2. ELECTROMAGNETIC COMPATIBILITY, 5. BIO-ELECTROMAGNETIC COMPUTATION AND APPLICATIONS, 11. NUMERICAL TECHNIQUES

Biological Effects of Wi-Fi Hot Spots in Indoor Environments: a Numerical Study

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Abstract — Along with the resounding growth of products and services utilized in modern information technology applications, wireless communication systems have become essential part of working life. Particularly, in indoor environment, the localized exposure assessment for installed wireless devices is complex, because persons are exposed to non-uniform fields subjected to fading, multiple reflections, diffraction and scattering. This paper presents a numerical approach in order to compute the Specific Absorption Rate and temperature rise in human head related to exposure to WLAN-like fields, at a frequency 2.45 [GHz] and for different types of exposure conditions. Considerations about results and exposure limits are presented.

I. INTRODUCTION

Wireless personal communication is a rapidly expanding sector, particularly in the fields of cellular mobile phones, and wireless local area networks (WLANs). WLANs were introduced in the early 1980s to reduce the installation and relocation costs for conventional wired LANs and to permit the mobility of connected elements in the workspace. The existing applications of WLANs are spread spectrum systems operating at the Industrial Scientific Medical (ISM) frequency (2.45 [GHz]) and the Unlicensed National Information Infrastructure (U-NII) (5.5 [GHz]) [1]. Although this framework has given numerously advantages to people, the steadily increasing use of these new technologies may result in greater radio-frequency (RF) exposure in homes and work places. Many international protection organizations and regulatory agencies have proposed recommendations for a safe exposure [2].

The goal of this paper is to evaluate and discuss the risks of human head exposure to such devices evaluating some important parameters, i.e., Specific Absorption Rate (SAR) and superficial temperature increasing. Within this framework, it is important to underline that WLAN systems use almost omni-directional antennas. The user can be close to the radiating antenna, where the ElectroMagnetic (EM) field assumes its highest values. As a consequence, it is important to consider the possible health hazard due to such systems and, in particular, to define criteria and thresholds for human safety [3].

In this paper, our goal is to verify if actual standards in wireless devices respect the Institute of Electrical and Electronic Engineers (IEEE), European Committee for Electrotechnical Standardization (CENELEC) and International Commission on Non-Ionizing Radiation Protection (ICNRIP) standards [4] - [7]. Particularly, our aim is to quantify the absorbed power by a biological organism exposed to a EM field and determine its distribution considering EM field that propagates inside several scenarios [8]. This work presents a numerical approach based on Finite Element Method (FEM) and it is divided into two phases. First we realize the indoor environment and set antenna specifications to evaluate EM field that propagate inside several scenarios. Afterward, using previously information, we adopt a FEM approach for geometrical and physical modeling of a human head. Simulations let us to determine how much of EM field is absorbed by the human head model and which are its effect.

II. STATE-OF-ART OF FIELD EXPOSURE

Human tissues exposed to EM field interact with it absorbing its energy and producing different effects depending principally on its frequency. We focus our attention on effects produced by high frequency radiations and particularly, as said before, at 2.45 [GHz], because of our interest in WLAN applications. Dosimetry is the science that quantify the interaction between an EM field and a biological tissues. The problem consists in the quantification of the absorbed power by a biological organism exposed to a EM field and determine its distribution. The analysis can be consequentially reduced to the determination of a parameter called SAR that expresses the power absorbed per unit of mass, as in (1):

$$SAR = \frac{\sigma \|\mathbf{E}\|^2}{\rho}\ [W/Kg] \qquad (1)$$

where σ is the conductivity of human brain tissue, ρ the density and $\|\mathbf{E}\|$ is the norm of the electric field.

The SAR value is an average over a region either 10 [g] or 1[g] of brain tissue, depending on national rules. The numerical approach used in this paper in order to determine this parameter is quite used and analog procedure are described in literature especially referring to EM field generated by cellular phones. Although this, studies about the interaction of EM field with human bodies were investigated since ‘80s when Wi-Fi technologies didn’t exist yet. Revolution in this sector has started in ’90s when computer more powerful and software more sophisticated were developed. The analysis has been concentrate in single part of human body (e.g. the head) and not to whole body since high frequency radiations. The main advantage of actual tools is the precise modeling of human head by importing MRI images and setting the parameters of different tissues. Evaluating WLAN field exposure is different from studying cellular radiations in head because the field source can be generally in close proximity to the user but not so near as in mobile telephone cases. In addition, it must be considered the effect of interaction of the field with the environment, so it has to model not only the direct radiation, but also the effects of scattering. Due to larger scenarios, FE approaches is affected by high computational complexity.

III. APPROACH TO THE IN-STUDY PROBLEM

The assessment is done numerically using two different approaches, respectively Ray-Tracing model and Finite Element Method (FEM).

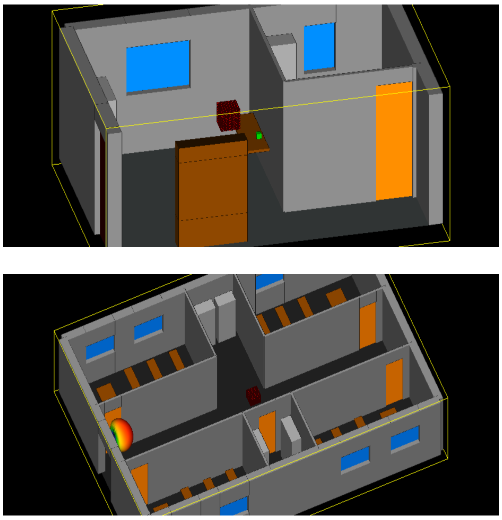

Fig. 1. Example of geometrical representations of a two different scenarios exploited with Ray-tracing approach

The dual approach is due to the fact that in presence of large scenarios, FEM is affected by high computational complexity. In order to decrease the computational load of FEM, we reduced the in-study environment, reproducing indoor scenarios in a Ray Tracing based environment, evaluating the EM field propagation and retaining the results for the subsequent FEM based step. Within this framework, Maxwell equations have been exploited to calculate energy filed that invests the head model. Particularly, our model solves the vector Helmholtz equation everywhere in the domain for an imposed frequency: $\nabla\times(1/\mu_r)\nabla\times\mathrm{E}-k_0^2\varepsilon_r\mathrm{E}=0$. Here μ_r is the relative permeability, k_0 is the free-space wave vector, and ε_r is the permittivity for a vacuum. Constant values of brain tissues have been taken from a G. Schmid presentation [9]. To evaluate temperature increases, moreover, Bio-heat equation has been exploited [10]: $\nabla\cdot(-k\nabla T)=\rho_b c_b \omega_b (T_b - T)+Q_{met}+Q_{ext}$. Here ρ_b is the density, c_b the specific heat, ω_b the perfusion rate and T_b the temperature of blood respectively; Q_{met} the metabolic and Q_{ext} the spatial termic source respectively. Different scenarios have been evaluated, mainly considering the hot-spot and the human being located in two different rooms. Numerical models remarked how intensity of SAR and temperature increments, as well as the exposed area of the human head, are strongly affected to the presence of obstacles or separation surfaces. The inspected quantities, in fact, change according to direct or scattered absorption of electromagnetic waves by the human head. More details will be given in the full paper.

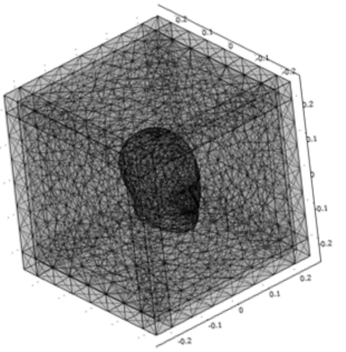

Fig. 2. Geometrical representation and mesh of human head in FEM approach.

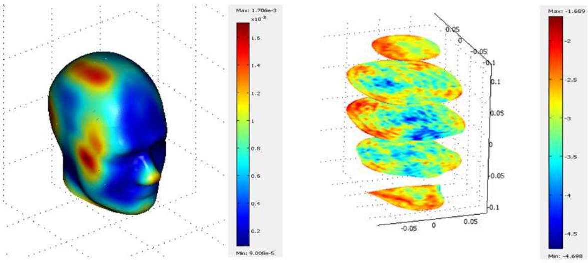

Fig.3. Surface plot of temperature distribution (on the left) and Slice view of SAR distribution (on the right)

IV. REFERENCES

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