ANALYSIS OF INDOOR RF-FIELD DISTRIBUTION

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Abstract: With the increasing use of wireless technologies great social concern has risen about health effects that might be caused by the interaction of electromagnetic waves with the human body. The compliance of exposure situations with international safety limits requires reliable methods capable of quantifying the RF field in every environmental scenario. This project focuses on the assessment of indoor field distributions caused by either indoor or outdoor base stations: We report on our semi-automated measurement method for high-resolution mapping of synthesized inhomogeneous field distributions in a semi-anechoic chamber. In addition we describe the numerical calculations of the field distributions using the finite difference time-domain (FDTD) method. The results gained by these complementary approaches will be well suited for developing recommendations for indoor exposure measurement techniques for public, national and international authorities.

1. Introduction

In recent years the increasing number of GSM mobile phone base stations has resulted in public concern about potential adverse health effects due to electromagnetic radiation exposure. Since the enforcement of the Swiss Regulation of Non-Ionizing Radiation (NISV) [1], exposure measurements in apartments and offices have been increasingly requested by the public and community authorities. The currently applied guidelines are those of the Swiss Agency for the Environment, Forests and Landscape (BUWAL) [2]. Most of the laboratories conducting such measurements use conventional antennas such as bilogarithmic, logarithmic periodic, logarithmic spiral, dipole, etc. However, these antennas are calibrated under laboratory conditions, whereas their performance in apartments or offices is not known (typically, multiple reflections, diffraction and refraction of radio waves in buildings result in complex inhomogeneous field distributions [3,4]). Consequently, the measurement uncertainty of these evaluations can only be estimated and is subject to considerable controversy. Furthermore, the degree of inhomogeneity of the field distribution in these rooms is not known, nor is it known how this inhomogeneity should be weighted in the evaluation.

The objective of this project is to provide the missing scientific data and methodologies for measurement techniques which allow the evaluation of non-ionizing exposure in apartments and offices. Engineering tools shall be developed which allow the accurate measurement of inhomogeneous field distributions, resulting in measurement recommendations with minimum measurement uncertainty.

2. Experiment

2.1 Test room

For the selection of an appropriate test room we have taken into consideration several criteria regarding size, accessibility, material composition of the walls, floor and ceiling, influence of neighboring rooms, feasibility of numerical simulations, etc. The best room meeting most of the above-mentioned requirements is the semi-anechoic chamber in our lab. This room is well defined for electromagnetic computations, is minimally influenced by neighboring rooms and has a volume ($5.6 \times 3.6 \times 2.9\ m^3$) that can be scanned in a reasonable amount of time. Some of the absorber elements can be removed, which facilitates the generation of various field scenarios.

2.2 Antennas (Transmitter/Receiver)

The transmitting base station will be simulated using one (or more) antennas positioned in or outside of the room. Three completely different field scenarios will be generated by appropriate placement of the antennas and absorbers/reflectors.

An important issue is the characterization of antennas which are used for measurement of inhomogeneous field distributions (experimental/numerical). The influence of the measuring operator on the antenna response will be discussed. The averaging volume and field distortion by the antenna must be quantified. Furthermore, the reliability of calibration methods for antennas used in inhomogeneous fields has to be investigated.

For the field measurements (GSM 900 MHz, frequency selective), we will use three kinds of antennas. We have chosen a conical dipole antenna with a frequency range from 80 MHz to 2.5 GHz (ARC Seibersdorf Research, AU), a logarithmic periodic antenna with a frequency range from 650 MHz to 4 GHz (A.H. Systems, USA), and a tuned dipole antenna (Schmid & Partner Engineering AG (SPEAG), CH). Each antenna has the sufficiently small dimensions (< 30 cm) dictated by the measurement procedure guidelines of BUWAL.

2.3 High resolution field mapping

For the 3D high-resolution mapping of inhomogeneous field distributions in the test room a semi-automated measurement tower has been designed. In this setup two horizontal platforms, separated by one meter in height, carry four miniaturized field probes each (SPEAG, CH). The platforms can be raised by one meter, guaranteeing a total accessible field measurement height of $24 \text{ cm} < z < 200 \text{ cm}$. The vertical positioning is computer-controlled, while the horizontal x-y-positioning will be done manually, moving the tower on a rail-guided system along the floor. The construction design guarantees a positioning accuracy of the field probes of better than three millimeters. The measurement points lie on a 3D grid with an adjustable period. For fine resolution a 5 cm period ($\approx \lambda/6$) is typically chosen; however, for fast screening a larger point distance can also be selected. By using mainly dielectric materials for the setup and by fiber-optic transfer of the signal from the probe to the remote read-out station, minimum disturbance of the measured fields is achieved. The employment of isotropic field sensors permits the simultaneous measurement of all three field components at each point.

2.4 Numerical simulation

There are not many reports in the literature on the prediction of electric field distributions in buildings. In most cases for the assessment of radio coverage by base stations, the so-called ray tracing method is applied, a method which is based on geometrical optics [5,6]. Another approach is the FDTD method, which is however seldom used due to limited computer calculation capacity [7,4].

Here, for the simulation of the field distribution in the test room and for the numerical evaluation of the antenna response and measurement protocols, the use of the FDTD approach is intended. The FDTD method is well suited for the prediction of field distributions in anechoic or semi-anechoic chambers [7]. We will use the software SEMCAD (SPEAG, CH), which enables a highly efficient, interactive and solid modeling of complex structures. The grid generation is fully automated and allows the creation of homogeneous and non-homogeneous grids in real-time. The creation of a realistic model of the test room with one or more radiating sources will constitute the first simulation approach. The goal is the optimum arrangement of sources, absorbers and reflectors in the room in order to achieve a realistic inhomogeneous field distribution. Three different distributions will be investigated.

3. Conclusion

The measurement and calculation of complex indoor field distributions has not yet been treated extensively. In this project we propose procedures for quantitative high-resolution mapping of inhomogeneous fields, experimentally and numerically. The data from these experiments will provide the basis for the generation of measurement protocols and uncertainty budgets for indoor exposure evaluation.

4. Acknowledgements

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5. References

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