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The materials of The Third International Scientific – Practical Conference is presented below. The Conference reflects the modern state of innovation in education, science, industry and social-economic sphere, from the standpoint of introducing new information technologies.

Digest of Conference materials is presented in 3 parts. It is interesting for a wide range of researchers, teachers, graduate students and professionals in the field of innovation and information technologies.

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- deviations and corrective actions;
- complaints, claims, and incidents involving violation of the product safety requirements;
- reports of internal audits.

If your enterprise does not have a general procedure, it should establish a procedure for approval, publication and transfer to other individuals and organization, review, coding and registration documents of the HACCP system [5].

HACCP is the original system due to the idea to focus on those process stages and production conditions, lack of control at which is critical for food safety, as well as to ensure that food products will not cause harm to a consumer. HACCP therefore is fundamentally different from previous systems used in the food industry, which were built on "quality control" (only purchased raw materials and end-product were controlled) [4].

When introducing the system, the organization is required not only to examine and describe its own product and production methods, but also to apply this system to suppliers of raw materials, accessory materials, as well as the system of wholesale and retail trade.

Development and implementation of quality management in the enterprise affects all departments and all the staff.

The HACCP system is a powerful management tool, the main function of which is to protect production processes from microbiological, biological, physical, chemical and other contamination risks.

Studies have shown that the HACCP system will improve the scientific basis of hazard analysis.

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TEMPERATURE DISTRIBUTION IN LAYERED BIOLOGICAL TISSUES EXPOSED BY MICROWAVE RADIATION

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Theoretical and experimental results of microwave radiation influence on the multi-layered biological tissues at 2450 MHz electromagnetic field frequency oscillations. Model and analytical calculation method of the temperature distribution inside the volume of biological tissue are presented. The prospects of the microwave radiation therapy are shown.

Keywords: microwave source, temperature field distribution, waveguide, resonator, microwave radiation, biological tissue

Currently microwave radiation receives more and more wide application in the field of medicine. One of the promising new directions in medicine is the microwave therapy. Under the influence of microwave therapy the blood vessels dilate increasing blood flow, spasm of smooth muscles decreases, the processes of excitation and inhibition of the nervous system normalize, the passage of impulses along nerve fiber accelerates, the protein, lipid and carbohydrate metabolism changes [1-2].

Microwave therapy has an anti-inflammatory and analgesic action. Microwave radiation also has a positive effect on the cardiovascular system - improves myocardial contractile function, activates metabolism in cardiac muscle [1-2].

The main problems of scientists are associated with the study of the microwave radiation action on various biological tissues mechanisms, as well as creation of a new hardware impact on the human body in the field of microwave therapy.

Power values of specific heat losses in homogeneous biological tissues are [3]:

$$P_{уд} = 0{,}278 \cdot 10^{-12} \cdot f \cdot \varepsilon'' \cdot E^2, \qquad (1)$$

where: f - electromagnetic field oscillations frequency [Hz]; E - electromagnetic field intensity [V/cm]; $P_{уд}$ - specific power of heat loss [W/cm^3]; ε'' - the imaginary part of the biological tissue relative permittivity.

The imaginary part of the relative dielectric constant in homogeneous biological tissue (ε'') is determined taking into account its conductivity [3]:

$$\varepsilon'' = \frac{\varepsilon''_c}{\varepsilon_o} + \frac{\sigma}{\omega \cdot \varepsilon_o}, \qquad (2)$$

where: ε''_c is the imaginary part of the ultimate homogeneous dielectric permeability of biological tissue; ε_o - absolute permittivity of vacuum; σ - conductivity of homogeneous biological tissue; ω - circular frequency of the electromagnetic field oscillations.

The present work contains the results of theoretical and experimental investigations of the temperature distribution in the multi-layered biological soft tissues with different physical parameters. The temperature of soft biological tissues was changed by the impact of microwave radiation emitted from the rectangular waveguide aperture on the main type H_{10} wave at a electromagnetic field frequency oscillations of 2450 MHz.

As a model, simulating the human body, a multi layer structure of biological animal tissues (skin, adipose tissue, muscular tissue) was used. Radio transparent material (polyethylene) was placed between the tissue layers in order not to take into account thermal conductivity between the different layers of the biological tissue.

Microwave radiation energy was applied to multi-layer structure of biological tissues using the antenna in the form of a rectangular waveguide aperture, located at a certain distance from its surface. The electromagnetic field power emitted from the aperture of a rectangular waveguide, working on basic H_{10} wave type, is unevenly distributed in space and is calculated by the Huygens-Kirchhoff's method of [4].

Fig. 1 shows a schematic representation of the radiation emitted from the aperture of a rectangular waveguide, and multilayer structure which consists of various layers of a biological tissue.

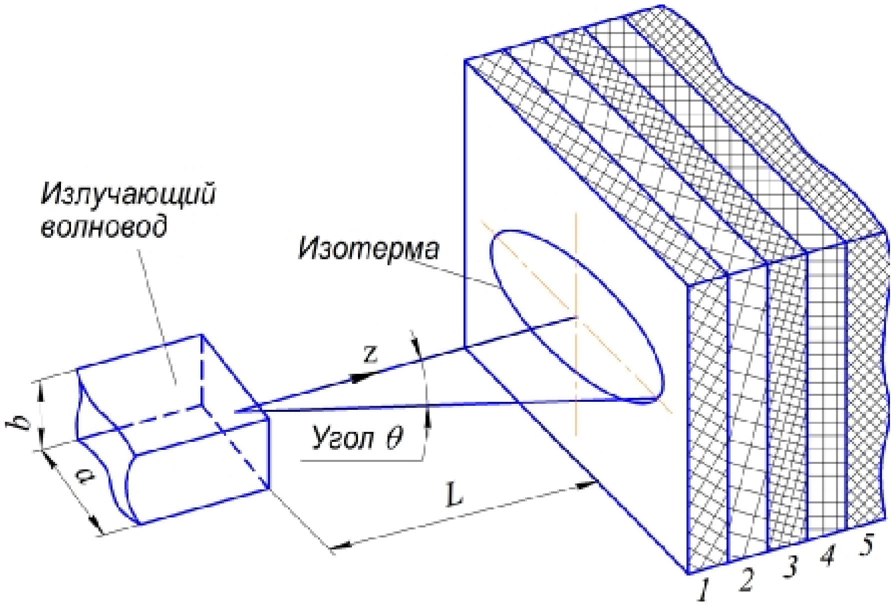

Fig.1. Schematic representation of microwave radiation emitted from the aperture of a rectangular waveguide, and multilayer structure which consists of various layers of biological soft tissues. L - distance from the emitting waveguide to the surface of the irradiated biological tissue.

The averaged parameters of biological tissues at a temperature of $36^{\circ}C$ and electromagnetic field frequency of 2450 MHz are presented in table 1.

Table 1

The averaged parameters of animals' biological tissues (pigs) at a temperature of 36°C and electromagnetic field frequency of 2450 MHz

Biological tissue	ε'	ε''	Density $\rho \cdot 10^3$ kg/m³	Thermal conductivity W/(m·°K)	Heat capacity kJ /(kg·°K)
Leather	38	6	0,3	0,15	3,2
Fat domestic deposits	5	1,5	0,93	0,2	2,3
Muscle tissue	50	10	1,03	0,48	3,36

Temperature measurement of various layers of biological tissues was held on the central line of the radiating waveguide, along the axis “z”, corresponding to the microwave radiation source output maximum value $(P = 550W)$, satisfying condition $(\theta = 0)$, the exposure time $(\tau = 120\text{sec})$ and the distance from the surface of the radiating antenna to multilayer biological tissue $(L = 250mm)$.

Experimental temperature distribution researches in layered biological tissues were held in metal chamber with its size of (600×600×600) mm. Microwave energy source was located in the center of the camera's top, as shown in fig. 2. For the purity of the experiment absorbent material was placed on the walls of the camera. It was made in order not to take into account the reflection of microwave energy from the walls of the chamber.

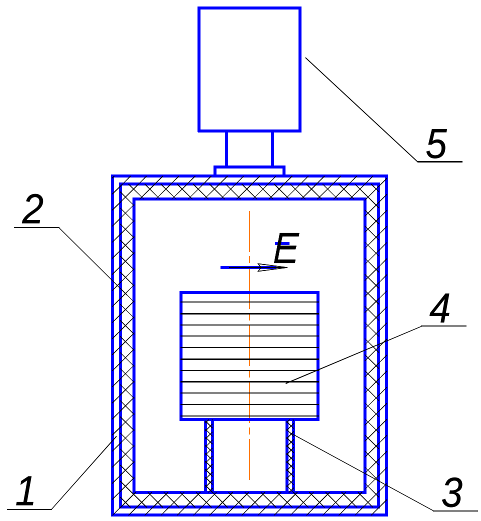

Fig. 2. Design of the camera for experimental studies of the temperature distribution in the volume of the processed material: 1 - metal camera; 2 - absorbing material; 3 - stand of radar material; 4 - layered biological tissue; 5 - source of energy.

Fig. 3 shows a beam-type chamber photograph.

After a biological tissues' multilayer material irradiation, the source of microwave energy was switched off, and the temperature value was measured in the center of each layer using a thermocouple thermometer with accuracy of $\pm 1^{\circ}$ C.

Fig. 3. Photo of the microwave chamber for pilot studies of temperature distribution in the volume of the material.

Results of the temperature distribution in the different layers of biological tissues experimental studies are presented in table 2. The table below shows the sequence of biological tissues' layers, as well as the value of their thickness.

Table 2

The experimental and the calculated temperature distribution in the multi-layered biological tissues (the calculated values of temperature are shown in parentheses)

No. layer bio-logical fabric	Name biological tissue	Layer thickness of the biological tissue (mm)	Initial the temperature of the biological tissue (°C)	Ultimate the temperature of the biological tissue (°C)
1	Leather	2	20	30 (29)
2	Adipose tissue	5	20	26 (26)
3	Muscle tissue	10	20	46 (43)
4	Muscle tissue	10	20	41 (38)
5	Muscle tissue	10	20	37 (35)

Model and the temperature calculation method inside the processed biological tissue is the most important from the point of view of therapy.

Heated multi-layered biological tissue is represented in the form of a half-space in the traveling wave's electromagnetic field. Taking into account the reflection coefficient each layer of biological tissue with thickness ℓ, is represented in the form of a loaded long-distance transmission line with given boundary conditions.

Fig. 4 shows the equivalent circuit of the heated tissue layer with dielectric losses in the traveling wave mode.

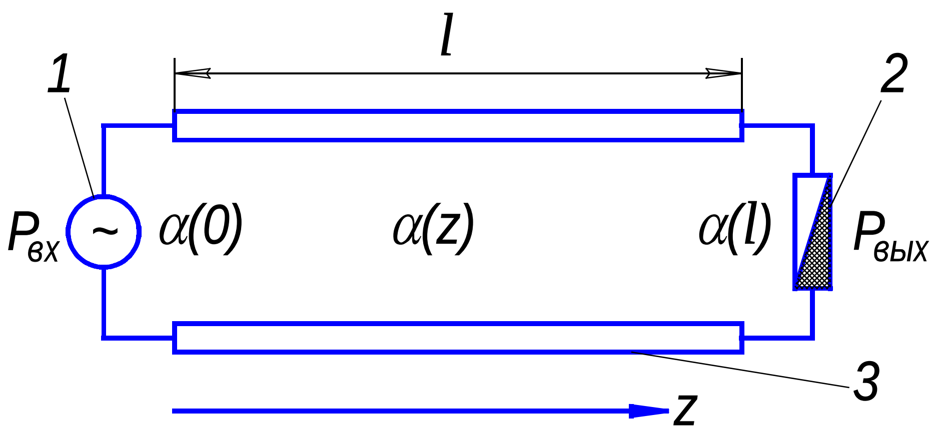

Fig. 4. An equivalent circuit of the microwave energy source with rectangular waveguide aperture as a radiating antenna, and a homogeneous tissue layer with dielectric losses. 1 - a source of microwave energy; 2 - impedance-matched load; 3 - homogeneous layer of biological tissue with thickness ℓ .

Each layer of biological tissue, as shown in [3] can be represented as two similar layers, namely: a layer of absolutely dry matter and water layer, with the use of superposition principle or tissue layer's equivalent parameters that can be defined by different methods.

Work [5] presents the relative dielectric constant experimental dependence on temperature for the water at the electromagnetic field frequency of 2450 MHz, which is linear and decreases with increasing temperature and for various dry substances which are linear, and increase with increasing temperature.

The amount of power is absorbed by biological material with dielectric losses according to the exponential law. In the first approximation the law of power changes in the material is determined by the electric field intensity amplitude constant decay $\alpha(z)$ in material :

$$P(z) = P_{вх} \cdot e^{-2 \cdot \alpha(z) \cdot z} \tag{8}$$

The relationship between propagation constant in various directions with the free space wavenumber and a homogeneous biological medium's dielectric parameters is determined by the characteristic equation [6]:

$$\Gamma_x^2 + \Gamma_y^2 + \Gamma_z^2 = -k^2 \cdot (\varepsilon' - j\varepsilon''), \tag{9}$$

or

$$(\alpha_x + j\beta_x)^2 + (\alpha_y + j\beta_y)^2 + (\alpha_z + j\beta_z)^2 = -k^2 \cdot (\varepsilon' - j\varepsilon''), \tag{10}$$

where $\Gamma_x, \Gamma_y, \Gamma_z$ propagation constants in various directions; $\alpha_x, \alpha_y, \alpha_z$ electric field amplitude decay constants in different directions; $\beta_x, \beta_y, \beta_z$ - phase constant in various directions; ε' is the real part of the biological tissues' relative dielectric constant [3]:

$$\varepsilon' = \frac{\varepsilon_c'}{\varepsilon_o} \ , \tag{11}$$

where ε_c' - the real part of the biological tissues' absolute dielectric constant; k - is the wave number for space (vacuum and air):

$$k = \frac{2\pi}{\lambda}, \tag{12}$$

where λ - wavelength of the microwave energy source

.

The characteristic equation (11) can be written in general case, in the form of two equations by equating the real and imaginary parts:

$$\alpha_x^2 + \alpha_y^2 + \alpha_z^2 - \beta_x^2 - \beta_y^2 - \beta_z^2 = -k^2 \cdot \varepsilon' , \tag{13}$$

$$2 \cdot (\alpha_x \cdot \beta_x + \alpha_y \cdot \beta_y + \alpha_z \cdot \beta_z) = k^2 \cdot \varepsilon'' . \tag{14}$$

These equations relate the phase constant and the electric field amplitude decay constant with the dielectric parameters of biological tissues and the wavelength of microwave energy source.

These equations can be used to define an electric field intensity amplitude decay constant in biological tissues.

According to equations (13) and (14)

$$\alpha_z^2 - \beta_z^2 = -k^2 \cdot \varepsilon', \qquad (15)$$

$$2 \cdot \alpha_z \cdot \beta_z = k^2 \cdot \varepsilon''. \qquad (16)$$

From the solution of this system of equations (15) and (16) follows:

$$\alpha_z = \frac{k \cdot \sqrt{\varepsilon'}}{\sqrt{2}} \cdot \sqrt{\left(\sqrt{1 + \left(\frac{\varepsilon''}{\varepsilon'}\right)^2} - 1\right)}, \qquad (17)$$

Power distribution in each homogeneous layer of biological tissue in the direction of the axis “z” can be represented in the form [6]:

$$P(z) = f(z,T) \cdot P_{вх} \cdot e^{-2\cdot\alpha_н \cdot z}, \qquad (18)$$

where $f(z,T)$ - taking into account the dependence of the dielectric parameters of bio-logical fabric of temperature and coordinates function.

Experimental dependence of the absorbed power value in material along the axis “z” on the value of the electric field amplitude decay constant has a straightforward character at the electromagnetic field oscillations' frequency of 2450 MHz.

The main point which is used in the derivation of expressions for functions $f(z,T)$ is that, according to the experimental research, the attenuation constant value is a linear function of the absorbed power values:

$$\alpha(z) = A - B \cdot \frac{P_{вх} - P(z)}{P_{вх}}, \qquad (19)$$

where *A* and *B* - coefficients, which are determined from the boundary conditions.

We suppose that the whole microwave energy source power is absorbed in biological tissue of thickness ℓ. In this case, from the equivalent circuit model of microwave devices with the irradiated homogeneous biological tissue, we can write the following boundary conditions:

$$\left.\begin{array}{l} P(z)\big|_{z=0} = P_{вх} \\ \alpha(z)\big|_{z=0} = \alpha_к \end{array}\right\}, \qquad (20)$$

$$\left.\begin{array}{l} P(z)\big|_{z\to\ell} = 0 \\ \alpha(z)\big|_{z\to\ell} = \alpha_н \end{array}\right\}, \qquad (21)$$

where $\alpha_н$ - the electric field intensity amplitude decay constant value at the initial temperature $T_н$ in homogeneous biological tissue; $\alpha_к$ - the value of the electric field amplitude decay constant at finite temperature $T_к$ in homogeneous biological tissue.

From boundary conditions (21) and (22) and equation (19) the coefficients *A* and *B* can be obtained.

$$\alpha(z) = \alpha_к - (\alpha_к - \alpha_н) \cdot \frac{P_{вх} - P(z)}{P_{вх}}. \quad (23)$$

Ratio is known from the theory of long lines [2]:

$$-\frac{dP(z)}{dz} = 2 \cdot \alpha(z) \cdot P(z). \quad (24)$$

Substituting (23) in (24), we obtain the equation:

$$\frac{dP(z)}{\left[\alpha_к - (\alpha_к - \alpha_н) \cdot \frac{P_{вх} - P(z)}{P_{вх}}\right] \cdot P(z)} = -2 \cdot dz \quad (25)$$

Solution of the equation (25) is:

$$P(z) = P_{вх} \cdot e^{-2 \cdot \alpha_н z} \cdot \frac{\alpha_н}{\alpha_к - (\alpha_к - \alpha_н) \cdot e^{-2 \cdot \alpha_н \cdot z}}. \quad (26)$$

Therefore:

$$f(z,T) = \frac{\alpha_н}{\alpha_к - (\alpha_к - \alpha_н) \cdot e^{-2 \cdot \alpha_н \cdot z}} \quad (27)$$

If homogeneous biological tissue has an initial temperature $T_н$, then after its irradiation by the microwave energy, biological tissue obtains the following temperature distribution along the axis "z":

$$T(z) = T_н + \frac{2 \cdot \alpha_к \cdot f^2(z,T) \cdot \tau}{S \cdot c_\partial \cdot \rho_\partial} \cdot P_{вх} \cdot e^{-2 \cdot \alpha_н \cdot z}, \quad (28)$$

where: c_∂ is the heat capacity of a homogeneous biological tissue; ρ_∂ is the density of the homogeneous biological tissues; τ - time of homogeneous biological tissue microwave irradiation; *S* is the area of the surface of a homogeneous biological tissue that is evenly heated with the use of microwave radiation.

If the half-space is irradiated, the value of the electric field amplitude decay constant can be written as [6]:

$$\alpha_н = \frac{k \cdot \sqrt{\varepsilon'_н}}{\sqrt{2}} \cdot \sqrt{\left(\sqrt{1+\left(\frac{\varepsilon''_н}{\varepsilon'_н}\right)^2} - 1\right)}, \quad (29)$$

$$\alpha_к = \frac{k \cdot \sqrt{\varepsilon'_к}}{\sqrt{2}} \cdot \sqrt{\left(\sqrt{1+\left(\frac{\varepsilon''_к}{\varepsilon'_к}\right)^2} - 1\right)}. \quad (30)$$

The constant value of the microwave power distribution on irradiated area of biological tissues in the calculations was adopted on the area in the form of a circle S =1cm^2.

Calculation was carried out for the layers of biological tissues, presented in table 2 and their electrophysical parameters presented in table 1. Calculated values of temperature in biological tissues are presented in table 2.

Calculation of the temperature distribution in the multi-layered biological tissues, carried out in accordance with the proposed model, confirmed the experimental results. If the parameters of different layers in biological tissues are known, the temperature in the area of interest can be calculated closely to the experimental results.

The obtained results can be used in developing a setup for therapy.

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