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Abstract

Background/Aim. This paper investigates the influence of electromagnetic field on the pituitary gland of the child from mobile phone. Electric field distribution in child head and values of Specific Absorption Rate (SAR) at the region of pituitary gland has been determined. This study was performed for the frequencies of 900 MHz, 1800MHz and 2100 MHz, which are most common used in mobile communications. The special attention is dedicated to the values of the electric field and the values of the SAR in the pituitary gland. **Methods.** In this study for all frequencies the 10g and 1g average SAR have been calculated. In order to obtain the more accurate results for this research 3D realistic model of child head whose size corresponds to an average child (7 years old) had to be created. The electric field distribution and values of average SAR over 10g and 1g through the model of child head, were obtained by the using numerical calculation based on the Finite Integration Technique (FIT). **Results.** The results discover where the maximum values of electric field and absorbed energy are, how the field penetrates, and how much the electric field strength decrease with the distance from the radiation source. The largest value of electric field in the region of the pituitary gland is at the frequency of 900MHz. This is a consequence of the highest penetration depth. Lower values of the electric field in the region of the pituitary gland are in case of frequencies 1800MHz and 2100MHz. As the electromagnetic characteristics of tissues depend on the frequency of electromagnetic waves and value for SAR will be different for different tissues and organs. The SAR in the pituitary gland decrease as the frequency increases as a direct consequence of lower penetration depth. **Conclusion.** The electric field strength from a mobile phone is higher than the value specified by standards for the maximum allowable exposure limits. The high values of electric field are not only in the vicinity of a mobile phone, but also in tissues and

organs of the human head. Particular attention should be paid to the exposure of children to radiation of mobile phones. Smaller dimensions of children's head and smaller thickness of tissues and organs have as a consequence greater penetration of electromagnetic waves.

Key words:

electric field, mobile phone, child, pituitary gland, specific absorption rate

Apstrakt

Uvod/Cilj. Ovaj rad istražuje uticaj električnog polja mobilnog telefona kao izvora elektromagnetnog zračenja na hipofizu deteta. Određena je raspodela električnog polja unutar glave deteta i vrednosti specifične količine apsorbirane energije (SAR) u predelu hipofize. Ovo istraživanje je izvršeno za frekvenciju od 900MHz, 1800MHz i frekvenciju od 2100MHz jer su ovo najčešće korišćene frekvencije u mobilnom komunikacionom sistemu. Posebna pažnja je posvećena vrednosti električnog polja i vrednosti SAR-a u hipofizi. **Metode.** U ovoj studiji za sve prethodno pomenute frekvencije je proračunat usrednjeni SAR za 10g i 1g. U cilju dobijanja što tačnijih rezultata bilo je neophodno napraviti realan 3D model glave deteta čije dimenzije odgovaraju dimenzijama deteta od 7 godina. Raspodela električnog polja i vrednosti usrednjenog SAR-a za 10g i 1g su dobijene korišćenjem numeričkog metoda koji je zasnovan na tehnici konačnih integrala (FIT). **Rezultati.** Rezultati pokazuju gde je maksimalna vrednost električnog polja i apsorbirane energije, koliko je prodiranje električnog polja i koliko jačina polja opada sa povećanjem rastojanja od izvora elektromagnetnog zračenja. Najveća vrednost električnog polja u hipofizi je na frekvenciji od 900MHz. Ovo je posledica veće dubine prodiranja. Za frekvencije od 1800MHz i 2100MHz vrednosti električnog polja u hipofizi su manje. Kako elektromagnetne karakteristike tkiva zavise od frekvencije elektromagnetnog talasa i vrednosti za SAR će biti različite za različita tkiva i organe. Vrednosti za SAR u hipofizi se smanjuju kako frekvencija raste što je direktna posledica manje dubine prodiranja. **Zaključak.** Vrednosti električnog polja koje su posledica zračenja mobilnog telefona su veće od maksimalnih graničnih vrednosti koje su propisane standardima. Velike vrednosti električnog polja nisu samo u okolini telefona, već i u organima i tkivima ljudske

glave. Posebnu pažnju treba obratiti na izlaganje dece zračenju mobilnih telefona. Manje dimenzije dečije glave kao i manja debljina tkiva i organa kao za posledicu ima veću dubinu prodiranja elektromagnetnih talasa.

Ključne reči:

električno polje, mobilni telefon, dete, hipofiza, specifična brzina apsorpcije

Introduction

The wide variety of available option of mobile phone such as games, internet, calls and video calls, as well as their accessible prices, has led to the daily use of mobile phones mostly in younger population (children) which can be measured in hours. The mobile phone is source of electromagnetic radiation which is located close to the head and because of that the intense use of mobile phones in younger population causes concern for health effects.

The influence of electromagnetic field from source of electromagnetic radiation (mobile phone) close to child head is bigger than influence on adult head. This is due to of smaller dimension of child head and consequently thinner pinnae and skulls. Because of this in case of child head, source of electromagnetic radiation is closer to the brain and pituitary gland than in case of adult head. Relevant data shows that the exposure of children is higher than adult exposure^{1, 2}

Because of ethical considerations, human exposure to electromagnetic fields in experimental purposes is limited. Due to this reason is much more convenient to develop a realistic model of the human head by using numerical simulation³. Numerical analyses of human head exposed to electromagnetic radiation of mobile phones provide useful information about absorbed electromagnetic energy under different conditions of exposure. The International Agency for Research Cancer (IARC) has classified the radiation of electromagnetic fields in 2B group and thus are classified as possibly carcinogenic to human, based on an increased risk of a malignant type of brain cancer. In this category

there is limited evidence of carcinogenicity in humans and less than sufficient evidence of carcinogenicity in experimental animals ⁴.

The most important indicator when considering the health risk as a result of the effect of electromagnetic fields is the Specific Absorption Rate (SAR). SAR is directly dependent on the electromagnetic properties of biological tissues exposed to the effects of electromagnetic waves and can be defined as:

$$SAR = \frac{\sigma |E|^2}{\rho} \quad (1)$$

where E is the maximum value of the internal electric field, σ is the conductivity of the tissue and ρ is density of the tissue. Maximum values of SAR which must not exceed, are defined in Regulation of the limits of exposure to non-ionizing radiation, Official Gazette of RS, no. 36/09. This regulation defines the limits of exposure to non-ionizing radiation, or the basic restrictions and reference boundary levels of the population exposure to electric, magnetic and electromagnetic fields of different frequencies ⁵.

In this research the level of electric field strength due to mobile phone and SAR values at the region of pituitary gland have been determined.

The pituitary is a small gland which has a diameter of around 1cm and a weight of about 0.5-1g, and it is located at the base of the brain. Physiologically it can be divided into two parts: the front part called the adenohypophysis and the rear part called neurohypophysis. Adenohypophysis secretes six very important hormones, which have a very significant role in the control of metabolic functions of the whole organism such as: Prolactin, Growth hormone (GH), Adrenocorticotrophic hormone (ACTH), Thyroid-stimulating hormone (TSH), Luteinizing hormone (LH), Follicle-stimulating hormone (FSH). The main role of rear part or neurohypophysis is to store Antidiuretic hormone (ADH) and Oxytocin. The hormones from the hypothalamus almost completely regulate the secretion of pituitary hormones which is delivered through the bloodstream to the pituitary gland.

A certain group of researchers was found the effect of exposure to 900 MHz GSM RF on pituitary hormone levels in healthy males such as: Thyroid-stimulating hormone, growth hormone, prolactin and adrenocorticotropin. This study showed that the concentrations of growth hormone and cortisol hormone were significant decreases of about 28% and 12%, respectively ⁶.

Due to higher level of electromagnetic radiation within the child's head than the level found inside adult's head, electric field can be one of the causes of serious biological effects on the pituitary gland. Because of harmful effect previously mentioned on the pituitary gland and consequently on the concentrations of growth hormone which is essential for normal growth of the child, in this paper special attention is devoted on numerical calculation and distribution of electrical field and SAR in region of this gland for 7-years old child. Also in this study an overview of the possible biological effects that may occur in pituitary gland due to exposure to electromagnetic fields is represented.

Methods

In order to obtain the more accurate results for this research 3D realistic model of child head whose size corresponds to an average child (7 years old) had to be created^{7,8}. This model of child head consists of following tissues and organs: skin, fat, muscle, skull, jaw with teeth, tongue, eyes, vertebrae, cartilage, spinal cord, cerebrospinal fluid, brain, and pituitary gland.

The all of this tissues and organs has to be described by adequate electromagnetic parameters such as electric conductivity, permittivity, heat capacity, density and thermal conductivity⁹.

These electromagnetic characteristics vary with frequency and their values for the previously mentioned frequencies (900MHz, 1800MHz and 2100MHz) are shown in Table 1, Table 2 and Table 3 respectively.

Modeling of 3D child head model was performed in two stages. First external look for every tissues and organs was created in 3D Max Studio¹⁰. The second step was creating full model with actual tissues and organs and connecting certain electromagnetic properties with adequately tissues and organs by using software package CST Microwave Studio¹¹. The same software has been used for simulation of electromagnetic field and its influence

on child head. Numerical calculation method which is used in this software is based on the Finite Integration Technique¹².

External look, horizontal and vertical cross-section with actual tissues and organs are shown in Fig.1 and Fig.2 with numbered organs according to number in previously tables for electromagnetic parameters.

In this study actual smart phone (Fig. 1) has been used as a source of electromagnetic radiation. The current mobile phone consists of following parts: planar inverted F antenna (PIFA), display and mobile housing. The planar inverted F antenna (PIFA) as a source of electromagnetic radiation was modeled for three different frequencies: 900MHz, 1800MHz and 2100MHz, with reference power of $P=1W$ ¹³ and impedance of $Z=50\Omega$.

Numerical calculation has been performed for open space e.g. reflected electromagnetic waves and the other sources of electromagnetic radiation are not taken in consideration. The only source of electromagnetic radiation in this simulation is mobile phone with output power of 1W, defined according to Standard IEEE C.95.3¹³. The accuracy of results depends of model construction.

Results

Electric Field Distribution

In this section electric field distribution within child head model will be presented. The additional attenuation will be dedicated on electric field values in middle pituitary gland horizontal cross-section which is normal on front of source of electromagnetic radiation (mobile phone). Also electric field strength in accordance with distance from source of electromagnetic radiation will be shown.

Electric field distribution was investigated for different frequencies of mobile phone as before mentioned and shown in following figures.

If we compared previously pictures of electric field distribution Fig. 3, 4, 5 it can be concluded that the penetration depth of electric field is the largest in the case of electric field at the frequencies of 900MHz. This is expected because the penetration depth of electric field at the higher frequencies is smaller, which results in a stronger electric field in the tissues that are close to the source of electromagnetic radiation (mobile phone). Also

the wavelength of electromagnetic waves has impact on penetration depth because it varies for different frequencies and it has to be taken in to consideration fact that electromagnetic properties are different for different biological tissues¹⁴.

This causes the different values of the electric field as can be seen by comparing the curves in the Fig. 6 where the peak of electric field at the frequencies of 2100MHz is less than peak of electric field at the frequencies of 1800MHz.

The most significant are the values of the electric field in the region of the pituitary gland, which is the one of the most important gland in the endocrine system. Values of electric field in the region of the pituitary gland can be seen from the Fig. 6 it can be concluded the largest values are at the frequency of 900MHz and amounts 5.6615V/m. This is a consequence of the highest penetration depth as mentioned before. Lower values of the electric field in the region of the pituitary gland are in case of frequencies $f=1800\text{MHz}$ and $f=2100\text{MHz}$ which can be seen from the same figure. The values of those electric fields for $f=1800\text{MHz}$ and $f=2100\text{MHz}$ as shown in Fig. 7 are 0.8643V/m and 0.3045V/m, respectively.

Specific Absorption Rate

Generally the one part of the energy due to propagation of electromagnetic waves penetrates in to certain biological object and it is being absorbed. Differences wave energy at the boundaries of a biological object (the input energy and output energy) represents the absorbed energy. Because of the need that this absorbed energy was introduced precisely it has been defined the term Specific Absorption Rate (SAR).

The values of the SAR are different for different tissues and electromagnetic waves of different characteristics, in this case different frequencies. It can be said that the SAR characterizes the interaction of electromagnetic fields with biological tissue. The SAR is related to a certain point that is an extremely small area in a biological tissue in which the electromagnetic field can be considered a homogenous. More practical value is averaged SAR as the ratio of the absorbed power in the body and the body mass of biological entity.

For this research values for the averaged SAR over 10g and 1g has been calculated. Because of different frequencies the values of SAR varies and all those values for each of frequencies will be shown on following figures.

On the figure 14 and 15 is a comparative analysis of SAR values averaged over 1g and 10g for all three frequencies respectively. The differences in SAR values in the region of the pituitary gland can be clearly defined with those graphics.

As previously stated, in order to determine the impact of electromagnetic radiation on biological tissue, in this case on the pituitary gland, term Specific Absorption Rate (SAR) has to be introduced. Based on the Eq. 1 and according to values of electric fields shown in the figures 3, 4, 5, 6 can be expected that peak of SAR will be the highest in the case of a frequency $f=1800\text{MHz}$. Because the penetration depth of electric field is the largest in case of a frequency $f=900\text{MHz}$ (Fig. 6), SAR value in the region of the pituitary gland will be the highest for this frequency and amounts $\text{SAR}_{1\text{g}} = 0.08521 \text{ [W/kg]}$ and $\text{SAR}_{10\text{g}} = 0.10325 \text{ [W/kg]}$ (Fig. 14 and Fig. 15).

The results obtained in this paper are compared with results obtained in the other study¹⁵. After comparison it can be concluded that the value of SAR in region of pituitary gland for realistic model (child model), used in this research, is greater than SAR in model (adult person) with few layers in the other study. The SAR in case of child model is almost five times greater than results in case of adult model. This is expected due to different construction of model: size of model, different thickness of layers and therefore the pituitary gland at greater distances from the source in case of adult person.

Discussion

There are many differences among different countries in Europe in terms of upper limits for RF radiation from GSM mobile telephony. Based on Recommendation 1999/519/EC, the limit values which are prescribed for the electric field strength for the following frequencies: 900MHz, 1800MHz and 2100 MHz, are 41V/m, 58V/m and 61V/m, respectively¹⁶. The certain European governments have adopted lower values such as for example Greece (32V/m, 45V/m and 47V/m), Belgium (21V/m, 29V/m and 31V/m), Serbia (16.5V/m, 23.3V/m and 24.4V/m), Slovenia (13V/m, 18V/m and 19V/m), Poland (7V/m, 7V/m and 7V/m), Italy (6V/m, 6V/m and 6V/m), Switzerland (4V/m, 6V/m and 6V/m), etc. for all three frequencies respectively¹⁷.

The values for the maximum field strength that are prescribed by the standard are given for free space in the absence of people. We have to keep in mind that the values for field strength inside the biological tissues or organs are lower because of propagation through the material environment and due to the increasing distance from the radiation source.

If the value of the field is known inside biological tissue than, based on the boundary conditions at the surface of the two separate areas, the value of the incident field can be evaluated. Since the value of the electric field in the pituitary gland is known, based on the relationship that is valid for the normal vector components of the electric field at the separate area, the value of the field before the penetration of EM waves in the pituitary gland can be determined.

Based on the value of the dielectric constant and conductivity of air and pituitary gland for different frequencies, the ratio of electric fields strengths at the separate surface of these two areas can be approximately determined. This is certainly the worst case, from the stand point of the electric field strength, because in this case it does not take into consideration the impact of other layers on the weakening of electromagnetic wave that spreads from the radiation source. However, this approach can give us information about the minimum field strength to which man is exposed, and if it is greater than allowed.

The ratio of normal vector components of electric field at the crossover semiconductor environment is determined from the expression

$$\frac{\underline{E}_1}{\underline{E}_2} = \frac{\sigma_2 + j\omega\epsilon_2}{\sigma_1 + j\omega\epsilon_1} \quad (2)$$

For different frequencies and the corresponding values for the dielectric constant and conductivity of the air and the pituitary gland, the ratio of the normal components of the electric field for these two environments is calculated by using previously formula (2) and results are:

$$\left| \underline{E}_{\text{air}} / \underline{E}_{\text{p. gland}} \right|_{f=0.9\text{GHz}} \approx 63, \left| \underline{E}_{\text{air}} / \underline{E}_{\text{p. gland}} \right|_{f=1.8\text{GHz}} \approx 60 \text{ i } \left| \underline{E}_{\text{air}} / \underline{E}_{\text{p. gland}} \right|_{f=2.1\text{GHz}} \approx 59.5.$$

Based on the previously obtained values for the electric field strength in the pituitary gland, the values of the electric field strength in the air are:

$$\underline{E}_{\text{air}}|_{f=0.9\text{GHz}} \approx 356.67 \text{ V/m}, \underline{E}_{\text{air}}|_{f=1.8\text{GHz}} \approx 51.86 \text{ V/m i } \underline{E}_{\text{air}}|_{f=2.1\text{GHz}} \approx 18.12 \text{ V/m}.$$

If we compared this value with the maximum permissible values specified in the above mentioned countries, we can conclude that they are considerably higher or in range

with the maximum allowable values. Of course, if we take into account the impact of all other layers between the radiation source and pituitary glands obtained values would have been far greater.

Biological Effects

Pituitary gland as one of the most important gland of the endocrine system, via adrenocorticotrophic hormone has an impact on the cortex of the adrenal gland. In this way it stimulates the secretion of steroid hormones. For this reason in this chapter all the potential biological effects on the pituitary gland from exposure to radiation of mobile phone will be represented.

In some earlier research, it was found that in the case of rats, which were exposed to mobile phone radiation, that plasma steroid levels in rats are significantly increased. These plasma steroid levels were above certain levels for which thresholds have been reasonably accurately determined. Later investigations revealed that stimulation of the adrenal axis due to electromagnetic radiation from mobile phone in case of experimental rats was usually a systemic process as a consequence of general hyperthermia. However, in experiments with rats those were exposed to high levels of electric fields, it was found to stimulate the Hypothalamic Hypophyseal-Adrenocortical (HHA) axis, and this was caused by the central nervous system (CNS) ¹⁸.

Another very important function of the pituitary gland is that it secretes gonadotropins FSH and LH that regulate testicular spermatogenesis and steroidogenesis. The impact of mobile phone radiation on gonadotropins level it has been considered in case of man and animals. The results of some previous studies have shown that mobile phone radiation cannot cause significant biological effects. But there is a possibility that the time of exposure to radiation from mobile phone in these studies was not long enough to show up some significant biological effects.

In case of research conducted by Fang showed progressive histological derangement in rats' pituitary glands. These derangements are manifested in the form of swollen mitochondria as well as dilatation of Golgi complex and diffusive lysosomes. Also this research revealed that with increasing duration of exposure and electromagnetic wave energy this disorder increase. For instance it has been observed also and mitochondrial vacuolization, formation of myelin figures, distinct dilatation of endoplasmic reticulum,

occurrence of numerous secondary lysosomes, and clustering of heterochromatin under the nuclear membranes¹⁹.

In the particular study it was shown that people who long period of time living in the vicinity of base stations have a significant reduction in the release into the blood of a number of hormones, including adrenocorticotrophic hormone which is produced and secreted by the anterior pituitary gland²⁰. It was also found the high significant decrease of serum cortisol levels for people exposed to electromagnetic radiation.

Conclusion

Based on the obtained results it can be concluded that the penetration depth of electric field is the largest in the case of electric field at the frequencies of 900MHz. This is expected because the penetration depth of electric field at the higher frequencies is smaller, which results in a stronger electric field in the tissues that are close to the source of electromagnetic radiation (mobile phone).

Results obtained by numerical analysis and shown in previously figures show that the greatest impact on the pituitary gland is in case of electric field at the frequency of $f=900\text{MHz}$. This is a consequence of the highest penetration depth as mentioned before.

Particularly, attention should be paid to the fact that the electric field strength from a mobile phone is significantly higher than the value specified by standards for the maximum allowable exposure limits. The high values of electric field are not only in the vicinity of a mobile phone, but also in tissues and organs of the human head. Particularly, attention should be paid to these values in the case of children. Smaller dimensions in case of children's head and therefore smaller thickness of tissues and organs than in adults have as a consequence greater penetration of electromagnetic waves through the head and greater accumulation of electromagnetic waves.

It should be noted that if we take into account the impact of all other layers between the radiation source and pituitary glands obtained values would have been far greater than previously obtained values and because of the fact that the level of electrical field strength inside pituitary gland in this study, is higher than the values for the maximum field strength that are prescribed by the standard, it should be noted that this level of radiation may cause substantial damage in certain biological tissues and organs.

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“Calculation of Electromagnetic Field from Mobile Phone Induced in the Pituitary Gland of Children Head Model”

Table 1

Electromagnetic properties of tissues and organs at $f=900\text{MHz}$ ⁸

900 MHz		ϵ_r	σ (S/m)	ρ (kg/m ³)	Heat Capacity (kJ/kgK)	Thermal conductivity (W/m°C)
1.	Cortical Bones	12,45	0,143	1908	1,313	0,32
2.	Brain*	45,805	0,7665	1046	3,630	0,51
3.	Cerebrospinal Fluid	68,60	2,410	1007	4,096	0,57
4.	Fat	11,30	0,109	911	2,348	0,21
5.	Cartilage	42,70	0,782	1100	3,568	0,49
6.	Pituitary Gland	59,70	1,040	1053	3,687	0,51
7.	Spinal Cord	32,50	0,574	1075	3,630	0,51
8.	Muscle	55,00	0,943	1090	3,421	0,49
9.	Eyes*	49,60	0,994	1052	3,615	0,53
10.	Skin	41,40	0,867	1109	3,391	0,37
11.	Tongue	55,30	0,936	1090	3,421	0,49
12.	Teeth	12,50	0,143	2180	1,255	0,59

* Electromagnetic characteristic of those organs were defined as average value.

ϵ_r - permittivity, σ - electric conductivity, ρ - density

Table 2

Electromagnetic properties of tissues and organs at $f=1800\text{MHz}$ ⁸

1800 MHz		ϵ_r	σ (S/m)	ρ (kg/m ³)	Heat Capacity (kJ/kgK)	Thermal conductivity (W/m°C)
1.	Cortical Bones	11,8	0,275	1908	1,313	0,32
2.	Brain*	46,1	1,710	1046	3,630	0,51
3.	Cerebrospinal Fluid	67,2	2,920	1007	4,096	0,57
4.	Fat	11,0	0,190	911	2,348	0,21
5.	Cartilage	40,2	1,290	1100	3,568	0,49
6.	Pituitary Gland	58,1	1,500	1053	3,687	0,51
7.	Spinal Cord	30,9	0,843	1075	3,630	0,51
8.	Muscle	53,5	1,340	1090	3,421	0,49
9.	Eyes*	46,3	1,369	1052	3,100	0,50
10.	Skin	38,9	1,180	1109	3,391	0,37
11.	Tongue	53,6	1,370	1090	3,421	0,49
12.	Teeth	11,8	0,275	2180	1,255	0,59

* Electromagnetic characteristic of those organs were defined as average value.

ϵ_r - permittivity, σ - electric conductivity, ρ - density

Table 3

Electromagnetic properties of tissues and organs at $f=2100\text{MHz}$ ⁸

2100MHz		ϵ_r	σ (S/m)	ρ (kg/m ³)	Heat Capacity (kJ/kgK)	Thermal conductivity (W/m°C)
1.	Cortical Bones	11,60	0,328	1908	1,313	0,32
2.	Brain*	45,50	1,880	1046	3,630	0,51
3.	Cerebrospinal Fluid	66,80	3,150	1007	4,096	0,57
4.	Fat	10,90	0,224	911	2,348	0,21
5.	Cartilage	39,50	1,490	1100	3,568	0,49
6.	Pituitary Gland	57,70	1,700	1053	3,687	0,51
7.	Spinal Cord	30,50	0,951	1075	3,630	0,51
8.	Muscle	53,20	1,510	1090	3,421	0,49
9.	Eyes*	47,88	1,530	1052	3,043	0,50
10.	Skin	38,40	1,310	1109	3,391	0,37
11.	Tongue	53,10	1,560	1090	3,421	0,49
12.	Teeth	11,60	0,328	2180	1,255	0,59

* Electromagnetic characteristic of those organs were defined as average value.

ϵ_r - permittivity, σ - electric conductivity, ρ - density

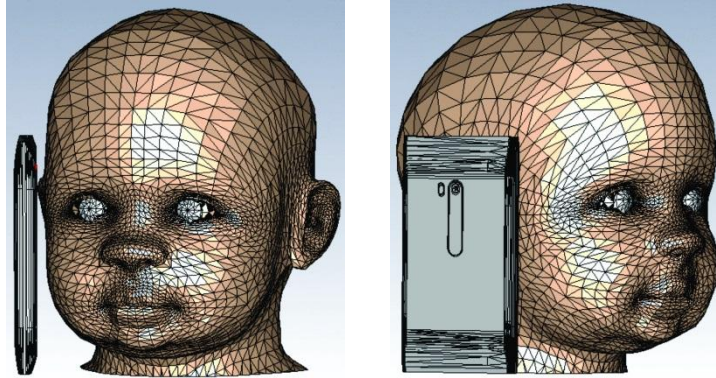


Fig. 1 - External look of model of child head

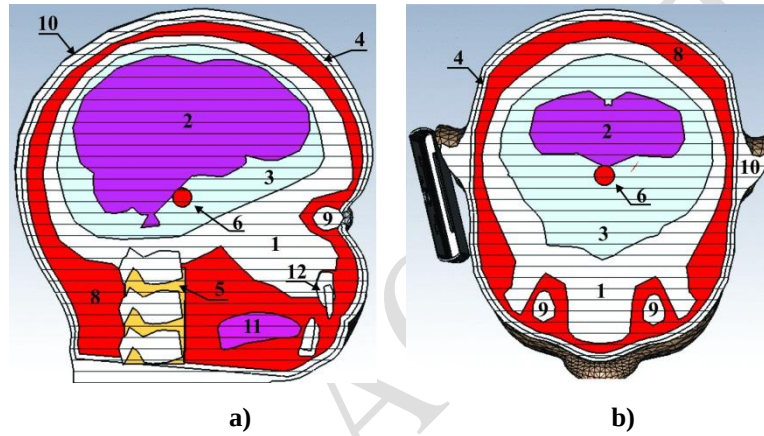


Fig. 2 –Vertical a) and horizontal b) cross-section of model of child head

1 - Cortical Bones, 2 - Brain, 3 - Cerebrospinal Fluid, 4 - Fat, 5 - Cartilage, 6 - Pituitary Gland, 8 - Muscle, 9 - Eyes, 10 - Skin, 11 - Tongue, 12 - Teeth. The numbers are the same as in Tables.

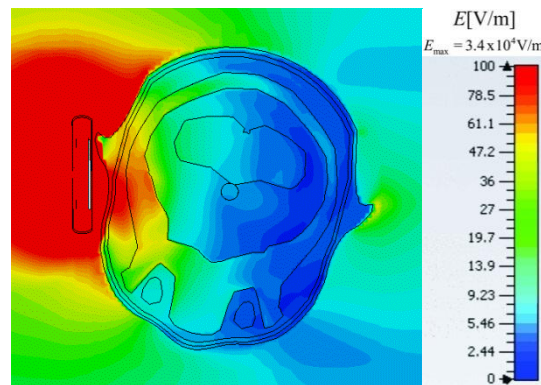


Fig. 3 –Electric field distribution within child head for $f=900\text{MHz}$

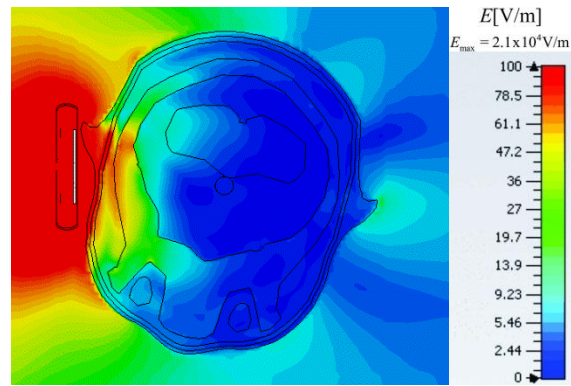


Fig. 4 - Electric field distribution within child head for $f=1800\text{MHz}$

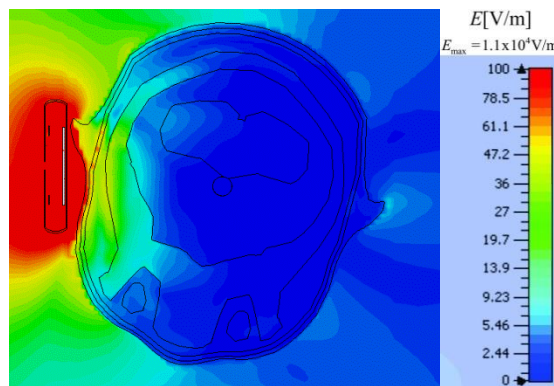


Fig. 5 - Electric field distribution within child head for $f=2100\text{MHz}$

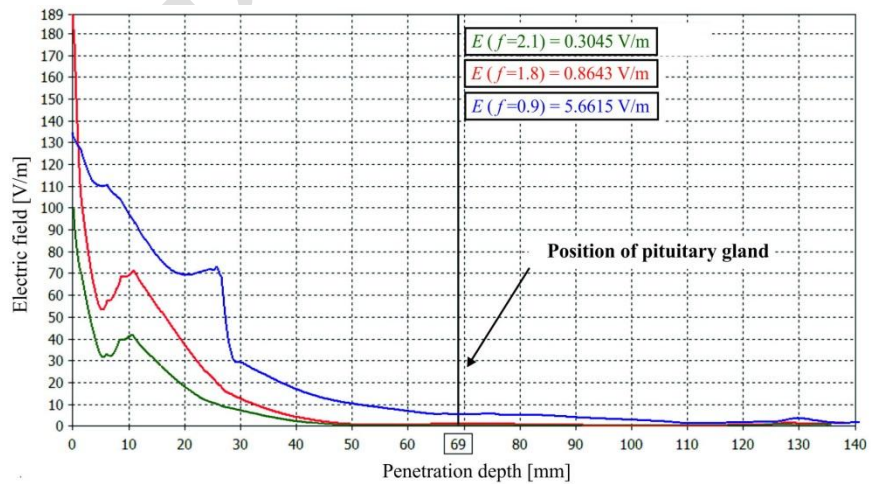


Fig. 6 – Penetration depth of electric field through child head for three different frequencies.

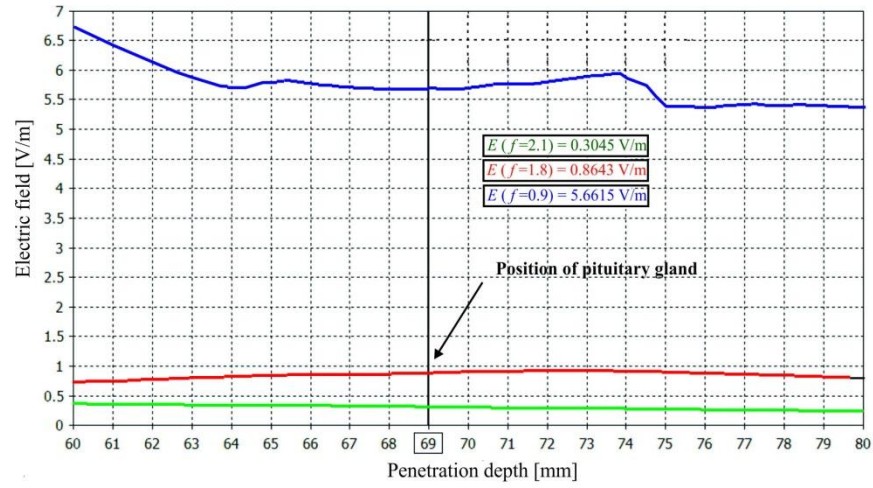


Fig. 7 – Penetration depth of electric field through child head for three different frequencies.

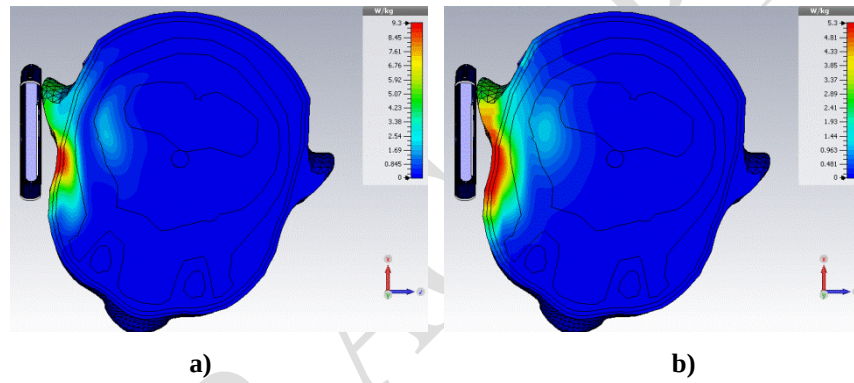


Fig. 8–Specific Absorption Rate inside child head: a) SAR_{1g} and b) SAR_{10g} for $f=900\text{MHz}$

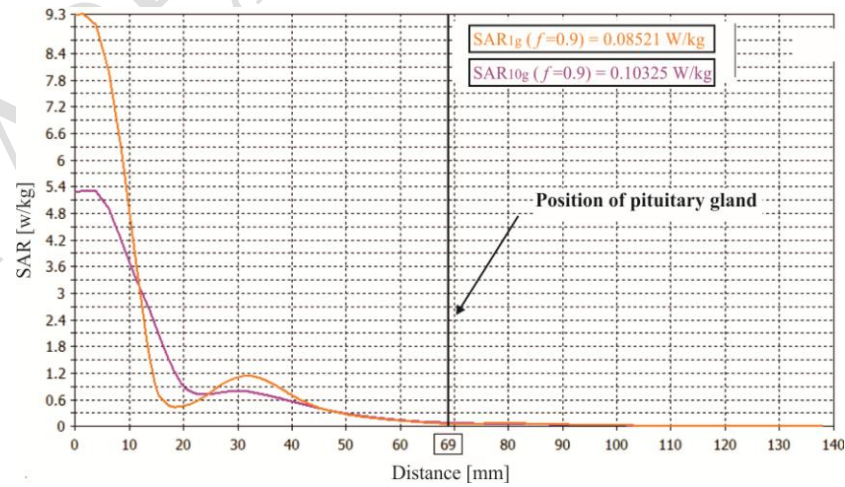


Fig. 9–1D representation of SAR_{1g} and SAR_{10g} for $f=900\text{MHz}$

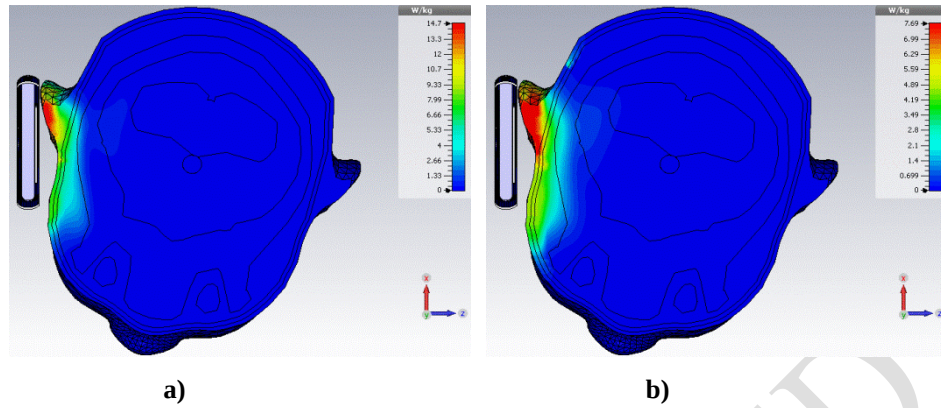


Fig. 10–Specific Absorption Rate inside child head: a) SAR_{1g} and b) SAR_{10g} for $f=1800\text{MHz}$

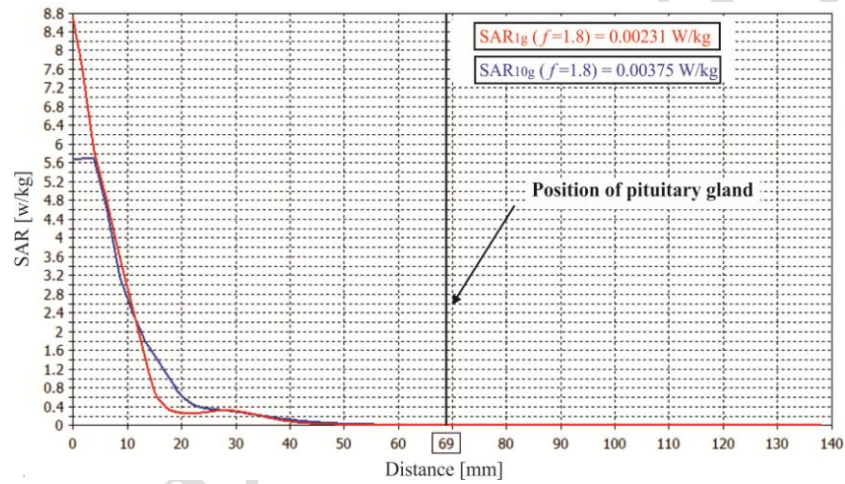


Fig. 11–1D representation of SAR_{1g} and SAR_{10g} for $f=1800\text{MHz}$

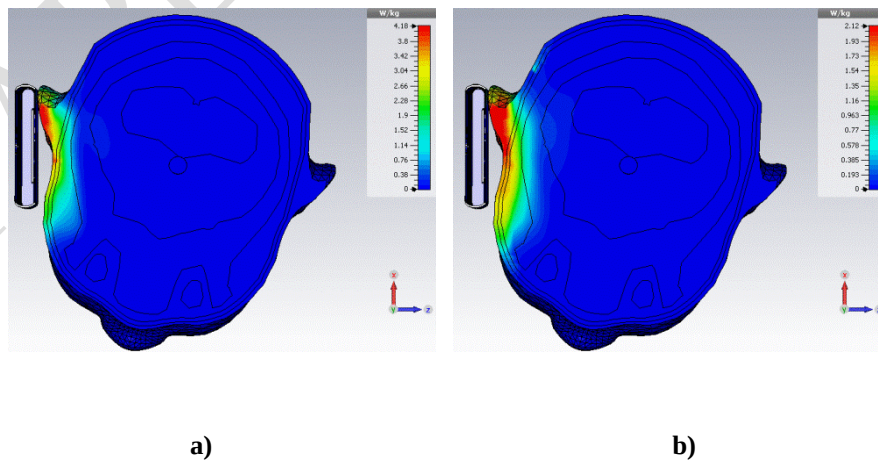


Fig. 12–Specific Absorption Rate inside child head: a) SAR_{1g} and b) SAR_{10g} for $f=2100\text{MHz}$

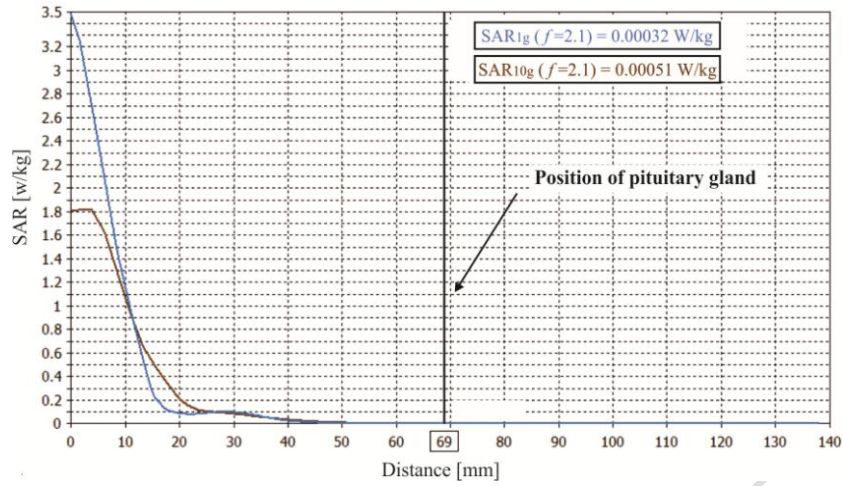


Fig. 13– 1D representation of SAR_{1g} and SAR_{10g} for $f=2100MHZ$

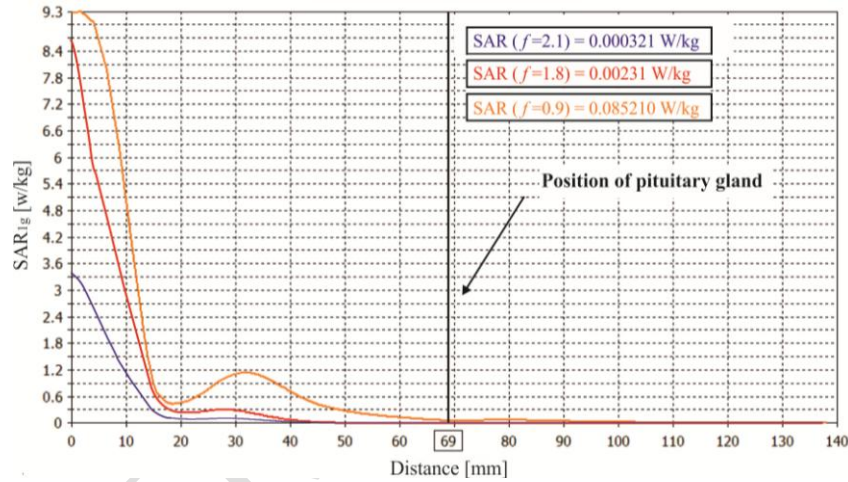


Fig. 14– Comparative analysis of SAR_{1g} for different frequencies through child head

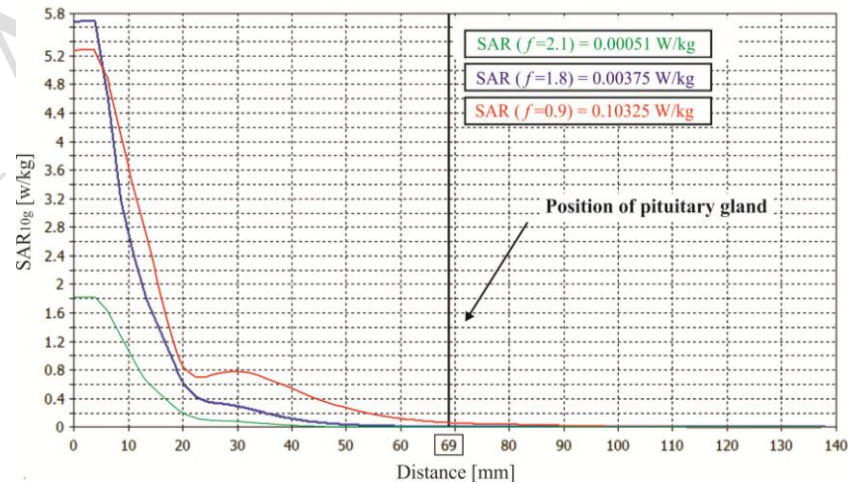


Fig. 15– Comparative analysis of SAR_{10g} for different frequencies through child head

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