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ABSTRACT (Maximum 200 words)

This report results from a contract asking Institute of Theoretical and Applied Mechanics as follows: Study is devoted to basic research of stability and transition of hypersonic boundary layer around blunted cone. Nosetip bluntness effects have very strong influence on laminar-turbulent boundary layer transition. These effects are very complex because the nosetip-region boundary layer may be under the influence of by-pass phenomena. Tollmien-Schlichting waves, and Goertler vortices. Results of fulfilled stability experiments do not agree with computations. Bu t such a comparison is not at all valid because natural disturbances were studied in former experiments. In the present project the artificial wave-packet method will be applied to get the necessary data f or waves for various single incidence angles. Obtained results will be used for a correct comparison between theory and experiment. The experimental investigations will be performed in the blowdown wind tunnel T -326 in Hypersonic Flow Laboratory of ITAM SB RAS at Mach 6 . A point-source g low-discharge perturber will be used to excite the boundary layer frequency band corresponding to the first and second mode waves. Mean f low and pulsations measurements will be carried out using hot-wire anemometer. Detailed experimental data on the position of the laminar-turbulent transition, characteristics of natural disturbances and evolution of artificial disturbances in the boundary layer of a cone with different nose bluntness at Mach number M=6 will obtained. The proposed project will allow a bank of experimental data on the stability of the hypersonic boundary layer to be compiled. As a result, a better insight into the processes taking place in hypersonic boundary layers will be qained.

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ISTC No.2362 p

FINAL
TECHNICAL REPORT
OF ISTC PROJECT NO.2362P

BASIC MATERIALS FOR ELECTROMAGNETIC FIELD STANDARDS

(From 01 June 2002 to 30 November 2003: 18 months period)

Youri Grigorievich Grigoriev
(Project Manager)

State Research Center – Institute of Biophysics

November 2003

The work was sponsored financially by European Office of Aerospace Research and Development (EOARD), London, UK under the agreement with International Science and Technology Center (ISTC), Moscow, Russia.

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The majority of contemporary Western standards of EMF is based upon the research results of physiological changes induced by short term electromagnetic irradiation of the thermal exposure level, as a rule. The existing standards do not take into account the possibility to develop specific effects under the modulated EMF exposure.

In the framework of work under the present Project, the selection and analysis of research studies devoted to the chronic exposure to electromagnetic fields of radiofrequency and low intensities (non-thermal levels) were elaborated as well as the studies of biological effects induced by modulated EMF in acute experiments reported in papers published in the USSR and Russia. The results of these studies were most important when developing current Russian standards of EMF.

Basing upon the elaborated contractual work, recommendations were given to improve approaches and principles of standardization for electromagnetic fields under controllable and uncontrollable conditions.

Key words: electromagnetic fields, radiofrequencies, modulated electromagnetic fields, power flux density, field strength, biological effects of chronic exposure, maximum permissible level, electromagnetic field standardization methodology.

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ISTC No.2362 p

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the following institutes and collaborators

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Project goals

The goal of the present Project was the selection and generalization of initial data of research studies devoted to fundamental biological effects of the long time (0.5–2 years) exposure to EMF of low intensity (below 500 μW/cm^2) and on acute biological effects of modulated EMF, which were elaborated in the USSR, Russia and Ukraine; these studies were most essential for the development and justification of current Russian standards of EMF exposure in human as well as to provide recommendations on EMF standards.

Scope of work and scientific technical approach

The scientific technical approach was based upon the selection and analysis of materials available in papers, reports and doctorate thesis establishing EMF levels recommended for standards.

The selection and analysis of data on animal experiments in case of chronic EMF exposure of low intensities (below 500 μW/cm^2) were elaborated.

The Report on *"Biological effects of electromagnetic fields of radiofrequency band applied to the standardization issue (results of experiments elaborated in the USSR and Russia)"* was provided for chronic EMF exposure in UHF and SHF frequency bands of 300 MHz to 3 GHz with power flux density of 1 to 1000 μW/cm^2. Besides, charts describing 52 experimental studies and initial experiment data (93 tables) were provided together with list of experiment author publications.

The selection and analysis of studies elaborated in the USSR and Russia on biological effects of modulated electromagnetic field of radiofrequency band (acute experiments under in vivo, in situ, and in vitro conditions) were elaborated.

The Report on *"Bioeffects of modulated electromagnetic field exposure in acute experiments"* was provided basing upon the analysis of 28 experiments done in Russia (USSR) applying modulated electromagnetic field (MEMF). The Annex of this Report provided 28 charts with detailed specifications of exposure conditions, examination techniques and statistical handling was prepared together with results of each described study.

Results of the generalization of 80 experimental studies (Tasks 1 and 2) and 42 additional publications are given in Task 3 Report on *"Recommendations for the improvements of approaches and principles of EMF standardization"*.

Resume of Project Technical Report

When elaborating the analytical research under **Task 1**, final materials of 52 studies were analyzed, which studies have provided results of chronic exposure of animals to electromagnetic fields of radio frequency and low intensity. Studies were done in five research institutions of the USSR in 1960–1980.

Taking into account the fact that considered experiments were tried in different institutions and different research teams, the elaborated analysis and comparison of results obtained under identical conditions give the opportunity to reveal the general trend for bioeffect induction in case of the chronic EMF RF exposure of law intensities.

The results provided for chronic EMF exposure of UHF and SHF frequency bands of 300 MHz to 3 GHz with power flux density of 1 to 1000 μW/cm^2 give the opportunity to get the following conclusions:

- 100–500 μW/cm^2 PFD in case of chronic daily exposure can induce expressed and persisting pathological biological reactions;
- ~ 50 μW/cm^2 PFD is the threshold value of the unfavorable biological effect;
- ≤10–20 μW/cm^2 PFD does not induce visible biological changes in small laboratory animals in case of the chronic exposure.

Chronic EMF exposure results for high frequency band of 10 to 300 MHz and electric field intensity of 20–150 V/m conclude to the followings:

- 100–150 V/m intensity can induce expressed and persisting biological changes in case of the chronic exposure;
- 20–30 V/m intensity is the threshold value of the unfavorable effect;

The **Task 2** analysis of 28 biological experiments conducted in vitro, in situ, and in vivo in the former Soviet Union (FSU) and later in Russia with usage of the modulated electromagnetic fields of radiofrequency allows to make the following basic conclusions:

- EMF exposure of biosystems with less or more composite regimens of modulation the development of bioeffects, both physiological, and unfavorable, which are distinct from bioeffects induced by not modulated EMF is possible;
- the acute modulated EMF exposure of low intensities (non-thermal levels) can result in development of pathological effects;
- there is a dependence of development of a reciprocal biological response on the intensity and directness of the concrete regimen of EMF modulation; this dependence was fixed at all levels of biological systems — in vitro, in situ and in vivo;
- as a rule, modulated EMF has invoked more expressed bioeffects, than continuous regimen of modulation;
- the effect of EMF RF modulation is more expressed at lower levels of intensity.

The obtained data have specified the possibility of the effect of EMF modulation on the development of biological effect at a level of composite systemic interactions in an organism. It allows to discharge modulated EMF in the special group of radiations, which biological effect depends not only from magnitude of an absorbed energy, but also on the form of modulation «addressed» to this or that functioning system. It determines the conclusion, that at an assessment of modulated EMF danger, it is important not only to assess magnitude of an absorbed energy, but also the fact of contact of the human with this aspect of radiation. This circumstance brings in major indeterminacy by development of the EMF standards.

The individual singularities of the man are essentially important, the individual sensitivity to a particular regimen of EMF modulation, that dilates a problem of hypersensitivity to EMF.

As a result of the conducted experiments with MEMF, the effect of an initial state of biosystem on expected effect is detected. The given fact is rather important, since does not allow to establish common regularity in the development of bioeffects at particular aspects of modulation. As a matter of fact, the initial background of a system of an organism can determine the character and directness of a reciprocal response that complicates the prognosis of expected effects in conditions of MEMF exposure on the population.

The role of modulation gains the major significance at low intensity (at non-thermal levels of EMF). In this connection, this factor becomes now leading at an assessment of population exposure to EMF RF.

The experimental recognition of dependence of development of bioeffect from an aspect of modulation specifies recruitment phenomenon of new gears of interaction of an organism with MEMF, which are not clear and demand the future study.

The surveyed results after additional analysis of 80 experiments, in which they have utilized chronic EMF exposure of animals at low intensities and modulated EMF and 42 additional publications (**Task 3**), allow to formulate a number of recommendations on perfecting the approaches and principles of the regulating.

1. We consider, that maximum permissible level should ensure health of the population in first and second generation and not suppose the incorporation of compensatory responses.

2. It is expedient to reserve a principle of development of the separate standards for controllable and uncontrollable conditions of EMF exposure.

We also consider rational development of the standards for separate sources of electromagnetic fields: radar stations, base stations of systems of mobile communication and for some other sources of EM radiation.

3. An original material for MPL justification for controllable conditions should be results of:

- complex hygienic examinations;
- clinical physiological examinations;
- study of a morbidity rate with temporal disability;
- examinations on volunteers under industrial conditions and in conditions of laboratory experiment;
- experimental examinations on animal.

The regulating for uncontrollable conditions should be conducted on the basis of results of the following complex of examinations of:

- hygienic assessment of conditions of exposure of the environment factor;
- studies of a state of health of the population who is subjected to exposure of the factor;
- studies of a EMR biological effect in animal.

4. The position of "critical systems and organs" should be formulated. We consider possible reference to critical systems of central nervous, endocrine and immune systems.

5. The determination of criterion for the unfavorable EMF health effects (threshold of damage), which health effects are basic phenomena to put the hygienic safety factor, is discussible with principally different approaches to deal with this issue.

According to the analysis results, the revisiting of the concept of *non-effective threshold* previously proposed in the USSR is justified to develop the population protection standards.

6. The common feature of the long-term exposure to various stress factors if the strain of regulatory processes in an organism and possibility of rather fast exhaustion of compensatory reserves. At considerably reduced scope of compensatory reserves of an organism, the adaptation abilities are decreased. Even after EMF cancellation, there can be a failure of adaptation in case of padding exposure to other unfavorable factors of the human habitat. Thus, the probability of development of various diseases is enlarged, first of all, on the part of central nervous and cardiovascular systems, disturbance of the immune status. In case of a cumulation of bioeffects, the development of the late consequences is possible.

7. It is necessary to take into account series of the factors, which till now have not the sufficient scientific basis to prediction: a role of modulation in paravariation of radiobiological effect; constant effect of electromagnetic fields of small intensity in the pregnant women, children and patients for the development of common somatopathies, and also combined effect of other physical factors of environment and social conditions.

8. The conducted analysis allows us to make a conclusion, that the magnitudes of the radiation exposure for controllable conditions should be decreased for 3–4 times at least, and for uncontrollable conditions (population), taking into account the overall spanning, including children and pregnant women, the magnitude of a radiation exposure should be decreased for more than 10 times.

9. When developing the EMF standards, the medicobiological assessments instead of engineering accessibility of fixed MPL should be leading issue. The hygienic standard should promote the development of new technical ideas directed on building of safe EMF sources and technologies and ensure the population protection from all of growing EMF presence in ecological environment.

Scientific Reports prepared under the elaboration of **Tasks 1, 2, and 3** of ISTC Project No.2362 p were provided to International Science and Technology Center and Partner as well as attached to the present Technical Report (in electronic format on CD ROM).

Project result description

List of published papers

- Grigoriev You. G. Cellular communication EMF: population health effects and danger assessment (the state of issue in 2002) // In: Electromagnetic fields and human health. RUDN publication, Moscow, 2002. pp. 14–48.
- Grigoriev You. G., Shafirkin A.V., Vasin A.L. Standardization of radiofrequency electromagnetic field (EMF RF) for the population of Russia. Retrospective study and modern viewpoint. In: Electromagnetic fields and human health. RUDN publication, Moscow, 2002. pp. 98–123.
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- Grigoriev You. G., Vasin A.L., Nestor Mendez, Grigoriev O.A. Comparative aspects of EMF standards and their harmonization issues. // In: Electromagnetic fields and human health. RUDN publication, Moscow, 2003. pp. 109–116.
- Grigoriev You. G., Shafirkin A.V., Vasin A.L. Bioeffects of chronic electromagnetic field exposure of radiofrequency and low intensity range (standardization strategy). // Radiation biology. Radioecology. 2003. vol. 43. No 5. pp. 501–511.
- Grigoriev You. G., Shafirkin A.V., Nikitina V.N., Vasin A.L. Late effects of chronic exposure to ionizing radiation and electromagnetic fields: hygienic standardization application. // Radiation biology. Radioecology.. 2003. vol. 43. No 5. pp. 565–578.

Reports at conferences and meetings

- Yu. Grigoriev, V.S. Stepanov, L.A. Tomashevskaya, A.V. Shafirkin, A.L. Vasin. “10 mW/cm^2 Level of EMF in Standards of Russia and 1000 mW/cm2 Level in ICNIRP’s Recommendations (experimental studies for the characterizing of these differences)”. // BEMS Abstract Book. Twenty-Fourth Annual Meeting. In Cooperation with the European Bioelectromagnetics Association. Hotel Loews Le Concorde. Quebec City, Quebec, Canada. June 23–27, 2002. P. 170.
- Grigoriev You. G., A.V. Shafirkin, A.L. Vasin. Standardization of radiofrequency electromagnetic field (EMF RF) for the population of Russia: retrospective study and modern viewpoint. // Proceedings of Third International Conference on Electromagnetic fields and human health. Fundamental and applied research. 17 – 24 September 2002, Moscow – St.-Petersburg, Russia. pp. 164.
- Ju. G. Grigoriev, V.S. Stepanov. “Problem of population electromagnetic safety”. International Medical Congress “New technologies in medicine. National and international medical security issues”. Slovenia, from March 28 to April 4, 2003. P. 13.
- Grigoriev Yu.G., Vasin A.L., Grigoriev O.A., Nikitina V.N., Pokhodzey L.V., Rubtcova N.B. Harmonization options EMF standards: proposals of Russian national committee on non-ionazing radiation protection (RNCNIRP). 3rd International EMF Seminar in China: Electromagnetic Fields and Biological Effects. Guilin, China. October 13–17, 2003. P. 55.
- Grigoriev You. G. Modulated electromagnetic fields and human health. 3rd All-Russian Congress of the Nature Protection. 21 November 2003. Moscow.

Cooperation with foreign co-workers and sub-contractors was not presumed by the Project.

The technology application plan

- Project results can be used to harmonize international and national EMF standards of different countries as well as to evaluate the population health danger of electromagnetic fields of mobile communication base stations.
  It is convenient to sent final materials of the Project to World Health Organization (WHO), The International Commission on the non-ionizing radiation protection (ICNIRP), the American Committee on Standards (Committee 28 at IEEE). We kindly request ISTC to agree the realization of our proposal with Project Sponsor.
- Prospectively, it is necessary to elaborate acute and chronic experiments under comprehensive modes of electromagnetic field modulation (simulation of real EMF exposure in population).

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Basing upon the elaborated contractual work, recommendations were given to improve approaches and principles of standardization for electromagnetic fields under controllable and uncontrollable conditions.

Key words: electromagnetic fields, radiofrequencies, modulated electromagnetic fields, power flux density, field strength, biological effects of chronic exposure, maximum permissible level, electromagnetic field standardization methodology.

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Table of content

Introduction

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To keep unified approach to the collection and analysis of the information, the standardized format was elaborated basing upon the modification of the format used by IEEE to evaluate EMF literature sources. This work was co-coordinated with Russian National Commission on non-ionizing radiation protection.

After the finalization of the survey of results obtained by the important experiments on acute and chronic exposure, the general analysis and data assessment were tried including the general classification and summarizing results as well as the additional statistical analysis of confidence and significance for EMF exposure standardization.

These data were applied to evaluate the danger of EMF exposure and to recommend improvements for approaches and principles of EMF standardization under controllable and uncontrollable conditions.

Results

Three tasks were elaborated under the Project:

Task 1. Data of animal experiments under chronic EMF exposure of low intensities (below 500 μW/cm^2) were analyzed. Results were provided by the scientific report on *Health effects of electromagnetic fields of the radiofrequency band: the application to the regulation problem (experimental results obtained in the USSR and Russia)*

Task 2. Acute exposure effects of modulated EMF were analyzed. Results were provided by the scientific report on *Biological effects of the modulated electromagnetic fields in acute experiment.*

Task 3. Basing upon generalization of results of tasks 1 and 2, the scientific report on *Recommendations on the improvement of approaches and principles of EMF regulating* was provided including standardization recommendations.

Task 1. *To analyze data of animal experiments under chronic EMF exposure of low intensities (below 500 μW/cm^2).*

When elaborating the analytical research, final materials of 52 studies were analyzed, which studies have provided results of chronic exposure of animals to electromagnetic fields of radio frequency and low intensity. Studies were done in five research institutions of the USSR in 1960–1980.

Taking into account the fact that considered experiments were tried in different institutions and different research teams, the elaborated analysis and comparison of results obtained under identical conditions give the opportunity to reveal the general trend for bioeffect induction in case of the chronic EMF RF exposure of law intensities.

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Chronic EMF exposure results for high frequency band of 10 to 300 MHz and electric field intensity of 20–150 V/m conclude to the followings:

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Task 2. *To analyze data of biological effects of modulated electromagnetic field in acute experiments .*

The Task 2 analysis of 28 biological experiments conducted in vitro, in situ, and in vivo in the former Soviet Union (FSU) and later in Russia with usage of the modulated electromagnetic fields of radiofrequency allows to make the following basic conclusions:

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- as a rule, modulated EMF has invoked more expressed bioeffects, than continuous regimen of modulation;
- the effect of EMF RF modulation is more expressed at lower levels of intensity.

Task 3. *To provide recommendations on electromagnetic field standards*

The surveyed results after additional analysis of 80 experiments, in which they have utilized chronic EMF exposure of animals at low intensities and modulated EMF and 42 additional publications, allow to formulate a number of recommendations on perfecting the approaches and principles of the regulating.

1. We consider, that maximum permissible level should ensure health of the population in first and second generation and not suppose the incorporation of compensatory responses.

2. It is expedient to reserve a principle of development of the separate standards for controllable and uncontrollable conditions of EMF exposure.

We also consider rational development of the standards for separate sources of electromagnetic fields: radar stations, base stations of systems of mobile communication and for some other sources of EM radiation.

3. An original material for MPL justification for controllable conditions should be results of:

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Conclusion

The Project was elaborated according to the Technical calendar schedule. Delays and logs of Technical calendar schedule were absent.

Thus, the whole scope of studies presumed by the Project was completely elaborated within approved terms.

Scientific Reports prepared under the elaboration of **Tasks 1, 2, and 3** of ISTC Project No.2362 p were provided to International Science and Technology Center and Partner as well as attached to the present Technical Report (in electronic format on CD ROM).

Bibliography

Task 1

1. Los I.P., Bitkin S.V., Soldatchenkov V.N. Mathematical planning of experiments on biological evaluation of electromagnetic fields. // Proceedings of 3rd Soviet-American working meeting on the Investigation of biological effects of physical factors of the environment, Kiev, 11–15 May 1981 г., Kiev, "Zdorovie" Publisher,1982, pp. 61–65. In Russian.
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List of published papers

1. Grigoriev You. G. Cellular communication EMF: population health effects and danger assessment (the state of issue in 2002) // In: Electromagnetic fields and human health. RUDN publication, Moscow, 2002. pp. 14–48.

Brief note. Generalized data on health effects of modulated electromagnetic fields were applied for the danger assessment of mobile phones and base stations.

2. Grigoriev You. G., Shafirkin A.V., Vasin A.L. Standardization of radiofrequency electromagnetic field (EMF RF) for the population of Russia. Retrospective study and mod-

ern viewpoint. In: Electromagnetic fields and human health. RUDN publication, Moscow, 2002. pp. 98–123.

Brief note. Materials on change of the immune status of animals during and thereafter the radiofrequency EMF exposure of low intensity were provided.

3. Grigoriev You. G., Shafirkin A.V., Nikitina V.N. Risk of late non-tumor pathology in case of the chronic exposure to ionizing and non-ionizing radiation: hygienic standardization application // In: Electromagnetic fields and human health. RUDN publication, Moscow, 2002. pp. 141–161.

Brief note. Approaches to the late non-tumor pathology risk assessment were considered basing upon epidemiological and experimental studies of EMF RF aftereffects.

4. Grigoriev You. G., Vasin A.L. Health effects of electromagnetic fields of radiofrquencies (Russian literature survey) In: Electromagnetic fields and human health. RUDN publication, Moscow, 2003. pp. 5–28

Brief note. Assessment of radiofrequency electromagnetic field effect is provided basing upon national literature references regarding acute and chronic exposure to modulated and non-modulated EMF RF.

5. Grigoriev You. G., Vasin A.L., Nestor Mendez, Grigoriev O.A. Comparative aspects of EMF standards and their harmonization issues. // In: Electromagnetic fields and human health. RUDN publication, Moscow, 2003. pp. 109–116.

Brief note. Proposals on standardization criteria are provided for radiofrequency electromagnetic fields taking into account the analysis of national literature

6. Grigoriev You. G., Shafirkin A.V., Vasin A.L. Bioeffects of chronic electromagnetic field exposure of radiofrequency and low intensity range (standardization strategy). // Radiation biology. Radioecology. 2003. vol. 43. No 5. pp. 501–511.

Brief note. The retrospective analysis of the USSR studies devoted to the research of radiofrequency electromagnetic field (EMF RF) human health effects is elaborated. The considered experimental results for chronic EMF exposure of immune and reproductive systems of laboratory animals certify to the fact that EMF of power flux density of 100–500 $\mu W/cm^2$ at 1750–2750 MHz has induced shifts of the immune status, functional structural changes of immune competent globulin fractions, and autoimmune process development. Changes of offspring reproductive functions and embryonic mortality were noted. The strategy of standardization previously used in the USSR was considered as well as the present Russian standardization.

7. Grigoriev You. G., Shafirkin A.V., Nikitina V.N., Vasin A.L. Late effects of chronic exposure to ionizing radiation and electromagnetic fields: hygienic standardization application. // Radiation biology. Radioecology.. 2003. vol. 43. No 5. pp. 565–578.

Brief note. The study compares the spectrum and rate of different non-tumor diseases at the follow-up period of chronic human exposure to ionizing radiation of different dose rates and super high frequencies of intensities above public sanitary hygienic limits. Radiation risk values were calculated for ionizing and non-ionizing (electromagnetic) radiation taking into account results of chronic experiments elaborated in the USSR.

List of reports at conferences

1. Yu. Grigoriev, V.S. Stepanov, L.A. Tomashevskaya, A.V. Shafirkin, A.L. Vasin. “10 mW/cm^2 Level of EMF in Standards of Russia and 1000 mW/cm^2 Level in ICNIRP’s Recommendations (experimental studies for the characterizing of these differences)”. // BEMS Abstract Book. Twenty-Fourth Annual Meeting. In Cooperation with the Euro-

pean Bioelectromagnetics Association. Hotel Loews Le Concorde. Quebec City, Quebec, Canada. June 23–27, 2002. P. 170.

Brief note. The report provides experimental study results for chronic animal exposure (up to 4 months) to electromagnetic radiation of super high frequencies of 850–2480 MHz and 2450–3000 MHz with different temporal mode of the exposure. The electromagnetic radiation exposure was elaborated with different low power flux densities (below 500 $\mu W/cm^2$) within 6–16 hours per day. The threshold EMF levels inducing persistent adaptation or compensatory reactions are concluded.

2. Grigoriev You. G., A.V. Shafirkin, A.L. Vasin Standardization of radiofrequency electromagnetic field (EMF RF) for the population of Russia: retrospective study and modern viewpoint. // Proceedings of Third International Conference on Electromagnetic fields and human health. Fundamental and applied research. 17 – 24 September 2002, Moscow – St.-Petersburg, Russia. pp. 164.

Brief note. 52 chronic experiments are summarized for low intensity EMF exposure, which studies were elaborated in the USSR. Standardization recommendations are given.

3. Ju. G. Grigoriev, V.S. Stepanov. "Problem of population electromagnetic safety". International Medical Congress "New technologies in medicine. National and international medical security issues". Slovenia, from March 28 to April 4, 2003. P. 13.

Brief note. The organism reaction characterization (in vivo) is done for the short time modulated EMF exposure of low intensity. Generalized results of experiments in adult animals and in embryos are provided in case of modulated electromagnetic field (MEMF) exposure. The bioeffect assessment criterion includes behavioral reactions, cerebral bioelectric activity changes, characteristics of specialized memorizing (imprinting) and other indices. The prognosis of peculiar development of biological effects in human exposed to MEMF is given.

4. Grigoriev Yu.G., Vasin A.L., Grigoriev O.A., Nikitina V.N., Pokhodzey L.V., Rubtcova N.B. Harmonization options EMF standards: proposals of Russian national committee on non-ionazing radiation protection (RNCNIRP). 3rd International EMF Seminar in China: Electromagnetic Fields and Biological Effects. Guilin, China. October 13–17, 2003. P. 55.

Brief note. Basing upon the USSR (Russia) EMF standardization experience and experiment results for acute and chronic experiments with non-modulated and modulated fields, the ways to international standard harmonization are proposed.

5. Grigoriev You. G. Modulated electromagnetic fields and human health. 3rd All-Russian Congress of the Nature Protection. 21 November 2003. Moscow.

Brief note. Man made EMF exposure human health danger is assessed taking into account different modulations, when the "dose-effect" principle is not the single leading criterion of the danger assessment.

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FINAL
TECHNICAL REPORT
OF ISTC PROJECT NO.2362P

BASIC MATERIALS FOR ELECTROMAGNETIC FIELD STANDARDS

(From 01 June 2002 to 30 November 2003: 18 months period)

Youri Grigorievich Grigoriev
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(From 01 June 2002 to 30 November 2003: 18 months period)

Youri Grigorievich Grigoriev
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State Research Center – Institute of Biophysics*

The goal of the present Project was the selection and generalization of initial data of research studies devoted to fundamental biological effects of the long time (0.5–2 years) exposure to EMF of low intensity (below 500 $\mu W/cm^2$) and on acute biological effects of modulated EMF, which were elaborated in the USSR, Russia and Ukraine; these studies were most essential for the development and justification of current Russian standards of EMF exposure in human as well as to provide recommendations on EMF standards.

The majority of contemporary Western standards of EMF is based upon the research results of physiological changes induced by short term electromagnetic irradiation of the thermal exposure level, as a rule. The existing standards do not take into account the possibility to develop specific effects under the modulated EMF exposure.

In the framework of work under the present Project, the selection and analysis of research studies devoted to the chronic exposure to electromagnetic fields of radiofrequency and low intensities (non-thermal levels) were elaborated as well as the studies of biological effects induced by modulated EMF in acute experiments reported in papers published in the USSR and Russia. The results of these studies were most important when developing current Russian standa5rds of EMF.

Basing upon the elaborated contractual work, recommendations were given to improve approaches and principles of standardization for electromagnetic fields under controllable and uncontrollable conditions.

Key words: electromagnetic fields, radiofrequencies, modulated electromagnetic fields, power flux density, field strength, biological effects of chronic exposure, maximum permissible level, electromagnetic field standardization methodology.

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The goal of the present Project was the selection and generalization of initial data of research studies devoted to fundamental biological effects of the long time (0.5–2 years) exposure to EMF of low intensity (below 500 μW/cm^2) and on acute biological effects of modulated EMF, which were elaborated in the USSR, Russia and Ukraine; these studies were most essential for the development and justification of current Russian standards of EMF exposure in human as well as to provide recommendations on EMF standards.

Final materials of 52 studies were analyzed, which studies have provided results of chronic exposure of animals to electromagnetic fields of radio frequency and low intensity. Studies were done in five research institutions of the USSR in 1960–1980.

Taking into account the fact that considered experiments were tried in different institutions and different research teams, the elaborated analysis and comparison of results obtained under identical conditions give the opportunity to reveal the general trend for bioeffect induction in case of the chronic EMF RF exposure of law intensities.

The results provided for chronic EMF exposure of UHF and SHF frequency bands of 300 MHz to 3 GHz with power flux density of 1 to 1000 μW/cm^2 give the opportunity to get the following conclusions:

- 100–500 μW/cm^2 PFD in case of chronic daily exposure can induce expressed and persisting pathological biological reactions;
- ~ 50 μW/cm^2 PFD is the threshold value of the unfavorable biological effect;
- ≤10–20 μW/cm^2 PFD does not induce visible biological changes in small laboratory animals in case of the chronic exposure.

Chronic EMF exposure results for high frequency band of 10 to 300 MHz and electric field intensity of 20–150 V/m conclude to the followings:

- 100–150 V/m intensity can induce expressed and persisting biological changes in case of the chronic exposure;
- 20–30 V/m intensity is the threshold value of the unfavorable effect;

The analysis of 28 biological experiments conducted in vitro, in situ, and in vivo in the former Soviet Union (FSU) and later in Russia with usage of the modulated electromagnetic fields of radiofrequency allows to make the following basic conclusions:

- EMF exposure of biosystems with less or more composite regimens of modulation the development of bioeffects, both physiological, and unfavorable, which are distinct from bioeffects induced by not modulated EMF is possible;
- the acute modulated EMF exposure of low intensities (non-thermal levels) can result in development of pathological effects;
- there is a dependence of development of a reciprocal biological response on the intensity and directness of the concrete regimen of EMF modulation; this dependence was fixed at all levels of biological systems - in vitro, in situ and in vivo;
- as a rule, modulated EMF has invoked more expressed bioeffects, than continuous regimen of modulation;
- the effect of EMF RF modulation is more expressed at lower levels of intensity.

The obtained data have specified the possibility of the effect of EMF modulation on the development of biological effect at a level of composite systemic interactions in an organism. It allows to discharge modulated EMF in the special group of radiations, which biological effect depends not only from magnitude of an absorbed energy, but also on the form of modulation

«addressed» to this or that functioning system. It determines the conclusion, that at an assessment of modulated EMF danger, it is important not only to assess magnitude of an absorbed energy, but also the fact of contact of the human with this aspect of radiation. This circumstance brings in major indeterminacy by development of the EMF standards.

The individual singularities of the man are essentially important, the individual sensitivity to a particular regimen of EMF modulation, that dilates a problem of hypersensitivity to EMF.

As a result of the conducted experiments with MEMF, the effect of an initial state of biosystem on expected effect is detected. The given fact is rather important, since does not allow to establish common regularity in the development of bioeffects at particular aspects of modulation. As a matter of fact, the initial background of a system of an organism can determine the character and directness of a reciprocal response that complicates the prognosis of expected effects in conditions of MEMF exposure on the population.

The role of modulation gains the major significance at low intensity (at non-thermal levels of EMF). In this connection, this factor becomes now leading at an assessment of population exposure to EMF RF.

The experimental recognition of dependence of development of bioeffect from an aspect of modulation specifies recruitment phenomenon of new gears of interaction of an organism with MEMF, which are not clear and demand the future study.

The surveyed results after additional analysis of 80 experiments, in which they have utilized chronic EMF exposure of animals at low intensities and modulated EMF and 42 additional publications, allow to formulate a number of recommendations on perfecting the approaches and principles of the regulating.

1. We consider, that maximum permissible level should ensure health of the population in first and second generation and not suppose the incorporation of compensatory responses. We have not the right "to demand" from the organism of the human to be in a state of a stress i.e. of a strain in conditions of chronic exposure of an electromagnetic field of small intensity.

2. It is expedient to reserve a principle of development of the separate standards for controllable and uncontrollable conditions of EMF exposure.

We also consider rational development of the standards for separate sources of electromagnetic fields: radar stations, base stations of systems of mobile communication and for some other sources of EM radiation.

3. An original material for MPL justification for controllable conditions should be results of:

- complex hygienic examinations;
- clinical physiological examinations;
- study of a morbidity rate with temporal disability;
- examinations on volunteers under industrial conditions and in conditions of laboratory experiment;
- experimental examinations on animal.

The regulating for uncontrollable conditions should be conducted on the basis of results of the following complex of examinations of:

- hygienic assessment of conditions of exposure of the environment factor;
- studies of a state of health of the population who is subjected to exposure of the factor;
- studies of a EMR biological effect in animal.

4. The position of "critical systems and organs" should be formulated. We consider possible reference to critical systems of central nervous, endocrine and immune systems.

5. The determination of criterion for the unfavorable EMF health effects (threshold of damage), which health effects are basic phenomena to put the hygienic safety factor, is discussible with principally different approaches to deal with this issue.

According to the analysis results, the revisiting of the concept of *non-effective threshold* previously proposed in the USSR is justified to develop the population protection standards.

6. The common feature of the long-term exposure to various stress factors if the strain of regulatory processes in an organism and possibility of rather fast exhaustion of compensatory reserves. At considerably reduced scope of compensatory reserves of an organism, the adaptation abilities are decreased. Even after EMF cancellation, there can be a failure of adaptation in case of padding exposure to other unfavorable factors of the human habitat. Thus, the probability of development of various diseases is enlarged, first of all, on the part of central nervous and cardiovascular systems, disturbance of the immune status. In case of a cumulation of bioeffects, the development of the late consequences is possible.

7. It is necessary to take into account series of the factors, which till now have not the sufficient scientific basis to prediction: a role of modulation in paravariation of radiobiological effect; constant effect of electromagnetic fields of small intensity in the pregnant women, children and patients for the development of common somatopathies, and also combined effect of other physical factors of environment and social conditions.

8. The conducted analysis allows us to make a conclusion, that the magnitudes of the radiation exposure for controllable conditions should be decreased for 3–4 times at least, and for uncontrollable conditions (population), taking into account the overall spanning, including children and pregnant women, the magnitude of a radiation exposure should be decreased for more than 10 times.

9. When developing the EMF standards, the medicobiological assessments instead of engineering accessibility of fixed MPL should be leading issue. The hygienic standard should promote the development of new technical ideas directed on building of safe EMF sources and technologies and ensure the population protection from all of growing EMF presence in ecological environment.

List of publications

1. Grigoriev You. G. Cellular communication EMF: population health effects and danger assessment (the state of issue in 2002) // In: Electromagnetic fields and human health. RUDN publication, Moscow, 2002. pp. 14–48.
2. Grigoriev You. G., Shafirkin A.V., Vasin A.L. Standardization of radiofrequency electromagnetic field (EMF RF) for the population of Russia. Retrospective study and modern viewpoint. In: Electromagnetic fields and human health. RUDN publication, Moscow, 2002. pp. 98–123.
3. Grigoriev You. G., Shafirkin A.V., Nikitina V.N. Risk of late non-tumor pathology in case of the chronic exposure to ionizing and non-ionizing radiation: hygienic standardization application // In: Electromagnetic fields and human health. RUDN publication, Moscow, 2002. pp. 141–161.
4. Yu. Grigoriev, V.S. Stepanov, L.A. Tomashevskaya, A.V. Shafirkin, A.L. Vasin. “10 mW/cm^2 Level of EMF in Standards of Russia and 1000 mW/cm2 Level in ICNIRP’s Recommendations (experimental studies for the characterizing of these differences)”. // BEMS Abstract Book. Twenty-Fourth Annual Meeting. In Cooperation with the European Bioelectromagnetics Association. Hotel Loews Le Concorde. Quebec City, Quebec, Canada. June 23–27, 2002. P. 170.
5. Grigoriev You. G., A.V. Shafirkin, A.L. Vasin Standardization of radiofrequency electromagnetic field (EMF RF) for the population of Russia: retrospective study and modern viewpoint. // Proceedings of Third International Conference on Electromagnetic fields

and human health. Fundamental and applied research. 17 – 24 September 2002, Moscow – St.-Petersburg, Russia. pp. 164.
6. Grigoriev You. G., Vasin A.L. Health effects of electromagnetic fields of radiofrquencies (Russian literature survey) In: Electromagnetic fields and human health. RUDN publication, Moscow, 2003. pp. 5–28.
7. Grigoriev You. G., Vasin A.L., Nestor Mendez, Grigoriev O.A. Comparative aspects of EMF standards and their harmonization issues. // In: Electromagnetic fields and human health. RUDN publication, Moscow, 2003. pp. 109–116.
8. Grigoriev You. G., Shafirkin A.V., Vasin A.L. Bioeffects of chronic electromagnetic field exposure of radiofrequency and low intensity range (standardization strategy). // Radiation biology. Radioecology. 2003. vol. 43. No 5. pp. 501–511.
9. Grigoriev You. G., Shafirkin A.V., Nikitina V.N., Vasin A.L. Late effects of chronic exposure to ionizing radiation and electromagnetic fields: hygienic standardization application. // Radiation biology. Radioecology.. 2003. vol. 43. No 5. pp. 565–578.
10. Ju. G. Grigoriev, V.S. Stepanov. "Problem of population electromagnetic safety". International Medical Congress "New technologies in medicine. National and international medical security issues". Slovenia, from March 28 to April 4, 2003. P. 13.
11. Grigoriev Yu.G., Vasin A.L., Grigoriev O.A., Nikitina V.N., Pokhodzey L.V., Rubtcova N.B. Harmonization options EMF standards: proposals of Russian national committee on non-ionazing radiation protection (RNCNIRP). 3rd International EMF Seminar in China: Electromagnetic Fields and Biological Effects. Guilin, China. October 13–17, 2003. P. 55.
12. Grigoriev You. G. Modulated electromagnetic fields and human health. 3rd All-Russian Congress of the Nature Protection. 21 November 2003. Moscow.

ANNEX

CHART NO. 1

Experiment 1

Dolgasheva L.P., Semenova T.P., Abzhalelov V.V., Akoev I.G. The effect of electromagnetic Radiation on monoamine oxidize A activity in the rat brain. J. Radiation biology and ecology (Russian academy of sciences) 2002, Vol. 40, No.4, pp.429–432.

The purpose. Examination of modulated EMF effect on A monoamine oxidize activity in the rat brain.

Experimental model. A suspension of the hypothalamus tissue.

Exposure conditions. EMF at 915 MHz , quantization of 2, 4, 6, 8, 12, 16 and 20 Hz. S=10 $\mu W/cm^2$. Time of exposure is 10 minutes.

Time (period) of examinations. At once after exposure.

Method of study. 28 Wistar rats. Animals were decapitated at once after MEMF exposure; the brain was extracted and prepared. Filing of tetrazole reaction rate response was conducted at a wavelength of λ=510 nm on "Specord UV VIS" spectrophotometer A statistical analysis of an experimental material was realized with usage of "Sigma Plot (4.0)" software.

Basic results. The greatest labilizing effect on MAO-A activity hypothalamus rendered MEMF with frequencies of modulation of 4, 6 and 12 Hz. In control the activity of an enzyme compounded 0.65±0.03 relative unites (r.u), at experimental animal 1.04±0.13 ($p < 0.01$) r.u., accordingly. The exposure with frequency of 16 and 20 Hz was escorted by dropping of activity MAO-A up to 0.56±0.02 ($p < 0.05$) and 0.49±0.01 ($p < 0.01$) r.u., accordingly (Table). Droppings of MAO-A activity in hyppocampus was not observed at EMF exposure in one of probed frequencies. Thus, the rising of MAO-A activity in hypothalamus of a rat brain was observed at frequencies of modulation of 4, 6 and 12 Hz, accordingly up to 143 ($p < 0.01$), 160 ($p < 0.01$), and 149 ($p < 0.01$)% from control values conditionally accepted for 100%. At frequencies of EMF modulation of 2, 8, 16 and 20 Hz dropping MAO-A activity of down to 82 ($p < 0.05$), 78 ($p < 0.05$), 86 ($p < 0.05$) and 74 ($p < 0.01$)% from a master level is marked. The effect of superweak pulsewise - modulated EMF on MAO-A activity in the hyppocampus of the rat brain was mainly labilizing. The maximal rising of activity of an enzyme (up to 174% in comparison with control) is registered at frequency of modulation of 4 Hz.

Table. Modification of MAO-A activity in a hypothalamus and hyppocampus of rat brain after the exposure to pulsewise - modulated electromagnetic radiations (In relative unites)

Pulse rate, Hz	Number of rats	Number of tests	Cerebral structures	
			hypothalamus	hyppocampus
Not exposed	5	20	0.65±0.33	0.59±0.02
2	3	12	0.53±0.02*	0.65±0.01*
4	4	16	0.93±0.13**	1.03±0.14**
6	3	12	1.04±0.13**	0.61±0.04
8	2	8	0.51±0.04*	0.74±0.06*
12	3	12	0.97±0.07**	0.85±0.08*
16	4	16	0.56±0.02*	0.90±0.11**
20	4	16	0.49±0.01**	0.56±0.02

* differences given from control on a t-Student criterion are reliable, $p<0.05$.

** same, $p<0.01$.

Conclusion. The modulated EMF of small intensity renders effect on an enzymatic system of a diminution of monoamines. Thus, the expressiveness of bioeffect depend on a kind of modulation.

CHART NO. 2

Experiment 2

Pashkovkina M.S., Akoev I.G. Effect of Low-Intensity of Pulse-Modulated Microwave on Blood asparthate Amine transferase Enzymatic System. J. Radiation biology and ecology (Russian academy of sciences) 2001. Vol. 41. No.1, pp. 59–61.

The purpose. To evaluate the MEMF effect on activity of asparthate amine transferase (ASAT) of serum of a donor blood of the human.

Experimental model. The assays of serum of a human blood (ASAT activity assessment).

Exposure conditions. The experiments were conducted in Institute of Biophysics of a Cell of RAS EMF using experimental installation to scan EMF modulation frequencies for in vitro tests. Irradiation of assays conducted in a temperature-controlled alveole of 1.5 cm^3 volume in a rectangular waveguide (8x50 cm^2) with the help of "Luch" generator (Russia). The generator has worked on frequency of 2375 MHz and was modified for work with a modulating signal, which was set from the G6–28 generator (Russia) in a frequency range of modulations of 50–390 Hz. To get low intensive exposures, an attenuator with a variable attenuation coefficient permitting to receive a power output in a band of unites to 5 hundreds of $\mu W/cm^2$ was connected in an output circuit of the generator. The exposure time was 5 min, PFD was 2 and 8 $\mu W/cm^2$, the band of modulation was 50–390 Hz.

Time (period) of examinations. At min 1, 2 and 3 after exposure.

Method of study. 1000 μL of KL chemical agent and 200 μL of blood serum were deposited to the pan of a spectrophotometer. After 5 minute incubation at temperature 37°C, 250 μL of Ya2 chemical agent were added the pan. The measurement of an extinction was conducted at min 1 during 3 mines. Collaterally, they have put assay in the radiation field on the indicated time (5 min) and then determined the value of an extinction at minutes 1, 2 and 3. They have compared average value ASAT activity obtained from the several donor assays to average value of activity in control assay. Comparisons of results were conducted under the plan of control /experiment.

Basic results. High ASAT sensitivity to the short time exposure to weak amplitude modulated EMF was obtained (Table).

In all cases of the exposure to PFD of 2 $\mu W/cm^2$, the rising ASAT activity was noted, especially at frequencies of modulation of 190 and 230 Hz (on 345 and 292%, accordingly). The cases of ASAT activity decrease below the control level were not observed.

At PFD of 8 $\mu W/cm^2$ the greatest rising of activity of an enzyme was observed at frequencies of modulation of 390 (592%) and 210 (503%) Hz. Only in two cases (frequency of 130 and 350 Hz) the activity of an enzyme was lower than a control level.

Table. Values of a relative modification of ASAT activity at miscellaneous frequencies of EMF modulation and miscellaneous intensity of exposure,% to control.

Modulation frequency, Hz	PFD, μW/cm^2	
	2	8
	(M±m)	(M±m)
50	146.6±6.7	175.3 ± 5.3
70	286.6±6.4	154.0± 14.0
90	162.6±3.8	184.0 ± 4.0
110	155.6±5.7	198.0 ± 3.6
130	235.6±3.5	76.0±6.2
150	125.3±3.7	325.0 ±5.7
170	247.3±8.3	371.1±5.5
190	345.6±3.4	156.4±5.4
210	133.7±3.5	503.7±4.9
230	292.8±7.0	254.6±6.2
250	243.3±6.2	127.3±3.4
270	187.7±5.0	100.6±7.5
290	158.3±2.2	162.7±4.9
310	129.7±4.7	254.3±5.6
330	217.3±8.5	211.0±7.2
350	114.7±3.5	77.7 ±3.5
370	479.4±8.5	139.6 ±1.6
390	400.4±8.4	592.3± 4.6

Directness and expressiveness of effect the exposures were saved in most cases. For example, at 2 μW/cm^2 a relative modification of ASAT activity (in comparison with the control) at 170 Hz modulation was practically identical in April and December (247 and 244%), and at 70 Hz — 284 and 302%.

Conclusion. The possibility of rising ASAT activity is shown at EMF exposure of low intensity (S = 2 and 8 μW/cm^2), as well as the effect in conditions of amplitude modulation in a frequency range of 50–390 Hz.

Note. The high sensitivity of a model system to EMF is shown, which activity was enlarged at some frequencies of modulation.

CHART NO. 3

Experiment 3

Pashovkina M., Akoev I. Effect of Low-Intensity of Pulse-Modulated Electromagnetic Radiation on Response of Alkaline Phosphates in Blood Serum. J. Radiation biology and ecology (Russian academy of sciences). 2001. Vol. 4, No.1, pp.62–66.

The purpose. To study modulated EMF effect in conditions of short-term low intensive exposures on an alkaline phosphatase (AP) of a blood serum.

Experimental model — an alkaline phosphatase (AP) in a blood serum of the Guinea pigs.

Exposure conditions. The generator of EMF microwaves ("Luch–3" (2375 MHz)), generator of a modulating audio frequency (G6–28), waveguide, temperature-controlled scoop of volume 1.5 cm^3. Solution irradiated in a rectangular strip waveguide. S=0.8; 8.0 and 40 $\mu W/cm^2$. Monitoring of power was done by the thermistor bridge (Ya2M-64). The frequency of modulation of 10 up to 310 Hz with porosity 2 at equienergy exposures. All parameters were thoroughly inspected. Time of exposure is 1 and 3 minutes.

Time (period) of examinations. At once after an exposure and through 20 and 30 minutes thereafter.

Method of study. Reference assessment of alkaline phosphatase activity in blood serum grounded on filing of absorbency in a wavelength of 405 nm as a result of a response of diethyl amine and n-nitrophosphate at the presence of magnesium with formation of the colored n-nitrophenol.

Activity of an enzyme was measured under the plan control — experiment for each frequency of modulation (five measurements per point).

The handling of materials was carried out under the Origin v.4.0 software. Reliability of difference from control was determined on a t-Student criterion ($p < 0.05$).

Basic results. Initially, they probed a role of modulation at minimum PFD of S=0,8 $\mu W/cm^2$, exposition time of 1 and 3 min. It has appeared, that at particular frequency of modulation the AP activity increases (first sample), and at other frequency of modulation it is reduced (second sample) in comparison with control.

First sample data are provided by Table 2.1. The efficiency of MEMF exposure with PFD of 0.8 $\mu W/cm^2$ was higher, than at 8 $\mu W/cm^2$. So, rising of activity of an enzyme for more than on 20% marked already at 7 frequencies of modulation (at 1-minute exposure), as against EMF exposure with PFD of 8 $\mu W/cm^2$, which invoked rising activity above 20% only on two frequencies, and it was much lower, than at 0.8 $\mu W/cm^2$. Major efficiency for 5–30 times for the exposure to ore weak radiation was marked at identical frequencies of modulation in these two animal groups. The similar results were at three minute MEMF exposure.

For study of cases of inverse directness of effect of the modulated microwaves at a modification of intensity of exposure, the available data have supplemented by experi-

ments on alkaline phosphatase effect of microwaves with PFD 40 μW/cm^2 at conservation of other conditions. The common materials (Table 1 and 2) have shown, that among frequencies of modulation in examined band of 10–310 Hz, there are two frequency groups appealing as dropping of activity of an enzyme (concerning control modifications) at augmentation of intensity of EMF exposure (from 0.8 μW/cm^2), and rising it in the same conditions. In the first frequency group the modification of effect is inverse to body height of power dose, and in the second group is corresponded to the obtained dose.

From the obtained experimental data it follows, that the highest biological efficiency of the exposure is possible in series of cases at the most low intensity of exposure. The analysis of results of experiments has allowed the authors to establish, that from all utilized parameters of exposure in this experiment (frequency of modulation, duration of an irradiation, intensity of exposure) greatest effect on activity of an alkaline phosphatase rendered frequency of modulation and intensity of exposure. So, for each frequency the intensity of EMF exposure at a modification of the magnitude in micro-watt levels was capable abruptly to vary a directness of effect to activity of an enzyme from the expressed promoting effect to considerable inhibiting effect and on the contrary (Fig. 3.2). All has depended on an interval of intensities for the given frequency of modulation. The augmentation of duration of an irradiation with 1 up to 3 min influenced to a lesser degree, and raised the effect of EMF exposure a little.

The authors show a possibility of conservation of a directness and efficiency of an effect of frequency of modulation at a backup of experiments after a considerable span.

The efficiency of frequencies of modulation can not show the labilizing or inhibiting properties in transition zones of intensities, where the sign of effect varies. For an alkaline phosphatase in the conducted examinations this region, approximately, is at a level 5–15 μW/cm^2. There are basis to guess, that it depends on frequency of modulation and from magnitude of effect in a little to other regions of intensities, where the effect shows.

Figure 1 provides the data obtained at frequency of 70 Hz (radiation time of 1 and 3 min). At S=0.8 μW/cm², the decrease was 13.3%, and at 40 μW/cm² it was 33% below control. At frequencies of 90, 110, 170, 190, 230 and 310 Hz the similar regularities are obtained.

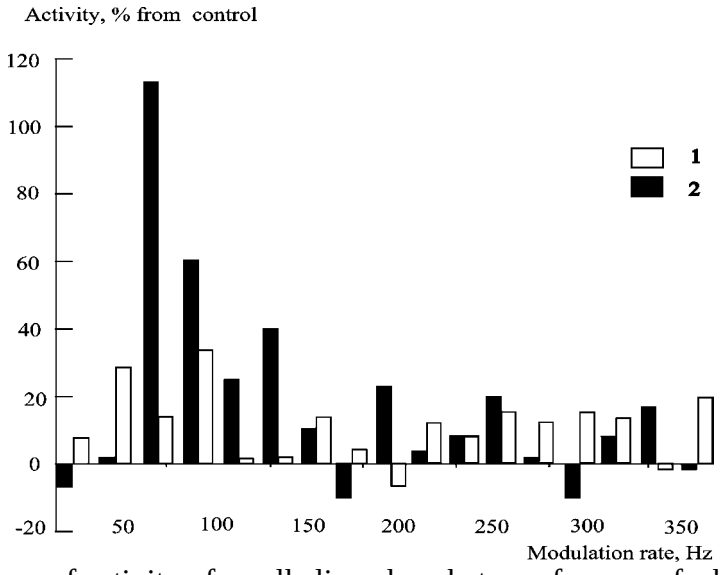

Figure 1. Dependence of activity of an alkaline phosphatase of serum of a blood of the Guinea pigs on frequency of modulation at 3 minute EMF exposure with PFD of 8 μW/cm^2 (1) and 0.8 μW/cm^2 (2).

Table 1. Relative modification of AP activity (% from control) in dependence from EMF intensities and time of exposure at miscellaneous frequencies of modulation. (First sample with AP activity decrease).

Modulation rate, Hz	PFD, μW/cm²	M±m (1 min)	M±m (3 min)
70	0.8	87.2±1.22	112.0±0.83
	8.0	13.3±0.76	15.3±0.31
	40.0	-33.1±0.67	-37.5±0.32
90	0.8	44.5±0.02	57.8±0.93
	8.0	3.4±0.61	33.8±1.82
	40.0	-26.8±0.29	-57.8±0.17
110	0.8	25.1±0.34	27.7±1.31
	8.0	2.45±0.22	2.6±0.03
	40.0	-25.4±0.35	-76.3±0.26
170	0.8	33.7±0.32	42.4±0.28
	8.0	0.83±0.12	4.6±0.02
	40.0	-29.4±0.08	-9.5±0.26
190	0.8	23.8±0.74	25.7±1.25
	8.0	-5.6±0.31	-8.3±0.08
	40.0	-8.3±0.03	-35.8±4.9
230	0.8	11.8±0.05	13.4±0.94
	8.0	2.4±0.09	4.3±0.03
	40.0	1.1±0.06	2.5±0.08
310	0.8	21.7±0.35	23.9±0.61
	8.0	2.2±0.04	3.1±0.13
	40.0	1.7±0.04	4.8±0.06

In the second sample at frequencies of 30, 150, 250, 270 and 290 Hz at S=0.8 μW/cm^2 the AP activity was more low, than in control, and at S=0.8 and 40 μW/cm^2 AP was increased (tab. 2).

Table 2. Relative modification of AP activity (% from control) in dependence from EMF intensities and time of exposure at miscellaneous frequencies of modulation (Second sample, with rising of AP activity).

Modulation rate, Hz	PFD, μW/cm²	M±m (1 min)	M±m (3min)
30	0.8	–12.2±0.08	–5.9±0.05
	8.0	7.4±0.07	9.1±0.08
	40.0	14.4±0.62	26.2±0.07
150	0.8	–5.6±0.05	–6.4±0.04
	8.0	1.7±0.81	3.2±0.14
	40.0	14.4±0.58	27.2±0.45
250	0.8	–24.7±0.34	–17.5±0.12
	8.0	7.2±0.03	9.7±0.16
	40.0	63.1±0.64	79.1±0.15
270	0.8	6.3±0.03	12.1±0.22
	8.0	15.8±0.03	18.4±0.03
	40.0	28.6±0.64	39.5±0.01
290	0.8	15.4±0.02	–14.6±0.35
	8.0	20.3±0.06	27.1±0.99
	40.0	40.0±0.09	59.0±0.54

Figure 2 provides the character of a modification of AP activity at frequency of 250 Hz. The similar modifications were obtained at frequencies of 30, 150, 270 and 290 Hz.

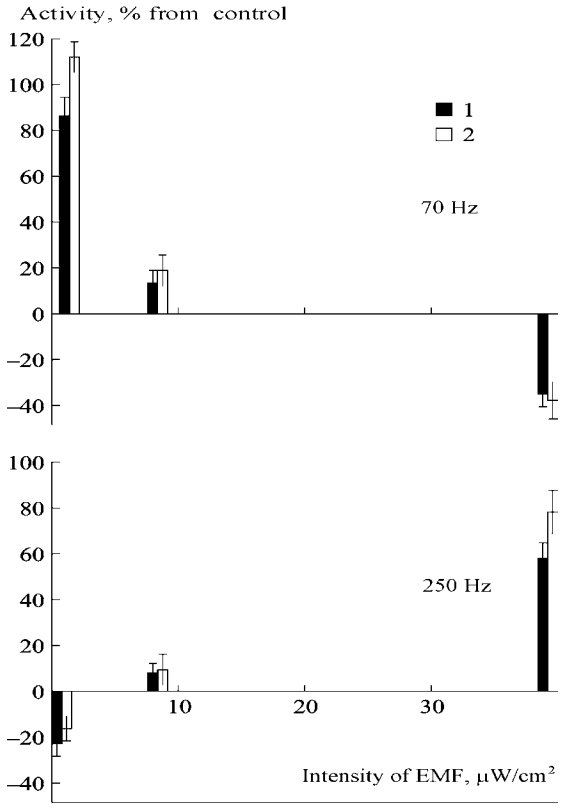

Figure 2. Two types of dependence of activity of an alkaline phosphatase of serum of a blood of the Guinea pigs from modifications of intensity of EMF exposure at frequencies 70 and 250 Hz with an exposition 1 min (1) and 3 min (2).

Conclusion.

1. The dependence of a modification of AP activity from a modulation frequency (these effects are obtained by the authors earlier in other experiments on stretch of more than 2 of years of accumulation of an experimental stuff on each frequency).
2. The effect of modulation depends from PFD.
3. The duration of effect did not exceed 20–30 minutes.

Note. The utilized procedure is sensitive to an assessment of a role of modulation at weak EMF intensity. With the help of this procedure the AP modifications in the blood Serum are obtained at S=0.8, 8 and 40 μW/cm² (Pashovkina M.S., Akoev I.G. Biophysics. 2000. vol. 45. No. 1. pp. 130–136).

CHART NO. 4

Experiment 4

Pashovkina M.S., Akoev I.G. The effect of exposure of actomyosine to 2375 MHz pulse-modulated microwave radiation. J. Radiation biology and ecology (Russian academy of sciences)1996, Vol 36, No5, pp.700–705.

The purpose. The examination of frequency - dependent modifications of ATPase activity of actomyosine complex at exposure to pulsewise - modulated EMF RF; detection of effective frequencies with usage of equienergy exposure.

Experimental model. Actomisine agent (AM) was discharged of a skeletal muscle of rat.

Exposure conditions. The "Luch" generator at 2375 MHz , modulation of 50–300 Hz, exposition for 1 min. An AM agent exposure was elaborated in a temperature-controlled alveole of 6 mL volume with the help of SV-20–3 ultrasonic head, a dia of 20 mm, built in a floor of an alveole. The power was measured on a compounded load with the help of a wattmeter. The integral energy of exposure was established for all frequencies of modulation to be equal to: S=40 and 200 mW/cm^2. The tests were conducted at temperature 30°C.

Time (period) of examinations. At once after the exposure.

Method of study. They have utilized fresh AM agent discharged of skeletal rat muscles applying Schtraube method. ATPase activity was determined by an amount of inorganic Natrii phosphas. The assessment of modifications of AM ATPase activity in the irradiated assay was conducted versus control assay from the same abjection. The activity of control assay was 100% with the count initial and final concentration of inorganic Natrii phosphas in control and test. Data processing was conducted with the help of the CSS software with $p < 0.05$.

Basic results. In a frequency range of 50–300 Hz at S=40 mW/cm^2 the ATPase activity was reliably enlarged (Fig. 1) for about a maximum at frequency of 270 Hz (285±25%, $p < 0.05$). The expressed suppression of ATPase activity however was marked at frequencies of 130 and 300 Hz. In series at S=200 мW/cm2 the augmentation of ATP activity was more expressed in a frequency range of 80–150 Hz (Fig. 2).

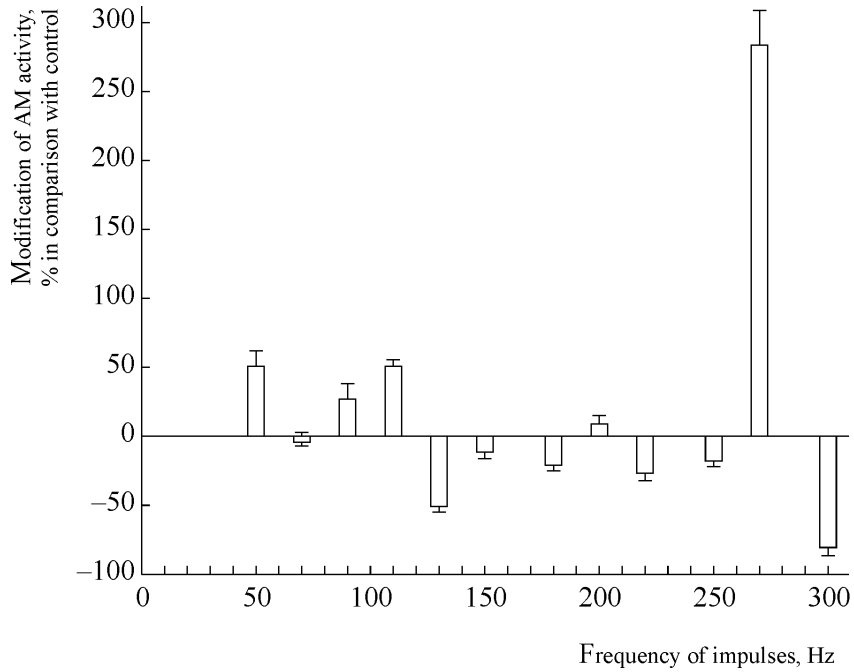

Figure 1. Dependence ATPase activity of AM from frequency of EMF modulation (S=40 mW/cm^2, t=1min). On an abscissa axis — frequency of impulses, Hz; on an axis of ordinates — modification of AM activity,% in comparison with control.

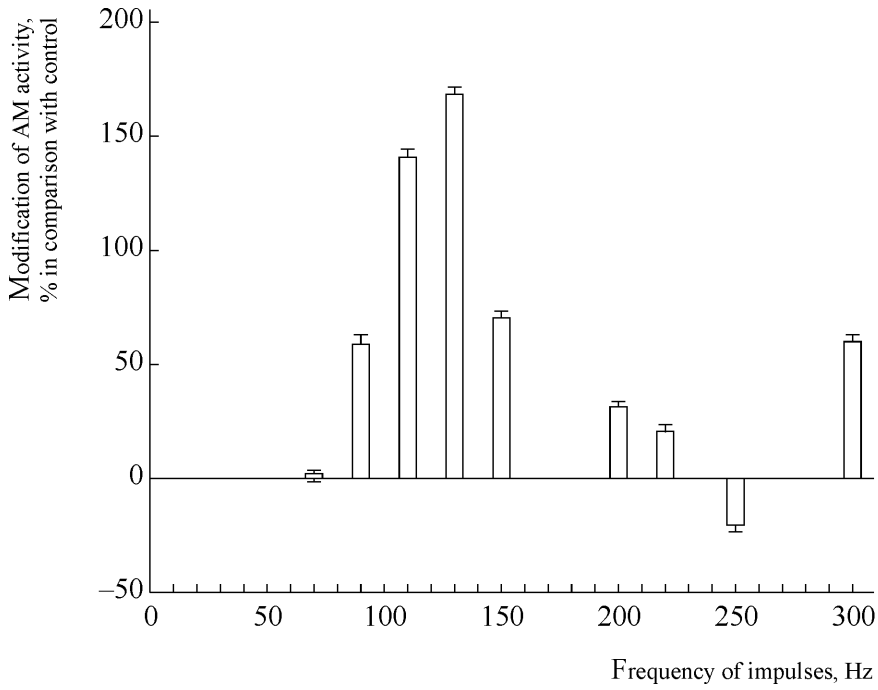

Figure 2. Dependence ATPase activity of AM from frequency of EMF modulation (S=200 mW/cm^2, t=1min). On an abscissa axis — frequency of impulses, Hz; on an axis of ordinates — a modification of AM activity,% in comparison with control.

Conclusion. The modification of ATPase AM activity of the mouse depends on modulation; the EMF effect also depends on intensity.

CHART NO. 5

Experiment 5

1. Yurinskaya M.M. Reaction of GAOA, glutamate and cholinergic brain systems in electromagnetic exposure of decimeter band. Thesis, Moscow, 1994.

2. Yurinskaya M., Kuznetsov V., Galeev A. et al. Response of synaptic receptors of the brain to low intensity microwave exposure. J. Biophysica. 1996. Vol. 41. No. 4, pp. 859–865.

3. Kuznetsov V., Yurinskaya M., Kolomytkin O, Akoev I. Microwave effect for different modulation frequencies and exposure time in GAOA receptor concentration in brain cortex of rats. Radiobiology, 1991, vol. 31, issue 2. pp. 257–259.

The purpose. Establishing of dependence of EMF effect in the decimeter band (800 MHz and 915 MHz) on GAOA, glutamate and cholinergic system of a brain from frequency modulation.

Experimental animals. Wistar male rats of 150–200 g weight. Rats were adopted to test conditions within 7 days.

Exposure conditions. The irradiator is constructed in Institute of biophysics of a cell of RAS. An irradiation was realized from an electromagnetic horn with a wave-guide duct for three animals in the organic glass chamber. Group with a "sham" irradiation. A carrier frequency of 800 or 950 MHz without modulation and with modulation by square-wave pulses at 2.5; 3; 5; 7; 16 and 30 Hz with usage of "Grom" installation; porosity of 85%: S=1 mW/cm^2. A radiation time of 5 minutes. There was a group with a sham irradiation.

Time (period) of examinations. At once after exposure and "sham" irradiation.

Method of study. As an agonist of a GAOA-receptor they have utilized radioactive muscimole (Johnston, 1978). Binding of ^{3}H-muscimole was conducted on synaptic neurosomas and on synaptic somal membranes.

Examination of bundling ^{3}H glutamate was conducted on synaptic somal fraction of brain cortex of rats (on Majewska et al., 1990).

Basic results. Statistically reliable and most significant modifications of bundling were obtained by a GAOA receptor of ^{3}H-muscimole at frequency of modulation of 16 Hz (800 MHz, S=1 мW/cm^2, radiation time of 5 minutes). The muscimole amount was decreased on 30–35% in comparison with control (Table 1). The root-mean square deviation at frequency of 16 Hz was minimum in comparison with a scatter on other frequencies of modulation.

Table 1. Dependence of bundling ^{3}H- muscimole by a GAOA receptor from frequency of EMF modulation (carrier frequency of 800 MHz, modulation from 3 up to 30 Hz, PFD of 1 mW/cm^2, Radiation time of 5 minutes).

Modulation frequency, Hz	B*
3	1.07±0.31
5	0.96±0.17
7	0.83±0.25
16	0.70±0.05
30	1.35±0.30
No modulation (CW)	1.12±0.13

*footnote: B — the ratio of muscimole bundling with GAOA-receptor at irradiated rats to muscimole bundling with a receptor at control (sham exposed rats).

At examination of bundling of a glutamate in rats irradiated to 915 MHz, S=1mW/cm^2, radiation time of 5 minutes, modulation of 2.2 and 16 Hz the greatest effect was observed at 16 Hz as well as in case of muscimole bundling, but the effect was of an inverse directness. (Fig. 1). The amount of a bound glutamate has increased on 200–220%.

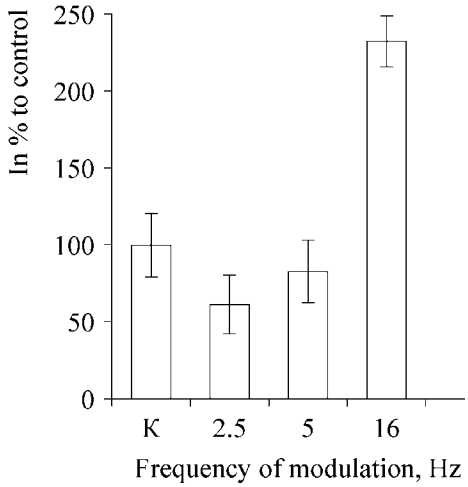

Figure 1. Dependence of bundling of a 3H-glutamate by synaptic membranes from frequency of EMF modulation (915 MHz, frequency of modulation from 2.5 up to 16 Hz, S=1 mW/cm^2, radiation time of 5 minutes). On an axis of ordinates — bundling of a ^{3}H-glutamate in% to control; on an abscissa axis — frequency of modulation.

Conclusion. The dependence of modifications is obtained for GAOA, the glutamate - and cholinergic system of a brain from EMF frequency modulation (maximal effect was at 16 Hz.).

Note. The utilized procedure is sensitive to an assessment of exposure.

CHART NO. 6

Experiment 6

Yurinskaya M., Kuznetsov V., Galeev A. et al. Response of synaptic receptors of the brain to low intensity microwave exposure. J. Biophysica. 1996. Vol. 41. No. 4, pp. 859–865.

The purpose. Examination of modulated low frequency EMF effect at EMF exposure with various magnitudes of intensity and time of exposure of experimental animal, "Wistar" rat adapted to conditions of experiment within 7–10 days.

Exposure conditions. Wistar rats were irradiated to EMF of 800 or 950 MHz, modulation with square-wave pulses of 2.5, 3, 5, 7, 16 and 30 Hz at porosity of 32%, S=10, 50 and 100 $\mu W/cm^2$. The time of exposure in miscellaneous series was 1, 5, 15 and 60 min. Animals were put in a cell from organic glass, the exposure was realized from the open waveguide docked with a wave-guide duct. An MEMF exposure was subjected simultaneously to three animals. In check experiments, rats were put in non-echo chamber on the conforming time without an irradiation.

Time (period) of examinations. Animals were decapitated at once after MEMF exposure and "sham" exposure.

Method of study. As a GAOA receptor they have utilized ^3H muscimole, the experiments were conducted on synaptic neurosomas and synaptic membranes. Bundling ^3H of a glutamate was realized on synaptic somal membranes. Synaptic neurosomas were received from a cortex of rat brain.

Basic results.

Dependence of bundling ^3H muscimole and ^3H glutamate from EMF power flux. The examination of MEMF effect at general organism exposure has shown, as GAOA and glutamatic system of the rat brain are very sensitive to low intensive MEMF (Fig. 1). At MEMF exposure, the modification in bundling receptors with GAOA and glutamate receptors has descended by a various mode: for GAOA receptors the decrease of bundling, for glutamate receptors — augmentation was observed. GAOA and glutamatic system of the rat brain have responded to MEMF by an inverse mode, as it takes place at a stress and some pathologies in the CNS. Modifications in functioning the indicated systems have depended upon MEMF rate: the more radiation power, the effect is more especially expressed. The maximal effect was observed at an energy flux density of $1 mW/cm^2$. It is necessary to mark, that modulated EMF rendered effect on bundling 3H-muscimole and 3H-glutamate was at smaller values of EMF rate. At value of an EMF power flux density of 10 $\mu W/cm^2$ the decrease of bundling 3H-muscinole has made 88±12% in comparison with control, and augmentation of bundling ^3H glutamate was equaled to 120±12%.

The dependence of bundling 3H-muscimole and 3H-glutamate from time of EMF exposure. Carrying out of examination have shown, that for GAOA system the maximal effect was observed in exposed animal during 1 min: the decrease of bundling labeled muscimole has made 50–55% in comparison with control (Figure 1), and at 15^{th} and 60^{th} minute of exposure the effect was less expressed (Figure 2).

At examination of bundling glutamate in a time dependence of the MEMF exposure, animal was irradiated during 1 and 5 min, frequency of modulation was 16 Hz. The maximal effect was observed at 5^{th} min of exposure, the augmentation of bundling has made 200–220% versus control (at 1^{st} minute irradiation augmentation of bundling ^{3}H glutamate is 130±6%).

Thus, even it is enough of 1 minute exposure of modulated emission, that at rather low intensity of microwaves is essential to change a reactivity of CNS. At a more long MEMF radiation time the effect became less expressed. It can specify that compensatory mechanism "is included" in an organism in reply to a radiation effect.

MEMF effect on concentration dependencies of bundling ^{3}H- muscimole and ^{3}H-glutamate. In separate experiments the problem was investigated, whether at the expense of that there is a modification of an amount of the bound marked ligand — the affinity of bundling of a ligand varies or the amount of linking fields in conditions of EMF modulated exposure varies. For this purpose the concentration dependencies of bundling ^{3}H- muscimole and ^{3}H-glutamate for control and irradiated animal were obtained and the Sketchard graphs are built.

The muscimole dissociation constant has varied insignificantly (Fig. 3) and made 480±60 nM, that is quite compounded with given one obtained by other authors. After the exposure, the muscimole dissociation constant has varied insignificantly, but thus the amount of linking fields has varied. The figure of binding sites for muscimole was sank from 17,4±0,8 pmol/mg of protein at control up to 10±2 pmol/mg of protein at irradiated animal. As it is visible in a Fig. 4, the dissociation constant of a glutamate at control animal (227±15 nM) is more than value of a dissociation constant in experiment (103±10 nM), i.e. after the exposure, the affinity of bundling has increased. As to an amount of places of bundling for a glutamate after the exposure, it practically did not vary. Thus, as it is visible from the provided data, at MEMF exposure constant of bundling, and number of linking fields have varied.

To the present time large data about microwave effects in different physiological and biochemical parameters of cerebral structures, specific organs and whole organism are accumulated. The adequate theoretical explanation of results is the complex problem. Nevertheless, these results are well compounded with the literary data on stressful effect (electroshock, pain stress, immobilization) on receptor properties of GAOA receptors. The experiments on MEMF exposed animals have shown, that the greatest modifications of GAOA receptor concentration descend within the first five minutes. Furthermore, at 15^{th} and 60^{th} minute of the exposure the effect became less expressed. It is interesting, that the similar dependence in a modification of receptor properties of GAOA receptors in a cortex of a brain is observed at 24^{th} hour of immobilization stress: the essential decrease of concentration of GAOA receptors at first minutes, then step-by-step homing to norm, and to 24^{th} hour even the augmentation in comparison with control. As a matter of fact various phases of a modification of receptor properties of GAOA receptors at MEMF exposure are similar to phases of the common adaptation syndrome.

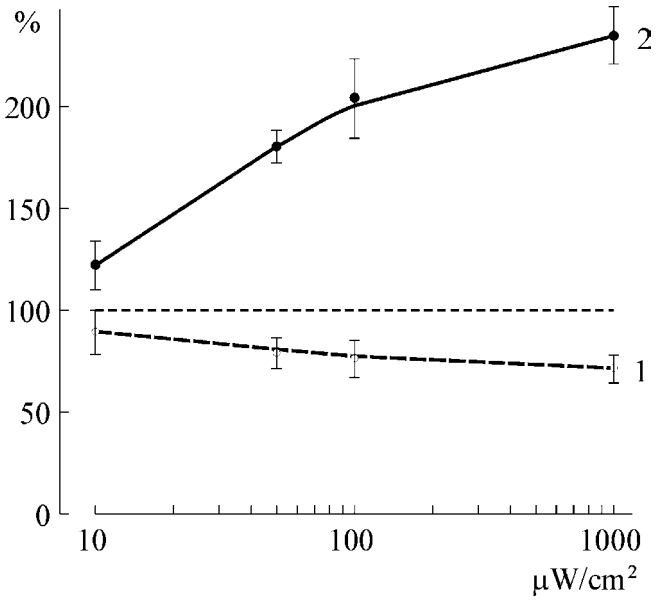

Figure 1. Dependence of bundling ^{3}H muscimole (1) and ^{3}H glutamate (2) from MEMF power flux density (carrier frequency of 915 MHz, radiation time of 5 min, frequency of modulation of 16 Hz). The bundling at control animal was closed to 100%. On an abscissa axis — an power flux density, on an axis of ordinates — bundling in% to control.

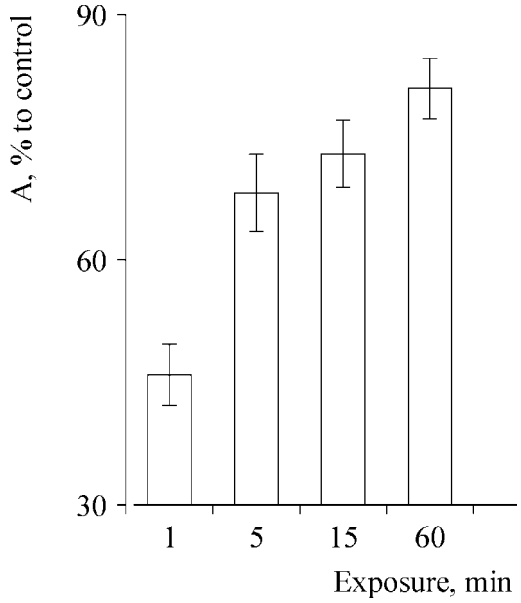

Figure 2. Dependence of bundling ^{3}H glutamate by synaptic membranes from time of EMF exposure. A — the attitude of bundling of a ligand with a receptor for irradiated rats to bundling for control animal (in% to control). The digits in columns designate a radiation time in minutes. A carrier frequency is 800 or 915 MHz, power flux density is 1 mW/cm^2, frequency of modulation is 16 Hz.

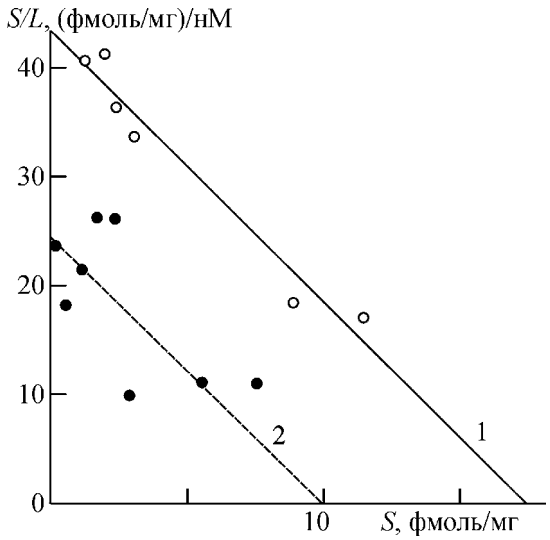

Figure 3. The Sketchard graph for the assessment of parameters of bundling ^{3}H muscimole by synoptic membranes. 1 — bundling ^{3}H muscimole in control, 2 — bundling ^{3}H muscimole after exposure. A carrier frequency is 915 MHz, power flux density is 1 mW/cm^2, frequency of modulation is 16 Hz, radiation time is 5 min. S is an amount of a bound ligand, L is the concentration of a free ligand.

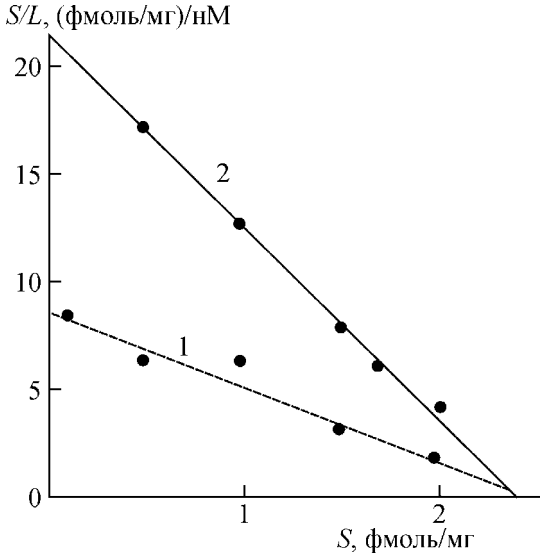

Figure 4. The Sketchard graph for assessment of parameters of bundling glutamate by synaptic membranes. 1-bundling of a ^{3}H-glutamate after exposure. Conditions of an exposure as in a Fig. 4. S is the amount of a bound ligand, L is the concentration of a free ligand.

Conclusion. It is shown, that the MEMF effect on receptor systems of a brain depends both on intensity, and from duration of EMF exposure.

CHART NO. 7

Experiment 7

1. Siomin Yu.A., Shwarzburg L.K., Zhavoronkov L.P. Dependence of Microwave Effect on the Secondary Structure of DNA on Molecular Weight of Polynucleotide. J. Radiation biology and ecology (Russian academy of sciences) 2002. Vol. 42. No. 2, pp.186–190.

2. Siomin Yu.A., Shwarzburg L.K., Zhavoronkov L.P. Electromagnetic radiation effect in secondary DNA structure. In: Book of Abstracts of 2nd Congress on radiation research, Moscow, 2001, p.794.

3. Siomin Yu.A. DNA damage mechanisms of normal metabolite aldehydes accumulated in irradiated cells. Thesis, Moscow, 2000.

The purpose. Examination of effect of pulsewise — modulated EMF of weak intensity on secondary DNA frames.

Experimental model. DNA samples of various molecular mass with the subsequent denaturation.

Exposure conditions. DNA samples (3 mL) in polypropylene vials a dia of 12 mm were put in a foam support (control and experiment) so that they placed in series with center distance of vials of 25 mm. Samples were subjected to the exposure of impulsive or continuous EMF of intensity of 600 $\mu V/cm^2$ and frequency of 1.05; 2.05 or 2.39 GHz during 30 mines at 18ºC within non-echo chamber. At a quantization of a field the frequency of a cycling compounded 4 Hz, duration of impulses was 25 ms, S=600 $\mu V/cm^2$. A support with exposed vials irradiated in the region of the formed wave (3 m from polishing material of the radiating antenna) in isodose field (±10%) at vertical orientation of a E-vector. The control assays also were in the chamber within the radiation time, shadowed by the ferrite screen.

Time (period) of examinations. The examinations were conducted at once after exposure.

Method of study. In experiments they have utilized DNA, secured of a thymus gland of mice by a phenolic method (molecular mass of 4×10^7, 40% hyperchromatic effect, albumin content of < 1%, formic aldehyde solution of supreme purity (“Merk”, Germany), of 11.67 mol/L concentration, pure β alanine (“Renal”, Hungary). As a result of the conducted examinations ascending value of a maximum of curves of a denaturation was obtained and fast reaching of a maximum at a quantization was observed (Fig. 7.1). The inverse effect was obtained at continuous exposure (CW). It was fixed, that the impulsive radiation at all three utilized carrier frequencies invokes statistically significant differences between kineticses of a DNA denaturation in the irradiated and control solutions. DNA degradation was done under an operation of ultrasonic sound conducted on sonic desmembranator, (model 300 “Fisher”, USA). Viscosity of DNA solutions in a dissolvent was kept at 0.15 mol/L of NaCl +0.015 mol/L of Sodium citratums +0.001 mol/L of EDTA determined on low gradient three-ball-type capillary viscosimeter (G=60–130 s^{-1}) by the extrapolation of the obtained data on a null gradient of alteration. The average molecular mass of fragmented DNA was counted via the establishment of intrinsic viscosity of agents under the formula $[\eta]=6.9\times10^{-4} M^{0.7}$.

Microwave exposure was applied to DNA solutions in Na-phosphatic buffer (0.01 mol/L, pH 7.2) at presence of β alanine and formic aldehyde. For this purpose, the DNA, β alanine and HCHO solutions at temperature of 18°C, as the indicated buffer, were ad-

mixed directly ahead of an irradiation, to achieve a final concentration of β alanine and HCHO of 0.72 mol/L and DNA of 6.4×10^{-5} mol/L (on nucleotides).

At once after an irradiation, the vial with DNA solutions was cooled down to +4°C and then they have compared a state of secondary DNA frame in the irradiated and control assays, conducting a thermal DNA denaturation in an admixture of HCHO to an amino acid. At each procedure of DNA melting in the pan of comparison of UV-2100 spectrophotometer ("Shimadzy", Japan) they have put control DNA assay and in the experienced pan — either the same control assay, or identical on a composition, but DNA solution subjected to EMF exposure. The pan of comparison was kept at 40°C and experienced at 41°C. the registration of DNA denaturation process at 270 nm was began at once after a location of pans in the pan handler. The variance of extinctions between identical DNA composition solutions occurred during the denaturation of a polynucleotide in the experienced pan and pan of comparison is stipulated by differences in a regimen of a thermostatting of pans and is featured by a curve under the form close to a parabola. Complete DNA denaturation at chosen temperature and utilized concentrations of HCHO and β alanine has descended within 16 min.

The results of experiments were treated statistically utilizing nonparametric criterion of Kolmogorov-Smirnov. For this purpose, in two and more independent tests recorded each minute within 14 min, the extinctions, A_t^{1j} and A_t^{2j} (J is the number of a sample, t is the time in min) were determined by fusible curves at least for four controls (A^1) and four tests (A^2). Basing upon magnitudes of A_t^{1j}, they have determined the average extinction value of control samples, $\bar{A}^1_t$, for each *t* in this test series and calculated the ratios of $A_t^{1J}/\bar{A}^1_t$ and $A_t^{2J}/\bar{A}^1_t$ at identical values of *t*. The obtained ratios have made comparable allocations of K (for the shielded DNA assays) and On (for irradiated DNA assays).

Basic results. The increase of the value of a maximum of curves of DNA assay denaturation and fast reaching of a maximum at a quantization as well as the inverse effect at a continuous irradiation (Fig. 1) were found. It was found, that the impulsive radiation at all three utilized carrier frequencies invokes the statistically significant differences between kineticses of DNA denaturation in the irradiated and control solutions.

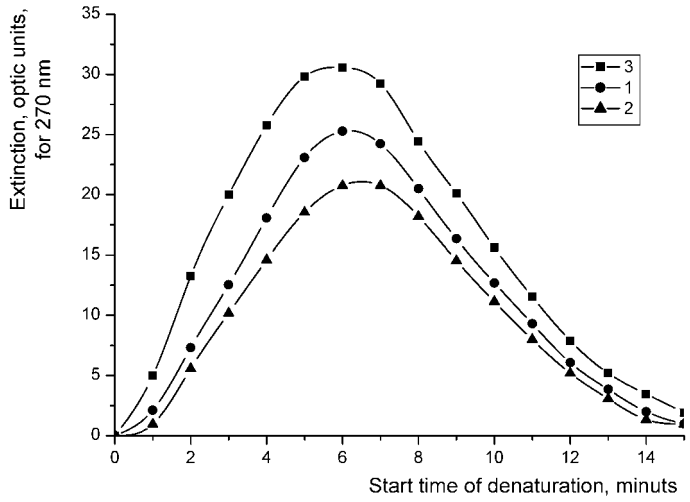

Figure 1. Kinetics of a denaturation in control (1) and DNA samples subjected to exposure to continuous (2) and modulated by frequency 4 Hz (3); (EMF of 1.05 GHz, S=600 μW/cm^2).

Conclusion. There is more strong process of DNA denaturation in conditions of the exposure to modulated EMF at 1.05, 2.12 and 2.39 GHz , modulation of 4 Hz, S=600 μW/cm^2 in comparison with a continuous irradiation (CW).

CHART NO. 8

Experiment 8

Kim Yu., Montrel M., Akoev V., Akoev I., Fecenko E. The influence of Electromagnetic Fields of Low Intensity of Hydration of DNA Films. J. Radiation biology and ecology (Russian academy of sciences) 2001. Vol. 41, No. 4, pp. 395–398.

The purpose. To examine EMF effect for small intensity and "oscillating" frequency (from 8.15 up to 10.0 GHz) on a hydration of DNA membranulas.

Experimental model. Sodic DNA salt from salmon fish semens. They have received a DNA film ДНК, which was put in the sealed chamber with stable humidity.

Exposure conditions. "Oscillating" frequency at the band of 8.15–10 GHz , S=5, 10, 20 or 40 mW/cm^2, duration of an irradiation of 1, 5, 15, 30 or 60 minutes. Exposure was conducted in the express thermostatically controlled pan. EMF was applied to DNA sample with the funnel-shaped or strip ultrasonic heads.

Time (period) of examinations. The infra-red spectrums were recorded at once after an irradiation, and within 2 hours after exposure.

Method of study. They have utilized an infra-red spectroscopy. The spectra were recorded on "Specord M80" spectrophotometer ("Carl Zeiss"). The IR spectra were analyzed with the help of the Micro Cal Origin Software. Delections of spectra were effected utilizing Fourier conversion. They have recorded curves of a dehydration, modification of DNA IR spectra.

Basic results. The short-term EMF exposure with "oscillating" frequency at 8.15–10.0 GHz and S=5 mW/cm^2 decelerates the rate of a desorption of water in DNA membranulas. It is shown, that the exposure of highly wet samples does not change spectral features of DNA molecules in the range of 900–4000 cm^{-1}, and consequently, their frame do not vary. At the same time, it varieties a conformation liability of these polymeric molecules, i.e. their ability to undergo conformation metamorphosises under an exposure to external factors. So, the exsiccation of unirradiated wet membranulas induces fast (within one minute) DNA passage from B to A conformation, while in the irradiated samples this passage does not descend during several hours after the decrease of humidity.

Conclusion. Under the effect of EMF exposure with "oscillating" frequency in a band of 8.15–10 GHz, at S=5 $\mu W/cm^2$ the hydration of DNA membranulas varieties.

CHART NO. 9

Experiment 9

1. Zakharova N.M. The enhancement of rhythm processes in the brain cortex sections under the exposure to pulsed modulated microwaves. Biophysics, 1995, vol. 40, issue 3. pp. 639–643.

2. Zakharova N.M., Alexeev S.I., Jadin M.N. SHF radiation effect in spontaneous pulsation activity of survived sections of the brain cortex. Biophysics, 1993, vol. 38, issue 3. pp. 520–523.

3. Zakharova N.M., Karpuk N.N., Jadin M.N. Cross correlation analysis of the interrelation of neuron pulsation in survived sections of neocortex under the microwave exposure. Biophysics, 1996, vol. 41, issue 4. pp. 913–915.

4. Zakharova N.M. The effect of decimeter band EMF in electrical activity of brain neurons of Guinea pig in vitro. Thesis, Pushino. 1998.

The purpose. Examination of modulated EMF effect at 0.9 GHz on background impulsive activity (BIA) of neurons of sections of a neocortex. Carrying out of comparative analysis of bioeffects at exposure to various frequencies and in a continuous regimen.

Experimental model. In vitro incubated sections of a neocortex of the Guinea pigs; recording of impulsive activity of neurons.

Exposure conditions. EMF at 0.9 GHz. The laboratory generator with a power output up to 30 W in a continuous regimen. A quantization: 7, 16, 30 and 60 Hz, the porosity was always identical and was equaled to 5, that allowed to equal specific absorbtion rate (SAR). The pulse duration was at 7 Hz — 28 ms, at 16 Hz — 12 ms, at 30 Hz — 6.7 ms. SAR=1.4 W/kg. The procedure ensuring monitoring and recording of BIA of neurons in the radiation time was implemented.

Time (period) of examinations. Up to, in time and at once after exposure.

Method of study. Probed background impulsive activity (BIA) of 80 neurons in experiments with the modulated exposure, 28 neurons with the not modulated exposure was examined. BIA was recorded by non-artifact electrodes. Electrical activity of neurons was recorded on the tape recorder for an aftertreatment on the computer. They have conducted a constant integration of streaming frequency of each neuron.

Basic results. At EMF exposure with modulation of 7 Hz, neurons in most cases (13 of 17 cells) already on the first minute of the exposure have responded by decrease of frequency of the discharges to 27%. Such frequency drift was saved during all radiation time. After the arrest of exposure, the tendency to regeneration of frequency was not observed (Fig. 1, A). The remaining 4 cells have not reacted on the irradiation.

At frequency of 16 Hz, 15 of 17 cells have the induced decrease of frequency of background activity by 24% on the first minute of an irradiation and on 65% to the end of the fourth minute of exposure. The tendencies to BIA regeneration was not traced (Fig. 1, B).

The exposure with frequency of 30 Hz modulation has invoked a response of BIA inhibition only at 7 of 16 probed cells approximately on 28%. In this case tendencies to regen-

eration was not traced after deenergizing the generator (Fig. 1, C). The remaining 9 cells in this series in reply to exposure have not reacted reliably.

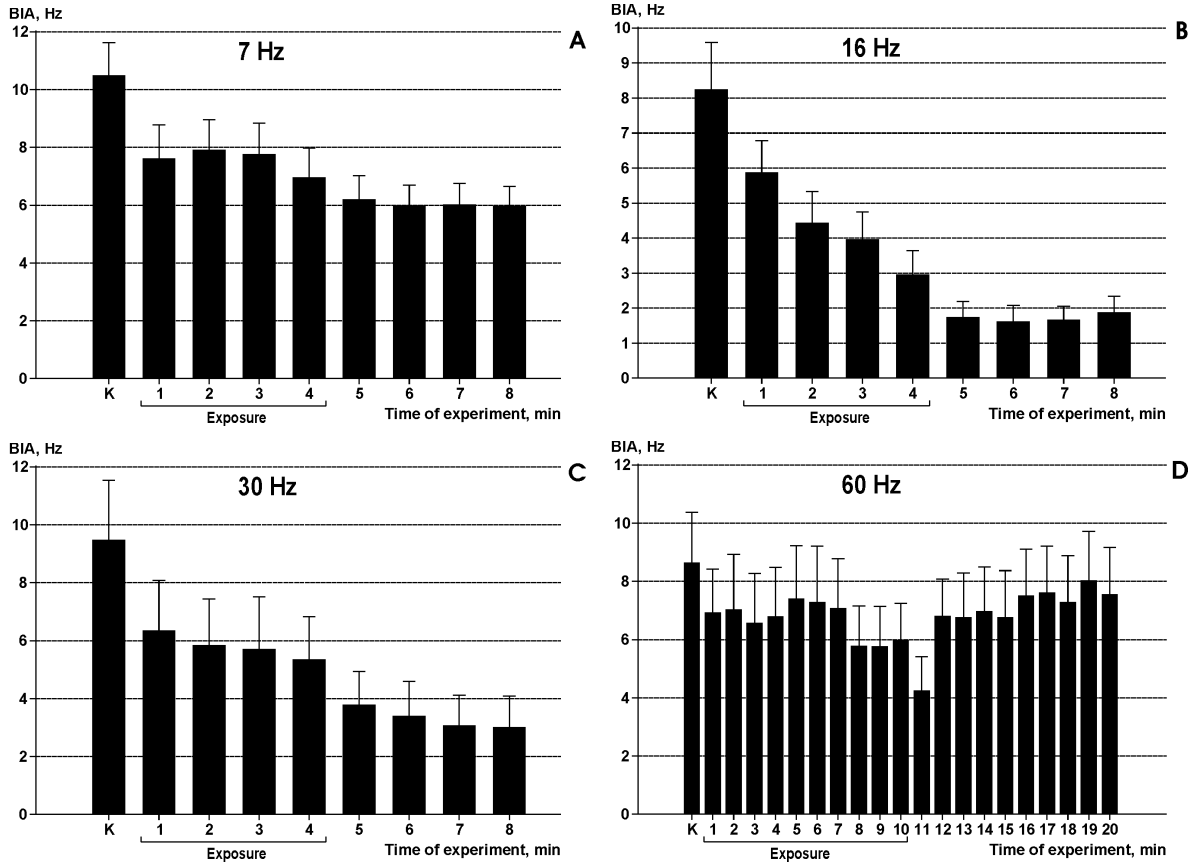

Figure 1. Effect by pulsed modulated EMF on background impulsive activity (BIA) of sections of a neocortex. Each column of the chart — average value of BIA frequency of all cells, probed in the given paste, in one minute and standard deviation average: K — in control, in a radiation time (line under the graphs), the subsequent columns reflect time after an irradiation by pulsed modulated EMF. The frequencies of modulation are indicated above each chart. Average SAR was 1.4 mW/g for all frequencies of modulation. A — 7 Hz modulation; B — 16 Hz modulation; C — 30 Hz modulation; D — 60 Hz modulation.

The exposure with frequency of 60 Hz has induced statistically significant short-term decrease of BIA frequency against control in less than third (5 of 19) probed cells approximately on 20% at first minute after the arrest of an irradiation. There was a tendency to regeneration of frequency at 2nd minute after an irradiation (Fig. 1, D).

In experiments with a continuous irradiation average SAR was selected to be equal to average SAR used in experiments with the modulated irradiation (1.4 mW/g). In examinations with a continuous irradiation, the BIA inhibition at 16 of 28 cells (Fig. 2) also is revealed, but change of a frequency drift observed at a constant integration was more monotonic, than at the modulated irradiation. At the not modulated irradiation the tendency to regeneration of BIA frequency after an irradiation to a level of control was traced. The significant inhibition occurred only to the fourth minute of an irradiation and the intensifying of effect was not observed after the arrest of an irradiation. (Figure 2).

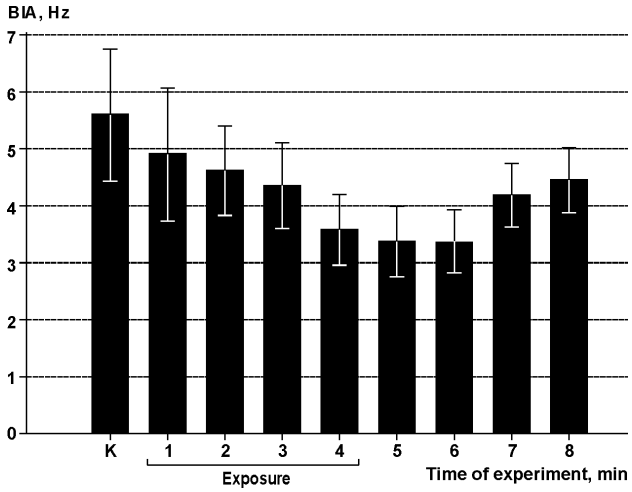

Figure 2. Average value of BIA frequency of neurons of sections of a neocortex in time and after exposure to not modulated EMF in each minute. K — up to an irradiation; in time (1–4 mines) and after (5–8 mines) irradiation with average SAR of 1.4 mW/g; on an abscissa axis — time of examination.

CHART NO. 10

Experiment 10

Zakharova N.M., Karpuk N.N., Jadin M.N. Cross correlation analysis of the interrelation of neuron pulsation in survived sections of neocortex under the microwave exposure. Biophysics, 1996, vol. 41, issue 4. pp. 913–915.

The purpose. To reveal modifications of brain neurons pulsation at MEMF exposure with usage of cross correlation of analysis.

Experimental model. Experiencing frontal sections of sensomotor cortex of the Guinea pig brain.

Exposure conditions. EMF at 900 MHz , SAR in the volume of 1 cm^3 with sections was 1.4 mW/g. Pulsed modulation of 7, 16, 30 и 60 Hz.

Time (period) of examinations. Up to, in time and at once after MEMF exposure.

Method of study. The spontaneous activity a steam of neurons was recorded exocellularly by one microglass electrode. Cross correlation functions (CCF) of cells were calculated. The CCF statistical analysis for cells obtained from 51 neighbor steams was conducted, which impulsive streams were clearly divided with the help of amplitude discrimination.

Basic results. The CCF statistical analysis for cells obtained from 51 neighbor steams was conducted, which impulsive streams were clearly divided with the help of amplitude discrimination. In CCF of the level of significance of 5% reliable deflections from a mean level h_{12} were found, showing mutuality in cellular pulsations of examined cell couples. On all frequencies of modulation the decrease of the correlation coefficient was in most cases observed during exposure with lack of the legible tendency to regeneration of degree of constraint of the steam of neurons after the arrest of exposure.

The decrease of correlation at an irradiation can testify, that MEMF desynchronizes work of crustal neurons in neuronic ensembles. The modification of correlation in activity of probed nervous cells at a microwave irradiation, apparently, is connected to effect of radiation on synaptic transmission between neurons. One of the causes of deterioration of carrying out synaptic signal in a nervous tissue can be depressing of a power metabolism or attrition of neurons mediator pool.

Conclusion. Thus, utilizing filing of spontaneous impulsive activity of neurons of experiencing sections of a neocortex and cross correlation analysis, it was shown, that the electromagnetic radiation renders noticeable downstroke of transneuronal correlation and accordingly there is a deterioration of synaptic transmission between cells of a cortex.

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CHART NO. 11

Experiment 11

Aphrikanova L. A., Grigoriev Yu. Influence of an electromagnetic radiation of various modes on heart activity (in experiment). J. Radiation biology and ecology (Russian academy of sciences). 1996. Vol. 36, No. 5, pp. 691–699.

The purpose. Examination of EMF effect for various regimens (modulation) on cardiac activity in experiment (on an isolated frog heart).

Biological object. The frog heart isolated on Graminitsky method. Heart was shrunk in Ringer solution within two days. In total experiment, 180 hearts were utilized.

Exposure conditions. In experiments, the composite regimen of modulation was utilized at low level of intensity. The principle of modulation frequency changed in time was applied at a constant countrexposure of frequency setting. An irradiation was conducted on experimental installation generating microwave with frequency of 9.3 GHz. As the dimensions of frog heart are comparable to a wavelength of radiation, an irradiation was conducted in conditions which are coming nearer to maximal absorption of the radiation energy. Modulated EMF on its amplitude was characterized by varying frequency of modulation from 1 up to 100 Hz at a depth of modulation of 30 and 100%; a pulse shape was rectangular, meander, S=0.016 mW/cm^2. Distance up to the object got out by such, that the irradiation was uniform. The general plan of conditions of experiments is provided by Table.

Time (period) of examinations. In a radiation time and after exposure within 24 hours.

Method of study. They have estimated a beat frequency of heart during each 30 minutes within 6 hours from the moment of manufacture of the isolated heart preparation, during exposure, and also within day after an irradiation. Simultaneously, observations were conducted in control (sham exposure) in the same terms.

The morphological criterion of a state of erethitic tissues of heart was the assessment of process of a vital staining of frames of an interatrial septum by a stain of azine group with neutral red (NR). The method of an intravital staining has enabled to judge vitality of frames by granule forming criterion, and also about a state of their permeability (on a degree and dynamics of staining). Other vital stain, methylene blue, was utilized for an assessment of a state of choline energetic synapses on independent neurons of a Ludwig node.

Basic results. Intact uncolored hearts for 24 hours of observations have decelerated the rate on the average on 7%; the cardiac standstill was not present (Fig. 1). Half-hour stays of a quarantined drug heart in solution of a stain in itself have resulted in the modification of its function. The figure of constrictions was decreased by 30%, and 14% of hearts ceased to be pruned (Fig. 1). At a stimulation of the stopped hearts by strong light or mechanical stimulus of pacemaker range (venous sinus) the beat was recovered. After the arrest of process of a staining of heart the rate of constrictions was gradually accumulated reaching the initial level. And only to the end of experiment in hour 24, the heart beat number was sunk on the average on 20%.

Table. General characteristics of conditions of experiments

Test No.	Animal number		PFD, mW/cm²	EMF mode and exposure time, min			Total exposure time, min
	Test	Control		CW	Pulsed, Hz	Time at each mode, min	
1	28	28	0.016	-	6–10	1	5
2	32	32	0.016	-	1–10	1	10
3	20	20	0.016	-	1–10, 20, 30, 40, 50, 60, 70, 80, 90, 100	1	19
4	10	10	0.016	CW	-	5	5

The response of hearts irradiated in a continuous regimen, was inappreciable, and differed from the colored unirradiated hearts a little.

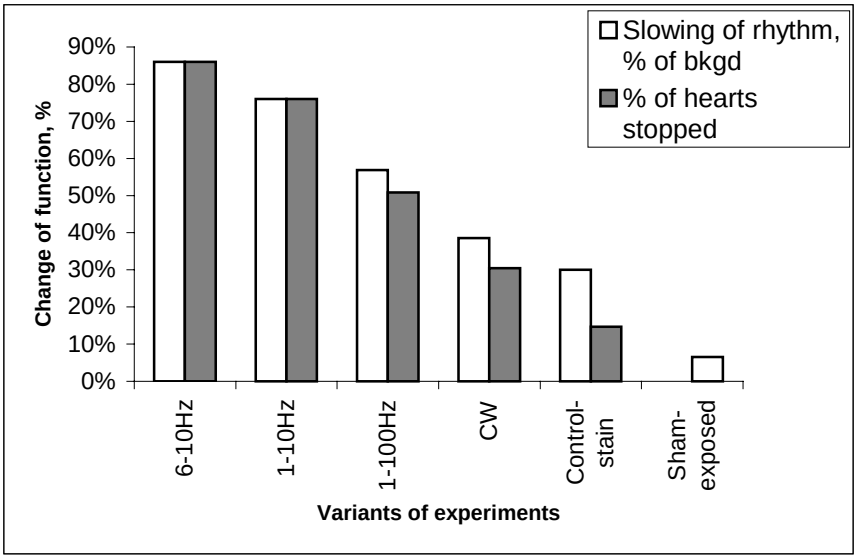

Figure 1. Change in the number of beating and stopped isolated frog hearts, EM irradiated using the continuous regime and for various pulse modulations from 1 to 100 Hz.

At an irradiation in the modulated regimen, the sharp decrease of heart beat number was marked, the number of the hearts which have ceased to beat (Fig. 1) was enlarged also. The greatest effect was obtained at a frequency drift of modulation in a band of 6–10 Hz and time of exposure of 5 minutes. Under these conditions of exposure, there was a retardation of a rhythm to the subsequent cardiac standstill at 85% of hearts (at a continuous regimen — 38%). The effects were particularly reversible.

The irradiated hearts washed from a paint have recommenced constrictions, and the accumulated rate, however, within 2–3 subsequent hours in major percent of cases has been noted to have sharp heart beat decrease and secondary cardiac standstill. In these cases, challenging procedures have ordered only to short renewing of cardiac constrictions. In 2–3 hours after MEMF exposure in neurons and muscle elements of heart, the violation of granule forming process was observed. The great number of neurons has gained the angle forms and diffuse coloring of a core and cytoplasm. In muscle fibers, the number of stain beads was diminished, cytoplasm was slightly tinted, and a number of muscle cores were

also colored in intensively red color. Simultaneously, the appearances of a gelatinization of synapses on cells of a Ludwig node and intensive tincturing of Schwann cells in region of a taper of an axon were marked. Such results can speak about violation of vitality of the irradiated frames of heart and about the development of process of paranecrosis.

Conclusion. In all series of the MEMF irradiation of hearts with changeable frequency of modulations in range from 1 up to 100 Hz, it has rendered much major effect on function of heart, rather than irradiation in a continuous regimen of generating.

Note. The procedure of an isolated frog heart is sensitive to EMF exposure. The modification of function of heart was observed at a regimen of a continuous irradiating (CW) within 5–19 minutes at S=0.016 mW/cm^2.

CHART NO. 12

Experiment 12

Aphrikanova L.A, Grigoriev Yu.G. Influence of on electromagnetic radiation of various modes on heart activity (in experiment). J. Radiation biology and ecology (Russian academy of sciences) 1996. Vol. 36. No. 5, pp. 691–699.

The purpose. Examination of the significance of correlation between an initial state of a system of an organism and conforming modulation (examination of resonance effect).

Experimental model. An isolated frog heart with conservation of heart beats within two days.

Exposure conditions: EMF of 9.3 GHz, S=0.016 mW/cm^2 with modulation in three regimens: (a) 20, 22, 24 and 25 Hz; (b) 32, 34, 36 and 38 Hz; (c) 40, 42, 44, 46 and 48 Hz. The regimens were chosen according to an initial beat frequency of an isolated heart. The duration of each irradiation was 1 minute. Control — a continuous irradiation (CW) and sham irradiation.

Time (period) of examinations. In time and at once after the terminal of exposure.

Method of study. In an initial state on a heart beat frequency they were divided into 3 groups: (I) 20–30 beats in 1 min; (II) 31–40 and (III) 41–50. The exposure regimens were chosen according to an initial beat frequency of an isolated heart (see above) and group IV (CW) was added. Magnitude of modifications was estimated on a 4 rank system, according to visual observations. The magnitude of frequency drifts of the heart beats was expressed in% from initial magnitude: 10–20% =1 ball; 21–30% =2 balls; 31% and more =3 balls; a reversible cardiac standstill =4 balls.

Basic results. In connection with miscellaneous initial frequency of palpitation and in a frequency dependence of modulation the various bioeffect (see table) was obtained.

At each of three regimens of modulation the greatest modifications in a rhythmicity of heart from the initial level were under condition of concurrence of their magnitudes (Table.). The greatest modifications were at EMF exposure in a regimen of modulation at 20–28 Hz in group of hearts with frequency of beats of 20–30 strokes a 1 minute.

Table. Frequency drift of frog heart beats in dependence from modulations of microwave field and initial frequency of heart beats

Group	No. of hearts	Modulation frequency, Hz	Rank number (group averages)			Total rank number
			Initial heart beat rate			
			20–30	31–40	41–50	
I	23	20, 22, 24, 25, 28,	**50**	3	3	56
II	28	30, 32, 34, 36, 38	11	**12**	9	32
III	22	40, 42, 44, 46, 48	9	1	**16**	26
IV	26	Continuous wave	1	-	-	2
V	30	“sham exposure”	-	-	-	0

Conclusion. The bioeffect at modulated EMF exposure depends as well on an initial state of a system of an organism.

CHART NO. 13

Experiment 13

1. T.P. Semenova, N.I. Medvinskaya, G.I. Bliskovka, I.G. Akoev. The Influence of Electromagnetic Fields on Emotional Behaviour of Rats. Radiation biology and Radioecology. 2000, vol. 40, No. 6. pp. 693–695.

2. I.G. Akoev, M.S. Pashovkina, L.P. Dolgacheva et al. Enzymatic activity of some tissues and serum of animal and human blood in case of microwave exposure and free radical hypothesis for non-linear effects and modification of the animal emotional behavior. Radiation biology and Radioecology. 2002, vol. 42, No. 3. pp. 322–330.

The purpose. Examination of modulated EMF effect on emotional and exploratory behavior.

Experimental model. 35 rats

Exposure conditions. EMF exposure at 915 MHz with a frequency modulation of 4, 6,16 and 20 Hz 915 MHz , radiation time was 10 minutes. At all given frequencies of modulation, S=10 $\mu W/cm^2$. They have utilized magnetron generator for exposure. There was an animal group with a "sham" irradiation.

Time (period) of examinations. At once after exposure.

Method of study. Immediately after an irradiation, the animal behavior was examined in conditions of an operation on them of series of stressors: a unfamiliar situation of open space, height, glare. With this purpose, they have conducted observations of behavioral singularities in the uplifted cruciform labyrinth, when animal should make jogs on narrow rays of a labyrinth at major height above ground level. This procedure is widely utilized for an assessment of an affective behavior of rats in particular expressiveness of the level of uneasiness. They have estimated time of "freezing behavior".

The labyrinth was consisted of two open (40×12 cm) and two closed (40×12 cm) sleeves restricted by opaque walls of 40x40 cm dimension. The orifices in the open sleeves were posed vice-versa apart 10 cm. The labyrinth was at height of 90 cm above a level of floor. All experiments were conducted in the morning — from 9.00. In the beginning of experiment, the animal was put in a central part of a labyrinth and during 5 min was observed. They have recorded the number of calls in the open and closed rays of the labyrinth, the number of passages in rays of a labyrinth and time of the freezing behavior response. After the end of work with animal, they have wiped the floor of the labyrinth and through 10–15 mines have began work with the following animal.

The statistical analysis of an experimental materials was conducted with usage of the computer software (Sigma Plot (4.1)), U-criterion of Wilcoxon — Mann — Whitney and t-Student criterion.

Basic results. As a result of EMF exposure modulated by frequencies of 4 and 6 Hz, the number of entries in the open rays of a labyrinth within 5 min observation has increased in 3.7 and in 4.5 times accordingly in comparison with control, that is a parameter of considerable dropping at an animal level of uneasiness from stay in a labyrinth (Table.). At modulation frequency of 16 Hz, the modifications of this parameter were expressed more weakly — number of entries was enlarged in 2.3 times, and at 20 Hz its value in essence did not differ from control.

Table. Singularities of rat behavior in a cruciform labyrinth after MEMF exposure

Modulation frequency, Hz	No. of rats	Number of entries to “open rats”	Number of entries to “closed rats”	Freezing time, s
control	9	1.1±0.2	6.8±0.6	24.0±4.0
4	7	4.1±0.7**	8.7±1.2	5.7±1.8**
6	4	5.0±0.6**	9.7±1.7	5.0±1.5**
16	6	2.5±0.3*	7.0±1.9	1.8±0.9***
20	9	1.0±0.1	4.0±0.7**	50.4±8.9*

Footnote. Differences from control on a t-Student criterion are reliable:
* — $p < 0.05$; ** — $p < 0.01$; *** — $p < 0.001$

On a parameter of time of freezing behavior describing a degree of manifestation of passive defensive behavior, multi-directed EMF effect was also detected depending on the frequency of modulation. Under EMF exposure at frequency of modulation of 4, 6 and 16 Hz, the time of freezing behavior was sunk in 4.2, 4.8 and 13.3 times, accordingly. At rising frequency of modulation up to 20 Hz, the time of freezing behavior, on the contrary, has increased in 2.4 times.

The motor performance determined on number of entries in the closed rays of the labyrinth, did not undergo reliable modifications after EMF exposure modulated by frequencies of 4, 6 and 16 Hz. However, at frequency of modulation of 20 Hz, the level of this parameter was sunk in 1.7 times.

Thus, the comparative analysis of EMF modifications of parameters of an affective behavior (table) has revealed, that the number of entries in the open rays of the labyrinth is changed by the EMF exposure with frequencies of modulation of 4 and 6 Hz, with increase up to 373 and 450% accordingly in comparison with control conditionally accepted for 100% ($p < 0.01$). On frequency of modulation of 16 Hz this parameter was enlarged up to 225% ($p < 0.05$), and at frequency of 20 Hz the tendency to its decrease was observed.

The comparative analysis of the data, submitted in the table characterizes modifications of responses of freezing behavior under low intensive EMF exposure at miscellaneous frequencies of modulation. It is shown, that at modulation of 4, 6 and 16 Hz the reaction duration is decreased in 76% ($p < 0.01$), 79% and 93% ($p < 0.001$), respectively. At frequency of the modulation of 20 Hz, the freezing period has exceeded a control level on 110% ($p < 0.05$).

Conclusion. The modulated EMF exposure of small intensity influences the affective behavior of animal.

CHART NO. 14

Experiment № 14

1. K.V. Sudakov, G.D. Antimonii. The hypnogenic effect of modulated electromagnetic field. Bulletin of Experimental biology and medicine. 1977. No. 8. pp. 146–149.
2. K.V. Sudakov, G.D. Antimonii. Central mechanisms of electromagnetic field effects. Physiological Science Success, 1973. No. 2. pp. 101–135.
3. G.D. Antimonii. The analysis of purposed behavior changes in rats exposed to modulated Emf. Thesis, Moscow, 1974.

The purpose. To investigate the modulated EMF effect on behavior of experimental animals

Experimental model. Rat behavior.

Exposure conditions. EMF of 40 MHz with the modulation of 50 Hz had depth of modulation of 80–100%, field strength of 100–120 V/m, duration of exposure was from 5 minutes till 2.5 hours. They have utilized the generator, which condenser plates were hardened along walls of the scoop.

Time (period) of examination. During exposure and at once after it.

Method of study. 76 rats were utilized in experiment. Some animals were made to develop conditional alimentary and defensive responses. They have conducted an EEG records. Some animals were in free behavior.

Basic results. At exposure within 5–45 minutes there were modifications of some parameters of conditional reflex activity. At 75% of animals, they have recorded epileptiform activity in hyppocamp, temporal and visual compartments of a cerebral cortex. At exposure within 45–60 minutes, 86% of animals were recorded to have epileptiform activity in all investigated frames of a brain. At exposure within 1.5–2.5 hours, 35% of animals have developed sluggish EEG wave (1–2 Hz), and 5% of rats had the true catalepsy with appearances “of wax flexibility”.

At animal in free behavior, within first minutes of the exposure, the general motor performance was enlarged. To the end of 1st hour, there was depressing a motor performances more and more intensified during EMF exposure. Already after the first hour of exposure, rats became practically “manual”, they did not react to sharp sounds and touch. After 1.5–2.5 h of exposure deep suppression of a motor performance was practically found in all animals. Thus, the rats ceased to react not only on sensory, but also to biological stimuluses, for example, on a location of the rabbit and even a cat in the experimental scoop. In 5% of animals the cataleptic state was educed.

Conclusion. During exposure within 2.5 hours to EMF at 40 MHz with modulation of 50 Hz at 100–120 V/m, the phase modifications of behavioral responses down to development of the cataleptic state were found in some animals.

CHART NO. 15

Experiment 15

Konovalov V.F., Serikov I.S.The distant effects of modulated and non modulated electromagnetic field on epilepti formic activity in rats. J. Radiation biology and ecology (Russian academy of sciences) 2001. Vol. 41. No.2, pp. 207–209.

The purpose. To examine possible effect of modulated EMF on epileptiform activity in rats

Experimental model. Rats with presence of audiogenic cramps.

Exposure conditions. Modulated and non-modulated EMF at 880 MHz, S=1mW/cm^2, 5 minutes/day, within 5 days. Series I: non-modulated EMF (CW); series II: 4 Hz modulation; series III: 16 Hz and series IV: sham exposed.

Method of study. 40 rats with presence of audiogenic cramps. For this animal selection before EMF exposure, they were invoked with cramps triply by sonic stimulus of 100 dB during 1–2 min. They have recorded all phases of a convulsive attack. Testing of presence of a convulsive state was conducted at once after 5 diurnal cycles of EMF exposures, further 1 time per one week within 1st month, further through 2, 3, 4, 5 and 6 months, 1 year and 1.5 years. The further observation prolonged up to animal death.

Basic results. As a result of MEMF exposure, there was the suppression of a convulsive predisposition in animals at modulation of 4 Hz and 16 Hz. At a continuous mode of exposure, this effect was expressed insignificantly and it was exhibited only in 3 months after an irradiation (Table)

Table. Exhibiting audiogenic cramps in rats (%) of four experimental groups after exposure to not modulated and modulated EMF

Time of repeated testing after a course of exposure (provocation of audiogenic cramps)	Animal group			
	1 (CW)	2 (4 Hz)	3 (16 Hz)	4 (Sham exposure)
Day 1	100	20*	20*	100
Week 1	100	20*	20*	100
Week 2	100	20*	20*	100
Week 3	100	20*	20*	100
Month 1	100	20*	20*	100
Month 2	100	20*	20*	100
Month 3	80	60	80	100
Month 4	80	60	80	100
Month 5	80	60	80	100
Month 6	80	80	80	100
Month 12	20*	80	20*	100
Month 18	37,5	66,6	25	100

* Statistically significant difference by Student criterion ($p < 0,05$)

Conclusion. Modulated EMF (880 MHz 4 and 16 Hz, S=1 mW/cm^2) are more effective at exposure on a nervous system, than not modulated EMF (on model of epileptiform activity of rats).

CHART NO. 16

Experiment 16

1. Sudakov K.V. Modulated EMF as the factor of selective effect in target behavior mechanism in animals. Supreme nervous activity journal, 1976. issue 5. pp. 899–108.
2. Sudakov K.V. Modulated EMF effects in emotional reactions. In: Proceedings of international meeting on EMF bioeffects and hygienic standardization, Moscow, 18–22 May 1998 pp. 153–158.
3. Sudakov K.V. Effect of a modulated electromagnetic field on emotional reactions. Proceeding of the Int. Meeting "EMF: biology effects and hygienic standardization", Moscow, 18–22 May, 1998. WHO. 1999, pp. 139–144.

The purpose. Examination of modulated EMF effect on a response of a self-stimulation in rats.

Experimental model. Rats.

Exposure conditions. EMF of 30 MHz, frequency of modulation of 2, 7 and 50 Hz, depth of modulation of 80%, field strength of 30 V/m. They have utilized the generator, which condenser plates were hardened along walls of the scoop. Duration of exposure was 10 minutes.

Time (period) of examinations. At the exposure time.

Method of study. 30 rats were utilized in the experiment. The irritation of frontal, lateral and back hypothalamus and middle and lateral kernels of the septum was effected by an electrical current of 10–12 A, duration of impulses of 0.1–0.5 ms. They have invoked a response of a self-stimulation in all animals.

Basic results. At an EMF exposure with frequency of 2 Hz modulation during the first 2 min, the augmentation of frequency of a response of a self-stimulation for 93% was observed, then the frequency of a response of a self-stimulation was sharply sunk and through 4 min petered completely (Fig. 1A). At an MEMF exposure with frequency of 7 Hz modulation in the first 2 min, the response of a self-stimulation practically did not differ from background and only then, during 12–15 min, the decrease of its frequency (Fig. 1B) was observed. Other picture was observed at an MEMF exposure with 50 Hz modulation — practically at once from the beginning of exposure all animal responses of a self-stimulation were quenched (Fig. 1C). Characteristically, that the indicated MEMF effects did not depend on localization o of stimulating electrodes endpoints (stimulated area of the brain).

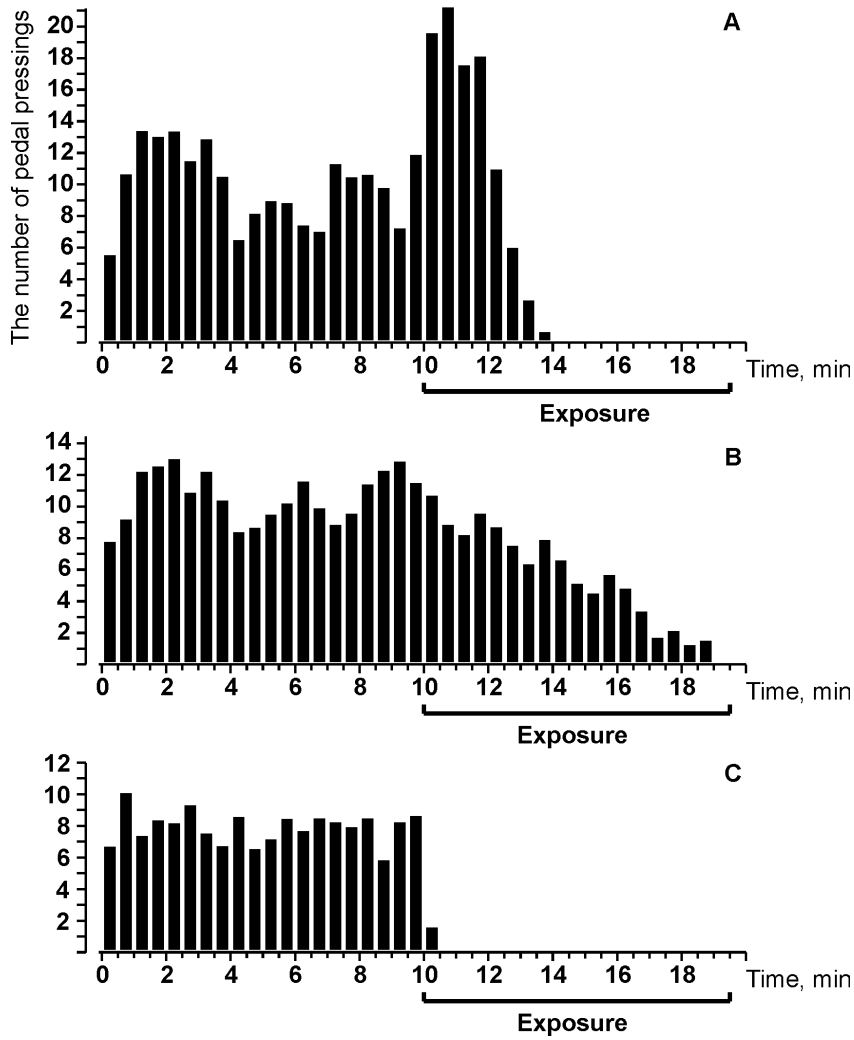

Figure 1. Dynamics of the self stimulation rate in case of EMF exposure at different modulation frequencies. A — 2 Hz; B — 7 Hz and C — 50 Hz. Each column is the number of pedal pressings per 30 s period averaged for 10 animals. The line is the MEMF exposure time.

Conclusion. MEMF of small intensity can influence a response of a self-stimulation at animal. This effect depends on an aspect of a frequency modulation.

CHART NO. 17

Experiment 17

Yu. G. Grigoriev, S. N. Lukianova, V. P. Makarov, V. V. Rynskov, N. V. Moiseeva. Motor activity of rabbits in of conditions of chronic low-intensity pulsed microwave irradiation. Radiation biology. Radiation ecology. 1995, vol. 35, No. 1, pp. 29–35.

The purpose. Examinations of modulated EMF effect on a motor performance of the rabbits in conditions of chronic exposure to microwaves of low intensity.

Experimental model. 20 rabbits.

Exposure conditions. EMF field at 1.5 GHz. The character of modulation was impulsive, impulse of the rectangular form, pulse duration of 16 ms, recurrence rate of impulse of 0.12 Hz, S=300 $\mu W/cm^2$. Animals were irradiated daily for 30 minutes within one month. Electromagnetic exposure and "sham irradiation" were applied in the random order.

Time (period) of examinations. The observations of the motor performance of the rabbits were conducted during daily exposure for 30 minutes within 1 month.

Method of study. In the term of 30 minutes of true or "sham" irradiation, the rabbits were put in specially made organic glass cell. Out of door piezocrystal permitting to differentiate motor reactions was attached to a floor of a cell. The graphic entry of motor reactions and their handling were led with the help of a polygraph and "Televideo-286" (USA).

Basic results. Only since day 14 of chronic exposure, the alarms were developed at animal reliable disadaptation motorial exhibitings as intensifying disturbing.

Conclusion. Only under the chronic modulated EMF exposure, the alarms were developed at animal reliable disadaptation motorial exhibitings as intensifying disturbing.

CHART NO. 18

Experiment 18

1. Moiseeva N.N. Experimental dates about reaction of neurons of the brain on low-intensity package pulsing microwaves irradiation. J. Radiation biology and ecology (Russian academy of sciences) 1996., Vol. 36. No. 5, pp.710–713.
2. Lukjanova S.N., Moiseeva N.V. To the analysis of pulsed bioelectrical activity of a cortex brain of a rabbit in reply to low-intensive microwave irradiation. J. Radiation biology and ecology (Russian academy of sciences) 1998. Vol. 38. No. 5, pp. 763–768.

The purpose. The response of separate neurons of a brain on a low intensive packed impulsive microwaves was investigated.

Experimental model. Bioelectric activity of neurons of a brain of the rabbits.

Exposure conditions. EMF exposure was applied at 1.5 GHz, 100% amplitude modulation, meander, pulse duration of 0.4 ms, recurrence rate of 1000 Hz, duration of packs of 16 ms, with frequency of their repetition of 0.12 Hz, S=300 $\mu W/cm^2$. The exposure was conducted in sound isolated non-echo chamber with a reflectance factor of 30 dB. The generator of a microwaves (G3–21) was used. The radiation time was 1 minute. As control, the animal group with "sham irradiation" was utilized.

Time (period) of examinations. A background, in time and at once after exposure.

Method of study. The experiments were conducted on 22 rabbits of Chinchilla breed with body mass of 3 kg. The bioelectric activity of 139 neurons of sensomotorial and parietooccipital ranges of a cortex of a brain was studied. The impulsive activity was noted with the help of a small-type micromanipulator with a walk of the screw by 500 microns. The submersed microelectrode was served by the glass capillar with a bottom diameter of 1–3 microns, filled with three-molar normal saline solution of sodium chloride (resistance of 5–30 MOhm). They have utilized chlorine vinyl tube with the same solution on the basis of agar wires.

Analyzed frequency of the discharges of neurons and their character in the period of 3-minute entry (1 min — background, 1 min — irradiation and 1 min — after-exposure). An irradiation and control were conducted in randomized order.

Statistically estimated exhibiting of the response of neuronic activity on an irradiation versus a background and conforming control examinations, has utilized Student and χ^2 criteria.

Basic results. Under MEMF exposure, the activity of neurons has reliably varied, the number of the neurons which have changed the frequency has increased. The character of a response of neurons depends on their initial activity (Tables 1–3). The neurons excitanted in the time of MEMF exposure have changed the response on inhibition in the time of after-exposure.

Table 1. Performance of responses of neurons of sensomotor range of the brain cortex of the rabbit on low intensive packed impulsive microwave radiation

Character of responses	An amount of neurons, % from total (63)	Central frequency		
		before	during	after
Excitation	24.14*	5.5±0.66	16.3±0.78	6.03±0.64
Inhibition	31.03*	11.82±0.7	4.3±0.49	4.3±0.49
Non reacted	44.83*	9.82±0.67	9.34±0.68	9.34±0.79

* $p < 0.01$ versus control (Table 3); ** $p < 0.01$ versus background.

Table 2. Performance of responses of neurons of parietooccipital range of the brain cortex of the rabbit on low intensive packed impulsive microwave radiation

Character of responses	An amount of neurons,% from total (63)	Central frequency		
		before	during	after
Excitation	23.23*	5.52±0.4	11.25±0.76**	2.83±0.47**
Inhibition	30.47*	9.67±0.73	3.58±0.68**	4.45±0.61**
Non reacted	46.3*	6.13±0.52	5.9±0.47	5.33±0.42

Footnote. See note to Table 1; * $p < 0.01$ versus total of the registered neurons;
** $p < 0.05$ versus an initial background

Table 3. Performance of responses of neurons of sensomotor and parietooccipital ranges of the brain cortex of the rabbit on sham irradiation (control series)

Ranges of a cortex	Reaction character	An amount of neurons,% from total (63)	Central frequency		
			before	during	after
Sensomotorial (72 neurons)	Excitation	3.04	5.2±1.32	6.94±1.5	7.8±1.09
	Inhibition	11.75	9.1±0.32	6.1±0.53	6.3±0.38
	Not reacted	85.21	8.7±0.4	8.0±0.44	8.6±0.41
Parietooccipital (73 neurons)	Excitation	5.65	2.26±2.2	4.1±1.6	8.4±2.15
	Inhibition	10.3	5.47±0.44	3.2±0.52	3.93±0.45
	Not reacted	84.05	6.2±0.42	5.8±0.38	6.5±0.39

Conclusion. Thus, at EMF exposure within 1 minute at 1.5 GHz, 300 $\mu W/cm^2$ at a packed quantization the modification of activity of neurons of the brain cortex was registered.

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CHART NO. 19

Experiment 19

S.N. Lukjanova, N.V. Moiseeva To the analysis of pulsed bioelectrical activity of a cortex brain of a rabbit in reply to low-intensive microwave irradiation. Radiation biology. Radioecology. 1998. vol. 38. issue 5. pp. 763–768.

The purpose. modulated EMF effect of low intensity on bioelectric activity of neurons of a cortex of a brain

Experimental model. 22 rabbits.

Exposure conditions. The irradiation of animal head was conducted in non-echo chamber, reflectance factor of 30 dB. EMF applied was at 1.5 GHz, quantization, pulse duration 0.4 ms with a recurrence rate of 1000 Hz, S=30 $\mu W/cm^2$. The generator G3–21 (Russia) was used. Time of exposure was 1 min. There was a series with "sham irradiation".

Time (period) of examinations: up to, in time and after exposure within 1 minute.

Method of study. The experiments were conducted on 22 not anesthetized male rabbits of Chinchilla breed, 3 kg body weight, which were softly fixed on the wood machine tool. They have studied extracellular bioelectric activity of neurons of sensomotor and parietooccipital ranges of the brain cortex.

They have recorded the impulsive bioelectric activity applying small-type micromanipulator made of organic glass with a walk of the screw of 500 microns, which was fastened on a head of the rabbit and allowed to record impulsive activity not only before and after, but also in the EMF valid time. The submerged microelectrode was served by the glass capillar with a bottom diameter of 1–3 microns, filled with molar solution of sodium chloride (resistance of 5–30 MOhm). The intact electrode was fastened on an ear of the rabbit. They have utilized chlorine vinyl tube with a normal saline solution on the basis of agar as the wires. They have analyzed frequency of the discharges of neurons and their character in 3 min of an entry (1 min — a background, 1 min — irradiation and 1 min — after-exposure).

Irradiation and "sham" irradiation were conducted in the randomized order. Statistically estimated exhibiting of the response on frequency pulsation of neuronic activity in the time of the irradiation was done in comparison with the background and conforming control of examinations, utilizing a t-Student and χ^2 criteria.

Basic results. The quantitative performance of modifications in impulsive bioelectric activity of sensomotor and parietooccipital ranges of the brain cortex in conditions of the conducted experiments is submitted in Table 1. From the table it follows, that the irradiation in comparison with control, has reliably resulted to lot of neurons reliably changing the frequency of bioelectric activity if compared to the initial background. Among responding neurons (from 55 up to 60%), the identical amount of cells as with a response of augmentation of pulsation frequency and with its decrease was observed.

In Tables 2 and 3 the performances of pulsation frequency of neurons in control and with MEMF irradiation are submitted. As follows from Table 2, the reliable modifications

in control pulsation frequency of neurons were practically missed. In the time of MEMF exposure, both decrease and increase of the pulsation frequency could reliable take place (Table 3).

Table 1. Comparative performance of percent of responses of neurons of sensomotor and parietooccipital ranges of the brain cortex of the rabbit in experiments with MEMF irradiation

Series (conditional name)	Brain cortex range	No. of recorded neurons	% of total neuron number		
			Confident pulsation change of:		Not reacted
			increase	decrease	
MEMF	Sensomotorial	105	27.62*	2.38*	40.0*
	Parietooccipital	84	25.0*	29.76*	45.24*
"sham" exposure	Sensomotorial	72	2.7	11.1	86.2
	Parietooccipital	73	5.48	10.96	83.56

* $p < 0.01$ versus control, by χ^2criterion

Table 2. Performance of frequency pulsation of neurons in sensomotorial and parietooccipital ranges of the brain cortex of the rabbit in experiments with a "sham" irradiation

Brain cortex range	Response character	Central frequency, Hz		
		before	during	after
Sensomotorial (72 neurons)	Excitation Inhibition Not reacted	5.2±1.32 9.1±0.62 8.7±0.4	6.94±1.5 6.1±0.83 8.0±0.44	7.8±1.09 6.3±0.98* 8.6±0.41
Parietooccipital (73 neurons)	Excitation Inhibition Not reacted	2.26±1.5 5.47±0.94 6.2±0.42	4.1±1.6 3.2±0.92 5.8±0.38	8.4±1.9 3.93±0.85 6.5±0.39

Footnote. The quantitative performance of responses is submitted in Table 1; * $p < 0.05$ versus an initial background on a Student criterion.

Table 3. Performance of responses of neurons of sensomotor and parietooccipital ranges of the brain cortex of the rabbit on the MEMF irradiation

Brain cortex range	Response character	Central frequency, Hz		
		before	during	after
Sensomotorial (105 neurons)	Increase Decrease Not responded	6.1±0.89*** 8.92±0.88 6.9±0.54	11.2±0.64* 4.32±0.7* 7.5±0.69	9.2±0.58*,** 8.85±0.69** 7.1±0.85
Parietooccipital (84 neurons)	Increase Decrease Not responded	4.92±0.45*** 6.53±0.39 5.4±0.83	8.4±0.53* 4.13±0.57* 6.38±0.71	6.9±0.48*,** 6.89±0.75** 6.05±0.66

* $p < 0.05$ versus an initial background on a Student criterion.

** $p < 0.05$ versus the exposure time on a Student criterion.

*** $p < 0.05$ at comparison to background values of neuron pulsations with inhibition character of responses.

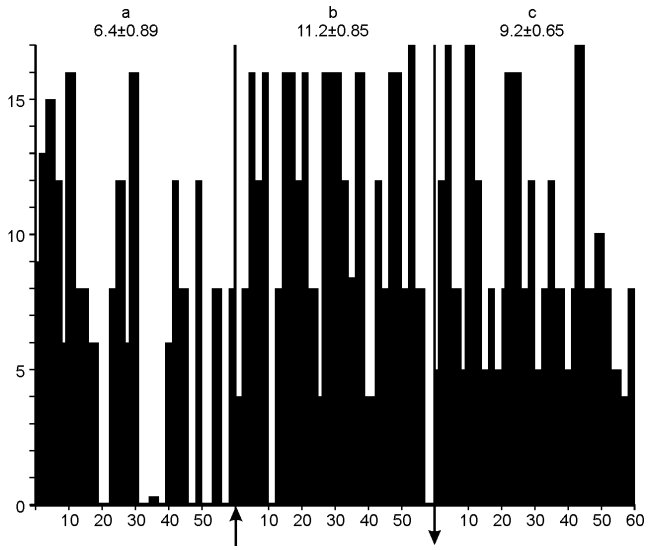

Figure 1. A histogram of allocation of frequency of neuron pulsation excitanted in reply to an one-minute MEMF irradiation; a — a background, b — the time of an irradiation, c — after an irradiation. On abscissa axis — time, s; on an axis of ordinates — pulsation frequency, s^{-1} (Hz).

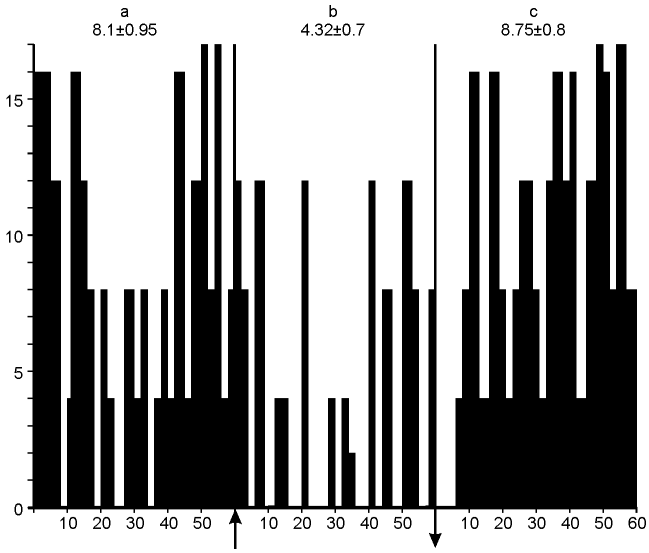

Figure 2. A histogram of allocation of frequency of neuron pulsation inhibited in reply to an one-minute MEMF irradiation; a — a background, b — the time of an irradiation, c — after an irradiation. On abscissa axis — time, s; on an axis of ordinates — pulsation frequency, s^{-1} (Hz).

At first minute after MEMF exposure in case of an activation of bioelectric activity, the tendency of homing to background magnitudes was marked, and, in case of inhibition, the bioelectric activity did not reliably differ from an initial background. It is necessary to mark, that the character of a modification of neuron pulsations due to the modulated EMF exposure was connected to an initial background.

Above-stated findings are reflected in histograms of the allocation of the frequency of neuron pulsation in MEMF experiments (Figures 1 and 2).

Conclusion. Thus, the presence of a response of extracellular bioelectric activity of neurons on low intensive MEMF is found. The character of a response was determined by a background, testifying correcting MEMF effect.

CHART NO. 20

Experiment 20

1. V.Yu. Ivanova, O.V. Martynova, C.V. Aleinik, and A.V. Limarenko. The influence of modulated Electromagnetic Microwaves and acoustic stimulation on the spectral characteristics of cat brain electroencephalogram. J. Biophysica 2000. Vol. 45, No. 5, pp. 935–940.
2. Martynova O.V., Motorkina A.A., Ivanova V.Yu., Kulikov G.A. Proceedings of the third international conference. Electromagnetic fields and human health. Fundamental and applied research, September, 17–24, 2002 Moscow-Saint-Petersburg, Russia

The purpose. Examination of an modulated EMF effect on bioelectric activity of a brain.

Experimental model. Awaken cats, EEG recording

Exposure conditions. 980 MHz EMF pulsewise modulated at 12 and 27 Hz, S=30–50 mW/cm^2 EMF 980 MHz. Time of single-pass exposure was 20 min. During repeated 1 min MEMF exposures, the augmentation of spectral rate of a spectrum of biological currents in the 12 – 18 Hz band. G4–37A generator, electromagnetic horn, S=30–50 μW/cm^2. Total time of exposure is 20 minutes. Animals were irradiated repeatedly.

Time (period) of examinations. During exposure and at once after an exposure.

Method of study. The tests were conducted 2–3 times per one week with an interval per 1–3 days. up to 15 tests were conducted in each animal with EMF stimulation and up to 10 tests were without exposure. EEG was recorded with the plate-like baked carbons posed on a shaved surface of a skin of the animal head. A fissile electrode was arranged in range of vertexum. Recorded electrical activity through the booster of biological potentials (pass-band of 1–200 Hz) was acquired to the computer with 500 Hz frequency digitizing. Magnitude of averaged spectral density (ASD) was calculated on 50 realizations with duration of 1000 ms each utilizing Hamming window. In each test, they have analyzed a spectral distribution of EEG in the beginning of test (up to a stimulation), through 1 min after the exposure to stimulants (in the first pause) and after the end of all exposures. In tests without exposure ("sham exposure"), EEG was recorded at the same time from the beginning of experiment, as in tests with the stimulation. Dynamics of spectral characteristics of EEG was estimated to determine modifications of an interrelation of ASD magnitudes for miscellaneous frequency bands and to calculate the magnitude of an compliance index (CI): CI=D1–D2/D1+D2, where D1 and D2 are ASD magnitudes in compared bands.

The reliability of a modification of CI values in case of various stimulants in comparison with initial background value and tests without exposure were estimated applying non-parametric Fisher criterion.

Basic results. A reliable modification of a spectrum of biological currents: the decrease of the averaged spectral power density (SPD) has prevailed in background bioelectric activity and SPD augmentation was in the band of 12–18 Hz ($p < 0,01$), which reliably exceeds spectral power of an initial background.

Conclusion. Modulated EMF at 980 MHz , S=30–50 μW/cm^2 can change a spectral distribution of EEG.

CHART NO. 21

Experiment 21

Yu. Grigoriev, S.N. Lukianova, V.P. Markov, V.V. Rynskov The total bioelectrical activity of various structures of brain in conditions of low — level microwave irradiation. Radiation biology. Radioecology. 1995, vol. 35, issue 1. pp. 57–65.

The purpose. Study of low intensive modulated EMF effect on integral bioelectric activity of various frames of a brain.

Experimental model. Rabbits. Bioelectric activity of a brain.

Exposure conditions. Four series of experiments were conducted:

1. Control - sham irradiation — K;
2. Series with an impulsive irradiation at frequency of 0.12 Hz (O_1);
3. Series with an impulsive irradiation at frequency of 1000 Hz (O_2);
4. Series with packed impulsive irradiation; a pulse-recurrence frequency — 1000 Hz, recurrence rate of packs — 0.12 Hz (O_3).

In all cases PFD was 300 μW/cm^2 in impulse. One rabbit have been exposed to only one regimen of an irradiation: single 30 min exposure. However, each animal in the casual order has participated in a control series with a sham irradiation. Detailed quantitative performance of experiments and the parameters of an irradiation are submitted in Tables 1 and 2.

Table 1. Quantitative performance of experiments

Series		No. of rabbits	No. of 30 min exposures
No.	Conditional name	In series	In series
1	K	30	-
2	O_1	10	10
3	O_2	10	10
4	O_3	10	10

Table 2. Parameters of MEMF irradiation

No.	Conditional name	Irradiation parameters							Exposure time, min.
		Carrier frequency, Hz	Mode	Characteristics of;					
				pulses			packs		
				S, μW/cm^2	Duration, ms	Frequency, Hz	Duration, ms	Frequency, Hz	
2	O_1	1.5	Pulsed	300	16	0.12			30
3	O_2	1.5	Pulsed	300	0.4	1000			30
4	O_3	1.5	Packed pulsed	300	0.4	1000	16	0.12	30

Method of study. The electrodes were implanted to each rabbit on the conventional method, according to coordinates submitted in the stereotactical atlas of E. Fifkova and J. Marshal. The ranges of a cortex and following subcortical formations were examined including: the basal amigdalum core (AB: AP-1, SD-5, V-16), hyppocampus (HiP: AP-5, SD-5, V-5), septum (NSL: AP-4, SD-1, V-3), front department of hypothalamus (AHA: Ap-2.5, SD-1.5, V-12), head of the tail kernel (PS: AP-4.2, SD-2.8, V-8.6). In a cortex and hyppocampus, most electrodes were implanted at the left and on the right, and on the right in remaining parts.

As electrodes and abducent wires have utilized chlorine vinyl pipette and tubes filled with normal saline solution on the basis of agar in a consistence of a gel. They had resistance of 1 MOhm and met the requirements showed to conductors of biological potentials. Abduction of biological currents was realized by a monopolar method with inert electrodes on nasal bones. In the time of experiment, the rabbit was softly fixed for paws on the wood machine tool. The experiments were conducted in conditions of electrophysiological experiments meeting the MEMF test requirements.

Basic results. As a result of the conducted experiment, the reliable modifications of bioelectric activity of frames of a brain were obtained at all three modes of exposure, approximately equally. It has not allowed the authors to share conditions of exposure on their efficiency. In all three series, modifications were determined by an initial background, however they did not fall outside the limits of normal functioning and concerned, mainly, θ ranges of hyppocampus. The reliable difference between control and irradiation was marked only in biological currents of hippocampuses.

Conclusion. Thus, the conducted experiments have shown, that low intensive short-term MEMF exposure in three used regimens can reliably vary bioelectric activity of the rabbit brain.

CHART NO. 22

Experiment 22

Kashtanov S.I., Sudakov S.K. Domination of the midbrain reticular formation in the mediation of UHF field preventive effects on excitation reactions of the hypothalamic emotiogenic centers. Bulletin of experimental biology and medicine. 1981. No. 11. pp. 523–526.

The purpose. To examine the modulated EMF effect on emotional centers of a hypothalamus.

Experimental model. The rabbit with implanted electrodes in ventricular core of a hypothalamus.

Exposure conditions. Animals were irradiated to EMF at 40 MHz with modulation of 7 Hz, field strength from 30 up to 300 V/m. SHF-66 generator, metal plates of 20x18 cm^2, where the fixed animal was placed. The duration of exposure was from 10 mines up to 2.5 hours.

Method of study. At the first stage, the effect of the suppression of somatic vegetative responses was found to be induced by the irritation of the ventral kernels of a hypothalamus. On the second investigation phase, they have conducted a serial coagulation of separate frames of the brain and found, that the reticular formation participates in realization of vegetative reciprocal responses at MEMF exposure. The test was elaborated in 42 rabbits.

Basic results. Under an modulated EMF, there was a suppression of the vegetative response. The effect depends on duration of exposure and EMF power. The role of a reticular formation in EMF effect realization in vegetative effects was found. At 14 of 42 rabbits the hypertensive responses were quenched.

Conclusion. Data are obtained about a role of separate frames of a brain in realization of bioeffect at exposure to modulated EMF.

CHART NO. 23

Experiment 23

Gorbunova A. V., Petrova N. V., Portugalov V. V., Sudakov S. K. The Acute Experimental Emotional Stress In Rabbits Under Conditions Of The Modulated Electro-Magnetic Field. Newsletter of the USSR Academy of Sciences (biological series). 1981. No. 5. pp. 774–780.

The purpose. To examine responses in various departments of a nervous system at exposure to modulated EMF in conditions of an emotional stress (histochemical examinations).

Experimental model. The rabbits in a state of an emotional stress.

Exposure conditions. Animals were irradiated to EMF at 39 MHz, modulation of 7 Hz, depth of modulation of 80%, field strength of 30 V/m. A field was framed between two plates of the capacitor coherent with the SHF generator. Immobilized animals were disposed between plates, so that saggetal line of the body was placed horizontally and perpendicularly to lines of MEMF force. A radiation time was 3 hours.

Time (period) of examinations. At once after an irradiation.

Method of study. The tests were conducted on 86 rabbits. The emotional stress was invoked by an electrical current irritation in hypothalamus, skin of extremities and ears. In a nodulose ganglion of a vagus nerve, upper cervical, star-shaped ganglions, sympathetic clusters and clusters of a sympathetic line-up at a level 4–6 of thoracic segments they have determined a content of water-soluble proteins. A spectrum of lactate dehydrogenase (LDH) was examined in clusters of an independent nervous system and conductive system of heart. The obtained results were statistically treated by nonparametric van der Verden criterion and Student test of significance.

Basic results. MEMF has selectively labilized limbic frames of the brain and depressed the bottom-up effect of a reticular formation on a cortex of major hemispheres, rising fastness to an emotional stress and enlarging ability to adaptation.

Conclusion. The modulated EMF effect on emotional stress is shown.

CHART NO. 24

Experiment 24

1. Grigoriev You. G. Modulation significance for EMF biological effects. Radiation biology. Radioecology. 1996, vol. 36, issue 15. pp. 659–670.

2. Grigoriev Yu.G., Stepanov V.S. Microwave effect on the embryo brain: dose dependence and the effect of modulation. BEMS Annual Meeting. 1998.

The purpose. To examine the modulated EMF effect on function of a brain (in experiment).

Experimental model: an organism of chicken embryo and chickens; imprinting model

Exposure conditions. 129 embryos of chickens were irradiated at day 16 of an incubation to EMF at 9.3 GHz; 5 min exposure, S=40 $\mu W/cm^2$ with a quantization of 10 and 40 Hz, meander, pulse duration of 2.5 ms. Besides, there were series with a continuous irradiation (CW) and "sham" exposure. The third series was control with the "sham" irradiation. Experiments included several repetitions. EMF exposure was realized in non-echo chamber.

Time (period) of examinations. Chicken imprinting was conducted in day 1 after delivery (in day 5 after EMF embryo exposure).

Method of study. Chicken imprinting was conducted in day 1 after delivery and light stimulation was applied with the blinking rate of 10 Hz and 2 Hz. Differentiation stimulation was of 8 Hz difference. The presence of formed imprinting was determined in day 2 after delivery by the following criteria: a stage of latency of the response on imprint stimulant; a dwell-time of a chicken near imprint-stimulant; number of the approaches and contacts to imprint stimulant. The statistical handling was conducted on ± Student test, Fisher test and other methods.

Basic results. The imprinting suppression (up to 50%) was found in newborn chicken only for series of EMF exposure at 10 and 40 Hz (Table 1.). In case of CW exposure (S=40 $\mu W/cm^2$) and in control group, the imprinting disturbance was not found.

Table 1. Imprinting in chickens after an EMF irradiation of embryos for continuous and modulated regimens

Series No.	Series name	PFD, $\mu W/cm^2$	Exposure time	No. of embryos	No. of chickens with imprinting
1	Control – sham exposure	-	-	83	81 (97%)
2	Continuous exposure	40	5	27	23 (89%)
3	10 Hz or 40 Hz modulated exposure	40	5	19	9 (50%)

Conclusion. The modulated mode of EMF exposure of low intensity invokes the greater effect in function of a brain (in experiment).

CHART NO. 25

Experiment 25

1. Grigoriev Yu.G. the modulation significance for EMF biological effects. Radiation biology. Radioecology. 1996, vol. 36, issue 5. pp. 659–670.
2. Grigoriev Yu.G. Stepanov V. Microwave effect on the embryo brain: dose dependence and the effect of modulation. BEMS Annual Meeting. 1998.

The purpose. To examine a possibility of electromagnetic signal bracing in the brain (regimen of modulation).

Experimental model. An organism of chicken embryo and chickens; imprinting model.

Exposure conditions. An irradiation of chickens was realized at incubation day 16 in non-echo chamber: EMF at 9.3 GHz with the quantization of 1, 2, 3, 7, 9 or 10 Hz, S=0.04 mW/cm^2, time of each irradiation was 5 minutes.

Method of study. The possibility for the development of temporal communications at 15 diurnal chicken embryos was earlier shown through an electrocurrent and sound. Taking into account these results, the authors have assumed, that the electromagnetic modulation waveform can be fixed by a brain and gain value of an imprint signal. The plan of experiment was as follows: incubation day 16 embryos were MEMF irradiated with modulation of 1, 2, 3, 7, 9 and 10 Hz. After birth of chickens, the sensing imprinting period (24 hours after birth) was passed and in this period any choronomic irritator was not shown to a chicken. In 48 hours after birth, strobe lights with the same frequency were shown to a chicken as imprint stimulant, from which the embryo was subjected to an electromagnetic irradiation for day 16 of an incubation. The difference between alleged light stimulant and differentiation stimulant was equal to 8 Hz. The experiments were conducted on 127 embryos (chickens).

Basic results. A possibility of imprinting exhibiting on imprint stimulant with the light frequency similar to EMF modulation, which has exposed embryos at day 16 of an incubation, and at light blinking frequency of 1, 2, 3, 7, 9 or 10 Hz is submitted in figure 25.1. The analysis of the obtained materials has allowed the author to make a deduction, that the obtained data testify that the embryo brain at day 16 of an incubation can fix electromagnetic stimulant with modulation of 9 or 10 Hz and store this information during particular time after birth.

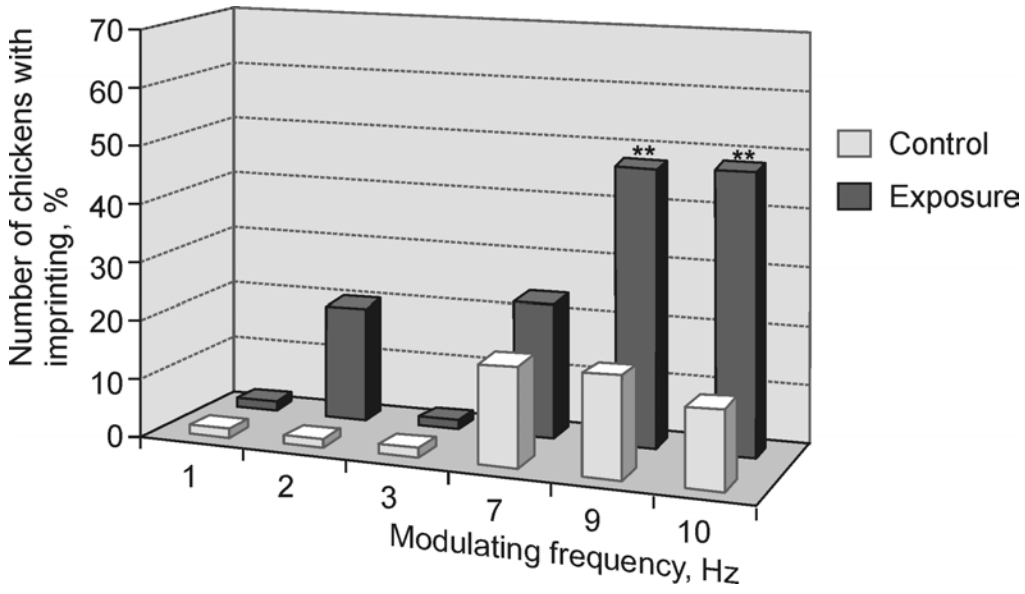

Figure 1 Number of chickens, which brain has fixed an electromagnetic modulation waveform (imprinting is established)

Conclusion. Thus, the obtained data assume, that the regimen of EMF modulation can be fixed by a brain.

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CHART NO. 26

Experiment 26

1. Bolshakov M, Knyazeva L, Lindt T. Et al. Effects of Low-Frequency Pulsed-Modulated 460 MHz Electromagnetic Radiation on Drosophila Embryos. J. Radiation biology and ecology (Russian academy of sciences) 2001. Vol. 41. No.4, pp. 399–402.
2. Bolshakov M.A. Physiological effect mechanisms of radiofrequency electromagnetic radiation in biological objects of different organizational levels. Thesis, Tomsk, 2002.

The purpose. To examine the effect of pulsewise - modulated 2.5–40 Hz EMF at 460 MHz on embryos of the fruit flies.

Examined object. Embryos of Drosophila melanogaster of Cantoz S line. Age of 15 hours 10 min.

Exposure conditions. Embryos were irradiated to MEMF at 460 MHz, quantization 2.5, 6, 10, 16, 22 and 40 Hz (porosity of 25), average SAR of 0.12 W/kg, absorbed power per impulse of 3 W/kg. The SAR impulsive magnitude was identical at porosity from 12.5 up to 6 at frequency of modulation of 16 Hz. “Romashka” generator was modified for pulsed modulated mode of operation. Embryos were irradiated at temperature +24.5°C. Control groups: a “sham” irradiation and physical control. Time of exposure is 5 minutes.

Method of study. Time of embryo development (age) was counted from a beginning of egging on a medium within 10 minutes accuracy. In experiment they have utilized embryos in the age of 15 hours and 10 minutes. The tests were tried in 30 thousand embryos and the sample size was not less than 1000 on each experimental point.

The results of experiments were estimated on an percentage of the interrupted development (PID) calculated as percent of imagoes from conforming egg number, which amount was 100%. PID was taken into account in three experimental groups: (1) test group, in which embryos were subjected to MEMF irradiation; (2) “the sham irradiated group”, in which embryos were subjected the same experimental procedures, as irradiated embryos, but without EMF exposure (delivery to a place of an irradiation, location on 5 min in temperature controlled conditions, the EMF generator was switched off, homing in a thermostat for an incubation); (3) control embryos group, which all time were in temperature-controlled conditions (24.5°C), on which they have estimated a streaming functional state of a laboratory population of flies. MEMF effect was calculated on a difference of SAR magnitudes in test groups and “sham irradiated” embryos. The statistical significance of effect was estimated on a difference of small lobes on the basis of Fisher ϕ-conversion.

Basic results. The results of the experiment has shown, that the MEMF irradiation has rendered effect on embryos of the fruit fly in the age of 15 hours 10 mines. This effect depends on frequency of modulation (Fig. 1 and 2). It is important to mark, that difference in modulated (0.12 W/kg) and not modulated (6 W/kg) SAR has resulted to almost 50 times difference.

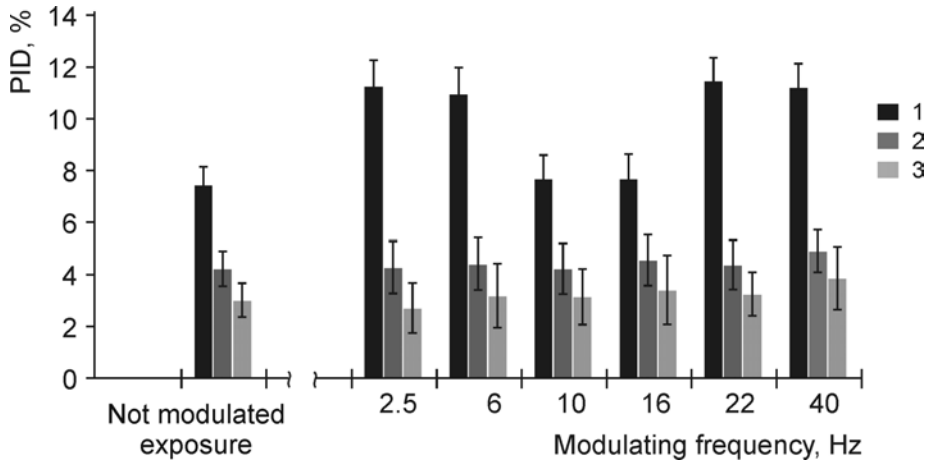

Figure 1. Effect of MEMF exposure at 460 MHz on SAR of the fruit flies (the average values and errors, average with level of significance < 0.05) is submitted. For comparison the results for 5 minute not modulated exposure with SAR of 6 W/kg are given. 1 — SAR after an MEMF irradiation; 2 — SAR for "sham irradiated" flies; 3 — SAR in laboratory control.

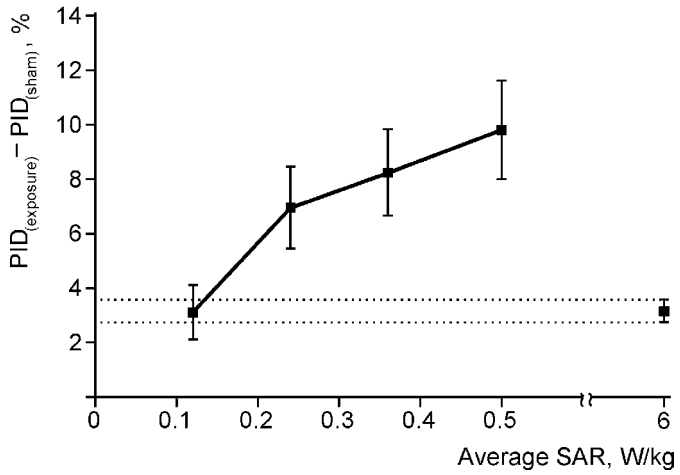

Figure 2. The dependence of MEMF irradiation effect in embryos of the fruit flies at frequency of 16 Hz (average SAR varied in dependence on porosity — from 25 up to 6). For comparison the average value of effect is submitted for not modulated EMF with SAR of 6 W/kg and error of mean (dashed lines).

Conclusion. Pulsewise - modulated EMF are more effective in comparison with not modulated ones on the development of the fruit fly embryos. This bioeffect is frequency dependent partially.

Note. The utilized procedure is adequate and is sensitive for a solution of the posed problem. It was earlier shown, that EMF at 460 MHz renders a teratogenic effect on the fruit flies. The effect was shown as the damage of wings, legs and other parts of a skew field imago, abortion and accordingly to augmentation of percent of the interrupted development (PID). This effect depends on the age of animal with maximal PID in the age of 15 hours 10 min.

CHART NO. 27

Experiment 27

Bolshakov M.A., Knyazeva I.R., Evdokimov E.V. Effect of 460 MHz Microwave Radiation on Drosophila Embryos under Increased Temperature. J. Radiation biology and ecology (Russian academy of sciences) 2002. Vol. 42. No.1, pp. 191–193.

The purpose. An assessment of modulated EMF effect on the background of the changed parameters of an environment (temperature of air) on embryos of the fruit flies.

Experimental model. Embryos of the fruit flies.

Exposure conditions. Embryos were subjected to not modulated EMF with SAR of 6 W/kg (in impulse) and 0.12 W/kg (in average) and modulated electromagnetic exposure at 6, 10, 16, 22 Hz, SAR of 3 W/kg. In all series, including control, the ambient temperature was 40°C.

Method of study. The tests were tried in 15 thousand embryos of Drosophila melanogaster of Canton S strain, 15 h and 10 min age. For all modes of exposure the sample was not less than 1000 embryos for each of groups. The results of exposure were estimated on percentage of the interrupted development (PID). PID magnitude was calculated as percent of imago from conforming total egg pool, which total amount was 100%. PID was estimated in four various groups: (1) continuous irradiation of embryos, (2) MEMF irradiated embryos; (3) “sham” irradiated embryos, which were subjected to elevated temperature only without EMF and (4) control embryos, which were constantly contained in temperature-controlled conditions at fixed temperature of 24.5°C. The effect of exposure was determined as a difference between PID of groups subjected to continuous EMF, modulated EMF and “sham” irradiated groups. The statistical significance of effect was estimated on a difference of small lobes on the basis of Fisher ϕ-conversion for sample of 3000 insects at least.

Basic results. The conducted experiments have shown, that the results of EMF exposure on SAR of the fruit flies on a background of elevated temperature can differ from EMF effects at standard temperature.

Combined exposure to not modulated EMF with SAR of 6 W/kg and heat up to 40°C has resulted to inappreciable PID augmentation; the effect has appeared statistically not significant in comparison with effect at standard temperature of 24.5°C: 3.8±1.1% in conditions of heat against 3.2±0,7% at standard temperature. The effect of elevated temperature exposure only (40°C) has made 1.3±0,7%.

The findings of investigation of MEMF effect on a background of heat is submitted in figure 1. As it is visible from this drawing, the effect essentially depends on frequency of a quantization. MEMF with frequencies of modulation of 6 and 22 Hz on a background of heat was specific to some enlarged PID, in comparison with PID at standard temperature. Vice-versa, at frequencies of modulation of 10 and 16 Hz, the exposure on a background of elevated temperature has initiated smaller PID ($p < 0,05$), rather than at standard temperature (drawing 27.1.). The PID magnitude under condition of elevated temperature was at PID level for “sham” irradiated embryos.

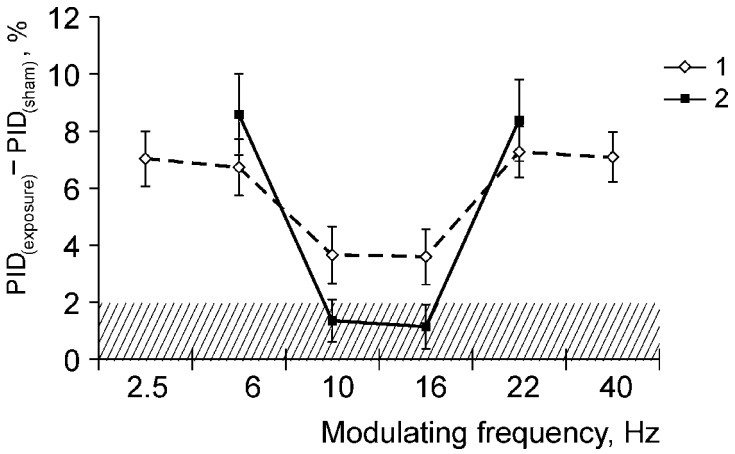

Figure 1. Modifications of percent of the interrupted development in the fruit flies after 5 minute MEMF exposure of embryos of age of 15 h 10 mines at standard temperature of 25°C (1) and on a background of elevated temperature of 40°C (2). The shaded space — 95% confidence interval for average PID values of “sham” irradiated embryos.

Conclusion. Thus, the effects of heat and exposure of a EMF quantization of 6 and 22 Hz are additive. At frequencies of 10 and 16 Hz the bioeffect was decreased.

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CHART NO. 28

Experiment 28

M.S. Burenkov, L.A. Burenkova, Yu.S. Korotkov, V.Yu. Pichughin, S.P. Chunikin, V.V. Engovatov. Microwave 1–4 GHz can enhance the development of Tickhyalomma Asiaticum (Acarina Ixodidae). J. Radiation biology and ecology (Russian academy of sciences) 1996. Vol. 36. No. 5. pp. 681–685.

The purpose. Effect of modulated low intensive EMF on development and vitality of Acarina Ixodidae.

Experimental model. Ovums, hungry larvas, satiated larvas and hungry nymphs of the first laboratory generation.

Exposure conditions. The MEMF irradiations was conducted through days 5 — 10 after the egg pool forming or after a saturation of insects and passage them in the following phase of development. They have utilized the following modes of exposure: R1 (K) — "sham" irradiation; R2 — broadband radiation in a band of 1–4 GHz, quantization of 7 Hz, pulse duration of 20 ms, average S=20 μW/cm^2; R3 — carrying frequency of 3 GHz, packed quantization, frequency of impulses of 1 kHz, frequency of following of packs of 7 Hz, duration of a pack of impulses of 20 ms, average S=10 μW/cm2; R4 — same, as R3, but at average S=20 μW/cm2; R5 — broadband radiation in a band of 1–4 GHz, quantization of 2 Hz, pulse duration of 20 ms, average S=30 μW/cm2; R6 — carrying frequency of 1 GHz, quantization of 2 Hz, pulse duration of 20 ms, average S=30 μW/cm^2.

Time (period) of examinations. At once after an irradiation and during the development cycle.

Method of study. Insects were kept at ambient temperature (22–23°C) in the humidified scoops. Each test has consisted of 2–4 repeated variants, and the separate variant has included either one complete egg pool or 10 larvas and nymphs.

Basic results.

1. *MEMF ootids irradiation effect in hungry larvas delivery*. Total number of delivered larvas was identical in all series. The differences were found in course and terms of their delivery, and also in dynamics of the subsequent activity. The delivery delay was observed in all experiment variants. In control, 50% of larvas were delivered at day 12 versus days 15–32 for irradiated ones (table 1). The least delay in development was marked in a regimen R2. The variance between experiment and control in this case has made 3.4 days ($p < 0.09$). The delivery of 50% of larvas in regimens R3 and R4 was at days 25.3 and 32.2, accordingly. The differences from control were statistically reliable ($p < 0.01$); the difference between control and experiment has achieved accordingly 13.4 and 20.3 days. The similar tendencies were noted in dynamics of activity of delivered larvas. Insects delivered from intact and irradiated parents in regimen R2 became fissile at the first day after delivery, while in regimens R3 and R4 the activation was delayed and the delay halftime, T_{50} was different ($p < 0.0001$) for intact and irradiated egg pools (regimens R3 and R4), so the essential differences were for variant R2 versus variants R3 and R4.

2. *MEMF effect on a survival rate of hungry larvas and nymphs*. The MEMF irradiation of hungry larvas and nymphs was conducted on days 7–10 after delivery. The duration of the surviving of larvas and nymphs in all variants of experiment was lower, than that in control. So, the parameter T_{50} for larvas and nymphs in control has made accordingly 13.8 ± 1.9 and 36.9±2.0 (table 1.), in experiment (regimens R4 and R5) it was less (9.5–11.9 and 27.1–28.2) at days 2–4 and 9–10.
3. *MEMF effect on development of satiated larvas.* The experiment was conducted on insects of spring and autumn generations. An irradiation of satiated larvas was conducted at day 10 after insect saturation. They have utilized regimens R3, R4, R5 and R6. First delivered nymphs have appeared in identical terms after an irradiation, both in spring, and in autumn generation: on days 16–18 after the saturation of larvas; the experimental and control variants did not differ. On other parameters the essential apostatizes were observed. The molting of both irradiated, and intact insects of spring generation flowed past in considerably more short terms, than for autumn one. The period of molting in the first series has occupied from 2 to about 5 days, whereas it was 8–12 days in second series. The greatest apostatizes are marked in an amount of delivered nymphs. The satiated larvas of spring generation have appeared less sensing to all EMF regimens. In all variants, 100% of metamorphosises of larvas in nymphs were observed. The subsequent survival rate of delivered hungry insects did not differ from control values and was close to 100% within 16^{th} –25^{th} subsequent day.

Table 1. MEMF Effect on delivery, activation and duration of a surviving of hungry nymphs of various phases of Hyalomma asiaticum development

Exposure regimen	No. of insects	No. of groups	Regression factor	$T_{50,}$ days
Delivery duration of larvas				
R1(K)	3000	2	0.24±0.002	11.9±1.0
R2	3000	2	0.25±0.01	15.3±0.1
R3	3000	2	0.08±0.01	25.3±0.1
R4	3000	2	0.07±0.01	32.2±0.7
Activation duration of larvas				
R1(K)	3000	2	-	1.0
R2	3000	2	-	1.0
R3	3000	2	0.08±0.01	17.03±0.4
R4	3000	2	0.07±0.01	23.9±0.5
Survival duration of hungry larvas				
R1(K)	20	2	0.14±0.01	13.8±1.9
R4	20	2	0.14±0.01	11.9±1.0
R5	20	2	0.14±0.01	9.5±4.0
Survival duration of hungry nymphs				
R1(K)	150	15	0.05±0.01	36.9±2.0
R4	150	15	0.05±0.01	27.1±2.7
R5	250	20	0.05±0.01	28.2±20

Conclusion. Thus, MEMF has practically invoked noticeable physiological modifications in Hyalomma asiaticum organism for all examined regimens. These modifications were expressed in the delivery delay of larvas from irradiated egg pools, in the decrease of the activity and survival rate of delivered insects. The similar findings were observed in the delivery course of hungry nymphs from the irradiated larvas. The augmentation of the average PFD from 10 up to 20 $\mu W/cm^2$ has enhanced the observable effect. So, the delivery

duration and activation of 50% of larvas was enlarged for 30–35%, and the survival rate of hungry nymphs of autumn generation, vice-versa, was sunk twice.

The experimental application of the broadband radiations in a band of 1–4 GHz (R2 and R5) with frequencies of modulation of 7 and 2 Hz has invoked generally similar, but essentially less expressed effects, than on carrier frequencies of 3 and 1 GHz with the same modulation. The most expressed biological effect of radiation was expressed in depressing of development and augmentation of the insect mortality, on miscellaneous phases of its life cycle, which was detected for exposure at 3 GHz with frequency of modulation of 7 Hz. The especially acute violations in weep of physiological processes have taken place during embryonic development and metamorphosis.

State Research Center - Institute of Biophysics
The Ministry of Health of Russian Federation

BIOLOGICAL EFFECTS OF THE MODULATED ELECTROMAGNETIC FIELDS IN ACUTE EXPERIMENTS

REPORT

Is prepared within the framework of performance of Task No.2 of ISTC Project No. 2362p

"Original materials for the standards of electromagnetic fields"

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Moscow, 2003

THE ABSTRACT

The Report contains of 96 pages of the text (with Annex), 20 drawings and 19 tables. The Annex contains 28 charts with exposition of experiments.

Modulation of an electromagnetic field, power flux density, field strength, biological effect, maximum permissible level.

In many publications, as abroad, and in Russia the necessity of the determination of a role of modulation of electromagnetic fields (EMF) in development of unfavorable biological responses is underlined. In the report the analysis of 28 experiments carried out in Russia (USSR), with usage of the modulated electromagnetic field (MEMF) is submitted.

The experiments were conducted in Institute of Biophysics of a Cell of RAS, Institute of Biophysics of ministry of Health of Russian Federation, Institute of physiology of RAMS, Institute of a medical radiology of RAMS, St.-Petersburg state university and Tomsk state university.

In the majority of the analysed works the dependence of development of biological effect on an aspect of modulation as in examinations in vitro, in situ and in vivo was shown. At EMF exposure on biosystems with less or more composite regimens of modulation it shows a possibility of development of bioeffects both physiological, and unfavorable. The dependence of development of a reciprocal biological response on the intensity and directedness from a concrete regimen of EMF modulation is shown. As a rule, modulated EMF invoke more expressed bioeffects, than continuous regimen of modulation.

At an assessment of MEMF danger, the magnitude of an absorbed energy can always not determine expected biological effect. In this case, the risk prognosis at MEMF exposure remains rather composite. This circumstance brings in major indeterminacy by development for the standards of safety. As a result of the conducted experiments, the effect of an initial state of biosystem on expected effect is detected at exposure of the modulated electromagnetic field. The role of modulation gains the major significance at low intensity of an electromagnetic field (below thermal levels).

Detailed performance of conditions of an irradiation of used procedures of examination and statistical handling, and also obtained outcomes are submitted in partition of Annex(chart 1–28).

TABLE OF CONTENTS

ABBREVIATIONS

AM	—	Actomisine agent
AP	—	Alkaline phosphatase
ASAT	—	Asparthate amine transferase
BIA	—	Background impulsive activity
CCF	—	Cross correlation functions
CNS	—	Central nervous system
CW	—	Continues waves
DNA	—	Desoxynucleic acid
EMF	—	Electromagnetic field
GAOA	—	Gamma-aminobutyric acid
LDH	—	Lactate dehydrogenase
MAO	—	Monoamine oxidize
MEMF	—	Modulated EMF
NR	—	Neutral red
PFD	—	Power flux dencity
PID	—	Percentage of the interrupted development
RF	—	Radio frequency
SAR	—	Specific absorbtion rate

INTRODUCTION

For last two decades series of outcomes of the scientific examinations indicating a singularity developments of bioeffects at exposure of modulated EMF (MEMF) in comparison with a continuous regimen (CW) were published in Russia and abroad.

The potential value of this phenomenon, in our judgement, yet is not realized by scientific community by way of an assessment of electromagnetic danger for the population. The approaches of the count of singularities of an MEMF effect till now are not defined by development of the conforming hygienic standards. It is important, that at some situations the biological effect will be determined not by an absorbed energy, but by the kind and character of EMF modulation.

Unfortunately, the results of the examinations conducted in Russia on a biological effect of modulated EMF till now are not known in the West and in the USA. The exclusion is only review by Pakhomov and Merphy, which has yielded the first information on outcomes of these examinations in English[*].

In the report, the analysis of results of 28 experiments is submitted, in which they have utillized modulated EMF of radio-frequencies of low intensity. The examinations were conducted as on models in vitro and in situ, and also on experimental animal in conditions of acute low intensive exposure to RF MEMF.

The experiments were conducted in Institute of biophysics of Cell of RAS, Institute of Biophysics of the ministry of Health of Russian Federation, Institute of physiology of RAMS Institute of a medical radiology of RAMS, St.-Petersburg state University, Tomsk state University. At preparing the report, the publication of A. Pakhomov and Merphy is also utilised as an information stuff.

The results of operational analysis can be conditionally divided into two groups. First group included results of experiments on establishing a role of EMF modulation in development of bioeffects, and also on establishing singularities of the modulated EMF exposure. In such case the comparative experiments with usage of the continuous and modulated magnetic fields were conducted. The results of the experiments only describing a biological effect of modulated EMF concern to the second group. In these experiences the comparison of the bioeffects called modulated and not modulated EMF was not conducted.

More detailed performance of conditions of an irradiation, used procedures of examinations, methods of statistical handling and obtained results are submitted in Annexseparate charts from 1 to 28.

The statistical handling of the obtained results was utilised in all works.

[*] A.G. Pakhomov, M.B. Murphy. Comprehensive review of the research on biological effects of pulsed radiofrequency radiation in Russia and the former Soviet Union. In: Advances in Electromagnetic Fields in Living System, V.3 (J. C. Lin, ed.), Kluwer Academic/Plenum Publishers, New York, 2000, 265–290.

EXAMINATIONS IN VITRO AND IN SITU

Series of examinations of enzymatic systems under an exposure to modulated EMF with establishing of the most effective frequencies of modulation were carried out. The dependence of activity of mono amine oxidize, asparthate amine transferase, ATPase, actomisin and alkaline phosphatase from frequency of EMF RF modulation was probed at short-term EMF exposure of low intensity (Chart No. 1–6 of Annex). The exposure in each experiment was equal for all probed frequencies of modulation owing to establishing equality of power performances. The biochemical examinations of activity of enzymes were conducted with usage of reference complex panel reagents, substratums and other bonds of firms “Sigma” (USA) and “Diakom” (Russia).

It was shown, that low intensive MEMF effect on enzymatic activity of monoamine oxidize (MAO-A) participating in the first stage catalyzing desamininig of monoamines, depends on a frequency modulation (Chart No. 1 of Annex). Rats were subjected to EMF at 915 MHz, with frequencies of modulation of 2, 4, 6, 8,12,16 and 20 Hz, S=10 $\mu W/cm^2$, radiation time — 10 minutes.

It was fixed, that modifications of MAO-A activity in hippocampus and hypothalamus of a rat brain depends on frequency of modulation (Table 1.1).

Table 1.1.

Modification of MAO-A activity in a hypothalamus and hippocampus of rat brain after the exposure to pulsewise-modulated electromagnetic radiations
(In relative unities)

Pulse rate, Hz	Number of rats	Number of tests	Cerebral structures	
			hypothalamus	hippocampus
Not exposed	5	20	0.65±0.33	0.59±0.02
2	3	12	0.53±0.02*	0.65±0.01*
4	4	16	0.93±0.13**	1.03±0.14**
6	3	12	1.04±0.13**	0.61±0.04
8	2	8	0.51±0.04*	0.74±0.06*
12	3	12	0.97±0.07**	0.85±0.08*
16	4	16	0.56±0.02*	0.90±0.11**
20	4	16	0.49±0.01**	0.56±0.02

* differences given from control on a t-Student criterion are reliable, $p<0.05$.

** same, $p<0.01$.

The greatest labilizing effect on MAO-A activity hypothalamus rendered MEMF with frequencies of modulation of 4, 6 and 12 Hz. In control the activity of an enzyme compounded 0.65±0.03 relative unities (r.u)., at experimental animal 1.04±0.13 ($p < 0.01$) r.u., accordingly. The exposure with frequency of 16 and 20 Hz was escorted by dropping of activity MAO-A up to 0.56±0.02 ($p < 0.05$) and 0.49±0.01 ($p < 0.01$) r.u., accordingly (Table). Droppings of MAO-A activity in hippocampus was not observed at EMF exposure in one of probed frequencies. Thus, the rising of MAO-A activity in hypothalamus of a rat brain was observed at frequencies of modulation of 4, 6 and 12 Hz, accordingly up to 143 ($p < 0.01$), 160 ($p < 0.01$), and 149 ($p < 0.01$)% from control values conditionally accepted for 100%. At frequencies of EMF modulation of 2, 8, 16 and 20 Hz dropping MAO-A activity of down to 82 ($p < 0.05$), 78 ($p < 0.05$), 86 ($p < 0.05$) and 74 ($p < 0.01$)% from a master level is marked. The effect of superweak pulsewise - modulated EMF on MAO-A activity in the hippocampus of the rat brain was mainly labilizing.

The maximal rising of activity of an enzyme (up to 174% in comparison with control) is registered at frequency of modulation of 4 Hz.

Thus, modulated EMF of small intensity renders effect on an enzymatic system of a deamination of monoamines. Thus the expressiveness of bioeffect depend on a kind of modulation.

The MEMF effect on activity of asparthate amine transferase (ASAT) of serum of a donor blood of the human (Chart No. 2 of Annex) was probed. The assays of serum of a blood were irradiated to EMF at 2375 MHz, range of modulation of 50–390 Hz, S=2 and 8 $\mu W/cm^2$, radiation time 5 mines. The modification of ASAT activity depends on a kind of modulation and from intensity (Table 2.1).

Table 2.1.

Values of a relative modification of ASAT activity at miscellaneous frequencies of EMF modulation and miscellaneous intensity of exposure,% to control.

Modulation frequency, Hz	PFD, $\mu W/cm^2$	
	2	8
	(M±m)	(M±m)
50	146.6±6.7	175.3±5.3
70	286.6±6.4	154.0±14.0
90	162.6±3.8	184.0±4.0
110	155.6±5.7	198.0±3.6
130	235.6±3.5	76.0±6.2
150	125.3±3.7	325.0±5.7
170	247.3±8.3	371.1±5.5
190	345.6±3.4	156.4±5.4
210	133.7±3.5	503.7±4.9
230	292.8±7.0	254.6±6.2
250	243.3±6.2	127.3±3.4
270	187.7±5.0	100.6±7.5
290	158.3±2.2	162.7±4.9
310	129.7±4.7	254.3±5.6
330	217.3±8.5	211.0±7.2
350	114.7±3.5	77.7±3.5
370	479.4±8.5	139.6±1.6
390	400.4±8.4	592.3±4.6

Despite of small difference in an power flux density the effect for PFD of 2 $\mu W/cm^2$ was more effective, than with PFD of 8 $\mu W/cm^2$. At more low intensity, the exposure was for more frequencies of modulation elevating the activity of an enzyme for more than 200% and not of any case of the decrease of efficiency was lower than a master level. ASAT has shown very high sensitivity to EMF and enlarged activity at some frequencies of modulation for almost in 4–6 times. Last singularity of an enzyme is connected, in our judgement, to extreme ASAT importance for delivering asparthate in cytozole and in mitochondrions for asparthate malate shunt, which is the basic transmitting agent of reduction equivalents from cytozole in a mitochondrion necessary for exercise of synthesis of macroergetic moleculas and expedited regeneration of neuro energetics of a brain at stressful and extreme exposures. Without this mechanism, all spe-

cific CNS functions can not be sustained, as the brain has no some considerable power reserves, and they at stressful situations can be exhausted within 3–6 minutes.

It is necessary specially to mark, that the directedness and expressiveness of effect was saved in repeated doubling experiments in simulated condition of exposure, but in various spans.

Probed effect of EMF modulation from 30 up to 310 Hz on a directedness and expressiveness of a response of an alkaline phosphatase (AP) of serum of a blood of the Guinea pigs at once after short-term exposure and follow-up through 20 and 30 minutes at various intensities, S=0.8; 8.0 and 40 μW/cm^2 was examined (Chart No. 3 of Annex). The dependence of character and expressiveness of a response from frequency of modulation was obtained. The possibility of considerable effect of modulation on activity of enzymes as in a leg of its rising, and smaller degree in a leg of dropping (Fig. 3.1 and 3.2, Table 3.1 and 3.2) is marked. It is important to mark, that dependence of development of bioeffects on an aspect of modulation is influenced by PFD (Table 3.1, 3.2). The efficiency of MEMF exposure with PFD of 0.8 μW/cm^2 was higher, than at 8 μW/cm^2. So, rising of activity of an enzyme for more than on 20% marked already at 7 frequencies of modulation (at 1-minute exposure), as against EMF exposure with PFD of 8 μW/cm^2, which invoked rising activity above 20% only on two frequencies, and it was much lower, than at 0.8 μW/cm^2. Major efficiency for 5–30 times for the exposure to ore weak radiation was marked at identical frequencies of modulation in these two animal groups. The similar results were at three minute MEMF exposure.

Table 3.1.

Relative modification of AP activity (% from control) in dependence from EMF intensities and time of exposure at miscellaneous frequencies of modulation
(First sample with AP activity decrease).

Modulation rate, Hz	PFD, μW/cm²	M±m (1 min)	M±m (3 min)
70	0.8	87.2±1.22	112.0±0.83
	8.0	13.3±0.76	15.3±0.31
	40.0	–33.1±0.67	–37.5±0.32
90	0.8	44.5±0.02	57.8±0.93
	8.0	3.4±0.61	33.8±1.82
	40.0	–26.8±0.29	–57.8±0.17
110	0.8	25.1±0.34	27.7±1.31
	8.0	2.45±0.22	2.6±0.03
	40.0	–25.4±0.35	–76.3±0.26
170	0.8	33.7±0.32	42.4±0.28
	8.0	0.83±0.12	4.6±0.02
	40.0	–29.4±0.08	–9.5±0.26
190	0.8	23.8±0.74	25.7±1.25
	8.0	–5.6±0.31	–8.3±0.08
	40.0	–8.3±0.03	–35.8±4.9
230	0.8	11.8±0.05	13.4±0.94
	8.0	2.4±0.09	4.3±0.03
	40.0	1.1±0.06	2.5±0.08
310	0.8	21.7±0.35	23.9±0.61
	8.0	2.2±0.04	3.1±0.13
	40.0	1.7±0.04	4.8±0.06

Table 3.2.

Relative modification of AP activity (% from control) in dependence from EMF intensities and time of exposure at miscellaneous frequencies of modulation (Second sample, with rising of AP activity).

Modulation rate, Hz	PFD, μW/cm²	M±m (1 min)	M±m (3 min)
30	0.8	–12.2±0.08	–5.9±0.05
	8.0	7.4±0.07	9.1±0.08
	40.0	14.4±0.62	26.2±0.07
150	0.8	–5.6±0.05	–6.4±0.04
	8.0	1.7±0.81	3.2±0.14
	40.0	14.4±0.58	27.2±0.45
250	0.8	–24.7±0.34	–17.5±0.12
	8.0	7.2±0.03	9.7±0.16
	40.0	63.1±0.64	79.1±0.15
270	0.8	6.3±0.03	12.1±0.22
	8.0	15.8±0.03	18.4±0.03
	40.0	28.6±0.64	39.5±0.01
290	0.8	15.4±0.02	–14.6±0.35
	8.0	20.3±0.06	27.1±0.99
	40.0	40.0±0.09	59.0±0.54

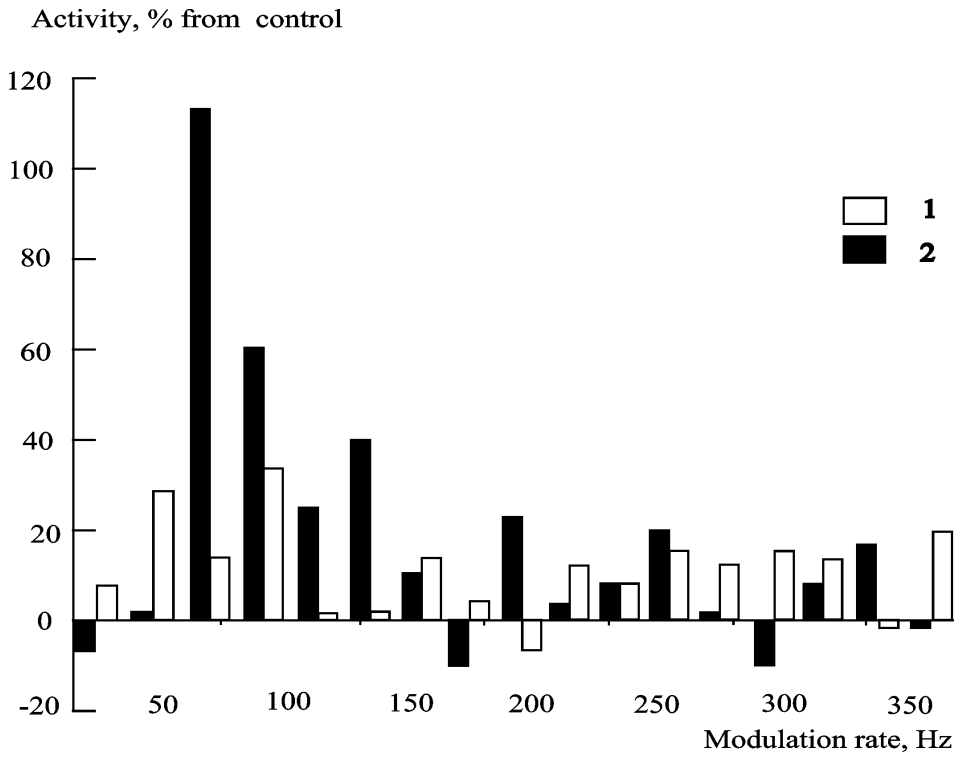

Figure 3.1. Dependence of activity of an alkaline phosphatase of serum of a blood of the Guinea pigs on frequency of modulation at 3 minute EMF exposure with PFD of 8 μW/cm^2 (1) and 0.8 μW/cm^2 (2).

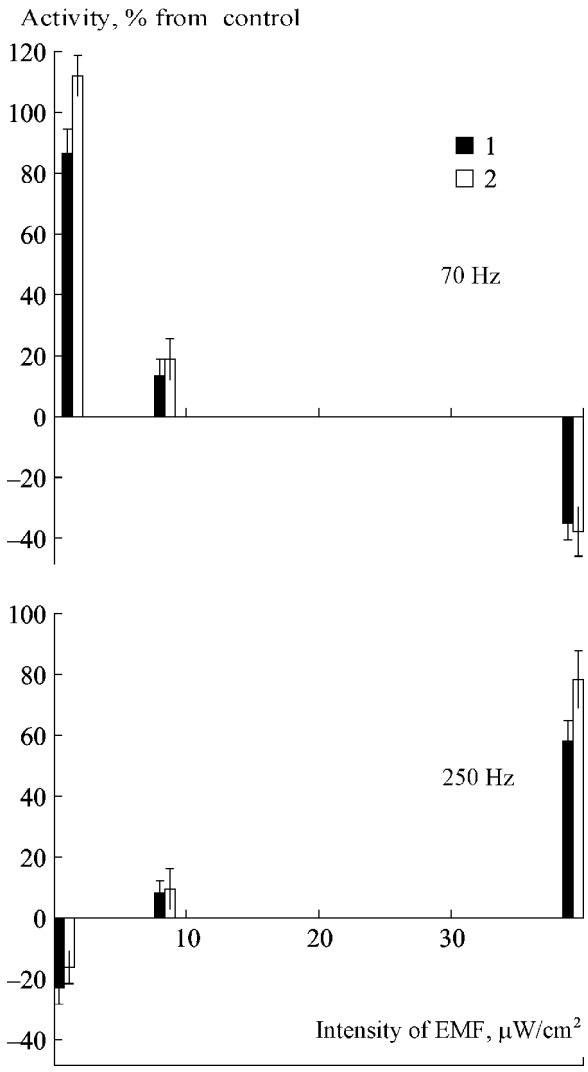

Figure 3.2. Two types of dependence of activity of an alkaline phosphatase of serum of a blood of the Guinea pigs from modifications of intensity of EMF exposure at frequencies 70 and 250 Hz with an exposition 1 min (1) and 3 min (2).

For study of cases of inverse directness of effect of the modulated microwaves at a modification of intensity of exposure, the available data have supplemented by experiments on alkaline phosphatase effect of microwaves with PFD 40 μW/cm^2 at conservation of other conditions. The common materials (Table 3.1 and 3.2) have shown, that among frequencies of modulation in examined band of 10–310 Hz, there are two frequency groups appealing as dropping of activity of an enzyme (concerning control modifications) at augmentation of intensity of EMF exposure (from 0.8 μW/cm^2), and rising it in the same conditions. In the first frequency group the modification of effect is inverse to body height of power dose, and in the second group is corresponded to the obtained dose.

From the obtained experimental data it follows, that the highest biological efficiency of the exposure is possible in series of cases at the most low intensity of exposure. The analysis of results of experiments has allowed the authors to establish, that from all utilized parameters of exposure in this experiment (frequency of modulation, duration of an irradiation, intensity of exposure) greatest effect on activity of an alkaline phosphatase rendered frequency of modulation and intensity of exposure. So, for each frequency the intensity of EMF exposure at a modification of the magnitude in micro-watt levels was capable abruptly to vary a directness of effect to activity of an enzyme from the expressed promoting effect to considerable inhibiting effect and on the contrary (Fig. 3.2). All has depended on an interval of intensities for the given frequency of

modulation. The augmentation of duration of an irradiation with 1 up to 3 min influenced to a lesser degree, and raised the effect of EMF exposure a little.

The efficiency of frequencies of modulation can not show the labilizing or inhibiting properties in transition zones of intensities, where the sign of effect varieties. For an alkaline phosphatase in the conducted examinations this region, approximately, is at a level 5–15 μW/cm^2. There are basis to guess, that it depends on frequency of modulation and from magnitude of effect in a little to other regions of intensities, where the effect shows.

The authors show a possibility of conservation of a directness and efficiency of an effect of frequency of modulation at a backup of experiments after a considerable span.

In vitro studied MEMF effect on ATPase activity of actomisine complex (Chart No. 4 of Annex). Actomisine agent (AM) was discharged of a skeletal muscle of rat and irradiated to EMF at 2375 MHz, modulation 50–300 Hz. Despite of high EMF intensity (S=40 and 200 mW/cm^2), the results of the given experiment were included in the report, since in this work the legible dependence of bioeffect on modulation was obtained.

In a frequency range of 50–300 Hz at S=40 mW/cm^2 the ATPase activity was reliably enlarged (Fig. 4.1) for about a maximum at frequency of 270 Hz (285±25%, $p < 0.05$). The expressed suppression of ATPase activity however was marked at frequencies of 130 and 300 Hz. In series at S=200 mW/cm2 the augmentation of ATP activity was more expressed in a frequency range of 80–150 Hz (Fig. 4.2)

The clear MEMF effect on GAOA-, glutamate and cholinergic system of a rat brain (800 MHz, S=1mW/cm^2 was detected in conditions of acute exposure (Chart No. 5 of Annex). Animal were irradiated within 5 minutes to both continuous EMF, and impulses of the rectangular form with frequency of 2.5; 3; 5; 7; 16 and 30 Hz. The examinations conducted at once after EMF exposure and “sham exposure”.

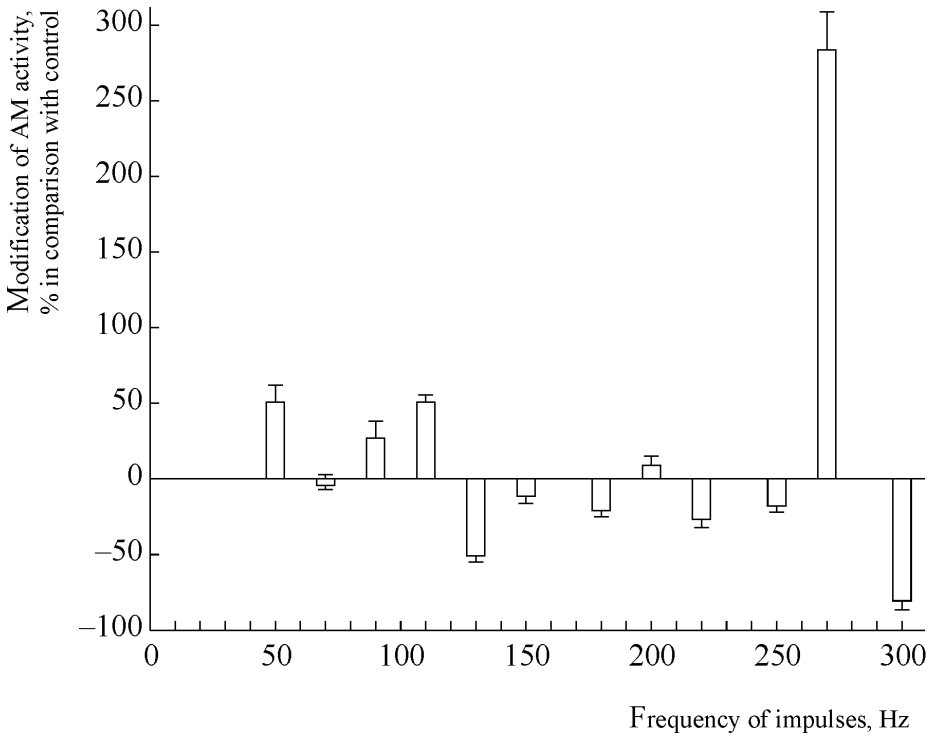

Figure 4.1. Dependence ATPase activity of AM from frequency of EMF modulation (S=40 mW/cm^2, t=1min). On an abscissa axis - frequency of impulses, Hz; on an axis of ordinates - modification of AM activity,% in comparison with control.

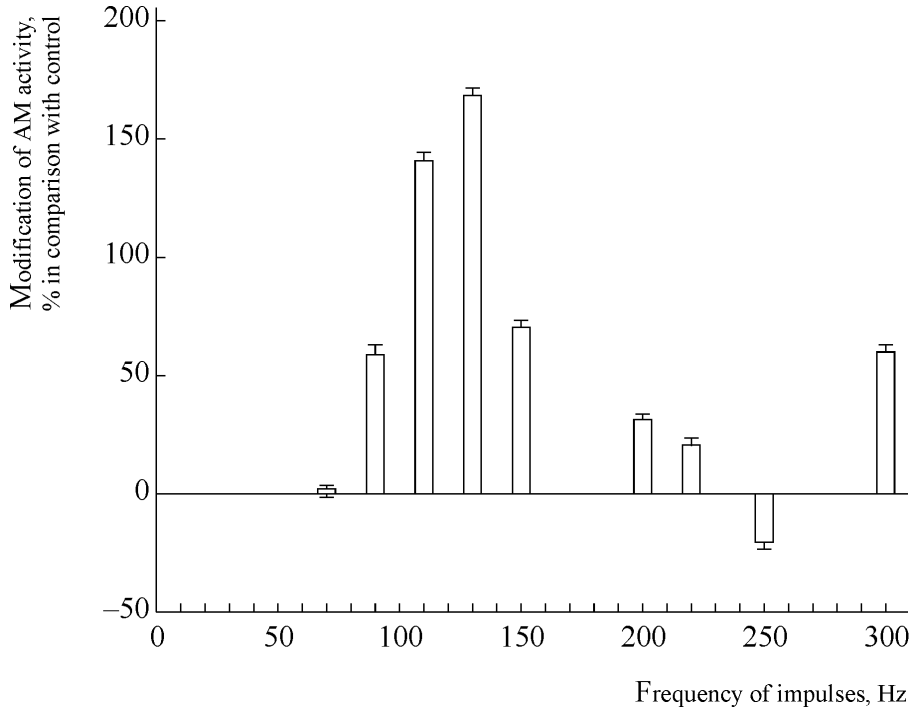

Figure 4.2. Dependence ATPase activity of AM from frequency of EMF modulation (S=200 mW/cm^2, t=1min). On an abscissa axis — frequency of impulses, Hz; on an axis of ordinates — a modification of AM activity,% in comparison with control

Statistically reliable and most significant modifications of bundling were obtained by a GAOA receptor of ^{3}H-muscimole at frequency of modulation of 16 Hz (800 MHz, S=1 mW/cm^2, radiation time of 5 minutes). The muscimole amount was decreased on 30–35% in comparison with control (Table 5.1). The root-mean square deviation at frequency of 16 Hz was minimum in comparison with a scatter on other frequencies of modulation.

Table 5.1.

Dependence of bundling ^{3}H- muscimole by a GAOA receptor from frequency of EMF modulation (carrier frequency of 800 MHz, modulation from 3 up to 30 Hz, PFD of 1 mW/cm^2, radiation time of 5 minutes).

Modulation frequency, Hz	B*
3	1.07±0.31
5	0.96±0.17
7	0.83±0.25
16	0.70±0.05
30	1.35±0.30
No modulation (CW)	1.12±0.13

*footnote: B — the ratio of muscimole bundling with GAOA-receptor at irradiated rats to muscimole bundling with a receptor at control (sham exposed rats).

At examination of bundling of a glutamate in rats irradiated to 915 MHz, S=1mW/cm^2, radiation time of 5 minutes, modulation of 2.2 and 16 Hz the greatest effect was observed at 16 Hz as well as in case of muscimole bundling, but the effect was of an inverse directness. (Fig. 5.1). The amount of a bound glutamate has increased on 200–220%.

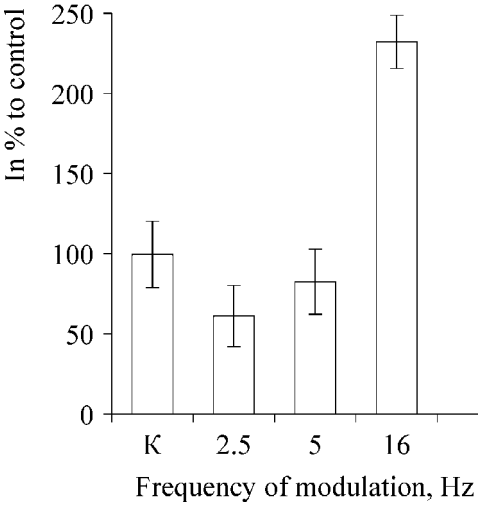

Figure 5.1. Dependence of bundling of a 3H-glutamate by synaptic membranes from frequency of EMF modulation (915 MHz, frequency of modulation from 2.5 up to 16 Hz, S=1 mW/cm^2, radiation time of 5 minutes). On an axis of ordinates — bundling of a ^{3}H-glutamate in% to control; on an abscissa axis — frequency of modulation.

The padding examination of effect of electromagnetic fields modulated by low frequency, on synapses receptors of a brain was conducted at exposure with various magnitude of intensity and time of exposure. (Chart No. 6 of Annex).

Wistar rats were irradiated to EMF of 800 or 950 MHz, modulation with square-wave pulses of 2.5, 3, 5, 7, 16 and 30 Hz at porosity of 32%, S=10, 50 and 100 μW/cm^2. The time of exposure in miscellaneous series was 1, 5, 15 and 60 min. Animals were put in a cell from organic glass, the exposure was realized from the open waveguide docked with a wave-guide duct. An MEMF exposure was subjected simultaneously to three animals. In check experiments, rats were put in non-echo chamber on the conforming time without an irradiation.

Animals were decapitated at once after MEMF exposure and “sham” exposure. As a GAOA receptor they have utilized ^{3}H muscimole, the experiments were conducted on synaptic neurosomas and synaptic membranes. Bundling ^{3}H of a glutamate was realized on synaptic somal membranes. Synaptic neurosomas were received from a cortex of rat brain.

Dependence of bundling ^{3}H muscimole and ^{3}H glutamate from EMF power flux.

The examination of MEMF effect at general organism exposure has shown, as GAOA and glutamatic system of the rat brain are very sensitive to low intensive MEMF (Fig. 6.1). At MEMF exposure, the modification in bundling receptors with GAOA and glutamate receptors has descended by a various mode: for GAOA receptors the decrease of bundling, for glutamate receptors — augmentation was observed. GAOA and glutamatic system of the rat brain have responded to MEMF by an inverse mode, as it takes place at a stress and some pathologies in the CNS. Modifications in functioning the indicated systems have depended upon MEMF rate: the more radiation power, the effect is more especially expressed. The maximal effect was observed at an energy flux density of 1mW/cm^2. It is necessary to mark, that modulated EMF rendered effect on bundling ^{3}H-muscimole and ^{3}H-glutamate was at smaller values of EMF rate. At value of an EMF power flux density of 10 μW/cm^2 the decrease of bundling ^{3}H-muscinole has made 88±12% in comparison with control, and augmentation of bundling ^{3}H glutamate was equaled to 120±12%.

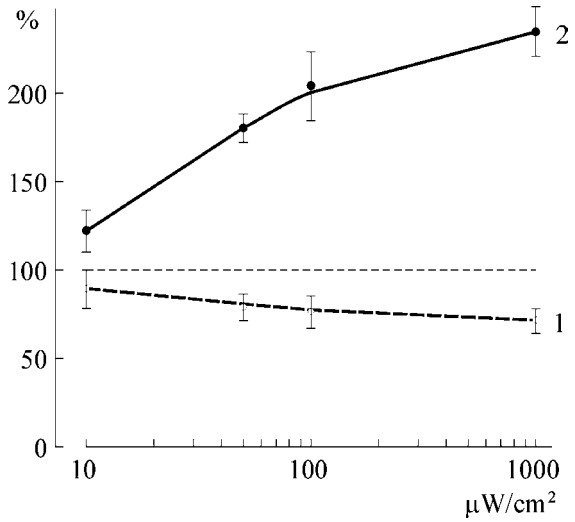

Figure 6.1. Dependence of bundling ^{3}H muscimole (1) and ^{3}H glutamate (2) from MEMF power flux density (carrier frequency of 915 MHz, radiation time of 5 min, frequency of modulation of 16 Hz). The bundling at control animal was closed to 100%. On an abscissa axis — an power flux density, on an axis of ordinates — bundling in% to control.

The dependence of bundling 3H-muscimole and 3H-glutamate from time of EMF exposure. Carrying out of examination have shown, that for GAOA system the maximal effect was observed in exposed animal during 1 min: the decrease of bundling labeled muscimole has made 50–55% in comparison with control, and at 15th and 60th minute of exposure the effect was less expressed (Figure 6.2).

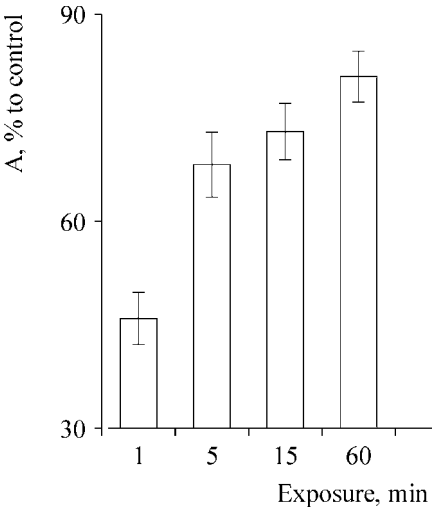

Figure 6.2. Dependence of bundling ^{3}H glutamate by synaptic membranes from time of EMF exposure. A — the attitude of bundling of a ligand with a receptor for irradiated rats to bundling for control animal (in% to control). A carrier frequency is 800 or 915 MHz, power flux density is 1 mW/cm^2, frequency of modulation is 16 Hz.

At examination of bundling glutamate in a time dependence of the MEMF exposure, animal was irradiated during 1 and 5 min, frequency of modulation was 16 Hz. The maximal effect was observed at 5th min of exposure, the augmentation of bundling has made 200–220% versus control (at 1st minute irradiation augmentation of bundling ^{3}H glutamate is 130±6%).

Thus, even it is enough of 1 minute exposure of modulated emission, that at rather low intensity of microwaves is essential to change a reactivity of CNS. At a more long MEMF radiation time the effect became less expressed. It can specify that compensatory mechanism "is included" in an organism in reply to a radiation effect.

MEMF effect on concentration dependencies of bundling ^{3}H- muscimole and ^{3}H-glutamate. In separate experiments the problem was investigated, whether at the expense of that there is a

modification of an amount of the bound marked ligand — the affinity of bundling of a ligand varies or the amount of linking fields in conditions of EMF modulated exposure varies. For this purpose the concentration dependencies of bundling ^{3}H- muscimole and ^{3}H-glutamate for control and irradiated animal were obtained and the Sketchard graphs are built.

The muscimole dissociation constant has varied insignificantly (Fig. 6.3) and made 480±60 nM, that is quite compounded with given one obtained by other authors. After the exposure, the muscimole dissociation constant has varied insignificantly, but thus the amount of linking fields has varied. The Figure of binding sites for muscimole was sank from 17.4±0.8 pmol/mg of protein at control up to 10±2 pmol/mg of protein at irradiated animal. As it is visible in a Fig. 6.4, the dissociation constant of a glutamate at control animal (227±15 nM) is more than value of a dissociation constant in experiment (103±10 nM), i.e. after the exposure, the affinity of bundling has increased. As to an amount of places of bundling for a glutamate after the exposure, it practically did not vary. Thus, as it is visible from the provided data, at MEMF exposure constant of bundling, and number of linking fields have varied.

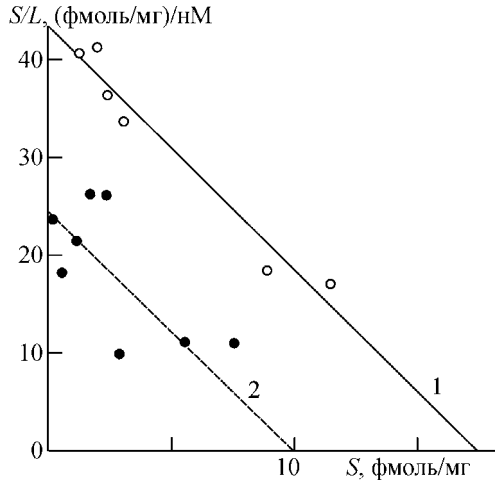

Figure 6.3. The Sketchard graph for the assessment of parameters of bundling ^{3}H muscimole by synoptic membranes. 1 — bundling ^{3}H muscimole in control, 2 — bundling ^{3}H muscimole after exposure. A carrier frequency is 915 MHz, power flux density is 1 mW/cm^2, frequency of modulation is 16 Hz, radiation time is 5 min. S is an amount of a bound ligand, L is the concentration of a free ligand.

To the present time large data about microwave effects in different physiological and biochemical parameters of cerebral structures, specific organs and whole organism are accumulated. The adequate theoretical explanation of results is the complex problem. Nevertheless, these results are well compounded with the literary data on stressful effect (electroshock, pain stress, immobilization) on receptor properties of GAOA receptors. The experiments on MEMF exposed animals have shown, that the greatest modifications of GAOA receptor concentration descend within the first five minutes. Furthermore, at 15th and 60th minute of the exposure the effect became less expressed. It is interesting, that the similar dependence in a modification of receptor properties of GAOA receptors in a cortex of a brain is observed at 24th hour of immobilization stress: the essential decrease of concentration of GAOA receptors at first minutes, then step-by-step homing to norm, and to 24th hour even the augmentation in comparison with control. As a matter of fact various phases of a modification of receptor properties of GAOA receptors at MEMF exposure are similar to phases of the common adaptation syndrome.

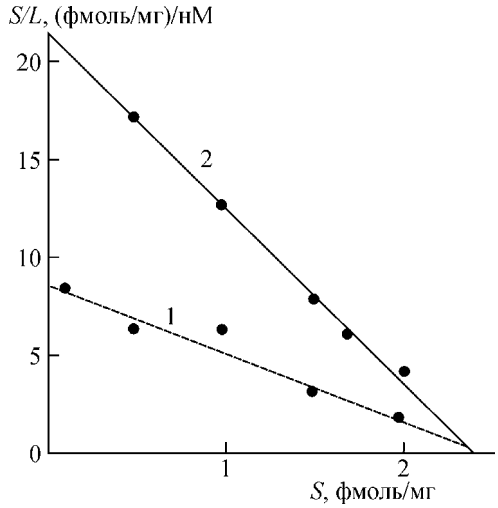

Figure 6.4. The Sketchard graph for assessment of parameters of bundling glutamate by synaptic membranes. 1-bundling of a ^{3}H-glutamate after exposure. Conditions of an exposure as in a Fig.. 4 S is the amount of a bound ligand, L is the concentration of a free ligand.

Thus, it is shown, that the MEMF effect on receptor systems of a brain depends both on intensity, and from duration of EMF exposure. It is possible to assume, that the modulated electromagnetic radiation “includes” a complex of stressful responses in an organism, which further, probably, educe under the scenario of a common adaptation syndrome.

They have examined the effect of pulsewise - modulated EMF of weak intensity on secondary DNA frames (Chart No. 7 of Annex).

DNA samples (3 mL) in polypropylene vials a dia of 12 mm were put in a foam support (control and experiment) so that they placed in series with center distance of vials of 25 mm. Samples were subjected to the exposure of impulsive or continuous EMF of intensity of 600 $\mu V/cm^2$ and frequency of 1.05; 2.05 or 2.39 GHz during 30 mines at 18ºC within non-echo chamber. At a quantization of a field the frequency of a cycling compounded 4 Hz, duration of impulses was 25 ms, S=600 $\mu V/cm^2$. A support with exposed vials irradiated in the region of the formed wave (3 m from polishing material of the radiating antenna) in isodose field (±10%) at vertical orientation of a E-vector. The control assays also were in the chamber within the radiation time, shadowed by the ferrite screen. The examinations conducted at once after exposure.

In experiments they have utilized DNA, secured of a thymus gland of mice by a phenolic method. As a result of the conducted examinations ascending value of a maximum of curves of a denaturation was obtained and fast reaching of a maximum at a quantization was observed (Fig. 7.1). The inverse effect was obtained at continuous exposure (CW). It was fixed, that the impulsive radiation at all three utilized carrier frequencies invokes statistically significant differences between kineticses of a DNA denaturation in the irradiated and control solutions.

The authors has specially marked, that the obtained bioeffect is steadily replicated and highly reliable at usage of the chosen mode of exposure.

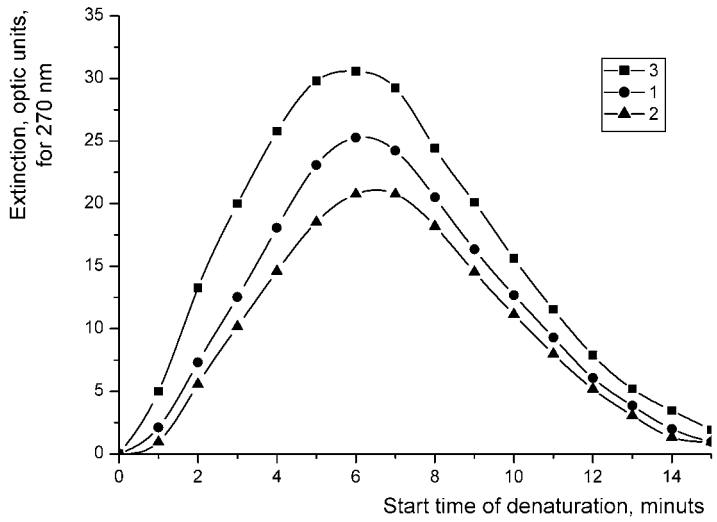

Figure 7.1. Kinetics of a denaturation in control (1) and DNA samples subjected to exposure to continuous (2) and modulated by frequency 4 Hz (3); (EMF of 1.05 GHz, S=600 μW/cm^2).

The attention, from our point of view, should be attracted to results of experiment, in which studied effect of EMF "oscillating" frequency on DNA discharged from of salmon fish semens (Chart No. 8 of Annex). A wet DNA film, stabilized with bound water, was irradiated to "oscillating frequency" in a band of 8.15–10 Hz at PFD of 5, 10, 20 or 40 mW/cm^2 with duration of 1, 5, 15, 30 and 60 minutes.

This kind of exposure already at S=5 mW/cm^2 has decelerated the rate of a desorption of water in DNA membranulas, influenced in conformation metamorphosises of polymeric molecules*. The irradiation quenched conformation passage of DNA molecules from a hydrated B-conformation in an A-conformation at a desiccation of membranulas. In irradiated membranulas during a desiccation (decrease of relative humidity of a film) the DNA molecules have prolonged to remain bound with molecules of water and, hence, saved high order state as against control. As it was not revealed of any reliable modifications in the most molecular DNA frames, it has entitled the authors to consider, that the detected effects of EMF effect on a possibility of conformation passages are stipulated by a modification of the frame of water, bound with DNA. Probably, it also serves the cause of the rate decrease of a desorption of water from DNA membranulas and stabilization of DNA molecules in hydrated high ordered double-helical B- conformation. It is supposed, that the ability of EMF of particular parameters will steady DNA frame to influence DNA functional properties as carrier of the genetical information.

Except for biochemical examinations in vitro the experiments on performance of responses of quarantined frames of a nervous system were conducted at MEMF exposure. A role of EMF modulation as the possible factor influencing background impulsive activity (BIA) of neurons of a section of a brain (Chart No. 9 of Annex) first of all was probed.

EMF exposure was realized at 0.9 GHz in a continuous regimen and with a quantization of 7, 16, 30 and 60 Hz. The porosity was always peer 5, the pulse duration was various: at 7 Hz — 28 ms; at 16 — 12 ms; at 30 Hz — 6.7 ms. The specific absorbtion rate (SAR) was peer 1.4 W/kg. Up to, in time and at once after exposure probed background impulsive activity (BIA) of

*Experiments where complex EMF exposure modes were applied though with high intensity can extend knowledge regarding bioeffect modulation induction

80 neurons in experiments with the modulated exposure, 28 neurons with the not modulated exposure was examined. BIA was recorded by non-artifact electrodes. Electrical activity of neurons was recorded on the tape recorder for an aftertreatment on the computer. They have conducted a constant integration of streaming frequency of each neuron.

At EMF exposure with modulation of 7 Hz, neurons in most cases (13 of 17 cells) already on the first minute of the exposure have responded by decrease of frequency of the discharges to 27%. Such frequency drift was saved during all radiation time. After the arrest of exposure, the tendency to regeneration of frequency was not observed (Fig. 9.1, A). The remaining 4 cells have not reacted on the irradiation.

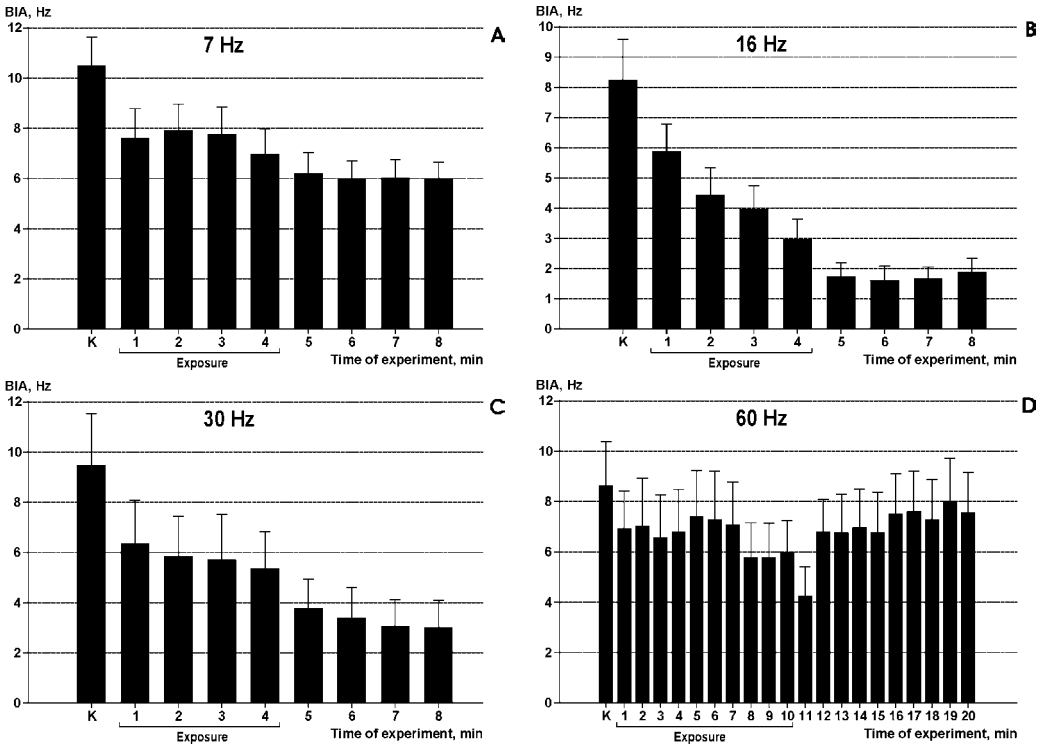

Figure 9.1. Effect by pulsed modulated EMF on background impulsive activity (BIA) of sections of a neocortex. Each column of the chart — average value of BIA frequency of all cells, probed in the given paste, in one minute and standard deviation average: K — in control, in a radiation time (line under the graphs), the subsequent columns reflect time after an irradiation by pulsed modulated EMF. The frequencies of modulation are indicated above each chart. Average SAR was 1.4 mW/g for all frequencies of modulation. A — 7 Hz modulation; B — 16 Hz modulation; C — 30 Hz modulation; D — 60 Hz modulation.

At frequency of 16 Hz, 15 of 17 cells have the induced decrease of frequency of background activity by 24% on the first minute of an irradiation and on 65% to the end of the fourth minute of exposure. The tendencies to BIA regeneration was not traced (Fig. 9.1, B). The exposure with frequency of 30 Hz modulation has invoked a response of BIA inhibition only at 7 of 16 probed cells approximately on 28%. In this case tendencies to regeneration was not traced after deenergizing the generator (Fig. 9.1, C). The remaining 9 cells in this series in reply to exposure have not reacted reliably.

The exposure with frequency of 60 Hz has induced statistically significant short-term decrease of BIA frequency against control in less than third (5 of 19) probed cells approximately on 20% at first minute after the arrest of an irradiation. There was a tendency to regeneration of frequency at 2nd minute after an irradiation (Fig. 9.1, D).

In experiments with a continuous irradiation average SAR was selected to be equal to average SAR used in experiments with the modulated irradiation (1.4 mW/g). In examinations with a

continuous irradiation, the BIA inhibition at 16 of 28 cells (Fig. 9.2) also is revealed, but change of a frequency drift observed at a constant integration was more monotonic, than at the modulated irradiation. At the not modulated irradiation the tendency to regeneration of BIA frequency after an irradiation to a level of control was traced. The significant inhibition occurred only to the fourth minute of an irradiation and the intensifying of effect was not observed after the arrest of an irradiation.

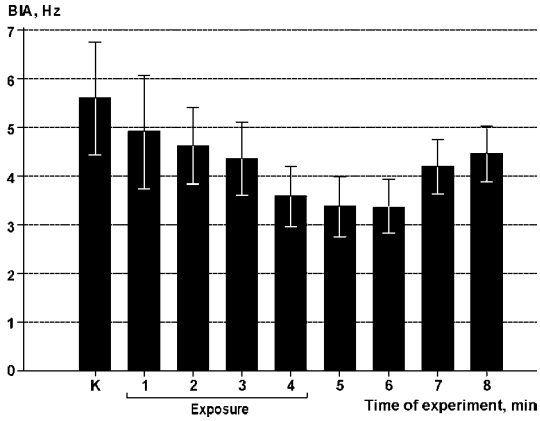

Figure 9.2. Average value of BIA frequency of neurons of sections of a neocortex in time and after exposure to not modulated EMF in each minute. K — up to an irradiation; in time (1–4 mines) and after (5–8 mines) irradiation with average SAR of 1.4 mW/g; on an abscissa axis — time of examination.

The attempt was made to reveal modifications of brain neurons pulsation at MEMF exposure with usage cross correlation analysis. (Chart No. 10 of Annex).

As model of examination the experiencing frontal sections of a sensomotor cortex of a brain of the Guinea pig were utilized.

The EMF irradiation was conducted at 900 MHz, SAR in an alveole of volume 1 cm^3 with sections there was 1.4 mW/g, a quantization was 7, 16, 30 and 60 Hz.

The examinations conducted up to, in time and at once after MEMF exposure.

The spontaneous activity a steam of neurons was recorded exocellularly by one microglass electrode. Cross correlation functions (CCF) of cells were calculated. The CCF statistical analysis for cells obtained from 51 neighbor steams was conducted, which impulsive streams were clearly divided with the help of amplitude discrimination.

In CCF of the level of significance of 5% reliable deflections from a mean level h_{12} were found, showing mutuality in cellular pulsations of examined cell couples. On all frequencies of modulation the decrease of the correlation coefficient was in most cases observed during exposure with lack of the legible tendency to regeneration of degree of constraint of the steam of neurons after the arrest of exposure.

The decrease of correlation at an irradiation can testify, that MEMF desynchronizes work of crustal neurons in neuronic ensembles. The modification of correlation in activity of probed nervous cells at a microwave irradiation, apparently, is connected to effect of radiation on synaptic transmission between neurons. One of the causes of deterioration of carrying out synaptic signal in a nervous tissue can be depressing of a power metabolism or attrition of neurons mediator pool.

Thus, utilizing filing of spontaneous impulsive activity of neurons of experiencing sections of a neocortex and cross correlation analysis, it was shown, that the electromagnetic radiation renders noticeable downstroke of transneuronal correlation and accordingly there is a deterioration of synaptic transmission between cells of a cortex.

With the purposes of examination of possible effect of modulated EMF of small intensity on a more composite functioning system the model of an isolated frog heart (Chart No. 11 of Annex) was utilized. In experiments, the composite regimen of modulation was utilized at low level of intensity. The principle of modulation frequency changed in time was applied at a constant countrexposure of frequency setting. An irradiation was conducted on experimental installation generating microwave with frequency of 9.3 GHz. As the dimensions of frog heart are comparable to a wavelength of radiation, an irradiation was conducted in conditions which are coming nearer to maximal absorption of the radiation energy.

Modulated EMF on its amplitude was characterized by varying frequency of modulation from 1 up to 100 Hz at a depth of modulation of 30 and 100%; a pulse shape was rectangular, meander, S=0.016 mW/cm^2. Distance up to the object got out by such, that the irradiation was uniform. The general plan of conditions of experiments is provided by Table 11.1.

Table 11.1.

General characteristics of conditions of experiments

Test No.	Animal number		PFD, mW/cm²	EMF mode and exposure time, min			Total exposure time, min
	Test	control		CW	Pulsed, Hz	Time at each mode, min	
1	28	28	0.016	-	6–10	1	5
2	32	32	0.016	-	1–10	1	10
3	20	20	0.016	-	1–10, 20, 30, 40, 50, 60, 70, 80, 90, 100	1	19
4	10	10	0.016	CW	-	5	5

The examinations were conducted in a radiation time, and after exposure within 24 hours. 180 frog hearts were utilized in total.

They have estimated a beat frequency of heart during each 30 minutes within 6 hours from the moment of manufacture of the isolated heart preparation, during exposure, and also within day after an irradiation. Simultaneously, observations were conducted in control (sham exposure) in the same terms. It is important for an assessment of a response on an irradiation, that heart in Ringer solution can be pruned within two days.

Besides, the morphological criterion of a state of erethitic tissues of heart was the assessment of process of a vital staining of frames of an interatrial septum by a stain of azine group with neutral red (NR). The method of an intravital staining has enabled to judge vitality of frames by granule forming criterion, and also about a state of their permeability (on a degree and dynamics of staining). Other vital stain, methylene blue, was utilized for an assessment of a state of choline energetic synapses on independent neurons of a Ludwig node.

Intact uncolored hearts for 24 hours of observations have decelerated the rate on the average on 7%; the cardiac standstill was not present (Fig. 11.1). Half-hour stays of a quarantined drug heart in solution of a stain in itself have resulted in the modification of its function. The Figure of constrictions was decreased by 30%, and 14% of hearts ceased to be pruned (Fig. 11.1.). At a stimulation of the stopped hearts by strong light or mechanical stimulus of pacemaker range (venous sinus) the beat was recovered. After the arrest of process of a staining of heart the rate of

constrictions was gradually accumulated reaching the initial level. And only to the end of experiment in hour 24, the heart beat number was sunk on the average on 20%.

The response of hearts irradiated in a continuous regimen, was inappreciable, and differed from the colored unirradiated hearts a little.

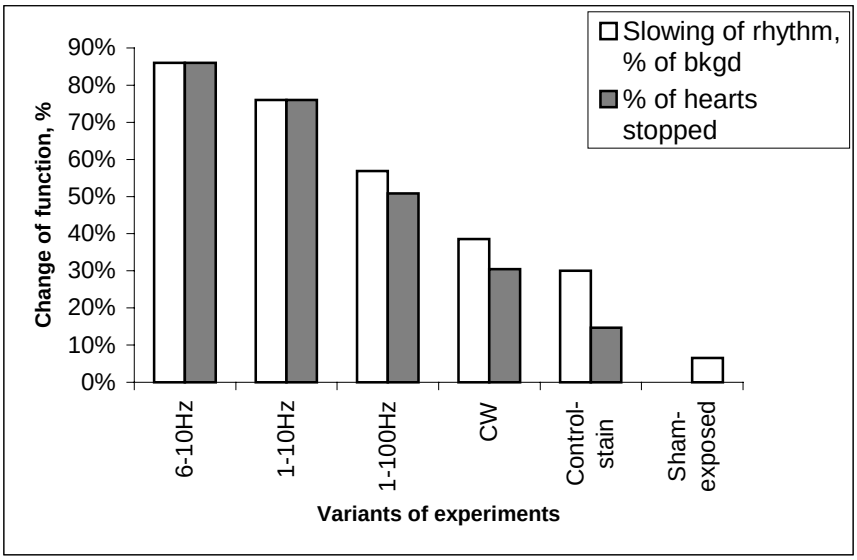

Figure 11.1. Change in the number of beating and stopped isolated frog hearts, EM irradiated using the continuous regime and for various pulse modulations from 1 to 100 Hz.

At an irradiation in the modulated regimen, the sharp decrease of heart beat number was marked, the number of the hearts which have ceased to beat (Fig. 11.1) was enlarged also. The greatest effect was obtained at a frequency drift of modulation in a band of 6–10 Hz and time of exposure of 5 minutes. Under these conditions of exposure, there was a retardation of a rhythm to the subsequent cardiac standstill at 85% of hearts (at a continuous regimen — 38%). The effects were particularly reversible.

The irradiated hearts washed from a paint have recommenced constrictions, and the accumulated rate, however, within 2–3 subsequent hours in major percent of cases has been noted to have sharp heart beat decrease and secondary cardiac standstill. In these cases, challenging procedures have ordered only to short renewing of cardiac constrictions. In 2–3 hours after MEMF exposure in neurons and muscle elements of heart, the violation of granule forming process was observed. The great number of neurons has gained the angle forms and diffuse coloring of a core and cytoplasm. In muscle fibers, the number of stain beads was diminished, cytoplasm was slightly tinted, and a number of muscle cores were also colored in intensively red color. Simultaneously, the appearances of a gelatinization of synapses on cells of a Ludwig node and intensive tincturing of Schwann cells in region of a taper of an axon were marked. Such results can speak about violation of vitality of the irradiated frames of heart and about the development of process of paranecrosis.

Thus, in all series of the MEMF irradiation of hearts with changeable frequency of modulations in range from 1 up to 100 Hz, it has rendered much major effect on function of heart, rather than irradiation in a continuous regimen of generating.

The value in shaping bioeffect of correlation between an initial state of a system of an organism and conforming EMF modulation (Chart No. 12 of Annex) was examined. In these purposes, the model of an isolated frog heart was also utilized. An isolated frog heart irradiated to EMF of 9.3 GHz, S=0.016 mW/cm^2 with modulation in three regimens: (a) 20, 22, 24 and 25 Hz; (b) 32, 34, 36 and 38 Hz; (c) 40, 42, 44, 46 and 48 Hz was investigated. In an initial state on a heart beat

frequency they were divided into 3 groups: (I) 20–30 beats in 1 min; (II) 31–40 and (III) 41–50. The regimens were chosen according to an initial beat frequency of an isolated heart. The duration of each irradiation was 1 minute. Also there was an exposure with a continuous EMF regimen (group IV) and "sham" irradiation (group V). Magnitude of modifications was estimated on a rank system.

Table 12.1.

Frequency drift of frog heart beats in dependence from modulations of microwave field and initial frequency of heart beats

Group	No. of hearts	Modulation frequency, Hz	Rank number (group averages)			Total rank number
			Initial heart beat rate			
			20–30	31–40	41–50	
I	23	20, 22, 24, 25, 28,	**50**	3	3	56
II	28	30, 32, 34, 36, 38	11	**12**	9	32
III	22	40, 42, 44, 46, 48	9	1	**16**	26
IV	26	Continuous wave	1	-	-	2
V	30	"sham exposure"	-	-	-	0

At each of three regimens of modulation the greatest modifications in a rhythmicity of heart from the initial level were under condition of concurrence of their magnitudes (Table 12.1). The greatest modifications were at EMF exposure in a regimen of modulation at 20–28 Hz in group of hearts with frequency of beats of 20–30 strokes a 1 minute.

EXAMINATIONS IN VIVO

It was supposed, that the role of modulation in development of bioeffects should be more brightly expressed at examination of a response of an integrated organism. In this connection, series of examinations were conducted with usage of behavioral responses.

The rat behavior after EMF exposure at 915 MHz with a frequency modulation of 4, 6,16 and 20 Hz was probed; a radiation time was 10 minutes (Chart No. 13 of Annex). At all given frequencies of modulation, S=10 mW/cm^2. they have utilized magnetron generator for exposure. There was an animal group with a “sham” irradiation.

Immediately after an irradiation, the animal behavior was examined in conditions of an operation on them of series of stressors: a unfamiliar situation of open space, height, glare. With this purpose, they have conducted observations of behavioral singularities in the uplifted cruciform labyrinth, when animal should make jogs on narrow rays of a labyrinth at major height above ground level. This procedure is widely utilized for an assessment of an affective behavior of rats in particular expressiveness of the level of uneasiness. They have estimated time of “freezing behavior".

The labyrinth was consisted of two open (40×12 cm) and two closed (40×12 cm) sleeves restricted by opaque walls of 40x40 cm dimension. The orifices in the open sleeves were posed vice-versa apart 10 cm. The labyrinth was at height of 90 cm above a level of floor. All experiments were conducted in the morning — from 9.00. In the beginning of experiment, the animal was put in a central part of a labyrinth and during 5 min was observed. They have recorded the number of calls in the open and closed rays of the labyrinth, the number of passages in rays of a labyrinth and time of the freezing behavior response. After the end of work with animal, they have wiped the floor of the labyrinth and through 10–15 mines have began work with the following animal.

As a result of EMF exposure modulated by frequencies of 4 and 6 Hz, the number of entries in the open rays of a labyrinth within 5 min observation has increased in 3.7 and in 4.5 times accordingly in comparison with control, that is a parameter of considerable dropping at an animal level of uneasiness from stay in a labyrinth (Table 13.1). At modulation frequency of 16 Hz, the modifications of this parameter were expressed more weakly — number of entries was enlarged in 2.3 times, and at 20 Hz its value in essence did not differ from control.

Table 13.1.

Singularities of rat behavior in a cruciform labyrinth after MEMF exposure

Modulation frequency, Hz	No. of rats	Number of entries to “open rats”	Number of entries to “closed rats”	Freezing time, s
control	9	1.1±0.2	6.8±0.6	24.0±4.0
4	7	4.1±0.7**	8.7±1.2	5.7±1.8**
6	4	5.0±0.6**	9.7±1.7	5.0±1.5**
16	6	2.5±0.3*	7.0±1.9	1.8±0.9***
20	9	1.0±0.1	4.0±0.7**	50.4±8.9*

Footnote. Differences from control on a t-Student criterion are reliable:
* — $p < 0.05$; ** — $p < 0.01$; *** — $p < 0.001$

On a parameter of time of freezing behavior describing a degree of manifestation of passive defensive behavior, multi-directed EMF effect was also detected depending on the frequency of modulation. Under EMF exposure at frequency of modulation of 4, 6 and 16 Hz, the time of

freezing behavior was sunk in 4.2, 4.8 and 13.3 times, accordingly. At rising frequency of modulation up to 20 Hz, the time of freezing behavior, on the contrary, has increased in 2.4 times.

The motor performance determined on number of entries in the closed rays of the labyrinth, did not undergo reliable modifications after EMF exposure modulated by frequencies of 4, 6 and 16 Hz. However, at frequency of modulation of 20 Hz, the level of this parameter was sunk in 1.7 times.

Thus, the comparative analysis of EMF modifications of parameters of an affective behavior (table 13.1) has revealed, that the number of entries in the open rays of the labyrinth is changed by the EMF exposure with frequencies of modulation of 4 and 6 Hz, with increase up to 373 and 450% accordingly in comparison with control conditionally accepted for 100% ($p < 0.01$). On frequency of modulation of 16 Hz this parameter was enlarged up to 225% ($p < 0.05$), and at frequency of 20 Hz the tendency to its decrease was observed.

The comparative analysis of the data, submitted in the table characterizes modifications of responses of freezing behavior under low intensive EMF exposure at miscellaneous frequencies of modulation. It is shown, that at modulation of 4, 6 and 16 Hz the reaction duration is decreased in 76% ($p < 0.01$), 79% and 93% ($p < 0.001$), respectively. At frequency of the modulation of 20 Hz, the freezing period has exceeded a control level on 110% ($p < 0.05$).

The rather serious responses were fixed in rat behavior at MEMF exposure (Chart No. 14 of Annex). Rats irradiated to EMF of 40 MHz with the modulation of 50 Hz had depth of modulation of 80–100%, field strength of 100–120 V/m, duration of exposure was from 5 minutes till 2.5 hours. The phase modifications of behavioral responses down to development a cataleptic state at a part an animal were registered in these experiments.

They have tested possible effect of modulated and not modulated EMF on epileptiform activity of rats with potential presence of audiogenic cramps. (Chart No. 15 of Annex). Animals were irradiated to EMF at 880 MHz, $S=1 mW/cm^2$, 5 minutes/day, within 5 days. 40 rats were divided into 4 series: I^{st} series — a continuous irradiation; II^{nd} series — modulation of 4 Hz; III^{rd} series — modulation of 16 Hz; and IV^{th} series — a “sham” irradiation. Animals were observed within 1.5 years thereafter.

As a result of MEMF exposure, there was the suppression of a convulsive predisposition in animals at modulation of 4 Hz and 16 Hz. At a continuous mode of exposure, this effect was expressed insignificantly and it was exhibited only in 3 months after an irradiation (Table 15.1)

Table.15.1.

Exhibiting audiogenic cramps in rats (%) of four experimental groups after exposure to not modulated and modulated EMF

Time of repeated testing after a course of exposure (provocation of audiogenic cramps)	Animal group			
	1 (CW)	2 (4 Hz)	3 (16 Hz)	4 (Sham exposure)
1	2	3	4	5
Day 1	100	20*	20*	100
Week 1	100	20*	20*	100
Week 2	100	20*	20*	100
Week 3	100	20*	20*	100
Month 1	100	20*	20*	100
Month 2	100	20*	20*	100
Month 3	80	60	80	100
Month 4	80	60	80	100
Month 5	80	60	80	100

1	2	3	4	5
Month 6	80	80	80	100
Month 12	20*	80	20*	100
Month 18	37,5	66,6	25	100

* Statistically significant difference by Student criterion ($p < 0,05$)

The effect of modulated EMF on the mechanism of targeted animal behavior (Chart No. 16 of Annex) was investigated. The experiments were conducted on rats, which were irradiated to EMF of 30 MHz, frequency of modulation of 2, 7 and 50 Hz, depth of modulation of 80%, field strength of 30 V/m. They have utilized the generator, which condenser plates were hardened along walls of the scoop. Duration of exposure was 10 minutes.

The MEMF effect on the response of a self-stimulation during exposure was examined. 30 rats were utilized in the experiment. The irritation of frontal, lateral and back hypothalamus and middle and lateral kernels of the septum was effected by an electrical current of 10–12 A, duration of impulses of 0.1–0.5 ms. They have invoked a response of a self-stimulation in all animals.

At an EMF exposure with frequency of 2 Hz modulation during the first 2 min, the augmentation of frequency of a response of a self-stimulation for 93% was observed, then the frequency of a response of a self-stimulation was sharply sunk and through 4 min petered completely (Fig. 16.1A). At an MEMF exposure with frequency of 7 Hz modulation in the first 2 min, the response of a self-stimulation practically did not differ from background and only then, during 12–15 min, the decrease of its frequency (Fig. 16.1B) was observed. Other picture was observed at an MEMF exposure with 50 Hz modulation— practically at once from the beginning of exposure all animal responses of a self-stimulation were quenched (Fig. 16.1.C). Characteristically, that the indicated MEMF effects did not depend on localization o of stimulating electrodes endpoints (stimulated area of the brain).

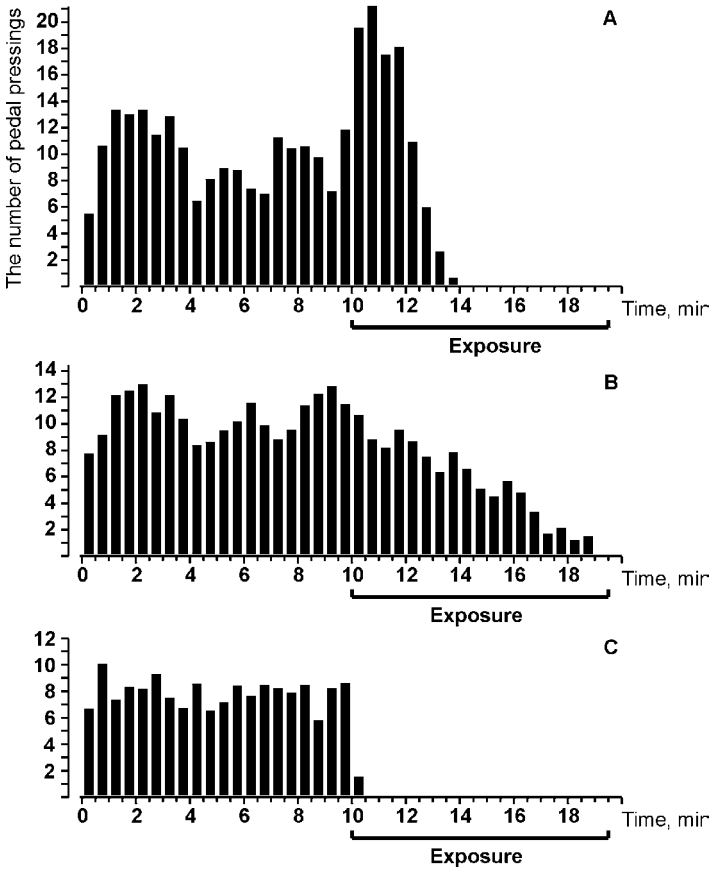

Figure 16. Dynamics of the self stimulation rate in case of EMF exposure at different modulation frequencies. A — 2 Hz; B — 7 Hz and C — 50 Hz. Each column is the number of pedal pressings per 30 s period averaged for 10 animals. The line is the MEMF exposure time.

The motor performance of the rabbits in conditions of a chronic impulsive irradiation to microwaves of low intensity (Chart No. 17 of Annex) was investigated.

The rabbits were irradiated with electromagnetic field at 1.5 GHz. The character of modulation was impulsive, impulse of the rectangular form, pulse duration of 16 ms, recurrence rate of impulse of 0.12 Hz, S=300 $\mu W/cm^2$. Animals were irradiated daily for 30 minutes within one month. Electromagnetic exposure and "sham irradiation" were applied in the random order.

The observations of the motor performance of the rabbits were conducted during daily exposure for 30 minutes within 1 month.

In the term of 30 minutes of true or "sham" irradiation, the rabbits were put in specially made organic glass cell. Out of door piezocrystal permitting to differentiate motor reactions was attached to a floor of a cell. The graphic entry of motor reactions and their handling were led with the help of a polygraph and " Televideo- 286 " (USA).

Only since day 14 of chronic exposure, the alarms were developed at animal reliable disadaptation motorial exhibitings as intensifying disturbing.

The response of separate neurons of a brain on a low intensive packed impulsive microwaves was investigated. (Chart No. 18 of Annex).

The experiments were conducted on the rabbits. EMF exposure was applied at 1.5 GHz, 100% amplitude modulation, meander, pulse duration of 0.4 ms, recurrence rate of 1000 Hz, duration of packs of 16 ms, with frequency of their repetition of 0.12 Hz, S=300 $\mu W/cm^2$. The exposure was conducted in sound isolated non-echo chamber with a reflectance factor of 30 dB. The generator of a microwaves (G3–21) was used. The radiation time was 1 minute. As control, the animal group with "sham irradiation" was utilized. The examinations were conducted up to, in time and at once after exposure.

The experiments were conducted on 22 rabbits of Chinchilla breed with body mass of 3 kg. The bioelectric activity of 139 neurons of sensomotorial and parietooccipital ranges of a cortex of a brain was studied. The impulsive activity was noted with the help of a small-type micromanipulator with a walk of the screw by 500 microns. The submersed microelectrode was served by the glass capillar with a bottom diameter of 1–3 microns, filled with three-molar normal saline solution of sodium chloride (resistance of 5–30 MOhm). They have utilized chlorine vinyl tube with the same solution on the basis of agar wires.

Analyzed frequency of the discharges of neurons and their character in the period of 3-minute entry (1 min — background, 1 min — irradiation and 1 min — after exposure). An irradiation and control were conducted in randomized order.

Under MEMF exposure, the activity of neurons has reliably varied, the number of the neurons which have changed the frequency has increased. The character of a response of neurons depends on their initial activity (Table 18.1, 18.2 and 18.3). The neurons excitanted in the time of MEMF exposure have changed the response on inhibition in the time of after-exposure.

Table 18.1

Performance of responses of neurons of sensomotor range of the brain cortex of the rabbit on low intensive packed impulsive microwave radiation

Character of responses	An amount of neurons,% from total (63)	Central frequency		
		before	during	after
Excitation	24.14*	5.5±0.66	16.3±0.78	6.03±0.64
Inhibition	31.03*	11.82±0.7	4.3±0.49	4.3±0.49
Non reacted	44.83*	9.82±0.67	9.34±0.68	9.34±0.79

* $p < 0.01$ versus control (Table 18.3); ** $p < 0.01$ versus background.

Table 18.2

Performance of responses of neurons of parietooccipital range of the brain cortex of the rabbit on low intensive packed impulsive microwave radiation

Character of responses	An amount of neurons,% from total (63)	Central frequency		
		before	during	after
Excitation	23.23*	5.52±0.4	11.25±0.76**	2.83±0.47**
Inhibition	30.47*	9.67±0.73	3.58±0.68**	4.45±0.61**
Non reacted	46.3*	6.13±0.52	5.9±0.47	5.33±0.42

Footnote. See note to Table 18.1; * $p < 0.01$ versus total of the registered neurons; ** $p < 0.05$ versus an initial background

Table 18.3.

Performance of responses of neurons of sensomotor and parietooccipital ranges of the brain cortex of the rabbit on sham irradiation (control series)

Ranges of a cortex	Reaction character	An amount of neurons,% from total (63)	Central frequency		
			before	during	after
Sensomotorial (72 neurons)	Excitation	3.04	5.2±1.32	6.94±1.5	7.8±1.09
	Inhibition	11.75	9.1±0.32	6.1±0.53	6.3±0.38
	Not reacted	85.21	8.7±0.4	8.0±0.44	8.6±0.41
Parietooccipital (73 neurons)	Excitation	5.65	2.26±2.2	4.1±1.6	8.4±2.15
	Inhibition	10.3	5.47±0.44	3.2±0.52	3.93±0.45
	Not reacted	84.05	6.2±0.42	5.8±0.38	6.5±0.39

Thus, at EMF exposure within 1 minute at 1.5 GHz, 300 $\mu W/cm^2$ at a packed quantization the modification of activity of neurons of the brain cortex was registered.

In repeated experiments, the modulated EMF effect on impulsive bioelectric activity of neurons of the brain cortex of the rabbit with the same aspect of modulation also was investigated, except for packed impulsive exposure. (Chart No. 19 of Annex).

The irradiation of animals was conducted in non-echo chamber, reflectance factor of 30 dB. EMF applied was at 1.5 GHz, quantization, pulse duration 0.4 ms with a recurrence rate of 1000 Hz, S=30 $\mu W/cm^2$. The generator G3–21 (Russia) was used. Time of exposure was 1 min. There was a series with “sham irradiation “.

The examinations were conducted up to, in time and after exposure within 1 minute. The experiments were conducted on 22 not anesthetized male rabbits of Chinchilla breed, 3 kg body weight, which were softly fixed on the wood machine tool. They have studied extracellular bioelectric activity of neurons of sensomotor and parietooccipital ranges of the brain cortex. They have recorded the impulsive bioelectric activity applying small-type micromanipulator made of organic glass with a walk of the screw of 500 microns, which was fastened on a head of the rabbit and allowed to record impulsive activity not only before and after, but also in the EMF valid time. The submerged microelectrode was served by the glass capillar with a bottom diameter of 1–3 microns, filled with molar solution of sodium chloride (resistance of 5–30 MOhm). The intact electrode was fastened on an ear of the rabbit. They have utilized chlorine vinyl tube with a normal saline solution on the basis of agar as the wires. They have analyzed frequency of the dis-

discharges of neurons and their character in 3 min of an entry (1 min — a background, 1 min — irradiation and 1 min — after-exposure).

Irradiation and "sham" irradiation were conducted in the randomized order. Statistically estimated exhibiting of the response on frequency pulsation of neuronic activity in the time of the irradiation was done in comparison with the background and conforming control of examinations, utilizing a t-Student and χ^2 criteria.

The quantitative performance of modifications in impulsive bioelectric activity of sensomotor and parietooccipital ranges of the brain cortex in conditions of the conducted experiments is submitted in Table 19.1. From the table it follows, that the irradiation in comparison with control, has reliably resulted to lot of neurons reliably changing the frequency of bioelectric activity if compared to the initial background. Among responding neurons (from 55 up to 60%), the identical amount of cells as with a response of augmentation of pulsation frequency and with its decrease was observed.

In Tables 19.2 and 19.3 the performances of pulsation frequency of neurons in control and with MEMF irradiation are submitted. As follows from Table 19.2, the reliable modifications in control pulsation frequency of neurons were practically missed. In the time of MEMF exposure, both decrease and increase of the pulsation frequency could reliable take place (Table 19.3).

Table 19.1.

Comparative performance of percent of responses of neurons of sensomotor and parietooccipital ranges of the brain cortex of the rabbit in experiments with MEMF irradiation

Series (conditional name)	Brain cortex range	No. of recorded neurons	% of total neuron number		
			Confident pulsation change of:		Not reacted
			increase	decrease	
MEMF	Sensomotorial	105	27.62*	2.38*	40.0*
	Parietooccipital	84	25.0*	29.76*	45.24*
"sham" exposure	Sensomotorial	72	2.7	11.1	86.2
	Parietooccipital	73	5.48	10.96	83.56

* $p < 0.01$ versus control, by χ^2 criterion

Table 19.2

Performance of frequency pulsation of neurons in sensomotorial and parietooccipital ranges of the brain cortex of the rabbit in experiments with a "sham" irradiation

Brain cortex range	Response character	Central frequency, Hz		
		before	during	after
Sensomotorial (72 neurons)	Excitation	5.2±1.32	6.94±1.5	7.8±1.09
	Inhibition	9.1±0.62	6.1±0.83	6.3±0.98*
	Not reacted	8.7±0.4	8.0±0.44	8.6±0.41
Parietooccipital (73 neurons)	Excitation	2.26±1.5	4.1±1.6	8.4±1.9
	Inhibition	5.47±0.94	3.2±0.92	3.93±0.85
	Not reacted	6.2±0.42	5.8±0.38	6.5±0.39

Footnote. The quantitative performance of responses is submitted in Table 19.1. $p < 0.05$ versus an initial background on a Student criterion.

Table 19.3.

Performance of responses of neurons of sensomotor and parietooccipital ranges of the brain cortex of the rabbit on the MEMF irradiation

Brain cortex range	Response character	Central frequency, Hz		
		before	during	after
Sensomotorial (105 neurons)	Increase	6.1±0.89***	11.2±0.64*	9.2±0.58*,**
	Decrease	8.92±0.88	4.32±0.7*	8.85±0.69**
	Not responded	6.9±0.54	7.5±0.69	7.1±0.85
Parietooccipital (84 neurons)	Increase	4.92±0.45***	8.4±0.53*	6.9±0.48*,**
	Decrease	6.53±0.39	4.13±0.57*	6.89±0.75**
	Not responded	5.4±0.83	6.38±0.71	6.05±0.66

* $p < 0.05$ versus an initial background on a Student criterion.

** $p < 0.05$ versus the exposure time on a Student criterion.

*** $p < 0.05$ at comparison to background values of neuron pulsations with inhibition character of responses.

At first minute after MEMF exposure in case of an activation of bioelectric activity, the tendency of homing to background magnitudes was marked, and, in case of inhibition, the bioelectric activity did not reliably differ from an initial background. It is necessary to mark, that the character of a modification of neuron pulsations due to the modulated EMF exposure was connected to an initial background. In the background, the tendency to the greater pulsation frequency in a case the decreased rate has taken place in comparison with an acceleration of the discharges of neurons under MEMF effect. In opinion of the authors, the correcting MEMF effect is present.

Above-stated findings are reflected in histograms of the allocation of the frequency of neuron pulsation in MEMF experiments (Figures 19.1 and 19.2). From Figure 19.1 it is visible, that the pulsation frequency of excitatory neurons is reliably enlarged and is saved during all period of the MEMF irradiation. In the time of an after-exposure, the bioelectric impulsive activity was sunk, though remained above background. Surveying a response of neurons pulsation sinking on MEMF exposure (Fig. 19.2), it was marked, that the pulsation frequency was reliably sunk in the time of MEMF irradiation and was recovered up to average background values in the time of “after-exposure”. In the time of MEMF exposure, the packed group irritation of neurons was observed, which in the time of “after-exposure” has regularly varied. These histograms follows, that the character of a neuron excitation was various and depended on an initial background.

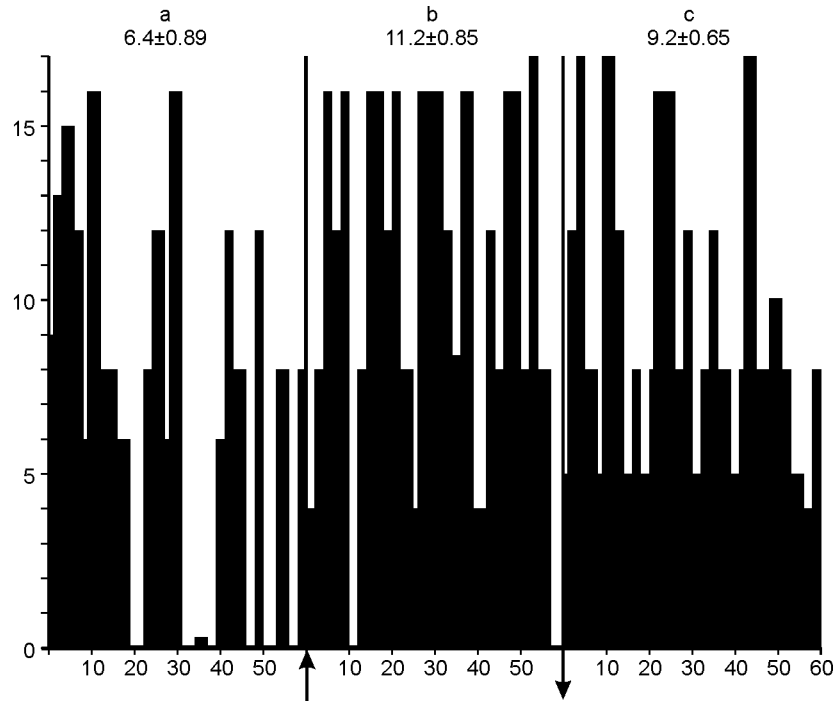

Figure 19.1. A histogram of allocation of frequency of neuron pulsation excitanted in reply to an one-minute MEMF irradiation; a — a background, b — the time of an irradiation, c — after an irradiation. On abscissa axis — time, s; on an axis of ordinates — pulsation frequency, s^{-1} (Hz).

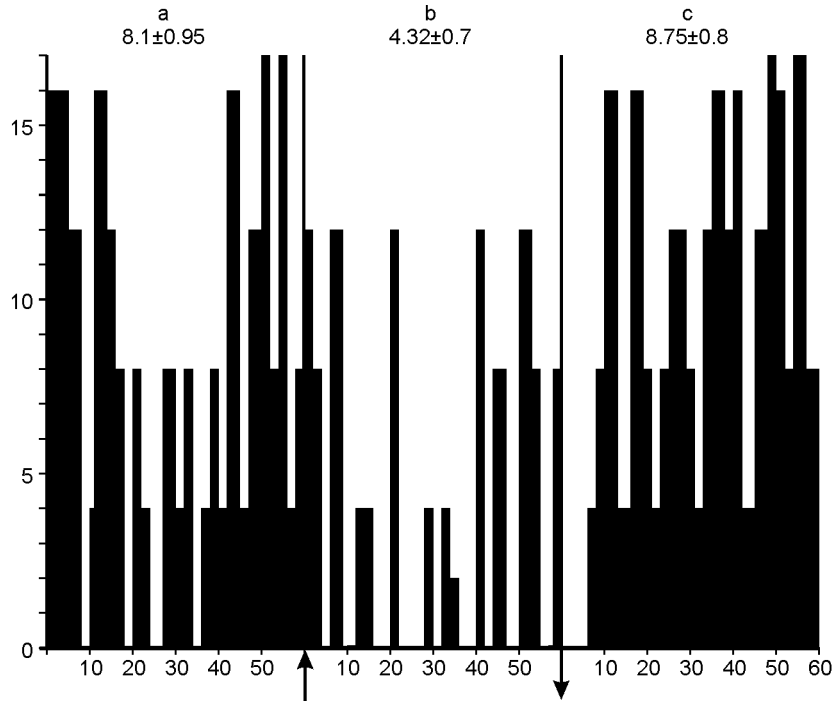

Figure 19.2. A histogram of allocation of frequency of neuron pulsation inhibited in reply to an one-minute MEMF irradiation; a — a background, b — the time of an irradiation, c — after an irradiation. On abscissa axis — time, s; on an axis of ordinates — pulsation frequency, s^{-1} (Hz).

Thus, the presence of a response of extracellular bioelectric activity of neurons on low intensive MEMF is found. The character of a response was determined by a background, testifying correcting MEMF effect.

Some examinations were dedicated to examination of modulated EMF effect on bioelectric activity of the animal brain. Certainly, the given pilot model does not allow quantitatively precisely to estimate character of modifications, however to reveal the particular tendency of modulated EMF effect on a spectrum of bioelectric activity of a brain.

The effect of 980 MHz EMF pulsewise modulated at 12 and 27 Hz, S=30–50 mW/cm^2 on bioelectric activity of the brain (Chart No. 20 of Annex) was examined. The experiment was conducted on cats. The EEG was realized by carbon leads in range of vertexum. Time of single-pass exposure was 20 min. During repeated MEMF exposures, the augmentation of spectral rate of a spectrum of biological currents in the 12–18 Hz band.

In the other experiment the effect on cooperative bioelectric activity of various frames of a brain for modulated low intensive EMF (Chart No. 21 of Annex) was investigated. Four series of experiments were conducted:

1. control — sham irradiation — K;
2. Series with an impulsive irradiation at frequency of 0.12 Hz (O_1);
3. Series with an impulsive irradiation at frequency of 1000 Hz (O_2);
4. Series with packed impulsive irradiation; a pulse-recurrence frequency — 1000 Hz, recurrence rate of packs — 0.12 Hz (O_3).

In all cases PFD was 300 μW/cm^2 in impulse. One rabbit have been exposed to only one regimen of an irradiation: single 30 min exposure. However, each animal in the casual order has participated in a control series with a sham irradiation. Detailed quantitative performance of experiments and the parameters of an irradiation are submitted in Tables 21.1 and 21.2.

Table 21.1.

Quantitative performance of experiments

Series		No. of rabbits	No. of 30 min exposures
No.	Conditional name	In series	In series
1	K	30	-
2	O_1	10	10
3	O_2	10	10
4	O_3	10	10

Table 21.2.

Parameters of MEMF irradiation

No.	Conditional name	Irradiation parameters							Exposure time, min.
		Carrier frequency, Hz	Mode	Characteristics of;					
				pulses		packs			
				S, μW/cm^2	Duration, ms	Frequency, Hz	Duration, ms	Frequency, Hz	
2	O_1	1.5	Pulsed	300	16	0.12			30
3	O_2	1.5	Pulsed	300	0.4	1000			30
4	O_3	1.5	Packed pulsed	300	0.4	1000	16	0.12	30

The electrodes were implanted to each rabbit on the conventional method, according to coordinates submitted in the stereotactical atlas of E. Fifkova and J. Marshal. The ranges of a cortex and following subcortical formations were examined including: the basal amigdalum core (AB: AP-1, SD-5, V-16), hyppocampus (HiP: AP-5, SD-5, V-5), septum (NSL: AP-4, SD-1, V-3), front department of hypothalamus (AHA: Ap-2.5, SD-1.5, V-12), head of the tail kernel (PS: AP-4.2, SD-2.8, V-8.6). In a cortex and hyppocampus, most electrodes were implanted at the left and on the right, and on the right in remaining parts.

As electrodes and abducent wires have utilized chlorine vinyl pipette and tubes filled with normal saline solution on the basis of agar in a consistence of a gel. They had resistance of 1 MOhm and met the requirements showed to conductors of biological potentials. Abduction of biological currents was realized by a monopolar method with inert electrodes on nasal bones. In the time of experiment, the rabbit was softly fixed for paws on the wood machine tool. The experiments were conducted in conditions of electrophysiological experiments meeting the MEMF test requirements.

As a result of the conducted experiment, the reliable modifications of bioelectric activity of frames of a brain were obtained at all three modes of exposure, approximately equally. It has not allowed the authors to share conditions of exposure on their efficiency. In all three series, modifications were determined by an initial background, however they did not fall outside the limits of normal functioning and concerned, mainly, θ ranges of hyppocampus. The reliable difference between control and irradiation was marked only in biological currents of hippocampuses.

Thus, the conducted experiments have shown, that low intensive short-term MEMF exposure in three used regimens can reliably vary bioelectric activity of the rabbit brain.

The experiment was posed with the purpose of clearing up of mechanisms of the suppression of somatic vegetative responses to modulated EMF (Chart No. 22 of Annex). The experiment was tried in rabbits. Animals were irradiated to EMF at 40 MHz with modulation of 7 Hz, field strength from 30 up to 300 V/m. The duration of exposure was from 10 mines up to 2.5 hours.

At the first stage, the effect of the suppression of somatic vegetative responses was found to be induced by the irritation of the ventral kernels of a hypothalamus. On the second investigation phase, they have conducted a serial coagulation of separate frames of the brain and found, that the reticular formation participates in realization of vegetative reciprocal responses at MEMF exposure.

The responses in various compartments of the nervous system were examined at modulated EMF exposure in conditions of an emotional stress (histochemical examinations). (Chart No. 23 of Annex).

The rabbits in a state of an emotional stress were utilized. Animals were irradiated to EMF at 39 MHz, modulation of 7 Hz, depth of modulation of 80%, field strength of 30 V/m. A field was framed between two plates of the capacitor coherent with the SHF generator. Immobilized animals were disposed between plates, so that saggetal line of the body was placed horizontally and perpendicularly to lines of MEMF force. A radiation time was 3 hours. The examinations were conducted at once after an irradiation.

The tests were conducted on 86 rabbits. The emotional stress was invoked by an electrical current irritation in hypothalamus, skin of extremities and ears. In a nodulose ganglion of a vagus nerve, upper cervical, star-shaped ganglions, sympathetic clusters and clusters of a sympathetic line-up at a level 4–6 of thoracic segments they have determined a content of water-soluble proteins. A spectrum of lactate dehydrogenase (LDH) was examined in clusters of an independent nervous system and conductive system of heart.

MEMF has selectively labilized limbic frames of the brain and depressed the bottom-up effect of a reticular formation on a cortex of major hemispheres, rising fastness to an emotional stress and enlarging ability to adaptation.

For an assessment of a role of modulation at MEMF exposure, the procedure detailed in general physiology of imprinting (Chart No. 24 of Annex) was utilized. The imprinting is an original aspect of memorizing: at birth the organism fixs in the memory, that it has seen for the first time.

129 embryos of chickens were irradiated at day 16 of an incubation to EMF at 9.3 GHz; 5 min exposure, S=40 $\mu W/cm^2$ with a quantization of 10 and 40 Hz, meander, pulse duration of 2.5 ms. Besides, there were series with a continuous irradiation (CW) and "sham" exposure.

The imprinting suppression (up to 50%) was found in newborn chicken only for series of EMF exposure at 10 and 40 Hz (Table 24.1.). In case of CW exposure (S=40 $\mu W/cm^2$) and in control group, the imprinting disturbance was not found.

Table.24.1.

Imprinting in chickens after an EMF irradiation of embryos for continuous and modulated regimens

Series No.	Series name	PFD, $\mu W/cm^2$	Exposure time	No. of embryos	No. of chickens with imprinting
1	Control – sham exposure	-	-	83	81 (97%)
2	Continuous exposure	40	5	27	23 (89%)
3	10 Hz or 40 Hz modulated exposure	40	5	19	9 (50%)

In one of experiments the problem was posed to examine the possibility of the brain bracing of a particular regimen of EMF modulation (Chart No. 25 of Annex). In this experiment, the imprinting model was also utilized, and the signal of a EMF quantization was utilized as imprint stimulant. An irradiation of chickens was realized at incubation day 16 in non-echo chamber: EMF at 9.3 GHz with the quantization of 1, 2, 3, 7, 9 or 10 Hz, S=0.04 mW/cm^2, time of each irradiation was 5 minutes.

The possibility for the development of temporal communications at 15 diurnal chicken embryos was earlier shown through an electrocurrent and sound (Hunt, 1949). Taking into account these results, the authors have assumed, that the electromagnetic modulation waveform can be fixed by a brain and gain value of an imprint signal. The plan of experiment was as follows: incubation day 16 embryos were MEMF irradiated with modulation of 1, 2, 3, 7, 9 and 10 Hz. After birth of chickens, the sensing imprinting period (24 hours after birth) was passed and in this period any choronomic irritator was not shown to a chicken. In 48 hours after birth, strobe lights with the same frequency were shown to a chicken as imprint stimulant, from which the embryo was subjected to an electromagnetic irradiation for day 16 of an incubation. The difference between alleged light stimulant and differentiation stimulant was equal to 8 Hz.

The experiments were conducted on 127 embryos (chickens). A possibility of imprinting exhibiting on imprint stimulant with the light frequency similar to EMF modulation, which has exposed embryos at day 16 of an incubation, and at light blinking frequency of 1, 2, 3, 7, 9 or 10 Hz is submitted in Figure 25.1. The analysis of the obtained materials has allowed the author to make a deduction, that the obtained data testify that the embryo brain at day 16 of an incubation can fix electromagnetic stimulant with modulation of 9 or 10 Hz and store this information during particular time after birth. Thus, the obtained data assume, that the regimen of EMF modulation can be fixed by a brain.

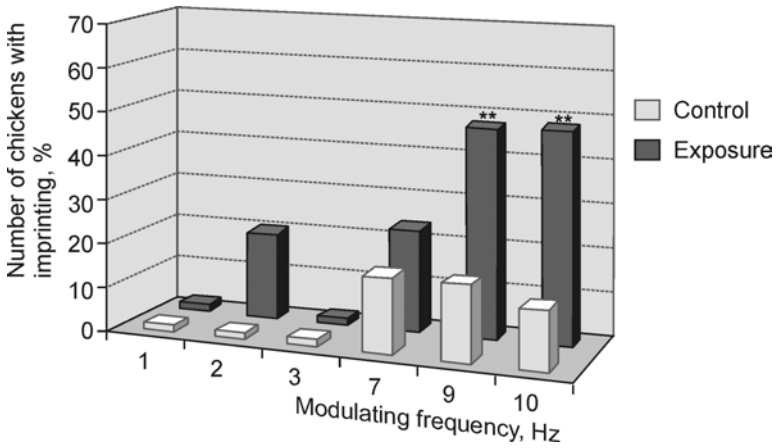

Figure 25.1 Number of chickens, which brain has fixed an electromagnetic modulation waveform (imprinting is established)

The fruit fly embryos were utilized for an assessment of the modulated EMF biological effect (Chart No. 26 of Annex). Embryos were irradiated to MEMF at 460 MHz, quantization 2.5, 6, 10, 16, 22 and 40 Hz (porosity of 25), average SAR of 0.12 W/kg, absorbed power per impulse of 3 W/kg. The SAR impulsive magnitude was identical at porosity from 12.5 up to 6 at frequency of modulation of 16 Hz. Embryos were irradiated at temperature +24.5°C. Control groups: a "sham" irradiation and physical control. Time of exposure is 5 minutes.

Time of embryo development (age) was counted from a beginning of egging on a medium within 10 minutes accuracy. In experiment they have utilized embryos in the age of 15 hours and 10 minutes. The tests were tried in 30 thousand embryos and the sample size was not less than 1000 on each experimental point.

The results of experiments were estimated on an percentage of the interrupted development (PID) calculated as percent of imagoes from conforming egg number, which amount was 100%. PID was taken into account in three experimental groups: (1) test group, in which embryos were subjected to MEMF irradiation; (2) "the sham irradiated group", in which embryos were subjected the same experimental procedures, as irradiated embryos, but without EMF exposure (delivery to a place of an irradiation, location on 5 min in temperature controlled conditions, the EMF generator was switched off, homing in a thermostat for an incubation); (3) control embryos group, which all time were in temperature-controlled conditions (24.5°C), on which they have estimated a streaming functional state of a laboratory population of flies.

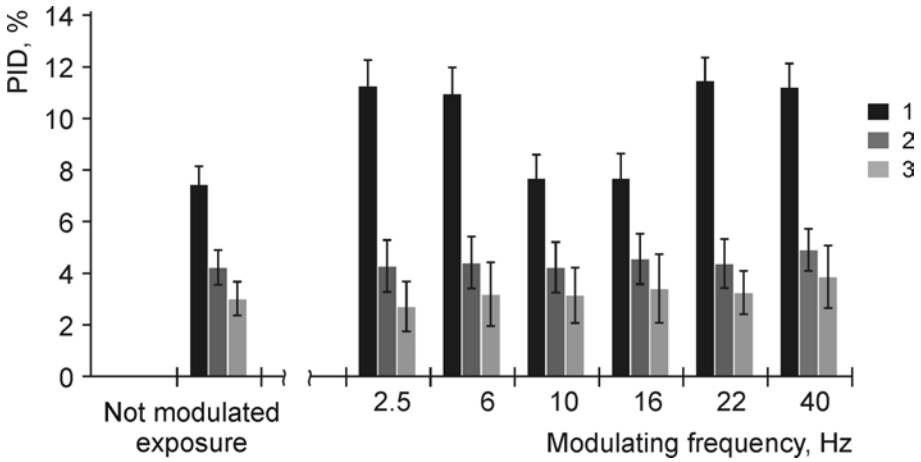

Figure 26.1. Effect of MEMF exposure at 460 MHz on SAR of the fruit flies (the average values and errors, average with level of significance < 0.05) is submitted. For comparison the results for 5 minute not modulated exposure with SAR of 6 W/kg are given. 1 — SAR after an MEMF irradiation; 2 — SAR for "sham irradiated" flies; 3 — SAR in laboratory control

The results of the experiment has shown, that the MEMF irradiation has rendered effect on embryos of the fruit fly in the age of 15 hours 10 mines. This effect depends on frequency of modulation (Fig. 26.1 and 26.2). It is important to mark, that difference in modulated (0.12 W/kg) and not modulated (6 W/kg) SAR has resulted to almost 50 times difference.

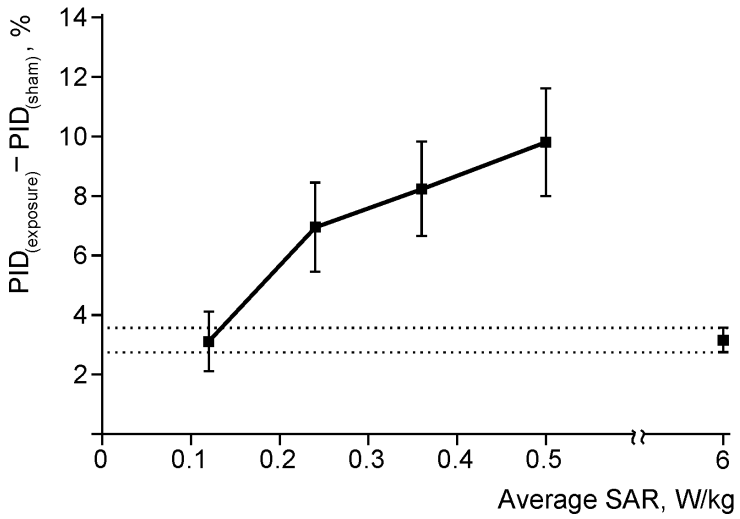

Figure 26.2. The dependence of MEMF irradiation effect in embryos of the fruit flies at frequency of 16 Hz (average SAR varied in dependence on porosity — from 25 up to 6). For comparison the average value of effect is submitted for not modulated EMF with SAR of 6 W/kg and error of mean (dashed lines).

The modulated EMF effect in the fruit flies embryos on the background of a temperature rise of environment (Chart No. 27 of Annex) was examined. The tests were tried in 15 thousand embryos, which were subjected to not modulated EMF with SAR of 6 W/kg (in impulse) and 0.12 W/kg (in average) and modulated electromagnetic exposure at 6, 10, 16, 22 Hz, SAR of 3 W/kg. In all series, including control, the ambient temperature was 40°C. For all modes of exposure the sample was not less than 1000 embryos for each of groups.

The results of exposure were estimated on percentage of the interrupted development (PID). PID magnitude was calculated as percent of imago from conforming total egg pool, which total amount was 100%. PID was estimated in four various groups: (1) continuous irradiation of embryos, (2) MEMF irradiated embryos; (3) “sham” irradiated embryos, which were subjected to elevated temperature only without EMF and (4) control embryos, which were constantly contained in temperature-controlled conditions at fixed temperature of 24.5°C. The effect of exposure was determined as a difference between PID of groups subjected to continuous EMF, modulated EMF and “sham” irradiated groups.

Combined exposure to not modulated EMF with SAR of 6 W/kg and heat up to 40°C has resulted to inappreciable PID augmentation; the effect has appeared statistically not significant in comparison with effect at standard temperature of 24.5°C: 3.8±1.1% in conditions of heat against 3.2±0,7% at standard temperature. The effect of elevated temperature exposure only (40°C) has made 1.3±0,7%.

The findings of investigation of MEMF effect on a background of heat is submitted in Figure 27.1. As it is visible from this drawing, the effect essentially depends on frequency of a quantization. MEMF with frequencies of modulation of 6 and 22 Hz on a background of heat was specific to some enlarged PID, in comparison with PID at standard temperature. Vice-versa, at frequencies of modulation of 10 and 16 Hz, the exposure on a background of elevated temperature has initiated smaller PID ($p < 0.05$), rather than at standard temperature (drawing 27.1.). The PID

magnitude under condition of elevated temperature was at PID level for “sham” irradiated embryos.

Thus, the effects of heat and exposure of a EMF quantization of 6 and 22 Hz are additive. At frequencies of 10 and 16 Hz the bioeffect was decreased.

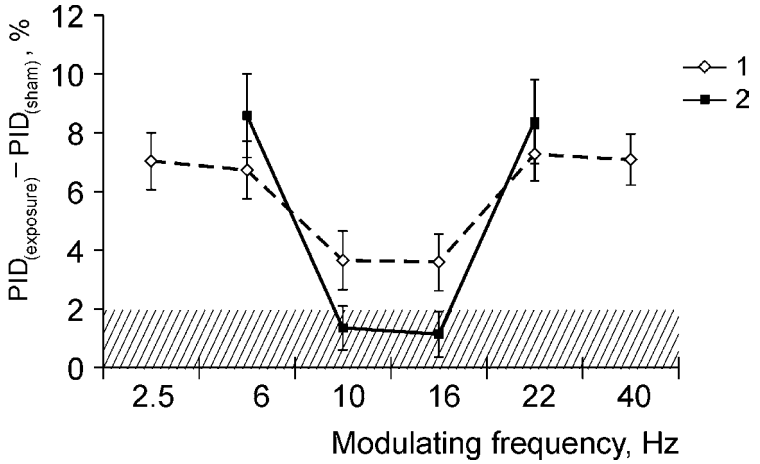

Figure 27.1 Modifications of percent of the interrupted development in the fruit flies after 5 minute MEMF exposure of embryos of age of 15 h 10 mines at standard temperature of 25°C (1) and on a background of elevated temperature of 40°C (2). The shaded space — 95% confidence interval for average PID values of “sham” irradiated embryos

The low intensive modulated EMF effect on development and vitality of Tickhyalomma Asiaticum (Chart No. 28 of Annex) was investigated. The tests were put on ovums, hungry larvas, satiated larvas and hungry nymphs of the first laboratory Tickhyalomma Asiaticum generation.

The MEMF irradiations was conducted through days 5–10 after the egg pool forming or after a saturation of insects and passage them in the following phase of development. They have utilized the following modes of exposure: R1 (K) — “sham” irradiation; R2 — broadband radiation in a band of 1–4 GHz, quantization of 7 Hz, pulse duration of 20 ms, average S=20 μW/cm^2; R3 — carrying frequency of 3 GHz, packed quantization, frequency of impulses of 1 kHz, frequency of following of packs of 7 Hz, duration of a pack of impulses of 20 ms, average S=10 μW/cm2; R4 — same, as R3, but at average S=20 μW/cm2; R5 — broadband radiation in a band of 1–4 GHz, quantization of 2 Hz, pulse duration of 20 ms, average S=30 μW/cm2; R6 — carrying frequency of 1 GHz, quantization of 2 Hz, pulse duration of 20 ms, average S=30 μW/cm^2. The examinations were conducted at once after an irradiation and during all development cycles.

Insects were kept at ambient temperature (22–23°C) in the humidified scoops. Each test has consisted of 2–4 repeated variants, and the separate variant has included either one complete egg pool or 10 larvas and nymphs.

The following basic results were obtained.

1. *MEMF ootids irradiation effect in hungry larvas delivery*. Total number of delivered larvas was identical in all series. The differences were found in course and terms of their delivery, and also in dynamics of the subsequent activity. The delivery delay was observed in all experiment variants. In control, 50% of larvas were delivered at day 12 versus days 15–32 for irradiated ones (table 16.1). The least delay in development was marked in a regimen R2. The variance between experiment and control in this case has made 3.4 days ($p < 0.09$). The delivery of 50% of larvas in regimens R3 and R4 was at days 25.3 and 32.2, accordingly. The differences from control were statistically reliable ($p < 0.01$); the difference between control and experiment has achieved accordingly 13.4 and 20.3 days. The similar tendencies were noted in dynamics of activity of delivered larvas. Insects delivered from intact and irradiated

parents in regimen R2 became fissile at the first day after delivery, while in regimens R3 and R4 the activation was delayed and the delay halftime, T_{50} was different ($p < 0.0001$) for intact and irradiated egg pools (regimens R3 and R4), so the essential differences were for variant R2 versus variants R3 and R4.

2. *MEMF effect on a survival rate of hungry larvas and nymphs*. The MEMF irradiation of hungry larvas and nymphs was conducted on days 7–10 after delivery. The duration of the surviving of larvas and nymphs in all variants of experiment was lower, than that in control. So, the parameter T_{50} for larvas and nymphs in control has made accordingly 13.8 ± 1.9 and 36.9±2.0 (tables 16.1.), in experiment (regimens R4 and R5) it was less (9.5–11.9 and 27.1–28.2) at days 2–4 and 9–10.
3. *MEMF effect on development of satiated larvas.* The experiment was conducted on insects of spring and autumn generations. An irradiation of satiated larvas was conducted at day 10 after insect saturation. They have utilized regimens R3, R4, R5 and R6. First delivered nymphs have appeared in identical terms after an irradiation, both in spring, and in autumn generation: on days 16–18 after the saturation of larvas; the experimental and control variants did not differ. On other parameters the essential apostatizes were observed. The molting of both irradiated, and intact insects of spring generation flowed past in considerably more short terms, than for autumn one. The period of molting in the first series has occupied from 2 to about 5 days, whereas it was 8–12 days in second series. The greatest apostatizes are marked in an amount of delivered nymphs. The satiated larvas of spring generation have appeared less sensing to all EMF regimens. In all variants, 100% of metamorphosises of larvas in nymphs were observed. The subsequent survival rate of delivered hungry insects did not differ from control values and was close to 100% within 16^{th} –25^{th} subsequent day.
4.

Table 28.1

MEMF Effect on delivery, activation and duration of a surviving of hungry nymphs of various phases of Hyalomma asiaticum development

Exposure regimen	No. of insects	No. of groups	Regression factor	$T_{50,}$ days
Delivery duration of larvas				
R1(K)	3000	2	0.24±0.002	11.9±1.0
R2	3000	2	0.25±0.01	15.3±0.1
R3	3000	2	0.08±0.01	25.3±0.1
R4	3000	2	0.07±0.01	32.2±0.7
Activation duration of larvas				
R1(K)	3000	2	-	1.0
R2	3000	2	-	1.0
R3	3000	2	0.08±0.01	17.03±0.4
R4	3000	2	0.07±0.01	23.9±0.5
Survival duration of hungry larvas				
R1(K)	20	2	0.14±0.01	13.8±1.9
R4	20	2	0.14±0.01	11.9±1.0
R5	20	2	0.14±0.01	9.5±4.0
Survival duration of hungry nymphs				
R1(K)	150	15	0.05±0.01	36.9±2.0
R4	150	15	0.05±0.01	27.1±2.7
R5	250	20	0.05±0.01	28.2±20

Thus, MEMF has practically invoked noticeable physiological modifications in Hyalomma asiaticum organism for all examined regimens. These modifications were expressed in the delivery delay of larvas from irradiated egg pools, in the decrease of the activity and survival rate of delivered insects. The similar findings were observed in the delivery course of hungry nymphs from the irradiated larvas. The augmentation of the average PFD from 10 up to 20 $\mu W/cm^2$ has enhanced the observable effect. So, the delivery duration and activation of 50% of larvas was enlarged for 30–35%, and the survival rate of hungry nymphs of autumn generation, vice-versa, was sunk twice.

The experimental application of the broadband radiations in a band of 1–4 GHz (R2 and R5) with frequencies of modulation of 7 and 2 Hz has invoked generally similar, but essentially less expressed effects, than on carrier frequencies of 3 and 1 GHz with the same modulation. The most expressed biological effect of radiation was expressed in depressing of development and augmentation of the insect mortality, on miscellaneous phases of its life cycle, which was detected for exposure at 3 GHz with frequency of modulation of 7 Hz. The especially acute violations in weep of physiological processes have taken place during embryonic development and metamorphosis.

CONCLUSOION

The analysis of 28 biological experiments conducted in vitro, in situ, and in vivo in the former Soviet Union (FSU) and later in Russia with usage of the modulated electromagnetic fields of radiofrequency allows to make the following basic conclusions:

- EMF exposure of biosystems with less or more composite regimens of modulation the development of bioeffects, both physiological, and unfavorable, which are distinct from bioeffects induced by not modulated EMF is possible;
- the acute modulated EMF exposure of low intensities (non-thermal levels) can result in development of pathological effects;
- there is a dependence of development of a reciprocal biological response on the intensity and directness of the concrete regimen of EMF modulation; this dependence was fixed at all levels of biological systems — in vitro, in situ and in vivo;
- as a rule, modulated EMF has invoked more expressed bioeffects, than continuous regimen of modulation;
- the effect of EMF RF modulation is more expressed at lower levels of intensity.

The obtained data have specified the possibility of the effect of EMF modulation on the development of biological effect at a level of composite systemic interactions in an organism. It allows to discharge modulated EMF in the special group of radiations, which biological effect depends not only from magnitude of an absorbed energy, but also on the form of modulation “addressed” to this or that functioning system. It determines the conclusion, that at an assessment of modulated EMF danger, it is important not only to assess magnitude of an absorbed energy, but also the fact of contact of the human with this aspect of radiation. This circumstance brings in major indeterminacy by development of the EMF standards.

The individual singularities of the man are essentially important, the individual sensitivity to a particular regimen of EMF modulation, that dilates a problem of hypersensitivity to EMF.

As a result of the conducted experiments with MEMF, the effect of an initial state of biosystem on expected effect is detected. The given fact is rather important, since does not allow to establish common regularity in the development of bioeffects at particular aspects of modulation. As a matter of fact, the initial background of a system of an organism can determine the character and directness of a reciprocal response, that complicates the prognosis of expected effects in conditions of MEMF exposure on the population.

The role of modulation gains the major significance at low intensity (at non-thermal levels of EMF). In this connection, this factor becomes now leading at an assessment of population exposure to EMF RF.

The experimental recognition of dependence of development of bioeffect from an aspect of modulation specifies recruitment phenomenon of new gears of interaction of an organism with MEMF, which are not clear and demand the future study.

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RECOMMENDATIONS ON THE IMPROVEMENT OF APPROACHES AND PRINCIPLES OF EMF REGULATING

REPORT

Is prepared within the framework of performance of Task No.3
of ISTC Project No. 2362p
" Original materials for the standards of electromagnetic fields "

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ABSTRACT

The report contains 32 pages of the text, 3 tables, 48 literary references

ELECTROMAGNETIC FIELDS OF RADIO-FREQUENCIES, REGULATING ELECTROMAGNETIC FIELDS, BIOLOGICAL EFFECT, MAXIMUM PERMISSIBLE LEVEL, THRESHOLD OF A HARMFUL EFFECT, ADAPTATION, COMPENSATORY RESPONSE.

The principles of regulating electromagnetic fields of radio-frequency band are surveyed in the report. The development of the problem in the USSR is submitted since 1973, when the first demands to standardizing EMF were formulated. The final materials on a justification of maximum permissible levels of electromagnetic fields of radio-frequencies carried out on tasks 1 and 2 of ISTC Project No. 2362p are toted.

The references on perfecting the approaches and principles of a regulating of electromagnetic fields, on magnitudes maximum permissible levels for controllable and uncontrollable conditions are submitted.

TABLE OF CONTENTS

ABBREVIATIONS

AMS	—	Academy of medical sciences
AS	—	Asthenic syndrome
CNS	—	Central nervous system
CRA	—	Conditional reflex activity
CVS	—	Cardiovascular system
EE	—	Energy exposure
EFD	—	Energy flux density
EMF	—	Electromagnetic field
EMR	—	Electromagnetic radiation
GOST	—	State branch standard
HET	—	Harmful effect threshold
HNA	—	Higher nervous activity
ICNIRP	—	International commission on non-ionizing radiation protection
ICRP	—	International commission on radiological protection
LH and OD	—	Labor hygiene and occupational diseases
LILP	—	The Leningrad institute of labor protection
LW	—	Long waves
MEMF	—	Modulated electromagnetic field
MMA	—	Military medical Academy
MPC	—	Maximum permissible concentration
MPL	—	Maximum permissible level
MW	—	Middle waves
NEL	—	Non-effective level
NII	—	Research institute
NPP	—	Nuclear power plant
RAMS	—	Russian Academy of medical sciences
RAS	—	Russian Academy of sciences
RF	—	Radio-frequency
RS	—	Radar station
SanPiN	—	Sanitary regulations and norms
SHF	—	Super high frequency
SW	—	Short waves
TPL	—	Temporal permissible levels
TSR	—	Temporal sanitary rules
UHF	—	Ultra high frequency
USW	—	Ultra short waves
VNII	—	All-Union research institute
VVD	—	Vegetative vascular dystonia
WHO	—	World health organization

INTRODUCTION

Till now there are essential apostatizes in the scientific approaches of a regulating electromagnetic fields of radio-frequencies (EMF RF), existing in Russia, in series of the European countries and USA. These differences concern first of all, to recognizing or non-recognition a possibility of development of unfavorable (not physiological) bioeffects under EMF exposure of so-called non-thermal intensity (up to 1 mW/cm^2).

There are various points of view on criterion of an assessment of a possible unfavorable EMF effect, on magnitude of coefficient of a hygienic reserve, on the count of possible effect of development of bioeffect of various aspects of modulation, on necessity of the count of results for a justification of EMF maximum permissible of levels (MPL) obtained as a result of clinical hygienic and experimental examinations, or only in experiments on animals.

Till now, international committee on non-ionizing radiation protection (ICNIRP) justifies the standards from results of acute tests. In 1973, in USSR the necessity of carrying out of chronic experiments on various animal species was determined at various levels of exposure for the development of EMF standards.

These and other issues of regulating EMF RF in the USSR and later in Russia are considered by this report. The recommendations on the improvement of the approaches and principles of a EMF RF regulating for controllable and uncontrollable conditions (for the workers professionally bound with sources of electromagnetic fields and whole population) are explained.

1. PRINCIPLES OF A REGULATING OF ELECTROMAGNETIC FIELDS IN THE USSR (RUSSIA)

The development of problems of the theory and practice of a regulation of electromagnetic fields in scientific establishments of country went simultaneously with deriving the new data on a EMF biological effect. The serious progress in generalization of results of examinations was made in 1970th. At that time, a considerable phenomenological material on the biological effect of electromagnetic fields of radio-frequencies was already accumulated abroad. The clinical picture of distresses and lesions originating in an organism under EMF exposure of high levels is enough circumscribed. The first clinical works on unfavorable modifications in an organism have appeared at EMF exposure of low levels. The modulations and other parameters of radiation were correlated to bioeffects on intensity, duration of action, and frequency band.

1.1. History of a regulating of electromagnetic fields of radio-frequencies in USSR (Russia)

In 1973 in Military Medical Academy (Leningrad) the workshop on principles and criteria of an assessment of a biological effect of radiowaves was held [1, 2].

By April 23, 1974, at session of section on "Hygiene of labor and biological effect of non-ionizing radiation», the Recommendations to carrying out of experimental examinations for a justification of maximum permissible levels of EMF of radio-frequencies were discussed and approved. The purpose of the document is to promote deriving of homogeneous materials permitting to conduct their comparison and generalization, with further usage at a justification of maximum permissible of EMF level for electromagnetic fields at workplaces.

In 1977, in the Moscow research institute of labor hygiene and occupational diseases (NII of LH and OD) of the Academy of medical sciences (AMS), the All-Union seminar on methodological problems of hygienic regulating of non-ionizing radiation was held [3]. To treat the indicated problems, the proceedings edited by prof. B.M. Savin (1979, [4]) were published [4].

Closing stage in tentative development of principles of a EMF regulating in the USSR was the scientific conference on "New aspects in hygienic regulating of non-ionizing radiation" hold in the Leningrad Military medical Academy (MMA) in 1989 [5].

1.1.1. Regulating electromagnetic fields for the professional workers

The applications of electromagnetic fields of ultra high frequencies (UHF) with the purposes of radiocommunication and medicine in 1930th have promoted appearance of the first Russian works on their harmfulness. The first limitations of EMF levels on workplaces have concerned the medical personnel working with UHF therapy installations [6, 7]. In 1938, the technical Specifications on protective measures at work with UHF in medicine have specified, that for the magnitude of the field strength should not exceed 0.1 V/m in any point of space of 5 meters apart from UHF apparatus. In the "Safety Rules in physiotherapeutic cabinets of medical institutions" it was noted, that "the operation of UHF generators with power rate higher than 200 W in a contour of the patient is linked to the presence of a harmfulness for the handling staff, which is long staying in fields framed by electromagnetic oscillations around of the installation" [8].

In 1953, basing only upon clinical and hygienic scientific examinations elaborated by the Leningrad research institute of labor hygiene and occupational diseases and Leningrad institute of labor protection (LILP) first approximate MPLs of electric fields of a high frequency band were offered [9]. The given frequency range of during this period of time was already

widely utilized in an industry for inductive and dielectric heat. The criterion of a harmfulness was served by a parameter of a prevalence of functional disturbances of a central nervous system (CNS), such as asthenic and asthenic-vegetative syndromes, vegetative dysfunction and others. As an approximate maximum permissible level at work with currents of a high frequency of a band of long and middle waves, the values of 10 V/m on workplaces at inductive contours and 5 V/m were proposed in those places of locations, where people could be present. First scientifically justified document of the sanitary law regulating EMF levels was the document on "Temporal sanitary regulations for work with vacuum-tube oscillators of a high-frequency heating"; No. 180–55 (1955) [10]. As on the establishment of results of clinical examinations MPL was fixed in range of UHF band of 5 V/m.

The further period of EMF bioeffects study with the purpose of regulation of exposure is characterized by wide development alongside with clinical hygienic examinations, experimental research projects on animal and examinations with volunteers. The number of scientific establishments working in a direction of a hygienic regulating of electromagnetic fields on workplaces is enlarged. First of all, these are institutes of a hygienic profile: research institutes of labor hygiene and occupational diseases of the USSR Academy of medical sciences, Moscow, Leningrad, Gorky, Kiev, Kharkov institutes, and also Leningrad Military medical Academy and Leningrad institute of labor protection. Simultaneously, in scientific establishments of country, the examinations on mechanisms of an EMF effect are unfurled.

Basing upon results of the conducted examinations, in 1958 the first electromagnetic radiation MPL on workplaces was fixed over super high frequency (SHF) band (0.3–30 GHz) [11]. Fixed admissible magnitudes of radiation intensity in this document are differentiated with the count of the temporal factor, as follows:

a) No more than 10 $\mu W/cm^2$ at duration of an irradiation during whole working day;
b) No more than 100 $\mu W/cm^2$ at duration of an irradiation of up to 2 h for a working day;
c) No more than 1 mW/cm^2 at duration of an irradiation no more than 15–20 min for a working day.

In 1962 the band of regulated frequencies was extended up to 300 GHz.

In 1966 the Temporal sanitary regulations (TSR) No. 180–55 were replaced by the sanitary Regulations released for the work with sources of electromagnetic fields of high and super high frequency [12] designed with participation of Leningrad NII of LH and OD of the USSR AMS for frequencies of 60 kHz – 3 MHz, 3–30 MHz and 30–300 MHz. In these rules, the radiation intensity on workplaces was estimated not only on magnitude of electrical component but also on magnetic component.

Maximal permissible magnitudes of an irradiation in a band of a high frequency (60 kHz – 30 MHz) were as follows:

For installations of induction heating:
On electrical component — 20 V/m;
On magnetic component — 5 A/m.
For installations of dielectric heat, locations of radiostations etc. — 20 V/m.

In a UHF band (30–300 MHz) the limit level of an electric field strength was fixed equal to 5 V/m.

In 1972, in addition to the mentioned above rules for microwave radiation, the standard which is taking into account combined action of a SHF with a mild X-ray radiation and a heat of air were approved. In such case, the maximal radiation intensity was limited to 100 $\mu W/cm^2$ at exposure within 2 h.

In 1975 the special standard for SHF radiation of radar stations (RS) was established: 100 $\mu W/cm^2$ at an irradiation within 8 h and 1000 $\mu W/cm^2$ at an irradiation within 2 h. These standards further were approved statutorily as the USSR State branch standard (GOST).

In 1976, in a System of the standards of safety of a labor, the GOST 12.1.006–76 on "Electromagnetic fields of radio-frequencies. General requirements of safety" was released and predicated by the Decision of State committee of the standards of the USS Council of Ministers (January 22, 1976 [13]). This standard was designed by Moscow NII of LH and OD of the USSR AMS, All-Union research institute (VNII) of Labor protection and VNII on normalization in mechanical engineering (VNIINMASH). The period of validity of the standard was established since 01.01.1977 up to 01.01.1982. The standard was spread to electromagnetic fields in a frequency range of 60 kHz – 300 GHz and has established limits of admissible values of EMF strength and power flux density on a workplace of the personnel of installations using EMF energy and on the workers EMF exposed under production conditions, and also methods of monitoring and means of protection.

In correspondence with this standard, EMF MPL for whole working day should not exceed:

On electrical component:

50 V/m — for frequencies from 60 kHz up to 3 MHz;
20 V/m — for frequencies from 3 MHz up to 30 MHz;
10 V/m — for frequencies from 30 MHz up to 50 MHz;
5 V/m — for frequencies from 50 MHz up to 300 MHz.

On magnetic component:

5 A/m — for frequencies from 60 kHz up to 1.5 MHz;
0.3 A/m — for frequencies from 30 MHz up to 50 MHz.

For EMF in a frequency range of from 300 MHz up to 300 GHz MPL fixed on the power flux density (PFD), was peer to 10 $\mu W/cm^2$ at exposure during 8 hour working day (except for cases of an irradiation from rotated and scanning antennas). Thus the MPL value from 10 up to 100 $\mu W/cm^2$ was proposed, if the EMF exposure duration did not exceed 2 h for a working day and in remaining operating time PFD did not exceed 10 $\mu W/cm^2$. The values from 100 up to 1000 $\mu W/cm^2$ were proposed at duration of an irradiation below 20 min for a working day under condition of use of safety spectacles and if in remaining operating time PFD has not exceeded 10 $\mu W/cm^2$.

For rotated and scanning antennas in a frequency range of 300 MHz – 300 GHz, MPL was fixed equal to 100 $\mu W/cm^2$ within whole working day and from 100 up to 1000 $\mu W/cm^2$, if the duration of an irradiation is below 2 h for a working day (in remaining time PFD has to less than 100 $\mu W/cm^2$).

At presence of X-ray radiation or the heat of air in a location (> 28°C) MPL of PFD for a band of 300 MHz – 300 GHz was regulated by values:

10 $\mu W/cm^2$ — at duration of exposure within a working day;
100 $\mu W/cm^2$ — at exposure within 2 h for a working day.

In remaining operating time, the maximum permissible power flux density was circumscribed to a level of 10 $\mu W/cm^2$. The dose of X-ray irradiation of the personnel should conform to values fixed by standards of radiation safety (NRB–69).

In the subsequent years, with the count of the new data and new approaches to the interpretation of previous results, the hygienic standards were repeatedly reconsidered.

In 1979 the passage to a regulating of SHF radiation on a radiation exposure (RE), which depends on intensity and duration of an irradiation was realized. Maximal RE level of SHF radiation for a working day at a continuous irradiation has made 200 ($\mu W/cm^2$) ·h, at intermit-

tent — 2000 ($\mu W/cm^2$) ·h. The maximal level of power flux density was fixed equal to 1000 $\mu W/cm^2$.

For conditions of the combined SHF exposure with low energy X-ray radiation and heat of air the radiation exposure to SHF was circumscribed at 200 ($\mu W/cm^2$) ·h. In such case, the maximal radiation intensity was propose to be equal to 100 $\mu W/cm^2$.

In 1984, time differentiated EMF MPL at frequency range of 0.3–3 MHz and 3–30 MHz were approved for crew of vessels, which members were not professionally linked to service of sources of radiation, but which were exposed to exposure of electromagnetic radiation from antennas of means of a marine radiocommunication on open decks. In 1990, for the same contingent SHF EMF MPLs ЭМИ were approved for ship radar stations.

In 1986, the passage to a regulating EMF radiation exposure on workplaces of the personnel at the frequency range of 0.06–30 MHz, and in 1987 — for a frequency range of 30–300 MHz was realized. The passage to regulation of a EMF RF radiation exposure in a band of 60 kHz – 300 GHz was fixed in the GOST No. 12.1.006–84 with a Modification No. 1 from 01.07.88. [14].

1.1.2. History a regulating of electromagnetic fields for the population

The hygienic EMF rules for the population have appeared much later, than MPL fixed for electromagnetic fields in case of working with sources.

In the USSR, the carrying out of examinations on a scientific justification of MPL of radio-frequencies for the population was entrusted by Kiev NII of common and municipal hygiene named after N.M. Marzeev. Till 1990, the scientists of institute have developed 21 maximum permissible levels of RF electromagnetic fields of a band of various frequency characteristics and regimens of radiation.

So, in 1978, the Sanitary norms and rules of the arrangement of a wireless, television and radar stations have established EMF MPL in occupied places. In the document, five MPLs were submitted for intensity of EMF exposure for following of five bands [15]:

- For LW (long waves, 30–300 kHz) — 20 V/m;
- For MW (middle waves, 0.3–3 MHz) — 10 V/m;
- For SW (short waves, 3–30 MHz) — 4 V/m;
- For USW (ultra short waves, 30–300 MHz) — 2 V/m;
- For SHF (0.3–300 GHz) at an around the clock irradiation from antennas of the radar station — 5 $\mu W/cm^2$.

In the following document on "Temporal sanitary norms and rules of the population protection from exposure to electromagnetic fields framed in radio engineering plants" (1984) MPL EMF exposures to LW, MW, SW, USW were less rigid: 25, 15, 10 and 3 V/m, accordingly [16]. In a SHF band, maximum permissible EMR levels for a continuous irradiation have made 10 $\mu W/cm^2$. The SHF exposure from antennas of the radar station of various assigning (meteorological, civil aircraft) was regulated in dependence on a frequency band and mode of vibration of stations (scan frequency of the antenna, radiation time with one-ordinal intensity, attitude of duration of work on radiation to a common operating time per day). EMR MPL was from 12 up to 140 $\mu W/cm^2$ for radiation from meteorological radar stations and from 15 up to 25 $\mu W/cm^2$ for the radar station of civil aircraft.

In the subsequent years, in addition to the sanitary Regulations of 1984, the sanitary regulations and norms were developed (SanPiN) on "Differentiated on frequency maximum permissible levels for the population of an electromagnetic field (VHF of a wave range of) framed by television stations", [17]; sanitary norms of the combined electromagnetic fields framed by meteorological radar stations [18] and Sanitary norms of EMR framed by coast radar stations.

1.1.3. Order of approval of the standards for the professionals and population in USSR

In the Soviet Union the following order of transit of the documents was accepted.

For the professionals. Under the representation of the USSR Ministry of Health, the institutes of a hygienic profile have developed EMF MPLs and presented materials on a scientific justification maximum permissible of levels to section of "Hygiene of a labor and biological effect of non-ionizing radiation" of the problem commission on "Scientific basics of hygiene of a labor and occupational pathology" of the Academy of medical sciences. The commission has worked on the basis of Institute of labor hygiene and occupational diseases of AMS. Further materials were referred on reviewing and then were surveyed at session of section. On results of treating of all documents, a decision was made on the approval (not the statement or necessity of finishing) of MPL. The positive solution of section was referred in the USSR Ministry of Health, which commissioned the new rules.

For the population. The materials on a scientific justification of EMF MPL for the population were presented to a Problem commission under the physical factors of environment. The problem commission worked on the basis of Kiev NII of common and municipal hygiene named after A.N. Marzeev. The materials were referred on reviewing and then were surveyed at session of a commission. On results of treating of all documents a decision was made on the statement (not the statement or necessity of finishing) of MPL. The positive solution was referred to the USSR Ministry of Health, which commissioned the new rules.

Such order of transit of the documents has existed till 1990.

1.1.4. Regulating electromagnetic fields of radio-frequencies in Russia

In 1994 the Temporal permissible levels (TPL) of exposure to electromagnetic radiation framed by systems of a cellular radiocommunication were released [19], which were spread to conditions of professional and not professional exposure to electromagnetic radiation. These hygienic standards were approved and implemented by the Decision of State Sanitary and Epidemiological Surveillance Committee of Russia in December 27, 1994, (No. 12) for the period of 3 years. It was provided, that as the much as possible admissible PFD value for the professionals should not exceed 1000 $\mu W/cm^2$, at an irradiation of the population living on habituated area, from antennas of base stations TPL should not exceed 10 $\mu W/cm^2$, and PFD at an irradiation of the users of radiotelephones should be no more than 100 $\mu W/cm^2$.

In 1996, the standards of Russian Federation —the sanitary Regulations and norms were implemented (SanPiN) on "Electromagnetic radiation of radio-frequency band (EMF RF)" [20], which have reserved normalized values of radiation exposures and maximal levels in a frequency range of 30 kHz – 300 GHz, fixed in the USSR standards. These standards were designed by Institute of labor medicine of RAMS, Moscow NII of hygiene named by F.F. Erisman of State Sanitary and Epidemiological Surveillance Committee of Russia, Samara branch of NII of wireless communication of the Ministry of Communications of Russia and approved by the Decision of State committee of sanitary epidemiological surveillance of Russian Federation in May 8, 1996. These standards have established the following values of a radiation exposure:

For electrical component

In a frequency range of 0.03–3 MHz — 20000 $(V/m)^2 \cdot h$

3–30 MHz — 7000 $(V/m)^2 \cdot h$

30–50 MHz — 800 $(V/m)^2 h$

50–300 MHz — 800 $(V/m)^2 \cdot h$.

For magnetic component

In a frequency range of 0.03–3 MHz — 200 $(A/m)^2 \cdot h$

3–30 MHz — are not designed
30–50 MHz — 0.72 $(A/m)^2 \cdot h$
50–300 MHz — are not designed

For power flux density

In a frequency range of 300 MHz – 300 GHz — 200 $(\mu W/cm^2) \cdot h$

In the standards, depending on the duration of exposure, MPLs were submitted for the power of electrical and magnetic component in a frequency range of 0.03–300 MHz and PFD in a frequency range of 300 MHz – 300 GHz. For example, it was provided, that MPL value of the power flux density at duration of exposure of 8 h and more should not exceed 25 $\mu W/cm^2$.

The unfavorable effect of EMF of various modes of vibration and modulation was taken into account by that at an irradiation of the professionals from antennas working in a regimen of an all-round view or scanning with frequency of less than 1 Hz and porosity of not less than 20, maximum permissible the level was determined from the attitude tenfold MPL at continuous exposure to duration of exposure (in hours). But, in such case, it should not be an excess of maximum of 1000 $\mu W/cm^2$. Studies carried out in 1980^{th} –1990^{th} on the MPL justification for local microwave irradiation of hands of the human have found the reflectance in this document, which has fixed, that PFD on hands depends on time of their irradiation and should not exceed 5000 $\mu W/cm^2$.

In SanPiN rules on "the electromagnetic radiation of a radio-frequency band (EMR RF)" MPL of EMF RF was also fixed for the population. These rules have cancelled standards developed by the Kiev institute to differentiate EMR MPL for the radar station of various purposes, which have been replaced by a single level of 100 $\mu W/cm^2$. In range of LW, MW, SW and USW, maximum permissible EMF levels have not varied till now.

In this document, for uncontrollable conditions of exposure, the EMF intensities on electrical component power (30 kHz – 300 MHz) and PFD for 300 MHz – 300 GHz in habituated area, buildings and places of mass rest, in locations of inhabited, public and industrial buildings (chronic EMF RF, including secondary radiation) were regulated; as well as on workplaces of the persons who have not achieved 18 years and the women in a state of pregnancy. These normative MPL values have made the following values for frequency bands(range):

0.03–0.3 MHz — 25 V/m
0.3–3 MHz — 15 V/m
3–30 MHz — 10 V/m
30–300 MHz — 3 V/m (except for television stations and radar stations working in a regimen of an all-round view or scanning).

In a frequency range of 300 MHz – 300 GHz, MPL on PFD have made 10 $\mu W/cm^2$ and 100 $\mu W/cm^2$ for cases of an irradiation from antennas working in a regimen of an all-round view or scanning.

Fixed MPL for fixed frequencies of electromagnetic radiation framed by television stations are as follows:

48.4 MHz — 5 V/m
88.4 MHz — 4 V/m
192 MHz — 3 V/m
300 MHz — 2.5 V/m

The EMR RF intensity of radar stations of different designation in a frequency range of 150–300 MHz in a regimen of electron scanning of a ray in area of the occupied places posed in short-range of zone of the chart of radiation of the radar station, should not exceed

10 μW/cm^2 (6 V/m) and in area of the occupied places posed in long-distance zone of the chart of radiation of the radar station — 100 μW/cm^2 (19 V/m).

Since May 1, 2003 in Russia the new document on Sanitary - epidemiological rules is enforced into an operation as well as standards of SanPiN 2.2.4.1191–03 on "Electromagnetic fields under production conditions" [21]. In the document the EMF levels on workplaces of the personnel, professionally bound with service of sources of radiation are submitted. In range of RF the document is spread to a frequency range from 10 kHz up to 300 GHz.

SanPiN standards are switched on MPL, which basic meanings for all frequency bands have remained invariable, as they are scientifically justified by clinical hygienic and experimental examinations which have been carried out in the USSR in 1960th – 1980th. All hygienic standards on EMF RF, submitted in last document (SanPiN 2.2.4.1191–03), have passed procedure of acceptance of the standards indicated in partition 1.1.3.

1.2. Forming principles of regulating electromagnetic radiofrequency fields in the USSR

In the USSR (Russia), the MPL concept of the physical factor was formed on the basis of concept of maximum permissible concentrations (MPC), which was designed in 1920th in connection with the arisen necessity of a regulating of a content of harmful materials in the air. On our view, it is pertinently to quote one of the first MPC concepts given by N.D. Rozenbaum, which defined MPC as "… concentrations, which at long-term (within human months and years) exposure on a human organism (and besides in conditions of work) do not invoke morbid modifications and can be recognized non- anxious at a present state of our knowledge" [22].

From the point of view of the biological response at a regulating the following levels of EMF exposure can be taken into account(discounted):

- maximum permissible levels for whole population, which are such exposures resulting to the normal adaptive answer of an organism without a strain of regulatory mechanisms at long-term exposure and do not invoke reliable modifications of parameters of various systems of an organism [23];
- maximum permissible levels for the working persons, which are at a level of a moderate strain of compensatory systems specific for the usual adaptive answer of an organism to chronic exposures (on duration for one day not exceeding working shift);
- the extreme tolerable exposures, which are such exposures resulting to the sharply expressed strain of regulatory systems, that is on an edge of their failure and passage in a steady morbid condition.

Besides, the degree of danger of the factors should be estimated not only on their effect on parameters of a functional state of an organism, but also on a state of health of the population [24]. According to a preamble of the WHO Charter, "the health is the state of complete physical, mental and social well-being, and not just lack of illnesses or physical defects". Therefore, in Russia, basing upon the principle of health protection of the population, EMF MPL are such values, which does not invoke diseases or deflections in a state of health discovered by modern research techniques in the period of exposure or in the distant period after its termination in case of daily exposure to the given source of radiation and exposure regimens in the population without limitation of a sex and age [25].

The basic criterion of establishing a level of EMF exposure as maximum permissible is the exposure which should not invoke even of temporal disturbance of a homeostasis in the human (including reproductive function), and also the strain of protective and adaptation-compensatory mechanisms neither in proximate, nor in the distant span. It means, that MPL, in our judgement, is the exposure magnitude from a minimum level of an electromagnetic field capable to induce any response.

1.2.1. Methodological aspects of a EMF hygienic regulating for the personnel and population

The accepted methodology of a justification of maximum permissible levels for controlled conditions provides carrying out of the following basic stages of examinations:

- complex hygienic examinations;
- clinical examinations;
- study of a case rate with temporal disability;
- examinations on volunteers under industrial conditions and in conditions of laboratory experiment;
- experimental examinations on animal.

Complex hygienic examinations. The purpose of hygienic examinations is the evaluation of effect of intensity, temporal parameters of EMF exposure in actual conditions of possible modulation of the basic carrier frequency. At carrying out of complex hygienic examinations, the problem of an assessment of working conditions on performances of electromagnetic radiation and on parameters of other unfavorable factors is solved, and also the assessment of a regimen and character of a labor of the workers is effected. Basing on results of the given stage, the model for experimental examination of electromagnetic factor effect in animals and human would be developed.

Clinical examinations. The clinical physiological examinations are directed on detection of disturbances in a state of health, structural and functional modification in the people, which are subject to EMF exposure and establishing of relationships of cause and effect between intensity and character of temporal allocation of a dose, on the one hand, and noted structural and functional modifications, on the other hand. At carrying out of clinical examinations, the long-term survey should cover large number of people, which are subject to systematic EMF exposure. The examinations can be realized in dynamics, during series of years, which is impossible to get in experiment. The examinations also allow to study functions appropriate only to human (psychological status, mental activity, some endocrine functions, specific immunological responses etc.).

Epidemiological examinations. This stage of examinations allows to study effect of the factors of small intensity, which, affects non-specific adaptation mechanisms and can influence a level of a common morbidity rate of the workers. The complex study of a morbidity rate and temporal disability of the workers would be carried out.

Examinations on volunteers under industrial conditions and in conditions of laboratory experiment. The examinations under industrial conditions allow to estimate efficiency of the existing hygienic rules. The results of examinations on volunteers in conditions of laboratory experiment do not demand any correction, as in case of experiment on animal. The given examinations allow to trace alterations of adaptive and cumulative character at a level of an integrated organism.

Experimental examinations on animal. These examinations possess the main part in a MPL justification. In such experiment, the actual parameters of the electromagnetic factor, affecting the human should be taken into account as much as possible. In acute, subacute and chronic experiments the functional state of critical organs and systems of an organism animal is determined. According to the Recommendations to carrying out of experimental examinations for a justification maximum permissible EMF levels of radio-frequencies, the duration of an irradiation in chronic experiment should be 4 months. The examinations in animal would be carried out in process both at the end of an irradiation and in 1–4 months after the termination of EMF exposure (recovery period).

The methodological approaches to EMF regulating for the population have essential differences. At a hygienic regulating in this case, the basis is not a threshold of a harmful operation but the ineffective level of electromagnetic fields (IL).

The regulating would be carried out basing on results of the following complex of examinations:

- hygienic assessment of conditions of exposure to the factor in the environment;
- studies of a state of health of the population subjected to exposure of the factor;
- experimental study of a biological EMR effect on animal.

Methodology of carrying out of experimental examinations, recommendations on mathematical handling of results, assessment of EMF biological effects, choice of a degree of safety and the approaches to establishing MPL are submitted in the conforming documents [2, 26, 27,].

1.2.2. Principles of a regulating in the USSR (Russia)

One of milestones of the theory of maximum permissible levels of exposure to the various factors of the environment is the threshold concept of an exposure at the chosen criteria of a harmfulness for health of the human. In the second half of 20^{th} century in the USSR, at analysis of results of experimental studies on animal and hygienic examinations dedicated to the study of effects of exposure to the chemical agents, ionizing radiation, EMF, and also series of other physical factors, a lot of attention was given to definition of threshold concept of responses of an organism to the exposure of physical and chemical factors.

The definition of threshold levels of exposure on an organism of the human for the various factors became a leading principle of hygiene and preventive toxicology. As underlined by N.F. Izmerov and I.V. Sanotsky [28], at exposure to any environmental factor in limits of particular intensity and conforming time, in an organism there were conditions of homeostatic oscillations of parameters of vital activity, that is in a state of health, but there are not qualitative changes. Only the excess above some level results to the disturbance of unity of the quantity (irritation) and the quality (response of an organism), that causes appearance of prenosological (premorbid) phases and then results in a course of a disease at long-term exposure to the factor.

The authors of work [29] have considered the harmful reactions of the organism, which though are in limits of physiological oscillations, but can transfer in pathological conditions of long constant exposure to the irritators. In their judgement, *the threshold of the harmful exposure is a reliable deflection from monitoring, and also from initial magnitudes of responses of a complex of the most sensing systems of an organism, which are on the border between a physiological measure of the protection and pathological processes.*

Izmerov and Sanotsky [28] have provided the following quantitative criteria for establishing the limit of a dose or intensity of the affecting factor, when determing possible harm for health of the human. The threshold of a harmful effect of the material is the minimum concentration (or dose), which causes changes in an organism described by the following indications:

- modifications are reliably ($P < 0.05$) different from monitoring and fall outside the limits ($\pm 2\sigma$) of physiological oscillations of a parameter for the given period;
- modifications are reliably ($P < 0.05$) different from monitoring and are in limits of physiological norm, however persist (in experiment on animal for more than 1 month after the end of the exposure).
- reliable ($P < 0.05$) modifications in comparison with monitoring are absent, the hidden misbalance with an external environment (a possibility of adaptation) however are ob-

served, detected, in particular, through functional and extreme loads (the responses fall outside the limits of M±2m of the conforming norm).

The threshold of a harmful exposure was accepted for a basis at establishing MPL of the physical factors [28, 30]. In the USSR (Russia), the methodology of a hygienic regulating is based on representations about harmful effect threshold of the factors, which was utilized at a justification of practically all MPL of EMF exposure at miscellaneous frequency bands.

According to representation of B.M. Savin [30], all band of intensities of radio radiation can be broken down on their biological potency on three zones: subthreshold zone, zone of adaptive perception and zone of a lesion, at which fast and nonperishable pathological modifications take place. And the zone of adaptive perception depends on the intensity of the affecting factor, so the author offers to subdivide it on three ranges: inert (weak adaptation) one, range of fissile adaptation and range of extreme adaptation. First of them adjoins on subthreshold zone (which is parted by the threshold of so-called radiosensitivity); the third one adjoins on zone of a lesion.

For inert range of adaptive perception, the minimum functional alterations, which do not go out of limits of physiological norm and rapidly disappear, are characteristic both during EMF exposure, and in the period of the proximate after-exposure. The major specificity of responses and conservation of them are specific for range of fissile adaptation both during exposure, and in the period of the proximate after-exposure. The range of extreme adaptation is characterized by variety of responses, with conservation of functional alterations for a long time after exposure, and also development of appearances of cumulative character.

In this work, the harmful level of an exposure to the factor was offered to assume boundary value, which is higher than the specific functional modifications characterized by fissile development of adaptation processes (by fissile incorporation of compensatory responses) take place. Thus, the author has stated, that the threshold of a harmful exposure (THE) lays on border parting range of fissile and extreme adaptation.

At a solution of problems of a hygienic regulating and justification of tolerance levels of exposure to the unfavorable factors of industrial environment, a number of other explorers also tried to establish THE. They have shared the concept explained in works [28–30], however, they have chosen the boundary threshold value of magnitude of dose or the intensities of the exposure factor between the second and third zones: between fissile adaptation and zone of pathological disturbances (zone of a lesion).

Hence, conforming limits of THE are characterized by modifications escorting with presence of one or several following signs:

- qualitative rearrange of vital processes;
- any quantitative changes of a state of vital processes, which fall outside the limit oscillations of physiological norm conforming to concrete conditions of vital activity, and stipulate drop of ability of an organism to exercise normal scope of compensatory possibilities on overriding an unfavorable exposure to other factors of environment or unusual psychophysiological states;
- development of appearances of toting of preceding effects of exposure having cumulative character and adducting at prolonged exposure to development of vital process shifts laying outside their admissible quantitative changes.

In connection with nonspecific character of functional modifications originating under EMF effect in human, when establishing THE and developing MPL of electromagnetic radiation of radio-frequency band, the leading value belongs to the experimental studies. It is underlined by many explorers, for example by Nikonova and Savin [31]. In this connection, extremely important role is gained by a problem of extrapolation of data obtained in experiments on animal. The differences in responses of an animal organism and human to the expo-

sure of electromagnetic fields of miscellaneous frequency bands can be stipulated as differences in absorption and energy distribution, which are linked to miscellaneous radiosensitiveness, rate of metabolic processes, miscellaneous degree of organization and functioning of "critical systems", which are crucial for early and late consequences [31].

The biophysical examinations and calculations of absorption of electromagnetic energy for models of the various forms and dimension allow to estimate values of coefficients for establishing equivalent on absorption of energy of levels of exposure for the human and animal [31, 32]. As to a role of a specific radiosensitiveness with reference to the early and late effects, EMF effect studies are not enough for that. In this case, it is possible, apparently, to utilize wide experience on establishing coefficients of extrapolation with reference to the early and late effects at a level of separate systems and integrated organism at exposure of ionizing radiation, certainly with the count of character of allocation of an absorbed energy.

When going from THE to maximum permissible levels of electromagnetic radiation, the solution of a problem on magnitudes of coefficients of a hygienic reserve with reference to exposure in controllable and uncontrollable conditions is very important. The purpose of introduction of these coefficients is the security of reliability of the hygienic standards.

Since 1974, for the SHF band, the coefficient of a hygienic reserve is equal to 10, as most often used in common hygienic practice.

For frequencies below 300 MHz, where the EMF intensity is estimated by power component of electrical and magnetic fields, the degree of safety is equal to 3. In a case, when the workers are simultaneously exposed to both electrical and magnetic fields, the augmentation of this coefficient up to 5 was recognized expediently [31]. With the purpose of establishing the uniform approaches to a regulating of radio-frequency radiation for various categories of the persons, the authors of this work have proposed to enter padding degrees of safety for a non-professional irradiation (2–3), and for whole population (4–5). The indicated approaches were particularly or completely realized at a justification of EMR maximum permissible levels accepted in the USSR per 1970^{th} – 1990^{th} and at MPL justification in Russia in the subsequent years.

1.2.3. Simulation of mechanisms of chronic exposure

At present time, the greatest progress in the attitude of an assessment of danger of acute and chronic exposures is reached at study of the early and late adverse effects of ionizing radiation.

At exposure of ionizing radiation, the accepted concept guesses the lack of a safe threshold. According to this concept, any irradiation is linked to a particular degree of risk and there are no absolutely safe levels of exposure. An international commission on radiological-protection, ICRP (Publications 26, 60) and the national commissions of the USA and Russia have recommend to avoid any irradiation which has not been resulted from the necessity and to sustain the exposure dose on such low levels, which only is substantially possible to achieve with the count of economic and social reasons. This principle known as ALARA principle ("as low as reasonably achievable") has received wide recognition. This principle was also endorsed by WHO Advisory Committee under the international program on "Electromagnetic fields and health of the human", 2001.

In various models of radiation lesion induction at a level of an integrated organism, the composite character of allocation of dose of ionizing radiation in time is considered to induce the particular portion of an irreversible damage proportional to a total absorbed dose [33, 34], or the irreversibility is related to steady downstroke of genetically stipulated scope of compensatory reserves of the human organism during an irradiation [34]. It is supposed, that the downstroke of compensatory reserves of an organism is more fast, if the dose rate of radiation exposure and rate of increase of a radiation lesion in time are more high. It invokes the incor-

poration of the increasing number of regulatory mechanisms and determines major strength of compensatory processes in an organism.

According to model of radiation rate of mortality [34], the downstroke of the scope of compensatory reserves of an organism descends on exponential law and depends on dose rate and dose of radiation exposure. According to postulates of model, it determines the exponential increase of mortality rate coefficients in dependence on age, that is completely compounded with the experimental radiobiological data at an acute exposure of animals in various doses or at their chronic irradiation with various values of dose rates.

Recent data analysis of the late radiation disturbances, case rate and mortality of the persons who have survived after A-bombing in Hiroshima and Nagasaki, results of 45 years observations of a state of health of the atomic industry workers, who have got rather high doses in the initial period of work, 10 year survey of a state of health of the liquidators of Chernobyl accident and population of the contaminated territories [35] has allowed to find wider spectrum of the unfavorable late radiation consequences and to receive higher assessments of radiation risk per unit of dose. Except for radiation risk of development of tumoral diseases and the mortality on this cause, in the late period at the mentioned above contingent unfavorable modifications of a state of veins and the gross infringements of a circulation took place. Thus, the essential deterioration of health of the people and ascending in some times frequencies of illnesses of central nervous and cardiovascular systems is noted at doses exceeding 150–200 cSv. Observed rising frequency of development of an idiopathic hypertension and myocardial infarctions was noted. The frequency of cerebrovascular diseases has increased and the failure of the cerebral circulation was noted. The increased frequency of cerebral atherosclerosis and amount of cerebral insults was found. The disturbances are found also on the part of the gastrointestinal tract. Many explorers have surveyed these modifications as exhibiting of quick-aging.

At present time, on the basis of model of radiation rate of mammalian mortality, the procedure is proposed and the calculations of cooperative radiation risk are elaborated for the life span of cosmonauts after interplanetary and orbital space flights of various duration and the most probable values of their life shortening are estimated [36]. The calculation values of cooperative radiation risk during cosmonauts life have appeared in some times major, than risk of a mortality from tumors, that is linked to the cooperative count of a padding mortality in the late period from all causes.

In work [35] analyzing the early and late radiation effects in the atomic plant workers, who have started to work in 1950th (first years of development of an atomic industry), it is shown, that there is a limiting value of dose rate of radiation exposure, which the organism still can compensate at the expense of an extreme strain of compensatory systems. At dose rate of about 100 cSv per one year, steady development of a radiation lesion and sharp increase of frequency of diseases in a CNS and cardiovascular system per the first 2 years of work have occurred. The considerable augmentation of frequency of a vegetative vascular dystonia (VVD) and asthenic syndrome (AS) at the personnel is marked. The clear exhibitings of a chronic radiation sickness were observed too. On many parameters, the unfavorable modifications accrued in time and could not be compensated at the given level of dose. The followed improvement of safety procedures and decrease of levels of an irradiation down to 15 cSv per one year has resulted to the decrease of the indicated unfavorable exhibitings for more than in 4 times. Thus, the cases of development of a chronic radiation disease were not diagnosed. 20 years after the beginning of work and followed dose decrease in early 1960th the permissible levels of an irradiation were decreased to 5 cSv/year, (registered values are in a range of 1–2 cSv/year), so the rate of the indicated syndromes has appeared sunk in comparison with a maximal level observed in 1950th (in 7 times), despite of continuing exposure to ionizing radiation. Rates of AS and VVD were approximated to frequency conforming to

other professional groups of the conforming age. The modifications did not accrue in time and were compensated at the expense of fissile incorporation of compensatory processes.

In the model of radiation rate of mammalian mortality submitted above, it was supposed, that with augmentation of intensity of the industrial chronic stress factor (in this case, the exposure to ionizing radiation) the degree of strength of compensatory systems of an organism is enlarged and the compensatory reserve is decreased with the greater rate. *Naturally to assume, that in case of the chronic exposure to the whole complex of various unfavorable ecological and social factors, including electromagnetic fields, the adaptation process tension will increase and the rate of descent compensatory reserves of an organism is enlarged.*

On the basis of this representation with the count of a nonspecific response of an organism in reply to various stress exposure and fixed exponential law of decrease of scope of compensatory reserves of an organism in time, we have developed the model of ecological danger for the population exposed to ionizing radiation, chemical environmental contamination and is long psycho-emotional stress [37]. It was accepted, that the factors can work either separately (in conditions of predominance of intensity of one of them), or in unison, as it takes place in most cases. The rate of descent of compensatory reserve scope, in this case, is determined by generalized parameters of intensity of the affecting factors (such as dose rates of exposure of ionizing radiation, generalized parameter of intensity of chemical environmental contamination in considered region and generalized parameter of intensity of psycho-emotional load). The application of this model, as shown in work [37], allows to conduct comparison of magnitudes for the population exposed to the indicated factors in dependence on intensity of the exposure.

This model, in our judgement, can be utilized as basic at exposure to electromagnetic fields of radio-frequencies with the count of available results of hygienic and epidemiological examinations conducted in the USSR (Russia) [38].

2. BASIC MATERIALS FOR A JUSTIFICATION OF MAXIMUM PERMISSIBLE LEVELS OF EMF OF THE RADIO-FREQUENCY BAND IN THE USSR (RUSSIA)

In the report on Task 1 of ISTC Project No. 2362p, results of analysis of 52 experiments were explicitly submitted. In these experiments, animals were chronically irradiated to EMF RF of low intensity, that is in conditions of lack of effects of the thermal exposure.

The examinations were conducted in 1960^{th} – 1990^{th} in five research institutes of the USSR:

- in NII of common and municipal hygiene named after A.N. Marzeev (Kiev);
- in NII of labor hygiene and occupational diseases of the USSR AMS (Moscow);
- in Institute of biophysics of the USSR Ministry of Health (Moscow);
- in NII of labor hygiene and occupational diseases (Leningrad);
- in Institute of experimental medicine of RAS (Leningrad)

To carrying out of examinations of biological effects EMF RF in conditions of chronic exposures, the preliminary work on design of experimental installations and an adequate dosimetry has preceded. The mathematical design of experiments was realized, the states of leading systems of an animal organism and their reproductive function were chosen. Most informative methods of an assessment of a modification of a metabolism were selected. The modern methods of statistical handling of results of experiments were utilized.

Analysis of results of long-term chronic exposure to microwave radiation at 850 MHz – 37.5 GHz with intensities of 50; 60; 100; 115; 140; 200; 420; 500; 1000 and 2500 $\mu W/cm^2$ has shown (in lack of heat effect) the presence of gross metabolism infringements, both considerable structural and functional modifications in various systems of an organism, which can be qualified as development of cumulative damages as a result of chronic exposure, which can decrease the fastness of an organism to an exposure to other factors of environment and can result in the serious unfavorable late consequences [39–41].

The analysis of 28 biological experiments conducted in vitro, in situ, AND in vivo in the former Soviet Union (FSU) and later in Russia with usage of the modulated electromagnetic fields of radiofrequency allows to make the following basic conclusions:

- EMF exposure of biosystems with less or more composite regimens of modulation the development of bioeffects, both physiological, and unfavorable, which are distinct from bioeffects induced by not modulated EMF is possible;
- the acute modulated EMF exposure of low intensities (non-thermal levels) can result in development of pathological effects;
- there is a dependence of development of a reciprocal biological response on the intensity and directness of the concrete regimen of EMF modulation; this dependence was fixed at all levels of biological systems — in vitro, in situ and in vivo;
- as a rule, modulated EMF has invoked more specific bioeffects, than continuous regimen of modulation;
- the effect of EMF RF modulation is more specific at lower levels of intensity.

The obtained data have specified the possibility of the effect of EMF modulation on the development of biological effect at a level of composite systemic interactions in an organism. It allows to discharge modulated EMF in the special group of radiations, which biological effect depends not only from magnitude of an absorbed energy, but also on the form of modulation "addressed" to this or that functioning system. It determines the conclusion, that at an assessment of modulated EMF danger, it is important not only to assess magnitude of an ab-

sorbed energy, but also the fact of contact of the human with this aspect of radiation. This circumstance brings in major indeterminacy by development of the EMF standards.

The individual singularities of the man are essentially important, the individual sensitivity to a particular regimen of EMF modulation, that dilates a problem of hypersensitivity to EMF.

As a result of the conducted experiments with MEMF, the effect of an initial state of biosystem on expected effect is detected. The given fact is rather important, since does not allow to establish common regularity in the development of bioeffects at particular aspects of modulation. As a matter of fact, the initial background of a system of an organism can determine the character and directness of a reciprocal response, that complicates the prognosis of expected effects in conditions of MEMF exposure on the population.

The role of modulation gains the major significance at low intensity (at non-thermal levels of EMF). In this connection, this factor becomes now leading at an assessment of population exposure to EMF RF.

The experimental recognition of dependence of development of bioeffect from an aspect of modulation specifies recruitment phenomenon of new gears of interaction of an organism with MEMF, which are not clear and demand the future study.

Having conducted the comparison of results obtained from Tasks 1 and 2 of ISTC Project No. 2362p, it is possible to get the following three aspects (zones) of responses of an organism in process of augmentation of electromagnetic fields intensity and exposure duration.

- zone of threshold initial responses of an organism reflecting a reactivity of the basic radiosensitive systems of an organism, incorporation of processes of normal physiological adaptation without a strain of basic regulatory systems (***zone 1*** of exhibiting of an initial reactivity);
- zone of responses of an organism bound with reliable modifications of metabolism characterized by structural and functional disturbances in various organs and systems, fissile incorporation of compensatory processes, strain of basic regulatory systems retained in the period of an after-exposure to electromagnetic radiation (***zone 2*** of fissile adaptation);
- zone of responses of an organism bound with considerable disturbances of albumins, carbohydrate, energy metabolism, with predominance of processes of catabolism escorting with essential structural and functional disturbances in central nervous system and deterioration of parameters of higher nervous activity, disturbances of the immunological status, decrease of fertility and vitality of offspring, invoking extremely high tension in regulatory systems and resulting to augmentation of duration of an irradiation and radiation exposure decrease of compensatory reserves (***zone 3*** of cumulative increase of lesion).

Thus, on the basis of analysis of results of chronic experiments with EMF exposure effects on the nervous system response (the electrodermal sensitivity, conditional reflex activity (CRA), behavioral responses), biochemical modifications (in carbohydrate, albumins and energy metabolism, enzymatic activity), on a state of cell-like and humoral immunodefence, disturbances of reproductive function and enlarged embryonic mortality, it is possible to make a conclusion, that the electromagnetic fields of SHF band with intensities of 50–2500 $\mu W/cm^2$ are extremely awake biologically and can result in development of cumulative accumulation of lesion in an organism and unfavorable late consequences (zone 3 of cumulative increases of lesion).

The analysis of experiments examined by Task 1 has shown, that at a chronic EMF exposure at SHF band with intensities of 25–40 $\mu W/cm^2$ the initial modifications in series of surveyed systems are noted, but they appear to be already compensated at the

initial period of the irradiation, there is not the increase of modifications during the further irradiation and the fast regeneration of parameters after the end of EMF exposure is noted. These modifications can be referred to zone 2 of fissile adaptations, where there is not considerable strain of regulatory systems of an organism.

The SHF EMF exposure with PFD of 10–20 μW/cm^2 did not result to reliable modifications in one of surveyed parameters, though separate studies have noted the tendency to their modification and augmentation of the range of variation of values in separate animals, which reflects reciprocal physiological response of the most sensing systems of an organism at radiosensitive subjects. The initial modifications have not place in all subjects at the given intensities of exposure, which reflects that the reactivity of an organism can be referred to zone 1 of exhibiting of an initial reactivity.

The submitted demarcation of responses of an organism in dependence on EMF intensity and duration of exposure allows to justify scientifically the value of the threshold of a harmful effect and maximum permissible EMF levels in superhigh frequency and high frequency bands and explains the modern MPL values accepted in Russia.

Besides, the special significance is gained by clinical physiological hygienic examinations. In this connection, we have found conveniently to consider series of clinical-hygienic works, which results have played the important role for the development of the EMF standards (medical-hygienic examinations on EMF exposure were not submitted in the reports on Tasks 1 and 2 according to conditions of the contract).

When examining long-term EMF effects in the human organism under controllable conditions, it was noted, that earliest (from the point of view of clinical exhibitings) functional disturbances are the part of the central nervous system and cardiovascular system (CCC) disturbances. These disturbances are manifested as vegetative vascular dystonia characterized by liability of pulse rate and arterial pressure, inclination to hypotonia, pains in range of heart, and asthenic syndrome.

In work [42] the results of hygienic and clinical physiological observations of long-term exposure on professionals working with EMF at frequency range of 3–30 MHz are submitted. The men, maintenance operators of marine radio navigational equipment were exposed to long-term modulated EMR exposure with a field power from several unites up to several tens of V/m. In simple cases workers were exposed to short-term exposure with EMF of 250 V/m. The daily irradiation was from several minutes till 3–4 hours. The comparison of EMF levels and exposure time has shown, that the radiation exposure at the workplace did not exceed maximum permissible level of 7000 $(V/m)^2 \cdot h$. Other physical agents (hum, temperature, air humidity) did not exceed sanitary norms.

The clinical survey of 72 (basic group) maintenance operators of radio transmitters was elaborated; 18 men exposed to EMF within 5–10 years up to the moment of survey (2nd special group) was conducted and 45 men who were not exposed, which have made control group. The mean values of age in groups have made 36.6; 33.2 and 34.6 years, accordingly.

The analysis of the complaints has shown, that maintenance operators of radio transmitters have complained in 4.1 times more often to the pain in the range of heart, in 2.7 times more often to headaches, in 2.5 times more often to the pain in epigastria area. The complaints to a boosted fatigue have increased in 2.8 times. In 8.3 % of basic group the complaints to disturbance of dream were reported, that was not marked in control group. The frequency of the complaints was enlarged in dependence on duration of work. The frequency of a case rate in a basic group was also higher in 2.7 times than in control group (77.8 % in comparison with 28.9 %, $p < 0.01$).

The table 1 provides the picture and frequency of pathological modifications in group of the workers exposed to EMF HF and in control group. As the frequency of disturbances in CNS and CVS diagnosed in the workers exposed to EMF, is visible from given the tables, it is

much higher than in control group. So, the frequency of CVS disturbances in the basic group appears in 5.2 times, and in the CNS in 3.8 times higher. The frequency of illnesses of a respiratory organs has also increased in 2.8 times. The tendency to augmentation is marked on frequency of illnesses of gastrointestinal tract and peripheral nervous system (the rates of the indicated illnesses have increased in 1.7 and 1.4 times, accordingly).

Table 1. A picture of pathological modifications and their rate in group of the workers who are subject to EMF exposure in a frequency range of 3–30 MHz, and in control group, % [42]

No.	Complain picture	Basic group (n=72)	Control (n=45)	Rate ratio (N_e/N_c)	Assessment of changes
1	CNS disturbances	50.0±6.0	13.3±5.1	3.8	Very significant ($p<0.001$)
2	CVS disturbances	34.7±5.7	6.70±3.8	5.2	Very significant ($p<0.001$)
3	GIT diseases: gastritis, cholecystitis	19.4±4.7	11.1±4.8	1.7	Increase trend
4	Peripheral nervous system diseases	9.7±3.5	6.7±3.8	1.4	Increase trend
5	Respiratory organ diseases	12.5±3.9	6.7±3.8	2.8	Significant ($p<0.1$)

The pathological CNS modifications were especially great in special group, in which the workers were exposed to HF EMR 5–10 years ago (in 5.8 times more than in observed group). Apparently, it is linked to that shown in experiments on animals with exposure of ionizing and non-ionizing radiation, where the morphological and functional CNS disturbances become more specific in the late period and accrue in process of augmentation of terms of survey. The frequency of CVS pathology in experimental and special groups has appeared also at 2.8–2.9 times higher in comparison with control group. The picture of CNS disturbances in radiotransmitter operators is submitted in the table 2.

Table 2. A picture of CNS disturbances and their frequency in group of the workers who are subject to EMF exposure at frequency range of 3–30 MHz, and in control group, % [42]

Pathological changes	basic group (n=72)	Control (n=45)	Rate ratio (N_e/N_c)	Assessment of modifications
Asthenic vegetative syndrome	25.0±5.2	2.2±2.2	11.4	Very significant ($p<0.001$)
Vegetative dysfunctions	13.8±4.1	8.9±4.3	1.6	Increase trend
Neuroasthenic syndrome	5.6±2.7	2.2±2.2	2.5	Increase trend
Cerebral atherosclerosis	5.6±2.7	0	-	Changes of basic group

The first place in CNS pathology structure is occupied by asthenic vegetative syndrome. Frequency of this syndrome is 11.4 times higher, than in control group. The tendency to augmentation of frequency of vegetative disturbances and neurasthenic syndrome is marked also. In a basic group exhibitings of cerebral atherosclerosis in 5.6 % of cases were observed,

which were not marked in control group. The cooperative frequency of functional disturbances for all ages in a basic group has appeared 5.8 times higher, than in control group. In an age interval of 20–29 years in control group, CNS functional disturbances were missed, while in a basic group almost 20 % of workers exposed to HF EMF, the disturbances in CNS are marked. In the age of 30–39, the frequency of functional disturbances in CNS was higher in 3.2 times, and in the age of 40–50 years in 3.8 times in comparison with control group.

In special group the frequency of cerebral atherosclerosis was higher almost in 2 times, than in a basic group, at its lack in control. It is necessary to underline, that the given pathology was observed in workers with EMF sources at earlier age of 38–47 years. In the basic group, it was also more often and more expressed CVS pathology, which was expressed in VVD of cardiac, hypertonic and hypotonic type (frequency increase in 4.1 times), the idiopathic hypertension (frequency are higher in 4.4 times), atherosclerosis and myocardiosclerosis, which frequency in a basic group was 6.9 %, while these exhibitings in control group have missed. The frequency of a case rate in CVS was considerably (3.1–4.1 times) higher in basic group in comparison with control in all surveyed age-grades.

The surveyed materials on long-term EMF exposure of radio transmitter maintenance workers at high frequency (3–30 MHz) with a field power of some tens of V/m, with 3–4 h daily exposure, which were also subject in some cases to short-term exposure to the field power of 250 V/m, testify to development of pathological alterations in central nervous and cardiovascular systems, which are observed in workers at much more younger age. It is necessary to note, that the normative level of radiation exposure for one day of 7000 $(V/m)^2$ h was not exceeded. The pathological exhibitings in considered systems anticipate similar in control group almost for 10 years, testifying to quick-aging. Therefore, the limiting normative value of the field power at this frequency band should be lower than 10 V/m and probably in the future standards the decrease of admissible value of a radiation exposure is also necessary.

The data of examinations of clinic of Moscow NII of labor hygiene and occupational diseases of the USSR AMS, where the long-term observation of major group of persons working at the plants of radioindustry was conducted, have allowed to reveal the late unfavorable consequences of SHF EMF exposure of various intensity (in zone of lack of heat effects). The state of metabolism, and also nervous, cardiovascular, neuroendocrinal and other systems were examined. At long-term exposures with PFD of 1000–2000 $\mu W/cm^2$ the inspected professional pathology was noted [43]. At levels of exposure in 100 times smaller, conforming to the present normative values and not exceeding 100-th portions of mW/cm^2 (20–50 $\mu W/cm^2$), some decrease of frequency of professional pathology was noted, however modifications of health were found. At the examined persons, asthenic, asthenic vegetative, subthalamic sets of symptoms were found. The 3 and 6 year observation results (100 examinees) have shown that, despite of repeated courses of treatment and the temporal termination of an irradiation, at homing in former working conditions the process progress has occurred, especially in the patients with asthenic vegetative and subthalamic sets of symptoms. At such patients the results in an idiopathic hypertension and ischemic illness of heart are more often noted.

In work [44], they have realized 5 year observation of the state of health of the workers of the industrial plant testing and servicing SHF generators. The authors have made a conclusion, that the mechanism of realization of a unfavorable EMF effect is linked to an overstrain of higher centers of vegetative regulation, the corollary that developed an attrition of functional capabilities of adaptive mechanisms of an organism of the human and decrease of the fastness to padding unfavorable chronic exposures, that was caused by the rising of frequency of a case rate. With augmentation of the experience of work the pathology was developed on the part of central nervous and cardiovascular systems. Thus, the frequency of illnesses of the circulation system was enlarged, the neurocirculatory dystonia mainly of cardiac and hyper-

tonic type with indications of subthalamic failure with angiospastic responses was observed, which in series of cases has resulted in disturbances of cerebral and coronary circulation.

When working at electromagnetic radiation, such age pathology, as an idiopathic hypertension, cerebral atherosclerosis resulting to augmentation of frequency of infarctions and cerebral strokes were diagnosed earlier, than at the persons of control group. With augmentation of duration of work, the pathological modifications educe on the part of other organs and systems [45]. These results are similar to modifications in a state of health observed at a long-term exposure of small intensities of ionizing radiation in the workers of the plants of an atomic industry.

The conducted analysis of morbidity with temporal loss of work capacity in women working with SHF generators has shown, that they more often have illnesses of generative organs, complication of pregnancy and labors, disturbance of the menstrual cycle in the age of 30–40 years; the frequency of inherited teratisms is enlarged [46, 47]. As a result of epidemiological examinations on study of an EMF effect of computers and other videoterminals, the conclusion was made, that the systematic work for more than 20 hours per one week should be surveyed as dangerous from the point of view of generative function.

In work [48] the data of clinical examinations of health of the women testing electronic devices and exposed to EMR with a wavelength of 3–10 cm (more than 3 GHz) with the power flux density of 10–50 $\mu W/cm^2$ are submitted. The authors have examined in dynamics the health of 70 women controllers, from which 15 working women was examined twice, and 55 — three times and more. At tentative survey the middle age in group was 28 years and experience of work was 3 years and 8 months. To the moment of the end of survey the middle age has made 31.7 years, and experience — 6 years and 7 months. Comparing a picture of the complaints of the employees on the state of health after the first and second survey, it is possible to make a conclusion about considerable deterioration of health of the working women, despite of small term between surveys. On the majority of the complaints (headache, giddiness boosted fatigue, disturbances of dream, irritability, pain in range of heart) the frequency was enlarged for 1.5–2.6 times, and in 5.1 times for dysmnesia. A picture of pathological modifications in various systems of the working women and their frequency at the first and second survey are submitted in the table 3.

Table 3. A picture of pathological modifications and their frequency in the women who are subject to SHF EMR exposure under controllable conditions with the power flux density of 10–50 $\mu W/cm^2$ at the first and second surveys, % [48]

Pathological modifications and marked sets of symptoms	First survey (n=70)	Last survey (n=70)	Multiplicity of a modification (N_f/N_l)	Significance of changes
CNS functional disorders	41.4±5.9	77.0±5.1	1.9	Very significant $p<0.001$
Asthenic vegetative syndrome	6.8±3.0	24.0±5.1	3.54	Very significant $p<0.01$
CVS diseases	8.8±3.4	20.0±4.8	2.3	Significant $p<0.1$
GIT diseases: gastritis, cholecystitis	2.8±2.0	8.5±3.4	3.0	Increase trend

The functional CNS disturbances, illness of cardiovascular system and illness of gastrointestinal tract are diagnosed in more often, as well as we have noted it earlier in SHF EMF workers (table 2). The frequency of a pathology has considerably increased with augmentation of duration of exposure. The functional distresses in CNS and CVS were enlarged in 1.9 and 2.3 times, and asthenic syndrome with vegetative dysfunctions in 3.5

and 2.3 times, and asthenic syndrome with vegetative dysfunctions in 3.5 times for about 3 years interspace between surveys. It testified to high rate of increase of damages in the organism at the given small EMF intensity and rather short temporal regimen of the stay of the working women on a workplace [48].

When estimating efficiency of EMF exposure under controllable conditions, it is necessary to mark, that the rate of augmentation of pathological modifications in the examined women was essentially exceeded with the character of increase of modifications with age in comparison with group of the persons not bound with the given character of works. The frequencies of disturbances in considered systems, indicated in the table 3, and the morbidity of women have exceed frequencies conforming to age norm and can testify to quick-aging.

Thus, on the basis of experimental data and results of epidemiological examinations, SHF EMR exposure with PFD of 10–50 $\mu W/cm^2$ is possible to survey as damaging, noticeably worsening state of worker health in concrete EMF conditions. To establish limit values of PFD levels, in our judgement, the carrying out of the further epidemiological examinations is necessary in controllable conditions with essential smaller PFD values.

3. RECOMMENDATIONS ON THE IMPROVEMENT OF THE APPROACHES AND PRINCIPLES OF REGULATING EMF FOR THE PERSONNEL AND POPULATION

The surveyed results after additional analysis of 80 experiments, in which they have utilized chronic EMF exposure of animals at low intensities and modulated EMF (reports on Tasks 1 and 2 of Contract No. 2362p), allow to formulate a number of recommendations on perfecting the approaches and principles of the regulating.

1. We consider, that maximum permissible level should ensure health of the population in first and second generation and not suppose the incorporation of compensatory responses. We have not the right "to demand" from the organism of the human to be in a state of a stress i.e. of a strain in conditions of chronic exposure of an electromagnetic field of small intensity.

2. It is expedient to reserve a principle of development of the separate standards for controllable and uncontrollable conditions of EMF exposure.

The regulating of exposure for the population demands the rigider approach, than for controlled conditions, especially taking into account, that, as a matter of fact, the problem of an assessment of danger of EMF exposure for the health of the population is while on an incipient state of examination and does not take into account a role of modulation in development of bioeffects. Besides, the increase of application of systems of cellular communication implies changed conditions of an irradiation of the population: a) a major contingent of the population (the users of cellular telephones) are voluntary subjected to the daily EMF exposure of the brain; b) a major contingent of the population (especially of megalopolises) is exposed to EMF of base stations, including children, pregnant women and patients on a background of effect of other unfavorable factors of the environment.

We also consider rational development of the standards for separate sources of electromagnetic fields: radar stations, base stations of systems of mobile communication and for some other sources of EM radiation.

3. An original material for MPL justification for controllable conditions should be results of:

- complex hygienic examinations;
- clinical physiological examinations;
- study of a morbidity rate with temporal disability;
- examinations on volunteers under industrial conditions and in conditions of laboratory experiment;
- experimental examinations on animal.

The regulating for uncontrollable conditions should be conducted on the basis of results of the following complex of examinations of:

- hygienic assessment of conditions of exposure of the environment factor;
- studies of a state of health of the population who is subjected to exposure of the factor;
- studies of a EMR biological effect in animal.

4. The position of "critical systems and organs" should be formulated. We consider possible reference to critical systems of central nervous, endocrine and immune systems.

5. At present, the problem of the EMF exposure combined with other unfavorable factors of habitat of the human gains the special urgency.

Because of the intensification of industrial activities, development of atomic engineering, oil and gas industry, building industry, development of a wide area network of railways and motor transport, revolutionary modifications in an information field and communication facilities, diffusion of computer technologies and Internet, development of radio telephone communication and building of base stations, the intensifying the late unfavorable conse-

quences for health of the population of the whole regions and separate professional groups with a rather high level of risk is possible at the expense of deterioration of ecology and long-term exposure to a complex of the unfavorable factors.

When concerning the danger of long-term exposure to the separate factors and the establishing the risk for health of the human during the life, considerable discrepancies in assessments are present for exploratory schools of miscellaneous countries. Still major apostatizes take place at assessments of complex exposure to unfavorable ecological and social factors acting in unison. In this connection, the problem of an assessment of effect on health of the human of the combined operation of series of the extreme factors is actual including EMF. Apparently, the most successful approach for a solution of the posed problem can appear the development of the concept of a non-specific effect of various stress factors enabling to estimate harmful additive or even a synergetic effect of a complex of the factors.

6. The determination of criterion of an assessment of unfavorable EMF effect on an organism (threshold of a damaging effect), as phenomenon from which coefficient of the hygienic reserve is obtained, invokes controversies with the essence of various approaches in a solution of this problem.

In our opinion, the renewing of the concept of *the threshold of an ineffective level* proposed in the USSR is justified for the development of the standards for the population.

Apparently, for the professionals (controllable conditions) the threshold of harmful effect corresponds to such intensity of EMF exposure, at which else there are reliable differences from mean control values of parameters describing a state of CNS and HNA, biochemical, immunological parameters, parameters describing reproductive function of animals, but the augmentation of a range of variation of parameters at separate individuals takes place reflecting the physiological reactivity and tendency to a modification of parameters at the most radiosensitive individuals. Thus, the responses of an organism as a result of EMF exposure will not result to fissile incorporation of compensatory systems of the organism, will not result in deterioration of health and noticeable augmentation of risk of the unfavorable late consequences as a result of the exposure to the complex of the unfavorable factors as in the present and in succeeding generations.

When considering the above submitted materials on an EMF effects in health of the human, it is possible to come to the following conclusion.

The common feature of the long-term exposure to various stress factors if the strain of regulatory processes in an organism and possibility of rather fast exhaustion of compensatory reserves. At considerably reduced scope of compensatory reserves of an organism, the adaptation abilities are decreased. Even after EMF cancellation, there can be a failure of adaptation in case of padding exposure to other unfavorable factors of the human habitat. Thus, the probability of development of various diseases is enlarged, first of all, on the part of central nervous and cardiovascular systems, disturbance of the immune status. In case of a cumulation of bioeffects, the development of the late consequences is possible.

It is necessary to take into account series of the factors, which till now have not the sufficient scientific basis to prediction: a role of modulation in paravariation of radiobiological effect; constant effect of electromagnetic fields of small intensity in the pregnant women, children and patients for the development of common somatopathies, and also combined effect of other physical factors of environment and social conditions.

The conducted analysis allows us to make a conclusion, that the magnitudes of the radiation exposure for controllable conditions should be decreased for 3–4 times at least, and for uncontrollable conditions (population), taking into account the overall spanning, including children and pregnant women, the magnitude of a radiation exposure should be decreased for more than 10 times.

RESUME

The retrospective analysis of results of large number of experiments with chronic EMF RF exposure at small intensity and with various regimens of modulation acknowledges the necessity to regulate electromagnetic exposure in uncontrollable conditions. The methodology of EMF regulating is grounded on perennial experience of carrying out of the conforming examinations in the USSR and practically there were not key modifications in the approaches to the regulating in Russia.

Basically, our recommendations are reduced to necessity of prolongation of examinations for range of a biological chronic EMF effects of non-thermal intensity, assessment of danger for various contingents of the population for the around the clock irradiation to EMF of very small intensity with the count of possible failure of adaptation processes and development of the late effects.

When developing the EMF standards, the medicobiological assessments instead of engineering accessibility of fixed MPL should be leading issue. The hygienic standard should promote the development of new technical ideas directed on building of safe EMF sources and technologies and ensure the population protection from all of growing EMF presence in ecological medium.

Authors have proposed to decrease maximum permissible level for controllable and uncontrollable conditions of exposure to electromagnetic fields of wireless of frequencies.

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