
ELECTRODYNAMICS AND WAVE PROPAGATION

Application of the Method of Auxiliary Sources to Study the Influence of Resonance Electromagnetic Fields on a Man in Large Spatial Domains

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Abstract—The paper presents the results of studies of the possible influence of electromagnetic radiation from wireless communication systems on a man in natural conditions. The studies were performed by the method of auxiliary sources (MAS). On the basis of computer simulation, the field distributions in rooms containing a model of a man and a radiator are investigated. The dependence of the radiation pattern on the position of the model and the radiator with allowance for the open part in the form of a window is studied. As a rule, the walls of a room have a certain transparency, depending on their design and the incident frequency. The simulation by the MAS method shows how this transparency can be regulated. Due to the resonance phenomena, the amplitude of the resonant field at certain frequencies and the transparency of the walls become extremely large, which is the reason for large values of absorbed electromagnetic energy and its undesirable effect on a man.

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INTRODUCTION

While the use of mobile and other wireless communication systems increases more and more, investigation of the negative effect of radiation on a man found in a close vicinity of a radiator becomes an urgent problem. From year to year, a permanent increase in the electromagnetic (EM) background is observed. Investigations performed show that the EM field can be dangerous to a man, and nowadays this fact is beyond any doubt [1]. There have been many publications concerning one or another aspect of the influence of the radiation from mobile phones to health and memory of a man [2]. According to these publications, there are two aspects of the action of radiation on living tissues: the thermal action, connected with heating, and the biological action. The biological action is understood as a negative action of the EM field on tissue cells and even on separate proteins. The thermal action is reduced to overheating of tissues, caused by the absorption of EM energy. Although, upon solar illumination, the skin is heated more intensively than when a mobile phone is used, the effect from the increase in temperature of internal tissues, which are more sensitive to heating, can be stronger.

The amount of absorbed energy depends on the situation in which a mobile phone is used. It also depends on the position of the phone relative to the head, the position of user's hand, and other external conditions. To estimate quantitatively the action of a

mobile phone on a man, a special parameter, SAR (Specific Absorption Rate), was introduced. The maximum allowable values of SAR to which the commercial devices should conform have been established. Producers of mobile phones must present to the user the maximum SAR caused by the work of a particular model.

Investigations performed in a number of laboratories (including the Laboratory of Applied Electrodynamics of the Tbilisi State University) have shown that the increase in temperature correlates with SAR. It has also been shown that SAR is influenced by the position of the phone and user's hand [3–13].

In the present work, the EM field distributions in the vicinity and inside the model of a man found in a room or in the open space are studied by MAS. This problem is especially urgent for the radiation from mobile and wireless communication systems used by police, geologists, and other services frequently using such equipment.

The danger from the use of communication systems is that the transmitting antenna is situated in a close vicinity of user's body, as a result of which it is found in the near-field zone with a high density of radiation energy. The high permittivity of a human body favors an intensive closure of field lines and formation of an intense internal field, which, due to a high conductivity of the body, leads to heating of tissues (the transition of the EM energy into thermal

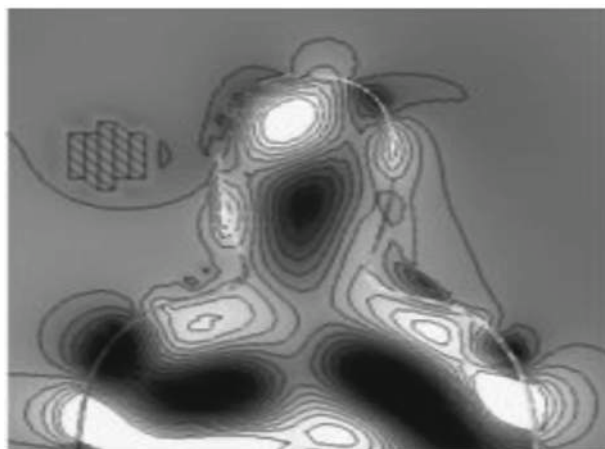


Fig. 1. Distribution of resonant EM field in the upper part of the model of a man at the resonance frequency of 340 MHz.

energy). The hand holding a mobile communication device absorbs the energy of EM radiation especially strongly, which negatively affects the communication level. In the case of bad communication, an acceptable signal level is reached by the automatic amplification of phone's radiation up to the maximum, which increases SAR in the head tissues. In this case, the main reason for the increase in the near EM field is a poor matching of the antenna to the free space. For more realistic estimation of the fields, e.g., in a closed room, it is necessary to take into account the resonance phenomena, when, due to standing waves, the field in the vicinity of the entire body can increase by orders of magnitude.

From the aforesaid, it may be concluded that the subject of this paper is a pressing issue. As is known, as early as in the beginning of this century, the World Health Organization demanded from producers of mobile communication devices to organize a special Mobile Manufacturing Forum (MMF) [1] for investigation of problems connected with the possible adverse effects of EM radiation on a man. We took part in these investigations for almost ten years in two phases [1]. As a rule, calculations are based on inhomogeneous models of human body: a man, a woman, a pregnant woman, and a ten-year-old child, constructed from the nuclear magnetic resonance (NMR) data. The parameters of tissues were obtained as a result of a very large number of measurements (see, e.g., [14]). For such inhomogeneous models, the solution to the problem of the penetration of the EM field into the human body can be obtained only by the finite-difference method in the time domain (FDMTD). For this purpose, a special computer program was developed, using which the corresponding studies were performed and the basic characteristics—SAR and the maximum variation in the head temperature—were calculated [3–13].

Despite a large number of results obtained, this problem has not been solved yet in full measure. From the known data, it is impossible to make general conclusions and give recommendations on a safer use of mobile communication devices. The general physical picture of the phenomenon has not been studied for the following reasons:

(1) at radiation wavelengths on the order or greater than the head dimensions (which corresponds to the frequency employed in wireless communication systems), detailed elaboration of the inhomogeneous head structure is not essential in calculations;

(2) the application of the FDMTD strongly restricts the analyzed region, making it possible to study a small vicinity of the radiating antenna and the head. Moreover, this method does not allow one to estimate the accuracy of the solution obtained.

(3) the shape and sizes of the bodies of different people are strongly different. Therefore, in real cases of irradiation, it is difficult to make any conclusions by studying only one of the aforementioned models;

(4) due to the limited sizes of the spatial computational domain, it is impossible to take into account the multiple reflections of the EM field from the walls and surrounding objects.

The application of MAS makes it possible to remove the aforementioned drawbacks, take into account external factors, and study the case in which the user is found inside a domain with open parts (a room with windows). As a rule, most of walls are made of reinforced concrete; therefore, they can strongly influence the formation of the near field, working at certain frequencies as a resonator. This means that, when a man uses a mobile phone in a room, the amplitude of the field can strongly increase due to multiple reflections from the walls. According to numerical calculations, the maximum value of the resonance EM field inside a room can significantly exceed the field outside. The resonance field, partially penetrating the man inside the room (Fig. 1), can have an adverse effect on him. MAS makes it possible to calculate the averaged characteristics and reveal the basic electrodynamic phenomena taking place upon the action of EM radiation on a man.

Taking into account the difference in the shape, weight, size, and anatomic organization of humans, it is expedient to average these parameters and use in calculations the averaged model. For this purpose, we developed a “mummy”: a computer model of a man (Figs. 2 and 3) with a simplified geometry of the human body. The source of the EM field was an elementary dipole. The mummy is homogeneous and has averaged values of permittivity and conductivity.

For the first time, MAS was used to simulate walls with different transparencies. The main idea is to vary the density of collocation points on the wall surface with the boundary conditions as on a conductor. If the density is low, the field—beside reflection—partly

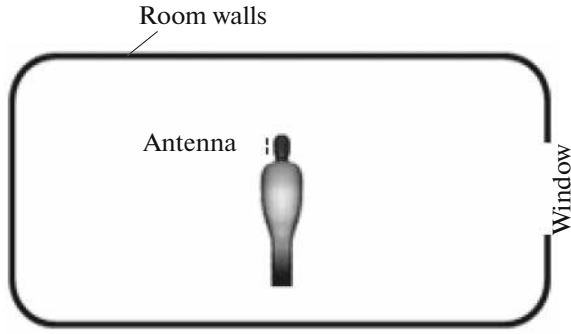


Fig. 2. The model of the system under consideration.

penetrates between collocation points, providing partial transparency of the wall. In this work, we present some results of detailed study of this idea. Radiation patterns of a system consisting of a room with walls with different transparencies, the user of a communication device, and the radiator (see Fig. 2) are also studied.

1. PROBLEM STATEMENT AND METHOD OF SOLUTION

From the theoretical point of view, it is required to solve the problem of diffraction of a time-harmonic wave by the given system. Taking into account that the EM wavelength is greater than the sizes of the phone, we use as a radiation source a point dipole situated near the head. This problem was solved by MAS, which makes it possible to study regions with large dimension with a minimal use of computer resources [14, 15]. One of the objectives of this work is to justify the possibility to calculate the irradiation of a man, using MAS and a uniform model of a man instead of using the FDMTD and a nonuniform model.

1.1. Application of MAS

In MAS, at a certain distance from the body surface and the walls of the room, auxiliary surfaces repeating the corresponding geometry are constructed (see Fig. 3).

The window is replaced with an imaginary surface with the properties of the free space. The unknown complex amplitudes of auxiliary sources are found by satisfying the boundary conditions by the collocation method. At the points situated on the surface of the model of a man and at the points of the imaginary window surface, the field matching conditions for a dielectric and the free space, respectively, are imposed [15]. At the points situated on the wall surface, the conditions of zero tangential component of the electric field is imposed.

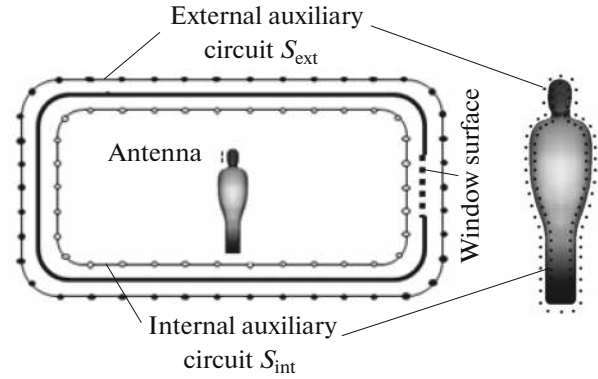


Fig. 3. Distribution of auxiliary sources in the system.

As the auxiliary source, we use two mutually perpendicularly oriented combined dipoles (of Huygens type) $\vec{E}_{\text{comb}}$ and $\vec{E}'_{\text{comb}}$ with the corresponding unknown complex amplitudes [15]. The field of the combined dipole is defined by the expressions

$$\vec{E}_{\text{comb}} = \vec{E}_{\text{el}} + \sqrt{\mu/\epsilon} \vec{E}_{\text{mag}}, \quad \vec{H}_{\text{comb}} = \vec{H}_{\text{el}} + \sqrt{\mu/\epsilon} \vec{H}_{\text{mag}},$$

where $\vec{E}_{\text{el}}$, $\vec{H}_{\text{el}}$ and $\vec{E}_{\text{mag}}$, $\vec{H}_{\text{mag}}$ are the fields of the electric and magnetic dipoles:

$$\begin{aligned} \vec{E}_{\text{el}} &= (\exp(ikR)/4\pi\epsilon) \\ &\times \left\{ (1/R^3 - ik/R^2) (3\vec{R}_0 (\vec{R}_0 \cdot \vec{p}_{\text{el}}) - \vec{p}_{\text{el}}) \right. \\ &\quad \left. - (k^2/R) (\vec{R}_0 \times (\vec{R}_0 \times \vec{p}_{\text{el}})) \right\}, \\ \vec{E}_{\text{mag}} &= \sqrt{\mu/\epsilon} (k^2 \exp(ikR)/4\pi) \\ &\times (1/R^2 - ik/R) (\vec{p}_{\text{mag}} \times \vec{R}_0), \\ \vec{H}_{\text{el}} &= (i\omega \exp(ikR)/4\pi) (1/R^2 - ik/R) (\vec{R}_0 \times \vec{p}_{\text{el}}), \\ \vec{H}_{\text{mag}} &= (\exp(ikR)/4\pi) \\ &\times \left\{ (1/R^3 - ik/R^2) (3\vec{R}_0 (\vec{R}_0 \cdot \vec{p}_{\text{mag}}) - \vec{p}_{\text{mag}}) \right. \\ &\quad \left. - (k^2/R) (\vec{R}_0 \times (\vec{R}_0 \times \vec{p}_{\text{mag}})) \right\}. \end{aligned}$$

Here, μ are ϵ the permeability and permittivity, k is the wavenumber, $\vec{R}_0$ is unit vector directed from the dipole to the observation point, R is the distance from the dipole to the observation point, and $\vec{p}_{\text{el}}$ and $\vec{p}_{\text{mag}}$ are the dipole moments. The system of auxiliary sources distributed over each auxiliary surface must describe the scattered field in the opposite part of the space.

The sought-for field inside the dielectric body is described by external auxiliary sources:

$$\begin{aligned} \vec{E}_{\text{body}}^{\text{in}} &= \sum_{n=1}^N (a_n \vec{E}_{\text{comb}}^{\text{out}} + a'_n \vec{E}'_{\text{comb}}^{\text{out}}), \\ \vec{H}_{\text{body}}^{\text{in}} &= \sum_{n=1}^N (a_n \vec{H}_{\text{comb}}^{\text{out}} + a'_n \vec{H}'_{\text{comb}}^{\text{out}}). \end{aligned}$$

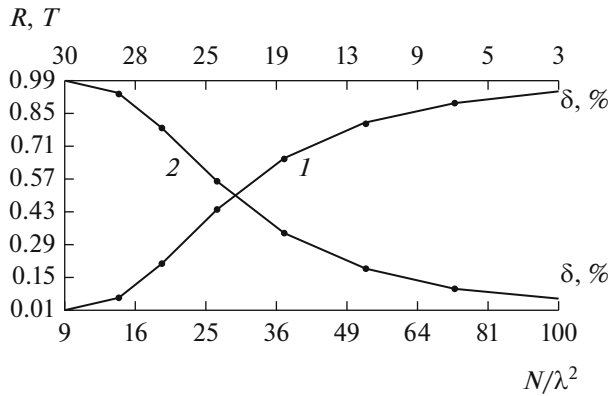


Fig. 4. Distribution of (1) reflection coefficient R and (2) transmission coefficient vs. the collocation point density N/λ^2 and relative accuracy δ of satisfying the boundary conditions at $kd \approx 0.3$.

Outside of the body, the fields $\vec{E}_{\text{body}}^{\text{out}}$ and $\vec{H}_{\text{body}}^{\text{out}}$ comprise the sum of the fields of the antenna, the auxiliary sources inside the body, and auxiliary sources external with respect to the semi-open surface:

$$\begin{aligned}\vec{E}_{\text{body}}^{\text{in}} &= \vec{E}_{\text{inc}} + \sum_{n=1}^N \left(b_n \vec{E}_{\text{comb}}^{\text{in}} + b'_n \vec{E}_{\text{comb}}^{\text{in}} \right) \\ &+ \sum_{m=1}^M \left(c_m \vec{E}_{\text{comb}}^{\text{out}} + c'_m \vec{E}_{\text{comb}}^{\text{out}} \right), \\ \vec{H}_{\text{body}}^{\text{out}} &= \vec{H}_{\text{inc}} + \sum_{n=1}^N \left(b_n \vec{H}_{\text{comb}}^{\text{in}} + b'_n \vec{H}_{\text{comb}}^{\text{in}} \right) \\ &+ \sum_{m=1}^M \left(c_m \vec{H}_{\text{comb}}^{\text{out}} + c'_m \vec{H}_{\text{comb}}^{\text{out}} \right).\end{aligned}$$

The field outside of the given structure is the sum of auxiliary sources internal with respect to the boundary of the room:

$$\begin{aligned}\vec{E}^{\text{out}} &= \sum_{m=1}^M \left(d_m \vec{E}_{\text{comb}}^{\text{in}} + d'_m \vec{E}_{\text{comb}}^{\text{in}} \right), \\ \vec{H}^{\text{out}} &= \sum_{m=1}^M \left(d_m \vec{H}_{\text{comb}}^{\text{in}} + d'_m \vec{H}_{\text{comb}}^{\text{in}} \right).\end{aligned}$$

The unknown complex amplitudes a_n , a'_n , b_n , b'_n , c_m , c'_m , d_m , and d'_m , where $n = 1, 2, \dots, N$ and $m = 1, 2, \dots, M$, are found from the boundary conditions by the collocation method. To this end, we obtain a system of linear algebraic equations, the solutions to which enable one to find the sought-for fields.

1.2. The Algorithm for Simulation of the Transparency of Walls

To calculate the transparency coefficient of walls, we applied the method of averaged boundary conditions. The main idea is that the transparency of walls can be regulated by varying the number of collocation points on their surface. The reduction in this number is followed by an increase in the total error in the corresponding boundary conditions. The results of numerical calculations show that, if the number of collocation points is small, the internal field can leak between these point, making the walls transparent.

For the quantitative analysis of the transparency coefficient, we considered the diffraction of a plane wave by a perfectly conducting surface. When simulating this problem, the conducting surface was replaced with a system of points at which the boundary conditions as on a perfect conductor were imposed. We performed a detailed study (Fig. 4) of the dependence of the reflection coefficient R and transmission (transparency) coefficient T on the number of these points (N/λ^2 is the number of collocation points per squared incident wavelength) at a fixed value $kd \approx 0.3$, where d is the distance from auxiliary sources to the walls.

Choosing an appropriate number N/λ^2 , one can obtain the desired value of the transmission coefficient T , which will better conform to the problem under consideration. Since the transmission coefficient is obtained as a function of the reduced wavelength, they will remain the same at all frequencies. Thus, with variation in frequency, the wavelength changes but the quantity N/λ^2 remains constant.

2. NUMERICAL RESULTS

The algorithm described above was implemented in a computer program for the numerical study of the field inside the model of a man, inside a room, and in the far zone. The program enables one to vary the basic parameters of the system: the dimensions of the room, the dimensions and position of the window, the positions of the man and the radiator, the polarization of the radiator, and the transparency of the walls. By choosing these parameters, one can calculate the frequency characteristic of the system and study its resonance properties. The system of algebraic equations is solved using the MKL library with double precision. An important parameter for obtaining a well-conditioned system of equations is the distance between the main and auxiliary surfaces. The construction of auxiliary surfaces was thoroughly studied in [16], on the basis of which the results presented below were obtained. To estimate the accuracy of the solution, the accuracy of satisfying the boundary conditions was estimated.

2.1. Comparative Analysis of the Algorithm

The main advantage of the FDMTD over MAS is that the FDMTD is the only method making it possible to consider nonuniform models. However, its application is strongly limited by the computer resources; therefore, at the frequencies of interest, only relatively small spatial regions can be studied on available computers. In addition, as was noted above, the estimation of the accuracy of the solution by this method is impossible. For large regions of space, including the model under study, one should use MAS. However, it should be noted that, in this method, it is possible to consider only a uniform model of a man with averaged values of the main electrodynamic parameters. To confirm the correctness of this approach, it is necessary to perform a comparative analysis of the results obtained by the FDMTD and MAS for small regions at the basic frequencies of communication systems (300, 450, 900, and 1800 MHz).

Figures 5a and 5b show the field amplitude distribution over the cross section of the uniform model of the head. We see a good agreement between the field structures obtained by MAS. Figure 5c shows the frequency dependence of the maximum SAR inside the head. As we see from the graphs, both methods give well-agreeing values of the maximum SAR for each studied frequency. Figure 6 resents the comparison of SAR distributions inside the entire body, obtained for the nonuniform and uniform models of a man in the free space, irradiated by a plane wave at the frequency of 300 MHz. The reason for choosing a plane wave was that, in this case, the visual comparison of the field distribution over the whole volume of the mummy is possible; if one uses a dipole or any other source, only a local region of the model is irradiated, which hampers the comparison of SAR distributions over the entire body. From the figures presented, we also see a sufficiently good agreement between the results of the FDMTD and MAS. Therefore, we will assume that the absolute values presented are within the calculation error. It should be noted once more that the accuracy of calculations by MAS can be strictly controlled, while the FDMTD gives no such a possibility.

A similar comparison was performed for the frequency of 1800 MHz (Figs. 7, 8). In this case, we observe some disagreement between the results, which can be explained by a small wavelength (≈ 17 cm), at which the contribution of the irregularities of the problem is more significant. The results of MAS were obtained with an error (the mean-square deviation in the boundary conditions at the collocation points on the mummy surface) within 15%; therefore, for the uniform model, these results are more reliable. The results at the intermediate frequencies (450 and 900 MHz) are also close. Thus, the comparison of the result of the FDMTD and MAS makes it possible to

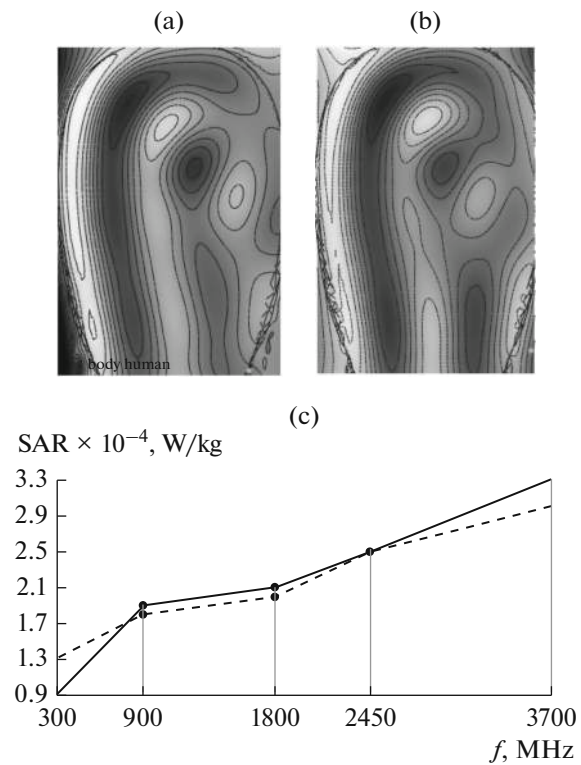


Fig. 5. Comparison of FDMTD and MAS. Internal field distribution calculated by (a) MAS and (b) FDMTD; (c) frequency dependence of the maximum SAR calculated by (solid curve) FDMTD and (dashed line) MAS.

restrict the consideration only to one model and apply MAS to large spatial regions.

2.2. Analysis of the Cases of Large Spatial Domains

Using the algorithm described above, several cases were studied for different values of the system parameters. The calculations were performed for the frequencies employed by wireless communication systems. The sizes of the model of a man were as follows: the height of 1.67 m, the shoulder width of 0.46 m, and the head diameter of 0.175 m. The mean permittivity for the corresponding frequency was chosen from the table presented. The conductivity of the given model was close to the conductivity of water.

Permittivity of different body tissues at different frequencies

Body tissue	f , MHz			
	300	450	900	1800
Muscles	58.2	56.8	55	53.5
Bones	13.4	13	12.5	11.8
Blood	65.7	63.7	61.4	61.4
Body-averaged	45.8	44.5	43.0	41.6

The average permittivity of the body over all frequencies is ≈ 44 .

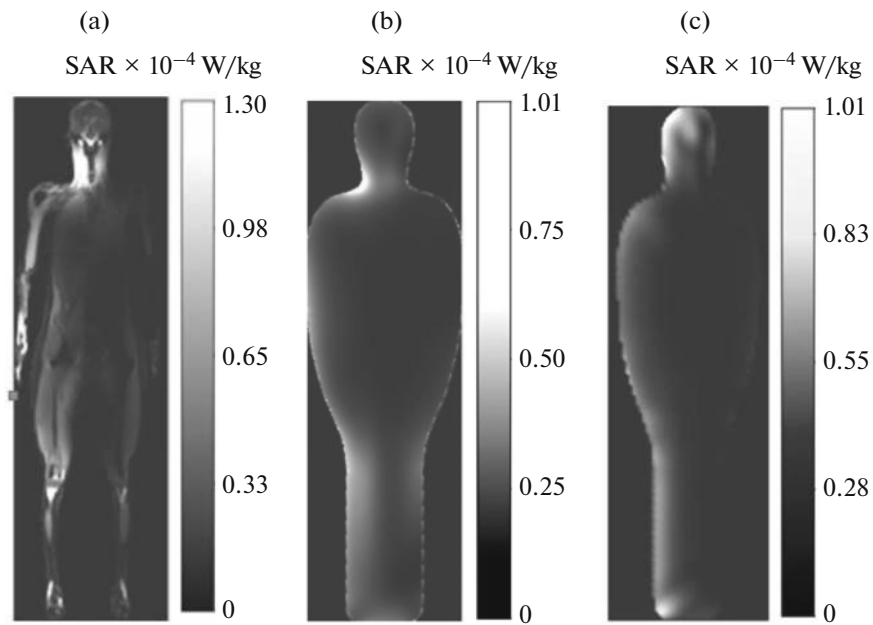


Fig. 6. Comparison of SAR distributions inside the body, obtained by FDMTD for the (a) nonuniform and (b) and uniform models and (c) MAS for the uniform model under irradiation by a plane wave with a frequency of 300 MHz.

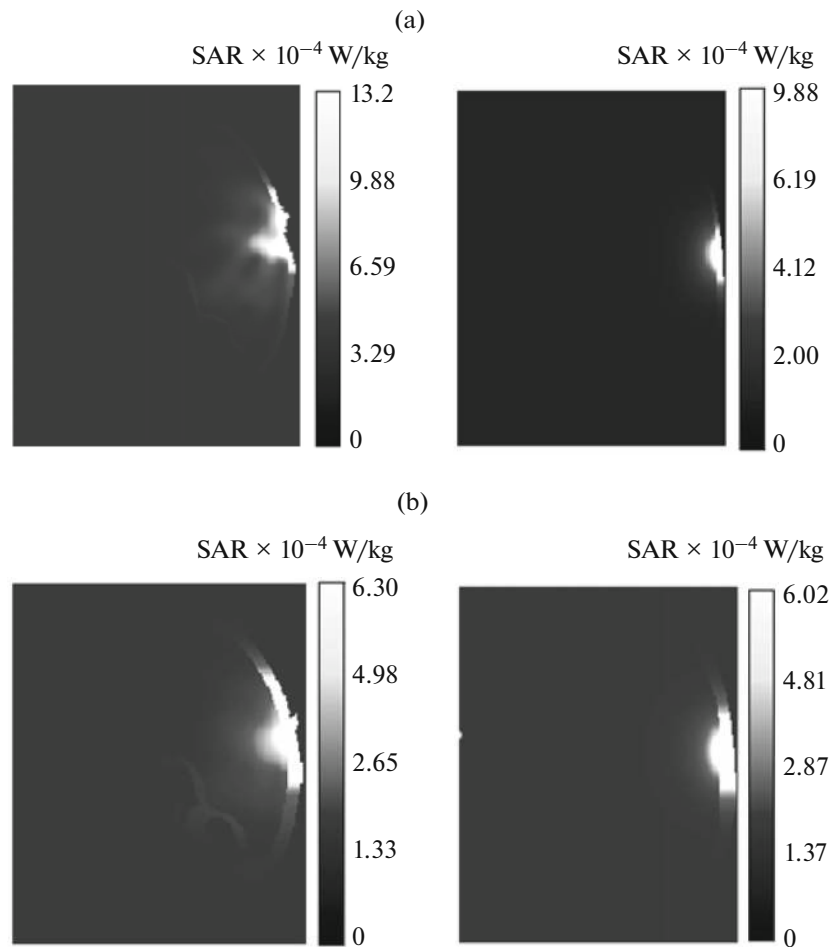


Fig. 7. Comparison of SAR distributions inside the head, averaged over (a) 1 g and (b) 10 g of mass, obtained by FDMTD in the (left) nonuniform and (right) by MAS in the uniform model under irradiation by a dipole antenna at a frequency of 1800 MHz.

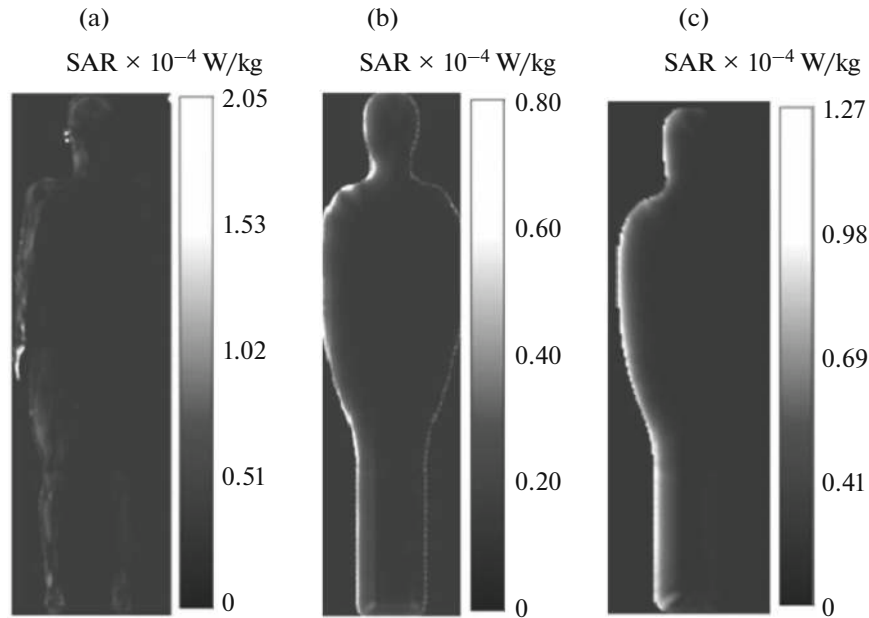


Fig. 8. Comparison of SAR distributions inside a body, obtained by (a, b) FDMTD for the nonuniform model and (c) by MAS for the uniform model under irradiation by a plane wave at a frequency of 1800 MHz.

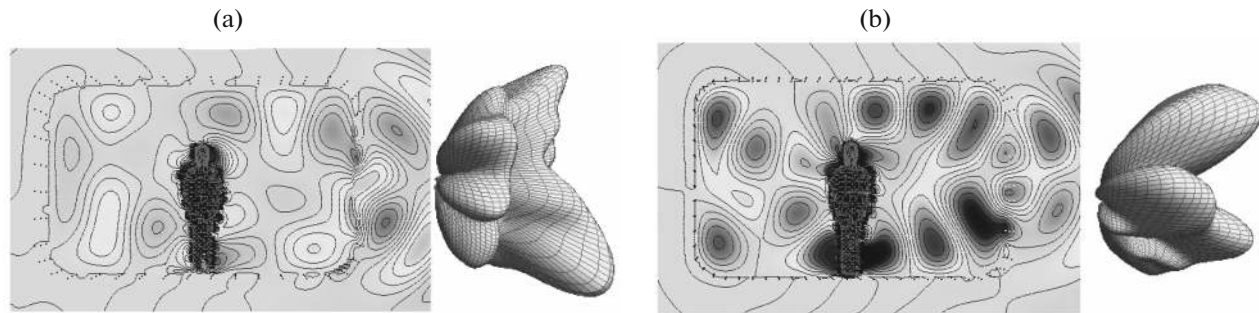


Fig. 9. Amplitude distribution of resonant EM field in the near zone and directional patterns for different transparency coefficients of walls $T =$ (a) 0.6 and (b) 0.3.

Figure 9 shows the amplitude distribution of the resonance near field and the directional patterns for two different values of the transparency coefficient of the walls. It is seen well that, at the lower transparency, the amplitude of the resonance field in the room is higher and the main radiation is transmitted through the window. However, due to the large permittivity, in both cases, the field energy inside the model of a man is significantly higher than that outside.

Then we studied large spatial domain for two different positions of the user and radiator at the frequency of 900 MHz. The density of collocation points on the walls provided the transparency $T \approx 0.75$ (see Fig. 4). Figure 10a corresponds to the position of the user near the wall against the window. This is the worst situation in terms of the absorbed energy, because, as a result of multiple reflections, the amplitude of the

resonance field in the vicinity of the head strongly increases. The optimal in terms of the absorbed energy is the position of the user near the window when the antenna is situated between the user and the window (Fig. 10b). This position impedes the formation of large resonance field, because the main part of radiation exits through the window. The SAR point distributions inside the head are presented in Figs. 11a and 11b. From these figures, we also see that, if the user is situated near the wall against the window, the value of SAR is greater almost by an order of magnitude than that when he is situated near the window (see Fig. 10b).

Figure 12 shows the distribution of the resonance field in the longitudinal and lateral cross sections of the room at the frequency of 900 MHz. In the lateral cross section, the field has higher amplitudes that it can be explained by the presence of a standing wave

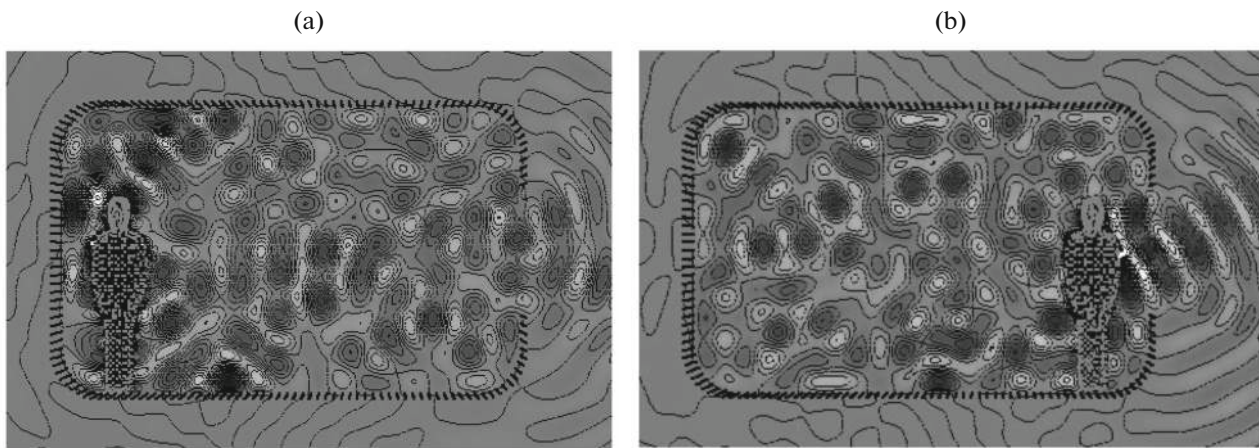


Fig. 10. Amplitude distribution of resonant EM field in two different situations: (a) the user is near the wall against the window and (b) the user is near the window.

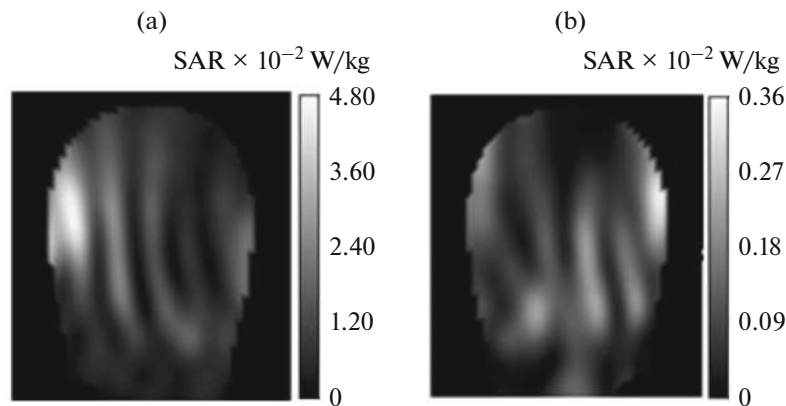


Fig. 11. SAR point distribution inside the head of a uniform model of a man when the model is found (a) near the wall against the window and (b) near the window.

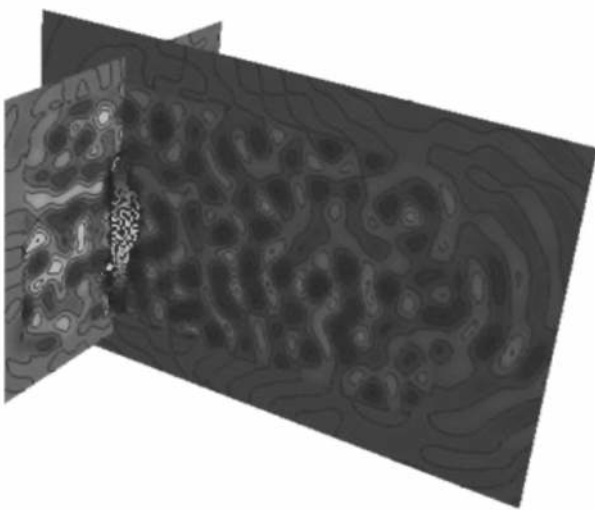


Fig. 12. Distribution of resonant EM field in the longitudinal and lateral cross sections of a room at the frequency of 900 MHz. In the lateral cross section (parallel to the window), the field has higher amplitudes.

between the nearest walls. Figure 13 shows the field distribution and the directional pattern in the case when the user is found in the free space. Obviously, this position is optimal for the user, because, in this case, the formation of the near standing resonance field is impossible and the main part of radiated energy propagates along the human body.

Now let us consider the case when the radiator frequency is 1800 MHz, which corresponds to the basic frequency of mobile phones. Figure 14 shows the corresponding near field distribution. As we see from the figure, at the given frequency, the field penetration depth to the model of a man is smaller than that at lower frequencies. The main part of the radiated energy also passed through the window. The transparency of the walls in this case is $T \approx 0.5$. Similar results were also obtained for other values of walls' transparency.

Similar calculations can be performed for much greater spatial domains, if high-capacity supercomputers are used. The numerical results presented above were obtained using a computer with the following

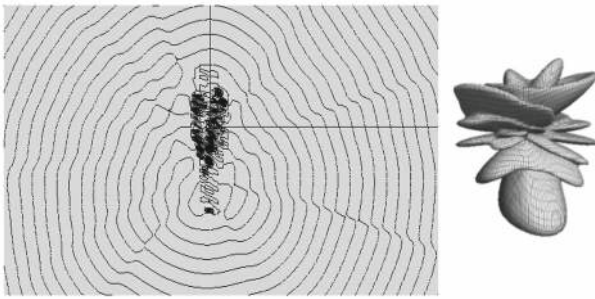


Fig. 13. Near-field distribution and directional pattern in the case of free space at the frequency of 900 MHz.

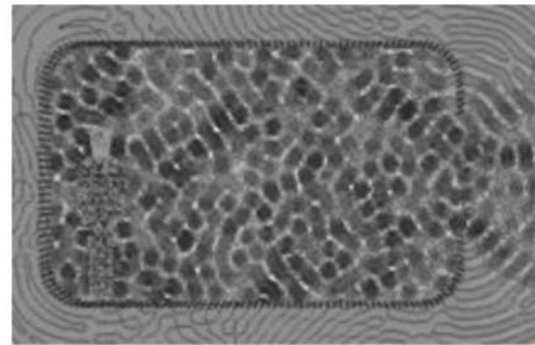


Fig. 14. Near-field distribution in the plane perpendicular to the window at the frequency of 1800 MHz.

parameters: Dual Intel Xeon X5650 processor, 24 threads, and 64 Gb RAM.

3. SOME RECOMMENDATIONS ON THE REDUCTION OF THE NEGATIVE EFFECT OF MOBILE PHONES ON USER'S HEALTH

The main objective is to reduce the penetration of the EM radiation energy (and, therefore, SAR) into head tissues as most sensitive. On the basis of numerous calculations, partly presented above, we can give some recommendation following which one can reduce the risk to health from the use of mobile phones.

(1) The better the connection with the base station, the lower the radiation power of the mobile phone. If possible, one should use the mobile phone at the places where the communication level is maximal; for instance, it is better to talk near the window than from a basement of reinforced concrete.

(2) It is desirable to use a phone with known SAR values. For each phone, it must be presented in the documentation. When choosing the model of a phone, one should prefer models with a lower declared maximum SAR.

(3) User's hand should not close the antenna of the mobile phone, which, in most of modern phones is placed in its lower part. One should not clasp the phone by the palm; it is desirable to hold the phone only by fingers.

(4) It is desirable to restrict the time of use of a mobile phone. It is known that the effects related to radiation tend to accumulate. Therefore, restricting the time for which the mobile phone is used reduces the risk to health.

(5) It is undesirable to use a mobile phone in subway cars and other closed rooms with metallic walls, especially with a low signal level of communication with the base station. In addition, in closed metallic constructions, resonance phenomena can occur, which can also increase the SAR values.

(6) Talking with a loudspeaker reduces the risk of using a phone. With an increase in the distance, the field in the head tissues decreases by the inverse-square law.

CONCLUSIONS

It has been shown that the results obtained by MAS for the uniform model are comparable with the result of the FDMTD for the nonuniform model. For the results presented in this paper, the difference in the maximum values of SAR was within 20%; thereby the possibility to use SAR, which is easier for computations, has been justified. It should be noted that, due to the irregularities of the model (corners, protrusions), the calculations by the FDMTD for the nonuniform model have a low stability to the antenna position and such comparison may be problematic.

MAS was applied to study the possible negative effect of reactive and resonance fields from wireless communication devices on the health of a man found in a room and in the open space. In contrast to the FDMTD, MAS enables one to take into account the objects surrounding the user, e.g., the room walls, which, in the case of resonances, can multiply increase the amplitude of the EM field. In addition, MAS made it possible to determine and regulate the calculation accuracy. In this work, we disregarded the details of the nonuniform structure of human head, because these irregularities do not introduce substantial changes at the given wavelengths. The developed computer model of a man—the “mummy”—comprises a homogeneous lossy dielectric whose electrodynamic parameters are close to the corresponding mean value for muscle tissue. Most attention has been paid to the possibility to vary the transparency of the walls surrounding the man, which is closely connected with the accuracy of satisfying the boundary conditions for the field and the choice of collocation points on them. The calculations performed with the program package developed have shown the presence of resonance and high-amplitude reactive fields for some large domains, which must negatively affect the user of

mobile communications. On the basis of calculations performed, general recommendations on the reduction of the risk of using wireless communication devices have been elaborated.

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