

Base Station Antenna's EM Exposure Study on a Homogeneous Human Model Located Inside the Car

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Abstract—The goal of this research is to investigate EM radiation influence, emitted by base station antenna, on a human homogenous model located in a car and study possible resonant fields inside with considering ground existence. The standard frequencies: 450, 900, 1800 [MHz] are selected for numerical experiments. For solving these problems were used the Method of Auxiliary Sources (MAS) with a user friendly program package, created for these particular problems. The results of the numerical simulations are presented and analyzed below.

Key words—Base station; EM field exposure; car; SAR; MAS; human homogenous model;

I. INTRODUCTION

The number of base stations in the vicinity of the populated areas are increased nowadays.

In paper [1] is tested the radiation compliance of a GSM base station antenna located in a rural area in Greece. The installation was consisted of a single antenna mast and was built on a hill. This research showed that the base station antenna was well below the given limits. That though, doesn't mean that every base station antenna follows the same practice.

The simple, accurate and computationally effective method for evaluation of near field of the GSM base station antennas in urban environment is presented in [2]. There were studied E-field nearby of antenna for different radiated power. Research showed that the approximated results are in good agreement with the full-wave analysis results.

In paper [3] electromagnetic radiation from base station antennas installed for various wireless communication purposes has been investigated based on equivalent isotropically radiated power calculations. For this purpose, a typical wireless communication site has been selected where GSM, CDMA, 3G/UMTS, and WiMAX antennas are installed. It has been found that impose any adverse health effects. For general public, the exclusion zone (compliance distance) from GSM, CDMA, 3G/UMTS, and WiMAX antennas have been found at 7.30, 6.076, 7.436, and 6.861 m, respectively.

The base station antenna's field diffraction on the room with the homogeneous human model (shaped body "Mummy") inside is studied in [4,5]. Numerical experiments

provided by this program package showed that the presence of resonance and reactive fields in several big scenarios which could be dangerous for a human health.

In this study a car and a homogeneous human model (Mummy) inside were considered. EM source is base station antenna. The standard frequencies: 450, 900, 1800[MHz] are selected for numerical experiments. It is important to take into account the ground existence and study possible resonant effects created by multiple reflections inside the car and study SAR distributions for these cases more carefully.

The goal is to find the near field distribution inside of the human body also inside and outside of the car, SAR distribution inside of the human body. We also have to estimate radiated far field pattern and investigate car resonant properties.

II. PROBLEM STATEMENT AND MAS METHODOLOGY FOR SIMULATION

During the EM Exposure influence investigation, it is forbidden to conduct real experiments on humans. Because of this the main tools of investigation represents the computer simulations based on numerical methods.

A model of a system consisting of a car and placed inside a human is considered. This system is under well known electromagnetic influence. The goal is to determine the fields that form inside the car, outside the car, and also inside the human. The source of the electromagnetic field is located outside the car. In our case, the radiation is emitted from the base station antenna

The car is assumed as an ideally conducting surface S (Fig.1).

It has open areas as the form of windows, σ_w , $w = 1, 2, \dots$.

The human model is an ideal homogeneous dielectric with losses limited by a closed surface S_0 , located inside the car.

Due to resonance, at certain values of the system parameters, high-amplitude resonance fields can form inside the car, which will negatively affect on the human inside. Therefore, the study of the considered problem for different scenarios and different values of the system parameters is very topical. It is important to study how the earth's surface influences on the formation of resonance fields.

We should define fields in three regions: (I) outside the car, (II) inside the car, (III) inside the human model.

The field in the first region consists of an incident field $\vec{E}_{inc}^1, \vec{H}_{inc}^1$ and a field described by the surface S'' . The field in the second region consists of the incident field $\vec{E}_{inc}^2, \vec{H}_{inc}^2$ and the fields described by the surfaces S' and S_0'' . In the third region, the field is described by the surface S_0' (Fig. 1).

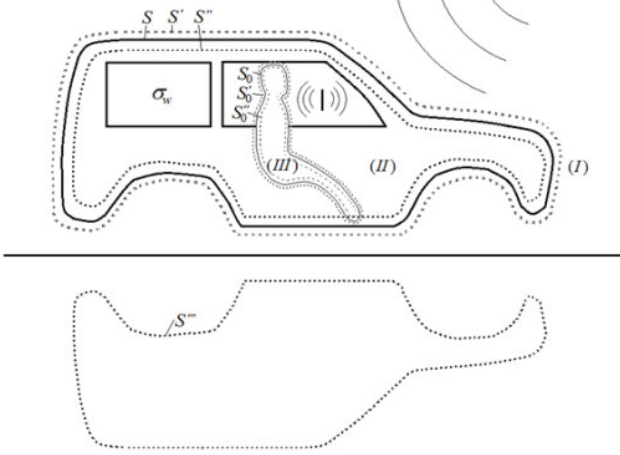


Figure 1. MAS model of cavity with using auxiliary surfaces.

In this way,

$$\vec{E}_{(I)}(\vec{r}) = \vec{E}_{inc}^1(\vec{r}) + \sum_{n=1}^N [A_n \vec{G}_E(\vec{r}, \vec{r}_n, \vec{p}_e, \vec{p}_h, \epsilon_0, \mu_0) + B_n \vec{G}_E(\vec{r}, \vec{r}_n, \vec{p}_e', \vec{p}_h', \epsilon_0, \mu_0)]_{\vec{r} \in S''} \quad (1)$$

$$\vec{E}_{(II)}(\vec{r}) = \vec{E}_{inc}^2(\vec{r}) + \sum_{n=1}^N [C_n \vec{G}_E(\vec{r}, \vec{r}_n, \vec{p}_e, \vec{p}_h, \epsilon_0, \mu_0) + D_n \vec{G}_E(\vec{r}, \vec{r}_n, \vec{p}_e', \vec{p}_h', \epsilon_0, \mu_0)]_{\vec{r} \in S'} + \sum_{m=1}^{N_0} [E_m \vec{G}_E(\vec{r}, \vec{r}_m, \vec{p}_e, \vec{p}_h, \epsilon_0, \mu_0) + F_m \vec{G}_E(\vec{r}, \vec{r}_m, \vec{p}_e', \vec{p}_h', \epsilon_0, \mu_0)]_{\vec{r} \in S_0''} \quad (2)$$

$$\vec{E}_{(III)}(\vec{r}) = \sum_{m=1}^{N_0} [K_m \vec{G}_E(\vec{r}, \vec{r}_m, \vec{p}_e, \vec{p}_h, \epsilon, \mu) + L_m \vec{G}_E(\vec{r}, \vec{r}_m, \vec{p}_e', \vec{p}_h', \epsilon, \mu)]_{\vec{r} \in S_0'} \quad (3)$$

$$\vec{H}_{(I)}(\vec{r}) = \vec{H}_{inc}^1(\vec{r}) + \sum_{n=1}^N [A_n \vec{G}_H(\vec{r}, \vec{r}_n, \vec{p}_e, \vec{p}_h, \epsilon_0, \mu_0) + B_n \vec{G}_H(\vec{r}, \vec{r}_n, \vec{p}_e', \vec{p}_h', \epsilon_0, \mu_0)]_{\vec{r} \in S''} \quad (4)$$

$$\vec{H}_{(II)}(\vec{r}) = \vec{H}_{inc}^2(\vec{r}) + \sum_{n=1}^N [C_n \vec{G}_H(\vec{r}, \vec{r}_n, \vec{p}_e, \vec{p}_h, \epsilon_0, \mu_0) + D_n \vec{G}_H(\vec{r}, \vec{r}_n, \vec{p}_e', \vec{p}_h', \epsilon_0, \mu_0)]_{\vec{r} \in S'} + \sum_{m=1}^{N_0} [E_m \vec{G}_H(\vec{r}, \vec{r}_m, \vec{p}_e, \vec{p}_h, \epsilon_0, \mu_0) + F_m \vec{G}_H(\vec{r}, \vec{r}_m, \vec{p}_e', \vec{p}_h', \epsilon_0, \mu_0)]_{\vec{r} \in S_0''} \quad (5)$$

$$\vec{H}_{(III)}(\vec{r}) = \sum_{m=1}^{N_0} [K_m \vec{G}_H(\vec{r}, \vec{r}_m, \vec{p}_e, \vec{p}_h, \epsilon, \mu) + L_m \vec{G}_H(\vec{r}, \vec{r}_m, \vec{p}_e', \vec{p}_h', \epsilon, \mu)]_{\vec{r} \in S_0'} \quad (6)$$

In the above expressions, there are unknown complex amplitudes $A_n, B_n, C_n, D_n, E_m, F_m, K_m, L_m$ of auxiliary sources, the total number of which is $4 \cdot (N + N_0)$. They can be determined from the boundary conditions that the required fields on the surfaces must satisfy S, S_0 and σ_w (number of car's windows), $w = 1, 2, \dots$

We assume that the earth's surface is an ideal flat conductor. This gives us possibility to apply the method of mirror mappings, to describe the reflected field. The contribution of

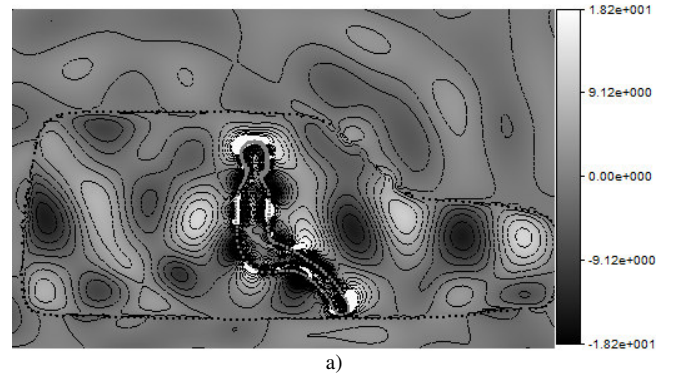
the reflected field will lead to the appearance of additional terms in the general mathematical expressions (1) and (4) for the field in the first region. As for the expressions for the fields in the second and third regions, the reflected field will only change the values of the amplitudes of the auxiliary sources. Since these amplitudes have not yet been determined and are of an arbitrary nature, the general mathematical expression of these fields will not change.

III. OBTAINED RESULTS OF NUMERICAL SIMULATIONS AND DISCUSSION

We use a homogenous dielectric human shaped body 'Mummy' with averaged permittivity and losses values (according to muscle, bone and fat), since their inhomogeneity does not affect the final results significantly [4]. The human model's height 1.67m, shoulder width 46 cm, head diameter 17.5 cm. The car dimensions are: 4.10m x 1.76m x 1.57m (LWH).

The EM field Source is the base station antenna located outside of the car. Base station antenna's input power is 80w and is placed in 25 meters from the car. The angle of incidence of the EM field is 30° from the front side of the car. Calculations were carried out at 450MHz, 900 MHz and 1800 MHz radiation frequencies.

Based on above proposed methodology (MAS) in our laboratory was developed new program package. There were studied near field distribution, far field pattern and SAR distribution inside the human body. For all results near and far field values are given in the relative units, whereas SAR values are provided in W/Kg and normalized to 80 W input power.



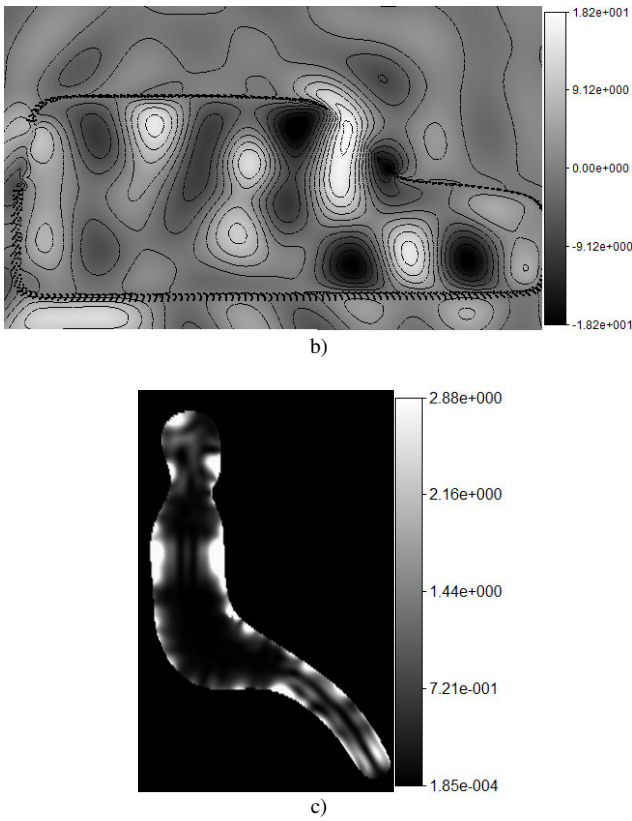


Figure 2. Near field distribution (XOZ plane) inside the car in different section, (a) with human model, (b) without human model and SAR distribution (W/Kg) for the human body (c) at 450 MHz radiation frequency.

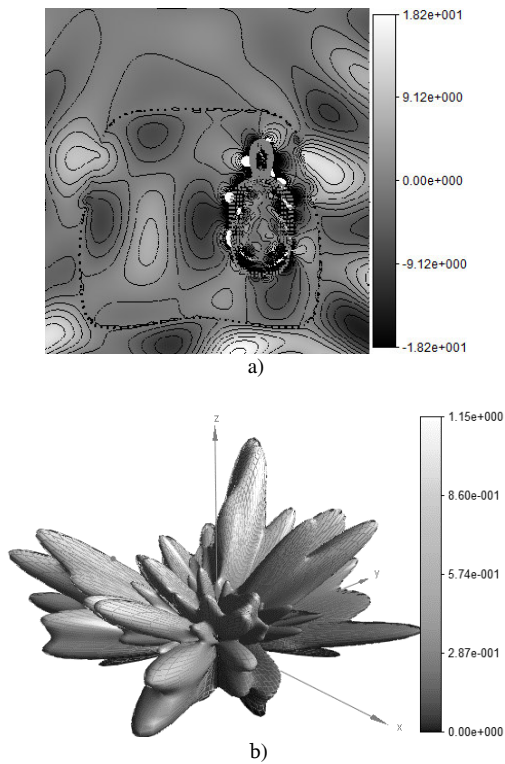
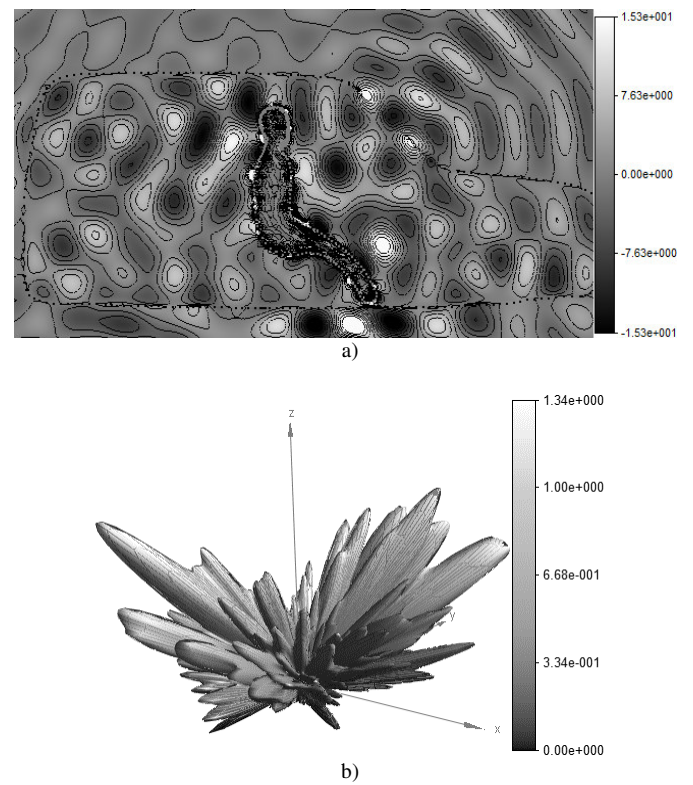


Figure 3. Near field distribution in YOZ plane inside the car (a) and far field pattern (b) at 450 MHz radiation frequency.

On figures 2, 3 are presented near field distribution inside the car in different section (with and without human model) and far field pattern at 450 MHz frequency. For this case SAR peak value inside of the human body is 2.88 W/Kg (figure 2c). It seems that wavelength is almost equal car window size and radiated energy penetrates inside the car though the side windows. Standing waves mainly are observed in the front part of car.

On figures 4 (a, b, c) are presented near field distribution inside the car in XOZ plane, far filed pattern and SAR distribution for the human body at 900 MHz radiation frequency. In this case SAR value inside the human body is smaller than for the 450 MHz frequency. This can be explained by the fact that a large part of EM energy goes out of the windows.



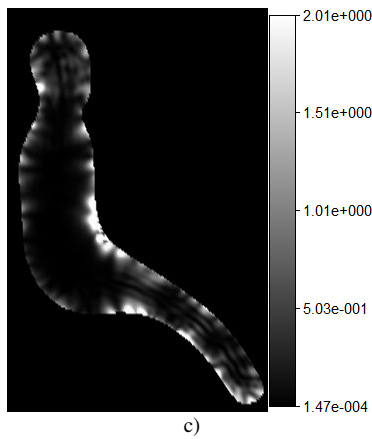


Figure 4. Near field distribution in the car (a), far field pattern (b) and SAR distribution inside of human body (c) at 900 MHz.

We have investigated car resonant properties and generate resonant characteristic near to the 900 MHz frequency. Figure 5 shows the detailed frequency characteristic on which we see the sharp, discriminated resonance frequency 901.56MHz.

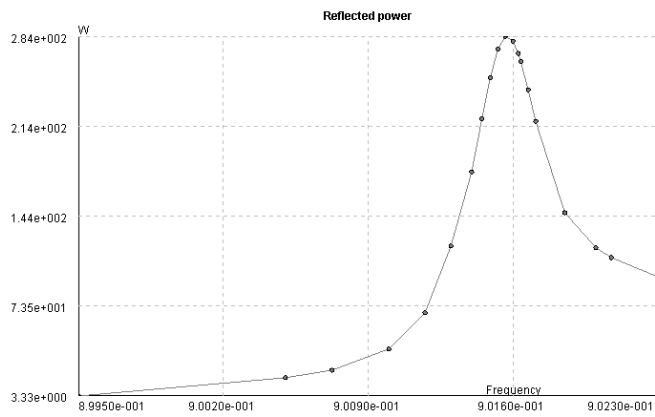


Figure 5. Frequency characteristic for the car at 900 MHz, when human model is located inside the car.

Figure 6 shows near field inside the car (a) and SAR distribution for the human body (b) at 901.56MHz resonant frequency. As it is seen the field and the peak SAR value is about ten times higher than it was for the 900 MHz frequency.

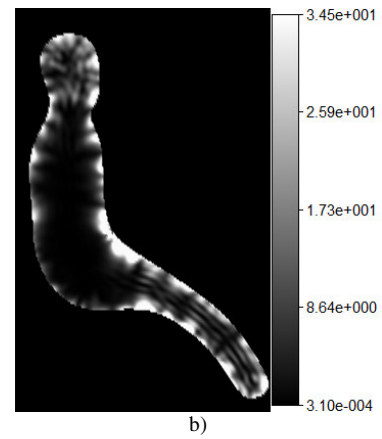
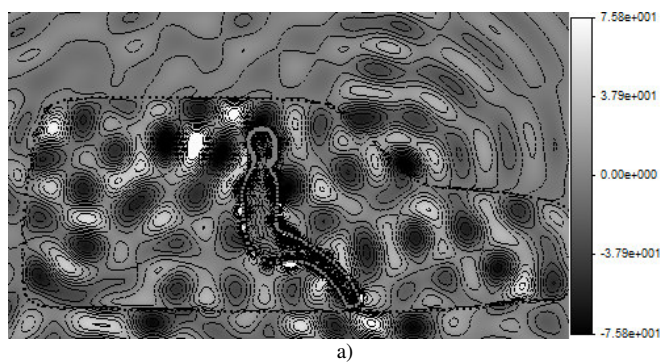


Figure 6. Near filed distribution inside the car (a) and SAR (b) distribution for the human body at the 901.56MHz resonant frequency.

We study the near filed distribution inside the car and SAR distribution inside the human body at 1800 MHz frequency. These results are presented on figures 7 a, b. Because of the high losses at this frequency the depth of the field penetration in the human model is smaller than for the lower frequencies and EM field absorption occurs mostly in the skin layer. The most part of the radiated energy goes through the window.

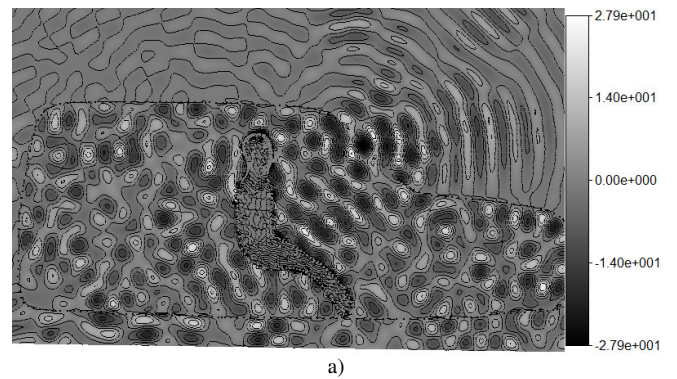


Figure 7. Near field distribution in the car (a) and SAR distribution inside of human body (b) at 1800 MHz frequency (source is base station antenna).

Finally, as it is seen from Figures 2-7 the EM field penetrates inside the car through the window. The resonant field is

generated inside the car for 450MHz, 900MHz and 1800 MHz frequencies, the part of radiated energy goes outside the car through the car's window and the significant part is absorbed by the human body.

The research, provided by the MAS based program package showed that the field, radiated by the base station antenna, could be amplified inside the car. The reason of this is that at the considered frequencies car's walls acts as the resonator.

IV. CONCLUSION

The numerical calculations were provided using the user friendly program package, which was developed for this particular problem. There were found resonant parameters of the system for the certain frequency range of the incident field. The results were obtained by parallel validation of the boundary condition satisfaction.

We study far field pattern and near field distribution inside the human body, also inside and outside of the car. Also we study SAR distribution inside the homogenous human model and we see that reactive field and pick SAR values are high for this considering case.

It is important to note that the part of EM radiation from base station antenna reflected by the car's metallic structure magnifies the radiation. Not just because human becomes distracted this could cause an accident. There might also be a direct effect on the human health.

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