A FEM Model of Human Head to Show the Risk of Brain Tumors When Using Cell Phone Over a Long Period of Time

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Abstract: - In this paper, the interaction of electromagnetic field (EF) and human head is modelled at 1800 MHz by using Finite Element Method (FEM), to bring to the fore imperiled areas and therefore to show the risk of brain tumors when using cell phone over a long period of time. Complexity of tissue structure imposes a need for explaining performed modelling results in more detail. Different tissue properties assigned to every element in the model are given in the form of a table. The results of a new and recent epidemiologic studies confirm the obtained results.

Key-Words: - Electromagnetic field – Human head - Finite Element Method – Imperiled areas - Epidemiologic studies

1 Introduction

Potential health risks with the increasing use of cell-phone have been pointed out in previous studies [1-4]. Many committees have been set and research programs were initiated with the collaboration of many countries.The main objective of this paper is to contribute on these research programs. Operating such a device is based on the use of radiofrequency (RF) electromagnetic field with a frequency of 1800 MHz. The consequences of tissue heating, for which radiofrequency magnetic is mainly responsible, are especially investigated for the tissues placed in a human head, because temperature elevation of these tissues could influence a change on the functional level. Although in the literature, many different numerical solutions concerning interactions of electromagnetic fields with human body at different frequencies exists, few studies are available at operating frequency of the frequently used cell-phone device [5]. To our knowledge, there exists no detailed study of the interaction of RF electromagnetic field and head at this frequency. This is the reason why finite element simulation of power deposition in a human head during exposure to RF frequency of cell-phone is performed in this paper. Furthrremore, to confirm the obtained results, we draw one's inspiration from the results of a new and recent swedish epidemiologic studies [6].

2 Applied Numerical Method

The calculations of the power deposition in the human head are performed by Finite Element Method (FEM) using isoparametric 3-D elements with 26 nodes. A very convenient property of it is the ability of modeling complex bent structures of tissues with different dielectric properties, because of the adaptable shape of the basic elements. Isoparametric formulation defines the relationship between the element quantities at any point inside a finite element and the element nodal quantities directly through the same interpolation function (higher order polynomials) for all the quantities. In this way, much higher accuracy is achieved in comparison to that of a linear interpolation [7]. Additionally, a much smaller number of the elements has to be modeled for the same accuracy, which saves computer time and reduces requirements on the computer memory.

The relation between largest dimension of the exciting head coil (0,35 m) and wavelength in a free space (4,69 m) enable the assumption of the quasi-stationary conditions. On this basis, a magnetic field distribution of exciting saddle shaped coils were calculated by Biot-Savart's law. As described in [8] on the example of the conducting homogeneous sphere, finite element formulation is based on the A, V, and Φ formulation. Vector magnetic potential A and scalar electric potential V describe the field in the conducting region (model of human head), while reduced scalar magnetic potential Φ is implemented outside the object. At interfaces between object and surrounding space the normal component of A is set to zero according to [8,9]. At the farthest boundaries reduced scalar magnetic potential Φ is set to zero, as well.

3 Electric Properties of Tissue

The inevitable prerequisite for performing a successful numerical simulation is the use of the as real as possible values of electric properties of tissues. The latter are defined by permittivity and conductivity. Since biological materials are not perfect dielectric, the lossy term must be considered, as well as the ohmic component contributed by the number of charges' carriers (ions). Thus, the complex conductivity which takes into consideration all these contributions has to be applied ($\sigma^*=\sigma'+j\omega\varepsilon_0\varepsilon'$). Used values of σ' and ε' for the numerical simulation are given in the Table 1.

Tissues	Conductivity σ'(S/m)	Permittivity ε'
Bone	0.04	26
Cartilage	0.04	26
White matter	0.4	70
Skin	0.73	73
Dura	0.73	73
Blood	1.15	80
Muscle	0.80	84
Nerve	0.47	90
Eye (vitreous humour)	1.9	100
Gray matter	0.65	105
CSF	0.625	106

Table 1: Conductivity σ' and permittivity ε' of the tissues at 1800 MHz used in simulation

4 Numerical Model of Head

Basic principle followed in the head-modelling was considering the anatomical shape and the significant changes in electric properties, i.e. following as fine as possible complicated structures of different tissue, skin, dura, white and gray matter, cerebrospinal fluid, nerves, eyes (vitreous humour), blood, muscles and bones. The aim of relatively fine description of the shape and internal structure (in comparison to the simpler models of homogeneous spheres or cylinders [10] was achieved with a reasonable low number of elements. This description was necessary because of the suggestion that local power deposition can be much higher than in superficial tissues due to homogeneous structures [11]. The head model consists of 11 slice was divided into 296 elements. Our calculation doesn't enforce the same shape for all the elements, which is a profitable advantage for modelling complex structures, but it requires also some constraints in the modelling. On refers to the condition that all the interior angles of the elements must be smaller than 180 degrees to ensure the non singularity of the Jacobian operator relating the natural (global) coordinate derivatives to the local coordinate derivatives. Satisfying the convergence criteria is possible only with complete and compatible, i.e. conforming elements as well a with the same number of elements per slice and the same distribution of elements (i.e. nodes) in each slice. The last restriction is maybe the strongest limitation of the finite element method applied in this kind of calculation.

Applied A, V and Φ formulation and related boundary conditions forced a modelling a surrounding space, which resulted in two additional slices and enlargement of the number of elements per slice. Applied external high frequency magnetic field was generated by a saddle-shaped head coil. As mentioned, the exciting magnetic field on the interface between the tow main areas (air-head) was calculated by Biot-Savart's law.

Summarising, the model of a head with the surrounding space consists for 13 slices with 4420 macroelements with 9 different electrical properties (assigned to every element, according to the Table 1), which can be, if necessary for more detailed investigations, further divided into finite elements.

5 Numerical Results

As shown in Fig. 1, there is a power deposition (hot-spot – imperiled areas) on the side of the human head where the cell phone is used. According to the possible accumulation of heating effects when using cell phone over a long period of time, we can assume that they could have biological damage.

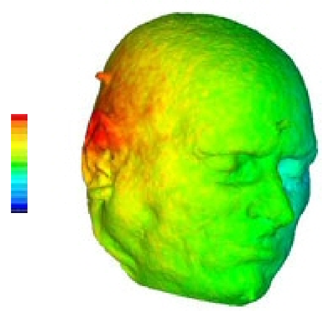
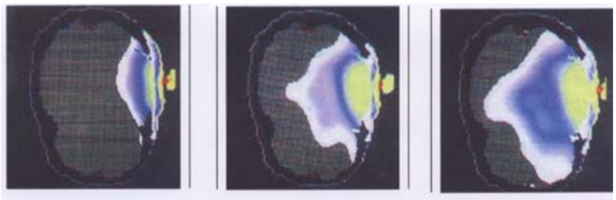


Fig. 1: Power deposition (hot spot - imperiled areas) in the human head (3D view) (scale: [blue to red]: [0,295E+01 to 0,308E+06 W/m^3 power deposition])

When studying the case of children, teenager and adult, by varying the conductivity σ' and permittivity ε', we note also that the risk depend on the age of the user because electric properties of the tissue are different for each age (Fig. 2). For example, it is shown that a child is more exposed on the risk (Fig. 2c) than an adult (Fig.2a).



a/ For an adult b/ For a teenager c/ For a child

Fig. 2: Power deposition (imperiled areas) in the human head (cut view from behind).

6 Validation

Because widespread cell-phone use is little more than a decade old, there has been limited opportunity to examine its long-term health effects. Moreover, experimentation with the human head is not possible because of the tissue damage caused by the experimental procedure. However, to confirm the obtained numerical results we can take as a reference many existing results in the literature, like the new and recent epidemiologic studies realised by the team of the Professor Kjell Mild [6]. The adopted approach is the next. The scientist examined cell-phone use among 905 people who had a brain tumor and compared them to a control group of 905 healthy people. All the volunteers were aged 20–80. 85 of the 905 people who had a malignant tumor were high users of cell-phones. They started using cell-phones a long time ago and have used them a great deal on average for about an hour a day. It is confirmed that if we spend many years using our cell-phone at least one hour a day, the risk of developing a brain tumors is 240% higher than a person who never uses one. In the other hand, the researchers found that even the location of the tumor, for extensive cell-phones users over many years, tends to be on the side of the head where the cell-phone is used. We note that the team's definition of a extensive use means over 2000 hours of cell-phone use, spread over many years. There is an agreement between both results.

7 Conclusion

Although the structure of a human head consists of different kind of tissues which are inhomogeneous and exact values of their dielectric properties cannot be measured, the simulation results show high accuracy of imperiled areas in human head exposed on EF radiated by cell-phone. The obtained results is in agreement with the epidemiologic studies results which confirm that the use of cell-phone over a long period of time can raise the risk for brain tumors. Thus, it was proven that the applied FEM gives highly reliable results, and can describe correctly the interaction of EF with complicated heterogeneous structures as for example human organism. Of course, the main problem of an experimental results still remains. Also, different other approach to the validation of the results are necessary, especially to detect non-thermal effects. So we propose the use of brain mapping and EEG tests before and after EF exposure. This is a good background for a further extension of the research in the extension of the numerical method to a higher frequency band.

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