulate the use of any UWB devices within their territory, provided that such devices do not impact stations of other administrations in accordance with the RR. National UWB regulations should reflect the charac-teristics and appropriate mitigation techniques and should take account of the protection criteria of all services in the affected frequency bands.

It is essential to ensure that UWB devices will not cause harmful interference to any radiocommu-nication service and in particular in the bands mentio-ned in RR No. 5.340 (bands where all emissions are prohibited). UWB devices are considered as short-range-devices (SRD) and are not claiming any protection. However, on the national basis, licensing of some specific UWB applications may provide them protection from radio-communication services operating within their national territory.

The susceptibility to interference from devices using UWB technology depends on the operational characteristics and sensitivity of the victim service, as well as on the spectral characteristics, deployment density and operational parameters of the devices using UWB technology.

The widespread UWB deployment could possibly raise the noise floor which is of particular concern to highly-sensitive passive-service receivers that measure very low energy levels for purposes such as weather prediction and (scientific) space research. As the passive services usually have instrumentation significantly more sensitive than other radio-communication services, they may be more vulnerable to interference from UWB transmissions.

2.1 Assessment of the impact of devices using the UWB technology

Considering that intentional transmissions from devices using ultra-wideband (UWB) technology extend over a very large frequency range, they may impact many systems operating within a number of radio-communication services, including those which are used internationally. Integrated into many wireless applications such as short-range indoor and outdoor communications, radar imaging, medical imaging, asset tracking, surveillance, vehicular radar, etc., it may be

2 *Administrations authorizing or licensing devices using UWB technology should ensure, pursuant to the provisions of the RR, that these devices do not cause interference to and do not claim protection from, or place constraints on radiocommunication services of other administrations, as defined in the RR and operating in accordance with those regulations.*

difficult to distinguish UWB transmissions from emissions or unintentional radiations in equipment that also contain other technologies, where different limits may apply.

In the frequency range below 10.6GHz it was observed that characteristics of the systems "beyond IMT-2000" are likely to be similar to IMT-2000 and thus their susceptibility to UWB interference is very similar. Based on the simulation results and in order to protect a typical handheld indoor receiver, the PSD should be equal or below –81.6 dBm/MHz at 3.1GHz and lower than –75.8 dBm/MHz at 6GHz.

To assess the impact of UWB devices, various methodologies may be used: the impact of a single device using UWB technology or impact of an aggregation of UWB devices or bandwidth correction factor (BWCF) which is relevant to both single and aggregate methodologies. One of them is "link budget methodology" where the maximum permitted e.i.r.p. level of an interfering UWB signal may be determined by using the following equation:

$$EIRP_{MAX} = I_{MAX} - G_R(\theta) + L_P + L_R \qquad (2)$$

$EIRP_{MAX}$: the maximum average permitted e.i.r.p. density of the interfering device, (dBm/B_{REF}), where the reference bandwidth B_{REF} is usually taken to be 1MHz

I_{MAX}: the maximum permissible interference power level at the receiver input, normalized (dBm/B_{REF})

$G_R(\theta)$: the victim receiver's antenna gain in the direction of the UWB device (dBi)

L_P: the propagation loss between transmitting and receiving antennas (dB)

L_R: the insertion loss (loss between the receiver antenna and receiver input, in dB). A zero (0) dB may be assumed if no value is available.

2.2 Safety and passive services

Civil aviation and maritime systems depend on radio frequencies that are allocated worldwide. Safety services, such as Maritime Mobile Service (MMS) Radionavigation Service and Radionavigation Satellite Service (RNSS) are radio-communication services used for safeguarding human lifes and property. The aeronautical-mobile service (route) and the aeronautical mobile-satellite service (route) are reserved for communications related to safety and regularity of flights. Safety services usually operate in the situation where interference can critically affect the reception of radio-communication being provided. Therefore, the need for safety systems to meet high level of integrity, reliability and availability, makes it essential that these systems operate in an interference-free environment.

The operations of Radio Astronomy Service (RAS) Earth Exploration Service (EESS passive) and Space Research Service (SRS passive) necessarily involve the measurement of naturally-occurring radiations of very low power levels, which contain essential information on the physical process under investigation. The relevant frequency bands are mainly determined by fixed physical properties (e.g. molecular resonance) that cannot be changed. Those properties support scientific activities, including weather forecasting and water and climate modeling. Even low level of interference at the input of the passive sensors may have a degrading effect on passive service operations. In most cases these sensors are also unable to discriminate between these natural radiations and man-made radiations.

Regulatory provisions should therefore take account of the inherent differences between the various types of UWB applications however, in developing the national framework for any UWB implementation, regardless of application and operational characteristics, administrations should consider the following:

– technical limits such as appropriate maximum limits for average and peak PSD,
– mitigation techniques as described in Recommendation ITU-R SM.1757 and in Report ITU-R SM.2057, to achieve the required prote-ction criteria of radio-communication services,
– technical control such as UWB activity factors and emitted power kept to the minimum necessary to support the intended operation, and
– operational restrictions, as required, according to geographical location, transportation mode and type of device into which UWB technology devices may be embedded and used.

3 Generic regulations for UWB technology applications in Europe

European Conference of Postal and Telecommunications Administrations (CEPT) has defined in 2005 an early version of harmonized conditions for the use of generic UWB devices below 10.6 GHz, subject to the final adoption in due course. The regulations for different applications included PSD masks and other regulatory provisions for generic UWB devices and vehicular radar systems. Other regulations were also being developed for specific classes of UWB devices (e.g. ground and wall penetrating radar). The final decision on the European regulatory framework was (at the time of approval of ITU Recommendations) suspended until later date.

On February 21, 2007, the Commission of European Communities issued a Decision (2007/131/EC) "on allowing the use of radio spectrum for equipment using UWB technology in a harmonized manner in the Community" thus providing the European regulatory framework with parameters and associated values as well as the limitations that apply to certain UWB applications and to its usage in particular frequency bands.

At the “upper band” from 6 to 8.5GHz, the maximum mean of e.i.r.p. spectral density is limited to -41.3dBm/MHz with no mitigation technique required. In terms of “long term” solution for UWB introduction in Europe, it is possible that the frequency band from 8.5 to 9GHz would be extended, providing that an efficient mitigation technique is applied. The requirement for Detect and Avoid (DAA) devices should ensure the protection of radiolocation service in the band 3.1 – 3.4GHz and 8.5 – 9GHz and BWA terminals in the band 3.4 – 4.2GHz.

At the “lower band” of the spectrum from 3.1 to 4.8GHz, the same limit of the maximum mean PSD may be increased if an efficient mitigation technique is used (DAA[3] or LDC[4]). Technical requirements for this mitigation technique are to ensure the protection of the FWA systems. In addition, the EC Decision includes different maximum e.i.r.p. limitations in the band from 4.2 to 4.8GHz to be applied in the period until December 31, 2010 and beyond that date.

The regulations include also the limitations on “outdoor” installations and infrastructure. Some categories of UWB devices, characterized by predominantly outdoor usage, are subject to specific restrictions or excluded from the scope of this regulation as they could present significant risk of interference to radio services, deployed outdoor. This category includes devices with externally mounted antennas, fixed outdoor installations and devices installed in road and rail vehicles, aircrafts and other flying models.

National administrations were encouraged to monitor UWB market development and potential impact on radio-communication services (Decision ECC/DEC/(06)04).

3.1 Generic spectrum mask for UWB applications (Decision ECC/DEC/(06)04 and (06)12)

Decision ECC/DEC/(06)04 was adopted in March 2006 and later amended in July 2007. It defines primarily the generic spectrum mask for UWB applications over the bands from 1.6GHz to 10.6GHz. Complementary studies in 2005/06 were oriented to review the UWB deployment scenarios and to assess the impact on outdoor FS/FSS radio-communication stations. Initial adoption of Decision (06)04 was subject to complementary studies in particular with regard to the

- phased approach for the band from 4.2 to 4.8GHz
- power levels in the band from 2.7 to 3.8GHz, to be amended and in the band from 8.5 to 9GHz (NOC)
- installation of UWB in the vehicles

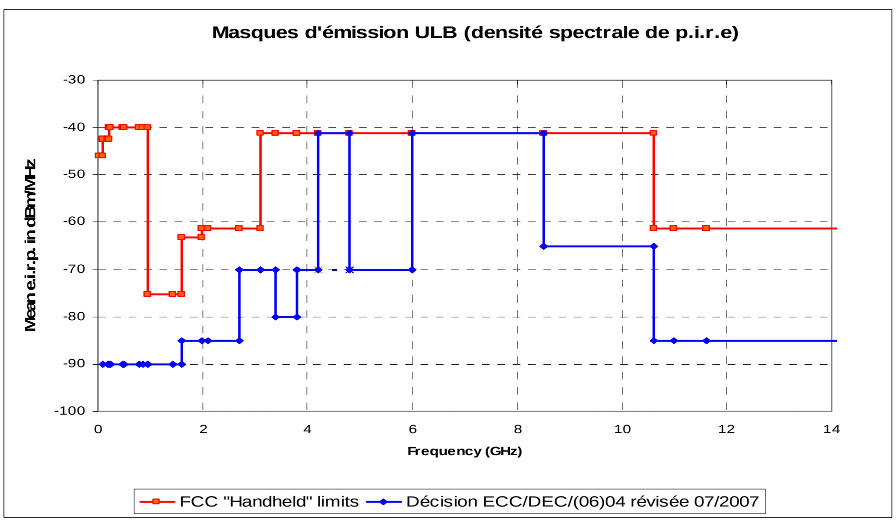

Figure 1: UWB (e.i.r.p.) emission mask
source ERO

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3 *Detect and Avoid (DDA) - mitigation technique as regulatory solution for high data rate UWB applications. The general principle is that UWB devices should detect the presence of signals from other radio systems and reduce its transmitted power as appropriate. The reliable implementation of DAA mechanisms is not trivial and their effectiveness has not yet been demonstrated. Further research and investigation of DAA is required and draft ECC Report 120 is under public consultation until 19 May 2008.*

4 *Low Duty Cycle (LDC) - mitigation technique as regulatory solution for low data rate, localisation and various sensors UWB applications. It was adopted in December 2006 (ECC Report 120). The measurement campaign on the impact of UWB LDC devices on S-band radar were to be performed by February 2008 (consideration of final results by ECC TG3 at its meeting in May 2008.)*

Table 2: Maximum e.i.r.p. densities in the absence of appropriate mitigation techniques

Frequency Band (GHz)	Maximum mean e.i.r.p. density (dBm/MHz)
Below 1.6 GHz	- 90
1.6 to 2.7 GHz	- 85
2.7 to 3.4 GHz	- 70
3.4 to 3.8 GHz	- 80
3.8 to 4.2 GHz	- 70
4.2 to 4.8 GHz	- 41.3 until 31.12.2010 - 70.0 after 31.12.2010
4.8 to 6.0 GHz	- 70
6.0 to 8.5 GHz	- 41.3
8.5 to 10.6 GHz	- 65
Beyond 10.6 GHz	- 85

The Decision ECC/DEC/(06)12 specifies technical requirements for Low Duty Cycle (LDC) mitigation technique thus enabling the operation of UWB devices at – 41.3dBm/MHz e.i.r.p. within the band 3.4 to 4.8 GHz. More studies on mitigation technique will still be conducted in 2008, namely, on LDC to be applied in 3.1 to 3.4 GHz band and DAA to be applied in the bands 3.1 to 4.2 GHz and 8.5 to 9 GHz. Amendments to the Decision ECC/DEC/(06)12 are expected for October 2008.

3.2 Specific technical requirements for automotive SRR in the 24 GHz and 79GHz band in CEPT

Short-range radars (SRR) are defined as radio-communication equipment that falls in general category of vehicular radar systems and provide collision mitigation and traffic safety applications. In order to allow early introduction of SRR applications, the 24 GHz frequency range was designated for SRR systems on a temporary, non-interference and non-protection basis as follows:

– 24.15 ± 2.5GHz for the UWB component with maximum mean power density of −41.3 dBm/MHz e.i.r.p. and peak power density of 0 dBm/50 MHz e.i.r.p

– 24.05 - 24.25GHz for the narrow-band emission mode which may only consist of an unmodulated carrier, with a maximum peak power of 20dBm e.i.r.p and low duty cycle (LDC) limited to 10% for peak emissions higher than −10dBm e.i.r.p.

Emissions within the band from 23.6 to 24GHz, that appear 30° or greater above the horizontal plane, shall be attenuated by at least 25dB up to 2010 and 30dB up to 1 July 2013 for SRR systems operating in the 24GHz range. They are transmitting in the band 23.6 to 24GHz with an e.i.r.p. higher than −74dBm/MHz or in any neighbouring band to which RR No. 5.149 applies with an e.i.r.p. higher than −57dBm/MHz, providing that they shall be fitted with an automatic deactivation mechanism to ensure protection of radio astronomy service. In order to allow an early implementation of 24GHz SRR systems the automatic deactivation was made mandatory from 1 July 2007.

The 24GHz frequency range may only be used for new SRR systems until July 01, 2013. After this date and for new SRR systems, the 79 GHz range or alternative technical solutions must be used for road vehicle collision mitigation and traffic safety applications. The existing 24 GHz equipment would be allowed to continue operating in this band up to the end of lifetime of the vehicles.

Future SRR equipment, as a device providing road vehicle based radar functions for collision mitigation and traffic safety applications, is planned to operate in the 79 GHz frequency range (77 – 81 GHz) on a non-interference and non-protected basis with a maximum mean power density of −3 dBm/MHz e.i.r.p. associated with a peak limit of - 55 dBm/MHz e.i.r.p. The maximum mean power density outside vehicle, and resulting from the operation of one SRR equipment, shall not exceed −9 dBm/MHz e.i.r.p.

3.3 Additional regulatory provisions and harmonized standard

They are related to fixed outdoor installations and to the installations in road and rail vehicles. Fixed outdoor UWB installations are operating at -41.3 dBm/MHz e.i.r.p. and are not compatible with outdoor stations from the Fixed Service (FS). The regulatory provision that is envisaged, for allowing the operation of fixed outdoor UWB installations, is the e.i.r.p. limit of:

– 55 dBm/MHz e.i.r.p. in the “upper band” and
– 60 dBm/MHz e.i.r.p. in the “lower band” without prejudice to other constraints resulting from the need to protect other systems than FS

As to the installations in road and rail vehicles, they may operate at - 41.3dBm/MHz e.i.r.p. subject to the implementation of Transmit Power Control (TPC) with a range of 12 dB (max -53.3dBm/MHz) e.i.r.p. This specific restriction is meant to reduce potential aggregate interference on outdoor stations from radio-communication services (FS/FSS).

A harmonized UWB standard on generic UWB was developed within ETSI in February 2008. Being consistent with ECC regulatory provisions, following are the additional technical requirements:

– minimum operational bandwidth 50 MHz,
– application of PRF (Pulse Repetition Frequency) higher than 1 MHz, and
– having possibility of transmitter timeout

There is ongoing work on this standard in view to make it amended, possibly in 2009. These activities are conducted by CEPT and ETSI with specific focus on mitigation technique. As DAA technical parameters alone do not ensure protection of radio services by themselves, this part has to be completed with an adequate DAA measurement procedure.

4 Conclusions

The UWB may be considered as very promising technology where the analysis of the impact to radio-communication services is still underway in view to define appropriate mitigation techniques. The volume of UWB industry is growing as well as the market penetration. Industry Canada is expected to issue its regulatory framework and define its rules this summer (2008) and FCC is supposed to review some regulatory provisions e.g. the UWB maximum distance limit in view to extend it. If the operational distance limit were extended up to 100m and beyond, then UWB technology might become a serious competitor to 3G network and future development of UMTS.

The regulatory framework as defined in ITU Recommendations proved as adequate and no measurement so far proved any interference type of impact that UWB devices may have had on any other radiocommunication service. On the other hand, a universal standard does not seem to be emerging and various industrial groups are opposing their views on the subject.

Manufacturing of UWB Ground penetrating radar (GPR) and Wall imaging services is mature and Medical imaging and Communication devices are taking off (start-up companies) in Canada and the USA. The Imaging radar and vehicular radar is entering intensively to the market. Wireless UWB USB is available in many countries and can be used to communicate high data rates up to 480 Mbps, certainly, on short distance.

Europe, with its regulatory platform for UWB implementation published in 2007 made considerable progress. Preparing for wide market penetration, the EC Decision 2007/131/EC set up the framework and agenda for the future UWB application space for 500 millions potential consumers. UWB implementation is expected in the bands above 6GHz for communication devices whereas UWB radar imaging will continue to use all bands below 10.6GHz and vehicular radar will use a band from 22 to 29 GHz. Some countries will open the band of 77 to 81GHz for vehicular radar, as appropriate.

Although the compatibility studies took years and they are still not complete, we believe into considerable UWB potential and its further evolution. The recent annual coordination meeting between the USA and Canada and Europe in Strassbourg in April 2008 dedicated great attention to UWB issues and its future development, industry advancement and market penetration perspectives, for the benefit of users.

And when shall we see it on a wide scale in Europe? This may happen in 2009 when the European industry is supposed to be ready for the first UWB applications.

5 References

- Report on UWB technology studies, ITU, 2005
- ITU-R Recommendations SM.1754, SM.1755, SM.1756, SM.1757 and Report SM. 2027

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