Theoretical assessment and analysis of the distribution of internal currents in the biological model tissues induced by low-frequency electromagnetic fields. Message 1.

Homogeneous 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 1. Homogenous phantoms

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SUMMARY

A theoretical assessment of the distribution of internal (induced) currents in homogeneous phantoms of muscle, adipose and bone tissues was carried out using the SEMCAD X program under the action of alternating electromagnetic fields. It is shown that the use of the theoretical dosimetry method is promising for studying and optimizing the therapeutic use of alternating magnetic fields.

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 homogenous phantoms of muscle, fat and bone tissue using SEMCAD X software are presented. The perspective of using the method of theoretical dosimetry to study and optimize the therapeutic use of alternating magnetic fields is shown.

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

Introduction

Currently, physical therapy uses a wide range of physical factors that differ in both the method and technique of application, and the mechanism of action and therapeutic efficacy. Therapy using physical factors of low intensity belongs to one of the most promising and fastest growing branches of practical medicine. Further increase in the effectiveness of therapy with physical factors with such intensity becomes impossible without studying the mechanisms of action, development and improvement of biophysical approaches to treatment methods. All this will give new criteria for assessing the influence of physical factors, including the determination of the therapeutic dose. One cannot but agree with the opinion of V.S. Ulashchik that the effect of therapeutic physical factors on the human body should be physiological, selective, adequate, diverse,

In medical practice, all available forms of electromagnetic energy are widely used - from static electricity to ultra-high-frequency electromagnetic fields, which provide a wide range of therapeutic effects: stimulation of metabolic processes, factors of nonspecific and specific immunity, normalization of neuroendocrine regulation, improvement of rheological properties of blood, microcirculation, etc. [2]. In recent decades, the emphasis on the use of electromagnetic energy in physical therapy has shifted towards the use of low-frequency electric and magnetic fields with different methods of generation and characteristics of exposure [3]. At the same time, the main direction

Research is concentrated in the field of therapeutic action and expanding the possibilities of using low-frequency electromagnetic fields, while the biophysical mechanisms of action, despite the recently appeared individual publications, attention is paid to a much lesser extent [4].

Various therapeutic techniques for using low-frequency electric and magnetic fields are described in the literature, however, information about their optimality is not always available, which is due to insufficient knowledge of the mechanisms of action, which does not allow implementing an adequate dosage of the therapeutic factor. At the present stage of the development of therapy with low-frequency electric and magnetic fields, these problems are solved by empirical selection of specific exposure parameters. In physiotherapy, when selecting a dose of high-frequency and ultra-high-frequency electromagnetic fields, they are guided by several gradations of the patient's sensation of heat arising when exposed to the field [2]. Such a dosimetry method based on human sensory reactions is subjective, and, quite naturally, its objectivity is highly questionable. However, with therapy with low-frequency electric and magnetic fields, even such a method becomes almost impossible. Sensory reactions of a person (phosphenes or magnetophosphenes) in response to exposure to, for example, low-frequency magnetic fields are visual and consist in the appearance of sensations in the form of flashes of light in a person when exposed to the head, which occurs with closed eyes. However, the phenomenon of magnetophosphenes is characteristic for a narrow frequency range (20–30 Hz) and at values of the induction of an alternating magnetic field from 10 to 12 mT. In this case, the effect occurs directly on the photoreceptor apparatus of the eye, and not on the structures of the brain, as previously thought [5]. Thus, the lack of dosimetry methods for variable low-frequency electromagnetic fields impedes the optimization of the treatment process. The above applies,

In this regard, the purpose of this work is to theoretically estimate the currents induced in models (phantoms) of some tissues when exposed to low-frequency magnetic fields.

Materials and research methods

Currently, the only mechanism of interaction of low-frequency electric and magnetic fields with biological objects has been established - the emergence of induced (induced) currents on the surface and in the depth of the body, which are the main dosimetric parameters that determine the biological effect of exposure [7]. As a quantitative value for assessing the permissible level of exposure to electric and magnetic fields in the range below 10 MHz per person and determining the therapeutic dose, the current density is used, the value of which is expressed in mA / m_2 [eight].

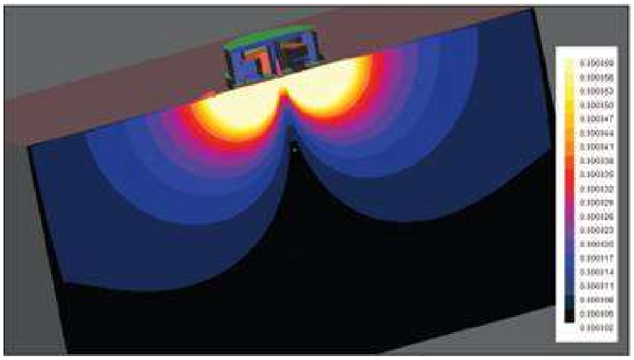
In this regard, theoretical dosimetry was used in the studies, with the help of which it is possible to obtain accurate data on the magnitude and nature of the spatial distribution of induced currents in homogeneous models (phantoms) that numerically simulate the main biological tissues. A distinctive feature of theoretical dosimetry methods is the ability to obtain results that cannot be obtained experimentally as a result of difficulties, both methodological and technical, in working with biological objects. So, for example, the methods developed by Hagmann and Babij for non-invasive measurement of currents induced in a biological object using a flat measuring frame allow only an integral characteristic to be obtained, while the fine structure of the distribution of eddy currents in various organs and tissues remains inaccessible for this method [9]. In addition, this measurement system is designed for dosimetry of high-intensity electric and magnetic fields, the effect of which is accompanied by the generation of heat in the object. The latter circumstance is also the reason for the unacceptability of such an instrumental dosimetry method when using low-frequency magnetic fields of relatively low intensities, which are used for therapeutic purposes.

In theoretical dosimetry, Maxwell's equations are solved for the E- and H-vectors of the electromagnetic field for a model (phantom) with given electrical parameters, for example, muscle, adipose, bone and other types of tissues [6]. The calculations use the finite difference method in the time domain, the mathematical apparatus of which is implemented in the SEMCAD X program (Simulation Platform for Electromagnetic Compatibility Antenna Design and Dosimetry), which is the closest for the solved problems of dosimetry, developed by Schmid & Partner Engineering AG, Switzerland[1] [ten]. This development, which is the latest generation of software designed to simulate electromagnetic fields and radiation in a very wide range of frequencies, from static fields to optical radiation, in 3-dimensional space, was used in our research.

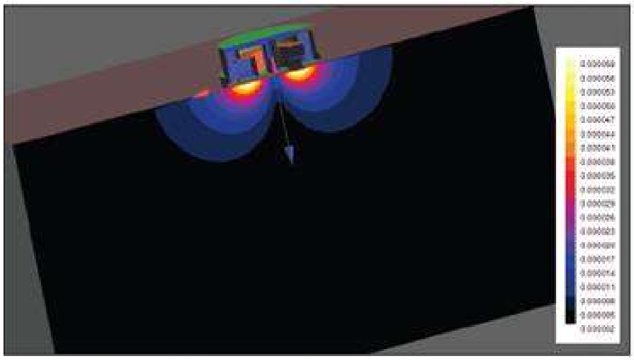
Planar homogeneous phantoms of the following tissues were modeled: skeletal muscle, adipose and bone tissue. In modeling, dielectric parameters of tissues generally accepted in dosimetric modeling were used in the investigated frequency range at a temperature of 37 ° C [11]. A solenoid inductor of the apparatus for exogenous bioresonance therapy "MINI-EXPERT-T" was used as a source of an alternating magnetic field. The magnitude of the magnetic field induction during the simulation was 2 mT, while the frequencies of 9.4 Hz, 20 Hz, 100 Hz, 250 Hz, 465 Hz, 600 Hz and 800 Hz were used. In the models, the inductor-solenoid was located directly on the surface of the plane tissue phantom (Fig. 1, 2, and 3).

Results and its discussion

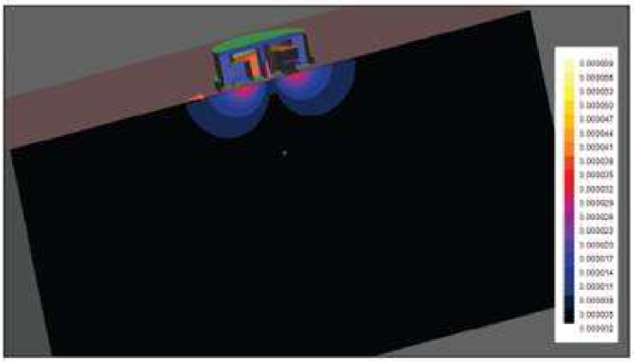
As a result of the studies performed, the values, frequency dependence and depth of induction of currents J in homogeneous phantoms of muscle, adipose and bone tissues were obtained as a result of exposure to an alternating magnetic field. The results are shown in Fig. 4, 5, 6 and 7.



Rice. 1. Visualization of the density of the induced current in a homogeneous phantom of muscle tissue at exposure to the inductor-solenoid of the apparatus for exogenous bioresonance therapy "MINI-EXPERT-T "at a frequency of 20 Hz and an exposure intensity of 2 mT. Solenoid inductor located close to the surface of the phantom.



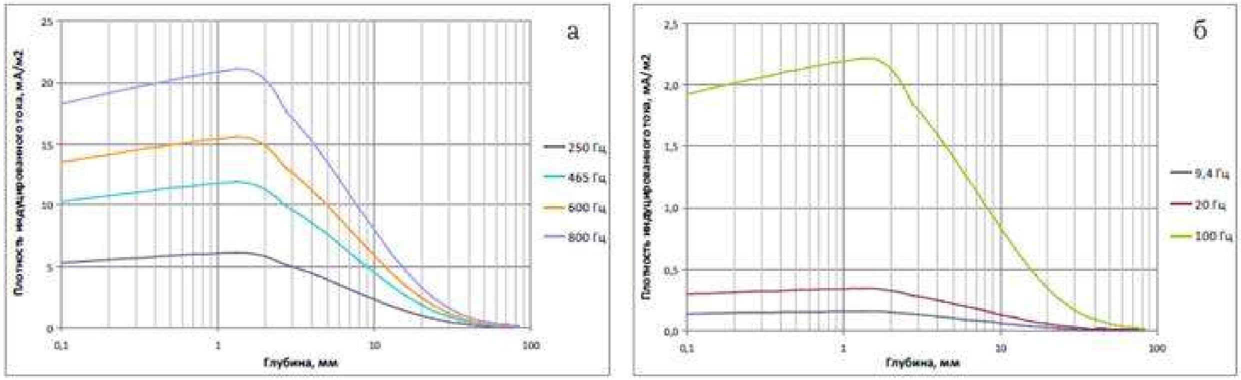
Rice. 2. Visualization of the density of the induced current in a homogeneous phantom of adipose tissue at exposure to the inductor-solenoid of the apparatus for exogenous bioresonance therapy "MINI-EXPERT-T "at a frequency of 20 Hz and an exposure intensity of 2 mT. Solenoid inductor located close to the surface of the phantom.



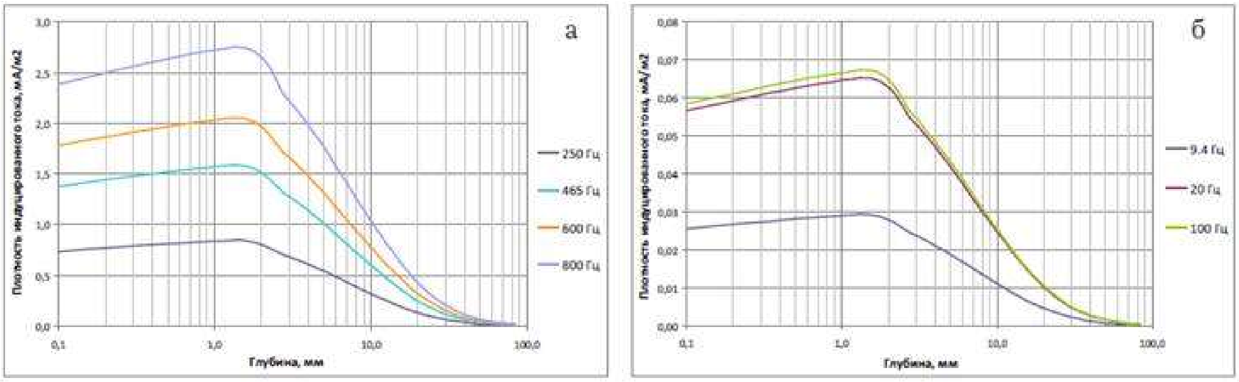
Rice. 3. Visualization of the density of the induced current in a homogeneous phantom of bone tissue at exposure to the inductor-solenoid of the apparatus for exogenous bioresonance therapy "MINI-EXPERT-T "at a frequency of 20 Hz and an exposure intensity of 2 mT. Solenoid inductor located close to the surface of the phantom.

The maximum distance from the phantom surface, at which the induction of currents J was noted for an alternating magnetic field, is the same for muscle, adipose and bone tissues, and the nature of its dependence is unidirectional for all frequencies used (Fig. 4, 5, 6). The values of the induced currents J are not the same for different tissues: the highest value (> 20 mA / m2) is noted for muscle (Fig. 4), much less for fatty (> 2.5 mA / m2) (Fig. 5) and the smallest for bone. tissue (> 1.25 mA / m2) (Fig. 6).

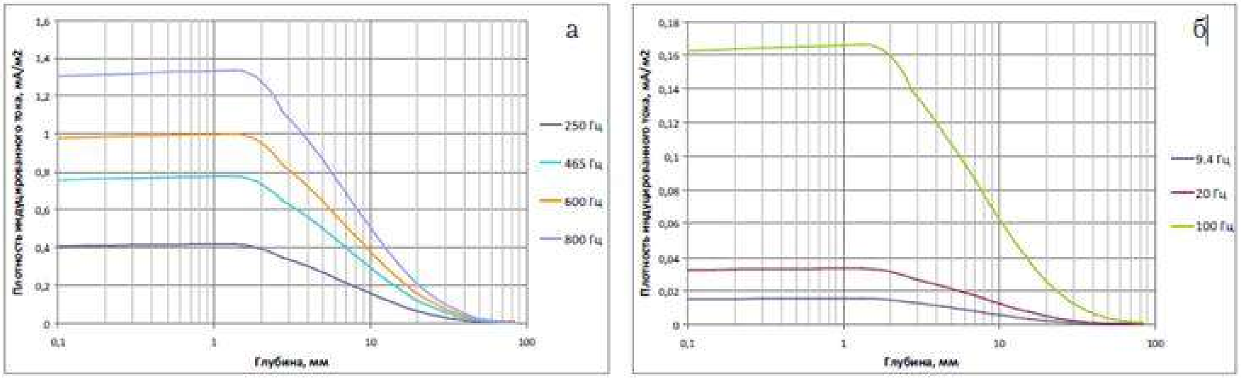
The given values were obtained for the highest frequency used in the calculations - 800 Hz, while with a decrease in frequency to 9.4 Hz, the values of the induced currents also decrease, and with the same nature of the dependence. Noteworthy is the frequency dependence of the depth of induction of currents: close, minimal values are observed at the lowest frequencies included in the study - 9.4 Hz and 20 Hz, while with increasing frequency this pattern is violated. In this sense, more indicative are the results of induced currents obtained for three types of tissues (muscle, adipose, bone) depending on the frequency of the alternating magnetic field and shown in Fig. 7. The presented data illustrate the highest frequency dependence of the magnitude of the induced currents for muscle tissue, less for adipose tissue and the lowest for bone tissue.



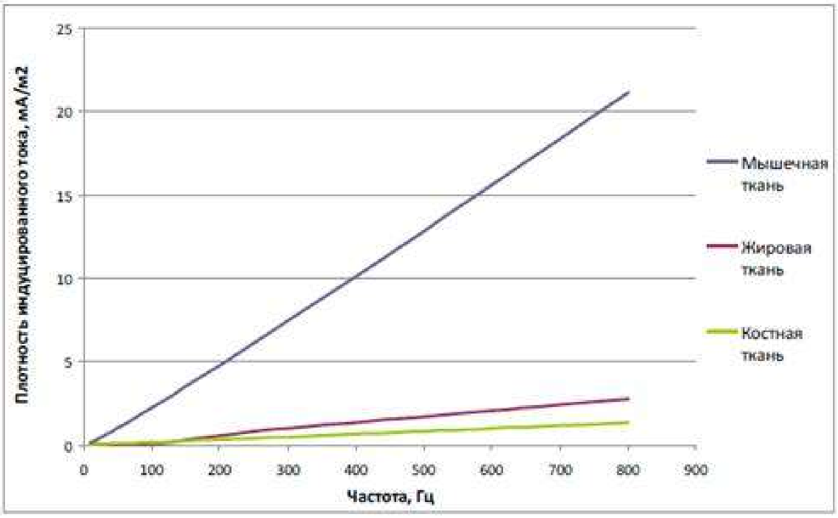
Rice. 4. Dependence of the density of induced currents (J, mA / m2) on the depth of penetration into a homogeneous phantom modeling muscle tissue when exposed to an alternating magnetic field with an induction of 2.0 mT at frequencies of 9.4 Hz, 20 Hz, 100 Hz (a) and 250 Hz, 465 Hz, 600 Hz, 800 Hz (b). Solenoid inductor located close to the surface of the phantom.



Rice. 5. The dependence of the density of induced currents (J, mA / m2) on the depth of penetration into a homogeneous phantom modeling adipose 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 (a) and 250 Hz, 465 Hz, 600 Hz, 800 Hz (b). Solenoid inductor located close to the surface of the phantom.



Rice. 6. The dependence of the density of induced currents (J, mA / m2) on the depth of penetration into a homogeneous phantom modeling 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 (a) and 250 Hz, 465 Hz, 600 Hz, 800 Hz (b). Solenoid inductor located close to the surface of the phantom.



Rice. 7. The nature of the dependence of the value of the maximum current density (J, mA / m2) induced in homogeneous phantoms modeling muscle, adipose and bone tissue from frequency an alternating magnetic field with an induction of 2.0 mT.

Unlike an electric one, an alternating magnetic field penetrates into the human body practically without distortion or damping if there are no magnetic inclusions there. At the same time, one cannot but take into account that the value of the magnetic induction decreases with distance from the source in proportion to the cube of the distance from it. At present, it is generally accepted that the biological effect is determined not by the induction of an alternating magnetic field, but by the magnitude of currents induced in tissues [12]. Most biological tissues are dielectrics, which are characterized by polarization due to the presence of a dipole moment in molecules and conductivity due to the diffusion of charges in the form of ions. Thus, in a biological object placed in an alternating electromagnetic field, currents of two types will flow - conductivity and displacement. Conduction currents arise due to the movement of free charges, and displacement currents due to the orientation of the bound ones. Conduction currents determine the value of electrical conductivity, and displacement currents - the value of the dielectric constant of a biological object. The most important for dosimetry dielectric parameters of biological tissues (dielectric constant and conductivity) have a pronounced dispersion (dependence on frequency). This dependence of their values on frequency is of the opposite character - the permeability decreases, while the conductivity increases with increasing frequency [13]. There are several types of dispersions, denoted as α-, β- and γ-dispersions at low, medium and high frequencies, respectively. In our studies, only α-dispersion is of interest, which is observed in the frequency range 1–104 Hz.

Probably, it is this dependence on frequency in the form of α-dispersion that determines the character of the currents induced in the tissues, which were obtained as a result of our modeling. This judgment is supported by the structure of the distribution of induced currents in a homogeneous phantom, which does not depend on the dielectric properties and is the same, and the differences are observed only in values. It should also be noted that the value of α-dispersion in the range of frequencies used for different tissues is not the same. The maximum dispersion is observed in muscle tissue, followed by adipose and bone tissue. Also, the conductivity of tissues, which is determined by the content of water in them, is not indifferent to the nature of the formation of induced currents. Thus, the maximum conductivity in muscle tissue, smaller in adipose tissue and lowest in bone tissue. All these dependencies determine the nature and magnitude of the currents induced in the studied tissue models, which play the most direct role in the formation of the biological effects of the action of a low-frequency alternating magnetic field, as shown in our studies.

conclusions

As a result of the simulation, the values and frequency dependences for the induced currents in homogeneous phantoms of muscle, adipose and bone tissues under the influence of an alternating magnetic field were obtained.

The analysis of the distribution of currents induced in homogeneous phantoms of muscle, adipose and bone tissues showed their dependence on the dielectric parameters of tissues and also on the nature of their dispersion in the investigated frequency range.

The possibility and 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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