Exposure Assessment Methods for Emerging New Technologies

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Abstract

The number of new wireless mobile communication tools is steadily increasing in the recent years. The development of these technologies raised new questions in terms of exposure assessment. Most of these applications making use of broadband signals compared to older technologies, e.g. UMTS has a bandwidth of 5 MHz compared to GSM having a bandwidth of 200 kHz. Moreover, several of these new technologies show pseudo noise characteristics. These specific properties of these signals made it imperative to develop new measurement technologies. A short overview on emerging wireless standards is given and assessment procedures for UMTS, WLAN and UWB are discussed.

1. Introduction

The use of mobile phones increased remarkable in the last decade. Worldwide more than 1 billion people were using mobile phones in 2002, in 2007 the number of 2 billion users was exceeded. These numbers are expected to continue to augment in the next years. Almost half of the 26.000 WLAN hotspots worldwide are located in Europe, considerable growth is also expected in this case. UWB is a new emerging technology mainly dedicated to allow offering the opportunity of high speed interconnection for wireless body area networks (WBAN) and wireless personal area networks (WPAN). The achievable data rates can reach up to 480 MBit/s and are considerable higher compared to other wireless communication technologies. In the recent years international organisations like ICNIRP, IEC, CENELEC, ETSI, IEEE, ITU, CEPT developed many standards, recommendations and guidelines for exposure assessment for both the general public and workers also applicable to new technologies. The ICNIRP guidelines of 1998 are the basis for the Council Recommendation 1999/519/EC [1] for exposure assessment of the general public and the EMF-Workers Directive 2004/40/EC [2] of the European Union. For radio frequency safety compliance of products the R&TTE-Directive 1999/5/EC [3] is in use in Europe. In the United States the FCC adopted guidelines developed by non-governmental organisations such as IEEE and NCRP for evaluating exposure due to radiofrequency transmitters licensed and authorised by the FCC. These FCC radiofrequency rules are published in volume 47 of the Code of Federal Regulations, Sections 1.1307(b), 1.1310, 2.1091 and 2.1093 [4]. US documents containing practical guidelines and information for performing field measurements in broadcast and other environments are the OET Bulletin 65 [5] and the ANSI/IEEE standards C95.1-2005 and C95.3-1991.

2. New Wireless Standards

Multiple wireless services exist nowadays and others are in the process of development. They cover a very wide frequency range starting from a few kHz up to 275 GHz. We will give an overview of prominent examples of some emerging and existing wireless technologies in the presentation, but it is not possible to cover all of them. In this paper we are focussing on UMTS, WLAN and UWB.

In many parts of the world a very prominent emerging communication technology is UMTS (Universal Mobile Telecommunications System), a broadband mobile communication standard of the 3rd generation. UMTS is able to fulfil many requirements, e.g. flexibility in terms of the possibility to integrate future developments, multiservice platform, high spectral efficiency and high transmission quality (data rates of 384 kBit/s for universal and up to 2 MBit/s for local coverage) [6].

Wireless network standards can be subdivided according to their area of connectivity, i.e. Personal Area Connectivity (WPAN, up to 10 m), Local Area Connectivity (WLAN, up to 100 m) and Metro and Wide Area Connectivity (WMAN and WWAN, both above 100 m). Examples for WPAN applications are ZigBee, Bluetooth and Ultra Wideband Technology (UWB). Ultra Wideband (UWB, e.g., IEEE 802.15.3a) systems transmit signals across a considerable wider frequency band than other systems. According to the FCC's definition a UWB signal occupies at least 500 MHz of bandwidth or has a fractional bandwidth of more than 20 % of the center frequency. The data rate of current UWB applications can be up to 480 MBit/s. Moreover, several different WLAN standards exist: the most prominent ones are the IEEE 802.11 family (IEEE 802.11, 802.11a, 802.11b, 802.11g and 802.11h) [7]. The connectivity ranges typically between about 50 to 200 m, maximum achievable data rates are varying between 2 and 54 MBit/s.

3. Assessment Procedures

UMTS is operated in the frequency range from 1,920 to 2,170 MHz having a channel bandwidth of 5 MHz. Key features are multiple access by code division, fast power control at a rate of 1,500 Hz and a non constant envelope modulation (QPSK). The CDMA access is achieved by multiplying the bit sequence with a higher frequency code sequence, the so called chip frequency of 3.84 MHz. Data rates may reach values of 2 MBit/s, however typical data rates range between 200 to 300 kBit/s [8]. There are several approaches how to measure exposure arising from UMTS base stations. The use of broadband field probes can give an estimate of the exposure. More specific information can be obtained by using frequency selective equipment. It is a suitable approach to use spectrum analysers offering the ability of a sufficient large resolution bandwidth, e.g. 5 MHz. The selection of an adequate detector is crucial. Due to the pseudo random characteristic a RMS detector can be recommended, the use of a PEAK detector will lead to considerable overestimation of the exposure. Finally, the sweep time should be long enough, e.g. 100 msec or more (depending on the number of bins).

WLAN-Systems according to IEEE 802.11x are using either a *Direct Sequence Spread Spectrum (DSSS)* or an *Orthogonal Frequency Division Multiplex (OFDM)* transmission scheme, leading to stochastic signal characteristics in time domain and a broad occupied frequency band of approximately 20 MHz. Therefore, for appropriate frequency selective measurements using a precision antenna in combination with a spectrum analyser, sufficient resolution bandwidth (or a corresponding correction factor in case of a narrowband measurement) and a RMS detector are absolutely necessary. On the one hand measurements with too small resolution bandwidth (without corresponding correction) would lead to arbitrarily underestimations of the actual RF fields, and on the other hand using a PEAK detector would lead to overestimations due to the stochastic signal characteristics. Moreover, one has to take into account that WLAN devices do not emit RF energy continuously. Only in case of data transmission a WLAN device emits RF bursts. The maximum effective duty cycle of WLAN devices is usually not more than 70-80%, even under high load data transmission conditions. In practice this means that highly dynamic, burst-like exposure without a predefined duty cycle or overall crest factor must be expected. Consequently, using the MAXHOLD mode, only the burst amplitude of the device closest by (causing the maximum burst amplitude in the considered position) will be recorded. More realistic exposure figures can be obtained by BAND POWER or CHANNEL POWER functionalities of (high quality) spectrum analysers in combination with time averaging functions. Only stating MAXHOLD measurement results as exposure figures is not a useful way, because this usually overestimates the actual (time averaged) exposure at least by 2-3 orders of magnitude.

The personal exposure caused by recently deployed UWB communication devices in the frequency range 3.1-10.6 GHz must be expected extremely low, because their maximum averaged spectral power density is restricted to -41.3 dBm/MHz EIRP by the current regulations in the USA and Europe. This means that, even in the theoretical case of 100 % usage of the allowed spectrum, the average output power (EIRP) of such devices is as low as approx. 0.5 mW in the USA. In Europe this upper bound is even lower (approx. 0.3 mW) because the European UWB regulation is more restrictive below 3.4 GHz, between 4.8-6.0 GHz and above 8.5 GHz. Consequently, this means that exposure assessment in practice will usually not be possible more than 1-2 m away from the devices due to the sensitivity achievable by standard measurement equipment. Narrowband measurements using a spectrum analyzer (e.g. RBW 100 kHz, VBW 3 MHz, RMS-Detektor, Band Power, time averaging) and application of a corresponding bandwidth correction factor should be preferably used. Using (highly sophisticated) broadband digital oscilloscopes for UWB exposure assessment can not be recommended due to their limited sensitivity and their high price compared to medium class spectrum analyzers.

4. Conclusions

Many of the existing international exposure assessment standards do not contain specific information on exposure assessment of electromagnetic fields from new emerging technologies. The situation changed in the recent years, in some standards, e.g. EN 50400 and EN 50401 or prEN 50492 give very valuable information on specific procedures for new emerging wireless technologies. Taken together, the selection of adequate measurement equipment is crucial. In addition it is important to use adequate settings of the measurement equipment, e.g. the appropriate detector. The precise documentation of these settings in reports on measurements procedures is crucial to make comparisons with results from other measurement campaigns meaningful.

5. References

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