Safety Engineering

UDK 537.811:613:377.5
DOI: 10.7562/SE2018.8.01.07
Original article
www.safety.ni.ac.rs

DEJAN KRSTIĆ[1]
DARKO ZIGAR[2]
MILAN JOVANOVIĆ[3]
VLADIMIR STANKOVIĆ[4]
NENAD CVETKOVIĆ[5]
ŽELJKO HEDERIĆ[6]

[1,2]Faculty of Occupational Safety, University of Niš
[3,4,5]Faculty of Electronic Engineering, University of Niš
[6]Banker radio, Niš

[1]*vesna.toxicology@gmail.com*

ESTIMATION OF ABSORBED ELECTROMAGNETIC ENERGY ON SERVICE TECHNICIANS FROM BASE STATION ANTENNA SYSTEMS

Abstract: *Service technicians on mobile phone base stations systems are exposed to electromagnetic waves in the near field. In this area, the values of electrical and magnetic field can overload maximal exposure limit defined by standards. The subject in this paper is health risk of a service technician. It is important to calculate electrical field in the body of a service technician who moves in the vicinity of base station in order to estimate their health status.*

Key words: Near electromagnetic field, service technicians, health risk from electromagnetic field.

INTRODUCTION

Mobile phone systems have been developed very intensively in last few years and involved high-speed internet communication. Nowadays, new services are available and mobile phones are used as multifunctional communication devices. Time spent for using mobile phones is growing, mobile phones became smart, and as a consequence, for mobile providers time without services is not allowed. Providers are now competing who will have more services and functionalities.

These facts implied to the fast migration on next generation mobile system (4G, LTE), which for service technicians increased the time they need to spend in the vicinity of antennas on the roof of buildings. These people work near the antenna systems, which emit electromagnetic radiation most of the time.

Usually, antenna systems are mounted for several different operators in these suitable sites. Professionals who often perform interventions in the vicinity of the antenna system are concerned about possible consequences to their health effect and want to know occupational risks. Moreover, they often work in the area of background beam of antenna radiation.

NUMERICAL METHOD AND MODELLING

The need to take care of workers' health and to estimate health risks is one of the aims of this paper. Therefore, it is necessary to calculate the specific absorption rate in a realistic computational model of the human body.

This paper is a continuation of investigation in this area, which started on the conference PES 2013 [1]. For precise results, it is most important to have a real situation setup with antenna position, power level on output base transceiver station. Antenna design is very variable and results of absorption in near field radiation environment or human subject may be different for different type of antenna design.

The question about simulation software used in this research is important. If researcher considers metallic structures only, the numerical method of choice is The Method of Moments (Mom) [2], but final goal of the analysis is the calculation of the power absorption within the body of a service technician. Due to these reasons, the authors need a method that can be carried very efficiently - resolution of inhomogeneous dielectric structures as human body. Volume based methods are adequate for this aim, and some of those are Finite Element Method (FEM) and Finite-Difference Time-Domain method (FDTD). The choice will depend on the availability of human body model for software programme simulation. For this case, FTDT would be the best software choice followed by an appropriate software package [3].

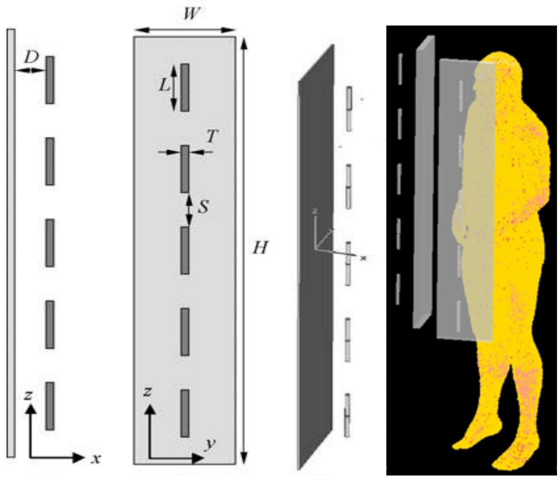
EXPERIMENTAL MODEL

Now, we investigate simple metallic sector antenna model and power absorption by workers behind a pair of base station antennas. In this simulation, a real antenna has been used consisting of a vertical array of dipoles and an additional reflector in order to focus the beam in azimuthal direction, Figure 1b. Telecommunication companies have started introducing 4G – LTE services in mobile network and it becomes operative. The topic of interest is how to radiate antenna systems for different band of mobile cellular systems. In our region, mobile companies use band 900MHz in LTE. Because of that, effective radiate power grows up in this band. The antenna basically consists of five vertical dipoles and a metallic reflector. The antenna systems with parameters like in the paper [1] (*L, T, H, S* and *W*) are used for this purpose.

The values used for these parameters in simulation process were as follows: 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 (Figure 1a).

Human model

Correct human body model is generated by several medical institutions. One of them originated from Visible Human Project, and can be found in the National Library of Medicine [4]. In this paper, we used a model for numerical simulation available from the US Air Force Research Laboratory. This model provides a very accurate description of real position of all tissues in human body and their electromagnetic characteristics, Fig.1.b.



a) b)

Figure 1. *Base station antenna - a) A simple model of the base station antenna with side view, front view and perspective view,* b) *Real situation antennas with two 90° sector antenna and a man behind the antenna*

The model is available in three different spatial resolutions: 1 mm, 2 mm, and 3 mm, and distinguishes between 40 different types of tissue. In addition, model contains a parametric model for the dielectric properties of these tissues and dielectric properties for some tissues shown in Table 1.

Table 1. *Dielectric parameters and the mass density of observed biological tissue at a frequency of 900* MHz, [4]

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

PROCES OF SIMULATION

The construction of antenna with a reflector produces the electromagnetic field components, where those in front of the antenna are significantly higher than those behind. The components of electromagnetic field behind the antennas are not negligible if a person is near the antenna. Numerical simulation methods of penetrating electromagnetic fields allow the calculation of the field components in biological subjects.

The antenna design used in simulation process with two Kathrein 736 078 antennas at the angle of 270 degrees is shown in Figure 1b. Parts of antenna as dipoles and the reflector are supposed to be lossless and modeled as perfect electric conductors. The dipoles are fed at the center point by a lumped port with impedance of 50Ω. The five ports are excited by signals with equal amplitude and phase. Available power of antenna is 1350W per antenna.

The components of electromagnetic field inside the biological subject determine the energy absorbed in that element space.

RESULTS OF SIMULATION

The simulation has the values of electromagnetic components in human body. The values were determined for four distances from antenna systems. An index points out on distance, and it can be 0- the worker almost touches the antenna's back (reflector of antenna) and the distance is few centimetres; 1- the worker is at the level of the reflector, 2 - the worker is at 25 cm from the edge of the reflector, 3 - the worker is at 50 cm from the edge of the reflector and 4 - the worker is at 3m from the edge of the reflector.

The values of electrical field in biological sensitive organs of humans are shown in Table 2.

Table 2 . *The maximum values of the electrical field in organs*

tissue	E_0 (V/m)	E_1 (V/m)	E_2 (V/m)	E_3 (V/m)	E_4 (V/m)
brain	649	581	525	344	70.3
eye	261	233	160	102	32.7
testis	309	260	274	132	64.4

Specific absorption rate (SAR) is a measure of the rate at which energy is absorbed by the human body. SAR in biological sensitive organs of humans for 1g and 10 g averaged mass of tissue are shown in Table 3 and 4.

Table3. *The values of SAR averaged on 1 gram in organs*

tissue	SAR_{1g} 0 (W/kg)	SAR_{1g} 1 (W/kg)	SAR_{1g} 2 (W/kg)	SAR_{1g} 3 (W/kg)	SAR_{1g} 4 (W/kg)
brain	21.5	17.90	9.47	7.31	0.354
eye	43.9	39.30	27.80	16.70	0.905
testis	25.1	9.34	12.00	4.63	0.201

Table 4. *The values of SAR averaged on 10 gram in organs*

tissue	$SAR_{10g}0$ (W/kg)	$SAR_{10g}1$ (W/kg)	$SAR_{10g}2$ (W/kg)	$SAR_{10g}3$ (W/kg)	$SAR_{10g}4$ (W/kg)
brain	14.1	12.70	9.41	5.30	0.262
eye	22.3	21.10	15.10	11.40	0.532
testis	19	7.91	9.00	2.10	0.271

Published data consistently indicate that 10g SAR is better correlated with increasing temperature than 1g SAR over a wide range of frequencies and for near and far field exposure [4]. The results of process simulation are given in Fig.2 - Fig.10.

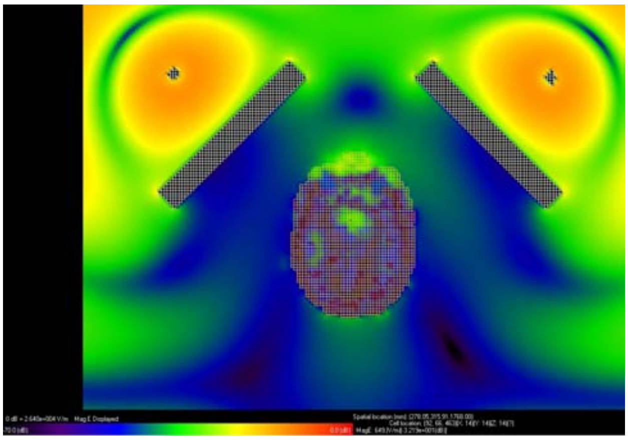


Figure 2 - *Distribution of electric field in brain in position 0*

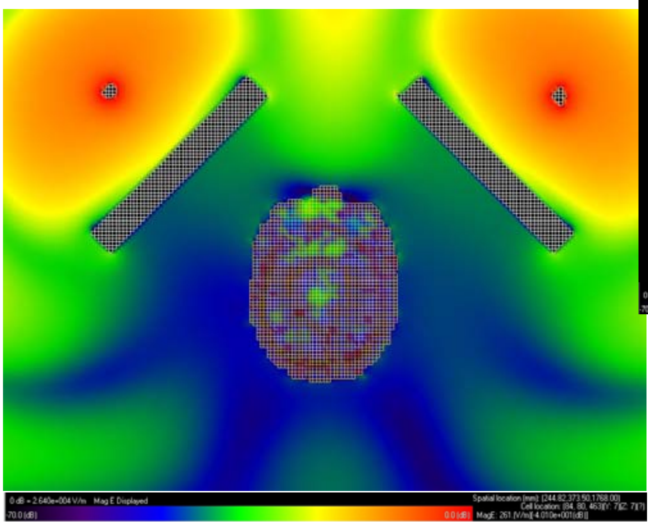


Figure 3. *Distribution of electric field in eyes in position 0*

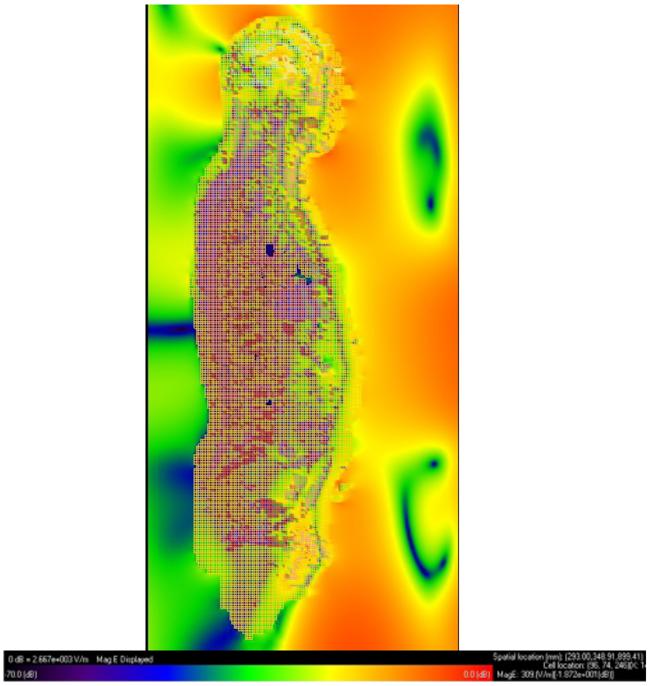


Figure 4. *Distribution of electric field in body in position 0*

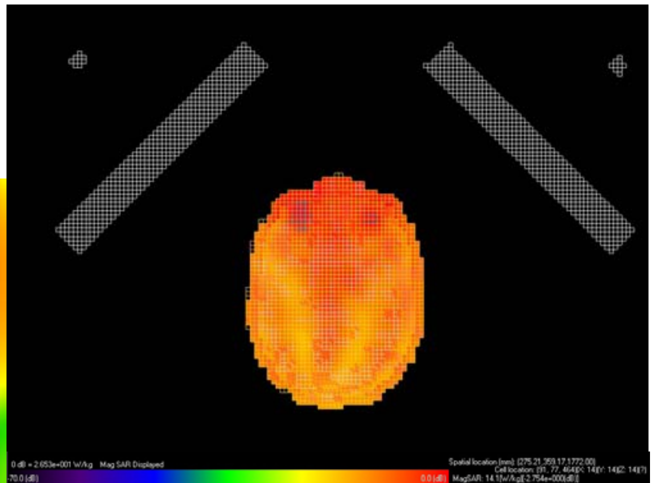


Figure 5. *Distribution of SAR_{10g}, cross section of eyes in position 0*

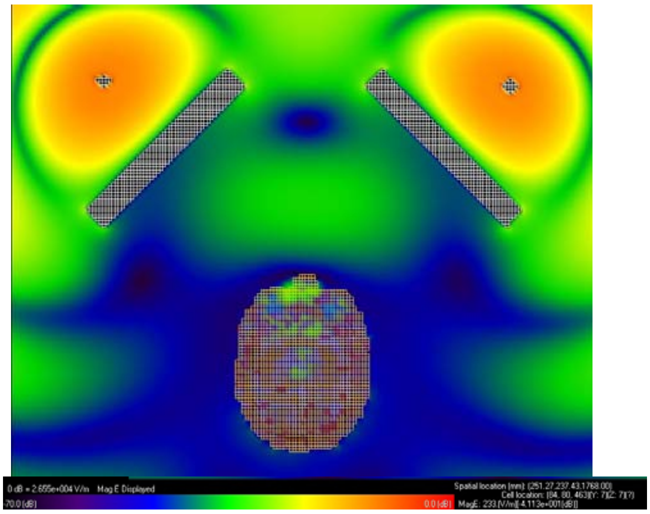


Figure 6. *Distribution of electric field in eyes in position 1*

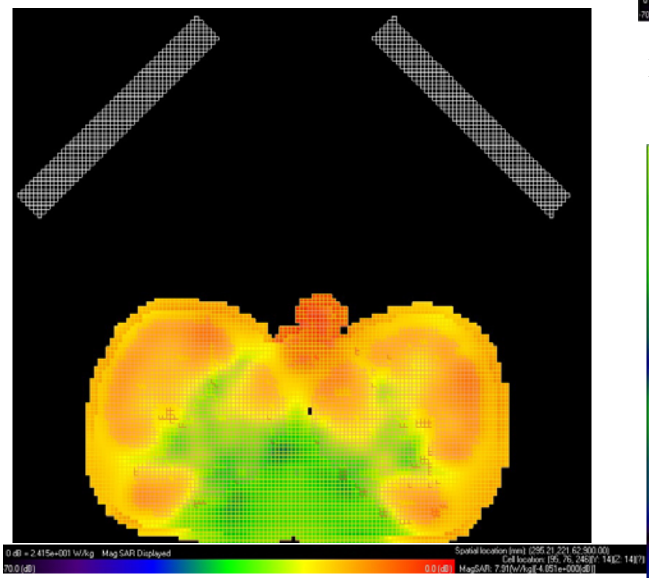


Figure 7. *Distribution of SAR_{10g}, in testis in position 1.*

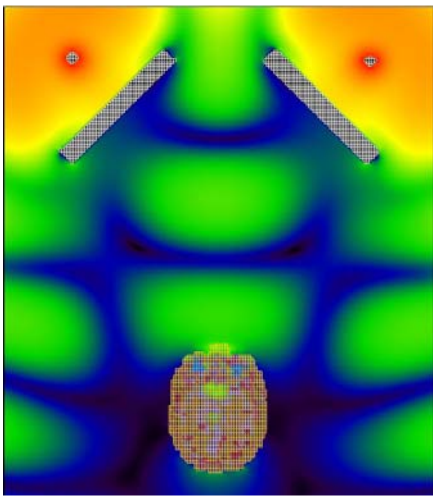


Figure 8. *Distribution of electric field, cross section of eyes in position 2*

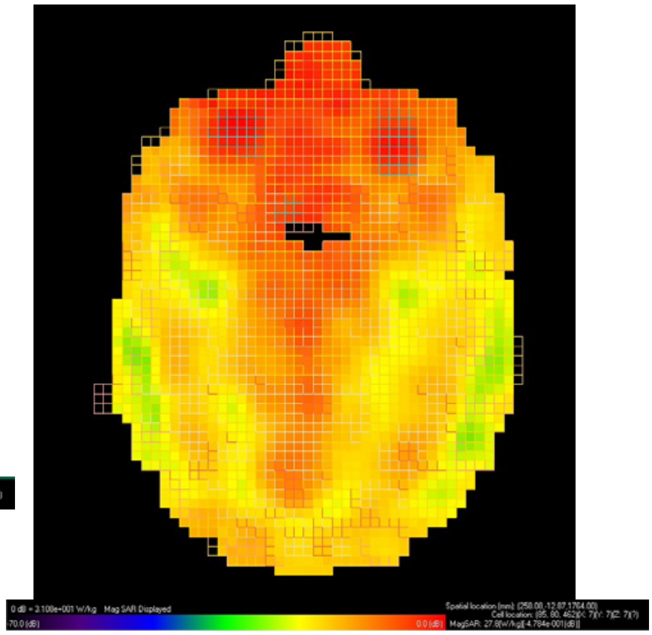


Figure 9. *Distribution of SAR_{10g}, cross section of eyes in position 2*

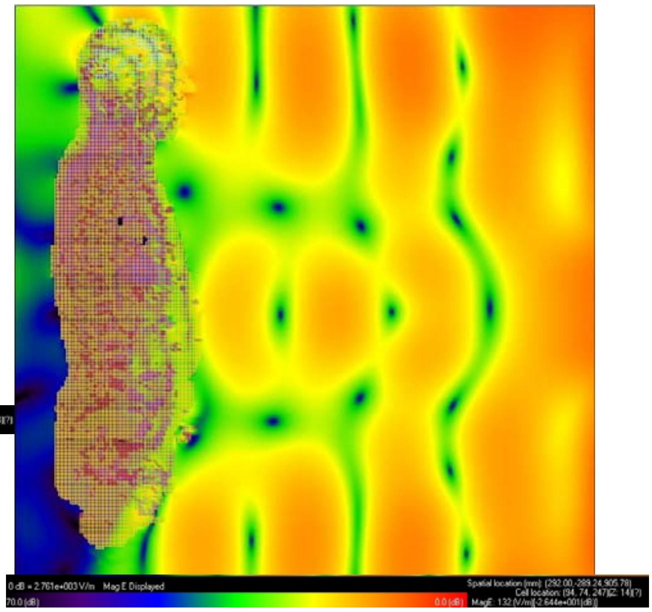


Figure 10. *Distribution of electric field in body in position 3*

DISCUSSION AND CONCLUSION

The aim of the paper is to warn people that working near a base station which is switched on can produce negative health effects. Usually, not much attention is paid to the exposure of service professionals to antenna systems, considering the fact that they are normally switched off. However, everyday practice has shown that they sometimes work close to the antenna systems of other providers. Therefore, such a simulation pointed to the real value of the field intensity and energy that these professionals can absorb if they are exposed.

According to INCNIRP [6] obtained simulation results for brain and testis for whole body averaged SAR and for localized SAR (head and trunk) are higher than limits. National legislation in Serbia for professional exposition has same limiting values [7]. The restriction according to ICNIRP is shown in Table 5.

Table 5. *Occupational exposure for time varying electric and magnetic fields for frequencies according to ICNIRP for mobile phone band GSM 900MHz*

Type of restriction	E-field strength (V/m)	Whole body average SAR (W/kg)	Localized SAR - head and trunk (W/kg)
Basic restriction	-	0.4	10
Reference levels	90	-	-

It may be concluded that the values obtained by simulation indicate increased values of electromagnetic fields and SAR in all examined organs (brain, eye and testis).

By analyzing the results and limits of exposure for this occupational group, the following conclusions can be made:

- Reference levels are exceeded and workers must not work on base station when system is switched on.
- Basic restrictions are exceeded at distance 50cm and lower for head.
- Values for electrical field in other organs point out possible harmful effects on these organs and endanger homeostasis of the whole body.

Detailed discussion of possible health effects from literature on sperm and lens of eye can be found in reference 1. Analyzing the literature data and comparing them to simulation results, degenerative changes may be expected in case of professional exposition. Thus, continuous monitoring of service technicians' health is required by specialists of occupational medicine. In addition, one should insist on strict compliance with the measures of protection implying exclusion of nearby equipment service.

ACKNOWLEDGEMENT

This work was supported by projects III43011 and III43012 of the Ministry of Education and Science of Republic of Serbia.

REFERENCES

[1] Dejan Krstić , Darko Zigar , Nenad N. Cvetković , Goran Ristić, "Numerical Simulation Apsorbed Electromagnetic Field on Service Technicians from Base Station Antenna System", 11th International Conference on Applied Electromagnetics, PES 2013, September 01–04, 2013.

[2] F. Gustrau, D. Manteuffel, *EM Modeling of Antennas and RF Components for Wireless Communication sistems*. Springer, 2006.

[3] Microwave Studio CST, www.cst.com

[4] Visible Human Project, U.S. National Library of Medicine, National Institutes of Health, Available at: http://www.nlm. nih.gov/research/visible/applications.html.

[5] A. Hirata and O. Fujiwara, "The correlation between mass-averaged SAR and temperature elevation in the human head model exposed to RF near-fields from 1 to 6 GHz," Phys Med Biol., vol 54, 2009.

[6] ICNIRP Guidelines for limiting exposure to time varying Electric, Magnetic and Electromagnetic Fields (up to 300 GHz), Health physics 74(4):494-522;1998.

[7] Guidelines and preventive procedures for safety and healthy work during the electromagnetic fields exposure (in Serbian), „Službeni glasnik RS", 117/12.

BIOGRAPHY

Dejan D. Krstić was born in Niš, Serbia, in 1969. He received the degree in Engineering and M.Sc. degrees from the Faculty of Electronic Engineering, University of Niš in 1994 and 1999 respectively. He obtained the 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 research interests are biological effects of electromagnetic radiation, numerical methods for electromagnetic field calculation and safety technical systems. He published 74 papers in international journals or conference proceedings as author and co-author, and seven textbooks.

ODREĐIVANJE ABSORBOVANE ELEKTROMAGNETNE ENERGIJE OD ANTENSKIH SISTEMA BAZNIH STANICA KOD SERVISNIH TEHNIČARA

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

Rezime: *Servisni tehničari na baznim stanicama mobilne telefonije izloženi su bliskom polju elektromagnetnih talasa. U ovoj oblasti, vrednosti električnog i magnetnog polja mogu preći maksimalno dozvoljene vrednosti u odnosu na standarde izloženosti. Predmet ovog rada su rizici po zdravlje servisnih tehničara. Izračunavanje električnog polja u telu servisnog tehničara koji se kreće u blizini bazne stanice je veoma važno za procenu njihovog zdravstvenog stanja.*

Ključne reči: Blisko elektromagnetno polje, servisni tehničari, zdravstveni rizici od elektromagnetnih polja.