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DISTRIBUTION OF THE MAGNETIC FIELD FROM A MOBILE PHONE AT 0.9, 1.8 AND 2.1 GHZ THROUGH A CHILD HEAD MODEL

Abstract: *Children's everyday use of mobile phones exposes them to significant levels of electromagnetic radiation, causing public concern over the potential adverse effects. This paper discusses the magnetic field distribution from a mobile phone at the frequencies of 0.9, 1.8, and 2.1 GHz through a child head model. Human tissues and organs are represented in terms of their corresponding electromagnetic properties. The results of magnetic field distribution for a horizontal cross-section of the child head model at the three given frequencies are presented in the paper.*

Keywords: mobile phone, electromagnetic characteristics of tissues, model of child head, magnetic field

INTRODUCTION

Mobile phones have become ingrained in people's everyday life. Their pervasiveness now goes beyond the mere use for business purposes, as they are also heavily used in the areas of education and entertainment. This phenomenon did not bypass the children, who are now using mobile phones as their new favourite toys. Through daily use, children are being increasingly exposed to electromagnetic radiation (EMR) emitted by mobile phones.

Most studies about the impact of electromagnetic radiation from wireless mobile devices focused on the impact of radiation on adult head models [1-4].

However, recent studies on the impact of electromagnetic radiation from mobile phones on children showed that the radiation exposure of adults differs from that of children and that children are more affected by EMR than adults [5-11].

A number of studies also showed that electromagnetic radiation causes a higher incidence of malignant brain tumours. Consequently, in 2011, the International Agency for Research on Cancer (IARC) proclaimed electromagnetic (EM) fields to be potentially carcinogenic, including them in the 2B group [12].

Since the standards and instructions regarding EM field exposure limits were created based on the research performed on adults, it remains to determine whether the safety limits can also be applied to the exposure of children [13].

This paper uses a child head model to examine the impact of the magnetic field from a mobile phone on children.

In Serbia, the area of EM field safety is regulated by the Law on Protection against Non-Ionizing Radiation [14]. The Law stipulates the conditions and measures for the protection of human health and the environment from the harmful effects of non-ionizing radiation. Additionally, The Rulebook on the Limits of Exposure to Non-Ionizing Radiation [15] defines the basic limitations and reference limit levels of exposure of the population to electric, magnetic, and electromagnetic fields of different frequencies that are regarded as safe for human health.

The majority of the studies concerning the potential harmful effects of electromagnetic radiation on mobile phones users focused on establishing the electric field values of inside the model body and the SAR (Specific Absorption Rate) values [1-10].

The magnetic field distribution through the child head model is calculated for the same horizontal cross-section of the model for three different frequencies – 0.9 GHz, 1.8 GHz, and 2.1 GHz.

According to the Serbian Rulebook, the magnetic field reference limit for the 0.9 GHz frequency is 0.044 A/m, for the 1.8 GHz frequency 0.063 A/m, and for 2.1 GHz it is 0.064 A/m [15].

CHILD HEAD MODELLING

A child head numerical model was developed for the purpose of this paper using 3ds Max, a specialized software package for 3D design [16]. The model corresponds to a 7-year-old child's head [5-7, 11] and realistically replicates its anatomical structure and properties. It consists of the following tissues and organs: the skin, the fatty tissue, the muscles, the skull, the jaw including teeth, the tongue, the eyes, the vertebrae, the cartilage, the spinal cord, cerebrospinal fluid, the brain, and the pituitary gland.

The tissues and organs need to be described in terms of their corresponding electromagnetic parameters, such as electric conductivity, permittivity, and density (Tables 1, 2, and 3).

The radiation source is represented by a numerical model of a smart phone [6]. The antenna was modelled for the frequencies of 0.9 GHz, 1.8 GHz, and 2.1 GHz.

Table 1. *Electromagnetic properties of tissues and organs at f=0.9 GHz [17]*

Tissues	ε_r	σ (S/m)	ρ (kg/m^3)
1. Cortical Bones	12.45	0.143	1908
2. Brain[a]	45.81	0.767	1046
3. Cerebrospinal Fluid	68.60	2.410	1007
4. Fat	11.30	0.109	911
5. Cartilage	42.70	0.782	1100
6. Pituitary Gland	59.70	1.040	1053
7. Spinal Cord	32.50	0.574	1075
8. Muscle	55.00	0.943	1090
9. Eyes	49.60	0.994	1052
10. Skin	41.40	0.867	1109
11. Tongue	55.30	0.936	1090
12. Teeth	12.50	0.143	2180

[a] Electromagnetic properties defined as the average value.

Table 2. *Electromagnetic properties of tissues and organs at f=1.8 GHz [17]*

Tissues	ε_r	σ (S/m)	ρ (kg/m^3)
1. Cortical Bones	11.8	0.275	1908
2. Brain[a]	46.1	1.710	1046
3. Cerebrospinal Fluid	67.2	2.920	1007
4. Fat	11.0	0.190	911
5. Cartilage	40.2	1.290	1100
6. Pituitary Gland	58.1	1.500	1053
7. Spinal Cord	30.9	0.843	1075
8. Muscle	53.5	1.340	1090
9. Eyes	46.3	1.369	1052
10. Skin	38.9	1.180	1109
11. Tongue	53.6	1.370	1090
12. Teeth	11.8	0.275	2180

[a] Electromagnetic properties defined as the average value.

Table 3. *Electromagnetic properties of tissues and organs at f=2.1 GHz [17]*

Tissues	ε_r	σ (S/m)	ρ (kg/m^3)
1. Cortical Bones	11.60	0.328	1908
2. Brain[a]	45.50	1.880	1046
3. Cerebrospinal Fluid	66.80	3.150	1007
4. Fat	10.90	0.224	911
5. Cartilage	39.50	1.490	1100
6. Pituitary Gland	57.70	1.700	1053
7. Spinal Cord	30.50	0.951	1075
8. Muscle	53.20	1.510	1090
9. Eyes	47.88	1.530	1052
10. Skin	38.40	1.310	1109
11. Tongue	53.10	1.560	1090
12. Teeth	11.60	0.328	2180

[a] Electromagnetic properties defined as the average value.

RESULTS

The magnetic field distribution inside the child head model was calculated using the finite element method, with the help of CST Microwave Studio software package [18].

The analysis was performed for the phone position during its use for standard voice communication.

Figure 1 shows the horizontal cross-section of the child head model with directions A_1, A_2, A_3, along which the magnetic field intensity distribution was analyzed.

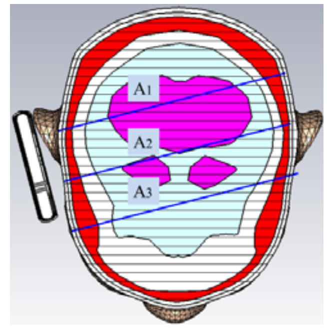

Figure 1. *Cross-section and directions A_1, A_2, and A_3 for the assessment of results*

Figures 2, 3, and 4 show the dependence of magnetic field intensity on the distance along the directions shown in Figure 1, for the frequencies of 0.9 GHz, 1.8 GHz, and 2.1 GHz.

The results correspond to a reference power of P = 1 W of the source of radiation [19].

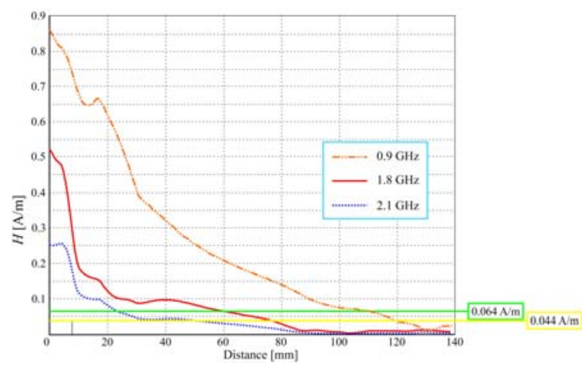

Figure 2. H[A/m] *distribution along direction A_1 at 0.9, 1.8, and 2.1 GHz*

According to Figure 2, the reference limits are exceeded along the direction A_1 for all three frequencies. The maximum value for magnetic field intensity at 0.9 GHz is almost 20 times higher than the reference limit, at 1.8 GHz it is almost 8 times higher than the reference limit, whereas at 2.1 GHz it is about 4 times higher.

At 0.9 GHZ, values higher than the reference limit are present up to a distance of 120 mm in the skin, the fatty tissue, the head muscles, the skull, the CSF, and the brain.

At 1.8 GHZ, values higher than the reference limit are present up to a distance of 60 mm in the skin, the fatty tissue, the head muscles, the skull, the CSF, and the brain.

At 2.1 GHz, values higher than the reference limit are present up to a distance of 24 mm in the skin, the fatty tissue, the head muscles, the skull, and the CSF.

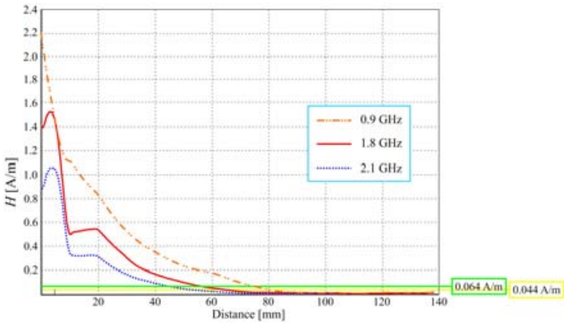

Figure 3. $H\left[\text{A/m}\right]$ *distribution along direction* A_2 *at 0.9, 1.8 and 2.1 GHz*

According to Figure 3, the reference limits are also exceeded along the direction A_2. In this case, the maximum value for magnetic field intensity at 0.9 GHz is almost 50 times higher than the reference limit, at 1.8 GHz it is almost 20 times higher than the reference limit, whereas at 2.1 GHz it is almost 16 times higher.

At 0.9 GHZ, values higher than the reference limit are present up to a distance of 80 mm; at 1.8 GHZ, values higher than the reference limit are present up to a distance of 55 mm and at 2.1 GHz they are present up to a distance of 44 mm. The reference limits for all three frequencies were exceeded in the skin, the fatty tissue, the head muscles, the skull, the CSF, and the brain.

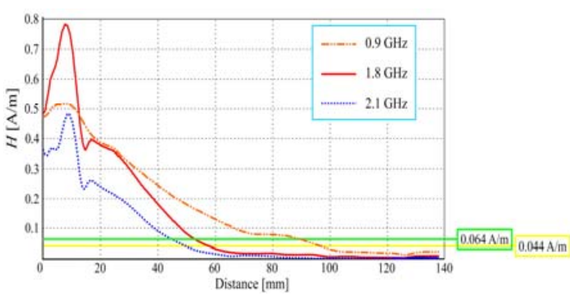

Figure 4. $H\left[\text{A/m}\right]$ *distribution along direction* A_3 *at 0.9, 1.8, and 2.1 GHz*

As with the previous two directions, the reference limits for multiple tissues and organs were also exceeded along the direction A_3 at all three frequencies (Fig. 4). The maximum value for magnetic field intensity at both 0.9 GHz and 1.8 GHz is almost 12 times higher than the reference limit, while at 2.1 GHz it is about 7.5 times higher.

At 0.9 GHZ, values higher than the reference limit are present up to a distance of 96 mm, at 1.8 GHZ, they are present up to a distance of 53 mm, and at 2.1 GHz they are present up to a distance of 44 mm. The reference limits for all three frequencies were exceeded in the skin, the fatty tissue, the head muscles, the skull, the CSF, and the brain.

CONCLUSION

This paper analyzed and discussed the distribution of the magnetic field, an integral part of the electromagnetic field emitted by mobile phones, through a numerical child head model at the frequencies of 0.9 GHz, 1.8 GHz, and 2.1 GHz. A model of a modern smart phone containing a PIFA antenna, a casing, and a display served as the source of electromagnetic radiation.

The magnetic field distribution in the child head model was analyzed for three different directions within the same horizontal cross-section. The position of the considered cross-section was chosen according to the mobile phone's radiating element, so the high field values were to be expected.

The analysis of the obtained values for magnetic field intensity showed that the calculated values exceeded the reference limits for all three frequencies and all three directions up to a certain distance through various tissues/organs. At the carrier frequency of 0.9 GHz, the obtained magnetic field intensity values were almost 50 times higher than the reference levels. At the same frequency, for all the analyzed directions in cross-section A, the areas displaying increased magnetic field intensity values included the skin, the fatty tissue, the head muscles, the skull, the CSF, and the brain.

At the carrier frequency of 1.8 GHz, the obtained magnetic field intensity values were almost 24 times higher than the reference levels. At the same frequency, for all the analyzed directions in cross-section A, the areas displaying increased magnetic field intensity values included the skin, the fatty tissue, the head muscles, the skull, the CSF, and the brain.

Likewise, at the carrier frequency of 2.1 GHz, the obtained magnetic field intensity values were also very high – about 11 times higher than the reference limits. At this frequency, for the analyzed direction A_1, the areas displaying increased magnetic field intensity values included the skin, the fatty tissue, the head muscles, the skull, and the CSF; for directions A_2 and A_3, the areas with increased magnetic field intensity also included the brain.

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Vladimir B. STANKOVIĆ was born in Niš, Republic of Serbia, in 1978. He received a B.Eng. in electronic engineering and a Ph.D. degree from the University of Niš, Faculty of Electronic Engineering, Department of Telecommunications. His main area of research involves electromagnetic radiation. He is employed at the Faculty of Occupational Safety in Niš as an assistant professor.

RASPODELA MAGNETNOG POLJA U MODELU GLAVE DETETA OD MOBILNOG TELEFONA NA 0.9, 1.8 I 2.1 GHz

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Apstrakt: Svakodnevna upotrebe bežičnih uređaja, pre svega mobilnih telefona, izazvala je veliku zabrinutost kod javnosti zbog mogućih štetnih efekata elektromagnetnog zračenja kojim su izloženi korisnici ovih uređaja, prevashodno deca. Ovaj rad sumira navike korišćenja mobilnih telefona kod dece i tinejdžera i vezu sa mogućim štetnim biološkim efektima elektromagnetnog zračenja ovih uređaja. Opisan je postupak kreiranja modela glave odraslih osoba i dece koji se koriste za numerički proračun prodrlog elektromagnetnog polja i apsorbovane energije. Kako se ljudsko telo sastoji od više različitih tkiva i organa, svaki od njih je neophodno opisati odgovarajućim elektromagnetnim karakteristikama.

Svakodnevna upotreba mobilnih telefona od strane dece značajno je uvećala njihovu izloženost elektromagnetnom zračenju. To je dovelo do zabrinutosti javnosti zbog potencijalnih štetnih efekata elektromagnetnog zračenja. Ovaj rad prikazuje raspodelu magnetnog polja u modelu glave deteta od mobilnog telefona koji radi na frekvencijama 0.9, 1.8 i 2.1 GHz. Ljudska tkiva i organi su predstavljeni u skladu sa njihovim odgovarajućim elektromagnetnim osobinama. U radu su predstavljeni rezultati raspodele magnetnog polja za horizontalni presek modela glave deteta na sve tri frekvencije.

Ključne reči: mobilni telefon, elektromagnetne karakteristike tkiva, model glave deteta, magnetno polje