PA-5 TEMPERATURE INCREASE IN THE HEAD REGION CAUSED BY A COMMERCIAL MOBILE PHONE

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OBJECTIVE. Temperature elevation in the body is one of the basic parameters to be considered when setting RF exposure standards. Up till now there are not much studies related to the temperature elevation, caused by RF exposure of a commercial mobile phone. The objective of this study was to evaluate the temperature elevation in the head region caused by exposure of a commercial mobile phone.

METHODS. In this computational study the FDTD technique is used to solve the bioheat transfer equation on the same grid which is used for electromagnetic SAR calculation. The CAD based model of the 8310 Nokia phone is used as the exposure source and the near field SAR has been studied numerically. 900 and 1800 MHz frequencies are considered. Both the touch and tilt positions of the phone using are considered.

RESULTS. The primary results of this study show that the temperature elevation in both frequencies is well below 1 C. The temperature elevation in brain tissues are less than 0.1 C.

DISCUSSION. This is one of the rare studies where a CAD based model of a commercial mobile phone is used to study temperature elevation in the head. Since only one head model and one commercial mobile phone is considered, it is not possible to generalize the results of this study to all mobile phones or other head anatomies. However, this study gives some general figure about RF energy absorption and temperature elevation caused by a commercially avialable mobile phone in head of a mobile phone user.

PA-7 *SPECTRUM ANALYZER SETTINGS FOR EVALUATION OF EXPOSURE DUE TO WIMAX SIGNALS

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Objective. In order to check the compliance of the electromagnetic fields of WiMax base stations (Worldwide Interoperability for Microwave Access; IEEE 802.16 [1]) with human exposure limits and regulations, these fields must be compared to the reference levels [2]. Current measurement procedures prescribe the use of a spectrum analyzer (SA) for the acquisition of the exposure from electromagnetic fields. The objective of this paper is the determination of optimal settings of the spectrum analyzer for the assessment of the exposure due to WiMax signals.

Methods. For exposure assessment, WiMax differs mainly from GSM and UMTS by the use of OFDM (Orthogonal Frequency Division Multiplexing) instead of Wideband CDMA (Code Division Multiple Access) for UMTS and TDMA/FDMA (Time- and Frequency-Division Multiple Access) for GSM. We investigate a WiMax signal implemented in SimuLink according to the specifications of 802.16-2004 [1]. Fig. 1 shows the model for the transmitting part of the WiMax signal according to the specifications of [1]. The datastream is modeled to be randomized. Outer Reed-Salomon coding concatenated with an inner convolutional code - this is represented by the block forward error correction (FEC) - and symbol mapping are implemented. The OFDM modulator is modeled according to the 256 carrier WirelessMAN-OFDM air interface [1]. Also the cyclic prefix and the different coding schemes are modeled. Finally the signal r(t) is generated.

The model for the SA is thoroughly discussed in [3]. The signal r(t) is multiplied with the local oscillator signal LO(t). The mixed signal u(t) is sent to the resolution bandwith filter $H_{RBW}(f)$ (with f the frequency in Hz). The filtered signal s(t) is then sent to the envelope detector, represented by the absolute value operator:

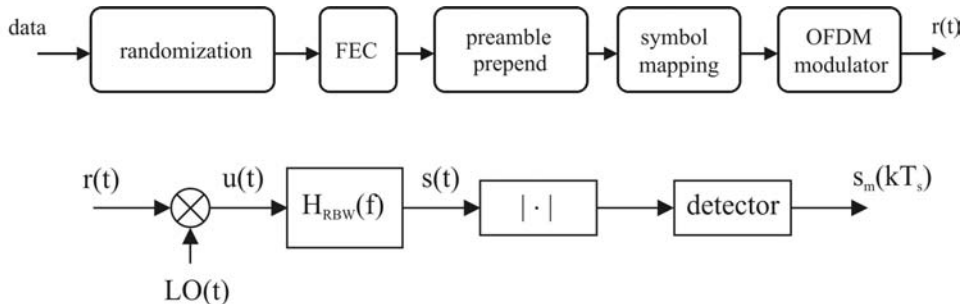$$|s(t)| = \left| \frac{1}{2} \int_{-\infty}^{\infty} r(t+u) LO(t+u) H_{RBW}(u) du \right| \quad (1)$$

FIGURE 1. Model for the WiMax signal and model for the SA.

Finally, the detector will produce after each sample period Ts a measurement value. The kth measurement value $s_m(kT_s)$ will depend on the signal $|s(t)|$ during the previous interval $](k-1)T_s, kT_s]$ (often referred to as the frequency bin Δf_{bin}) and on the detector mode (sample, root-mean-square (RMS) or positive-peak (PP) detection) [3]. Further, the sweep rate v_{sw} is defined as $\Delta f_{sp}/\Delta T_{sw}$, where Δf_{sp} represents the span of the SA and ΔT_{sw} the sweep time.

Results. We first study the influence of the resolution bandwidth (RBW) filter of the SA when "measuring"a 3.5 MHz WiMax channel. Fig. 2 shows the ratio of the power level indicated by the SA (P^{SA}) and the true signal power (P^{true}) as a function of the resolution bandwidth for the range of 1 kHz to 10 MHz. This range for the RBW is common for most SA, 10 MHz is already a large RBW (e.g., R&S FSEM30 has a maximal RBW of 10 MHz, the RBW of the HP8561B is maximally 2 MHz). In this figure both the RMS and PP level are investigated and their 95 % confidence interval is shown on the figure. For

this investigation the WiMax signal was simulated 100 times for each resolution bandwidth. The span is chosen such that the frequency bin equals 20 kHz. The sweep rate was set equal to 200 MHz/s. This figure shows that for resolution bandwidths from about 5 MHz on, the RMS detector delivers correct values ($\mathrm{P}^{SA}/\mathrm{P}^{true}$ is close to 0 dB). These RBWs are larger than the channel bandwidth BW = 3.5 MHz. A smaller RBW results in an underestimation when using the RMS detector but by using the PP detector a good estimation can be obtained for e.g., a 360 kHz filter (ratio close to 0 dB). The use of the PP detector for larger resolution bandwidths results in overestimation of the measured power. This figure shows that the 95 % confidence interval narrows for larger RBWs since the impulse answers will be shorter (formula (1) and [3]).
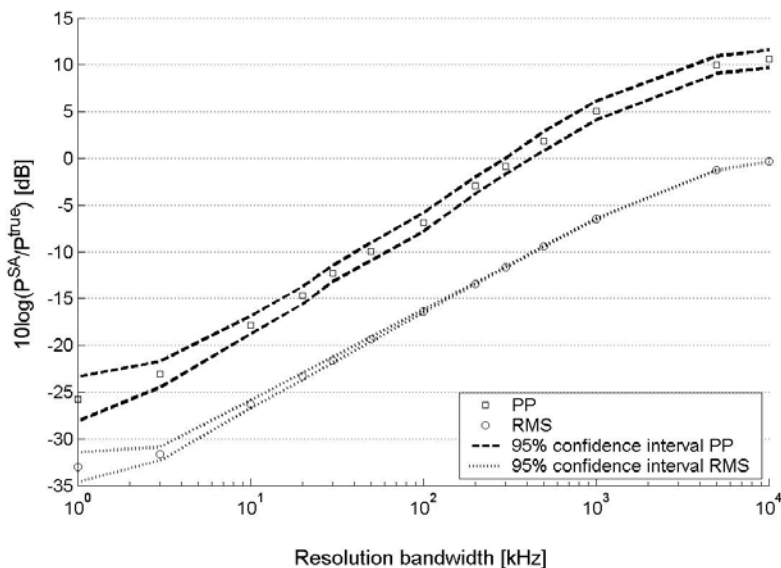

FIGURE 2. The ratio of the power level determined with the SA and the true signal power as a function of the resolution bandwidth from 1 kHz to 10 MHz for a channel BW of 3.5 MHz.

In the next step we investigate the influence of the sweep rate v_{sw} on the measurement of a WiMax signal with channel BW = 3.5 MHz, using a RBW = 360 kHz for the PP detector and a RBW = 4.8 MHz for the RMS detector. The choice of these RBW filters is based upon the results of Fig. 2 (ratio $\mathrm{P}^{SA}/\mathrm{P}^{true}$ is close to 0 dB). For this analysis we only tolerate deviations smaller than 1.5 dB. Fig. 3 shows that the measurement with the PP detector and RBW = 360 kHz delivers almost correct values for all sweep rates for this case. The maximal deviation is only 1.3 dB. The highest deviations occur for very large sweep rates (or short sweep times, sweep time is inversely proportional to the sweep rate). A compromise will have to be made between measurement time and accuracy. Up to 200 MHz/s the values obtained with the RMS detector are almost not influenced by the sweep

rate. The RMS detector underestimates then the correct value with less than 1.5 dB. From 200 MHz/s on, the ratio decreases further. A sweep rate of 200 MHz/s delivers still an acceptable deviation of only 1.3 dB.

Conclusion. Exposure assessment of WiMax signals using a spectrum analyzer is discussed in this paper. The influence of resolution bandwidth and sweep rate on the determination of the actual power of a WiMax channel have been discussed. Optimal settings of the spectrum analyzer are proposed for a 3.5 MHz channel and an accurate estimation of the exposure due to WiMax signals can be obtained.

References. 1. IEEE Std. 802.16 - 2004, IEEE Standard for Local and metropolitan area networks, Part 16: Air interface for fixed broadband wireless access systems, 2004.
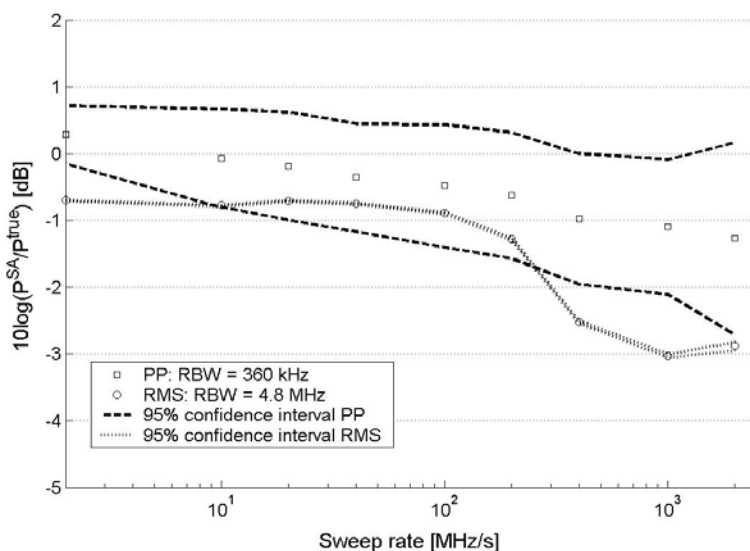 2. International Commission on Non-ionizing Radiation Protection, Guidelines for limiting

FIGURE 3. The ratio of the power level determined with the SA and the true signal power as a function of the sweep rate for a channel BW = 3.5 MHz using a RBW = 360 kHz (PP) and a RBW = 4.8 MHz (RMS).

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3. C. Olivier, and L. Martens, Optimal Settings for Narrow-Band Signal Measurements Used for Exposure Assessment Around GSM Base Stations, IEEE Trans. Instr. Meas., vol. 54, No. 1, pp. 311 3173, Feb. 2005.

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