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INVESTIGATION OF IMPACT OF HIGH-FREQUENCY ELECTROMAGNETIC FIELDS ON HUMAN BODY

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Abstract: An important topic of these days is the impact of high-frequency electromagnetic fields on biological objects especially on human body. To determine it generally, theoretical and experimental methods are used. The paper deals with some of these methods. For the sources of high-frequency electromagnetic fields, mobile phones and base stations have been considered. Because of impossibility to obtain an exact solution of Maxwell´s equations in analytical form(except for some simple cases), the simulations belong to preferred methods.

Keywords: High – frequency electromagnetic fields, mobile phones, base stations, biological effects of EM fields, simulation methods.

1 Introduction

Electromagnetic exposure of biological objects and human rapidly increased during last decades as a result of information and telecommunication technology progress. First interactions of HF EM field with nerve - muscle biological tissues were observed in the end of 19-th century. Nowadays not only physical mechanisms but also first scientific knowledge of long-term effects of these fields on human health and environment are known. With the development of Global System for Mobile Communication (GSM) in nineties of 20-th century that was accompanied by expansion of telecommunication and information technology to the microwave frequency band of electromagnetic spectrum, qualitatively new changes have taken place. For frequency band over 300 MHz thermal conversion of EM energy radiation at bonds of hydrogen atoms is typical. We can say, that effect of high-frequency electromagnetic field

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causes a temperature rise in biological tissue. In general, effects of electromagnetic field can be thermal and non-thermal.

2 Interaction of electromagnetic fields with biological tissue

Let us consider linear ideal isotropic dielectrics. Complex electric qualities in any material medium are characterised by dielectric constant ε and dielectric losses $tg\delta$. For purely practical reasons, dielectric constant ε is replaced by relative dielectric constant ε_r that expresses, how many times is given material medium (ε_{env}) electrically more "impassable "than a vacuum (ε_0) i.e. $\varepsilon_r = \varepsilon_{env} / \varepsilon_0$. For light velocity is given by $c = (1/\sqrt{\mu_0 \varepsilon_0}) = 300\ 000$ km / s, velocity in any mass medium with relative dielectric constant ε_r is then $v = c/\sqrt{\mu_r \varepsilon_r}$ here μ_r is relative magnetic permeability. Biological tissues have $\mu_r = 1$ and velocity is $v_b = c/\square\varepsilon_r$. Similarly, wavelength of EM wave in vacuum λ_0 defined by the expression $\lambda_0 = c/f$ is shortened proportionally to ε_r i.e. $\lambda_r = \lambda_0/\square\varepsilon_r$. At lower frequencies physical mechanisms of interaction EM wave with biological medium show itself with the agreement with conductive characteristics of electrolytes. Dielectric qualities of any medium become fully evident until higher frequencies. The frequency, starting from which the complex dielectric qualities of the medium begin to predominate over conductive qualities, is indicated as critical one i.e. , f_{crit}. In medium with characteristics close to biological medium $f_{crit} = 300$ MHz ($\lambda_0 = 1$m) and in distilled water $f_{crit} = 900$ MHz ($\lambda_0 = 0{,}33$m). An important quantity is so called penetration depth of electromagnetic wave to material medium $L = 1/e^{\beta\lambda}$, where β is a propagation constant. In biological sciences a half-depth of penetration of electromagnetic wave [1] is well-established quantity, defined as distance from interface of two dielectrics, when initial amplitude (magnitude) of electromagnetic wave goes down to one half of its value. In biological tissues, where magnetic characteristics of a medium can be neglected, half-depth is as a rule given by $L \square \lambda_0/\varepsilon_r$.

3 Mobile phones and their base station masts as sources of high- frequency EM fields

Exposure of biological objects and then a human being has exponentially increased for last decades. In European countries there were installed over some tens of millions of mobile telephone stations in frequency band that is unfavourable to biological objects. Older type of mobile system NMT (analogous) works in frequency band of 450 MHz, widely used GSM (digital) works in frequency band of 900 MHz and 1800 MHz, the latest system PCS works in frequency band of 1950 MHz. Shortly after that the 3G technology will be introduced working in the band of 2900 MHz. Interaction of all of these frequencies with biological objects is very adverse. Still very little work has been done on the long- term health implications of mobile phone use. In fact this type of research is really only starting to happen now. This means that current mobile phone users are acting as involuntary, and often unsuspecting, test subjects. They are often reporting headaches, skin tingling or twitching, eye "ticks", poor memory, buzzing in their ear at night, and other effects.

Mobile-phone base station masts emit a continuous stream of microwave pulses radiation level of which is usually quite low. It depends on the size of region or "cell" that they are designed to service. They use linear RF power amplifiers, typically 40W and broadcast on a number of frequencies simultaneously. On digital systems the power effectively rises as more calls are active and there are no missing time slots. Maximal value of EM fields from the mast, at its ground level, is usually between 30 ÷ 100m from the mast. At 150m from the mast, signal level is equivalent to 0,003 W/m^2 (0,3 $\mu W/cm^2$), that is comparable to the radio and television signals that already surround us. Energy of EM field is absorbed in the body and produces heat, but the normal thermoregulatory processes of the body carry this heat away.

4 Investigation of EM field interaction with human body

EMF radiation can be investigated both theoretically and experimentally. Measurements may be realized on voluntary persons, or in laboratory condition, or some adequate models with dielectric properties equal to those of parts of the human body can be constructed and then exposure by EM field can be measured. There have been developed various types of such models. In testing of simpler models obtained results are not accurate ones and models where various characteristics of single types of tissues are taken into account are very expensive. Simulations are very perspective methods of investigation of EM field both of its source and receiver. In recent years one of these methods has become very popular. It was for the first time introduced by Kane S. Yee [2] and it is called The Finite Difference Time Domain (FDTD) method.

The Maxwell´s equations in an isotropic medium are given in form:

$$\frac{\partial \bar{B}}{\partial t} + \nabla \times \bar{E} = 0$$

$$\frac{\partial \bar{D}}{\partial t} - \nabla \times \bar{H} = \bar{J}$$

The system of the six equations can be written as six scalar equations in Cartesian coordinates where each magnetic field component is dependent on two electric field components orthogonal to its direction and each electric field component is dependent on two magnetic field components orthogonal to its direction. It forms the base of the Yee´s algorithm.

$$\frac{\partial H_x}{\partial t} = \frac{1}{\mu}\left(\frac{\partial E_y}{\partial z} - \frac{\partial E_z}{\partial y}\right) \qquad \frac{\partial E_x}{\partial t} = \frac{1}{\varepsilon}\left(\frac{\partial H_z}{\partial y} - \frac{\partial H_y}{\partial z} - \sigma E_x\right)$$

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A 3D region under consideration is divided into cubical rectangular cells. Central finite difference approximations for space and time derivatives are used for transformation of these scalar equations to discrete form [2]. Then all field components are calculated in each time step. To yield accurate results, the grid spacing δ in the finite difference simulation must be less than the wavelength λ, usually less than 1/10 of λ. Then the cells are small enough to give the results with accuracy required. Generally it is recommended not to exceed the number of the cells to the order of 1 million on modern computers, otherwise the simulation is demanding relate to computational time and memory of the computer.

5 Conclusions

Paper deals with influence of high-frequency electromagnetic fields to human body. Some problems concerning to investigation are indicated. The use of FDTD method is under development and it request still much work.

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