SIMULATION OF CELLULAR PHONE RADIATION PROPAGATION IN BIOLOGICAL TISSUE AND MULTILAYER SHIELDING STRUCTURES

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Summary: The process of cellular phone radiation propagation in biological tissue and multilayer shielding structures was simulated using mathematical modeling. Antenna patterns are calculated and their changes when applying protective shields are studied. The reflection and transmission coefficients of antenna were calculated.

I. INTRODUCTION

Rapid development and introduction into the daily life of new information technologies and means of information transmission and processing (computers, mobile communications, etc.) led to the emergence of new types of manmade factors — the emission of electromagnetic radiation in the range from subsonic to super-high frequencies. The mechanism of interaction between electromagnetic radiation (EMR) and biological tissues and human organism is not ascertained, but the common approaches are based on thermal effect or low-level radiation influence [1]. It was shown that this type of effects, especially after long term exposure and with inadequate protection from such effects, leads to increased fatigue and the development of various types of diseases of the human organism. In many cases the negative consequences of actions can only be detected through a decade or a few generations.

At the same time ensuring of the electromagnetic safety of the human operator from electromagnetic radiation of new types devices requires a lot of intellectual, material and time resources. According to the results of research in this area are developed state standards, sanitary rules and norms, which include regulations that limit the levels of electric and magnetic fields of different frequency bands, as well as regulations that establish the maximum permissible exposure levels for specific exposure conditions and groups of people.

The first aim of this work is to establish the quantitative characteristics of the influence of electromagnetic radiation on the human body, depending on the quality indicators of the technical protection tools, using mathematical modeling. The second one was to develop hardware and software for evaluation the effectiveness of protective devices of the human body from the EMR of personal computer or cell phone.

II. EXPERIMENT

Modeling of electromagnetic waves propagation in a system source of radiation – biological object – protection tool was performed using the finite difference method, with assistance of the software package XFdtd (version Bio-Pro). To study the interaction of the EMR with a biological object the model of the human head was used.

To investigate the dependence of the distance between the source of and the biological object on the EMR propagation characteristics receiving antenna was placed in the center of the human head model and transmitting antenna was placed at distances 10, 20 and 50 mm from it.

Electromagnetic shielding effectiveness was measured out by measuring equipment SNA 0.01–18, which allows measuring the reflection and transmission coefficients in the frequency range 0.7–2.14 GHz.

III. RESULTS AND DISCUSSION

It was shown that the electrical component of the EMR penetrates into the human head less than magnetic one, thus electrical component is characterized by greater absorption in biological tissues. This is due to the fact that the magnetic component force (Lorentz force) acts on electrically charged particles less than the force of the electric component [2]. An increase of distance between the transmitting antenna and the biological object from 10 mm to 20 mm leads to a decrease of the transmission coefficient of 1 dB to –53 dB, which is caused by increase of losses during the propagation of electromagnetic wave in air space. In addition the reflection coefficient is reduced from –22 dB to –35 dB, which is caused by the multiplicity of the distance to the wavelength of EMR frequency range, while leading to greater absorption in the biological tissue. Increasing the distance up to 50 mm allowed reducing the transmission coefficient up to –58 dB, while the reflection coefficient increased to –13 dB.

The impact of EMR on biological tissues leads to a change of the water structure involved in biochemical processes [3]. The antenna pattern of EMR source (cell phone antenna) is determined by such impact. Therefore, to create a tool to protect the biological objects from intentional radiation with a view to minimize impact on the source parameters it is reasonable to use water-containing shields [4]. Moreover, it is possible to create a material with electromagnetic characteristics similar to biological tissues. To calculate influence of water-containing shield on the electromagnetic characteristics the shield model was placed between the models of the biological object and the EMR source. The dimensions of the shield varied in length 80 mm, 120 mm and in width of 10, 20, 40 and 60 mm, similar to a metal shield. The thickness of the shield (3.2 mm) was not changed, which is two cells of a countable space. It was shown on the basis of calculations that the use of water-containing shield reduced the transmission coefficient by 1–3 dB at its width 40, 60 mm, and at its length 120 mm. In addition the reflection coefficient remains within the –14÷16 dB, which is greater by 2–15 dB than without its use and fewer 2–6 dB than with the use of metal shield. This change is due to partial absorption of EMR by shielding material [5].

It was shown that the antenna pattern at the shield width of 40, 60 mm, and the length of 120 mm became greater at the angle of 90° by 1 dB, at the angle of 165° up to 17 dB and at the angles of 185° and 270° by 3 dB in comparison with its absence. The highest value of the antenna pattern observed at a distance 20 mm and 50 mm.

Placement of 120×60 mm water-containing shield between the biological object and the EMR source does not affect the antenna pattern in comparison with its absence. The metal shield is more effective water-containing one, but its application is characterized by greater reflection coefficient, which can increase the number of radiation effects in biological objects.

To increase the efficiency of water-containing shield, you can use a multilayer structure. Enhancing of its effectiveness could be ensured by placing a metal foil between the two layers of shielding material. The first layer will reduce the electromagnetic wave reflected from the second layer in air space. The second layer is necessary to provide the effectiveness of the whole of shield. The third layer is necessary for the absorption of electromagnetic wave that is reflected from the human head. The dimensions of protection tool was determined in accordance with the results of previous experiments (120×60 mm). The thickness of a water-containing layer was 3.2 mm, corresponding to two cells of a countable space. The thickness of the metal layer corresponds to one edge of the cell counting space. The model of the three-layer structure was placed close to the model of a biological object at a distance of 20 mm from the EMR source. The dependence of the reflection and transmission coefficients on the frequency in the presence and in the absence of the multilayer shield was calculated. On the basis of the calculations it was shown that the use of the multilayer shield the reflection coefficient decreased by 4.3 dB and the transmission coefficient decreased by 2.3 dB compared to the metal shield. In comparison with water-containing shield the reflection coefficient increased by 4.1 dB and the transmission coefficient decreased by 25.1 dB.

From simulation results revealed that the 120×60 mm multilayer shield is most effective (transmission coefficient –79.1 dB), but the antenna pattern of EMR source has no significant changes compared with the antenna pattern in its absence. Reducing the reflection coefficient of this shield will reduce re-reflection of the electromagnetic wave from various surrounding objects to the cell phone user. In this regard, the use of a multilayer shield will not only reduce the impact of radiation on biological objects, but also reduce the impact on the EMR source.

The experimental frequency dependencies of the transmission and reflection coefficients were obtained. It was shown that the single-layer shield reduces radiation from –12 to –18 dB. Its reflection coefficient varies from –3 to –8 dB. The use of multilayer shielding structures provides an increment of the transmission coefficient to –35 dB, but the reflection coefficient decreased from –2 to –6 dB.

Full-scale testing of cellular phone radiation propagation with different shielding structures was performed using a cellular phone Nokia N78. The dependencies of the signal power level on the type of shield at the measurement point were obtained.

The power level of the cellular phone was decreased to 10.9 dB in the measuring point by a metal screen/ It was caused by electromagnetic wave being reflected by the high conductivity material.

Use of the single-layer shield led to a reduction of the electromagnetic radiation to 3.9 dB. The use of multilayer shielding structures provided a reduction of the electromagnetic radiation to 17.8 dB.

CONCLUSIONS

The model of the interaction of electromagnetic radiation with a biological object (human head) and the protection tool was proposed. It allows assessing the impact of electromagnetic radiation on a biological object in a system source of radiation – biological object – protection tool using calculated reflection and transmission coefficients. The calculation of these coefficients is performed with assistance of finite-difference method which allows taking into account the features of the electromagnetic wave propagation in the interfaces of air, protection tool as well as a biological object, which allows to characterize the influence of protection tool and biological objects on the antenna pattern of the EMR source.

The peculiarities of the interaction of radio waves (frequency 1800 MHz) with a biological object (ε=43.2; σ=1.29 S/m) are established. The increase of the distance from the radiation source to the biological object from 10 to 50 mm leads to an increase in the transmission coefficient from –53 to –60 dB with simultaneous increase of the reflection coefficient from –35 to –12 dB, which allows reduce the impact of EMR on a biological object.

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