Biomedical applications of microwave radiation: innovative approaches

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Now it is widely known postulate that all the major discoveries in recent years occur at the junction of different sciences. In this regard, one of the most important innovative areas uniting physics, biology and medicine is the use of microwave technologies. In this regard, the purpose of this work was to clarify the practical possibilities of diagnostic and therapeutic microwave technologies.

Microwave technology in medical imaging

Medical visualization is currently one of the most dynamically developing areas of medical science. Analysis of the literature on the methodology of microwave imaging, implemented in Biomedicine, allows us to identify two main sensing techniques that differ in the estimated parameters: microwave thermometry (passive) and near-field resonance tomography.

In the framework of microwave thermometry (radiometry), the volume dynamics of the subsurface temperature distribution is recorded by the trapping device. At the same time, it is known that in a number of pathological conditions (for example, in oncomammology) there is a significant local hyperthermia, which will be detected by a microwave sensor.

On the contrary, in recent decades actively developed by resonant near-field microwave imaging, allowing you to visualize the structure of biological tissues on the basis of spatial distribution their electrodynamic characteristics - dielectric constant (ε) and conductivity (σ) [Fig. 1], characterizing the type and structural features of the biological object. The possibility of using this type of tomography for diagnostic purposes is due to the fact that the formation of pathological changes in biological tissues is a distinct change in their electrodynamic characteristics.

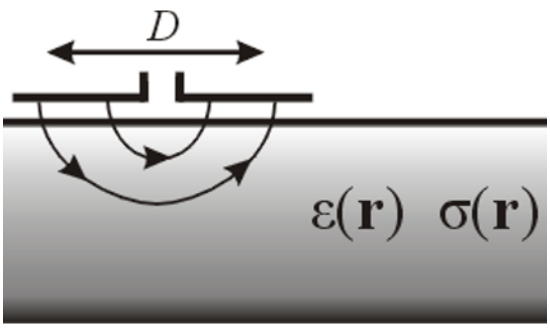

Fig. 1. Scheme of the stud of dieectric characteristics of the object

Near-field resonance microwave diagnostics is based on the measurement of electrodynamic characteristics of biological tissues. Work in this direction with biomedical positions are relatively recent, but the physical principles underlying near-field microwave tomography, studied much more fully. Thus, the fundamental basis of the method is the measurement of impedances located on the surface of the bio-object of a system of electrically small antennas with different scales of localization of the probing electric field. The spatial distribution of dielectric permittivity and electrical conductivity of tissues is restored by the values of impedances (active and reactive resistance) of antennas on the basis of a special mathematical apparatus.

Measuring the impedance of antennas is implemented in a special resonant sensor. The sensor is a microwave resonator in the form of a transmission line segment (coaxial, two-wire or strip) [1]. At one end of this segment there is a probing near-field antenna (measuring capacitance), at the opposite end there is a magnetic frame. Excitation of the resonator and reception of its response is carried out by means of magnetic coupling loops located near the magnetic frame of the resonator. All elements of the resonance system, except for the measuring capacitance, are located in a metal cylindrical body. Own resonant frequency of the sensor, as a rule, is in the range of 600-800 MHz, the characteristic quality factor – 150.

The scheme illustrating deep sounding of biological tissue within the near-field microwave tomography is presented in Fig. 2. Near-field antenna is located on the surface of the object under study, its quasi-static electric field penetrates into the medium to a depth determined by the design of the antenna and the size of its aperture (D). The depth of penetration of the electric field into the medium will increase with increasing aperture D.

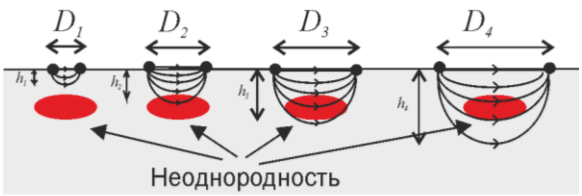

Fig. 2. Scheme of a deep sensing of inhomogeneous media by the method of resonance near-field microwave tomography

The study of heterogeneous biological media is carried out as follows. First, the measurements are carried out by the sensor with the lowest D_1 value and, accordingly, with the lowest sounding depth h_1, the measurement results reflect the integral properties of the medium in the surface layer. For sensor with sensing h_2 depth | integral properties of the medium in the near-surface layer of greater thickness, etc. Knowing the responses of measuring systems with

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different sensing depths, it is possible to restore the deep structure of the inhomogeneous medium.

Have presently developed near-field diagnostic systems key value "the size of the aperture of the probe (D) / wavelength of the probing microwave signal (λ)" comes to the level of 10^{-5}-10^{-6} that in comparison with the wave techniques gives the opportunity to examine the condition and structural features of the tissue on their electro-dynamic properties with subwavelength spatial resolution (much smaller than the wavelength λ).

Thus, near-field resonance microwave sensing, thanks to its physical principles, makes it possible to vary the depth and surface area of the study of biological objects, using electrodynamic characteristics of the medium - its dielectric permeability and conductivity – as diagnostic criteria.

Microwave technologies for treatment

Plasma medicine is one of the most modern synthetic scientific directions, born at the junction of plasma and Biomedicine physics, dealing with fundamental and applied issues of interaction between plasma and living matter. In this case, the greatest attention of researchers attracts the field of plasma medicine associated with the disclosure of biological and sanogenetic effects of cold plasma. Currently, the cold plasma is usually understood as ionized gas of different composition, cooled to a temperature comparable to the physiological (30-40 C). In recent decades for this factor a number of effects is potentially useful for medical purposes have been demonstrated experimentally and clinically. Among them, the most well studied and described antibacterial activity associated with the direct damaging effect of cold plasma on the cell wall of microorganisms. On the other hand, with a more thorough analysis of even this aspect of the problem, it reveals numerous poorly studied issues, including the effectiveness of the action, the absence of damage to the own tissues of the macroorganism, etc.

Special interest, in our opinion, have a bioregulatory properties of cold plasma in relation to functional and metabolic parameters of living systems. Thus, the pro-regenerative activity of the factor [6, 14], its ability to inhibit tumor growth [4, 10], etc. that was demonstrated earlier. Undoubtedly, the given empirical facts require multistage verification, but the very presence of such data testifies to the presence of secondary, indirect biological effects in cold plasma, which makes it possible to consider it as a potential bioregulator.

In our previous studies, is performing both in vitro and in vivo, the existence of secondary bioregulatory properties in cold plasma was shown and verified. In particular, even a short-term treatment (1-3 min.) of blood samples by the flow of helium cold plasma led to the formation of the biosystem response (by metabolic and physico-chemical criteria), and it is important to emphasize the dose dependence of the detected shifts [2, 3]. It should also be noted that the nature of the changes significantly differed from the "pattern" of the response to a similar effect of non-ionized helium flow from the same source [3]. Interestingly, the reaction of blood isolated from the body as a simple model biosystem as a whole was co-directed to shifts of the same blood parameters of rats exposed to short-term (1-2 min.) exposure to cold plasma on the pre-epilated areas of the back. As in the case of in vitro experiments, in this case shown moderate antioxidant activity of the factor, its positive effect on the intermediate link in the energy exchange etc. in addition, it was demonstrated modulating effect on the parameters of systemic and local hemodynamics.

Thus, plasma biomedicine is a promising, dynamically developing direction, integrating biophysical and biomedical approaches and capable of forming fundamentally new medical technologies, potentially useful for the correction of various diseases, pathological conditions, injuries and burns.

References

1. *Martusevich A.K., Peretyagin S.P., Vanin A.F.* The study of some porducts is generating with medical device for the synthesis of NO-containing cold plasma // Medical physics. 2012. No 4. P. 80-86.

2. *Martusevich A.K., Soloveva A.G., Yanin D.V., Galka A.G., Krasnova S.Yu.* The influence of gelium cold plasma on the parameters of blood oxidative metabolism in vitro // Gerald of New Medical Technologies. 2017. V. 24, No 3. P. 163-166.

3. *Martusevich A.K., Yanin D.V., Bogomolova E.B., Galka A.G., Klemenova I.A., Kostrov A.V.* Possibilities and perspectives of the use of microwave tomography in sin testing // Biomedical Radioelectronics. 2017. No 12. P. 3-12.