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Original article

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ELECTROMAGNETIC SCREENING PLATE IN PROTECTION SERVICE TECHNICIANS FROM BASE STATION ANTENNA SYSTEMS

Abstract: *Service technicians on base station mobile phone systems are exposed to electromagnetic waves in the near field. This is an area where the values of the electrical and magnetic fields often exceed maximum limits defined by standards. The timing of exposure of people close to the antenna system, even if permitted values are not exceeded, indicates possible negative health effects. There is a need to use personal protective equipment in order to reduce the penetration of fields into human bodies. Therefore, it is important to analyze the protective screens in the form of a network of conductive materials that could be incorporated into workers' clothes.*

Keywords: near electromagnetic field, service technicians, health risk from the electromagnetic field.

INTRODUCTION

Service technicians work close to the antenna systems which are turned on and those systems emit waves i.e. electromagnetic radiation most of the time. Usually, the antenna systems are mounted at the top of the roof, and there are several different operators in these sites. In most cases, the antenna on which they operate is turned off, but in some situations, service technicians work on antenna systems that are turned on. The investigation of the effects of electromagnetic radiation from technical equipment of telecommunication systems has been explained in our recent research article [1, 2]. We performed the calculation of the electromagnetic field on the body pointed to the increased field values, relative to the values allowed by the standard, even when the servicer is not in the direct radiation beam.

The aim of this paper is to take care of workers' health as well as the authors' wish to investigate possible means of protection. For passive shielding, we chose a conductive grid plate of a rectangular shape with dimensions similar to the human body.

Knowing that these fields can endanger human health emphasized the necessity to reduce the field components in the body during work.

THEORY OF ELECTROMAGNETIC SHIELDING

A possible way of protection is to use electromagnetic screens in the form of wire meshes. There are two screening options: good e-conductivity shielding and high permeability shielding. Good conductivity material induces currents whose EM field, depending on the problem configuration, can weaken and partially cancel the existing EM field. High permeability material - ferromagnetic, is a good magnetic "conductor" that represents a short circuit for a magnetic field. The magnetic field enters the ferromagnet, and in this way reduces the intensity of the field in the shielded space. At this moment, conducting wire mesh structure is analyzed. The physical flexibility of these structures is appropriate for plastic deformation and can be impregnated as part of protective clothes [3]. For this purpose, the behaviour of mesh screens is analyzed with square mashes and sizes which are small in comparison to the free-space wavelength.

For this purpose, shielding effectiveness which consists of electric field and magnetic field shielding effectiveness SE_e and SE_m has been calculated in theory,

$$SE_e = 20\log\frac{E_i}{E_t} \quad SE_m = 20\log\frac{H_i}{H_t} \tag{1}$$

where indices i and t correspond to the incident and transmitted wave. The shielding performance of mesh screens is considered wherein the individual meshes are square and of small size in comparison to the free-space wavelength.

The shielding effectiveness of a wire mesh screen not only depends on the frequency of operation and dimensions of the screen mesh but also on the angle of incidence of plane wave [3]. For this reason, the expressions of analytical forms for SE are unsuitable for

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the analysis of the absorption of an electric field in a human body. The solution can be found in numerical simulation procedures that can be obtained by penetrating field components in biological objects.

NUMERICAL METHOD AND MODELLING

Shielding effectiveness can be studied numerically using, e.g., methods of moments (MOM), finite element method (FEM) or finite difference time-domain (FDTD) approaches to compute the transmission through meshes. These methods are generally restricted by memory requirements to structures of a few wavelengths [3].

For calculation of the power absorption within the body of a service technician, there are only a few methods that can carry efficiency fine-resolution inhomogeneous dielectric structures like the human body. Volume-based methods turned out to be adequate for this aim; therefore, the Finite-Difference Time-Domain method (FDTD) and the appropriate software package [4] have been used in this paper.

EXPERIMENTAL MODEL

Here we will investigate a simple metallic sector antenna model with a screen of planar wire conducting meshes (Fig 1). The individual meshes are square and the wire junctions are assumed to be bonded.

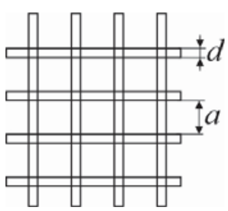
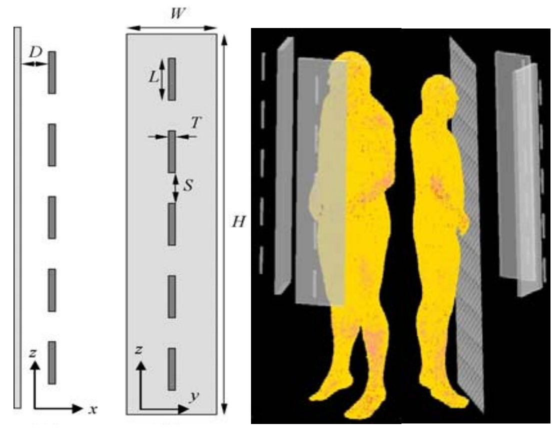


Figure 1 – *Geometry of wire mesh*

A real antenna has been used in simulation which consisting of a vertical array of dipoles and an additional reflector to focus the beam in the azimuthal direction, Fig. 2b. The antenna consists of five vertical dipoles and a metallic reflector. For this purpose, the antenna systems with parameters as in paper [1], (*L, T, H, S* and *W*) have been used.

The model of a human for numerical simulation available from the US Air Force Research Laboratory is used [5]. This model provides a very accurate description of the real position of all tissues in the human body and their electromagnetic characteristics, Fig.2.b.

In the simulation process, a human model of 1 mm spatial resolution and 40 different types of tissue have been used.



a) b)

Figure 2 – *Base station antenna; a) Simple model of the base station antenna with side view and front view,* b) *Real situation antennas with two 90° sector antenna and the man behind of antenna without and with shielding screen*

Electromagnetic parameters for some interesting types of tissues are shown in Table I.

Table I – *Dielectric parameters and the mass density of observed biological tissue at a frequency of 900* MHz, [5].

Tissue	ε_r	σ [S/m]	ρ [kg/m^3]
Brain (white matter)	73.62	0.3169	1038
Lens	112.74	0.4933	1163
Testis	82.33	1.1889	1158

SIMULATION PROCESS

Telecommunication companies have been widely using 4G – LTE services in a mobile network with the band on 900MHz. The components of the electromagnetic field behind the antennas are not negligible if a person stands near the antenna. The point of interest is the absorption by workers behind a pair of base station antennas, with and without screen from wire conducting meshes. Numerical simulation methods of penetrating electromagnetic fields allow the calculation of the field components in biological subjects.

The antenna design used in the simulation process with two Kathrein 736 078 antennas at the angle of 270 degrees is shown in Fig. 2b. The value used for these parameters in simulation process for base station antenna were: Dipole diameter - T = 1.2 cm, Dipole length - L = 14 cm, Reflector height - H = 129 cm, Reflector width - W = 25.5 cm, Horizontal distance dipoles to reflector - D = 8 cm and Vertical distance between dipoles - S = 11.5 cm (Fig. 2a). Parts of the antenna as dipoles and the reflector are supposed to be lossless and modelled as perfect electric conductors. The dipoles are fed at the center point by a lumped port with an impedance of 50Ω. The five ports are excited by signals with equal amplitude and phase. The available power of antenna is 1350W per antenna and this power is very often used by the mobile operator.

The values used for these parameters in the simulation process for the screen were: d=1mm and a=1cm, 2cm, and 4cm. The distance between the torso of a man and a screen is 1 cm, and between the head of a man and a screen is 8 cm.

SIMULATION RESULTS

Simulation provides the values of electromagnetic components in the human body. The components of the electromagnetic field inside the biological subject determine the energy absorbed in that element of space. The values are calculated for three distance screens and the man from the antenna systems.

An index, behind the mark of quantity name, points out to distance as 1- the screen almost touches the back of the antenna (reflector of an antenna) and the distance is few centimeters, 2 - the screen is at 25 cm from the edge of the reflector, 3 - the screen is at 50 cm from the edge of the reflector

The values of the electrical field in biological sensitive organs for different position of man without the screen are shown in Table 2.

Table 2 - *The maximum values of the electrical field in organs without screen*

Tissue	E_{10} [V/m]	E_{20} [V/m]	E_{30} [V/m]
brain	581	525	344
eye	233	160	102
testis	260	274	132

Table 3 – *Reduction ratio of the E field with screen for a=1cm*

Tissue	E_1/E_{10}	E_2/E_{20}	E_3/E_{30}
brain	7.80	15.09	11.82
eye	10.31	9.94	5.73
testis	13.83	37.43	19.64

Table 4 – *Reduction ratio of the E field with screen for a=2cm*

Tissue	E_1/E_{10}	E_2/E_{20}	E_3/E_{30}
brain	5.89	10.61	6.16
eye	5.05	7.34	4.64
testis	8.93	30.58	14.98

Table 5– *Reduction ratio of the E field with screen for a=4cm*

Tissue	E_1/E_{10}	E_2/E_{20}	E_3/E_{30}
brain	5.64	8.50	5.68
eye	4.51	6.72	4.16
testis	11.56	28.69	14.65

Figures 3 - 5 show the electric field intensity with different colours in front of and behind the screening plate and its effect on the reduction.

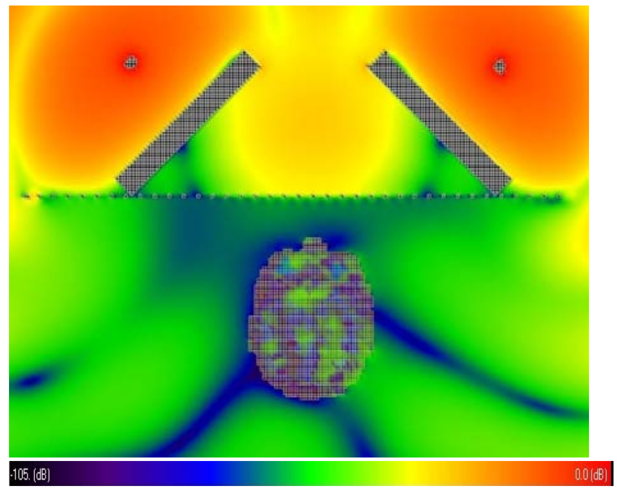


Figure 3 – *Distribution of electric field in the brain for distance 1 from screen*

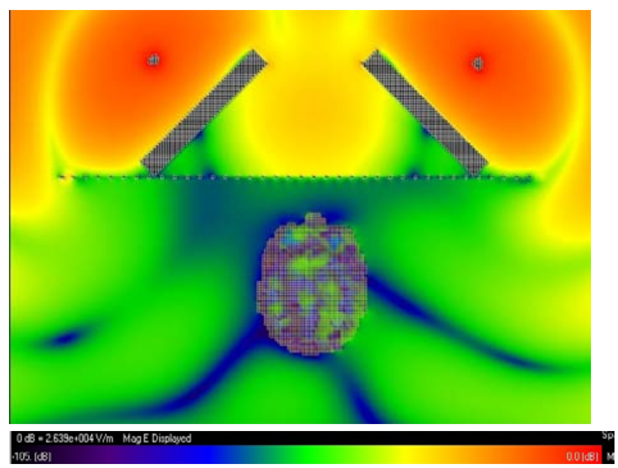


Figure 4 – *Distribution of electric field in cross-section eyes for distance 1 from screen*

Specific absorption rate (SAR) is a measure of the rate at which energy is absorbed by the human body.

SAR [W/kg] in biological sensitive organs of humans for 1g and 10 g averaged mass of tissue are shown in Tables 6-10.

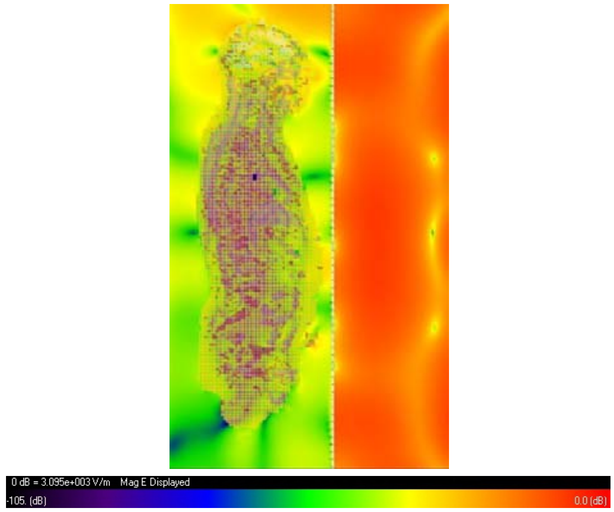


Figure 5 – *Distribution of electric field in the body for distance 1 from the screen*

Table 6 - *The values of SAR in organs without screen*

Tissue	$SAR_{1g}1$	$SAR_{10g}1$	$SAR_{1g}2$	$SAR_{10g}2$	$SAR_{1g}3$	$SAR_{10g}3$
brain	17.9	12.7	9.47	9.41	7.31	5.3
eye	39.3	21.1	27.8	15.1	16.7	11.4
testis	9.34	7.91	12	9	4.63	2.1

Table 7 - *The values of SAR in organs with screen for a=1cm*

Tissue	$SAR_{1g}1$	$SAR_{10g}1$	$SAR_{1g}2$	$SAR_{10g}2$	$SAR_{1g}3$	$SAR_{10g}3$
brain	0.322	0.27	0.196	0.137	0.224	0.135
eye	0.592	0.319	0.199	0.102	0.232	0.126
testis	0.0584	0.0859	0.0184	0.0104	0.003	0.00271

Table 8 - *The values of SAR in organs with screen for a=2cm*

Tissue	$SAR_{1g}1$	$SAR_{10g}1$	$SAR_{1g}2$	$SAR_{10g}2$	$SAR_{1g}3$	$SAR_{10g}3$
brain	0.592	0.297	0.227	0.15	0.252	0.15
eye	0.6	0.341	0.199	0.106	0.236	0.135
testis	0.0831	0.0825	0.0184	0.0104	0.0035	0.00271

Table 9 - *The values of SAR in organs with screen for a=4cm*

Tissue	$SAR_{1g}1$	$SAR_{10g}1$	$SAR_{1g}2$	$SAR_{10g}2$	$SAR_{1g}3$	$SAR_{10g}3$
brain	0.529	0.298	0.246	0.15	0.252	0.156
eye	0.6	0.341	0.199	0.106	0.234	0.135
testis	0.0831	0.0859	0.0184	0.0104	0.0035	0.00271

SAR averaged on 10g is in a better relationship with increasing temperature than 1g SAR over a wide range of frequencies and for near and far-field exposure [5].

Temperature increases due to the thermal effects of electromagnetic radiation on particularly sensitive tissues such as the brain, eyes and testicles can be a cause of health problems for service technicians.

The results of process simulation, measured through SAR, are given in Figures 6 and 7.

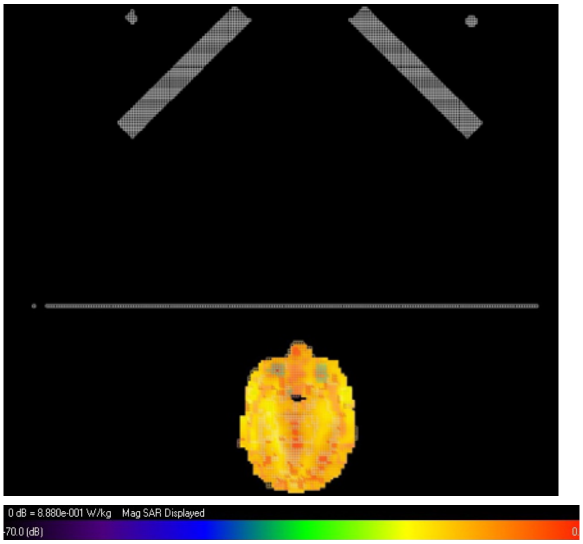


Figure 6 – *Distribution of SAR_{10g}, a cross-section of eyes in position 2 (25 cm from reflector)*

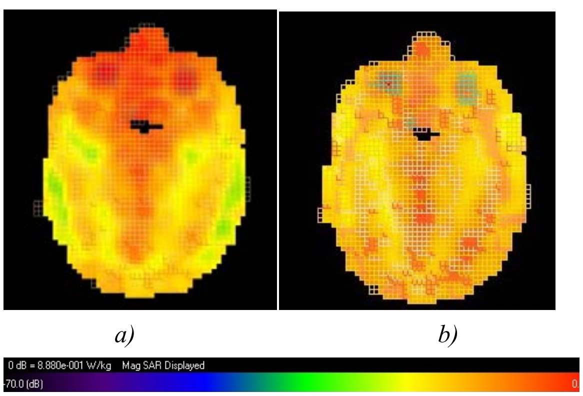


Figure 7 – *Distribution of SAR_{10g}, a cross-section of eyes in position 2; 25 cm from reflector; a) without screen b) with screen*

DISCUSSION AND CONCLUSION

Systematic monitoring of service technicians shows that, during their workday, they spend significant time near the active antenna of mobile communication systems. This indicates the need to construct a detector that will monitor the level of exposure of these employees in real-time. Working in the close antenna of base station lead to negative health effects. The need to reduce the intensity of the field which penetrated the bodies of service technicians has triggered the investigation of the possible use of shielding screens to reduce the absorbed energy and the quantities in correlation, as electrical field and SAR. Very thin conducting mash positioned in front of the body of service technician led to a significant reduction in the penetrated field into the human body. The data in table 10 and table 11 confirm this conclusion.

Table 10 – *Reduction ratio of the electrical field with screen for position 1- the screen is near the reflector for a different parameter of mesh*

Tissue	*a=1cm*	*a=2cm*	*a=4cm*
brain	7.80	5.89	5.64
eye	10.31	5.05	4.51
testis	13.83	8.93	11.56

Table 11 – *Reduction ratio of the SAR_{10g} with screen for position 1- the screen is near the reflector for a different parameter of mesh*

Tissue	*a=1cm*	*a=2cm*	*a=4cm*
brain	47.04	42.76	42.62
eye	66.14	61.88	61.88
testis	92.08	95.88	92.08

This type of shielding screen could be easily formatted to adapt to body shape and fit into protective clothing. Conductive wires can be woven into a cloth that can be used in protective clothing of service technicians.

Acknowledgment

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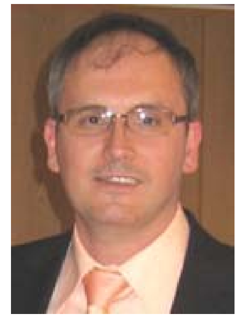

Dejan D. Krstić was born in Niš, Serbia, in 1969. He received a degree in Engineering and M.Sc. degrees from the Faculty of Electronic Engineering, University of Niš in 1994 and 1999 respectively. He obtained a Ph.D. degree from the Faculty of Occupational Safety, University of Niš in 2010. He has been engaged as a lecturer at the Faculty of Occupational Safety from 1995. He is the founder of the Laboratory of Electromagnetic Radiation and Center for Technical Systems Safety. Dr. Krstić's research interests are biological effects of electromagnetic radiation, numerical methods for electromagnetic field calculation and safety of technical systems. He published 148 papers in international journals or conference proceedings, as author and co-author, as well as eight textbooks.

ELEKTROMAGNETNI EKRANI KAO ZAŠTITA SERVISNOG OSOBLJA NA ANTENSKIM SISTEMIMA BAZNIH STANICA MOBILNE TELEFONIJE

Dejan Krstić, Darko Zigar, Nenad Cvetković, Željko Hederić, Dejan Jovanović, Vladimir Stanković

Rezime: *Servisni radnici na baznim stanicama mobilne telefonije su izloženi elektromagnetnom zračenju bliskog polja. Intenziteti električnog i magnetnog polja u ovom prostoru često prekoračuju dozvoljene vrednosti domaćih i međunarodnih standarda. Vreme koje ovi zaposleni provode u poljima u blizini samih antenskih sistema čak i kad su vrednosti polja blizu dozvoljenih vrednosti ukazuje da mogu biti prisutni negativni zdravstveni efekti po ove ljude. Zbog toga je potrebno korišćenje tehničkih sredstava odnosno lične zaštitne opreme da bi se redukovala prodrla polja u ljudska tela. Iz ovih razloga su predmet analize zaštitni ekrani u obliku mreže provodnika koji se mogu ugraditi u radnu odeću.*

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Ključne reči: blisko elektromagnetno polje, servisno osoblje, zdravstveni rizik od elektromagnetnih polja.