# The Ultra-Wideband Technology in Europe: Regulatory Issues and Research Activities

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*Abstract* – **We have reviewed the European regulatory status and research activities in the sphere of UWB technology. Evaluations have been made of the achievable performance and the perspectives before UWB technology depending on the possible decisions of the European regulatory authorities.**

## I. Introducion

Usually a system is termed ultra-wideband (UWB), if it has a fractional bandwidth $B/f_c > 0.25$ or if it occupies bandwidth wider than 500 MHz. In the past UWB signals have been used in radar applications and for military purposes. Recently, we witness an increased interest in them. The use of the so-called impulse radio (IR) – a form of UWB spread spectrum signaling, is most often proposed. The signal used in IR is a train of base-band pulses with duration in the order of tenth of the nanoseconds, which leads to spreading of its energy in a range of near d. c. to several GHz. The information is conveyed through the use of different modulation schemes, such as for example Pulse position (PPM) or pulse-amplitude modulation (PAM), combined with pseudo-random time hopping, in order to allow multiple access and provide spectral smoothing. This signal is transmitted without the conventional up-conversion, so it is sometimes called "carrier-free". The latter leads to possibility for low-cost low-complexity transceiver design. [1,2]

The UWB signals have extremely large bandwidth, therefore have low power spectral density and are usually noise-like. They contain also spectral components with relatively low frequencies. These peculiarities lead to some of their distinguishing features and capacities: They enable communication with very high data rates. They have low susceptibility to multipath fading and immunity to interference from conventional radio communication systems. They allow covert communication and reusing of spectrum already allocated to the established services, without causing significant interference. Thus the UWB signals are very appropriate for short-range high data rate (100 s of Mb/s) communications. They allow very fine time resolution; therefore they are suitable for precision positioning systems and radar applications. In particular, the presence of low-frequency spectral components allows penetrating in materials – this leads to their use and application in ground penetrating radars (GPR), wall- and through-wall and medical imaging systems. Another significant application is also the short-range automotive radars.

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## II. Main Objectives

This article aims at reviewing the state of UWB technology in Europe and assessing its further prospects. For the purpose, a rough assessment of achievable performance is going to be made, according to possible regulatory constraints.

## III. Coexistence Issues And Regulatory Status

The fact that the UWB systems reuse the spectrum, given to other users, leads to the problem for interference protection of the existing conventional radio communication systems, especially of systems, related to the security and safeness of the flights, Search and Rescue Satellite (SARSAT), enhanced 911 etc. Several years ago in the USA, one of the first alarming signs was that, that the UWB emissions could lead to lowering in performance of Global Positioning System (GPS) receivers and selected Federal Government radar systems operating below 3.1 GHz, even when the transmitted power is lower than the limits set by the then operating FCC Part15, referring to the non licensed emissions. These issues were widely discussed in USA. The National Telecommunication and Information Administration (NTIA) made researches, which confirm that the concern shown is quite reasonable [3-5]. It is good mentioning that the Earth Exploration Satellite Service (EESS) and the passive radio astronomy are threatened, especially by the automotive short range radars (SRR), planned to work roughly about 24 GHz. It is completely clear that rules are needed, specially elaborated for the UWB. On 14.02.2002 FCC launched the well known "First Report and Order" (FRO), which determines the rules and regulations for work of the UWB devices. [6] Quoting one of the FCC-members FRO is "ultra-conservative". On 13.02.2003 FCC confirmed, the announced one year earlier with a few slight amendments and relieving corrections [7]. FRO is a first cautious step. It is expected that after experimental and experience data be gathered from the work of the UWB devices, which will very soon emerge on the market, additional alleviations in the limitations to be undertaken.

FCC divides the UWB devices into imaging systems, vehicular radar systems, indoor systems and hand held systems. Imaging systems are divided in low frequency ($f <$ 960 MHz), mid-frequency (1.99-10.6 GHz) and high frequency (3.1-10.6 GHz) imaging systems. The spectral masks for indoor and handheld devices are given on figure 1.

IEEE works at the standard IEEE 802.15 for wireless personal area network (PAN). The IEEE 802.15 High Rate Alternative PHY Task Group (SG3a) deals with UWB and in

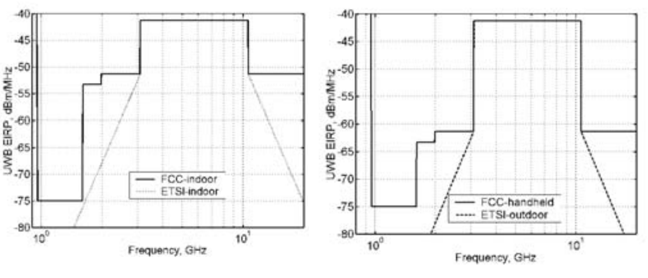


Fig. 1. UWB spectral masks

the end of 2003 will issue a draft standard [8].

In Europe, still[2] the regulatory issues are not solved. They are responsibility of the European Conference of Postal and Telecommunications Administrations (CEPT) and the European Telecommunications Standard Institute (ETSI). The data, which could be found, are very few. On behalf of CEPT with UWB deal the Work Groups Spectrum Engineering SE21 and SE24. Their tasks, connected to the UWB are choice of appropriate interference scenarios and path loss models and to assess required distance and interference margins, which to be imposed to the UWB devices. On behalf of ETSI a task group was established, specially formed for UWB: TC ERM (Technical Committee Electromagnetic compatibility and Radio spectrum Matters) TG31A.

For the moment in Europe the UWB devices are divided into indoor and portable [9] (in some sources one can also find "outdoor" instead of "portable" [10]. For imaging applications such as GPR nothing could be heard for the moment. By ETSI (in some sources the authorship is accredited to CEPT [10]) sloped masks are proposed, which very well overlap those of the FCC, as is demonstrated on figure 1. The slope is $\pm 87\log(f)$. The difference will not lead to lowering in performance of the UWB devices, at the same time it will result in better interference protection. The fact that, according to SE24, some conventional radio communication systems need from 10 dB to 30 dB more protection over the FCC in-band limit causes uneasiness in the UWB proponents. According to [11,9] this is referred to separate frequencies, but according to [12] there is risk the emission limits to be lowered for all frequencies. This could happen if when evaluating the potential interference theoretical worst-case models are used instead of models based on "real world data", and also due to the shown over CEPT SE24 strong pressure from participating administrations (regulatory agencies) to protect primary services such as fixed services, mobile services, etc.

Another issue at question is the car SRR, working on 24 GHz, which could disturb the Earth Explore Satellite Service (EESS) and the passive radio astronomy. Suitable frequencies are being searched. Candidate frequencies are 26.5 and 35 GHz where the occupied bandwidth will be 4.2 GHz [13]. At least till 20.02.2003 decision has not been taken.

More clarity over the UWB-regulatory issues in Europe is expected in the end of 2003. In particular, in November when the publishing of the EN 302 065 and EN 302 066 standards of ETSI, is expected.

[2] The article is written in April 2003

## IV. Performance and Interference Assessment

If at the end the proposed by ETSI mask is approved, in Europe data rates and ranges will be accessible as these in USA. Whereas in the sphere of applications such as GPR and Wall-imaging there will remain lost opportunities.

More fears arouse the possibility to impose in-band emission limits, with 10 to 30 dB lower than those allowed by FCC. If this occurs only for specific frequencies, bit rates and ranges are still possible, comparable to those achieved in USA. These limitations, especially if they tear the frequency band apart, they will probably lead to significant changes in the conception of the UWB transmission. One possible way of development is to go on the track of multi band IR, [14] or to leave the carrier free signals and to pass trough the "Spectrally filtered UWB", which allows a precise control of the radiated spectrum, but leads to the conventional up/down-conversion architectures [15]. Suitable candidate will be the OFDM [16], which also allows precise PSD tailoring. The last two solutions increase the complexity, therefore the price of the transceivers, and thus lower they competitiveness.

If the limitations with 10-30 dB below those permitted by FCC (-41 dBm/MHz) encompass the whole range from 3.1 to 10.6 GHz, in that case the future of the UWB technologies in Europe will become problematic.

A rough estimation will be made of the upper bound of the accessible bit rates/ranges in that case. For that purpose, the well-known theorem of Shannon [17] will be applied. We assume the most optimistic scenario: There are no interferers, but only AWGN, we dispose of ideal receiver with noise figure $NF = 0$ dB, which captures the whole energy that comes to it. It is necessary to find SNR. For those purpose the following path loss model will be used [18]. Similar is also the dependence given in [10].

$$\begin{aligned} PL(d,f)_{[\text{dB}]} &= PL(d_0,f)_{[\text{dB}]} + 10n\log(d/d_0), \\ PL(d_0,f)_{[\text{dB}]} &= 20\log(4\pi f d_0/c). \end{aligned} \tag{1}$$

$PL(d_0)$ is the mean path loss at the reference distance $d_0$ (in our case $d_0 = 1$ m), at which the propagation can be considered to be close enough to the transmitter such that multipath and diffraction are negligible and the link is approximately that of free space. In indoor environment we can assume that the path loss exponent $n = 2$ in conditions of line of sight (LOS) and $n = 4$ in non-line of sight of sight of sight of sight (NLOS) between the transmitter and receiver.

In order to find the received power $P_r$, when using the whole band allowed from 3.1 to 10.6 GHz, integration will be needed. Then assuming isotropic transmit- and receive antennas we have:

$$P_r = \int_{f_l}^{f_h} \frac{PSD_{\max}(f)}{PL(d,f)} df, \tag{2}$$

where $PSD_{\max}$ is the maximum admissible emitted power in unity bandwidth, and $f_l$ and $f_h$ are the limits of the used frequency range, respectively 3.1 GHz and 10.6 GHz.

After simple transformations, assuming $N_0 = -174$ dBm/Hz and $B = 7.5$ GHz and replacing in the Shannon's

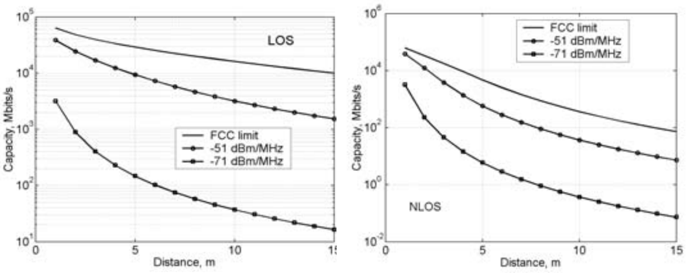


Fig. 2. Channel capacity

formula, we obtain the channel capacity. On figure 2 its dependency is shown from the distance and in different limitations of the transmitted power for LOS and NLOS condition, respectively.

The issue is to what extent the proponents of strict restrictions are correct. The rough influence of the UWB devices upon the conventional victim receiver will be estimated. When B $\ll$ PRF, where B is the IF Bandwidth of the influenced receiver, and PRF is the pulse repetition frequency of the UWB transmitter, the interference, caused by the UWB is similar to white gaussian noise [19]. This is often carried out. One figure of merit commonly used to assess interference issues is the distance between the UWB transmitter and the victim receiver, at which the interference will cause an effective rise in the noise floor at 1 dB [20]. It is easy to prove that in order to happen this, the interference level must be 6dB below the current noise floor.

Or for interference power $P_i$ we can write:

$$\begin{aligned} P_{i[\text{dBm}]} &= PSD_{t[\text{dBm/Hz}]}(f) + 10\log(B) - PL(f, d_{+1dB})_{[\text{dB}]} \\ &= -174[\text{dBm/Hz}] + 10\log(B) + NF - 6\text{dB}, \end{aligned} \quad (3)$$

where $PSD_t(f)$ is the transmitted power in a unity bandwidth, $NF$ is the noise figure (in dB) of the victim receiver, and $d_{+1dB}$ is the distance between the UWB- and the victim device. After simple transformations, assuming isotropic antennas, for worst case (LOS) we have:

$$\log(d_{+1dB}) = 13.35 + 0.05(PSD_{t[\text{dBm/MHz}]} - NF) - \log(f) \quad (5)$$

According to data of the FCC spectral masks and the ETSI spectral masks, using (5), the shown in figure 3 graphs are obtained. They represent dependency of the distance $d_{+1dB}$, which leads to an effective rise in the noise floor of 1 dB, from the working frequency of the victim receiver. For the latter it is assumed to be $NF = 8$ dB.

One can find out that in some circumstances, the interference, caused by the UWB transmitters can be felt at very large distances and is difficult to underestimate this risk. Even more serious are the issues for the aggregated effect from the operation of several such devices. The statement that we some times come across, that the effect could be taken into account only from the closest emitter, in the common case is not true. In certain conditions aggregate effect from multiple, high PRF emitters could be significantly more deleterious than the effects of the closest, single emitter [5]. It is expected a quick proliferation of the UWB devices and it is

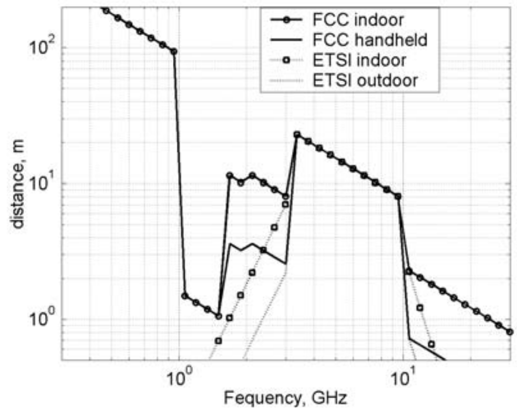


Fig. 3. The distance $d_{+1dB}$

possible, especially in office buildings to have several UWB devices operating at a place of several square meters. One can see that the, spectrum masks, proposed by ETSI, present significantly better protection of the systems, working on frequencies under 2 GHz, in comparison to FCC mask. In that range many radio navigation and safety-of-life systems are operating as well the mass widespread systems as DVB-T, T-DAB, GSM, PCN.

## V. European UWB Research Activities

European research activities are structured around consecutive five-year programs, or so-called Framework Programs (FP). They have multi-theme structure and contain in themselves Thematic Programs One of them is the program Information Society Technologies (IST). This program at the time of FP5 (1998-2002) initiated work on 4 projects, connected to the UWB technologies. Some leading companies and participants from various universities take part in them:

*Whyless.com – the open mobile access network*. “Whyless.com will research scalable radio technology and network resource trading principles in order to avoid gigantic infrastructure paradigm shifts caused by current network development principles, while enabling steady evolutionary growth and ’swift’ adaptation to future user and business requirements.” [15]

*Ultra-wideband Concepts for Ad-hoc Networks (U.C.A.N.)*. Overall objective is to develop and demonstrate a complete ultra-wideband (UWB) system demonstrator. They treat the air channel characterization, the coexistence issues, and the communication system: physical layer (RF and baseband), medium access control (MAC) and network layer. Ad-hoc networking and positioning aspects will be demonstrated, as a potential component of the future 4G-communication infrastructure [21].

*Universal Remote Signal Acquisition For hEalth (U-R-SAFE)*. The objective of the U-R-SAFE project is to propose a Personal Health Care system, allowing convalescent and elderly a quasi-normal life, providing continuous monitoring. A Wireless Personal Area Network based on the UWB will be used on the patient himself. This Network will be interfaced with the Home, Fixed and mobile Networks [22].

*ULTRA Wideband Audio Video Entertainment System (ULTRAWAVES)*. Main Objectives: To provide a high performance and low cost wireless home connectivity solution for multi-streaming of high quality video and broadband multimedia; design and implement a complete UWB based system [23].

A perspective proposal for FP 6 is *PULSERS (Pervasive Ultra-wideband Low Spectral Energy Radio System)*. It is an inter-national consortium, established in 2002 as a joint venture of IBM Research (Zurich) and Philips Research (Redhill, England). The purpose is to create a short-range wireless system, based on UWB, which allows high-rate transmission in multimedia applications (hundreds of Mb/s on a few meters), and also low-rate transactions, together with position location, sensing or identification (hundreds of Kb/s to several tens of meters) [12].

It became also known that, Philips Semiconductors and General Atomics develop in cooperation UWB wireless communication chipsets [24].

## VI. Conclusions

The state of the UWB technology in Europe was reviewed and its further prospects were assessed. For this purpose, a rough assessment of the achievable performance was implemented, according to the possible regulatory constraints.

One notices that Europe works very seriously in the sphere of the UWB-technologies. Great importance for its future will have the decisions of the regulatory authorities. There is a risk some far too conservative regulations to delay the development of the UWB technologies, by limiting the achievable performance, questioning their practical usefulness. At the same time, The introduction of strict emission limits would require approaching the theoretical limits of UWB device performance, resulting in UWB devices that are unlikely to be low-cost low-complexity. Probably the applications would be limited to low-rate communications, for instance information transfer from remote sensors, covert communication, or connection to extremely short distances, for example in systems for contact-less identification. Such a development could lead to a backwardness of the European producers from their American rivals. From other hand, by gathering experience from the exploitation of the first UWB devices and accumulating data for the interference, caused by them in real life, it is possible the limitations to be lessened. Of great importance would be the activity of the interested producers, as this happens in USA.

For the time being, there is no talk at all about allowing the UWB systems, working under 1 GHz, or in other words for the moment we cannot think of applications such as GPR. For the automotive SRR, it is obvious that a suitable solution is searched and their implementation will not be hindered. As it was shown above, the cautiousness in the regulatory sphere is not completely groundless. What remains is to hope that a wise compromise will be found between the protection of the nowadays-existing non-UWB systems and the creation of conditions for development of the promising and prospective UWB technology.

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