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EFFECTS OF HIGH FREQUENCY ELECTROMAGNETIC RADIATION ON NEUROTRANSMITTERS IN THE BRAIN

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Abstact. The effect of a single exposure to non-thermal intensity extremely high-frequency alpha-modulated electromagnetic radiation (EMR) on the content of biogenic monoamines (BMA) in different brain structures in rats is reviewed. The obtained data indicate a complex reorganization of neurodynamic processes under the influence of EMR exposure in the cortical and subcortical structures of the brain, which are responsible for the formation of emotional states of the body. At the same time, the final result of EMR exposure depends on the initial level of excitation of brain structures and is reflected in the state of and the activity of the MA-ergic systems of the brain.

Keywords: *electromagnetic radiation, biogenic mono-amines, brain.*

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1. Introduction

The study of biological objects under external influences is one of the problems of modern physics and biology, including biophysics. Therefore, he has been conducting extensive research in this direction recently (Nasibova, 2023; Hajiyeva *et al.*, 2023; Bayramov *et al.*, 2023). One of such studies is the study of the effect of electromagnetic waves on biological objects. The development of modern technology has led to the emergence of unnatural electromagnetic radiation effects on the human body and living things. Thus, electromagnetic radiation is currently one of the most widely used physical factors in communication and radiological devices and in industry, medicine and other areas of human activity. The exception of the utterly harmful effect of electromagnetic radiation on the human body and nature in general, as it seems, is not realistic. However, the study of the mechanisms of the effect of this factor on biological objects remains in the sphere of interest of many scientific directions (Adayev *et al*., 2005; Aghayeva, 2023; Cuicui Hu *et al.*, 2021; Grigorev, 2005).

The generally accepted view is that the nervous system is very sensitive to the effects of low-intensity extremely high-frequency electromagnetic radiation (EMR). The set of experimental facts collected on this problem suggests various modifications of the

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physicochemical properties of the excitable neuron membrane under the influence of EMR, which should ultimately affect the state of different functional systems of the brain. The high efficiency of the analysis of the rhythmic structure of the EEG was demonstrated in the study of the effectiveness of the low-intensity modulated EMR effect. However, the insufficient inconsistency of the collected material does not allow us to clarify the regularities of the reconstruction of neural processes under the influence of EMR and indicates the need for further research (Chichnadze, 2002; Mammadov, 2002; Sandström *et al*., 2001).

2. Experimental part

To study the effect of high-frequency electromagnetic waves on the activity of the monoaminergic system in the brain structures, research was conducted using behavioural and biochemical methods in white rats after the effect of electromagnetic radiation.

The research was conducted on 130 rats weighing 180-210 g. Experimental animals with 4-5 heads were kept in 75×40×40 cm chambers with free access to food and water. Before the experiments, the animals are adapted to the experimental conditions for 3-4 days. For this purpose, the experimental animals were kept in a 15×18×12 cm Plexiglas box for 30-40 minutes. As a rule, on the 3rd and 4th days of adaptation, the spontaneous motor activity of the experimental animal's decreases and the animals calm down. Animals that have reached this level are tested by the open-field method.

In the initial part of the study, the limits of the thermal effect of electromagnetic radiation were determined. For this purpose, copper-constantan thermocouples with a diameter of 0.2 mm were epidurally injected into symmetrical areas of the cerebral hemispheres in 4 white rats under nembutal anaesthesia. They, in turn, are later connected to the automated data calculation system based on IBM PC/AT. The experiments were performed 2-3 days after the electrode placement operation. During the experiment, the animals are placed in a special transparent chamber. A generator was used as a source of electromagnetic radiation. The parameters of extremely high-frequency electromagnetic radiation are determined based on research carried out in the laboratory ($\leq$10 mW/cm^2; 41.7 HHs.) In the main experiments, one-time (for 30 minutes) and long-term (30 minutes for 5 days) irradiation of EEG with modulated and unmodulated radiation in the alpha range was applied (Mamedov *et al*., 2006; Wilkswo *et al*., 1999).

Based on the known concepts of the modulatory role of BMA in the regulation of the level of excitation of nerve cells (Mamedov *et al*., 2006), it should be assumed that the impact of EMR in a certain way should also affect.

Initially, the number of monoamines was determined in the areas of the cerebral cortex, hippocampus and hypothalamus of control and electromagnetic radiation-exposed animals. After the animals were decapitated, the brain was removed from the skull box and frozen at -20 C for 2-3 minutes. The weight of the sample was determined by separating the above-mentioned areas of the brain. Monoamines were determined using the well-known fluorimetric method (Kogan *et al*., 1979). Fluorescence intensity was measured in an MPF-4 (Hitachi, Japan) spectrofluorimeter. The statistical analysis of the results was calculated based on Student's t-criterion and with the help of the Microsoft Office Excel-2007 program.

3. Results and discussion

The results of the conducted studies show that the effect of a single exposure to low-intensity, extremely high-frequency electromagnetic radiation for 30 minutes on the amount of monoamines in separate structures of the brain depends on the modulation of electromagnetic waves. It was clear that the amount of monoamines in the control was higher in the cerebral cortex than in the subcortical structures, and the highest level of this neurotransmitter was observed reached (Figure 1).

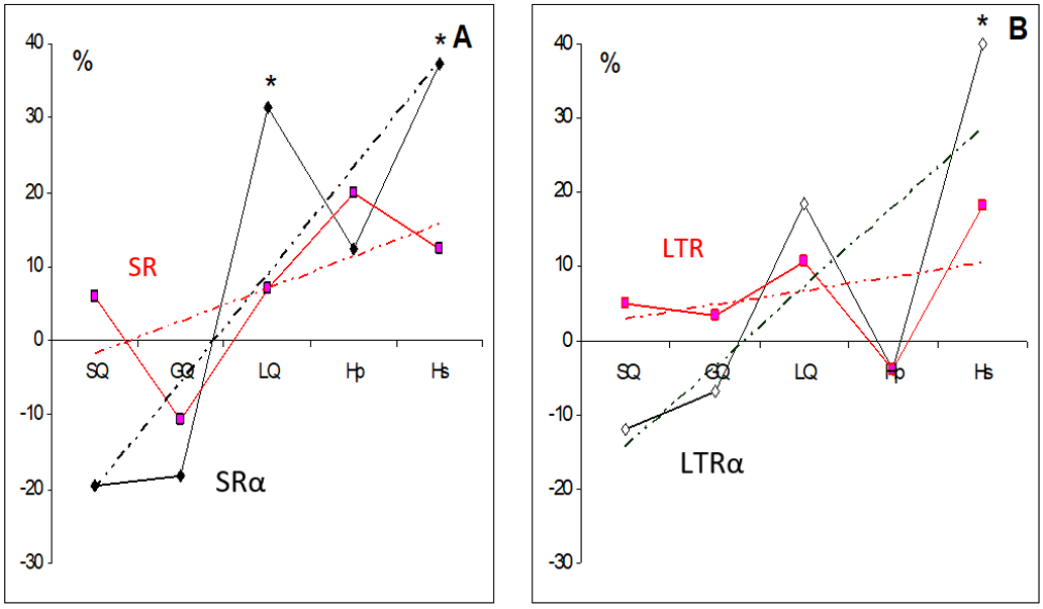

Fig. 1. Comparative analysis of single (A) and long-term (B) effects of ultra-high-frequency modulated (black lines) and unmodulated (thick lines) EMR for 30 minutes on the amount of monoamines cortical and subcortical structures of the brain. SQ- sensorimotor cortex, GQ- visual cortex, LQ- limbic cortex, Hp- the hippocampus, Hs- the hypothalamus. Solid lines – compared to controls, dotted – linear approximation. * - $P \leq 0.05$

Thus, the single effect of modulated EMR is reflected in many brain structures (Vc, Lc, Hp and Hs) that have a more significant effect on the MA-ergic system. It can be said that high-frequency radiation has a differential effect on the components of the MA-ergic system.

The brain structures we studied (sensorimotor cortex, visual cortex, limbic cortex, hypothalamus, and hippocampus) were selected based on the literature on the body's participation in the generation of various emotional states, memory, and learning processes. It is known that individual emotional states are closely related to parts of the cerebral cortex and subcortical structures and form a functional union with the upper and lower levels of the central nervous system. The hypothalamus sends information directly to the parts of the neocortex of the brain responsible for maintaining a high level of cognitive function. At the same time, the important role of these structures in the processes of learning and memory is well known from the literature (Kavet *et al*., 1986; Jauchem *et al*., 1991)

Considering that the activation of the serotonin ergic system at the level of the hypothalamus, which is considered an emetogenic structure, is functionally related to a positive emotional state, it is clear that a single effect of modulated EMR reduces the

level of emotional tension in white rats. At the same time, a similar situation occurs at the level of the limbic cortex. Based on these facts, it can be assumed that the reduction of the level of emotional tension is performed as a result of the activation of the 5-HT-ergic system at the level of Hs and Lc of the studied brain structures (Cadogan *et al*., 2001)

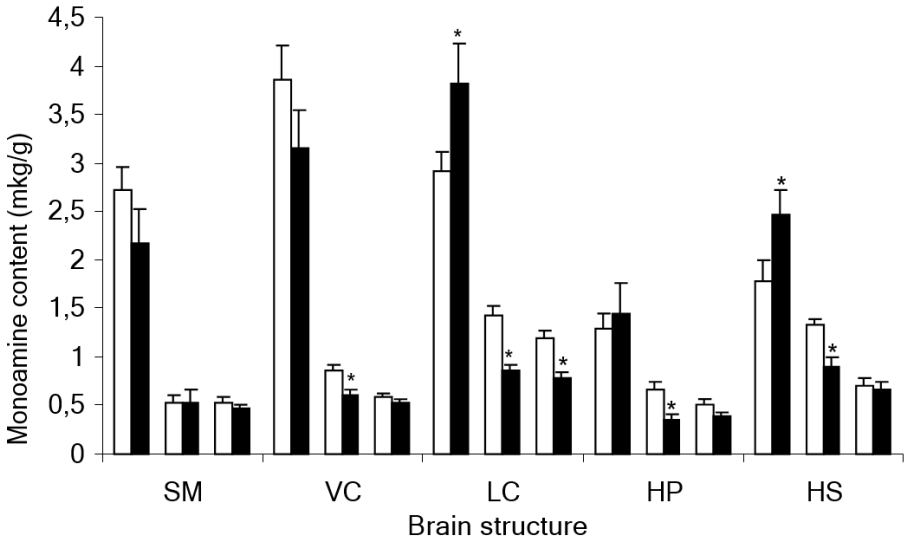

Fig. 2. Comparative analysis of the effect of EHF EMR of non-thermal intensity EHF for 30 minutes on the content of biogenic monoamines in various areas of the brain in rats. each triad demonstrates 5-HT, NA and DA, respectively. White bars – control, dark bars – after hHF irradiation. SM – sensorimotor cortex, Vc – visual cortex, Lc – limbic cortex, HP – hippocampus, Hs – hypothalamus. * – $p < 0.05$

Thus, it is possible to record the neurophysiological effects of extremely high-frequency electromagnetic radiation at an intensity of radiation of 10 mW/cm2. The neurophysiological effects of such low-intensity radiation can be obtained only at low levels of emotional stress and modulation of the leading frequency of the EEG in the alpha range. Due to the effect of low-intensity EMR, there are changes in the innate behavioral responses of adapted animals, but the characteristics of these changes depend on the parameters of the applied EMR. In contrast to long-term radiation, changes in innate behavioral responses during a single exposure to EMR in the α-range of EEG are more pronounced (Chokroverty *et al*., 1995; Mamedov *et al*., 2006).

In the course of the experiment, it became clear that the disruption of learning and memory processes caused by radiation is in some cases associated with changes in the amount of monoamines. These relations are of special interest in terms of the importance of the participation of the studied structures in the learning and memory processes. From the results of our observations in this direction, it is clear that the amount of 5-HT increases in the cortical-subcortical direction and reaches a maximum at the Hs level due to a single exposure to low-intensity EHF EMR (Electromagnetic Radiation of Extremely High Frequency) for 30 minutes. As can be seen from the figure 2, the slope of the modulated emission approximation line (the angle formed by the abscissa axis) develops in this direction, which indicates an increase in the reactivity of the Hs structure with respect to 5-HT compared to other structures due to the effect of modulated EMR.

Considering that activation of the 5-HT ergic system at the level of the hypothalamus, considered an emotogenic structure, is functionally associated with a

positive emosional state, it is clear that a single exposure to modulated EMR reduces the level of emotional arousal. tension in white rats. At the same time, a similar situation occurs at the Lc level. As can be seen from the figure, the activity of the 5-HT ergic system in this area of the cortex is located in the positive region of the x-axis and the approximation line. Based on these facts, it can be assumed that the level of emotional stress is reduced due to the activation of the 5-HT ergic system at the level of Hs and Lc from the studied brain structures.

Moreover, despite the change in the activity of the 5-HT ergic system at the level of other studied cortical and subcortical structures, the participation of these structures in the creation of a new emotional state of the body as a result of irradiation is minimal. The results of experimental studies accumulated to date make obvious the need for a more in-depth study of the effects of EHF radiation on various aspects of nervous activity (Aghayeva, 2023; Ağaeva *et al*., 2011; Frey, 1993).

Previously, we showed that under the influence of the EHF electromagnetic pulse modulated in the alpha region, a long-term restructuring of the correlation-spectral characteristics of the total activity of various areas of the cerebral cortex is observed. A characteristic feature of this effect was the formation of regular rhythms at a frequency close to the EMI modulation frequency, and was accompanied by an increase in coherent connections between cortical leads (Mammadov, 2002.). Based on these and literature data, a hypothesis was put forward about the possible role of (BMA) in the observed effects. The purpose of this work was to study the effect of modulated EHF EMR on the BMA content in the cerebral cortex of rats.

The results of the studies indicate ambiguous changes in the activity of MA-ergic systems innervating various areas of the cerebral cortex. With the exception of Lc, in general, the data obtained demonstrate the synergistic nature of changes in the BMA content as a result of exposure to EHF electromagnetic radiation of non-thermal intensity. Since the BMAs are of subcortical origin, it should be assumed that the observed changes are based on presynaptic mechanisms of regulation of the MA-ergic neurotransmission of the BMA under the influence of EHF electromagnetic radiation.

Previously, by analyzing innate behavioral reactions in rats in the “open field” test, we showed that under the influence of EHF electromagnetic radiation of similar parameters, the initial level of emotional tension decreases in accordance with modern concepts, a decrease in the level of emotional tension and, as a consequence, behavioral activation in the “open field” test indicated an increase in the functional activity of the 5-nTergic system with a simultaneous decrease in the activity of the neuroergic system of the brain (Kogan *et al*., 1979; Sandström *et al*., 2001)

Thus, changes in the activity of individual components of the MA-ergic neurotransmitter system as a result of exposure to modulated low-intensity EMR of the EHF do not differ from the information available in the literature about the neurophysiological mechanisms of individual emotional states. At the same time, the synergistic functional connection between NA and DA-ergic systems and the reciprocal connection between 5-HT and KA-ergic systems correspond to changes in the probability of activation of individual innate behavioral reactions

What is not completely clear to us is that the processes of learning and memory are disrupted under conditions of weakening emotional stress as a result of changes in the activity of MA-ergic systems due to exposure to radiation.

It is interesting that, regardless of the nature of its origin, the formation and development of emotional tension in both cases is carried out with the help of the same

MA-ergic neurotransmitter systems, and in many cases, the same functional systems of the brain. Such ideas can be found in P. V. Simonov's information theory of emotions (Simonov, 1997), Z. H. Mammadov's concept of dual principle of MA-ergic neurotransmission (Mammadov, 2002).

4. Conclusion

This kind of data substantiates the point of view according to which the nature of changes in the activity of the MA-ergic system of various brain structures under the influence of EHF EMR is a consequence of complex neurodynamic processes responsible for the formation of emotional states of the body. In this case, the final result of the effects of EMR EHF depends on the initial level of excitation of emotiogenic structures and is reflected

However, this situation is consistent with the results we obtained only at the level of Lc, while in the Vc and Sm regions changes in BMA demonstrate a synergistic nature of changes under the influence of EHF emI. It can be assumed that the nature of changes in the level of BMA in cortical areas under the influence of EHF EMR is due to differences in neurodynamic processes responsible for the presynaptic mechanisms of regulation of maergic neurotransmission.

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