Accurate Assessment of WLAN Exposure in a Wireless Sensor Testbed

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INTRODUCTION

Wireless local area networks (WLANs) are common technology in current office buildings and people are thus exposed to these WLANs during working hours. Moreover, wireless sensor testbeds are already in use by a lot of research institutions worldwide in order to effectively test the wireless protocols or applications in a real-life environment. Examples of sensor testbeds are the WiLab: http://wilab.test/index.php at IBBT-Belgium and Motelab: http://motelab.eecs.harvard.edu at Harvard-USA. Exposure due to WLANs using Wi-Fi technology is only rarely investigated [1], [2] and never in wireless sensor testbeds.

Here *all* optimal settings of the measurement equipment (i.e., spectrum analyzer (SA)) used for the WLAN exposure assessment are for the first time proposed, enabling correct measurements to determine compliance with safety standards [3]. The settings have a huge influence on the measurement results and that it is very important to quantify this impact. WLAN exposure is measured on-site and determined for 7 WLAN networks in an office environment on 222 locations and for the first time to our knowledge, general public exposure in a wireless sensor testbed is determined.

MATERIALS AND METHODS

WLAN exposure is determined in a modern office building. In this building 7 different Wi-Fi networks are present using IEEE 802.11b/g technology. In this building also the wireless sensor testbed WiLab, consisting of 200 nodes spread over three floors of the office building, is deployed. The architecture of the testbed is based on the widely used MoteLab testbed concept from Harvard University. The nodes (iNodes) are embedded PCs equipped with ethernet, USB, etc., and each node has two 802.11 a/b/g wireless network interfaces (type COMPEX WLM54-SAG23) with each a 5 dBi antenna.

If we want to measure exposure due to WLAN with a SA, the maximum-hold mode (i.e., a measurement of a signal with the maximum-hold setting until the SA reading stabilizes) will have to be used during a certain amount of sweeps. In this way the maximal field value during a measurement time is determined. But because these WLAN signals are not continuously transmitted, the maximal value has to be multiplied with a duty cycle in order to obtain an accurate estimation of the total RMS (root-mean-square) power density averaged over 6 minutes or 30 minutes (ICNIRP, IEEE C95.1-2005). The following measurement procedure is recommended for WLAN. Firstly, the *active* WLAN channels are determined with a WLAN-packet analyzer, here we used the software tool Airmagnet. Secondly, the *duty cycle* of the active channels is determined with a tri-axial R&S TS-EMF Isotropic Antenna in combination with a SA of type R&S FSL6. Thirdly, *max-hold measurements* of the electric field of the different WLAN channels are performed with SA and a tri-axial measurement probe. Finally in a fourth step, the *total average electric field* E_{tot}^{avg} is calculated by multiplying the maximum hold value (= average *active* electric field) with the root of the appropriate duty cycle.

RESULTS

Table 1 summarizes the proposed settings used for the WLAN assessment**.** These settings have been validated by in-situ measurements and will be explained in detail at the BEMS conference. In Table 1, *n* is the number of display points of the SA (n = 455 for the considered SA) and t_{active} is the active duration.

method: measurements	SA parameters	values
duty cycle single sweep zero span mode	center frequency [MHz]	channel frequency 2412 + k·5 (k=0-12)
	resolution bandwidth RBW	1 MHz
	sweep time SWT	1 ms
	video bandwidth VBW	10 MHz
	Detector	RMS detector
	span	0 MHz
	number of single sweeps	2200
max-hold measurement in frequency domain	center frequency	2.45 GHz
	RBW	1 MHz
	SWT	• 10 ms if signal is not known • t_{active}×n if signal is known
	VBW	10 MHz
	Detector	RMS-detector
	Span	100 MHz
	maximum hold time	1 minute or until signal stabilizes

Table 1: Proposed settings of the spectrum analyzer for WLAN exposure assessment.

In total 222 measurement positions are considered, where exposure is measured for all present WLAN signals: 27 with WiLab off, 195 with WiLab on.

WiLab off: Duty cycles of 0.4 % to 2.8 % and once 9.7 % are obtained. Average exposure to WLAN (WiLab off) is 0.12 V/m and a 95th percentile of 0.90 V/m is obtained (68 times below the ICNIRP 1998 guidelines). These values are comparable with those of [1], [2].

WiLab on: When the WiLab is on, all WiLab APs transmit maximal in broadcast mode: average exposure increases to 1.9 V/m, and the 95th percentile is 4.7 V/m (13 times below the ICNIRP guidelines). All values are thus below the ICNIRP guidelines of 61 V/m but are higher than those reported by [1], [2]. The exposure due to the “normal” APs (low duty cycles of typical 0.5 to 2.8 %) is much lower than the exposure to the WiLab (worst case duty cycles of 86 to 100 % for dedicated experiments) due to the much lower duty cycles.

CONCLUSIONS

An accurate measurement procedure for WLAN radiofrequency exposure is proposed. For the first time all optimal settings of the measurement equipment used for the WLAN exposure assessment are presented. WLAN exposure is measured on-site and determined for 7 Wi-Fi networks in an office environment at 222 locations and for the first time general public exposure in a wireless sensor testbed (200 WiLab nodes with each 2 Wi-Fi IEEE 802.11 radios) is determined.

REFERENCES

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