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Influence of High-frequency Electromagnetic Radiation at Non-thermal Intensities on the Human Body

(A review of work by Russian and Ukrainian researchers)

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1. Introduction

This review examines primarily direct experimental studies of the effects of low-intensity high frequency electromagnetic fields (HF EMF) on biological subjects, including humans. Unlike epidemiological observations, direct experiments allow parameters of the acting EMF to be established more accurately, the condition of the subject to be monitored before and during exposure and for a certain period afterwards, and scientific hypotheses on the mechanisms of the effects to be verified. Clinical experiments done with the intention of improving the condition of the patients are the only legitimate experiments on people, and for this reason, published articles more often deal with the positive effects of HF EMF. One should consider, however, that EMFs with therapeutic effects comprise only a minuscule portion of all acting fields, and that there is a large probability of harmful effects from incidental generalized exposure, as confirmed in experiments on animals.

Currently we still do not know the specific receptor in humans for perception of extremely high frequency electromagnetic radiation (EHF EMR). Nevertheless, the presence of sensory reactions has been established during local peripheral exposure of humans to EHF EMR [Andreev, Beliy and Sit'ko, 1985]. At this moment in time, the following can be considered established:

1) Humans are capable of differentiating reliably between exposure to EHF EMR and a sham exposure;

2) Electromagnetic sensitivity in humans is determined by the biotropic characteristics of the EHF EMR: frequency, power, time and place of exposure;

The most typical reaction in humans is of a resonant character and is observed during changes in the exposure frequency [Andreev, Beliy and Sit'ko, 1985].

The use of extremely low power EHF EMR of 10^{-19} W/Hz in millimeter wave resonance therapy for treating people involves selection of an individual frequency which has the maximum therapeutic effect [Andreev, Beliy and Sit'ko, 1985; Sit'ko, Skripnik and Yanenko, 1999].

3) The so-called points of Chinese acupuncture play a particular role in this reception, and are notable for having been used for thousands of years in treating practically all systems of the human body.

2. Natural Electromagnetic Background

Natural sources of background EMF consist mainly of objects of cosmic origin: radio emissions from the sun and planets, relict radiation, and noise from atmospheric events [Pisanko, Pyasetskiy].

Background microwave radiation—relict radiation—is cosmic radiation with a spectrum characteristic of an absolutely black body at a temperature of 2.7 K; it determines the intensity of the background radiation of the universe in the shortwave radio band (in cm, mm and sub-mm waves). It is characterized by the highest degree of isotropy. The main contribution to the energy density is made by radiation with wavelengths from 6 to 0.6 mm. In this range, the energy density is 0.25 eV/cm^3. Radio emissions from an active sun, during eruptions and flares, are observed at frequencies of 1.2, 3, 9.5, 35 and 70 GHz, raising the total activity by 30%. The intensity of natural background EMR is at a maximum in the morning hours and at a minimum in the evening. A power flux density (PFD) of 3×10^{-7} mW/cm^2 in the range of 100-300 GHz was recorded on the Earth's surface when the atmospheric concentration of water vapor was 2.7g/m^3. EMR with wavelengths less than 3 cm is absorbed by resonance in the atmosphere:

1) in precipitation (rain, fog, snow);

2) by molecular absorption in water vapor and oxygen.

Researchers [Yesepkina, Korol'kov and Pariyskiy] note the resonant absorption of water vapor at frequencies of 26 and 188 GHz. Atmospheric oxygen has absorption maxima at frequencies of 60 and 118.7 GHz. In addition, this band contains windows of transparency at wavelengths of 8.6 mm, 3.2 mm, 2.1 mm and 1.2 mm.

Radiation in the mm band penetrating from space through the windows of transparency can be considered to be the primary radiation. On Earth, the heating of various physical bodies also gives rise to radiation in the mm band, which can be considered secondary. Such sources of EHF EMR are water, sand, bricks, plaster, granite, marble, wood, etc. [Sit'ko, Skripnik and Yanenko, 1999].

Since living organisms have evolved under conditions of low natural background EHF EMR, they lack a ready-made mechanism of evolutionary adaptation to heightened levels of radiation resulting from technogenic factors.

3. History of Research in the USSR

In the 1950s in the USSR, there was development in a new scientific direction—mastery of the millimeter (EHF) portion of the spectrum of coherent electromagnetic oscillations [O.V. Betskiy, 1997]. This work was conducted in the organizations of the Ministry of Electronic Industry, in the Academies of Science of the USSR and Ukrainian SSR, and in institutions of higher education. The Scientific Council on the Problem of "Generation, Amplification and Transformation in the mm Wave Band" was founded under the direction of academician N.D. Devyatkov.

In the 1960s, all necessary instrumentation was created for the millimeter and sub-millimeter wavelength bands.

In 1965, N.D. Devyatkov and his coworkers set forth an original idea that all living organisms on Earth are not adapted to this type of radiation, because under natural conditions it is practically absent due to strong absorption by the Earth's atmosphere (mainly by water vapor). A proposition was also put forward about the possibility that low-intensity electromagnetic waves have specific effects on biological structures and organisms. Research was begun on the interaction of mm-waves with biological objects.

The research showed that generation of coherent waves by cells is a systemic process in which cell membranes, protein molecules and transport mechanisms are involved.

There are data on excitation in cells of coherent oscillations in a wide range of frequencies, but a particularly large part of the data are concerned with frequencies of 30 to 300 GHz, which corresponds to the mm wavelength range.

Three possible channels were pointed out for conduction of operative signals within an organism over considerable distances: the nervous system, the humoral system and the system of acupuncture points. In addition, a number of peculiarities of these channels were discovered:

• Conduction of signals through the nervous system is accomplished in the myelin sheaths of the axons.

• Conduction of signals through the humoral system is connected with the movement of generating cells through the blood and lymphatic systems. In this way, within the organism, the transmission of signals is accomplished, apparently, not by conduction of radiation, not by movement of charges, but by the displacement of generator-cells, the oscillations of which reflect the information being carried.

• Water molecules strongly absorb EHF radiation, and play a big role in various biophysical effects involving mm waves.

Many biochemical processes, including processes in biomembranes, are sensitive to environmental mixing (as the result of local heating and convection). It was found experimentally that low-intensity EHF radiation can cause acceleration of active transport of sodium ions (at an energy flux density (EFD) of 1 mW/cm^2), a change in the permeability of erythrocyte membranes to potassium ions (EFD of 1-5 mW/cm^2), acceleration of peroxide oxidation of unsaturated fatty acids in liposomes (EFD of 1 mW/cm^2), increase of ion conductivity of bilayered lipid membranes (EFD of 1-10 mW/cm^2), etc.

One of the more interesting experimental facts discovered by A.Z. Smolyanskaya, L.A. Sevastianova, and others in irradiating various microorganisms with mm waves in 1968-71, was the dependency of biological effects on frequency.

Under the influence of EHF EMR (wavelength of 5.6 mm, EFD of 0.5 mW/cm^2), the nature of the change in potential difference of the plasma membrane of a growing cell was identical to that which arises during exposure to photosynthetic active radiation [Petrov, Betskiy]. It was deduced that mm wavelengths have the ability to stimulate the synthesis of ATP in the cell.

[Tambiev and Kirikova] studied the effect of low-intensity EHF EMR on the growth of biomass of Spirulina, a blue-green alga. Over the course of multi-year experiments it was shown that along with growth in biomass of the alga (as much as 300%), there was significantly increased synthesis of biologically active substances (vitamins, carbohydrates, etc.) which are excreted into the environment.

From the beginning of the 1960s in the USSR, a wide range of research was conducted on the health of people who had contact with EMF on the job. The results of clinical research showed that prolonged contact with EMF in the SHF band can lead to development of diseases, the clinical profile of which is determined above all by changes in the functional condition of the nervous and cardiovascular systems. It was proposed to define it as a specific illness—**radiowave sickness.** This illness can have three syndromes according to the acuteness of the disease:

- asthenic syndrome;
- astheno-vegetative syndrome;
- hypothalamic syndrome.

4. Physical Approach to Resonant Absorption of Low-intensity HF EMR

The basis of the chosen approach was a concept about the dissipation of energy of EHF radio waves in a non-homogenous object upon their resonant penetration into the object [Petrosyan, Zhiteneva, Gulyaev]. During this process, energy in the form of monochromatic mm waves should be transformed into thermal energy in the molecular environment of the object according to Planck's law of radiation. It has also been thought that this additional noise energy may be taken as a change in intensity of the radio wave noise produced by the object itself, or the radioecho of the object, in a wide range of frequencies in the SHF region, including the decimeter. Because the depth of penetration of decimeter waves into aqueous media is greater by several orders of magnitude than the skin layer for the mm range, the detection of a radioecho from the object in the dm range would signify penetration of EHF EMR into the object at resonant frequencies.

To avoid possible experimental errors, special measures were adopted. Detection of the radioecho of the object exposed to EHF radiation was done radiometrically with the aid of a highly sensitive SHF radiometer working in a bandwidth of 50 MHz with a fluctuational sensitivity of 0.1 K(<10^{-20} W) at a time constant of one second. Another SHF radiometer was used as a control, tuned to a frequency of 0.4 GHz with analogous parameters. Use of an antenna allowed radioecho signals to be taken from any point on the object. The source of monochromatic EHF EMR was a set of tunable generators, which continuously covered the range of 4-120 GHz. For controlling the quality of the radiation from the generators, a standard generator was also used.

Research was done on the human body, on animals, on water under various conditions, and on a number of other objects in liquid or aqueous dispersed conditions.

The basic result of this experimental research was the discovery of "physical" EHF resonance. Physical resonance explains maximum radioecho of an object in a narrow range of EHF EMR frequencies. It is well known that a non-linear medium responding to an external periodic influence may be found in one of three dynamic conditions—chaotic, oscillating or stationary—depending on the intensity of the influence. All of these three conditions were observed clearly when the power of the EHF radiation was changed. A stationary state was achieved by cardinal reduction of the EHF power from 10 mW/cm^2 to a level of less than 10 µW/cm^2. Only under these conditions were the echoes received adequate, in relation to the intensity of the EHF radiation, to allow physical resonances to be detected. In this sense, **EHF resonance is a threshold effect at a low enough level of power compared to the fundamental parameter—the intensity of the medium's own molecular vibrations—with no effect found at levels higher than this.**

From the experimental results they obtained, the authors [Petrosyan, Zhiteneva, Gulyaev] drew the following conclusions:

- **There exist radiophysical resonances of size interaction of EHF radiowaves with objects;**
- **Spontaneous shifts of resonant frequency and low-frequency auto-oscillations are observed;**
- **EHF resonances of biological objects (humans) coincide with those of physical objects (water);**
- **Various liquids and aqueous dispersed media have individual characteristic EHF spectra.**

It can be stated that penetration of EHF radiowaves into a medium (object) occurs at the resonant frequencies of the molecular oscillators of the medium, and the resonant interaction must be interpreted as resonant transparency of the medium to EHF radiowaves, not as the absence of absorption by that medium.

5. Reception of EHF EMR at the Cellular Level

[Alipov, Belyaev, *et al.*] investigated the action of mm waves on the genome conformational state of *E. coli* cells and thymocytes of male rats of the Wistar line. The maximum effect was at a frequency of 41.303 GHz, with a resonant halfwidth band of 6 MHz (for the thymocytes); a frequency of 51.755 GHz and a halfwidth of 23 MHz and 3.3 MHz when the power flux density was 10^{-7} W/cm^2 and 10^{-18} W/cm^2, respectively (for *E. coli*), with a time of irradiation of 10 minutes. It was shown in both cases that there are commonalities in the reactions of live cells to mm waves: resonant echo, sensitivity of cells to super-low intensity EMF, and evidence of rules of selection by helicity. It was established that the quality of resonances increases (reduction of the halfwidth of the resonant line) as the intensity of the mm waves is reduced.

A comparison of the effects of EHF EMR in the near (induction) field and the far field of an antenna on the activity of immune system cells was made in the research of [Gapeev, Safronova, Chemeris and Fesenko]. The studies were done using peritoneal-extracted neutrophils from mice of the SPF category (free of pathogenic microorganisms). One of the main complications in conducting experiments on cells is the high level of absorption of EHF EMR by aqueous media [Novskova and Gayduk]. This difficulty can lead to non-uniform results and poor repeatability. We will introduce detailed descriptions of the experimental conditions in which the researchers tried to allow for the majority of complicating factors.

Irradiation of the neutrophils was done from beneath the bottom of plastic containers. The thickness of the bottom of the containers was 0.2-0.3 mm. When the neutrophils were placed in the container, they adhered to the bottom and after a few minutes formed a monolayer with a thickness of less than 0.1 mm, the total height of the solution inside the container being 2 mm. Calculation of the absorbed energy flux density (AEFD) at distance x from the radiating face of the slotted radiator was done according to the formula $P = P_0/(1 + x/a)^2$, where a = 98 mm, P_0 = 3.76 mW/cm^2, when maximum power at the exit of the generator was about 58 mW. Taking into consideration that the depth of the skin layer for EHF EMR is about 0.78-0.23 mm over the range of frequencies of 30-300 GHz, and after estimating the specific absorption rate (SAR) in a layer of solution with a depth of about 0.1-0.2 mm, they obtained the AEFD value corresponding to absorption of radiation by the layer of solution containing the cells. In the near field region of the slotted radiator, at distances of 10-100 mm from its face, the SAR was estimated with the aid of a microthermocouple by the rate of temperature increase in the experimental container filled with the physiological solution. The AEFD in the near field was calculated proportionally to the SAR, taking into account the area of the bottom of the container and the mass of the solution.

Most frequently, irradiation of biological objects in the EHF band is done in the near field of the source, at distances of $R<2D^2/\lambda$ from the radiating face of the antennas. The non-uniformity of the EMF in the near field, however, may be one of the causes of artifacts. In the plane of the object there may exist a multi-modal interferential pattern of distribution of SAR, which determines the unevenness of absorption of EHF EMR energy by the object [Khizhnyak and Ziskin]. It was shown by thermographic methods that the slotted radiator guarantees (in contrast to horn or dielectric antennas) distribution of the SAR in the plane of the phantom without local spots of overheating throughout the entire range of frequencies used (37.5-53.5 GHz). Only one spot of warming was detected with an elliptical form, the area of which grew in direct proportion to the square of the distance from the face of the radiator. In this way, it was shown that the slotted radiator has good directionality, and guarantees wide-band coordination of the radiation with the irradiated object over the entire range of frequencies used, and uniform distribution of SAR in the plane of the object both in the near field and the far field of the antenna, which, as we think, allows this radiating system to be used for irradiation of biological objects without artifacts in either the near or far field of the radiator. Considering the dimensions of the zone necessary for uniform irradiation of the biological object being studied and optimal AEFD, the plane of the object was positioned at a fixed distance from the face of the radiator: 65 mm in the near field or 400 mm in the far field of the antenna. In this situation, the AEFD in the near field was an even 240 µW/cm^2, and in the far field, about 100 µW/cm^2.

Methodologically it would be more correct to irradiate biological objects in the far field of the radiators, where conditions of irradiation are more precisely defined: 1) the wavefront is formed and there is a flat transverse wave; 2) the E and H vectors are orthogonal to each other and orthogonal to the direction of propagation of the wave (in contrast to the near field, the far field has only a travelling wave); 3) the components of the E and H vectors in the far field are inversely proportional to the first power of the distance from the antenna, and their relationship to each other is constant, while in the near field the energy of the electric field predominates; 4) in the far field the coordination of the radiation with the load is determined basically by parameters of the load itself, in contrast to the near field, where the antenna has a strong influence.

At a carrying frequency of 41.95 GHz, maximal inhibition of the synergetic reaction was discovered to be about

25%, differing reliably from the effect of EHF EMR for other carrying frequencies. The AEFD in this series of experiments was approximately 50 µW/cm². The size of the effect depended weakly on the AEFD, and when the AEFD was between 20 and 150 µW/cm², it averaged 24%. Based on the experimental data, it can be proposed that EHF EMR affects the calcium-dependent systems of intracellular signaling. The effect may be connected with changes in [Ca^{++}] or affinity of proteins, including proteinkinase C, for calcium ions [Safronova].

[Alovskaya, Gabdulkhakova, *et al.*] studied the influence of EHF EMR on cells of the immune system. It is known from the literature [Arzumanov, Betskiy, Devyatkov, Lebedeva, *et al.*] that the action of EHF EMR leads to modulation of immune reactions in humans and animals. From the position of the information theory of interaction of low-intensity EHF EMR with biological systems [Devyatkov, Golant and Betskiy], there is no substantial influence of low-intensity EHF EMR on a normally functioning cell, but if the functioning of the cell is disturbed, even weak external influences can change its metabolic profile. [Geletyuk, Kazachenko, Chemeris and Fesenko; and Safronova, Gapeev, *et al.*.] considered that for the effect of EHF EMR there may correspond a physiological status of the cell. It is possible that the immunomodulating action of EHF EMR during illnesses is directed to those specific cells with changed functional status. Neutrophils provide the swiftest reactions of the immune system to harmful influences. In the body, neutrophils may be in resting, primed or activated states. Neutrophils in the activated state carry out their physiological function, directed to protecting the body from harmful factors. Primed neutrophils are characterized by metabolic restructuring taking place in the cell, but the functional activity of the cell does not change until a subsequent activating stimulus enhances its responsiveness many-fold. Authors [Alovskaya, Gabdulkhakova, *et al.*] showed that the reaction of neutrophils to EHF EMR with given parameters (frequency and power) depends on their functional status. They evaluated the functional activity of neutrophils according to their production of active forms of oxygen (AFO) by the chemiluminescence (CL) analysis method. The level of [Ca^{++}] was measured with the help of a fluorescent probe. For irradiation of the neutrophils, a broadband slotted radiator was connected to a high-frequency signal generator. The distance from the radiator to the object was set at a uniform 400 mm, which corresponded to the far field region of the antenna, as described above. The cells were irradiated in a mode of continuous generation at a frequency of 41.95 GHz, with the absorbed energy flux density in the far field of the antenna being 150 µW/cm². Irradiation was accomplished at room temperature of 19-22ºC over the course of 20 minutes. Two samples were irradiated at a time: 1) resting and primed or activated cells; 2) cells in the presence of priming or activating agents, and the same with the addition of a blocker. For each sample, consisting of 3-4 containers, there was a corresponding control of non-irradiated cells. After completion of the irradiation, the initial level of CL was recorded, and then activating agent was added to each container and recording of CL continued for the necessary time. The reaction of the cells in different conditions to EHF EMR was as follows:

1) After irradiation of resting cells with EHF EMR, their reaction to stimulating agents of various natures remained unchanged. The authors of another study [Rojavin, Tsygankov, and Ziskin] reported that certain functional indices of immune cells extracted from mice with normal immunity that were irradiated with EHF EMR did not differ from the controls. It is possible that this is a common property of biological systems in interaction with low-intensity radiation.

2) EHF EMR potentiates the activity of primed neutrophils. Priming was done 20 minutes before activation. The cells were irradiated with EHF EMR in a mode of continuous generation at a frequency of 41.95 GHz in the far field of the antenna with absorbed energy flux density of 150 µW/cm² over a course of 20 minutes at room temperature. Priming the cells prepares them to make a stronger reaction upon subsequent activation. The result of irradiating the primed neutrophils was a consistent increase in production of AFO in comparison to non-irradiated cells.

3) Addition of a calcium ionophore to the incubated solution led to increased levels of CL and [Ca^{++}], which determined the initial level of activation of the cells. It is probable that the level of activation of Ca^{++}-dependent enzymes prior to irradiation determines the metabolic changes of the neutrophils provoked by the action of EHF EMR. Inhibition of phospholipase may modify the effect of EHF EMR on neutrophils.

The experimental data from this research show that the functional status determines the effect of exposure to EMR EHF on cells, strengthening, weakening or not changing their response to an activating agent. In all probability, the interaction of EMR with a cell occurs on the level of activated enzyme systems. The processes of priming and activation of neutrophils may have common paths. The authors think that key elements in priming and activation of neutrophils are a system of Ca^{++}-signaling, acting via serine/threonine kinases, and a system of tyrosine kinase signaling. It is possible that the metabolic changes provoked by EHF EMR in primed and activated neutrophils may be determined by the level of phosphorylation of certain enzymes. We note that the use in these experiments of a power of irradiation ten times lower than the corresponding thermal norms (2-3 mW/cm²) led to significant biological effects.

6. Experiments on Animals

We will review the effects of EHF EMR on microorganisms. Experiments conducted by [Rudenko, Kolbun and Tolkach (1989, Kiev)] showed high sensitivity of bacteria to millimeter wave radiation at extremely low power levels. It was established that under the influence of EMR in the millimeter band the adhesive activity of microorganisms decreases significantly, regardless of their species.

We also note the effect of EHF EMR on microorganisms of different species [Rozhavin, Sologub, Mikityuk; Sologub; Tishchuk and Yakunov]. [Balibalova, Bozhanova, Golant and Rebrova] proposed a relatively simple method (synchronized cell cultures) of registering a sharply resonant response of living organisms to EHF, with high enough accuracy and reproducibility. Another advantage is that it enables the resonance curve forms to be studied.

[Kryukov, Subbotina and Yashin] investigated the influence of EHF EMR (34.52 GHz, EFD 120 mW/cm²) on micronucleus induction in cells. Toads *(Bufo viridis)* were placed in water and irradiated for a period of 3-24 hours. After that, peripheral blood specimens were prepared. Considering that the animals were in water during the irradiation, the power used should not be considered high. A statistically significant effect of EHF EMR on the frequency of formation of micronuclei was demonstrated.

[Subbotina and Yashin] researched the direct bioinformational effect of EHF EMR on exposed organs by studying the dynamics of morphological change in rat liver tissue. Exposure was at a frequency of 73 GHz and EFD of 0.2-0.4 mW/cm², for 15 minutes. It was shown that characteristic morphological changes occurred only during irradiation of the entire animal. These are reflected in:

1) progressive strengthening of the microcirculation with compensatory outflow of blood;

2) activation of processes at the level of the cell genome and stimulation of processes of regeneration;

3) increased resistance of hepatic cells to harmful factors;

4) suppression of intra-hepatic biliary hypertension under conditions of ligation of the common bile duct.

Irradiation of surgically exposed livers of rats was conducted with EMR of 14.3 GHz frequency and 0.3 mW/cm² power [Subbotina, Yashin and Yashin]. The effects of direct negative influence of low-intensity SHF EMR were observed on the living organism. It was shown that the destructive effect is connected with disturbance of the trans-membrane gradient of hydrogen ions in cellular mitochondria. This was characteristic of frequencies of SHF radiation which have the most destructive effects.

In the research of [Tomashevskaya and Dumanskiy], 160 rats were irradiated in groups with EFD of 140, 100 or 60 μW/cm² for twelve hours a day for four months. Observations were made on the 30th, 60th and 120th day of exposure. Changes were observed in protein and carbohydrate metabolism, which manifested as increased urea and residual nitrogen content in the blood serum, a lower level of glycogen in the liver, and disturbance of a number of enzymatic systems—increased activity of ceruloplasmin and reduced iron saturation of transferin in blood serum, and reduced activity of cholinesterase in blood, and succinate dehydrogenase and cytochrome oxidase in mitochondria. These changes were cumulative.

In the research of [Soldatchenkov, Bitkin, Tomashevskaya, *et al.*], two-month-old rats were irradiated with EMF of 59 GHz frequency and EFD of 1 mW/cm² everyday during early (1st to 6th day) or late (6th to 16th day) terms of gestation. In the offspring of the irradiated rats, changes were noted in motor activity, conditioned-reflex activity and latent period of reaction.

[Khramov and Zubin] irradiated 102 mouse embryos at single-cell to 16-cell stages with EMF of 58-78 GHz and EFD of 1-5 mW/cm² for 15 minutes. Beginning from the two-cell stage, modulating effects of EHF EMR were observed. From this moment, transcription of the embryo's own genome is switched on, and an external EMF can affect its functioning.

The reproductive functions of experimental animals were studied under the influence of millimeter wave EMR: EFD of 60, 25 and 10 μW/cm², irradiation for four months [Nikitina and Andrienko]. Under EFD of 60 μW/cm², disturbance of female cycles; reduction in fertility, number and weight of offspring; increase in postnatal deaths of the rat pups by a factor of 2.5; and dystrophic changes in the reproductive organs of the animals were noted. The presence of tangible biological effects was established experimentally for EMR with wavelength of 2.5 mm; it is also proposed that EMR with wavelengths of 1.7, 0.9 and 0.77 mm may be therapeutic [Volchenko, Kolbun, Lobarev].

According to [Nefedov, Protopopov, Sementsov and Yashin], there is a basis to assert that the bioinformational significance of EMR should increase as frequency increases, because

a) as frequency increases, the level of interference from technogenic and natural (cosmic) sources decreases;

b) as can be inferred from analysis of processes of historical biocenosis, the most natural, bioinformational frequencies established over the course of biogeochemical eons in living organisms are the frequencies in the ultraviolet, infrared and short-wave parts of the EHF range.

Authors [Afromeev, Zagural'skiy, *et al.*] attempted to create a compact, high-coherency EHF EMR generator, working in the 90-160 GHz range in accordance with the hypothesis discussed in the work of [Nefedov, Protopopov, Sementsov and Yashin]. Appraisal of the EHF-therapy device through experimental research—in treating extensive artificially induced gastric ulcers in dogs, both primary and secondary—confirmed its high effectiveness. Under clinical conditions, the device was appraised using a frequency of 94 GHz for the treatment of bronchial asthma patients, where use of devices with traditional radiation frequencies was not effective enough.

Isolated cells damaged by ionizing radiation [Bundyuk, Kuz'menko, Ryabchenko and Litvinov] were irradiated with EMR at frequencies of 54-76 GHz and PFD of 10^{-14}-10^{-16} W/cm^2 for seven minutes. The effect of mm waves on the growth of implanted tumors (carcinomas) in mice and rats was studied. The PFD was 3 mW/cm^2, at frequencies of 35.9-55.1 GHz. They were irradiated for ten days, 3-7 minutes per day, via acupuncture points. The effect of mm waves (five minutes per day for five days, 54-76 GHz) on cellular and humoral immunity was studied in mice exposed to ionizing radiation. These experiments showed that mm waves at non-thermal intensities act to normalize the growth of cells damaged by ionizing radiation, and in their action on biologically active zones in animals they have an immunomodulating effect. The therapeutic effect increases as the power of the EMR is reduced to 10^{-14} W/cm^2.

Rats of the Wistar line were irradiated for 15 minutes with EHF EMR of 37 GHz frequency, 0.3 mW/cm^2 PFD and amplitude modulation at frequencies of 1-10 Hz, with subsequent morphological study of the cellular composition of the red bone marrow [Kazakova, Svetlova, Subbotina and Yashin]. The controls were irradiated with unmodulated EHF EMR. The results obtained give evidence that **a single exposure to low-intensity EHF EMR without modulation, and with modulation at low frequencies of 5-10 Hz, induce opposite effects in red bone marrow (RBM).** In the former case, we have pronounced stimulation of proliferative processes in the RBM, which are reversible. In the latter case—progressive depression of the process of blood production, right down to the formation of hypo- and aplastic conditions in the RBM on the sixth day of observation. This process is obviously of pronounced negative nature for the vital activities of the organism, is irreversible, and has a tendency to progress. The studied modes of action of EHF EMR exert a steady harmful effect on RBM functions and are a pathogenic physical factor.

The following tendency has been grasped: modulation with frequencies of 0.01 to 4-5 Hz and 16-100 Hz exert a positive effect on the functioning of the organism; these correspond to basic biorhythm frequencies. AM frequencies of 5-16 Hz exert a direct damaging effect, and they are not resonant for the organism. It is possible that infra-low frequencies are associated with the acoustic background of earthquakes, tsunamis, thunderstorms, tornadoes and other cataclysms. There are indications that FM 6-16 Hz is the range of maximal sensitivity of marrow tissue.

On the basis of a large volume of research done in the USSR from the 60s to 1990, [Devyatkov, Betskiy, 1981; Devyatkov, Gel'vich, 1981; Devyatkov, Golant, 1982; Devyatkov, Golant, Rebrova, 1982; Devyatkov, Didenko, 1983; Gordon, 1969; Balakireva, 1982; Zalyubovskaya and Kiselev, Electron…, 1975; *Study of Mechanisms of Non-thermal Effects…*, 1983; Ismailov, 1987; *Millimeter Waves…*, 1989; *Non-thermal Effects…*, 1981; *Use of mm Radiation…*, 1985; *Use of mm Radiation…*, 1986; *Fundamental…*, 1989; *Effects of Non-thermal Influence*, 1983; Kyselev; Zaloubovskaya, 1977; Golant, 1986] the author of a detailed review [V.D. Iskin] reached the following conclusions about the biological effects of millimeter waves (BEF MMW):

1) They do not depend on the intensity of EMR, starting from the threshold to noticeable heating of tissue.

2) There exist narrow "resonance" bands of EMR frequencies in which BEF are observed.

3) The relative width of these frequency bands is 0.01-1%.

4) Resonance frequencies stable for the object are found during a definite phase of development.

5) Irreversible BEF occur only during prolonged or cyclical exposure.

6) During amplitude or frequency modulation of MMW, bioeffects are maintained or strengthened as the power of exposure is significantly reduced.

7) The body "remembers" the effect of EMR for a relatively long time.

8) In some cases, EMR influences sensitivity to other factors (chemicals, ionizing radiation, etc.), and the effects may persist through time.

9) Local irradiation of the body at different frequencies may exert similar BEF.

10) Positive effects of MMW occur within the limits of possible normal functioning of the body.

The upper energetic threshold for non-thermal BEF was put at 10 mW/cm^2 (which does not cause heating of biological substances of more than 0.1 K). Iskin noted that proposed lower thresholds of 1 mW/cm^2 for animals and 10 μW/cm^2 for simple organisms were compromises, and that many researchers had found effects far below these limits. For example, in humans, in 1987 [Kolbun and Sit'ko] registered sensitivity to 10^{-3}-10^{-8} W/cm^2. The duration of exposure was from 1, 3 or 5 minutes to 1, 2 or 12 hours (effective time of irradiation). There is evidence of the occurrence of BEF seconds after the beginning of irradiation. The frequency-dependency of BEF of millimeter waves qualifies as a new phenomenon (in comparison with centimeter and decimeter waves) and is cause for the most careful research and keen discussion. The relative width of

TABLE 1: A FEW BIOLOGICAL EFFECTS (according to the review by [Iskin])

Biological Object	EMR Wave-length (mm)	~46 GHz Effect
Blood	6.52; 7.31	Change in outflow of free Hb.
Cell culture	5.9-7.2	Change in morphology of cells, increased rate of division.
Kidney cells	6.5; 5-8	Change in morphology, destruction of membranes; degeneration of protoplasm, decreased survival.
Thrombocytes	4.0; 4.6; 4.8; 5.0; 5.2; 5.45	Increased rate of aggregation.
E.coli	6.5	Increased synthesis of colicin.
	5.8; 6.5; 7.1	Changes in enzymatic activity, growth rate; lethal effect.
Bacteria	7.095; 7.1; 7.12; 7.15	Stronger biochemical activity and growth rate.
	5.7-7.1	Lethal effect.
Sacch. cerevisia (Yeast)	8.2; 7.18	Stimulation of growth, biochemical activity and biosynthesis.
	6.8-7.2; 6.05; 6.035	Changes in growth cycles and morphology.
Blue-green algae	8.3; 6.66; 7.1; 7.89; 8.34	Stimulation of growth, changes in rate of photosynthesis.
Fruit flies	5.7-8; 7.2; 6.5; 7.5	Mutagenicity, sterilization of females, changes in fertility and viability
Chicken embryos	6.5; 7.15	Reduced weight, changes in incubation period by 2-3 days.
Rats	6.5; 5.6	Effect on physiological processes and metabolism.
Humans	3.8-5.7; 10.7-11.0; 4.61-6.66	Accelerated regeneration of biological tissues, generalized reactions of the body: excitement or somnolence, changes in arterial pressure and pulse, reliable sensory reactions.

the band is 10^{-3} or more. The stability of response to a specific frequency is up to seven months [Andreev, Beliy and Sit'ko].

Of importance for the appearance and detection of BEF are the initial conditions of the biological medium: composition of the nutritional solution, concentration of cells in suspension, volume and surface area of irradiation, age and physiological condition, temperature during culture and processing, synchronization [Devyatkov, Golant and Tager, 1983], phase of cellular cycle, etc.

7. HF EMR in Medicine

In connection with the intensive development of radiotechnical media—television, radio-relay, radar—our modern environment is saturated with electromagnetic fields of various frequency bands. The effect of EHF EMR on the functioning of the human body was the subject of discussion at the 1st All-USSR Symposium held 10-13 May 1989 in Kiev, with international participation. A fairly complete bibliography of research to the mid 90s is given in the book [*Millimeter Waves in Biology and Medicine* (bibliography)], and also in the book [*Millimeter Waves in Medicine: Collection of Articles*, Vol. 1 and 2, editors N.D. Devyatkov and O.V. Betskiy]. EHF EMR should also be viewed as one of the factors in the external environment affecting the homeostasis of the body and promoting its functional correction with subsequent production of a new stable condition in the given environment. The use—in a sanctioned version—of the technical EHF EMR range with the goal of correcting the functions of the human body has led in the past ten years to the creation of a new branch of medicine: EHF therapy, or MRT—microwave resonance therapy [Sit'ko and Mkrtchyan; Grubnik, Sit'ko and Shalimov; Bundyuk, Kuz'menko and Ponezha]. For example, in the research of Mkrtchyan, *et al.*, a wide range of clinical material is presented on the treatment of gastritis, duodenal ulcers, cerebral palsy in children, diabetes, angioneuropathy, chronic alcoholism and drug addiction by the method of microwave resonance therapy, and the immunomodulating effects of MRT are examined. They are also examined in works presented at the symposium [*Millimeter waves…*, 1997].

It is essential to take into account the radiophysical parameters of the SHF and EHF EMR bands in evaluating the physiological condition of a human during sanctioned and unsanctioned exposure. To the latter belong a wide range of effects, including effects of EMR from industrial and residential facilities, and effects on human health of radiation from radar stations.

It is already a proven fact that the effectiveness of EHF therapy is determined to the greatest extent by the frequency of EMR, spectral characteristics (modulation), level of irradiating power, method of introducing EMR to the human body, directionality and homogeneity of the EMF in the irradiated organ, duration of the therapeutic procedure and entire cycle of treatment, and combination of EHF therapy with medicinal procedures [Afromeev, Nagorniy]. Among the new trends one may note the research of [Beliy, Khokhlov, Tsikora and Yakunov], devoted to digital noise. Digital noise is an artificially synthesized signal which has the properties of a monochromatic and wide-band signal. Generators of digital noise in the millimeter range are promising sources of EMR for resonance effects on living systems. Traditional methods of medical monitoring of the physiological condition of the human body are biochemical blood analysis, electroencephalography, roentgenography, fluoroscopy, electrophotography, ultrasound diagnostics, computer and NMR tomography, etc. At the same time, new, more modern methods of monitoring and research are being intensively developed. Frequently the incentive for seeking new methods is the effort toward more effective evaluation of the most delicate processes of homeostasis.

The correlation between disturbances in body functions and pathology of its separate component cells, in particular, blood cells, is an established fact if one is talking about general illness. Any disease of the body changes the flow of metabolic processes in cells, initiating by this means the processes of functional reorganization of cells and variations in the spectra of radiation of the cells' own EMR [Sit'ko and Yanenko; Skripnik, Peregudov and Yanenko].

For example, in the noise spectrum characterizing the total EMF of the cells' own radiation, the presence of pathology presents itself with a change in the spectrum at some frequencies. The connection between the intensity of radiation from the human body and the condition of the person's health and nutrition was studied. In addition to the radiation from surface zones and points on a person's skin, the electromagnetic activity of the bones of living organisms was investigated. It was shown that bones fill the role of generators of EHF oscillations within the organism, in contrast to the skin, which actively absorbs low-intensity signals in the mm range [Sit'ko, Skripnik and Yanenko].

Significant possibilities have been discovered in the use of specific properties of biologically active points (BAPs) in human skin [and reflexogenic zones and regions]. **It should not be doubted that these points and zones are sources of radiofrequency radiation in the super-low *f*<1 Hz and low frequency *f*<2 kHz ranges, as well as in the SHF and EHF ranges.** The low frequency radiation ranges are dependent upon the general physiological rhythms of the body, and the high-frequency ranges, the EMF of the body's own cells.

At the same time, these points, zones and regions in electrophysical treatment are non-linear systems, but this means that when electromagnetic waves (EMW) are applied to a BAP or a reflexogenic zone, there occurs a process of interaction of the EMW with the EMR of the point, zone or region itself. As follows from the laws of radiophysics, the result of such interaction is modulation of the incident EMW in the radiating frequency of the BAP. Separation of this frequency from the spectrum of modulated reflected waves and its analysis (amplitude-frequency) enable one to obtain information about the condition of the body and evaluate its response to external influences on the body, in particular, physical fields.

A number of practical methods are known for diagnosing diseases of the body according to the condition of the BAPs; the majority of them are based on measuring the electrical conductivity of the skin in the vicinity of the points (or meridians) [Zablotskiy and Spitkovskiy]. According to various data, the bioelectric potential of the surface of human skin reaches 180-200 mV. At inactive points it is equal to 2-70 mV, while at BAPs it is greater than 120 mV. It is significant that when pathology exists in the human body, the electrical potential of the skin is single-valued and lower than the indicated values. A high correlation has been noted between the magnitude of the bioelectric potential of the skin, especially at BAPs, and certain diseases [Ivanchenko and Andreev; and Ivanchenko and Gridina].

The effect of signals with high, uncontrolled levels of amplitude or frequency-modulated noise and with indeterminate values of harmonics of the basic frequency can either give a zero effect or have a distorting influence on the body. In other words, either the strength or the direction of the effect may be changed.

The conclusion here is as follows: the use of such delicate therapeutic procedures based on poorly understood mechanisms of interaction of physical fields with living matter, firstly, does not tolerate dilettantism, and secondly, requires implementation of a governmental program of development, introduction and utilization of apparatus meeting basic safety requirements.

In particular, an effective method of objective selection of therapeutic frequencies for each individual patient is the introduction of feedback coupling in the frequency and amplitude of the cardiorhythm [Mironov and Nikitin]. It is even more effective to include among the equipment an electron-optical plethysmograph. Nonetheless, this is the essence of interim solutions, requiring further perfection in objectivization of the therapeutic procedure and in diagnosis of the patient by preferably non-invasive methods.

The natural channels for the introduction of EHF EMR into the body are the reflexogenic zones, therefore research on their radiating (and receiving) properties is an important step in the integral solution to the task of EHF therapy, correction and monitoring. In this regard, biologically active points can be seen as an analog of control points of an electronic circuit and their non-linear properties can be used for biocorrection by EHF EMR irradiation. An important role here is played by the informational properties of the bioelectrical potential of the surface of the bio-object (the skin).

One of the first described methods of treatment by EHF EMR is in the work of [Andreev, Beliy and Sit'ko]. The test subjects were 188 people, both healthy and ill in terms of medical diagnosis. It was established that the healthy subjects in the overwhelming majority of cases did not react to radiation in the range of 27-78 GHz with power density up to 10 mW/cm^2. This same situation in many cases was observed also during exposure of ill subjects. However, irradiation of strictly defined parts of the body of ill subjects with EMR at fixed frequencies in the range of 45-65 GHz induced a sensory reaction in the region of an organ with marked disturbance. It became clear that the sensory reactions induced by exposure coincided with actual changes in physiological condition: the pulse rate decreased by 10-20 beats per minute, arterial pressure by 10-15 mm Hg, and the effective renal plasma clearance by 10-20%. Also noted were significant changes in the number of free radicals in the saliva, fluctuations in the acidity of the stomach cavity, etc. Some changes could even be observed visually: reddening of parts of the body far from the zone of exposure, tremors in separate groups of muscles, somnolence and sleep of a hypnotic nature. It was noticed that a positive (therapeutic) effect arose at frequencies which produced comfortable feelings in the patient: decreased pain, sensations of local warming, muscular relaxation, etc. At the same time, the functioning of the diseased organs effectively recovered.

The constancy of frequency of many resonances during the time of chronic illnesses, the individuality of the frequency values for different organs, the narrowness of the resonant responses—all of this gives a basis for surmising the presence in living systems on the supramolecular level of discrete quantum states corresponding to the characteristic frequencies themselves.

Igor Rodschtadt [I.V. Rodshtadt] has proposed a hypothesis on the nonspecific perception of EHF EMR by all parts of the skin. On the basis of the fact that EHF EMR can penetrate into the skin to a depth of up to 1 mm, it has been proposed that millimeter radiation has an effect on the microcirculatory system of the skin which lies at a depth of 150 microns. Further routes of influence of EHF EMR on the body have been considered, which lead to the secretion of biologically active substances (endogenous medicines). In our view, the hypothesis of a non-specific effect of EHF EMR is poorly effective to describe the effects of low-intensity radiation.

[Bogdanov, Mel'nikov, Pisanko and Pyasetskiy] have proposed that the system of opioid peptides is one of the elements mediating the effect of EHF radiation on living objects. An important role in the humoral functioning of an organism is played by the regulatory peptides, synthesized and secreted into the internal environment of the body by endocrine glands, and by groups of cells of various tissues and organs. One important class of these bioactive substances are the opioid peptides, including endorphins and leu-enkaphalins, which function in the body as intercellular and inter-tissue regulators and participate in the formation of stress-limiting analgesic systems, as well as other systems of the body.

The hypothesis was clinically confirmed that one of the important, possibly specific effects of EHF therapy is activation of the system of opioid peptides and foremost of all, enkephalins, which are connected with adaptogenic, anti-stress effects.

The diffuse endocrine system obviously provides a morpho-functional substrate for the inclusion of opioids, along with the neuro-endocrine system, in the answer regarding the effects of EHF fields. It is distinguished by the variety of hormone-producing cells located in mucous membranes and also in skin, where they act as a front line of quick response to the action of external agents, and even more so to EHF, which the body did not happen to encounter in the process of phylogeny and ontogeny.

Under the influence of EHF EMR, macrophages and eosinophils are concentrated at the site of the immune response, functioning as regulatory cells. Enzymes secreted by the eosinophils inactivate histamine and other mediators [Radionov]. The immune system is also directly connected with the peculiarities of hormonal exchange. Heightened levels of estrogen increase the basal secretion of prolactin and thymosin; which in turn stimulate the maturation and functional activity of T and B lymphocytes, which have receptors for prolactin, which has been found to have a direct influence on cells of the immune system. It seems that bioenergetic processes are connected with the peculiarities of absorption of EHF radiation by certain skin, collagen and blood cells, immunocompetent cells, and many non-cellular compounds. EHF radiation causes bioresonant modification of only certain structural units of cells, which are able to absorb the given radiation with the given frequency. By changing the value of the membrane potential in various populations of immunocompetent cells, functional restoration of specific receptors for hormones, neuromediators and neuropeptides is accomplished, which can lead to various changes in neurons and glial cells, which in turn can produce reverse effects.

Some researchers have proposed that initial reception may be accomplished by the epithelium of the crystalline lens of the eye, the venous network of the outer layers of skin, and the membranes of blood cells. The convective motion of water may turn out to be a primary mechanism of MMW perception by biosystems.

At the symposium "Mechanisms of Biological Effects of Electromagnetic Radiation" held in Pushchino in 1987, a number of experimental data were presented, providing evidence of the effect of EMR on the conformational state of proteins and membranes [Golinskaya and Alekseev; Beliy, Kolbun and Lobarev]. The majority of the research was done *in vitro,* which allows only to a certain degree prediction of the possible effect of EMR on living organisms. Much attention was given to the problem of the effect of EMR on hormone-receptor and mediator-receptor interactions. In research on the effect of pulsed and modulated EMR in the decimeter range on receptor structures, it was shown that the sensitivity of the receptors had a non-linear relationship with the frequency of modulation of the EMR and depended on the duration and power of the radiation. It was revealed as new in principle that EMR induces the release of protein structures from membranes into solution. A considerable amount of research was dedicated to studying the biological activity of cortical neurons of the cerebral hemispheres (R.A. Chigmenkova, Ye.P. Khizhnyak and V.V. Tyazhelov in Pushchino; S.V. Zotov in Kiev). The high sensitivity of the hemo-immune system to EHF radiation (Bubnov and Kidarov in Leningrad) is connected with conformational changes in proteins of the hemo-immune system as a primary mechanism of the initial immune response to the influence of EMR. A report from L.I. Savchenko in Minsk showed a possible effect of decimeter waves on levels of hormones and mediators under conditions of altered hormonal background in a living organism. The necessity of combined evaluation of the functional condition of the immune system and concentrations of hormones under the influence of EMR was pointed out. It was shown that the human body reacts to the effects of EMR at any intensity, therefore it is essential to look at gradations of reactions to exposure, which is very difficult *in vivo.* At the symposium it was recognized that it is necessary to study the dynamics of the after-effects of physical factors in order to avoid cumulative effects from EMR. The problem of applying EMF in medicine and biology is drawing great interest in the scientific and medical community. It is noted that unlike medicinal effects, to which the body normally adapts, no adaptation to the informational effects of MMW has been observed to date. In Ukraine and Russia, symposiums and conferences are held regularly on this theme [*Electromagnetic Fields in Medicine and Biology: Proc. All-Russ. Sci. Conf.*; *Problems of Quantum Medicine in Ukraine and Abroad: Proceedings of the Second International Scientific-Practical Conference,* Donetsk, 22-25 Oktober 1997].

The neurodynamic activity of the brain is the most dynamic self-organized subsystem of the human body. It is therefore important to study the relationships of this activity to outside electromagnetic influence, in order to understand the structural-functional mechanisms of the transition of a biological system into a state of maximal stability among the set of quantum states. The human brain is continuously generating electrical waves, which occur in quasi-stationary rhythms of various frequencies. Of special note is the α-rhythm, with a frequency of 10 Hz, which is most pronounced in a state of peaceful alertness [Voropaev, Ostrovskiy]. The frequency- and time-dependency of the effects on the amplitude of α-rhythms confirm the suggestion of a systemic mechanism of interaction of external HF EMF with biosystems. The process of energetic correction of the system over time is accompanied by continuous change in the frequency of induced "resonances" with a time constant of a few minutes.

One of the bioeffects observed when EMR is applied to biologically active points is change in the character of the EEG of the brain. **Experimental data show that at certain frequencies, EHF EMR induces activation or depression of α-rhythms in the EEG. At the same time, sensory feelings occur in the patient, and a therapeutic effect occurs** [Gerashchenko, Pisanko and Mus'kin]. A more stable and objective criterion is muscle tone in a hypnotic state. The frequencies at which the bioelectrical activity of the muscles change in deep stages of hypnosis reveal physiological activity. At PFD of less than 1 mW/cm^2, these are 57-78 GHz, with a reaction time of 10-20 seconds. Thus, one of the likely mechanisms of action of local EHF irradiation of the human body at physiologically active frequencies at non-thermal intensities lies in a change in tonus of the brain cortex. This affects the induction of nervous processes and weakens foci of pathological excitation in the nervous centers (for frequencies reducing residual bioelectrical activity).

There is evidence that the influence of low-intensity EMR at physiologically active frequencies on some parts of the body changes the flow of natural sleep, and in particular, induces the phase of paradoxical (REM) sleep.

The dynamics of electroencephalographic indices were studied during microwave resonance therapy (MRT) of cerebral arteriosclerosis patients [Kuz'menko]. MRT was done according to the established method, with EFD of up to 1 µW/cm^2. The complexity of changes in the bioelectrical activity of the brain was shown, and in a number of cases, their multi-directionality during the process of irradiation. [Sit'ko, Shakhbazov, Rudko] described a non-traumatic, sensitive, quick method of determining the reaction of the human body to super-low-intensity EMR in the millimeter range. It was shown in cells of the buccal epithelium that the resonant effect of EHF EMR occurs at the level of the cell nucleus and cell morphology.

[Podtaev and Fedorov] proposed that psychophysical reactions to EHF EMR occurring in humans are connected with the initiation of a spatial-temporal pattern of synchronous activity of the neurons of the somato-sensory system, which has bearing on the possible effect of EHF EMR on higher nervous activity.

8. Mechanisms of Action of EHF EMR on Biological Objects

The current state of research on the use of EHF EMR of non-thermal intensity in medicine and experimental biology is characterized by an increasing volume of theoretical research and practical utilization, with wide introduction into clinical practice. This is very significant, considering that to this day there is not yet a consistent general conception of a mechanism for the effects of EHF EMR on the human organism, although a few concepts have gained currency in Russia and Ukraine. In the west, research on this theme is carried forward mainly in an applied nature.

Historically, the first hypothesis was put forward by the Moscow school of radiophysicists, the basis of which was an assertion of the coherent nature of interaction of external EHF EMR with the cells' own EMF. The Pushchinskaya school of cellular biophysicists, N.K. Chemeris *et al.*, insist that stochastic resonance plays a dominant role, in other words, it is a question of the energetically dominant action in a bioenergetic informational field. Here, though, we have already stressed the role of modulating frequencies. The Tulskaya school of field, radiation and bioinformatics biophysics stresses the role of the frequencies of physiological rhythms of the body. However, in view of the relatively recent beginning of mass utilization of EHF therapy procedures, the question of genetic factors in the consequences of EHF irradiation remains open.

As early as 1968, [A.S. Presman] noted that in any living organism there exists a reliable protection against external natural and artificial electromagnetic noise disturbances (signals not coherent with any of the signals used by the system), and against other incommensurate external influences. Apparently, it is the action of this multi-stage (passive or active) protection in the organism that is connected with the experimentally detected biphasic dependency of the bioeffects of electromagnetic fields on their intensity, i.e., the initiation of opposite physiological changes under the influence of EMF of low and high intensities. By way of illustration in experiments on dogs, the following results were obtained: 100-200 mW/cm^2 – suppression of conditioned reflexes; 5-10 mW/cm^2 – stimulation; 0.2-2 mW/cm^2 – suppression.

On the basis of experimental data in the work of [I.V. Rodshtadt], an attempt was made to calculate the reflex arc under the influence of EHF EMR. According to all the calculated data, EHF radiation of low intensity significantly modulates the frequency of spontaneous discharges of Ruffini's corpuscles. But Ruffini's corpuscles are mainly concentrated in the region of the large joints and on the hairy part of the head. The region of the shoulder joints was selected as the zone for therapeutic irradiation. Firstly, the skin in the region of large joints (in this case, the shoulders) is strongly hydrated because of folds of collagen, great content of proteoglycans, significant movement of biologically active substances, including histamine and proteinase and their inhibitors, and excess concentrations of fat cells. Excessively hydrated tissues, as is known, absorb extremely high frequency electromagnetic waves especially strongly. Secondly, the regions of the large joints coincide in a number of cases with the zones of Zakharyin-Ged and the segmentary acupuncture points, which ensure adequate targeting of the therapeutic effects to the corresponding ailing organ.

With regard to the reflex arc of the therapeutic action of EHF EMR, a few key components can be described. The information from EHF oscillations of low intensity is transmitted from Ruffini's corpuscles by the so-called LIF (low-intensity fluorescing) neurons. They enter into the structure of the vegetative ganglia, secreting into their vascular channels and synaptic fissures adrenaline and noradrenaline in the course of their rhythmic activity. This rhythmic activity has a latent period of 30 seconds and is revealed in the modulating effect of a fluorophor (dopamine) on the slow excitatory, acetylcholine-dependent post-synaptic potential. A further reference point for calculating the reflex arc is provided by data from N.P. Zalyubovskaya on increased levels of adrenaline and noradrenaline in the blood, and also adrenaline in the hypothalamus, in experimental animals under the influence of EHF EMR of low intensity. That is, the humoral part of the reflex arc begins with the LIF-neurons. Noradrenaline, reaching the vessels of the brain via blood flow, crosses the blood-brain barrier in the region of the pituitary gland, inducing a mild spasm of the brain arterioles. The sensory reception of EHF EMR waves of low intensity is completed with optimization of the activity of the brain owing to adequate correlation of its microcirculation and metabolism. Unlike noradrenaline, adrenaline does not cross the blood-brain barrier. Therefore, the origin of the increased level of adrenaline in the hypothalamus during EHF exposure is not fully clear. Apparently, having overcome the blood-brain barrier in the region of the pituitary, noradrenaline gives a signal for the secretion of adrenaline by the chromaffinocytes and glial cells of the hypothalamus. This has been confirmed in experiments. In turn, adrenaline, as is well known, is a limiting factor in the secretion of corticotropin-releasing hormone by neurons of the hypothalamus, which determines the production of adrenocorticotropic hormone (ACTH) by the adeno-pituitary cells. According to the data of various authors, the time from the moment adrenaline and noradrenaline appear in the blood to when ACTH also appears in the blood is 10-30 seconds. Thus, in calculating the reflex arc of the therapeutic effects, good correspondence is obtained between the sum of the latent periods of its nervous and humoral parts (40-60 seconds), and the time for indication of sensory feeling during EHF exposure at low intensity of the skin of basically healthy volunteers (40-50 seconds). The experimental data of N.P. Zalyubovskaya say that an increase in the level of ACTH under the influence of EHF exposure of low intensities actually occurs. In particular, she noted an increase in the amount of 17-OCS in the blood against a background of decreased ascorbic acid in the adrenal cortex.

Crossing over to the questions of biochemical reception of EHF exposure at low intensities, we must keep in mind that the effects occur at the transduction stage, when the natural humoral signals penetrating into the cells are modulated. This type of physiological effect is realized through the phospholipids of the cells' plasma membranes, and in our case, apparently, is achieved through some acceleration of their peroxide oxidation. The described effects of EHF exposure at low intensities occur through a change in the rate of diffusion of the substrates and products of peroxide oxidation of lipids. This situation is fully possible at the level of capillary vessels, i.e., in the microcirculatory system, where, for example, in the case of functional hyperemia, and consequently against a background of stronger processes of filtration-absorption, there occurs facilitation of diffusion in the interstitial canaliculi. The temperature threshold for dilation of skin vessels is quite low, only 0.06ºC, i.e. is on the border of millimeter wave heating of tissue. Apparently, this happens to the venous walls, leukocytes and fibroblasts, inasmuch as they belong to type-B tissue according to Labori, which is equipped with metabolic blocks of the pentose-phosphate cycle and is therefore sensitive, according to the data of N.P. Zalyubovskaya, to EHF EMR waves of low intensity. We must bear in mind that millimeter waves penetrate irradiated skin to a depth of 1 mm, but the microcirculatory system of the skin begins to function at a depth of 150 microns, i.e., is fully accessible to direct EHF exposure. Reception of EHF EMR of low intensity by the intradermal venous network, apparently, is accompanied by intensification of the pentose-phosphate cycle, which according to all physiological canons, should lead to a change in the concentration of potassium ions. In turn, the potassium, or more accurately, its physiologically high concentration, in the presence of calcium ions, is an adequate stimulus for nerve fibers secreting neuropeptides. Biochemical reception of EHF EMR of low intensity is thus accompanied by the release of physiologically active substances, which often play the role of endogenous medicines. Moreover, the therapeutic effect does not depend on localization of the EHF exposure, because the microcirculatory channels are distributed throughout the surface of the skin sufficiently evenly.

We introduce detailed data from I.V. Rodshtadt on differences in therapeutic effects from EHF therapy during irradiation of the right and left halves of the body, which have a direct bearing on the theme of our review. Irradiation of the left half of the body by millimeter waves of low intensity is targeted primarily to the right hemisphere in healthy volunteers and stroke patients, and in experimental animals is accompanied by increases in the population of long-lived lymphocytes in the lymph nodes on the irradiated side. An increase in the total phosphatase activity in the mitochondria of these recirculating small lymphocytes (irrespective of EHF exposure) is a hopeful prognostic feature for stroke patients in terminal conditions. Apparently, an increase in antigen-specific T-cell activity occurs in parallel, especially in cases of damage to the right hemisphere. The effect observed during irradiation by millimeter waves of low intensity of the right half of the body in experimental animals consists of an increase in the population of short-lived lymphocytes and lymphocytes normally found in the lymphoid organs and, taking into account clinical observations as well as research on healthy volunteers, is explained by more equal targeting of the effects to both hemispheres of the brain. As a result it can be supposed that EHF modulation of the activity of the brain during irradiation of the left half of the body is accomplished via both nervous and humoral mechanisms. In the first case, the effect is addressed primarily to the right hemisphere, and in the second, i.e., through humoral mechanisms, the effect is addressed to the hypothalamus. EHF modulation of the activity of the brain during irradiation of the right half of the body is accomplished mainly through nervous mechanisms, and the effect is more equally addressed to both hemispheres.

In modern times, one may consider the concept of proteins as dynamic systems to be fully confirmed [Demchenko, 1986; and Demchenko, 1988]. Efforts by researchers should be directed toward analysis of specific types of movement and location in connection with function. The frequencies of oscillation of groups of atoms in the active center of an enzyme are located in the range of 10-100 GHz. The approximate resonant frequencies in Hz have been determined experimentally for a few structures in living cells: somatic cell – 2.39×10^{12}; somatic cell nucleus – 9.55×10^{12}; mitochondria from liver cells – 3.18×10^{13}; human cell genome – 2.5×10^{13}; interphase chromosome – 7.5×10^{11}; metaphase chromosome – 1.5×10^{13}; DNA – $(2\text{-}9) \times 10^{9}$; nucleosome – 4.5×10^{15}; ribosome – 2.65×10^{15}; cellular membrane – 5×10^{10}; cytoskeleton – 10^{8}; erythrocyte – $(3.5\text{-}4.0) \times 10^{10}$ [Illarionov].

Application of information theory to biology [Presman] showed that along with energetic interactions in biological processes, a significant (if not main) role is played by informational interactions. These are characterized by the transformation of information and its transmission, codification and storage. Biological effects associated with these interactions depend not on the strength of the energy carried into one or another system, but on the information carried into it. A signal carrying information only induces redistribution of energy in the system itself and directs the processes happening in the system. If the sensitivity of the perceiving systems is sufficiently high, the transmission of information may occur with the help of very little energy. Information may accumulate in the system with the help of small signals [Nefedov, Protopopov, Khadartsev and Yashin]. In living organisms, systems for perceiving information transmitted with the help of EMF are reliably shielded from natural electromagnetic interference, but when there are pathological conditions in the organism, spontaneous changes in EMF (from solar eruptions or lightning) disturb the regulation of physiological processes. Whole organisms have maximal sensitivity to EMF, isolated organs and cells lesser sensitivity, solutions of macromolecules even lesser. Significant differences are observed in reactions to EMF in one and the same biological system (molecular, cellular, organ or systemic) depending on whether it is located in an intact organism or in an isolated condition. Differences are noted in these two cases even in the nature of the dependency of the reaction of the system on EMF parameters.

All this indicates that systems especially sensitive to EMF were apparently formed in the process of evolution only at the macroscopic level. In other words, the perception of weak natural EMF occurs only on the level of sufficiently complex biological systems, and is fully developed only in intact organisms.

As mentioned above, one of the first hypotheses was that put forward by the biophysical school of academician N.D. Devyatkov (Institute of Radio Engineering and Electronics, Russian Academy of Sciences) on the coherent nature of activation of the cells of an organism [Devyatkov, Golant and Betskiy]. According to this hypothesis, the microstructure of the cell membrane (the aggregate of mitochondrial membranes) ensures the formation of the dipolar component of the cell. This oscillating electrical dipole, combined with acoustical vibration of the membrane, is the cellular generator of the cell's own EHF EMF. In a healthy cell, the nature of the vibrations is stochastic (especially considering the interaction of the EMF of the ensemble of cells), and the spectral nature of the field is near to noise at some intermediate intensity. During pathological changes in the cell, the reaction of the cell is expressed in growth in intensity of generation in relatively narrow bands of the spectrum. It can be proposed that, when considering one or another form of disturbance of metabolic processes in the cell, an increase in the intensity of generation is connected with the redistribution of free energy and its influx into the part producing the spectrum characteristic of the disturbance (the simplest, most understandable analog at the macro-organism level is an increase in body temperature during inflammatory illness).

According to the hypothesis of coherent resonance, strictly speaking, the process is bioinformational [Afromeev, Subbotina and Yashin], insofar as the intensity of external EMF plays no particular role in the occurrence of a chain reaction in the cell; what is important is its information content (frequency, modulation, polarization, etc.). A weak point of this concept is the absence of the proven selection of discrete frequencies of external EMF used widely in therapeutic practice: 3-4 therapeutic monochromatic frequencies in the range from 2 to 8 mm. A possible variant (particularly subjective) selection of these frequencies is considered by [Khadartsev and Yashin].

Regarding this question, one may note the research being conducted under the leadership of N.K. Chemeris at the Institute of Cellular Biophysics, Russian Academy of Sciences, in the city of Pushchino-na-Oke. The results of theoretical and experimental research by [Gapeev and Chemeris] led to the concept of stochastic resonance with a special role played by double resonance at EHF frequencies carrying a low-frequency modulated signal; the latter, by all appearances, is located in a region of frequencies of the basic physiological rhythms of the body. Redistribution of the free energy of cellular metabolism takes place not in the form of frequency resonance, but resonance which is energetic in a quite wide frequency spectrum. Therefore, one of the preliminary conclusions is not about the bioinformational, but the bioenergetic nature of activation of cellular generation by external EMF. At the same time, it follows simply from experiment that the energetics of external electromagnetic exposure plays no role; even relatively low (threshold) levels suffice. In principle, this is in complete agreement with the biological mechanism of the chain reaction of free energy formation in cellular metabolism, but in order to reject the informational component, it would be necessary to undertake a large series of experiments at all EMF ranges which play a vitally important role in cell functioning. The most attractive aspect of this concept is the expressly experimental approach.

It is obvious that it is meaningless to argue over the primacy (or dominance) of biochemical or biophysical processes in the creation of a cell's own EMF. It is clear that the free energy, needed by the cell for processes including generation of EHF EMF, is produced through biological oxidation in the mitochondria. The most important role here is played by adenosine triphosphate (ATP). And this energy is transmitted further in the cell by chemical means.

The natural biological field of a living organism is EMF in the ranges from infrared to ultraviolet, and possibly, even shorter waves. A second, also natural field for an organism is the field which depends upon physiological rhythms. These are low-frequency oscillations from fractions of a hertz to hundreds (or thousands) of hertz, physically realized as acoustical-electrical oscillations. Here arises, from the point of view of radiophysics, a very significant question: within the boundaries of the organism, all fields should be simultaneously tied together as (we repeat) biocybernetic and biophysical systems; in this case, the correlational bond occurs only as a modulation (in the model, amplitudinal, but in reality, carried in a very complex, combined manner). Therefore, and only for this reason (rather than because of the response to external, natural EMF) there exist oscillations within an organism, part of whose spectrum most likely coincides with both the long wave and EHF ranges. Their function in the natural biophysical process is correlational-connecting; median-modulating. In other words, the EHF range is a medium frequency between low and high ranges, allowing the correlation of fields within an organism and the transfer of information by modulation [Afromeev, Subbotina and Yashin].

[Khar'kyanen] came to the conclusion in his research that a cooperative system of a large number (10^5-10^{10}) of molecular centers transmitting energy to some collective, distributed degree of freedom should serve in the capacity of an effective primary target of weak-intensity EHF EMR. It was shown that such a collective degree mode is achievable for a system with a large number of cooperatively functioning channel-receptors on a membrane or a large number of molecular reagents, the state of which is fixed near a critical point.

The search for effective molecular mechanisms of EHF bioeffects has led to the necessity of clear accounting of the dynamics of active biomolecular structures participating in a complex system of chemical chain reactions, as a rule, of a catalytic nature. In most cases the question may be about the processes of synthesis and breakdown of the same biopolymers, about conformational transitions and about the dynamics of hydrated membranes [Serikov].

On the basis of the magnetic-resonance mechanism of action of EMR of low (non-thermal) intensities on biological objects, [Dmitrievskiy] found a highly effective action of circular-polarized radiation on the permeability of biological membranes, experimentally determined over the range of visible light as well as across the entire range of EHF frequencies. There is also polarization of radiation in the Zeeman effect (and in NMR and EPR, and in chemical polarization of ions and free radicals in the constant magnetic field of the Earth or separate parts of the organism). Excitation of the corresponding levels may be caused by EMR from external sources or arising due to internal biochemical processes.

[Subbotina and Yashin] proposed in their research the task of determining the basic mechanisms of action of EHF EMR on separate human systems and organs. According to modern concepts, the effect of irradiating the human body with EHF EMR lies in activation of the biologically active points (BAPs), the signals from which are transmitted along the main acupuncture channels (meridians) to the responding organs or systems and act further at the cellular level. The biophysical mechanism of action should occur on the level of normal functioning of the whole body. At the same time, low-level action of EHF EMR on isolated biological tissue should not create a characteristic effect which can be detected in preparations taken from biopsies. Research conducted on EHF EMR irradiation of biopsied and intact livers of experimental animals showed that morphological changes are characteristic only of irradiation of the intact animal. This confirms the bioinformational nature of low-level, non-thermal exposure, derived from the concept of the body as a complex self-organizing system. From the informational effect of MMW we may anticipate mobilization of the reserve potentials of an organism in anomalous conditions.

Thus, to this day there is no precise concept of the physical-chemical mechanisms of action of EHF radiation on biological systems, and there is likewise no precise clarity on the nature of sensation of extremely high frequencies in living subjects. Regarding this there exist only a number of hypotheses: the hypothesis of coherent excitement and interaction [Devyatkov, Golant and Betskiy], the informational hypothesis [Nefedov, Protopopov, Sementsov and Yashin], the hypothesis on the soliton mechanism of energy transmission [Davydov] and a few others connected with effective absorption of energy from EHF radiation by water molecules [Gapeev, Safronova, Chemeris and Fesenko].

We will consider the hypothesis of the Kiev school (Prof. S.P. Sit'ko in Ukraine), which has been developed in considerable detail and confirmed experimentally. Living things are considered as a fourth quantum level (after nuclear, atomic and molecular levels) of structural organization in nature. In this way, the physics of the alive, as opposed to biophysics, is arrived at from a definition of life in terms of fundamental natural science: any independent living thing is a quantum-mechanical whole, the self-coordinated, non-local potential of which is formed through a type of laser-coherence in the mm wavelength range [Sit'ko and Mkrtchyan]. A number of facts support the possibility of the existence of such a coherent field in an organism in the mm range:

• intensity of the electrical field in the protoplasmic membranes of each cell of a living organism (10^{-5} V/m);

• frequency of vibration of its own membranes, 10^{10}-10^{11} Hz;

• the density of EHF EMR inside the body is maintained beyond a threshold of non-equilibrium phase transition because of the mechanism of full internal reflection by the skin;

• the genomes of all somatic cells of any organism are identical, and this means that these cells may be regarded as active centers of the system in a regime of multi-modal coherence.

In his articles, S.P. Sit'ko has reported the direct detection of a non-equilibrium component of EMR from the human body in the mm range. This, he says, is a decisive experiment which converts the working hypothesis into the scientific trend "Physics of the Alive" [Sit'ko and Yanenko].

The results of clinical and experimental research on the effect of super-low levels of EMR in the mm range on biological objects of various levels of complexity are the basis for ideas about the means of expression of genetic information at the macroscopic level of the whole organism. An important test of the new concepts is the possibility of restoring the functional state of the body with only a few quanta of EMR (10^{-20} W/Hz cm^2). Quantum medicine has now demonstrated this with a few thousand patients [Sit'ko and Mkrtchyan].

9. Standards and Normalization of HF EMR

In the USSR, wide research into electromagnetic fields was begun in the 1960s. Much clinical material accumulated on undesirable effects of magnetic and electromagnetic fields, and it was proposed to introduce a new nosological illness, "radiowave sickness" or "chronic injury from microwaves." Thenceforth work by scholars in Russia established that, firstly, the human nervous system, especially higher nervous activity, is sensitive to EMF, and, secondly, that EMF possesses a so-called informational action in its effects on humans at intensities below the threshold values of thermal effects. The results of this work were used in the development of normative documents in Russia. As a result, the norms established in Russia were very strict and differed from those in America and Europe by a few orders of magnitude (for example, in Russia, the maximum permissible level for workers is 0.01 mW/cm^2; in the USA, 10 mW/cm^2). It is mentioned that subsequently a Soviet-American group was formed with scholars from the USSR and America, which acted from 1975 to 1985. This group organized joint biological research, which confirmed the correctness of the concepts of the Soviet scholars.

All norms and standards represent a compromise between the advantages afforded by using new technologies and possible risks connected with their use. Therefore, the maximum permissible levels of exposure to any factor depend on the degree of knowledge about health damage, on criteria of risk adopted in this regard, and on established capacity for endurance. Taking this into account, permissible (operational) levels, cumulative (daily) exposure limits and maximum endurable levels (for emergency procedures) were established [Dumanskiy and Prokhvatilo, All-Union Standards]. Permissible operational levels for an 8-hour workday were:

	USSR	**USA (1996)**
30-300 kHz	400 μW/cm^2	none
0.3-3 MHz	27 μW/cm^2	100 mW/cm^2
3-30 MHz	4 μW/cm^2	1-100 mW/cm^2
30-300 MHz	1 μW/cm^2	1 mW/cm^2
0.3-300 GHz	5 μW/cm^2	1-5 mW/cm^2

According to OST 11.12.004-84 "Radiofrequency electromagnetic fields of 300 MHz-300 GHz", maximum endurable levels are 1000 μW/cm^2 = 1 mW/cm^2, and the allowable energy load during a working day is 200 μW-hour/cm^2. Maximum permissible exposure is calculated as (allowable energy load)/(time of exposure (hours)).

In [Pyasetskiy and Pisanko, 1991], on the basis of much clinical and experimental material, the following were noted:

1) EHF EMR of low intensity (less than 10 mW/cm^2) is capable of changing the functional condition of living organisms of different levels of organization. The acting and initiating factor is the power and duration of exposure.

2) Physiological reactions resulting from exposure to EHF EMR at non-thermal levels of power lie within the limits of normal values and may be registered by length of time of reordering the functions of the pathological system or organ subjected to EHF exposure.

3) During prolonged exposure of a living organism, low-intensity EHF EMR may change from a normalizing, stimulating factor into a factor able to induce bioeffects uncharacteristic of the functioning of the stricken organ or system as a whole. Negative effects and their strength depend on the time of exposure to EHF radiation and the level of development and differentiation of the living organism.

4) When creating devices which generate low-intensity EHF EMR, it is essential to foresee the technical development of the instruments and devices for medical-biological research and therapeutic use.

Medical-biological instruments should be retuned, in terms of frequency, power and time of exposure, to the guiding informational signals from the biosystem which is undergoing EHF exposure. Therapeutic instruments should possess stable power of EMR, not induce negative bioeffects, and limit the time of exposure to 15-30 minutes. In this connection, the Ukrainian government published a "Resolution of Necessity of Testing and Certifying EHF Instruments Used in Medical-Biological Practice." A laboratory was established in the Ministry of Public Health of Ukraine for monitoring and certifying EHF instruments.

As was noted in *A Brief Ecological Encyclopedia* [Person in Electromagnetic Fields], issued by the Center for Electromagnetic Safety, Institute of Biophysics, the systems most sensitive to EMF are the central nervous, cardiovascular, hormonal and reproductive systems. Groups requiring closer attention are children, pregnant women, people with illnesses of the central nervous, hormonal or cardiovascular systems or with weakened immunity or allergies. They should carefully observe rules of electromagnetic safety in their lifestyles and protect themselves from the influence of EMF.

It is considered that under Russian Sanitary Norms such values of EMF have been adopted as maximum permissible levels for irradiation of the population that in everyday irradiation under conditions characteristic of the given source do not induce illness or divergence from health detectable by modern research methods during the period of irradiation or for periods of time after its cessation in the population, regardless of sex or age.

10. Effects of High-Frequency Communications Media on Human Health

During the last 50 years, the round-the-clock power of radio emissions has increased by a factor of more than 50,000. In epidemiological studies of the population of Ukraine, a connection was established between leukemia in children and cancer in adults, and exposure to EMF at industrial frequencies. Specific injuries under radiowave exposure are development of cataracts, instability in leukocyte make-up of peripheral blood, and vegeto-vascular disorder [Grigoriev, Grigoriev, Stepanov and Pal'tsev]. Radar stations, which are the most powerful and dangerous sources of radiofrequency influence on the environment, are widely used in aviation for controlling air traffic, in radioastronomy, in anti-aircraft defenses, and in space research [*Occupational Hygiene at Radio Location Stations and Other Facilities Using Electronic Apparatus,* Chernetsov, Lyutov and Volodin]. One model for calculating doses absorbed by bioobjects in the EHF range is provided by [Sveshnikova, Chovnyuk].

According to the results of [Miroshnikova], the millimeter and centimeter ranges of radiation have the biggest effect on initiation and development of blood disorders, and the mm range, on diseases of the circulatory system. The risk of developing diseases of the central nervous system increases under exposure to decimeter waves. Data on development of psychic disturbances [Orlova *et al.*] under EMR exposure show effects ranging from asthenia and changes in mood to nonsensical ideas and aural and visual hallucinations, and disturbances in behavior all the way to attempts at suicide. A connection was noted between EMF exposure and the development of malignant tumors: the likelihood of cancer was three times greater under SHF exposure [Yu.G. Grigoriev]. **It can be proposed that the current increase in electromagnetic pollution of the environment exceeds human adaptational capacities.**

The organs and tissues most susceptible to thermal effects have poor blood supply (making it harder to dissipate heat)—for example, the crystalline lens of the eye—or have high water content (the blood, liver, reproductive glands, stomach, urinary bladder, etc.). Therefore, when SHF energy is absorbed, it produces so-called "hot spots" of local heating, including in vital organs. During this process, a person might not feel any heating of internal organs inasmuch as heat receptors are located in the skin. For example, most dangerous from the point of view of formation of "hot spots" in the head are frequencies of 700-2500 MHz in the decimeter range, and it is precisely here that the frequencies of 900 MHz, 1800 MHz and 2.45 GHz of cellular communications fall. Absorption of EMF in biologically active points is many times more effective than in other parts of the skin, and this energy, through the system of Chinese medicine, affects internal organs and the body as a whole. The danger of mobile telephones consists of the fact that in addition to direct effects on the brain, the whole body is irradiated via the biologically active points of the concha of the ear.

Today it is important that any potential user can receive needed information at any desired moment in time in the necessary form at his preferred point in physical space. Such an approach to guaranteeing access to information resources in recent times has led to an outburst of activity in the field of creation of all kinds of communications systems and, foremost, space communications systems, which have the needed characteristics in operativity and globality of information provision [Grinyaev and Rodionov]. These communications systems will work in SHF and EHF bands of electromagnetic radiation and, according to estimates, will be able to create on the Earth's surface a power density of radiation of 10^{-6} to 10^{-7} W/cm^2 and in special modulated modes, 10^{-2} to 10^{-3} W/cm^2 [Aleshenkov, 1997; Aleshenkov, 1998].

Studies have repeatedly proven that the basic carrier of information both within a biological object and between separate biological objects, including people, is electromagnetic radiation. In this process, circulation of an enormous flow of information in the course of a person's life activities is possible only through the use of low-power signals. The expenditure of energy in the formation of these signals is determined by the energetic capabilities of the person. According to estimates by experts, the sum power of the informational signals does not exceed 1 to 10 mW, or 10^{-3} to 10^{-4} of the thermal power radiated by the organism [Afromeev], and the power of EHF radiation of a cell is $P=10^{-23}$ W/Hz [Nefedov, Protopopov].

In recent times, we have observed a growing interest by researchers in the paradoxical effects of exposure of living organisms to small doses of various biologically active substances. What is "paradoxical" is that these effects are generally observed at concentrations of four to ten orders of magnitude lower than normally used and thus not expected to produce any response, and that unusual patterns of response are typical of the effects of super-low doses (polymodal dose dependency, etc.). The level of biological organization at which the effects of super-low doses are detected is highly varied—from cellular, macromolecular, organic and tissue to animals, plants and entire populations. General experimental results obtained from various animals and humans gives evidence that exposure to radiation or chemical substances may induce identical reactions to those experienced at doses differing by five to ten orders of magnitude [B.N. Rodionov and R.B. Rodionov]. The clearest example of such an effect is the use of homeopathic preparations or cancer medicines at super-low doses [Potebnya, Lisovenko, Shalimov; Sit'ko, Skripnik]. Similar results are also seen under the influence of super-high frequency radiation (SHF radiation). Thus on the curve of the relationship of the value of the physiological effect to the power density of irradiation, two maxima are seen [Grinyaev and Rodionov]. These maxima are also separated by a "dead zone," the presence of which is explained as the result of the inclusion of active barrier mechanisms and compensating systems in the working of the organism. When these powers cease working, total agitation is observed, culminating in death of the organism.

In the natural course of evolution, the receptor system was formed in such a way that it reacts only to the most significant signals of low intensity. This, for example, was successfully demonstrated in rats in experiments on development of the conditioned "avoidance" reflex depending on parameters of weak electromagnetic signals. The reaction developed best of all to signals with a frequency of 300 Hz at a power density of 10^{-11} W/cm^2. Increasing or decreasing the power density by one or two orders without changing other parameters of the signal made it impossible to develop a conditioned reflex. Changing the frequency to 500 or 50 Hz had the same effect.

One of the main peculiarities of the creation of resonance effects is the scant power and short time of irradiation. Thus, the informational-wave therapy apparatus "Porog-1" and "Minitag" work at a super-low power flux density of roughly 10^{-17} W/cm^2 [Illarionov] over the course of a few seconds or minutes.

Observed higher resonance frequencies of a living cell coincide with frequencies of radiation of communications satellites. The power densities and duration of irradiation created by these satellites will significantly exceed (by ten or more orders of magnitude—such irradiation is possible over the course of a whole lifetime) the energetic doses inducing changes in living cells.

In this connection we consider possible consequences from the effects of electromagnetic radiation from communications satellites on biological objects. Phased array antennas are capable of scanning the earth with a dispersion angle of 0.3 degrees. The installation of such antennas in a global system of low-orbit satellites, transmitting with a power of 800 W, working at frequencies of 20 and 30 GHz, at an orbital height of 1400 Km, may provide the Earth's surface with power densities of 10^{-8} to 10^{-9} W/cm^2 or pulsed 10^{-2} to 10^{-3} W/cm^2 in the microsecond range. Negative consequences of this may be changes in cell structures and physiological processes, genetic changes, and alteration of psychophysiological conditions and behavior (development of conditioned reflexes). As a result of superpositioning fields from several sources of radiation, standing waves may arise, the frequency of which may coincide with resonance frequencies of living cells or rhythms of various organs and functional systems of an organism. Therefore there will be a likelihood of changes (including negative changes) in the genetic apparatus of living cells during prolonged exposure to low-energy electromagnetic radiation from communications satellites. As a result of such effects on genetic mechanisms of transcription, translation and repair, and also on the mechanism of gene expression, there may result the production of significantly different biological species with unpredictable characteristics. Mutations which carry a selective advantage have a tendency to increase, i.e., give rise to instability. In this way, natural selection is actually based on instabilities, brought about by the appearance of favorable mutants which lead to the collapse of earlier stable structures, and evolution itself consists of an endless replacement of some stable conditions by others through instability.

This representation of evolution fits well with modern ideas about synergetics. Modern synergism is the recognition of the role of small fluctuations in energy which can change the structure of complex systems at a point of bifurcation. It is believed that these low-energy signals influence the choice of routes of further development at the moment of bifurcation, when there are a number of equal-valued choices.

Inasmuch as mutations for the most part are deleterious, no one biological species can allow itself to accumulate them rapidly in its own reproductive cells. Preservation of the species requires that the reproductive cells of organisms be protected from rapid genetic changes, but preservation of each specific individual requires just that kind of protection for all the other cells of the organism as well. Nucleotide substitution in somatic cells can enable the natural selection of those cells which are better suited to the existing conditions. This can lead to their uncontrolled proliferation, for example, to development of cancer, which in the Western hemisphere causes more than 20% of premature deaths. Convincing research shows that death in this case is mainly due to accumulation of changes in DNA sequences in somatic cells. A ten-fold increase in the frequency of mutations would likely lead to a catastrophic increase in the number of cases of cancer.

In an article by [Rodionov, 1999], a number of evidences of the bioeffects of EMR are presented. For example, exposure to SHF and EHF EMR at a PFD of 5 μW/cm^2 significantly influences the properties of physiological systems and changes the flow of physiological processes, because the frequency of oscillation of DNA is 2 x 10^9 to 9 x 10^9 Hz; of chromosomes, 7.5 x 10^{11} to 1.5 x 10^{13} Hz; and of the human cell genome, 2.5 x 10^{13} Hz; which speaks of the relationship between the acting physiological factor and the receiving biological structure, with the power of the cell's own EMR being 10^{-23} W/Hz. Biosystems of a high level of organization, in particular, humans, can react to subthreshold-intensity signals or have the ability to react additively, because the higher the level of organization, the greater the sensitivity. The sensitivity of a human to the effects of SHF and EHF radiation is estimated at a level of 10^{-16} W/cm^2. It has been experimentally established that when PFD is more than 10^{-4} W/cm^2, it induces auditory sensations in humans, and at 10^{-11} W/cm^2 it induces conditioned reflexes in rats. Prolonged non-intensive or short intensive (at powers greater than 10^{-4} W/cm^2) exposure induces a reaction of alarm over the course of a few days, and later, compensation and adaptation. Under prolonged intensive exposure, there occur a stage of alarm, a stage of exhaustion and the emergence of pathology in the organism. Under prolonged intensive exposure, genetic changes are possible and also impaired immunity.

Therapeutic devices working in EHF (millimeter), centimeter and decimeter ranges of EMR wavelengths have some specific actions on those ill with one or another pathology.

The results of experience in therapeutic effects of EMR with power density of 10^{-5} W/cm^2 and a smooth tuning of modulation frequency from 1 to 100 Hz are presented in Table 2 (575 patients) [Rodionov, 1999].

Comparison of the parameters of therapy with the parameters of EMR created by elements of mobile communications shows that the use of mobile communications may

TABLE 2

Disease	Type of Therapy (EMR Range)	Results of Treatment %		
		Improvement	No Change	Worsening
Bronchial asthma	EHF	69.2	30.8	0
	CMW	75.0	25.0	0
	DMW	70.6	29.4	0
Ischemic heart disease	EHF	70.0	20.0	10.0
	CMW	73.3	26.7	0
	DMW	70.0	30.0	0
Hypertension	EHF	70.0	30.0	0
	CMW	75.0	25.0	0
	DMW	70.0	30.0	0
Gastric and duodenal ulcers	EHF	73.3	26.7	0
	CMW	70.6	29.4	0
	DMW	76.9	23.1	0
Radiculitis	EHF	60.0	30.0	10.0
	CMW	66.7	33.3	0
	DMW	76.5	23.5	0
Vascular-cerebral insuffiency	EHF	71.4	28.6	0
	CMW	69.2	30.8	0
	DMW	72.7	27.3	0
Arthrosis	EHF	60.0	40.0	0
	CMW	68.8	31.2	0
	DMW	76.5	23.5	0
Neurosis with predominance of agitation	EHF	80.0	20.0	0
	CMW	63.6	31.2	0
	DMW	76.5	23.5	0
Neurosis with predominance of depression	EHF	75.5	25.0	0
	CMW	66.7	33.3	0
	DMW	66.7	33.3	0

exacerbate the diseases listed in Table 2.

Patients suffering from neurosis with agitation were exposed to an EHF-field of 2 mm wavelength and 2 Hz modulation frequency for 10 minutes, bringing about improvement in their condition. In treating neurosis with depression, positive results were obtained with EMR of 2 mm wavelength and frequency modulation at 20-21 Hz. Irradiation of healthy people with EHF radiation with the noted parameters puts them in danger of agitation at FM 20-21 Hz and of depression at FM 2 Hz. It also appears possible to artificially manipulate the psycho-physical condition of people [Kozhokaru; Men'shikov, Rodionov and Grinyaev].

Much research by various authors has been dedicated to studying the biological effects of radiation from computer terminals. [Anisimov, Zabezhinskiy *et al.*] showed that chronic irradiation from the video terminals of personal computers causes acceleration of sexual maturation and premature termination of reproductive functions in female mice, and reduces nocturnal levels of melatonin in blood serum. The data obtained give evidence of the expression of biological effects of irradiation by PC video terminals and their possible negative effects on the health of users. Special neuroendocrinological research by [Khusainova and Kornienko] showed that six-year-old children regularly using computers in kindergarten were observed to have an increased basal level of urinary secretion of adrenaline, reduced secretion of DOPA, and increased salivary concentration of 11-oxycorticosteroid, which gives evidence of increased functional activity of the hypothalamo-pituitary-adrenal system and reduction of its reserve potential, and may be the basis of acceleration of sexual maturation.

For understandable reasons few items are found in the open press on studies of the negative effects on human health from EHF EMR from communications equipment.

[Simonenko, Chernetsov and Lyutov] presented data from an investigation over a span of four years of groups of workers having contact in the course of their work with low-power EHF EMR. The first group received irradiation at a level of 30-40 μW/cm^2 for up to six hours a day. The second group received irradiation at a level of 10-30 μW/cm^2 for from two minutes to 2-4 hours a day. The third group received irradiation at a level of 1 μW/cm^2. All other conditions among the groups were identical. In the first group, the most frequent illnesses proved to be neurotic syndrome with vegetative dysfunction and astheno-vegetative syndrome. There was a high frequency of hypertension, early development of ischemic heart disease, and bronchospasms. Nearly all the persons studied complained of: headache and dizziness; irritability; fatigability; general weakness; sleep disturbance; daytime sleepiness; pain in the region of the heart; difficulty breathing; and stomach pains and indigestion. The frequency and nature of the complaints were identical for men and women, and the nature of the complaints were identical for all groups, but quantitatively they increased depending on age and number of years on the job.

11. Discussion

[Kryukov] considered biological adaptation, which is a protective response of an organism to a change in the condition of the external environment (i.e., the current norms). In the case of EHF EMR adaptation occurs predominantly on the cellular and genetic levels. This process is extremely slow, beyond the length of a human life. Therefore, any increase, however significant, in the range of changes in the radiation norms may lead to remote negative effects. Fields in the near and far zones of a radiating antenna are different in principle, and consequently may lead to different biological effects.

Under a sharply resonant response, change in the nature of functioning over a relatively long time is understood as a remembrance by the organism of the result of EHF exposure. A sharply resonant response in living organisms is difficult to verify through the integral functions of a healthy organism (not changed by external influences). The bands of frequencies of response of separate systems of the organism to external influences are usually overlapping. As a result, the dependency of integral functions on frequency lacks a pronounced resonant character. The biological effect at resonant frequencies is usually connected with the presence in the organism of small disturbances and is insignificant. A factor acting strongly on the organism, however, may lead to a sharp change in the response. Thus in the experiments by L.A. Sevastianova conducted shortly after the explosion at Chernobyl (in 1986), when grain exposed to the radiation was used as animal feed, it led to significant changes in the animals' reactions to EHF exposure.

Although in our estimation the peak of research on HF effects in the former USSR occurred in the mid-80s, in the subsequent years publications appeared (for example, a review by [Gapeev and Chemeris, 1999]) on the presence of so-called resonance effects in bioobjects under EMF exposure, and on the role in bioeffects of some forms of modulation; the presence of so-called frequency and amplitude windows was demonstrated, which have high biological activity at the cellular level, and also in the case of the influence of EMF on the central nervous and immune systems. Many studies indicated an "informational" mechanism for the biological effects of EMF. Data were published on unpredictable pathological reactions of humans to modulated electromagnetic fields.

Analysis of theoretical and experimental data on the biological effects of HF EMR indicates the necessity of conducting correct radiation dosimetry for the specific conditions of the experiment and radiating system, otherwise interpretation of the results obtained may be unreliable, inasmuch as artifacts connected with the radiation may cause disturbances in the effects with no correspondence whatever with the specific action of the EMR. This would allow systematizing of the data by degree of their reliability, and consequently, their significance for development of further avenues of research into the mechanisms of action of HF EMR on living systems. The known biotropic parameters of HF EMR, such as frequency, flux density of the energy of radiation absorbed by an object, time of exposure, and polarization and modulation of the radiation, are not a fully exhaustive list of factors affecting an irradiated object. It is necessary to take the condition of the bioobject and its connections to the environment into account in more detail.

Mastery of the mechanism for controlling expression of genes with the help of electromagnetic radiation may open up the possibility of controlling the behavior and condition of biological objects [Nefedov, Protopopov *et al.*]. With regard to humans, it leads to the danger that undesirable consequences on the genetic and physiological levels may be provoked in populations in irradiated territories. Thus, in irradiating the human organism it is possible to inhibit a number of parts of the genome of lymphocytes. This may lead to various abnormalities, including in immune protection, which is the body's most complex system. Such effects, by inhibiting the translation of certain genes, can cause the cessation of synthesis of immunocytes responding to the manufacture of antibodies for certain antigens. For some time after exposure, the immune system of those irradiated will not be in a condition to fight infections provoked by antigens, the reaction to which has been inhibited, and even influenza can prove fatal. [Kryukov, 1998] presented a diagram of trends in total irradiation over the course of the 20th century. One should note the sharp growth in EHF EMR since 1975. One must not exclude the possible influence of increased levels of EHF EMR on the appearance and acceleration of the spread of acquired immune deficiency syndrome during this same period of time.

12. Conclusions

The following means of action of HF EMR at non-thermal intensities on biological systems are possible:

1) Frequencies of 10^9 to 10^{12} Hz are similar to the frequencies of oscillation of protein molecules, DNA and RNA; of membranes and other parts of cells; and of conformational transitions in enzymes, which creates the possibility of resonant absorption of HF EMR.

2) The organism as a whole may have its own resonant frequencies: from living cells to human beings [Sit'ko and Yanenko].

3) EHF fields, modulated at low frequencies close to the rhythms of the brain, heart and internal organs, have a strengthening action. Modulation at infra-frequencies in the range of 5-16 Hz exerts a strongly negative effect on humans and animals.

4) Absorption of EMF in biologically active points is many times more effective than in other parts of the skin, and this energy influences the internal organs and the body as a whole through the system of Chinese meridians.

5) At the moment of cellular division, genetic information becomes "open," chromosomes become immobile and far more susceptible to the influence of HF EMR. An external resonance field may induce expression of genes connected with cancer and change the program of cellular development.

6) Manifestation of the effects of EMF depends on conditions of health and age: healthy adults have minimal sensitivity; embryos, children, elderly persons, and those with hidden psychological or physical disorders experience significant effects, all the way to lethal outcomes.

7) Combination with other deleterious factors: ionizing radiation, toxic substances, geomagnetic anomalies and stress significantly increase the effects of HF EMR.

8) Accumulated discord in the work of cells during chronic and quasiperiodic irradiation leads to confused biorhythms, scattered attention, indistinct phases of sleep and arousal; the body is not in a condition to make a recovery.

9) The effects of HF EMR occur through the hormonal system and immune system with amplification and accumulation of effects; and through catalysts of cellular respiration and biosynthesis. These reactions are non-specific, and it is often difficult to connect them with the fact of irradiation by EMF at non-thermal intensities.

10) Occurrence of a narcotic-type dependency (by stimulating production of endorphins) is possible under regular irradiation with HF EMR.

Much research in the field of biological effects of EMF makes it possible to define the most sensitive systems in the human body: nervous, immune, endocrine and reproductive. These systems of the body are critical. The reactions of these systems must without fail be considered in evaluating the risks of EMF exposure to a population.

On the level of a nerve cell, of structural formations for transmission of nerve impulses (synapses), and on the level of isolated nerve structures, significant deviations occur during exposure to EMF of low intensities. Higher nervous activities, including memory, change in people having contact with EMF. These persons may have a tendency to develop stress reactions. Certain structures of the brain have heightened sensitivity to EMF. Changes in the permeability of the blood-brain barrier may lead to unexpected, unfavorable effects. Especially high sensitivity to EMF is displayed in the embryonic nervous system.

Under exposure to EMF, processes of immunogenesis are disturbed, most often in the direction of suppression. It has also been established that in animals irradiated with EMF, the nature of the infectious process changes—the course of the infectious process is aggravated. Initiation of autoimmunity is connected not so much with changes in the antigenic structure of tissues, as with pathology in the immune system, the result of which is that it reacts against normal tissue antigens. In agreement with this concept, the basis of all autoimmune conditions consists, firstly, of immunodeficiency in the thymus-dependent cellular population of lymphocytes. EMF can cause non-specific suppression of immunogenesis, increase in the formation of antibodies to fetal tissue, and stimulation of an autoimmune reaction in the body during pregnancy.

Considering the important role of the cerebral cortex and hypothalamus in the expression of psychological functions in humans, one may anticipate that prolonged repeated exposure to maximum permissible HF EMR may lead to psychological disorders.

Public health norms in force in all countries, however, are based only on regulation of the energetic load determined by the intensity and duration of contact with EMF, and do not enable application of maximum permissible limits to be extended to conditions of exposure to EMF with complex physical characteristics, in particular, with specific modes of modulation.

When standardizing allowable levels of HF EMR, the following should also be considered:

• the category of users of the device-radiator or those undergoing irradiation (children, elderly, diseased, etc.);

• the biological activity of the basic range of HF EMR of the source-radiator, harmonics, modulation, polarization, and also the spatial configuration of the radiation.

People who are constantly subject to exposure to HF EMR in connection with professional activities must be examined regularly. People with heightened sensitivity should not be allowed to do these activities, or at least should be aware that such activities are contraindicated.

As research has shown, super-low power HF EMR is highly effective in its action on humans. It does not appear possible to lower the allowable norms to such a level. **An alternative way out of the situation is seen in the development of a program of individual diagnostics and creation of a data bank on the effects of HF EMR on the health of the nation in order to substantiate conclusions.** In addition to general methods of examination, monitoring the health of individuals subjected to HF EMR exposure may involve such special methods as LCS study of blood plasma, electropuncture diagnosis of the reaction of the body to specific HF EMR exposure and other methods applied during treatment with HF resonance therapy for objective monitoring of the reaction of the body to exposure (cellular microelectrophoresis, infrared thermography, factor analysis of immune system indicators, etc.). The first method allows mass examination of health conditions to be done quickly and cheaply with identification of signs characteristic of that type of exposure. The other methods allow individual reactions of people to be determined over a specific range and power of exposure or to a specific source of radiation. These kinds of examinations should be available to all who want them. All these methods are far more informative if they are applied dynamically. A number of large-scale immunological methods exist for quick monitoring of human health conditions [Malykhin].

The results of all examinations should be processed centrally at the government level for making safety standards for HF EMR more precise, for clarifying the possible statistical connections between HF EMR exposure and increased numbers of genetic anomalies in the population, and for determining the level of danger from HF EMR to the health of the nation.

13. Appendix

Energy transmitted from a source of EM radiation through a normally positioned unit area over a unit of time: energy flux density (EFD), power flux density (PFD), intensity, energy flux, power flux, power density, Umov-Pointing vector, exposure rate (W/m^2).

The upper energetic threshold of non-thermal bioeffects is about 10 mW/cm^2 (not causing heating of the biomedium of more than 0.1 K).

TABLE 3

Range	Wavelength	Frequency, Hz	Energy, J
UV	200 nm – 400 nm	1.5×10^{15} - 7.5×10^{14}	9.95×10^{-19} - 4.97×10^{-19}
Visible Light	400 nm – 800 nm	7.5×10^{14} - 3.75×10^{14}	4.97×10^{-19} - 2.49×10^{-19}
IR	1 μ – 100 μ	3×10^{14} - 3×10^{12}	300–30 GHz 10^{-21}
mm (EHF)	1 mm – 1 cm	3×10^{11} - 3×10^{10}	1.99×10^{-22} - 1.99×10^{-23}
cm	1 cm – 10 cm	3×10^{10} - 3×10^{9}	30–3 GHz 99 $\times 10^{-24}$
dm	10 cm – 1 m	3×10^{9} - 3×10^{8}	1.99×10^{-24} - 1.99×10^{-25}

3 GHz to 300 MHz

ACTH	adrenocorticotropic hormone	EPR	electron paramagnetic resonance
AEFD	absorbed energy flux density	FM	frequency modulation
AFO	active forms of oxygen	GOST	Governmental All-Union Standard
AM	amplitude modulation	HF EMR	high frequency electromagnetic radiation
AN USSR	Academy of Sciences of the Ukrainian SSR	IRE RAN	Institute of Radioelectronics, Russian Academy of Sciences
AN SSSR	Academy of Sciences of the USSR	LCS	laser correctional spectroscopy
ATP	adenosine triphosphate acid	MM, SUBMM	millimeter, submillimeter (range)
BAP	biologically active point	MMW	millimeter wave
BEF MMW	biological effects of millimeter waves	MPH RF	Ministry of Public Health of the Russian Federation
CL	chemiluminescence	MRT	microwave resonance therapy
CMW	centimeter waves	NMR	nuclear magnetic resonance
DMW	decimeter waves	NPO	Scientific Industrial Union
DNA	deoxyribonucleic acid	OST	All-Union Standards
DOPA	3,4 dioxyphenylalanine – amino acid, an intermediate product in the synthesis of melanin	PD	power density
		PFD	power flux density
EEG	electroencephalogram	RAN	Russian Academy of Sciences
EFD	energy flux density	RBM	red bone marrow
EHF EMR	extremely high frequency electromagnetic radiation	RNA	ribonucleic acid
		SAR	specific absorption rate
EKG	electrocardiogram	SHF	super-high frequency
EMF	electromagnetic field	VNK	Provisional Scientific Collective
EMW	electromagnetic wave	17-OCS	oxycorticosteroid

TABLE 4: Summary of a Few of the Experimental Results Mentioned in this Review

No.	Frequency and Power of EHF EMR	Period of Exposure to EHF EMR	Organism or Part Exposed	Results of Exposure	Reference, Year
1.	34.52 GHz, 120 mW/cm^2	From 3 to 24 hours	Full irradiation of toads in water	Reliable effect of EHF EMR on frequency of formation of micronuclei in peripheral blood cells	Kryukov, 1998
2.	41.95 GHz, 150 µW/cm^2	20 min. at a temperature of 19-22° C	Cells irradiated under a mode of continuous generation	The functional status of a cell determines the effect of exposure to EHF EMR on the cell, strengthening, weakening or not changing its response to an activating agent.	Alovskaya, 1998
3.	λ=5.6 mm, P = 0.5 mW/cm^2		Green leaf cells from plants	Stimulation of the ATP synthesis in green leaf cells from plants.	Petrov, 1984
4.	59 GHz, 1 mW/cm^2	Daily	Rats at 1st-6th or 6th-16th day of gestation	The offspring of the rats had changes in motor activity, conditional-reflex activity and latent period of reaction.	Soldatchenkov, 1989

No.	Frequency and Power of EHF EMR	Period of Exposure to EHF EMR	Organism or Part Exposed	Results of Exposure	Reference, Year
5.	58-78 GHz; 1-5 mW/cm[2]	15 min.	Mouse embryos	Modulating effect of EMR, starting from the two-cell stage of development.	Khramov, 1989
6.	60 µW/cm[2]	4 months	Rats	Reduction of fertility and the number and weight of offspring, increase in post natal deaths of rat pups by a factor of 2.5; dystrophic changes in reproductive organs of animals.	Nikitina, 1989
7.	37 GHz; 0.3 mW/cm[2]	15 min.	Rats	Stimulation of prolifera-tive processes in red bone marrow.	Kazakova, 1999
8.	37 GHz; 0.3 mW/cm[2]; Amp. Mod. of 5-10 Hz	15 min.	Rats	Suppression of blood formation, all the way to aplastic condition of the red bone marrow.	Kazakova, 1999
9.	λ = 6.52; 7.31 mm		Blood	Change in the outflow of free Hb	Zalyubovskaya, Gordienko, 1975
10.	λ =(5.9-7.2) mm		Cell culture	Change in cell morphology, increase in speed of mitosis.	Sevastianova, 1979; Zalyubov-skaya, Kiselev, *Principles…*, 1975
11.	λ = 6.5; (5-8) mm		Kidney cells	Change in morphology, destruction of membranes, degeneration of protoplasm, reduction of viability.	Marki, 1980; Zalyubovskaya, 1978
12.	λ =4.0; 4.6; 4.8; 5.0; 5.2; 5.45 mm		Thrombocytes	Increased speed of aggregation.	*Use…, Pro-ceedings…*, 1989 (Maksimenko)
13.	λ = 6.56 mm		E. coli	Increased synthesis of colicin.	Smolyanskaya, 1973; Zalyubovskaya, Kiselev, *Principles…*, 1975
14.	λ = 5.8; 6.5; 7.1 mm		E. coli	Change in enzyme activity and growth rate; lethal effect.	Devyatkov, Betskiy, 1981; Vilenskaya, 1972
15.	λ = 7.095; 7.1; 7.12; 7.15 mm		Bacteria	Intensification of biochemical activity and growth rate.	Sevastianova, 1979

No.	Frequency and Power of EHF EMR	Period of Exposure to EHF EMR	Organism or Part Exposed	Results of Exposure	Reference, Year
16.	λ = 5.7-7.1 mm		Bacteria	Lethal effect.	Arber, 1980
17.	λ = 8.2; 7.18 mm		Yeast	Stimulation of growth, biochemical activity and biosynthesis.	Beliy, 1989
18.	λ = (6.8-7.2); 6.05; 6.035 mm		Yeast	Change in growth cycles and morphology	*Medical…*, *Collection…*, 1987 (Manoylov)
19.	λ = 8.3; 6.66; 7.1; 7.89; 8.34 mm		Blue-green algae	Stimulation of growth, change in speed of photosynthesis.	*Medical…*, *Collection…*, 1987 (Tambiev); Tambiev, 1991
20.	λ = (5, 7-8); 7.2; 6.5; 7.5 mm		Drosophila	Mutagenesis, sterilization of female specimens, change in fertility and viability.	*Successes…*, 1973 (Zalyubovskaya); Smolyanskaya, Gel'vich, 1979
21.	λ = 6.5; 7.15 mm		Chicken embryos	Reduced weight, change in incubation period by 2-3 days.	*Successes…*, 1973 (Zalyubovskaya); Smolyanskaya, Gel'vich, 1979
22.	λ = 6.5; 5.6 mm		Rats	Effect on physiological processes and metabolism.	*Successes…*, 1973 (Zalyubovskaya)
23.	λ = (3.8-5.7); (10.7-11.0); (4.61-6.66) mm 10^{-3}-10^{-8} W/cm^2 (Kolbun)	1 min. to 12 hrs. (Kolbun)	Humans	Acceleration of regeneration of biological tissues, general reaction of the body; agitation or somnolence, change in arterial pressure and pulse, reliable sensory reactions.	Volchenko, 1989; Cherkasov, 1978; Kolbun, 1987
24.	45-65 GHz; power up to 10 mW/cm^2		Human BAP	Sensoryl reactions in the region of the organ with marked disturbance, change in the pulse rate by 10-20 beats/min., arterial pressure by 10-15 mm Hg., and effective renal plasma flow by 10-20%; tremors in separate groups of muscles; sleep of a hypnotic nature.	Andreev, 1984; Andreev, 1985

No.	Frequency and Power of EHF EMR	Period of Exposure to EHF EMR	Organism or Part Exposed	Results of Exposure	Reference, Year
25.	57-78 GHz; power less than 1 mW/cm^2	10-20 seconds	Human BAP	Change in bioelectric activity of muscles in deep stages of hypnosis.	Gerashchenko, 1991
26.	(54-76) GHz; 10^{-14}-10^{-16} W/cm^2	7 min.	Isolated cells damaged by ionizing radiation	Normalizing effect on cell growth.	Bundyuk, 1994
27.	(35.9-55.1) GHz; 3 mW/cm^2	3-7 min./day for 10 days	Rats and mice with implanted carcinomas	Immuno-modulating effect	Bundyuk, 1994
28.	54-76 GHz; 10^{-14} W/cm^2	5 min./day for 5 days	Mice exposed to ionizing radiation	Immuno-modulating effect	Bundyuk, 1994

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