UDK 537.867+576.08

High-frequency electromagnetic radiation action and influence resonators-converters on frequency of chromosome aberrations in bone marrow cells of male Wistar rats

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Action of electromagnetic radiation (EMR) of a standard Wi-Fi router and influence of Aires Defender resonators-converters on frequency of chromosome aberrations in bone marrow cells of Wistar rats was studied. Increase of mitosis aberrations upon exposure to EMR was found. The most harmful mode of the router operation was identified. It was noted that the resonators reduced effect of EMR action on frequency of chromosome aberrations in bone marrow cells. Mathematical model of EMR conversion, using Aires Defender resonators, was presented. Possible mechanisms of EMR action on somatic cells and approaches to development of means, protecting from harmful exposure thereof were considered.

Keywords: *high-frequency electromagnetic radiation, resonators-converters, chromosome aberrations, bone marrow, rats.*

The influence of electromagnetic radiation (EMR) of Wi-Fi router and resonators Aires Defender (RA) on the frequency of chromosome aberrations (FCA) in the bone marrow cells of Wistar rats was investigated. An increase in the FCA was observed under the influence of EMR and the operating mode of the router with the greatest damaging effect was revealed. RA reduced the damaging effect of the EMR on the bone marrow cells. The mathematical model of the transformation of EMP with the help of resonators Aires Defender is presented. The mechanisms of the action of EMR on somatic cells and the mechanisms of protection are discussed.

Keywords: *electromagnetic radiation, resonators, chromosome aberrations, bone marrow, rats.*

Sharp increase in widespread use of ultra-high frequency (microwave) radiation over the last 20 - 30 years, resulting in increase of intensity thereof, and integration of such radiation sources into different devices (mobile phones, Wi-Fi routers) requires study of effect thereof on living organisms. Impairment of electromagnetic background of the environment, which is recorded everywhere, causes steady increase of various diseases, including microwave syndrome and hypersensitivity to electromagnetic radiation (EHS). The bibliography on EMR action on human and animals is quite extensive [1-3]. It is known that EMR enhancement affects genetic apparatus of cells of different organs of human and animal body. For the first time, mutagenic effect of certain electromagnetic fields frequencies was demonstrated in 1959 in Heller, Teixeria-Pinto's paper, published in Nature magazine [4]. Currently, there is evidence that electromagnetic fields of different ranges, including mobile phones and Wi-Fi ranges are able to induce a wide range of genetic damages, modify genes expression, affect structural and functional properties of cell nuclei [5, 6]. Thus, it was demonstrated that exposure to microwave radiation (frequency 7.7 GHz, power 0,5,10,30 mW/cm^2) within the exposure period 10...60 min causes increase of chromosome aberrations in human lymphocytes [7]. Upon extended exposure periods, signals with 5 W/kg specific radiation absorption rate (SAR) also cause damage of chromosomes in blood cells [8]. However, mechanisms of these processes are still not quite clear.

Creation of the systems, protecting from harmful EMR effect and study of mechanisms of action thereof on genetic processes in cells of central and peripheral organs of model objects is a pressing issue. Currently, Aires Foundation has designed devices, which efficiently redistribute EMR and produce therapeutic effect based on effects of incident EMR range conversion by the self-affine relief [1, 2]. Still, mechanisms of the indicated devices protective action on chromosomal apparatus of cells have not been studied yet.

Study objective: 1) to study EMR action on frequency of chromosome aberrations in dividing bone marrow cells in different modes of operation of a standard Wi-Fi router to find out conditions of mitotic disruptions induction, caused by high-frequency EMR in male Wistar rats; 2) to evaluate protective action of Aires Defender fractal-matrix resonators-converters on frequency of chromosome aberrations in bone marrow cells in male Wistar rates upon exposure to harmful EMR, generated by the router; 3) to construct a mathematical model of electromagnetic radiation conversion, using Aires Defender resonators.

Material and Methods

The work was performed in male Wistar rates, weighing 250... 300 g. The rats were taken from the biological collection of FSBIS Pavlov Institute of Physiology of RAS (No ГЗ 0134-2016-0002). After the animals were received, they were held in the laboratory animal facility for no less than two weeks to ensure adaptation thereof. The males were kept in groups of six in standard cages on standard diet.

The study was performed, using the Wi-Fi router (LinkSys E1200-EE/RU wireless router) with the following technical specifications: wireless communication frequency 2.4 GHz; two built-in antennae; standard antenna power gain - 4 dBi.

To study action of EMR, emitted by the router, the "home" cage with animals was put into the Faraday cage (Fig. 1). The router was placed under the upper cage cover in the center of the detachable shelf. The experimental groups were exposed to the router in the following modes: 1) one time during two hours (8 a.m. - 10 a.m.); 2) daily during four days, six hours a day (8.a.m. - 2 p.m.); 3) daily during three weeks, six hours a day (8.a.m. - 2 p.m.). The controls were groups of rats, which were placed into the Faraday cage for the same time, however, were not exposed to the router, and intact animals.

Aires Defender fractal matrix resonators (special annular diffraction grids), serving as universal spatial-wave Fourier filter [9], were also used in the experiment. The interaction of electromagnetic field with Aires Defender results in structural conversion thereof.

Six resonators were used to assess the resonators influence on harmful effects of EMR, generated by the router. They were placed in the center of each plane of the Faraday cage (Fig. 1). One of the experimental groups was exposed to the router action in the Faraday cage according to the following schedule: four days, six hours of exposure to resonator per day.

Bone marrow cells specimens handling. Bone marrow cells were fixed 24 h after exposure in the freshly prepared Carnoy's fixative (1 part of glacial acetic acid per 3 parts ethanol) at least for an hour. The material was kept at +4°C until specimens handling according to the standard procedure [10, 11].

Bone Marrow Specimens Analysis Bone marrow squash preparation was analized using Micromed -3 microscope with 640-1600 power magnification. Chromosome aberrations at anaphase - telophase stages (standard ana-telophase method) subject to additional recommendations [11] were recorded. At least 200 cells of each animal were analyzed. Number of normal and aberrant anaphases - telophases with the below mentioned disruptions were recorded: single displacements (fragment, bridge, laggards), multiple displacements (two and more disruptions of any type per cell).

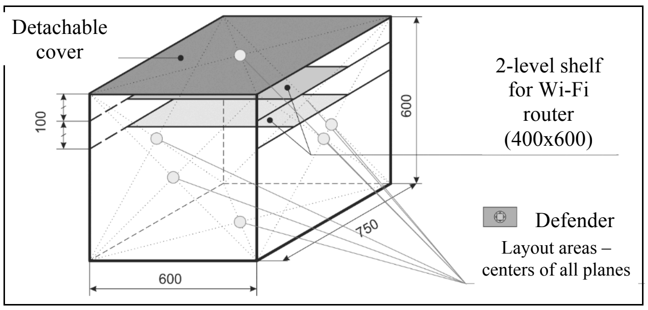

Fig. 1. The diagram of the Faraday shield (cage) used for a study with a layout of the resonators placement.

Statistical analysis. The findings were checked for homogeneity by nonparametric multiple-field *chi* square method . Individual data were combined within groups based on check results. To arrange results in tables, frequency of detected mitosis aberrations, expressed as a percentage with percentage error, was calculated. Significance of differences among variants and comparison of mitotic disorders ranges were determined by *chi* square method [12] and by the rank test and analysis of variance (ANOVA), using Statgraphics Centurion XV11 and Statistica 6.0 software.

Effect of Different Modes of Wi-Fi Router Operation on Frequency of Chromosome Aberrations of Marrow Bone Cells in Wistar Rats

It was shown that high-frequency electromagnetic radiation, emitted by the router in the four days, six hour a day exposure mode, resulted in the most severe destabilization of dividing bone marrow cells genetic apparatus in male Wistar rats: total frequency of mitotic disorders increased on an average by 4.5 times in comparison with control 2 (Faraday cage, 4 days x 6 h) and by 3.9 times in comparison with intact control 1 (Table), degree of reliability of the indicated data was high according to all applied statistic criteria. Single exposure to the router within 2 hours caused increase of chromosome aberrations by 1.9 times in comparison with intact control 1 (Table), statistical significance was confirmed by the multiple range test (Multiple Range Test, Diff = 6.03, +/−Limits = 3.33) and ANOVA test ($F = 19.65$, $p < 0.004$), however, not chi square method. In comparison with the group of animals, exposed to the router in the four days, six hours a day mode, disorders frequency was 2.1 times less (Table). After animals exposure to electromagnetic radiation, emitted by the router, during three weeks, six hour a day, mitotic disorders frequency increased by 1.8 times in comparison with control 3 (Faraday cage, three weeks, six hours a day) (Multiple Range Test, Diff = 5.02, +/−Limits = 3.63; ANOVA, $F = 3.13$, $p < 0.01$) and by 1.5 times in comparison with intact control 1(Multiple Range Test, Diff = 4.1, +/−Limits = 3.9; ANOVA, ($F = 2.49$, $p < 0.04$), however, it decreased by 2.6 times in comparison with the group of animals, exposed to the router in the four days, six hours a day mode (Table).

Table. ***Frequency of mitotic disorders of bone marrow cells in male Wistar rats after exposure to electromagnetic radiation, emitted by the router, in different modes, and after exposure to Aires Defender resonators***

Action variant	Number of analyzed cells (number of cells with disorders among them)	Total frequency of mitosis disorders ($\bar{x} \pm S$, %)	Statistical significance $\chi 2$ ($\nu = 1$, $p < 0.01$)
Control 1 (intact animals)	1378 (92)	6.7 ± 0.7	–
Control 2 (Faraday cage, 4 days x 6 h)	1986 (114)	5.7 ± 0.5	75.8
Router (4 days x 6 h)	1360 (354)	26.0 ± 1.2	18.9
Router + resonators (4 days x 6 hours)	1961 (127)	6.5 ± 0.6	16.8
Control 3 (Faraday cage, 3 weeks x 6 h)	1714 (96)	5.6 ± 0.5	8.9; 6.5
Router (3 weeks x 6 h)	1789 (180)	10.1 ± 0.7*#	
Router (2 h)	1175 (149)	12.7 ± 0.9*	

Notes: # – difference from control 3 is significant (Multiple Range Test, ANOVA ($p < 0.01$), * – difference from control 1 is significant (Multiple Range Test, ANOVA ($p < 0.01$).

Findings of evaluation of chromosome aberrations level in bone marrow cells of Wistar rats showed that electromagnetic radiation, emitted by the router, under different exposure modes (2 h, 4 days, 6 h a day, 3 weeks, 6 h a day) is citogenetically active, it can induce mitotic disorders. It can affect functioning of immune system elements, related to bone marrow activity.

The most significant changes of the chromosome apparatus were detected after exposure of the animals in the Faraday cage when the router was switched on during four days, six hours a day, from 8 a.m. to 2 a.m. This very mode of the router operation can be used for pronounced induction of mitotic disorders by high-frequency EMR in Wistar rats for subsequent study of protective devices efficiency and study of underlying mechanisms thereof.

Change of stability of dividing bone marrow cells genetic apparatus upon exposure to EMR, emitted by the router, can be seen as the result of cell oxidative stress, which mutagenic activity is based on genotoxic action of internal causes of humoral nature and free-radical products of peroxidation [13]. The indicated mechanisms may result in immune system suppression, immunopoesis and hematopoesis depression, thus impacting body state. However, findings, showing that a long-term three-week exposure of animals to EMR results in decrease of mitotic disorders in comparison with a four-day session, indicates to possible existence of adaptive mechanisms, resulting in elimination of the cells with disorders and/or activation of reparative processes.

Influence of Aires Defender Fractal-Matrix Resonators-Converters on Frequency of Chromosome Aberrations in Bone Marrow Cells upon Damaging Effect of EMR, Emitted by the Router, on Male Wistar Rats

Protective action of Aires Defender fractal-matrix resonators was evaluated, using the four day, six hours a day mode of the router operation, producing the most severe damaging effect on chromosome apparatus of bone marrow cells. When resonators were used together with the router, frequency of bone marrow cells mitosis disruption decreased by 4 times in comparison with unprotected exposure to the router, and the indicated level was comparable to control 2 (Faraday cage, 4 days, 6 hours a day) and intact control 1 (see the Table).

It is to be highlighted that this research paper is the first to show that Aires Defender fractal-matrix resonators have a protective effect on genetic apparatus of dividing bone marrow cells in male Wistar rats upon exposure to EMR, emitted by the router. The interaction of electromagnetic field with Aires Defender results in structural conversion thereof [9].

Mathematical Model of Electromagnetic Radiation Conversion, Using Aires Defender Resonator.

Electromagnetic radiation falls on the Aires Defender plate and by means of free electrons, created on the plate, diffraction and mirror reflection in the environment, the transformed radiation is generated, which differs from the one falling on the plate. Principle of conservation for electrons in the plate can be formulated as follows [14]

$$\frac{\partial n_e}{\partial t} = q - \mu_e\left(\frac{\partial En_e}{\partial x} + \frac{\partial En_e}{\partial y} + \frac{\partial En_e}{\partial z}\right) + D_e\left(\frac{\partial^2 n_e}{\partial x^2} + \frac{\partial^2 n_e}{\partial y^2} + \frac{\partial^2 n_e}{\partial z^2}\right) - bn_e, \quad (1)$$

where E – electric field strength; n_e – free electrons concentration; D_e – electron diffusion factor; μ_e – electron mobility; q – rate of free electrons appearance; b – absorption coefficient of electrons; t – time; x, y, z – Cartesian coordinates.

If the wave falls on the plate

$$E_{\text{пад}} = E_0 \cos\omega(t - z / c), \quad (2)$$

then

$$E = E_0 \cos\theta + \Delta E_0 \cos(\theta - \pi / 2), \ \theta = \omega(t - я / c), \ \Delta E_0 = \frac{2\pi k_0 n_e e^2 \omega}{cm_e(\omega_0^2 - \omega^2)} E_0 \Delta z, \quad (3)$$

$$\omega_0 = \sqrt{\frac{4\pi k_0 e\rho}{m_e}}, \quad (4)$$

where e – electron charge; m_e – electron weight; ω_0 – frequency of electrons oscillation in the plate; Δz – plate thickness; c – light speed; $\rho = n_e e$ – charge of the unit plate volume; $k_0 = 9 \cdot 10^9$ N·m^2/C^2 – constant [15].

In (3) the first summond is conditioned by reflection, the second summond is conditioned by free electrons. As there are narrow slots on the surface of the plate, it is necessary to take diffraction into account:

$$\frac{I_\beta}{I_0} = \frac{\sin^2\left[(\pi b / \lambda)\sin\beta\right]}{\left[(\pi b / \lambda)\sin\beta\right]^2}, \quad (5)$$

where I_β – intensity of waves, propagating angle-wise β; I_0 – intensity of waves, propagating angle-wise $\beta = 0$; b – slot width; β – angle; λ – wave length [15].

Since wave intensity is proportionate to the amplitude square, $I = E^2$. Hence, the total intensity

$$E = E_{\text{отражение}} + E_{\text{электроны}} + E_{\text{дифракция}}, \quad (6)$$

where $E_{\text{отражение}}$ – by means of reflection; $E_{\text{электроны}}$ – by means of free electrons; $E_{\text{дифракция}}$ – by means of diffraction.

Solution of (1)-(6) set of equations by numeric techniques enables to find distribution n_e (in the plate) and E (in the space). Calculations were made, using high-performance parallel computing cluster under different initial and boundary conditions. Thus, it was assumed that there was no drain in the center and at the sides of the plate when making calculations for 201x201 μm square plate in the 200 μm high parallelepiped. Upon exposure to 5×10^{14} Hz frequency radiation (wave length 0.6 μm) radiation with wave length approximately 40μm was generated over the central area of the plate. Intensity E V/m of the indicated radiation exceeded the intensity of the incident radiation by several times. Fig. 2 shows plate dimensions, μm, plotted along axes x and y, and intensity, plotted along axis z $I = E^2$. Figure 3 shows intensity, plotted along axis y, and distance from the plate, μ, plotted along axis x. Similar changes of E and I over the plate are developed upon other initial and boundary conditions and radiation frequencies.

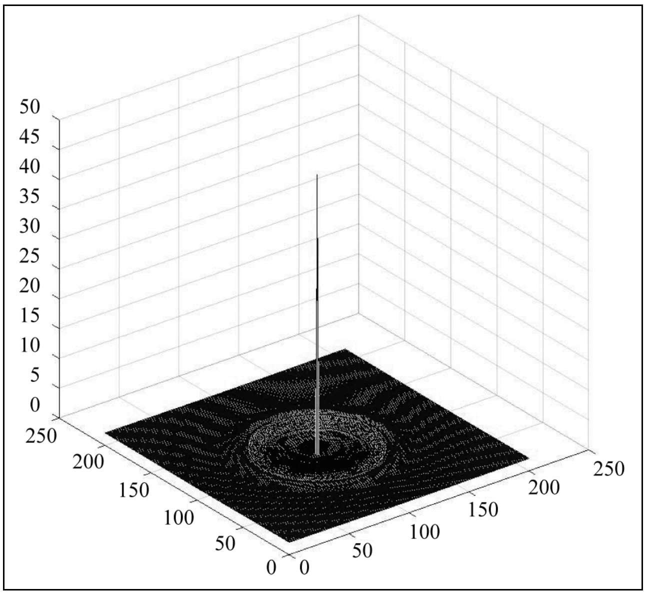

Figure 2. Graphical form of intensity of waves, propagating over the plate

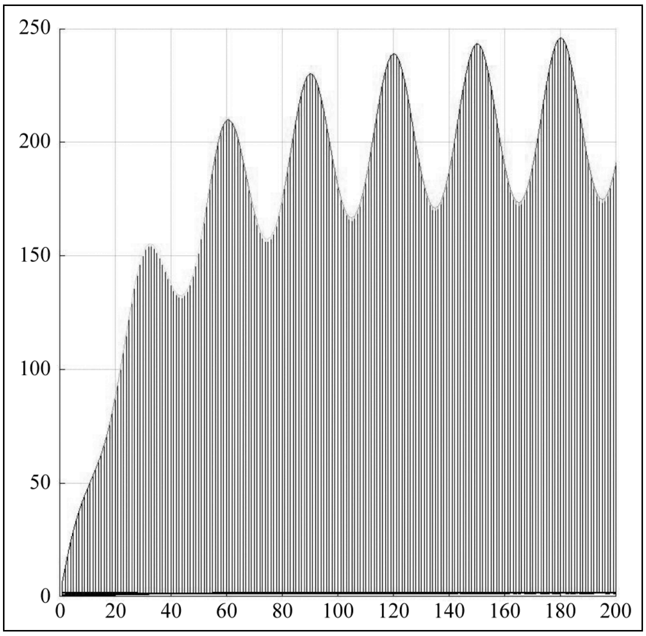

Figure 3. Diagram, representing dependency on distance to the plate and waves intensity over the central part of the plate

Mathematical simulation shows that upon interaction of electromagnetic radiation and the plate with a certain pattern, applied thereon in a certain way, the plate emits the radiation, which is different by its structure from the incident radiation, into the environment. It is determined that the changes are most significant over the central area of the plate, they exceed parameters of the incident radiation by several times. It can be explained by the fact that the pattern on the plate is such that electromagnetic field strength is concentrated over the central area of the plate, while strength thereof considerably decreases over other areas of the plate, that in general results in attenuation of total electromagnetic effect (over the side parts of the plate), which is beyond the organism's electromagnetic radiation sensitivity threshold. Consequently, protective action of the resonators is, apparently, based on restructurization (conversion) of incident EMR, which diminishes its damaging action on dividing cells.

- The performed study enables to identify the most damaging mode of the router operation, to explain possible mechanisms of EMR action on somatic cells and to suggest approaches to develop means of protection against damaging action thereof. Application of Aires Defender resonators enabled to decrease EMR effect on frequency of chromosome aberrations in bone marrow cells, to explain this phenomenon a mathematical model of EMR conversion by means of resonators was reviewed.

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Received on January 15, 2018.

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