MODELLING AND SIMULATION OF THE ELECTRIC FIELD STRENGTH DISTRIBUTION IN A HUMAN HEAD MODEL BY 2,4 GHZ RADIOFREQUENCY RADIATION

Z. Pšenáková, M. Šmondrk, M. Beňová

Faculty of Electrical Engineering, University of Žilina, Univerzitná 1, Žilina, Slovakia

e-mail: zuzana.psenakova@fel.uniza.sk, maros.smondrk@fel.uniza.sk, mariana.benova@fel.uniza.sk

Abstract

The issue of effects of radiofrequency radiation to human body is discussed very often in this time. This paper deals with modelling and simulation of the electric field strength distribution in human head model by 2.4GHz radiofrequency radiation using COMSOL Multiphysics.

1 Introduction

The increased use of wireless technologies in last decade leads to increased level of electromagnetic radiation to which human are exposed. Since the potential physiological effects of radiofrequency radiation and its thermal and non-thermal effects are still under scientific investigation, the specific absorption rate or the induced current density in human body is evaluated for health risk assessment. In general, it is very difficult to measure internal electric field intensity or temperature elevation in the human body using non-invasive methods. Therefore the common way to do this is to use modelling tools such as COMSOL Multiphysics. The aim of this study was to model and simulate the electric field intensity distribution on the surface of the human head model exposed to a Wireless Fidelity (Wi-Fi) antenna embedded in cellular phone.

2 Methods

The electromagnetic waves problem is addressed in the wave equation for intensity of electric and magnetic field. Distribution of the electric field strength **E** is defined as follows:

$$\nabla \times \mu_r^{-1}(\nabla \times E) - k_0^2\left(\varepsilon_r - \frac{j\sigma}{\omega\varepsilon_0}\right)E = 0 \qquad (1)$$

and distribution of magnetic field strength **H**:

$$\nabla \times \left(\left(\varepsilon_r - \frac{j\sigma}{\omega\varepsilon_0}\right)^{-1} \nabla H\right) - \mu_r k_0^2 H = 0 \qquad (2)$$

where k_0 – is wave vector in free space, ∇ - rotation vector operator, ε_r – relative permittivity, ε_0 – vacuum permittivity, μ_r – relative permeability, σ – electrical conductivity and ω – angular wave frequency [1]. The effects of external exposure to radiofrequency radiation on the human head depend mainly on the exposure time and strength of the electromagnetic fields [2]. Knowing these quantities and physical parameters of exposed tissue, it is possible to evaluate the specific absorption rate (SAR). The SAR is measure of the rate at which energy is absorbed by the tissue when exposed to the electromagnetic field. It is defined as:

$$SAR = \frac{\sigma|E|^2}{\rho} \qquad (2)$$

where $|\mathbf{E}|$ is norm of electric field intensity, σ – electrical conductivity of a particular tissue and ρ – mass density of particular tissue [3].

We used the software COMSOL Multiphysics to solve spatial distribution of electric field intensity by using a combination of the human head model and model of antenna embedded into a cellular phone [4, 5]. The artificial human head model provided by COMSOL Multiphysics comprises a different thicknesses layers; modelling the skin, bone, and brain tissue. In this paper, we have been interested in the head surface distribution of the electric field intensity. Therefore, we have taken into account only geometrical shape of the human head model. This shape was modelled as a skin layer having the material properties summarized in Table 1.

Table 1: ELECTROMAGNETIC PROPERTIES OF THE SKIN TISSUE FOR 2.4 GHZ ACCORDING TO THE IT'IS DATABASE FOR THERMAL AND ELECTROMAGNETIC PARAMETERS OF BIOLOGICAL TISSUES [6].

Relative permeability	1
Electrical conductivity	1.45 [S/m]
Relative permittivity	38

The model of the inverted-F antenna embedded into cellular phone was used as a source of electromagnetic radiation with frequency of 2.412 GHz. Due to its multiple frequency band option and small form factor, this type of antenna is commonly used in cellular phones. The antenna was modelled as a lumped port with a reference impedance of 50 Ω and excitation voltage of 1, 5 and 10V. The metal antenna part was modelled by using a perfect electric conductor boundaries, thus eliminating losses of radiated electromagnetic energy. The distance between the mobile phone and the head model in simulation was set up to 1 cm (**Chyba! Nenalezen zdroj odkazů.**).

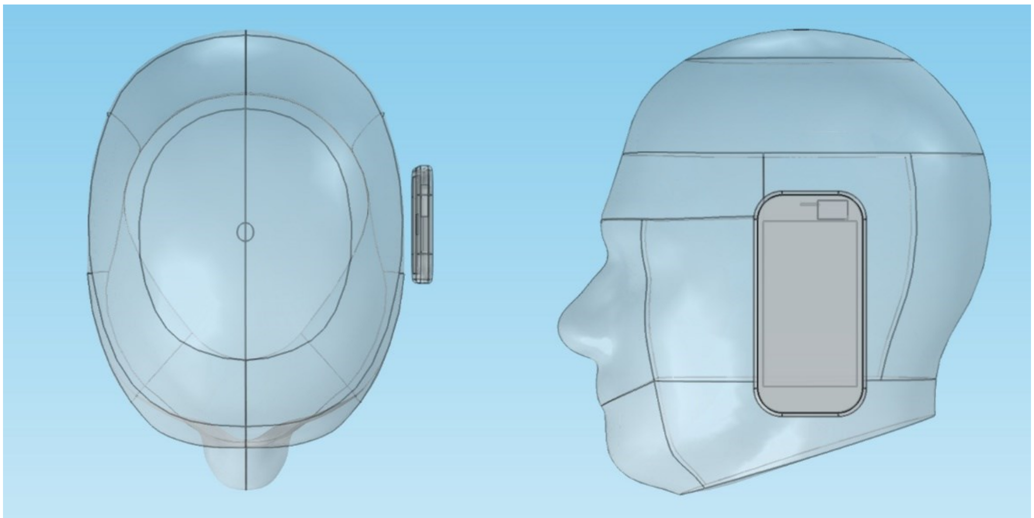

Figure 1: The geometrical layout of a used model which consists of a human head model and a model of inverted-F antenna embedded into cellular phone.

The maximal element size of the hexagonal mesh was set up to be smaller than 0.2 wavelengths, according to the program guidelines. This was performed in order to reduce solver's degrees of freedom. For the calculation of electromagnetic filed propagation, the COMSOL Multiphysics uses the proven finite element method.

3 Results

First of all, the impedance matching properties of the antenna were calculated in terms of S-parameters for frequency band of Wi-Fi. The figure 2 illustrates the antenna far-field norm in horizontal plane and the antenna far-field radiation pattern.

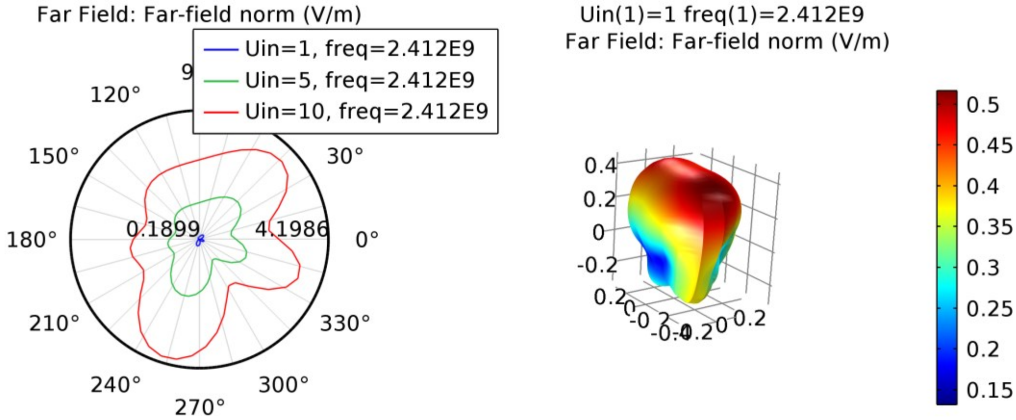

Figure 2: The antenna far-field norm in horizontal plane and far-field radiation pattern.

The spatial distribution of electric field intensity norm for three different voltage levels of antenna excitation is reported in Fig. 3. The maximal instantaneous values of electric field intensity were 57.9V/m, 290 V/m and 579 V/m for excitation of 1V, 5V and 10V, respectively.

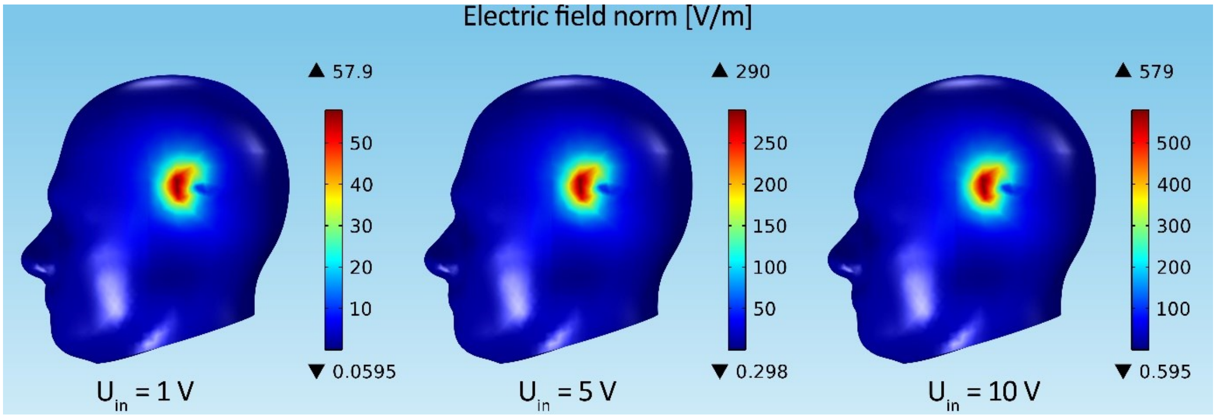

Figure 3: The geometrical layout of a used model which consists of a human head model and a model of inverted-F antenna embedded into cellular phone.

According to the Radiation Protection Standards [7], measured values are within maximum exposure limits. The results of simulation has shown that higher excitation voltage leads to higher electric field intensity values. However, its spatial distribution was constant because the changes of antenna radiation pattern were negligible.

4 Conclusion

The interaction between the human head and electromagnetic radiation caused by cellular phones can induce electric currents and electric fields inside human head, what could lead to side health effects. This phenomena could be simulated by using modelling tools such as COMSOL Multiphysics. Knowing the exact internal structure of human head in terms of its electrical, magnetic and other material parameters, the COMSOL Multiphysics could be used to simulate and calculate the SAR which would be our further step.

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Ing. Zuzana Pšenáková, PhD.
Department of Electromagnetic and Biomedical Engineering,
Faculty of Electrical Engineering,
University of Žilina
Univerzitná 1
010 26 Žilina
Slovak Republic
tel.: +421+41-513 2142
email: zuzana.psenakova@fel.uniza.sk

Ing. Maroš Šmodrk
Department of Electromagnetic and Biomedical Engineering,
Faculty of Electrical Engineering,
University of Žilina
Univerzitná 1
010 26 Žilina
Slovak Republic
tel.: +421+41-513 5062
email: maros.smondrk@fel.uniza.sk

doc. Ing. Mariana Beňová, PhD.
Department of Electromagnetic and Biomedical Engineering,
Faculty of Electrical Engineering,
University of Žilina
Univerzitná 1
010 26 Žilina
Slovak Republic
tel.: +421+41-513 2119
email: mariana.benova@fel.uniza.sk