guidelines and standards [1]. We have implemented a hybrid Finite Element Method (FEM) / Method of Moments (MoM) technique for the efficient and accurate calculation of the spatial-peak and whole-body-averaged SAR in a human phantom close to a base station antenna [2]. The main advantage of the hybrid FEM/MoM compared to the popular FDTD technique is the efficiency with which the large free-space region around the base station antenna can be modeled. In previous work, we investigated the level of detail that needs to be included in the numerical models, and in particular, the base station antenna [3]. This demonstrated another important advantage of the FEM/MoM and that is the accuracy with which the antenna elements can be modeled, which turned out to be critical for accurate exposure assessment of humans within a few hundred millimeters of such an antenna. We also applied the technique to the calculation of a three-dimensional (3D) SAR compliance zone around a generic base station antenna in [3]. In the work presented in this paper the technology has been applied to a real commercial base station antenna used in GSM networks. We have validated the antenna model by comparing measured and simulated results. As shown before [3], this validation is of critical importance due to the significant influence the phantom can have on the feed network, and thus on the active power of the antenna elements. Numerical experiments have been performed to quantify the effect of the shape and size of different phantoms on SAR and investigations were done on a homogeneous vs heterogeneous phantom to ensure conservative but realistic SAR profiling. The phantoms were rotated and translated to obtain a complete 3D SAR profile. The efficiency of the FEM/MoM technique [2] together with the automated SAR extraction routines implemented [4], enable SAR calculations within realistic solution time and computer memory requirements.

RESULTS AND CONCLUSIONS: The results obtained yields a three-dimensional (3D) SAR profile around the commercial base station antennas. This profiles is compared to the 10g spatial-peak and whole-body-averaged basic restriction [1] of the exposure guidelines. This, in turn, yields an occupational exposure compliance zone around such an antenna which is more realistic and accurate and less restrictive than the compliance zone based on reference levels [1].

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P-C-18

OPTIMAL SETTINGS FOR FREQUENCY-SELECTIVE ELECTROMAGNETIC FIELD MEASUREMENTS FOR EXPOSURE ASSESSMENT AROUND BASE STATIONS. C. Olivier, L. Martens. Ghent Univ, Dept. of Information Technology, Ghent, Belgium.

Objective: To derive the optimal configuration of the spectrum analyzer when used for the exposure

assessment around base stations, together with the associated uncertainty and the underlying rationale for the chosen settings.

Method: A base-band simulation model for both the spectrum analyzer and the GSM and UMTS communication signals have been developed to investigate the behavior of the spectrum analyzer when used for exposure assessment. Simulations enable to determine the theoretical bounds on the achievable accuracy for the measurement of a mobile communications signal and to examine the impact on the measurement result of one individual setting of the spectrum analyzer. The simulation models have been validated with measurements on realistic mobile communication signals.

Results: (a) *GSM:* The resolution filter should on the one hand be wide enough to measure the actual power of the GSM signal, but on the other hand, the contribution of the neighboring GSM channel to the channel under investigation should be minimized. Since for the exposure assessment, the worst-case situation where the GSM channel is continuously emitting at maximum power has to be considered, the positive-peak detector is preferred, since it will deliver an accurate power level, even if the GSM signal is time-intermittent (e.g., because of low traffic). Moreover, because the GSM signal has a constant envelope, the use of the positive-peak detector with a resolution bandwidth of 30 kHz enables to estimate the actual RMS power of the signal, which is illustrated in Fig. 1. For the sweep time, an increased accuracy has to be weighed up against a longer measurement time. Repeating the scan several times over a certain frequency range, instead of executing one slow measurement, delivers a measurement result that is less dependent on the instantaneous traffic. The resulting optimum settings (see also [1]) are given in Table 1.

(b) *UMTS*: Although for UMTS, a channel decoder will provide more information (e.g., the power of the pilot channel) to estimate the maximum possible exposure, the use of a spectrum analyzer remains an attractive alternative because of its general applicability. Due to the noise-like behavior of the UMTS signal, the RMS-detector of the spectrum analyzer is preferred. However, it is possible to estimate the RMS level from a measurement with the positive-peak detector by taking into account a correction factor. This factor depends on the - a priori unknown - number of channels that are transmitted simultaneously. This is illustrated in Fig. 2, where also the worst-case correction factor that should be applied, is indicated. If a resolution filter smaller than the UMTS bandwidth is chosen, the measured level (both for the RMS as for the positive-peak detector) have to be corrected, since only a portion of the signal is measured. But on the other hand, the resolution bandwidth cannot be too wide because otherwise neighboring channels would contribute significantly to the measured power of the UMTS channel under consideration. Although the standard deviation on the measured power level decreases for larger sweep times, the sweep time by itself, is constrained because the power of the UMTS signal only remains constant during a limited period. Indeed, because of the fast power control (at a rate of 1500 times per second) of the UMTS signal, every 0.67 ms the power of the UMTS signal is augmented or diminished by a certain power step. Moreover, it is recommended to fix the sweep time over one measurement point to two times the power control period, to ensure that the maximum measured power level is caused by only one power control period where the UMTS signal was transmitted at its maximum power level. The resulting settings for the spectrum analyzer are also summarized in Table 1 for the measurement of a UMTS signal.

Conclusions: By using simple simulation models for the spectrum analyzer and the signals under investigation, the optimal settings of the spectrum analyzer for assessing the exposure around a base station have been derived, together with the uncertainty associated with the stochastic characteristics of a certain modulation signal.

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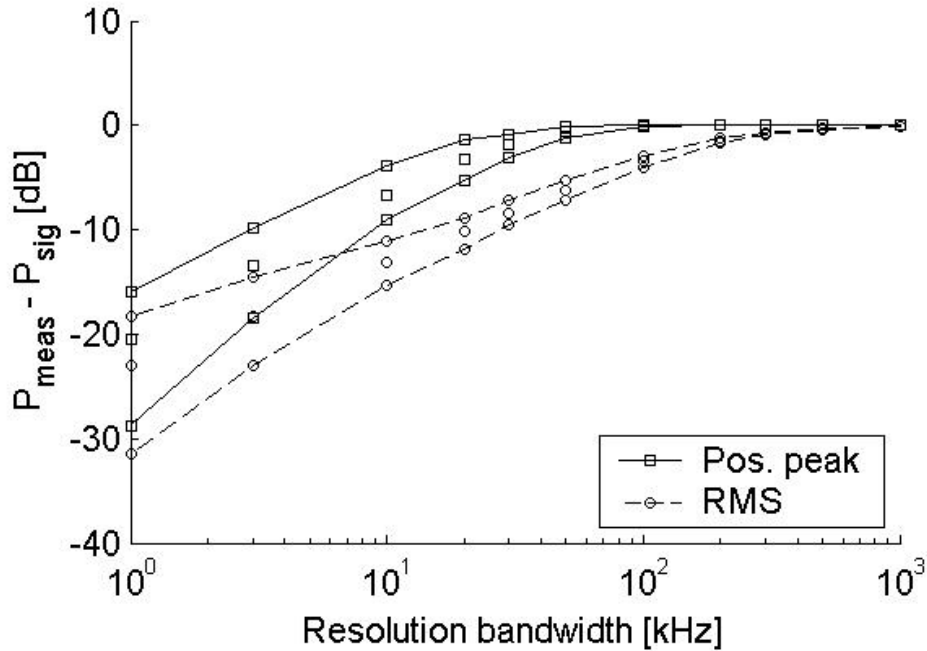
Fig. 1. Mean level of a GSM channel measured by the RMS and positive-peak detector for different resolution bandwidths, together with its 95% confidence interval.
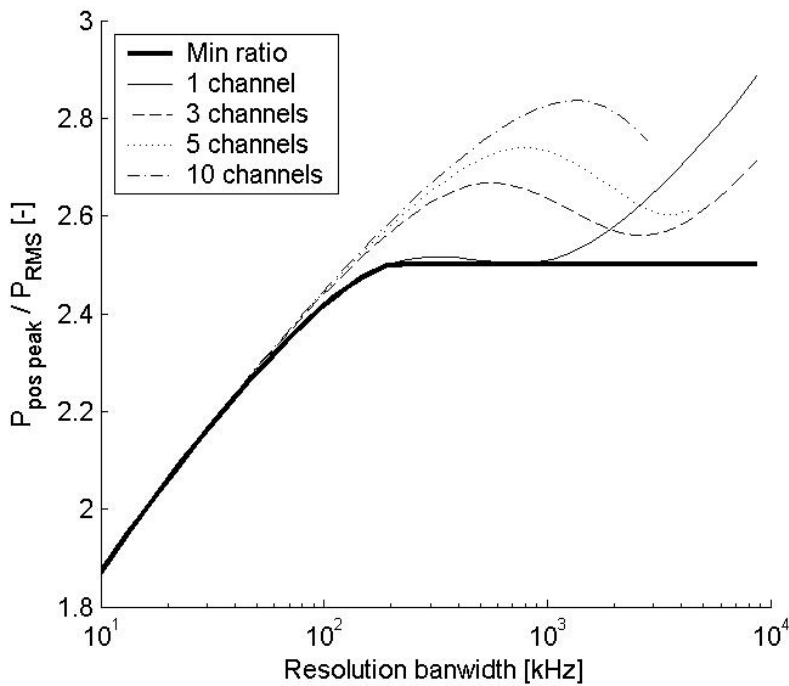

Fig. 2. Relation between the power level of a UMTS signal measured with the positive-peak detector and with the RMS detector for different configurations of the UMTS signal.

Table 1: Proposed spectrum analyzer settings		
	GSM	**UMTS**

Detector	Positive peak	RMS [1]
Resolution bandwidth	30 kHz	500 kHz
Sweep time	F_{span} [MHz] / (20 MHz/s) [2]	N_{bin} x 1.33 ms

F_{span}: frequency span. N_{bin}: number of measuring points in one frequency span.
[1]For the positive-peak detector a correction factor of 2.5 should be applied.
[2]Preferrably 10 subsequent sweeps are taken.

P-C-21

SAR MEASUREMENT EMPLOYING ELECTRO-OPTIC (EO) PROBE WITHOUT USING METAL.

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BACKGROUND: Using an optical electric field probe to measure the Specific Absorption Rate (SAR) is expected to be superior to using conventional probes with respect to RF exposure from a mobile radio terminal and in-vitro or in-vivo exposure systems. This is because the optical probe can measure the field distribution at a low level of invasiveness and is capable of measuring both the frequency spectrum and phase. A previously proposed optical probe [1] uses metal dipole antennas to enhance the sensitivity. However, this approach still causes a disturbance in the field and has a limited bandwidth due to the use of the metal dipole antennas. Furthermore it is difficult to miniaturize the probe.

OBJECTIVE: The objective of this study is to develop a noninvasive SAR measurement probe, which can measure the SARs at multiple frequencies simultaneously and has high spatial resolution, employing a small Electro-Optic (EO) crystal without using metal [2].

METHODS: Figure 1 is a picture of the prototype Electro-Optic (EO) probe, which comprises an EO crystal, dielectric mirror, and optical fiber in glass. CdTe is selected as the EO crystal and its scale is 1 mm x 1 mm x 1 mm. The EO crystal is directly connected to the optical fiber and can detect an electric field parallel to the EO surface. A main feature of this construction is that there is no metal in the probe. In this study, 1950 and 2450 MHz are selected as the frequencies because they correspond to the frequencies used in IMT-2000 and W-LAN systems, respectively. The tissue-equivalent liquid for 1950 MHz is filled in a cubic container (200 mm x 200 mm x 200 mm) and a 1950 MHz half-wave dipole is located at 10 mm below the container. The degree of the probe sensitivity is evaluated using this configuration. In order to verify the frequency discrimination, a 2450 MHz half-wave dipole antenna is arranged at the interval of 10 mm along the antenna axis.

RESULTS: The SAR sensitivity of this prototype is approximately 0.015 W/kg at 1950 MHz. The results nearly satisfy the minimum detection limit defined in [3]. Figure 2 shows the measured SAR distributions at 1950 and 2450 MHz, respectively, when both dipole antennas are active. For comparison, distributions measured using the conventional probe, which comprises the small dipole and the diode, are also plotted. It is clear that the EO probe can discriminate between 1950 and 2450 MHz even though both antennas were active. The SAR at 1950 MHz is almost zero in the area of the 2450 MHz dipole and vice versa. On the other hand, the conventional probe detected both frequencies as anticipated.

CONCLUSION: SAR measurement was performed employing the small EO probe that does not use any metal. The results show that the EO probe measured the SARs at both frequencies simultaneously.

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