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CHANGE IN THE ELECTROPHYSICAL PROPERTIES OF WATER BY MICROWAVE RADIATION

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A study is made of the change in the electrophysical properties of water subjected to low-power superhigh-frequency radiation. Experimental values of high-frequency conductivity and ion current are obtained for water irradiated within the ranges of 3.8 and 10-12 GHz. Spectra of the optical density of water in the ultraviolet region are also presented. An analysis is made of the connection between these spectra and the observed changes in the high-frequency properties of water.

It is known [1, 2] that electromagnetic radiation absorbed by water can affect the informational as well as the thermal state of the water. By a change in the informational state, we mean that under certain conditions water exposed to radiation changes to a nonequilibrium (metastable) state characterized by a certain rearrangement of its structural elements. This state, referred to as the "memory" of the water, can persist for a relatively long period of time. For applications in both electromagnetic ecology and electromagnetic medicine, it is importance to have a reliable criterion for detecting the "informational memory" of water. In particular, having such a criterion would make it possible to evaluate the power and duration of radiation that can lead to stable "structurization" of water. Among recent studies in this area, the investigation [3] is of particular interest. In it, changes in the properties of water under the influence of radiation were detected by studying its ultraviolet spectra of optical density. Property changes were also detected with the use of NMR, on the basis of changes in the magnetic spectra of the protons.

The goal of the present investigation is to quantitatively determine the electrophysical parameters of water after its treatment with superhigh-frequency radiation. Results are presented from experimental studies of the high-frequency characteristics of water subjected to SHF radiation, along with spectra of the optical density of water in the UV region. An analysis is made of the relationship between the observed changes in the high-frequency properties of water and its optical density.

We conducted numerous experiments involving the irradiation of volumes of water by an electromagnetic field. The irradiation was done to determine the changes in water's HF characteristics during and after the exposure. The irradiation was done at fixed frequencies within the range 3.8-12 GHz at powers P = 5-200 mW. Besides the conventional radiation method employing a horn, we used the resonance method. The latter made it possible to significantly improve the efficiency of the radiation process.

A change in absorption at superhigh frequencies was seen in the resonance regimes. Simple estimates show that at SHF power levels of 20-60 mW and with complete transformation of the radiation into heat, water temperature increases by no more than tenths of a degree (0.1-0.3°C). This allowed us to regard the electrophysical characteristics of water as being responsible for the deviations of the absorption curve. Assuming that these changes are also manifest in other sections of the frequency range, we studied the high-frequency (HF) conductivity of water after its treatment with SHF radiation. The measurements were made on a capacitive cell with a fixed volume of water, and the parameters of the water were recorded on digital meter E7−12.

Since we used deionized water in the experiments, we carefully cleaned the working cuvettes and the vessels used to store the treated water. We soaked the containers for several days prior to the experiments and washed them repeatedly, also regularly checking their cleanliness during the investigation.

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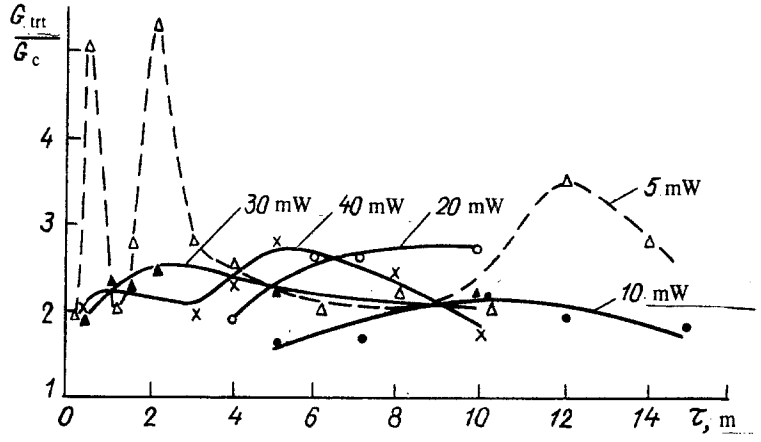

Fig. 1. Normalized values of the HF conductivity of water after microwave irradiation (f = 3.8 GHz) in relation to time of exposure τ.

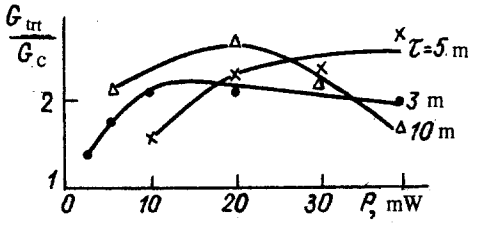

Fig. 2. High-frequency conductivity of water after irradiation in relation to the power of the radiation P (f = 3.8 GHz).

Experiments in which water was subjected to different doses of radiation (with a power from several milliwatts to 200 mW and a time of exposure from 15 sec to 30 min) established that the HF conductivity and the initial ion current of the capacitive cell with the irradiated water could differ appreciably from the "control." Figures 1 and 2 show averaged curves of normalized values of the HF conductivity of water exposed to a SHF field at a frequency of 3.8 GHz G_{trt}/G_c (where G_c is the conductivity of the water in the control volume). The values are shown as a function of time of exposure τ for certain levels of power P. The points on the curves correspond to the values of G_{trt}/G_c obtained from the exposure of identical volumes of water to an SHF field during the corresponding time τ.

The parameter G_{trt}/G_c (Fig. 1) changes within the range from 1 to 3-5, and nearly all of the curves have flat sections differing in position for different levels of power. This can be interpreted to mean that there is a certain dose at which the effects of the exposure begin to stabilize somewhat. A characteristic feature of the experiments conducted with water at room temperature was the fact that the results could not be reproduced – especially for short exposures (30 sec-3 min). In this case, the curves contain narrow high-amplitude spikes (Fig. 1) that change and sometimes disappear in repeat tests.

Analyzing the reasons for the nonreproducibility, we divided them into two groups: external factors, which can in principle be eliminated or accounted for in a statistical analysis of the measurements; internal factors, which pertain to the nature of the object being studied. Among the external factors are "ionic impurities" entering the radiation-activated water during its interaction with the bounding surfaces, as well as the possible effect of air dissolved in the water on HF conductivity. We used a cuvette cleaned by the method described above to alleviate these factors.

As regards the internal factors in the nonreproducibility of the measurements of HF conductivity, we make the following observations. The radiation experiments were conducted at room temperature (15-25°). It is known that an increase in temperature from 0°C is accompanied by an increase in the amplitudes of the O–O and O–H vibrations, as well as intermolecular vibrations. However, the structural disorder that exists in water compared to ice has its advantages with respect to the packing of the molecules, and this is expressed in a shift in equilibrium in water in the direction of bent hydrogen bonds [4]. The structural disorder in water, with its associative properties, can also be represented in the form of ice-like cluster-structures that float in a medium consisting of free molecules forming a dense cubic packing [5].

TABLE 1. Values of the HF Conductivity of Water in Relation to Temperature

τ, min	G_{trt}, mS							$(G_{trt}/G_c)_{av}$
5	0,020	0,021	0,019	0,021	0,021	0,022	0,021	1 65±0,08
10	0,030	0,028	0,024	0,026	0,027	0,026	0,027	2,08±0,21
20	0,041	0,022	0,024	0,026	0,031	0,025	0,028	2,15±0,95

Irradiation regime: f=3,8 GHz, P=20 mW, G_c=0,013 mS/.

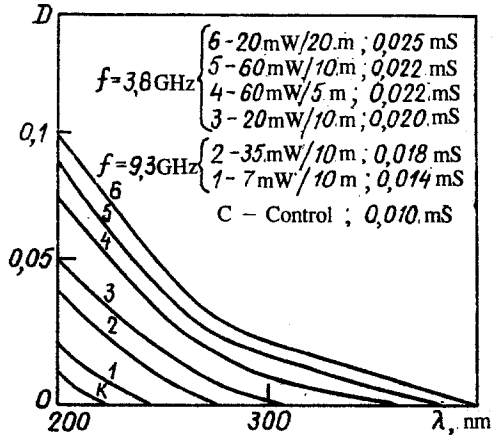

Fig. 3. Spectra of optical density D of irradiated water.

In this situation, a variable external field that results in orientational polarization of the dipole molecules of water and electronic polarization in the molecules themselves will also lead to group transitions of protons. This in turn creates ionic defects and can be regarded as a form of dissociation of the molecules in addition to thermal dissociation. In the external circuit, it is manifest as an increase in HF conductivity and ion current. A certain contribution to dissociation can also be expected from the clusters after they are subjected to the external field [6]. The structural disorder can be regarded as the main factor responsible for the statistically nonequilibrium transitions of the protons and their displacement due to convection from the region in which HF energy is absorbed. The increase in HF conductivity is greater in the lower part of the SHF range, mainly as a result of the greater depth of penetration of the field.

The next series of experiments was conducted in water that had been held for periods ranging from several days to a week at temperatures close to freezing (to −3°C). The experiments were conducted without thermostatting, and to maintain the low temperature of the water during irradiation the cuvettes were precooled and the radiation process was kept relatively brief.

The results of the experiments are shown in Table 1 for a regime in which multiple exposures were used (f = 3.8 GHz, P = 20 mW, volume of the water 15 cm^3). Relatively stable values of HF conductivity were obtained when the necessary measures were taken to clean the cuvette. For example, with τ = 3-5 min and P = const, the scatter of G_{trt} was 5-10%. For longer exposures (10-20 min), when the water began to heat due to heat exchange with the surrounding medium, the scatter increased to 30-50% but the mean remained nearly unchanged. This corroborates the above data on the existence of a "saturation" region, when water exposed to electromagnetic radiation forms a constant "response" within a broad range of radiation doses.

In conclusion, we conducted experiments involving the irradiation of ice. After natural thawing, the parameters of the irradiated water were measured 1, 2, and 3 days after exposure to a SHF field. It was assumed that the irradiation of slowly frozen water might make it possible to obtain stable parameters for the water in repeat tests. This notion was based on the fact that normal hexagonal ice is a regular structure composed of molecules of water surrounded by a single network of linear hydrogen bonds. Thus, any microregion of such a structure should react to external radiation in a manner similar to the adjacent regions. The results obtained from the irradiation of cooled water and ice permit the following statements. The water undergoes larger changes in HF conductivity G_{trt} and initial ion current I_{trt} relative to the control values G_c and I_c for unexposed water:

TABLE 2. "Memory" of Irradiated Water

τ, min	G_{trt}, mS				State of the substance
	immediately	after 1 day	after 2 days	after 3 days	
0,5	0,019	0,023	0,022	0,022	Water with ice
2	0,025	0,027	0,027	0,027	Water with ice
5	0,020	0,020	0,020	0,020	Cooled water
5	0,031	0,029	0,029	0,029	Ice

Irradiation regime: $f=9,3$ GHz, $P=40$ mW, $G_c=0,016$ mS .

TABLE 3. High-Frequency Conductivity and Initial Ion Current of Water Obtained from Irradiated Ice

τ, min	Irradiation regime: $f=9,3$ GHz, $P=40$ mW; $f=12,1$ GHz, $P=200$ mW; G_{trt}/G_c				Initial ion current I_{trt}/I_c ($f=12,1$ GHz, $P=200$ mW)	
	after 1 day	after 3 days	after 1 day	after 3 days	after 1 day	after 3 days
0,5	1,30	1,32	1,30	1,30	1,25	1,30
1	1,75	1,76	1,80	1,85	1,6	1,7
2,5	1,35	1,40	1,40	1,45	1,4	1,45

a) the value of $\Delta G = G_{trt} - G_c$ is higher compared to the regimes of irradiation of water at the same frequencies (Fig. 3 and Tables 2 and 3); b) the maximum effect is achieved with shorter exposures: 1 min instead of 5 min; c) the structurization effect reaches "saturation" beginning at a certain power (for the given frequency and given volume of water). A change in power P by one order – from 40 to 400 mW – did not lead to an increase in G_{trt}.

Let us briefly discuss the reasons for the increase in the "structurization" of water when it is exposed in the form of ice to microwave radiation. One of the important properties of ice crystals is the disorder in the location of the protons, which is manifest in the formation of different types of orientation defects and their movement along hydrogen bonds (HBs). These defects are caused by intramolecular transitions of protons during thermal vibrations of the molecules. Such transitions rotate H_2O molecules 120° about their own axis or 180° around the HBs [7]. In accordance with Behrum's postulate [7], these are D-defects (defects with two protons on the HB line) and L-defects (generally no protons on the bond line). The rotational or HF conductivity σ_∞ of ice or water is due to the migration of orientation defects and, in accordance with [8], is represented as the sum of conductivities $\sigma_\infty = \sigma_D + \sigma_L$. Furthermore, the motion of the orientation defects ensures continuity of ion conductivity. After the "jump" of a proton, this motion creates the necessary orientation of the molecule for the passage of the next proton. Two phenomena – electronic polarization and the formation of orientation defects in the structure – play the main role in the "structurization" process when ice is irradiated. Here, the number of orientation defects increases under the influence of the external field. Since a molecule of water is simultaneously a symmetric donor and acceptor of protons [4], it may act as a proton donor in one bond between two molecules and a proton acceptor in another bond. In either case, it undergoes vibrational motions on the HB line between the molecules. If the dipole orientation of two adjacent molecules at a given moment is close to the direction of the external field, then electronic polarization takes place and the electron cloud is deformed mainly near the molecule that is the proton acceptor. As a result, the symmetric potential curve of proton transport, formerly having two identical minima, is distorted in such a way as to increase the depth of the minimum near the acceptor molecule. The increased probability of finding a proton near this molecule temporarily places the two molecules in a defective state. In the event of their spatial separation, the defective state causes the molecules to be transformed into a pair of ionic defects OH^- and H_3O^+. Separation occurs as a result of the motion of the orientation defects; in particular, an OH^- ion can be displaced if a proton migrates in the direction of the field from an adjacent HB to the donor molecule and occupies the former site of the departed proton; in this case, a Behrum L-defect is created at that site.

The regularity and linearity of the HBs in an ice crystal, accompanied by a substantially greater proton mobility than in water, ensures more efficient transport of ionic and orientation defects in ice because of the presence of the radiation field

and the concentration gradient at the boundary of this region. The latter leads to an increase in the HF conductivity and ion current in water obtained from irradiated ice. The formation of orientation defects by microwave radiation leads to ruptures of hydrogen bonds at the sites of defects, since either the absence of protons on the HB line (L-defect) or the presence of two protons on the bond line – which is accompanied by their strong electrostatic repulsion (D-defect) – can be regarded as the absence of a hydrogen bond. On the whole, the pattern just described corresponds to a weakening of the H-bonds in microvolumes of water with a regular structure, and it is consistent with data on the magnetic spectra of protons [3]. Microwave radiation leads to a shift in proton NMR signals in strong fields, which signifies an increase in electron density near the hydrogen nucleus and is usually seen with the rupture of HBs [9].

It is interesting to determine whether or not there is a correspondence between the changes in the HF conductivity of irradiated water due to changes in the spatial charge distribution and changes in the absorption spectra of irradiated water in the ultraviolet region. We used a "Specord M-40" unit to record spectra of the optical density D of irradiated water (Fig. 3). It was found that an increase in the intensity of absorption is seen in the region of 200 nm, and more long-wave absorption occurs compared to the control. The observations made in the UV region can be taken as proof of a change in the energetics of unshared pairs of electrons in water molecules. In fact, while SHF radiation cannot directly change a water molecule to the excited state, it can realize this change by having the SHF field create ionic and orientation defects. The formation of these defects is accompanied by an intensification of proton transport and disturbance of the equilibrium of the Coulomb forces in the molecules. For example, in the presence of an L-defect near a molecule, there is an increase in Coulomb repulsion in the electron cloud. This weakens the attraction between unshared electrons and the nucleus of oxygen, and the unshared pair changes to a higher energy orbit.

Thus, it has been established that the high-frequency conductivity and ionic current of water increase under the influence of microwave radiation. In the case of the irradiation of frozen water, electronic polarization and orientation defects are responsible for this effect. The irregular associative part of water's structure plays a larger role in the irradiation of warm water, which explains the scatter of measurements of HF conductivity.

Superhigh-frequency irradiation of water leads to changes in its absorption spectra in the UV region. These changes correlate with changes in the characteristics of the high-frequency conductivity of water.

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