Theoretical assessment and analysis of the distribution of internal currents in the model of biological tissues, induced by low-frequency electromagnetic fields. Message 2. Heterogeneous phantoms

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Theoretical evaluation and analysis of distribution of internal currents induced by low frequency electromagnetic fields in the model of biological tissues. Publication 2. Heterogeneous phantoms

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SUMMARY

A theoretical assessment of the distribution of induced currents under the action of alternating electromagnetic fields in heterogeneous (multilayer) phantoms consisting of sequentially located layers of skin, adipose, muscle and bone tissues was carried out using the SEMCAD X program. muscle - bone tissue) currents with the formation of their maxima at the interfaces of tissues with different dielectric characteristics.

Key words: theoretical dosimetry, low-frequency electromagnetic fields,homogeneous model muscle tissue, adipose tissue, bone tissue, internal currents.

RESUME

Results of theoretical evaluation of distribution of internal currents induced by alternating electromagnetic fields in heterogeneous (multi-level) phantom consisting of consequently located layers of skin, fat, muscle and bone tissues using SEMCAD X software are presented. The complex structure of distribution of induced currents in multi layer phantom with areas of maximum located at the borders of tissue layers with different dielectric characteristics was determined.

Keywords: theoretical dosimetry, low-frequency electromagnetic fields, homogenous model of muscle, homogenous model of fat, homogenous model of bone, internal currents.

Introduction

In the previous communication, as a result of the performed simulation, the values and frequency dependences were obtained for the induced currents in homogeneous phantoms of muscle, adipose and bone tissues when exposed to an alternating magnetic field [1]. The nature of the distribution of induced currents in homogeneous phantoms of muscle, adipose and bone tissues showed their dependence on the dielectric parameters of tissues in the investigated frequency range.

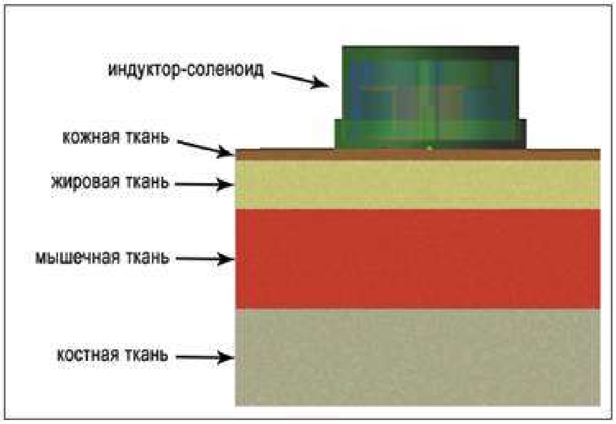
At the same time, homogeneous phantoms are only a rough approximation of the real, more complex, multilayer structure of human body tissues and can serve as starting points for subsequent, more in-depth studies.

In this regard, the purpose of this work is to theoretically estimate the induced currents under conditions of exposure to low-frequency magnetic fields in multilayer phantoms, which, to a greater extent, approximate the real structure of the tissues of the human body.

Materials and research methods

In our studies, the calculations use the finite difference method in the time domain (FTC), the mathematical apparatus of which is implemented in the dosimetry closest to the problems being solved in the SEMCAD X program (Simulation Platform for Electro-magnetic Compatibility Antenna Design and Dosimetry), developed by Schmid & Partner Engineering AG, Switzerland [1] [2].

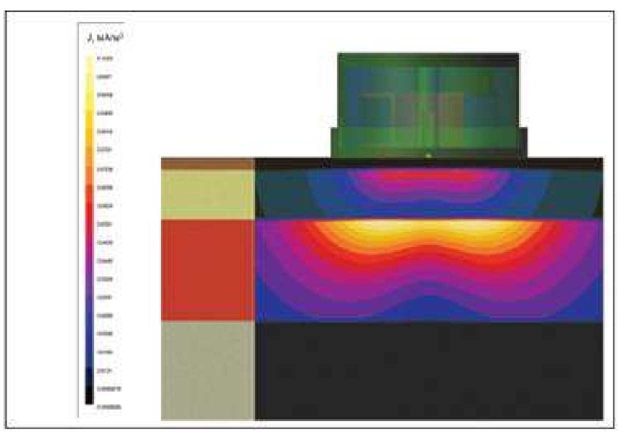
Planar heterogeneous (multilayer) phantoms, consisting of layers the following tissues: skin, adipose, muscle and bone tissue. A schematic representation of the location of the solenoid inductor on a multilayer phantom and specific linear dimensions for each of the tissue layers are shown in Fig. 1. In the calculations, the dielectric parameters of tissues generally accepted in such dosimetric modeling were used in the investigated frequency range at a temperature of 37 ° C [3]. As a source of an alternating magnetic field, a model of an inductor-solenoid of the apparatus for exogenous bioresonance therapy "MINI-EXPERT-T" was used. The simulation was carried out for the magnitude of the magnetic field induction at 2 mT, using frequencies of 9.4 Hz, 20 Hz, 100 Hz, 250 Hz, 465 Hz, 600 Hz and 800 Hz.



Rice. 1. The layout of the inductor-solenoid on a multilayer phantom consisting of skin (0.2 cm), adipose tissue (0.9 cm), muscle tissue (2.0 cm) and bone tissue (1.8 cm).

Results and discussion

As a result of the studies performed, the values of the frequency dependence and the depth of induction of currents J were obtained in a multilayer phantom consisting of layers of basic tissues (skin, adipose, muscle and bone tissue) when exposed to an alternating magnetic field at different frequencies with the same induction value. In the simulation, the solenoid inductor was located close to the surface of the multilayer phantom. The general structure of the distribution of induced currents in a heterogeneous phantom at an induction of an alternating magnetic field of 2.0 mT and a frequency of 20 Hz is shown in Fig. 2a and Fig. 2b.

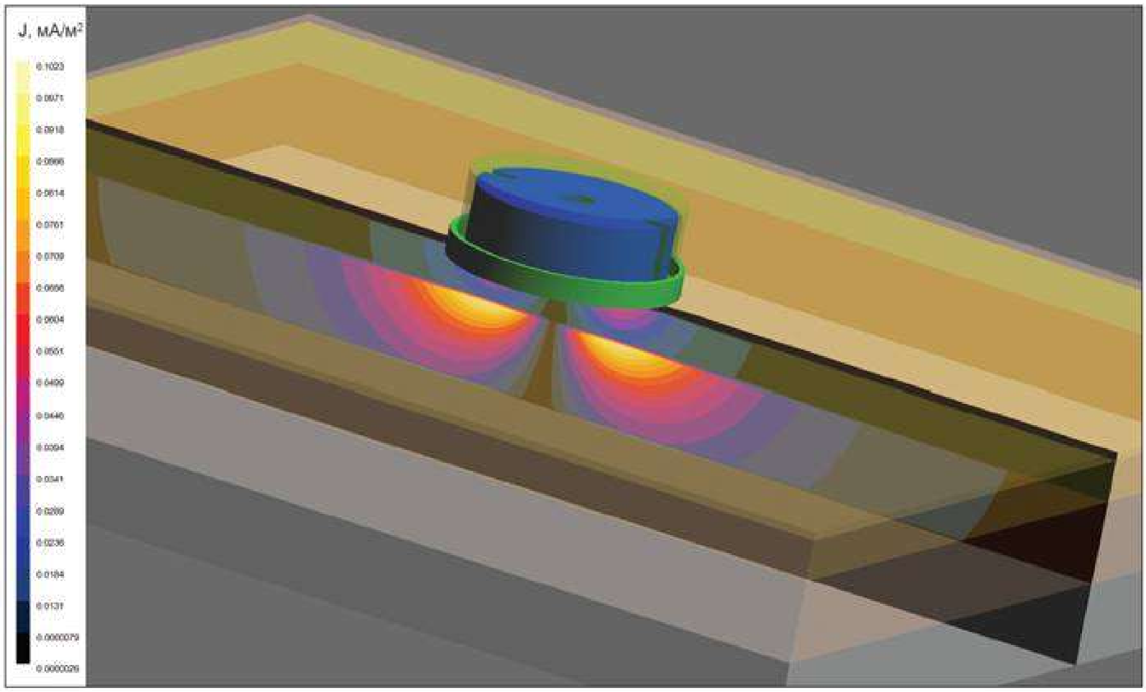


Rice. 2a. Induced current density visualizationJ in a heterogeneous phantom when the solenoid inductor is located close to the surface. The magnitude of the induction of an alternating magnetic field is 2 mT, frequency 20 Hz.

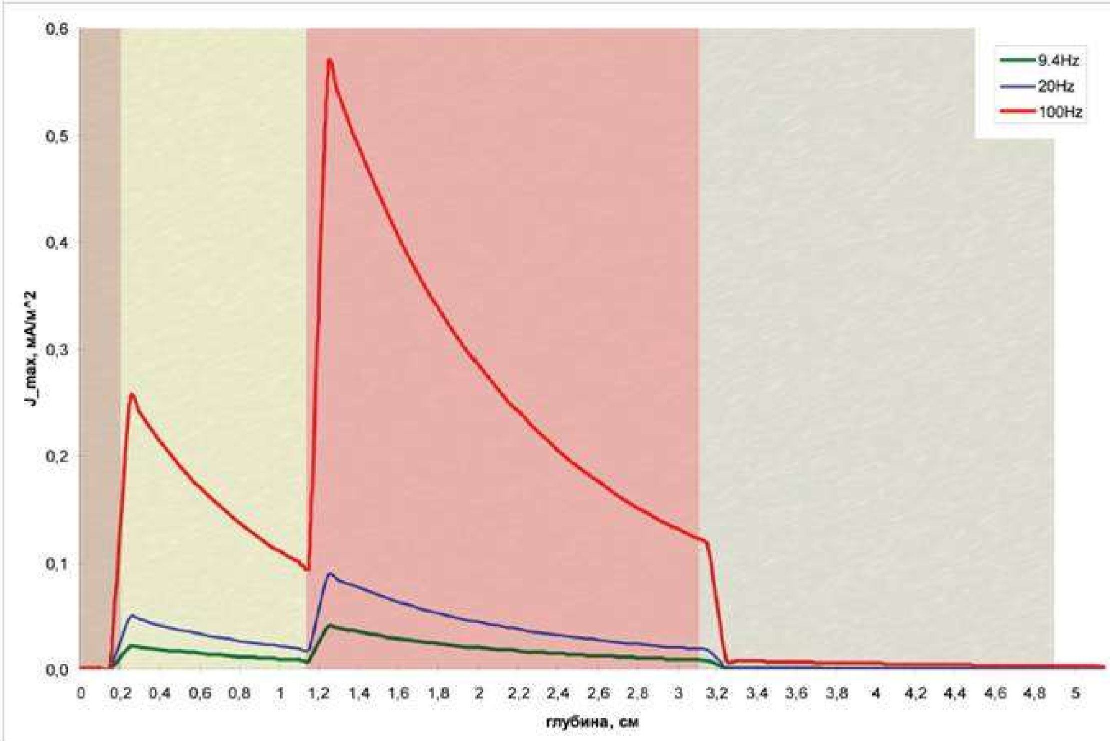
The performed simulation, the results of which for frequencies of 9.4 Hz, 20 Hz, 100 Hz are shown in Fig. 3, and for frequencies 250 Hz, 465 Hz, 600 Hz, 800 Hz - in Fig. 4.

The results obtained demonstrate the unidirectional nature of the structure of the distribution of induced currents for all frequencies used and is the same for skin, muscle, adipose and bone tissues. The maximum values of the currents induced in the structure of the heterogeneous phantom were noted in muscle (> 5.0 mA / m2 at 800 Hz) and adipose (2.0 mA / m2 at 800 Hz) tissue, and the minimum - in skin and bone tissue. Attention is drawn to the same nature of the frequency dependence for the induced currents in all tissues used in the simulation.

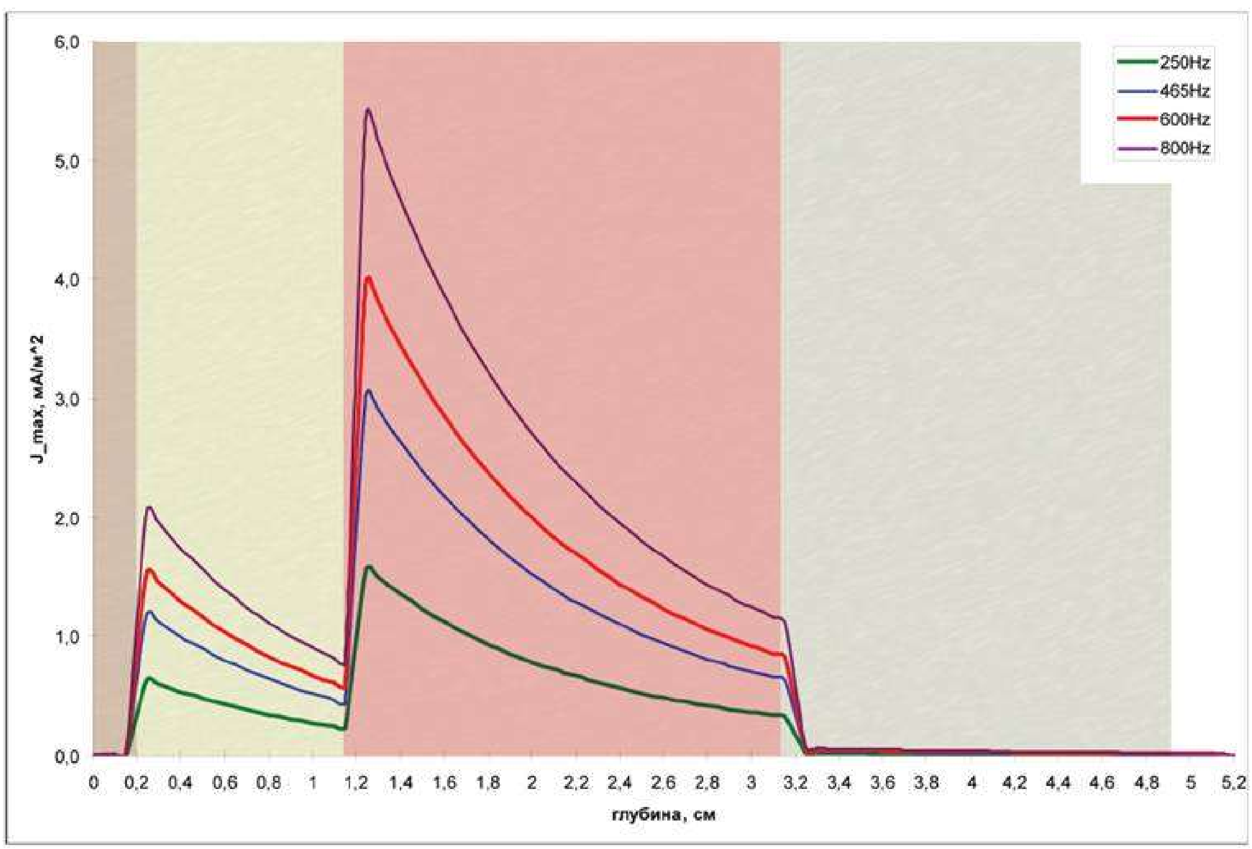
In such a complex biological structure, which is the human body, each tissue has both its own linear dimensions (thickness) and dielectric properties. All these values, as well as other indicators of the human body, vary significantly, which is associated with individual, gender and age characteristics [4].



Rice. 2b. Induced current density visualizationJ in a heterogeneous phantom when the solenoid inductor is located close to the surface. The magnitude of the induction of the alternating magnetic field 2 mT, frequency 20 Hz.



Rice. 3. The dependence of the density of induced currents (J, mA / m2) in a heterogeneous phantom that simulates skin, muscle, adipose and bone tissue when exposed to an alternating magnetic field with an induction of 2.0 mT at frequencies of 9.4 Hz, 20 Hz, 100 Hz. The solenoid inductor is located close to to the surface of the phantom.



Rice. 4. Dependence of the density of induced currents (J, mA / m2) in a heterogeneous phantom,

modeling skin, muscle, adipose and bone tissue when exposed to an alternating magnetic field with an induction of 2.0 mT at frequencies of 250 Hz, 465 Hz, 600 Hz, 800 Hz. The solenoid inductor is located close to the surface of the phantom.

First of all, to understand the processes of interaction of alternating electromagnetic fields with the tissues of the human body, it is necessary to know the dielectric properties of these tissues. According to their dielectric properties, all fabrics can be divided into two large groups: a) fabrics containing a large amount (about 70%) of water, and b) fabrics with a lower water content. Group a) includes muscle tissue, as well as tissues of organs such as the liver, kidneys, heart and brain. This group also includes blood and cerebrospinal fluid. Group b) includes tissues with a lower water content - skin, bone and lung tissue. Depending on the water content, the main parameter of the dielectric properties of tissues - electrical conductivity - also varies. Table 1 shows the values of electrical conductivity (S / m) of some tissues with high and low water content in the frequency range from 10 Hz to 1 kHz.

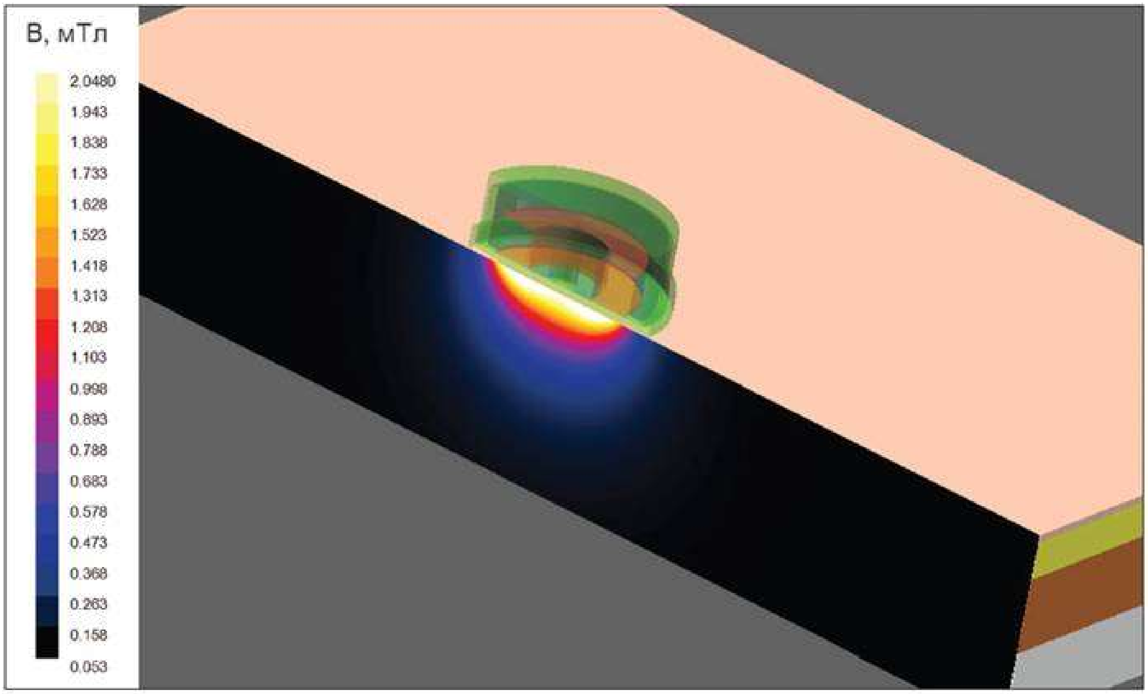
Table 1

The values of electrical conductivity (S / m) of some tissues with high and low water content in the frequency range 10 Hz - 1 kHz. According to [3]

Частота	Ткани с высоким содержанием воды						Ткани с низким содержанием воды		
	Кровь	Ликвор	Мышца (скелетная)	Миокард	Мозг (серое в-во)	Мозг (белое в-во)	Легкое	Кожа	Кость
10 Гц	0,700	2,000	0,202	0,054	0,027	0,026	0,039	0,001	0,020
20 Гц	0,700	2,000	0,207	0,062	0,043	0,039	0,052	0,001	0,020
50 Гц	0,700	2,000	0,233	0,083	0,075	0,053	0,068	0,001	0,020
100 Гц	0,700	2,000	0,267	0,094	0,089	0,058	0,073	0,001	0,020
150 Гц	0,700	2,000	0,283	0,096	0,092	0,059	0,074	0,001	0,020
200 Гц	0,700	2,000	0,291	0,098	0,094	0,060	0,075	0,001	0,020
250 Гц	0,700	2,000	0,296	0,099	0,095	0,060	0,076	0,001	0,020
500 Гц	0,700	2,000	0,310	0,101	0,096	0,061	0,077	0,001	0,020
1000 Гц	0,700	2,000	0,321	0,106	0,099	0,062	0,079	0,001	0,020

Significant differences in the values of electrical conductivity of the skin, subcutaneous fat layer, muscle and bone tissues and cause a complex picture of the formation of maximum densities of induced currents at the boundaries between tissues.

Unlike an electric one, an alternating magnetic field penetrates the human body without distortion or damping. In fig. 5 shows the distribution of the induction of the magnetic field created by the solenoid inductor at a frequency of 20 Hz, the structure of the field did not change depending on the frequency, and the nature of propagation in the heterogeneous phantom remained constant. However, despite the absence of distortions, the nature of the formation of absorption maxima (for an alternating electric field) and the densities of induced currents (for an alternating magnetic field) at the boundaries between tissues has many common features [5, 6]. It is likely that the leading role in this is played by the specific behavior of the dielectric properties of biological tissues at low frequencies, including nonlinear effects [7].



Rice. 5. Visualization of the magnetic fieldB in a heterogeneous phantom when the solenoid inductor is located close to the surface. The magnitude of the induction of an alternating magnetic field is 2 mT, the frequency 20 Hz.

conclusions

As a result of the simulation, the values and frequency dependences for the induced currents under the influence of an alternating magnetic field in heterogeneous phantoms that simulate the real structure of human body tissues were obtained. The analysis of the distribution structure of currents induced in a multilayer phantom (skin - adipose - muscle - bone tissue) showed the dependence of the formation of their maxima at the interfaces of tissues with different dielectric characteristics.

The nature of the frequency dependence of the structure of the distribution of currents induced in a multilayer phantom depends on the dielectric parameters of the tissues that make up it.

The prospects of using the method of theoretical modeling using the SEMCAD X program in dosimetric studies aimed at optimizing the therapeutic use of alternating magnetic fields in exogenous bioresonance therapy are shown.

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[1] The authors of the article are grateful to prof. N. Kuster (IT'IS Foundation Swiss Federal Institute of Technology, Zurich) for providing SEMCAD for research.

Gotovsky, M.Yu. Theoretical assessment and analysis of the distribution of internal currents in the model of biological tissues, induced by low-frequency electromagnetic fields. Message 2. Heterogeneous phantoms / M.Yu. Gotovsky, S.Yu. Perov // Traditional medicine. - 2012. - No. 2 (29). - P.6-11.

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