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INTERACTION OF ELECTROMAGNETIC FIELD WITH HUMAN ORGANISM AND SOME INVESTIGATION METHODS

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Abstract: Paper deals with some effects of various kinds of electromagnetic fields on human body. Some methods of investigation are introduced.

Key words: EM fields, interaction of EM fields with human body, methods of investigation, theoretical approach, visible light, heat and human organism, high-frequency electromagnetic fields

INTRODUCTION

Existing electromagnetic fields are of various kinds. They differ from one another by their sources, frequencies, wavelengths, characters and effects on human body. Because of problem complexity, usual approach is to investigate individual kinds of EM fields separately. Thus obtained data of EM field quantities are processed and consequently analyzed. It is very useful from the point of view of their possible health risks.

But EM fields of various kinds act simultaneously and often at the same time and they all contribute to health effects. In the paper, some kinds of EM fields, their analysis and their impact on human body are introduced.

1 VARIOUS ELECTROMAGNETIC FIELDS AND HUMAN ORGANISM

Wavelength of individual kind of electromagnetic fields is different and the way in which they affect living organism is different too. Problem is very wide and that is why the paper deals only with some kinds of electromagnetic fields and their influence on human health. Studies in the paper are concentrated to the part of electromagnetic fields belonging to non-ionizing radiation. In this context we consider only visible part of whole electromagnetic spectrum, visible light coming from its natural source i.e. Sun or from artificial sources as lamps, bulbs, etc. Heat in this paper is meant firstly as heat used for healing (produced by infrared lamps, or special equipments) and heat produced as a secondary

consequence of radiation from high-frequency sources of electromagnetic fields, mainly from mobile phones.

1.1 Light and human health

For more than last two centuries there has been good knowledge about vision system in humans but we do not know as much as we have thought. The newest research indicates that our knowledge of light and lighting and their influence on living organism is not satisfactory yet. It is necessary much to learn for better understanding of these issues. After there will be more information about light and lighting, then brand new criteria for design of indoor lighting need to be created and came to the practice during next few years.

Recently, neurobiologists have discovered a photoreceptive sensory system situated in eye, but not involved in vision [1], [2], [3]. There is necessity of good understanding all relationships between visual, photoreceptive non-visual and human circadian (biological rhythm) system. But there are still many unexplained things, e.g., what is the system in which living organism (humans, mammals...) senses decreasing amount of light after sunset. Organism of people who have lost their vision or have been blind from their birth surely has developed other way of circadian rhythm setting and regulation.

Health effects of light and lighting can be roughly divided into two groups: favourable and unfavourable wanted and unwanted. Artificial light of certain wavelengths is often successfully used for treatment of

some psychical disorders, e.g. SAD (Seasonal Affective Disorder), some skin problems, problems connected with shift work and jet lag etc. Unfavourable effects of artificial lighting are sleep disorders, eyes tiring and inflammation, breast cancer risks, etc.

1.2 Heat and human health

Similarly as in the case of light, thermal effects of electromagnetic fields can be wanted and unwanted. Healing effects of heat are known for more than 2000 years. Heat therapy is used for bone regeneration, for chronic wound healing, for cancer treatment, for detoxification of organism, for treatment of pressure ulcers, for relief of back pain and back injuries etc.

On the other hand, heat may represent a danger for living organism. Most often it is overheating of organism mainly during hot summer days. Some groups of people, children, elderly, etc. are more sensitive to high temperature. First of all it is a problem of big cities where fresh air circulation is poor because of high buildings and lack of trees. To the effects of heat that may represent potential risk for human health, belong also thermal effects of high frequency electromagnetic fields. One of most frequently used appliances acting as a source of those fields is a cellular (mobile) phone widespread all over the world among all age's groups of people.

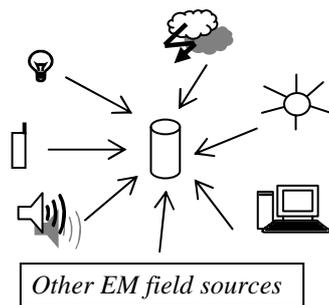


Fig.1: Various sources of EM fields affecting human organism

2 THEORY

All abovementioned problems are connected with electromagnetic fields that are all around us and also within us. There is a need to find true and accurate relationships for interaction between electromagnetic fields from external sources and electromagnetic field produced by living organism itself.

Theoretical background for describing of all problems of electromagnetic fields in a medium is based on Maxwell's equations

$$\begin{aligned} \text{rot}\mathbf{E} &= \mathbf{J} + \frac{\partial\mathbf{D}}{\partial t} & \text{div}\mathbf{D} &= \rho \\ \text{rot}\mathbf{H} &= -\frac{\partial\mathbf{B}}{\partial t} & \text{div}\mathbf{B} &= 0 \end{aligned} \quad (1)$$

According to usual classification of electromagnetic phenomena in various media and at various frequencies,

equations then are modified and solved. Only few problems (with simple geometry) may be solved analytically. In most cases it is obvious using of various simulations. There are many of them usually derived from the finite element method. Because complexity of the problem, some simplifications need to be used. Then there is a question of accuracy and validity of obtained data. They need to be, where possible, compared with experimental data. But it is not always possible.

For serious information of biological response of living organism to EM fields it is necessary to have huge amount verified data. It must also be taken into account that various kinds of EM fields act simultaneously not separately. It is difficult to say that one concrete kind of EM field causes certain health problem without evaluation of other kinds of field acting at the same time. Further, one kind of EM field may cause various effects and for this reason it has to be investigated from this point of view.

2.1 Some parameters characterization

Since biological tissues are non-homogeneous, nonlinear, non-ideal and anisotropic materials, the task is very difficult. The Maxwell's equations should be solved as complete system with the regard to all initial and boundary conditions, what is almost not realizable. Obtaining of field quantities is possible only after introducing of some simplifications.

The EM field properties depend on the distance from the source. We distinguish between far-field regions (EM field from base stations) and near-field regions (EM field from mobile phone antenna) [8].

In the case of EM field radiated by mobile phone, usual approach generally accepted by scientists and authorities is to investigate SAR (Specific Absorption Rate), given in watts per kilogram. Since SAR cannot be investigated or measured directly, there many phantom models of a whole human body or some of its parts (head, hand...) have been developed all over the world. But SAR itself cannot be felt but coherent heat during mobile phone calls has been widely sensed by mobile phone users.

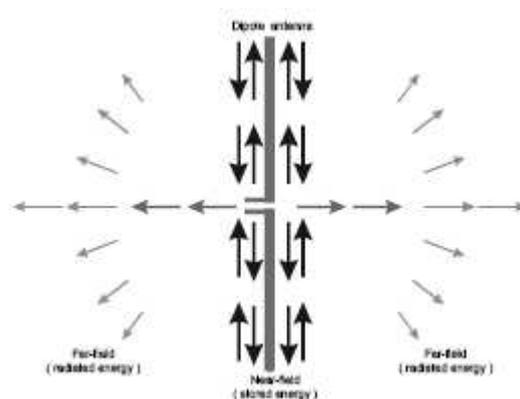


Fig.2: Electric dipole antenna showing the directions in which the electromagnetic energy flows [8]

Our approach is to determine and analyze some of parameters concerning to mobile phone radiation. During the phone call, antenna of a mobile phone radiates power. Its value changes as a function of distance from a base station and depends also at number of participants registered at this moment in mobile network and it is influenced by local environment. For abovementioned reasons, nor any model nor any simulation cannot exactly substitute or model the real situation. But since measurements cannot be performed on living things, the only way is improvement of existing methods or discovering new ones.

To calculate of power radiated by mobile phone a simple model using a dipole instead of mobile phone antenna has been used.

Energy is radiated equally in all directions i.e. at a certain radius of a sphere it is constant [6].

As seen on Fig.3, radius of the sphere is denoted as r , length of dipole is l . Then a surface element of the sphere is expressed by

$$ds = 2\pi r \sin\Phi d\Phi = 2\pi r^2 \sin\Phi d\Phi \quad (2)$$

Here Φ makes an angle between vertical axis denoted as dash line and radius r .

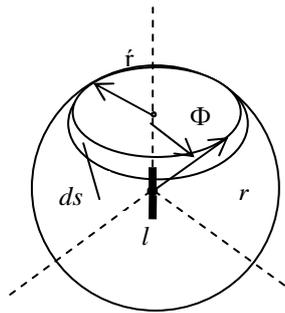


Fig.3: A simple model for calculation of power radiated by mobile phone

Then full instantaneous power through whole surface of sphere is expressed from the Poynting vector by

$$\int S ds = \int (\mathbf{E} \times \mathbf{H}) ds \quad (3)$$

After substituting components modules of electrical and magnetic intensity vectors and editing we get [6]

$$\int S ds = 20 \frac{l^2 \omega^2}{c^2} I^2 \quad (4)$$

The term $20 \frac{l^2 \omega^2}{c^2}$ is so called radiating resistance

R_z given in ohms. Radiated power is composition of root-mean-square-amperes quadrate (of antenna) I^2 and radiation resistance

$$R_z = 20 \frac{l^2 \omega^2}{c^2} \quad (5)$$

Radiated power causes heating of tissues where the mobile phone is attached, usually tissues of ear. But mechanism of heating is also connected with blood circulation in small vessels and capillary system. Real existing fields' patterns are not the same as in case of simplified models.

3 PROBLEM SOLUTION

Many works and studies have been performed in order to determine mutual acting of EM field radiated by mobile phone and human organism. Electromagnetic field quantities distribution is deformed by vicinity of human head and hand holding an apparatus, respectively.

In this work the simple model of human head and a mobile phone has been designed and solved. Two types of human head models have been created. The first was consisting of two tissues, i.e. bone and brain, and the second was created with the use of only one tissue, i.e. brain tissue. Mobile phone was modeled as a conductor. At the Fig.4, there are displayed results of a simple 2D simulation. In the case human head has been modeled as circular with flattened parts in temporal area. Model of human head was planar and problem was solved as electrostatic, not as electromagnetic. Despite this fact it can be clearly seen from intensity of electrostatic field distribution, that human head deforms field patterns and also that EM field penetrates human head.

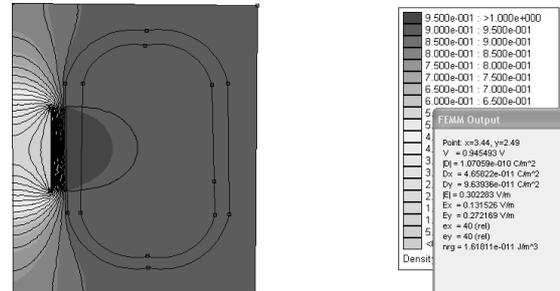


Fig.4: Equipotential lines of EM field radiated by mobile phone enclosed to human head

At the Fig. 5 the results of 2D simulation, where human head model has been circular are presented.

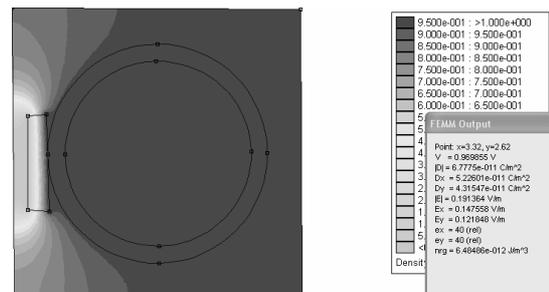


Fig.5: Distribution of electric field

At the Fig.6, there are displayed triangle elements in case of the model shown at the Fig.7.

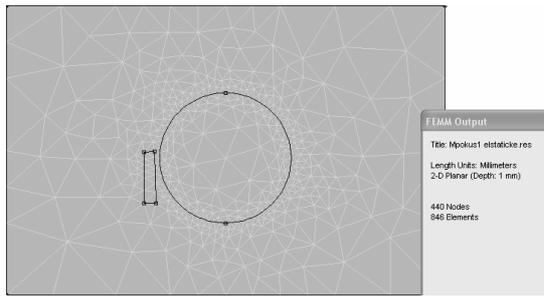


Fig.6: Model of human head and mobile with triangles

At the Fig.7, there are shown equipotential lines in case where a human head has been modeled by a circle and only with one kind of tissue, i.e. brain.

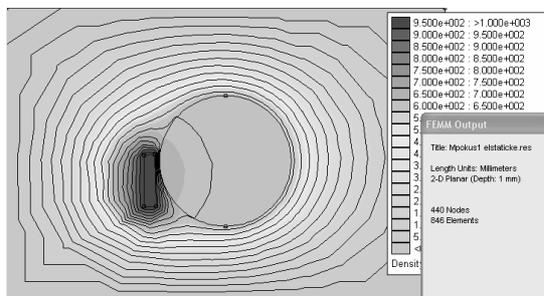


Fig.7: Equipotential lines of mobile phone EM field in case of circular model of human head

Both from theory and these simple simulations, it can be stated that EM field radiated by mobile phone penetrates the body but to determine amount of absorbed energy is not so easy. This quantity determination has not been aim of the simulation.

There has been performed also computing with other type of models, where various parameters were changed. One of them was model of human head with three tissue types, i.e., skin, bone and brain, where flattened and circular model of human head has been designed. Also parameters of mobile phone model were various. But differences between them were not so significant.

During the phone call (and not only at this moment) at the same time, also other EM fields including inner EM field of human organism, known as bioelectromagnetism, are acting .

Effects of other fields, from other sources (including EM fields from base stations) are not comprised to our calculations and for this reason their influence cannot be taken into account.

4 CONCLUSION

In the paper, problems of electromagnetic fields and their influence on human organism were introduced. Some kinds of fields has been analyzed with emphasize

to their heat and light effects. The special attention has been paid to problems of mobile phone. Models of human head and mobile phone with a simple geometry have been designed and then solved as a planar problem by the use of free available program FEMM 4.0.

Obtained results can be compared with those obtained from more accurate 3D programs, because EM field quantities distribution is analogous (due to symmetry).

Some of new discoveries from various fields enable scientists to understand of processes in living organisms better. Human organism has been well adapted during thousands of years to the Earth's electromagnetic field, but there is only very little known how it reacts to the fields radiated from man made sources. It is important to know mechanisms in which human organism maintain balance inside.

There is still much work to do. It is necessary to have more and more information about whole complex of problems concerning to influence of electromagnetic field to human organism.

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