To the issue of organization of the communication system in microorganisms

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Abstract. The role of EMF (electromagnetic field) in biological systems is considered in a large number of works performed by various foreign scientists. The energy imparted to the EMF system by the ELF (extremely low frequency) field is much less than the energy of thermal movements. But no work discusses the issues of impulse exchange in biological systems, and first of all, between the molecules of the (flexible) γ-protein and membranes that act as a capacitor of electrical impulses. The purpose of the article is to fill this gap in science by discussing the literature data on the effect of ELF and ULF (ultra low frequency) EMFs on biological systems, primarily, the protein envelope of the virus + the host cell membrane.

At present, as a result of generalization of a large number of works, it is known that a constant magnetic field (PMF) can significantly change the rate and nature of the growth of microorganisms. Since they, like all other living microorganisms, in the process of their vital activity receive, process and use information about the world around them, it is natural due to their high sensitivity to EMF, especially to ULF (ultra low frequency) and ELF (extremely low frequency) EMF (1,2), the question arises about the presence of a communication channel in microorganisms due to various physical fields, which are otherwise called distance interaction. It is possible that the main role in this interaction belongs to ELF and ELF EMF. In this regard, it is necessary to consider the influence of these fields as a factor that is of the same importance in the life of bacteria as temperature, pressure, humidity, radiation, etc. The purpose of this work is to theoretically consider the processes of information exchange between cells and their surrounding compounds (environment) using weak electromagnetic waves.

The effect of a weak EMF on microorganisms has the character (nature) of stress, as a result of which the number of colonies sharply decreases, but after some time the number of microorganisms is restored. In addition, after a slight decrease in the number of microbes by 3-5 times in comparison with the control. This nature of population change is well known in microbiology. Under the influence of a certain unfavorable factor, a decrease in the number occurs, followed by adaptation of surviving individuals to it, which is subsequently accompanied by their active reproduction, as a result of which the population size exceeds the optimal one, which causes a decrease in reproduction. The considered phenomena lead to decaying waves of population size in time. So, in the case of ELF EMF action, a stress response of microbes to the effect is observed. Consequently, there is now significant progress in understanding the influence of ELF EMF on physicochemical and biological systems [3].

Currently, there are a number of hypotheses explaining the mechanism of the ELF EMF action on the above systems. The most discussed in the scientific community among them are the following: cluster, NMR, EPR, stochastic resonance, cyclotron resonance, modulation of the velocity of individual
particles and particle fluxes under the influence of ELF EMF. At first, the efforts of scientists were directed to the study of the influence of ELF EMF on chemical processes, then, consequently, it is capable of influencing biological systems as well. Chemical reactions underlie the growth and development of cells, the conversion of energy into a form suitable for various biological processes, the coding of genetic information, changes in the membrane potential capable of transmitting electrical impulses over distances (communication). When an electric pulse passes through a liquid medium, convection flows can arise in it, which can lead to a redistribution of the substances contained in them, which can cause changes in electrochemical reactions occurring at the membrane-liquid interface [4].

The interaction energy of an ion in a solution with a weak electrical potential is very small compared to thermal energy. The ELF EMF can significantly affect the orientation of large asymmetric molecules with a dipole moment, which can affect the steric factor P. Molecules can be oriented in a magnetic field in a direction favorable for the reaction, which increases or decreases the probability of a favorable collision, respectively. Under the influence of ELF EMF, magnetoanisotropic molecules and particles of a substance, which freely diffuse in a solution, can orient themselves in space. This orientation will occur when the number of monomers is of the order of n = 108-1016, which significantly exceeds the number of amino acids in the protein coat of the virus and can correspond to an RNA molecule. However, the orientation of RNA in solution is primarily determined not by the entire molecule, but by the Coulomb stiffness segment, consisting of several hundred base pairs (n = 102). The very low degree of orientation of the stiffness segments observed in the ELF EMF can lead to significant changes in the three-dimensional structure of RNA, thereby hindering the process of RNA replication. If molecules, due to intermolecular interactions, form cooperative regions with a preferred orientation of molecules, then these regions are often called domains. An external magnetic field is, in principle, capable of causing the orientation of domains in a macroscopic sample, which leads to a change in many characteristics of solutions. If the domain occupies a membrane area with linear dimensions of several microns, then the orientation effect can be significant [5].

When studying the effect of ELF EMF on the protein structures of SARS viruses, it is necessary to take into account the effect of the aquatic environment, in which, due to the existence of an aquatic environment on magnetobiological effects, including those associated with communication phenomena of spatially directed γ-bonds, macromolecules acquire the necessary conformation and the ability to perform their differentiated functions. With a certain moistening of the protein, it becomes mobile (labile) due to the formation of a layer of bound water on its surface, which is fixed when the virus enters the host cell. According to Rayleigh scattering of γ-quanta: when the critical value of humidity is reached, the rms amplitude of oscillations of non-hydrogen atoms sharply increases, and the mechanical properties of the protein also change (allotropic changes). Studying the mechanisms of ELF EMF action, a number of effects were found to depend on changes in the properties of the aqueous phase. These data on the influence of ELF and ELF EMFs make it possible to consider the aquatic environment as one of the universal receptor systems in the process of intermolecular communication. Significant changes in the properties of solvents when a portion of water treated with ELF EMF is added to them, as well as a significant dependence of the manifestation of the effects of EMF on aqueous solutions on the concentration of substances that react selectively, indicate a significant effect [6].

There is a large class of chemical reactions, the rate of which can be significantly influenced by EMF. These reactions are associated with the stage of interaction of paramagnetic particles. This pair can be in different electronic spin states, which determine different reactions of the system. According to the spin conservation law, a reaction product can be formed only through some channels ("spin ban"). The interaction of an external magnetic field with the spins of the reactants can lead to the opening of new or redistribution of old reaction channels, which, in the case of a short lifetime of a pair in comparison with its spin-lattice relaxation time, can change the rates of the forward and reverse reactions.

There are two possibilities for converting the energy of the magnetic field into the energy of the particles' orbital degrees of freedom, which ultimately control biochemical (immunochemical) reactions. Direct transformation allows the classical analogy of actions on a particle in the form of the Lorentz force. The indirect transformation is related to the spin of the particles. The power of the direct process
approaches the quantum limit in limited areas of biophysical systems (membranes) that are sufficiently protected from the external environment. In these locations, which are often key to biochemical (immunoc)chemical reactions, nuclear spins become a significant factor. It is noted that the details of the configuration of the magnetic field that are essential for the response of a biological system are: 1) the dependence of the frequency of the effective magnetic field on the magnitude of the direct current; 2) temporary orientation of uniform constant and variable magnetic fields; 3) the states of polarization of the variable ELF EMF. All of these facts are characteristic of the phenomenon of spin magnetic resonance [6].

Irreversible chemical reactions create favorable conditions for the biological amplification of weak signals. Many biophysical molecular systems that ensure the proper course of immunocchemical reactions have regions protected from external influences, which allows us to conclude that there are no fundamental prohibitions that limit the consideration of molecular biochemical systems as primary receptors for MFs with the participation of spin degrees of freedom [7].

In the course of their vital activity, cells exchange information. In this case, they generate electromagnetic signals. The ability of biological objects to maintain the constancy of the internal environment under changing external conditions, as well as to adequately respond to signals, is largely due to the functioning of cooperative systems with a threshold response. An example of such a system is the system of voltage-gated ion channels. In such systems, the steady state switching parameter value is close to the threshold, so a small change is sufficient to cause the system to switch. Now the attention of researchers is attracted by the phenomenon of stochastic resonance, which consists in the fact that in a bilayer or multistable system influenced by noise and a periodic signal, the signal-to-noise ratio in the response of the system passes through a maximum when the external noise increases. When there is no periodic signal, the switchings are also purely random, while when a signal appears, they more or less correlate with it. This component of the response correlated with the signal is indistinguishable at low and high noise intensities, but at some intermediate (resonant) value of the noise intensity, the correlation improves. If we consider the effect of a weak EMF on a cell within the framework of the stochastic resonance hypothesis, then it can be assumed that the primary antenna is a bistable ion channel. Periodic exposure causes a synchronous change in the conductivity of the ion channel (pull-push), accompanied by a change in the conformation of the corresponding protein (for example, a virus protein). Also, synchronous rearrangements of many channel proteins can then lead to a synergistic effect with the creation of complex structures on the membrane [8].

Of particular interest are the effects of ELF and ELF EMFs on the virus-host cell communication systems, especially in light of the recent COVID-19 pandemic. Studying the links between the increase in solar activity and the spread of various diseases, it was shown that outbreaks of plague, cholera, diphtheria, influenza and other viral infections coincide with periods of increased solar activity. Investigating photobacteria has shown that on magnetically quiet days bioluminescence is stationary, but significantly changeable during magnetic storms. Based on a large number of studies, it has been established that a constant magnetic field can quite strongly affect the growth and reproduction of microbes [1] To study the possibility of influencing the cultural environment and its microflora AM (amplitude-modulated) MF by additionally-amplitude-modulated rectangular pulses of AM PI, it was processed on an installation created by G.I. Kasyanov et al. [1]. To do this, 250 ml of a culture medium with microflora with the following parameters: purity (τ 83.8%), dry matter (DM - 11.8%), sucrose (Cx - 10.2%) was introduced into the chamber, where AM acted on it MF with a carrier frequency fm = 9 kHz, modulating frequency fm = 17 Hz and additionally AM PI with a duration of 15-200 ms for 55 min at a field strength of 1350 A / m, in the pause between pulses, AM electrical signals with fp = 9 were fed to the emitter kHz fm2 = 20Hz, the maximum field strength reached 1350 A / m. Analysis of microflora and purity of the culture medium was carried out in accordance with the method described in [1]. The results of the experiments are summarized in table 1.
Table 1. Results of processing the culture medium AM MP with a carrier frequency of 9 kHz and modulating frequency \( fm_1 = 17 \text{ Hz} \).

| Type of modulating MP | \( fm \), \( \text{kG}_\mu \) | \( fm_1, \text{Г}_\mu \) | \( fm_2, \text{Г}_\mu \) | \( H, \text{ A/m} \) | \( t, \text{ min} \) | \( \tau \text{ pause}, \text{ mks} \) | \( \tau \text{ imp}, \text{ mks} \) | Change of purity | Number of colonies |
|-----------------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| AM                    | 9              | 17.0          | 20            | 1350           | 55             | 15             | 200            | 3.6            | 26             |
| AM                    | 9              | 17.0          | 20            | 1350           | 55             | 20             | 150            | 2.5            | 15             |
| AM                    | 9              | 17.0          | 20            | 1350           | 55             | 30             | 100            | 1.3            | 10             |
| AM                    | 9              | 17.0          | 20            | 1350           | 55             | 40             | 50             | 0.1            | 3              |
| AM                    | 9              | 17.0          | 20            | 1350           | 55             | 50             | 20             | -1.4           | 5              |
| AM                    | 9              | 17.0          | 20            | 1350           | 55             | 40             | 200            | 1.2            | 6              |
| AM                    | 9              | 17.0          | 20            | 1350           | 55             | 30             | 150            | 2.4            | 9              |
| AM                    | 9              | 17.0          | 20            | 1350           | 55             | 20             | 100            | 1.4            | 5              |
| Control               | -              | -             | -             | -              | -              | -              | -              | -              | 0              |

The results obtained indicate that the longer the pulse time, the greater the increase in the purity of the medium in the experiment in comparison with the control, and the increase in the pause time aimed at suppressing the bacterial microflora, where the number of colonies decreases and since the MF with a frequency of \( f = 20 \text{ Hz} \) leads to a decrease in the purity of the medium, then an increase in the \( \tau \)-pause leads to a decrease in the purity of the medium. The carrier frequency was supplemented by AM PI with a duration of 15-200 mks and a pause between pulses of 10-50 μs for 55 min at a field strength of 1350 A/m, and in the pause between pulses, AM electrical signals with a carrier frequency \( fm = 9 \text{ kHz} \) and a modulating frequency \( fm_2 = 20 \text{ Hz} \) were applied to the emitter with a maximum field strength of 1350A/m.

Thus, the results of our experiments confirm the theoretical views on the possibility of AM and FM EMF influencing biological objects by additionally modulated rectangular pulses. This allows you to create a technology for the simultaneous impact on several indicators of the biosystem. The influence of AM and FM EMF of extremely low frequency ranges on the nutrient medium and its biosystem was also investigated. Affected by sinusoidally varying MFs with a harmonic corresponding to the fundamental frequency of the signal \( F \), arriving at the emitter in the range of changes from 5 to 28 Hz, were weakened by 70 dB (the value of the magnetic induction is 4.9 mT).

Figure 1. Results of the study of changes in the purity of the culture medium when processing it with a MF with a frequency lying in the ELF range and a magnetic induction value of up to 4.9 mT.
Figure 1 shows several areas, both of an increase in the purity of the medium and a decrease in it. Since the quality factor Q of the maxima and minima of the change in the purity of the medium is rather high (lies in the range of 25-95), the dependence is clearly resonant in nature.

The action of the EMF of CHG with an induction of 1: 20 mT leads to resonant electrical oscillations in the protein molecule due to the presence of an electrostrictive effect in them; a mechanical wave propagates in the volume of the protein globule. The order of magnitude of the resonator mass was calculated, when exposed to a periodic force (ELF), it is possible to achieve mechanical resonance. In terms of mass, this object corresponds to DNA. Oscillations are growing, i.e. resonance is observed with an amplitude of 1.8x10^-12 M. Mechanical resonance is possible for DNA in the frequency range. This indicates the danger of ELF for biological objects, namely, a change in the genetic apparatus (mutation), which was proven by experiments [2].

Resonance at the acid level or DNA cannot be the main factor in the observed effects of changes in the purity of the culture medium, and it is likely that the effect is associated with the effect of ELF EMF on proteins. The changes we observed are associated with electromechanical resonance in globular proteins, i.e. modulation of protein conductivity occurs, as a result of which there is a redistribution of mechanical vibrations of individual links of the molecule. They become more orderly. This is accompanied by a change in the solubility of the protein, which leads to a change in the interaction energy in the active center of the protein and a change in the probability of the reaction. The resonant effect of ELF EMF leads to a change in protein solubility, pH and viscosity of the medium change. Our studies have shown [3,4,5] that the viscosity of the medium should increase with a simultaneous decrease in pH, which leads to a decrease in protein solubility and precipitation.

It was unsuccessful to describe the effects we observed by various known hypotheses. For example, the theory of ion cyclotron resonance is able to explain only resonant magnetobiological effects. There were also significant difficulties in applying the theory of interaction of triplet-singlet pairs. It turned out to be fruitful only in attracting the phenomenon of dissipative resonance (the phenomenon of increasing oscillations under the influence of external periodic forces due to the formation of an order structure in the system). In this case, we used some provisions from the theory of noise of electronic amplifiers to calculate the possible value of FDS induced at the ends of the polypeptide chain of a protein, which is directly related to the process of self-organization in dissipative structures, which is distinguished by the quasi-periodic nature of changes in some parameters of the system. Closer to this is the theory of the redistribution of temperature fluctuations in a macromolecule under the influence of ELF EMF. According to this theory, it is possible to take into account the influence of several disturbing forces, for example, constant and variable MF, on the system. Nevertheless, the phenomena we have considered are still difficult to explain and require further study, both experimentally and theoretically. Despite the successful description of magnetobiological effects in superweak fields, using the existing theoretical views, the explanation of the observed consequences of the ELF EMF effect on biosystems using this theory is too problematic [6,7,8].

Conclusions. Thus, the effect of ELF EMF on the biological system (with induction from 1 to 120 mT) leads to resonant electrical oscillations in the protein molecule, due to the electrostrictive effect in proteins, a mechanical wave propagates in the volume of the protein globule, which, possibly, affects the processes communication between the protein coat of the virus and the membrane of the host cell. In addition, literature data indicate that the main communication processes occur in the diffusion layer, in which there are no cells and are not associated with membrane processes and RNA. In any of the considered theoretical options, the dominant role is assigned to the protein molecule, which is easily subject to allosteric changes due to its specific spatial structure.

Thus, it has been shown that it is possible to register AM EMF due to nonlinear changes in the conductivity and relative elongation of protein and other polymer molecules. The probability of conversion by biosystems of FM oscillations of EMF into AM oscillations with subsequent registration due to nonlinear changes in the relative elongation of molecules of proteins and other polymers has been proved. The results show that EMF and ELF can act on a DNA molecule. Analysis of resonance...
processes and experimental data shows that the most probable receivers of the effects of ELF EMFs are protein molecules.

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