

See discussions, stats, and author profiles for this publication at: <https://www.researchgate.net/publication/349610138>

Investigation of Specific absorption rate (SAR) near model of fetus in uterus

Conference Paper · May 2020

DOI: 10.1109/ELEKTRO49696.2020.9130308

CITATIONS

3

READS

105

3 authors, including:



Zuzana Psenakova
University of Žilina

43 PUBLICATIONS 154 CITATIONS

[SEE PROFILE](#)



Mariana Benova
University of Žilina

61 PUBLICATIONS 276 CITATIONS

[SEE PROFILE](#)

Investigation of Specific Absorption Rate (SAR) near Model of Fetus in Uterus

Zuzana Psenakova, Mariana Beňová, Timea Lauková
Department of Electromagnetics and Biomedical Engineering
Faculty of Electrical Engineering and Information Technology
Zilina, Slovakia
zuzana.psenakova@fel.uniza.sk

Abstract—This article deals with effects of electromagnetic fields (EMF) to different models that represent the model of a pregnant woman- AustinWoman, model in first trimester of pregnancy and model of fetus in uterus in 35 weeks of pregnancy. There are differences between specific absorption rate (SAR) near model of fetus in uterus and AustinWoman model in open area. In the presented approach, the investigation is focused on modelling of EMF proceeded on the finite integration method. The simulations were carried out for specific scenario where a person-pregnant woman was placed in the open space using a cellular phone. The results were evaluated in terms of the SAR values – the determination of electromagnetic (EM) energy absorption inside the human models. Two antennas- dipole antenna with a frequency of 2,4 GHz and planar monopole antenna were designed and work as radio frequency sources in our simulations. In the proposed matching method, two models of human body – Model of fetus in uterus and AustinWoman model - were chosen to simulate in different situations with different models of antennas. Both have the dielectric properties determined to the evaluated frequency of source. The numerical results have shown that the obtained maximal SAR values in AustiWoman model is higher than are maximum values determined according to maximum SAR in European standards limit.

Keywords—numerical model, electromagnetic field, planar monopole antenna, dipole antenna, model of fetus in uterus, AustinWoman model, Specific absorption rate (SAR)

I. INTRODUCTION

The use of mobile phones is on the rise, so their connection with human health is also an important global issue due to EM radiation. The pregnant women are in the most risk group for influence of external EMF from environment, because, in the first trimester is a fetus in uterus the most sensitive to another negative factors from surroundings.

Oxidative stress is a major pathomechanism of the EM field's effect on the oocyte, embryo and the environment in which they develop. The formation of oxidative stress affects ion channel function and protein structure. The thermal effects of EMF play an important role in the functioning of male testes, but in the case of the ovaries, the importance of thermal effects is absent. Given the technical and bioethical limitations associated with oocyte acquisition, the available reports and studies regarding the effect of the EMF on their functions are mainly based on animal models. Gul et al. [1], during exposure of female rats to 900 MHz, recorded a decrease in the number of ovulating follicles formed. During a mouse oocyte study,

Roshangar L. et al. [2] demonstrated that oocytes in the group exposed to 50 Hz low-frequency EMF for 4 hours per day exhibited core shrinkage and their zone pellucida appeared to be thinner compared to oocytes from the control group. The number of microvils was greatly reduced, lipid drops were observed in their cytoplasm and the organelles of the cells were dispersed. In granular cells and radiata corona cells harvested from the observed EMF-exposed group, signs of apoptosis such as e.g. nuclear condensation, chromatin marginalization and nuclear membrane dilatation. The basic morphological changes found in granular cells consisted in their shrinkage and microvill atrophy. Mailhes, J. B. et al. [3] who exposed mouse oocytes to a single 60 Hz frequency for 17 hours also noted that positioning the mouse oocyte in EMF causes multiplication of the double helix of chromosomes. Panagopoulos D.J. et al. [56] evaluated the effect of GSM-900 MHz and DCS-1800 MHz electromagnetic waves on fruit fly reproductive cells (*Drosophila*) and observed intensification of nuclear DNA fragmentation and signs of apoptosis in egg cells housed in EMF. Fedorov, A. et al. [4] based on a similar animal model (*Drosophila*) showed an adverse effect of EMF at a frequency of 0.1-2.2 THz. They found that mature oocytes exposed to this radiation for 30 minutes are more susceptible to THz radiation compared to lower developmental stages. Studies by Guney et al. [58] on female rats exposed to 900 MHz for 30 days, half an hour per day demonstrated that these wave ranges cause oxidative stress that leads to an inflammatory state of the endometrium. These studies further demonstrated that exposed female rats showed a decrease in endometrial superoxide dismutase (SOD) and catalase. This phenomenon can be inhibited by the addition of vitamins C and E. Iaremchuk M. M. et al. [5] examined fish embryos (quadruped quadruped) exposed to similar RF waves (900 MHz) for 1, 5, 10- and 20-minutes during embryogenesis. He observed an initial increase in SOD activity (1 to 10 minutes), followed by a significant decrease below the values observed in the control group. These studies have also shown that the content of reproductive cell lipid peroxidation products is subject to significant changes under the effect of low intensity EM radiation. The relationship between endometrial superoxide dismutase (SOD) and pregnancy problems has been addressed by Wdowiak A. et al. [6], who conducted a study on 168 observed women who were divided into two groups based on age. It notes that in the female body the activity of SOD and catalase affects the quality of the embryos and the dynamics of their development, while the rate of development decreases with age [7]. The sensitivity of usage

models is significant. The International Commission on Nonionizing Radiation Protection (ICNIRP) sets a limit of exposure for human safety purposes of EM fields [8]. We have interested about SAR limits and our simulations will be compared with these limits in this paper.

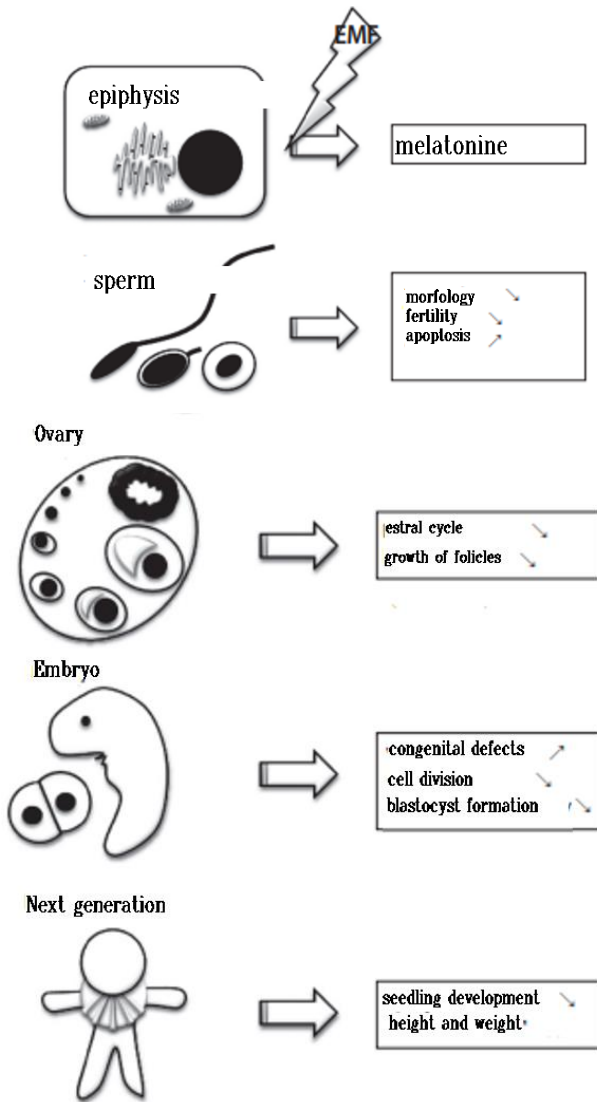


Fig. 1. Effects of EMF to human body and reproduction organs

Our goal is to simulate and analyse distribution of EMF produced by mobile phone sources within two models of Model of fetus and the AustinWoman model in distance 10mm.

II. NUMERICAL MODELS AND ANTENNAS

First we had to plan, which models we will use in our simulations and by which frequencies and antennas.

A. Model of fetus

In the simulation we modified the ball only to a certain part representing the pregnant belly. The radius of the considered part - the hemisphere is 15 cm. The ball-skin tissue was loaded

from the material library offered by CST Studio. The model of fetus in uterus is shown in Fig 2.

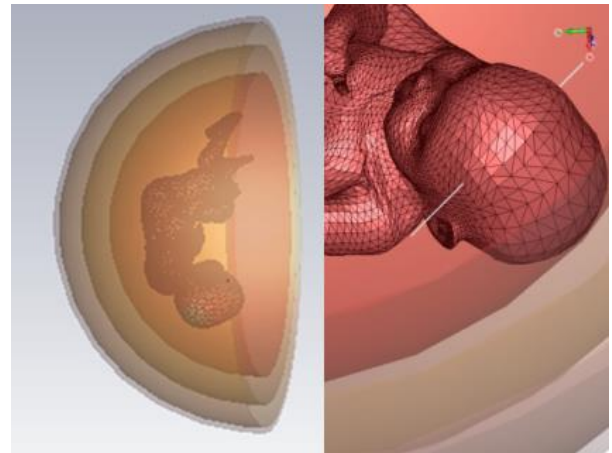


Fig. 2. Model of fetus in uterus space- cutting -plane view and view with the line in the head.

Similarly, other structures of the pregnant belly were created - a layer of adipose tissue, a layer of muscle tissue and the other space of the hemisphere - the pregnant belly was formed by amniotic fluid. For amniotic fluid, the blood material was used to simulate the dielectric properties of amniotic fluid, as amniotic fluid is not available in the CST Materials Library. After creating the belly model, we imported the baby model into the program at 35 weeks of pregnancy.

B. Austinwoman- human model with all types of tissuses

An AustinWoman is a voxel models of the human body that was created for physics simulations patterned on the National Library of Medicine's Visible Human Project data set column, consisting of 1878 sections that have been created using nuclear magnetic resonance and computer tomography. AustinWoman is available in four possible spatial resolutions, 1x1x1, 2x2x2, 4x4x4 or 8x8x8, with 1x1x1 resolution being the largest spatial resolution. For our numerical simulations we have used the spatial resolution 4x4x4, which gives us the enough detailed anatomical structure of the body for our simulations [9].

The aim of our simulations was to calculate and determine the spatial distribution of SAR in individual human body models using the generated antennas. First, we performed a simulation with the Austin Woman model (Fig. 3), to which we imported the created dipole antenna. When calculating the specific absorption rate, we considered a cubic volume element of 10 g of tissue and the radiation power of the antennas used was set to the maximum permissible value by the standard. We placed the dipole antenna on the left side of the model in the lumbar region, which simulated a mobile phone placed in the pocket of the trousers. The distance between the antenna model and the human body model was set to 10 mm.

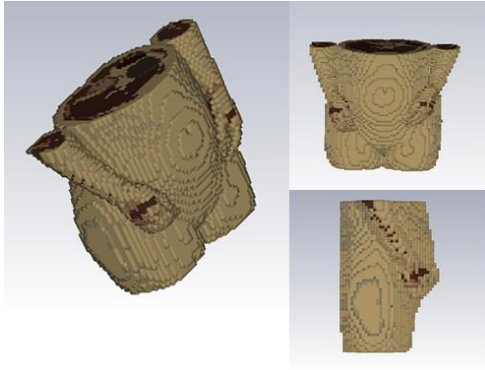


Fig. 3. The AustinWoman model with different tissues [10]

C. Dipole antenna

As the first source we were chosen a standard dipole antenna tuned to the frequency of 2.4 GHz (frequency band used eg for Wi-Fi) and we were created the model of this antenna in CST Studio Suite. Dipole is the basic type of antenna for receiving and transmitting radio waves. This kind of antenna usually consists from two symmetrical arms and a power transmission line. The properties of the dipole depend on the ratio of the length of the dipole itself to the EMF wavelength used. Most often a dipole with a length equal to half the wavelength - the so-called half-wave dipole - is used. The antenna is made of PEC (Perfect Electric Conductor) and is powered by a discrete port. The following figure (Fig. 4) shows the proposed dipole in CST Studio Suite and its S11 parameter (Fig. 5).

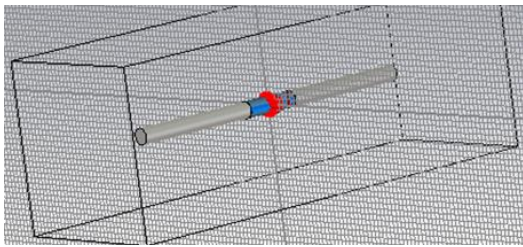


Fig. 4. Model of Dipole antenna for 2.4GHz

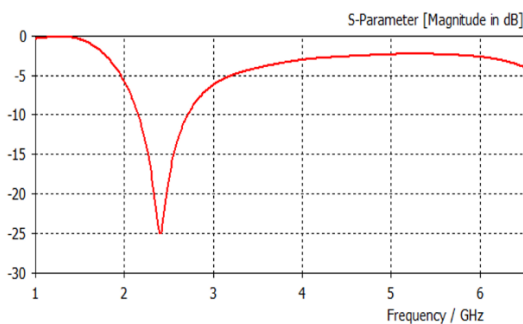


Fig. 5. S11 parameter of dipole antenna

D. Planar monopole antenna

As the second source of the EM field we have chosen a planar monopole antenna. The designed antenna has a compact structure, a plane configuration and occupies only a small area- $36 \times 20 \text{ mm}^2$. The designed antenna can work in several frequency bands 800 - 1280 MHz and 2100 - 3000

MHz. Tuned frequency bands cover, for example, the GSM 850, GSM 900, UMTS 2100 and LTE 2300, LTE 2600 cellular networks, efficiency and low cost. The antenna consists of a T-shaped power strip and is made on a FR4 substrate with a thickness $h = 1.6 \text{ mm}$. The size of the designed antenna is $36 \times 120 \text{ mm}^2$. The overall geometry of the designed antenna is shown in the following figure (Fig. 6) and its S11 parameter (Fig.7) [11].

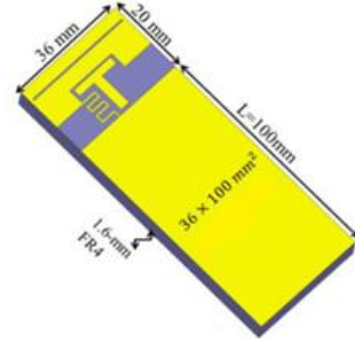


Fig. 6. Planar monopole antenna

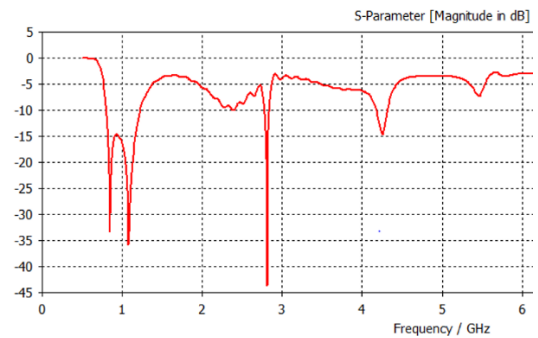


Fig. 7. S11 parameter of planar monopole antenna

III. SIMULATIONS OF EMF EFFECTS AND EVALUATION OF SAR

Some studies of EM fields and their impact on the human body point to the relationship between exposure to EMF and increased levels of leukemia, cancer, brain tumours, and other health problems. In order to reduce EMF exposure, safety standards and guidelines established by regulatory authorities such as IEEE, WHO, ICNIRP and other similar organizations [12].

The effects of EM fields to the human body can be defined according to the findings to the thermal and non-thermal. Thermal effects are caused by the heating of tissues at the Specific Absorption Rate (SAR), which corresponds to a temperature increase of several degrees. They can be defined as effects resulting from the absorption of EM energy, mainly at frequencies higher than 10 MHz. The non-ionizing radiation of the RF waves produced by the mobile phones and their base stations is capable of inducing the oscillation of the molecules and thereby causing the local tissue heating. The depth of penetration of RF radiation that penetrates the tissue depends on the frequency, and at MT (frequency 900 - 1800 - 2100 MHz), this depth in the adult ranges from 1 to 4 cm. The SAR is expressed in Watt per kilogram (W / kg). For localized near-field exposure, such as a cell phone near the

human head or neck, standards have also introduced limitations on the average SAR for small tissue masses (1 or 10 g). The head, neck, and torso maximum SAR is ICNIRP 1.6 W / kg in the US, or 2.0 W / kg calculated on 10g of tissue in Europe. The average SAR for the whole organism is 4.0 W / kg per 10 g of tissue and is considered a threshold for potential adverse thermal effects [13].

Non-thermal effects are considered more harmful than thermal effects. Their health and biological effects are currently being discussed and studied by many scientific groups around the world. The effect of non-thermal effects is that, in extrapolation of EM emissions, electrical currents can be induced in biological objects and, with sufficient intensity, can stimulate, for example, the nervous system, induce DNA oscillations as well as resonance of ionic molecules or protein colloidal particles. The mechanism of non-thermal effects is still unclear.

The International Agency for Research of Cancer (IARC), which is part of the WHO World Health Organization, classified low-frequency ELF magnetic fields in 2002 as potentially carcinogenic to humans (Group 2B), and in 2011 also included radio-frequency (RF) radiation [14], [21], [22], [23].

Specifically, the values of SAR depend on γ – electrical conductivity [S/m], $|\mathbf{E}|$ – maximal value of intensity of the electric field [V/m], ρ_m – mass density [kg/m³] and $\mathbf{r}$ – position [m], all of them in the tissue [15], [16], using equation (1)

$$SAR(\mathbf{r}) = \frac{1}{V} \int_{element} \frac{\gamma(\mathbf{r})|\mathbf{E}(\mathbf{r})|^2}{\rho_m(\mathbf{r})} d\mathbf{r}^3 \quad (1)$$

The exposure limits for EM fields have been established by International institution ICNIRP. [17], [18], [19] The recommended safety values are shown in the Table I.

TABLE I. THE SAR BASIC RESTRICTIONS FOR RANGE OF FREQUENCY BETWEEN 10MHz AND 10 GHz [19]

Exposure characteristics	Whole-body average SAR [W/kg]	Localized SAR (head and trunk) [W/kg]	Localized SAR (limbs) [W/kg]
Occupational exposure	0,4	10	20
General public exposure	0,08	2	4

We have evaluated the value of specific absorption rate SAR, where we have been used computer simulations in CST studio suite for realization. [20], These simulations helped us evaluate the behaviour of electromagnetic fields in two situations, both outdoors- open space, thus expressing SAR values. This value SAR was calculated for a cubic volume element of 10 g tissue. In the simulation, we have placed the first radiation source – dipole antenna and second radiation source-planar monopole antenna near the object under investigation (10 mm) near the torso and near the model of fetus in uterus. Examples of graphical results of simulations are in the figures 8., 9. And 10.

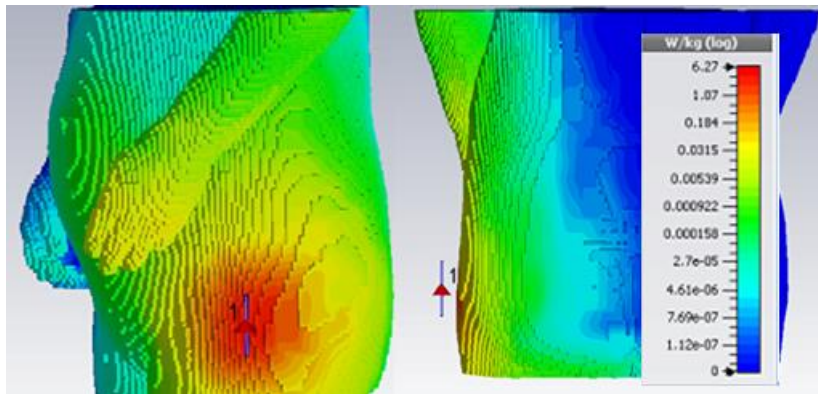


Fig. 8. Example of distribution of SAR in AustinWoman model by dipole antenna

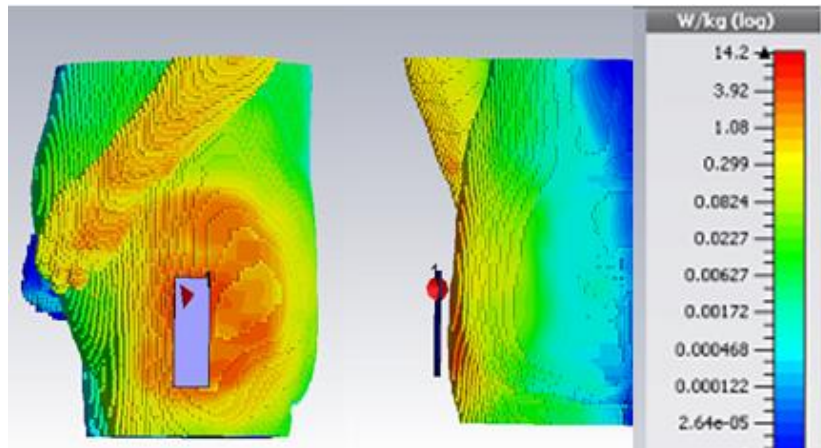


Fig. 9. Example of distribution of SAR in AustinWoman model by planar monopole antenna

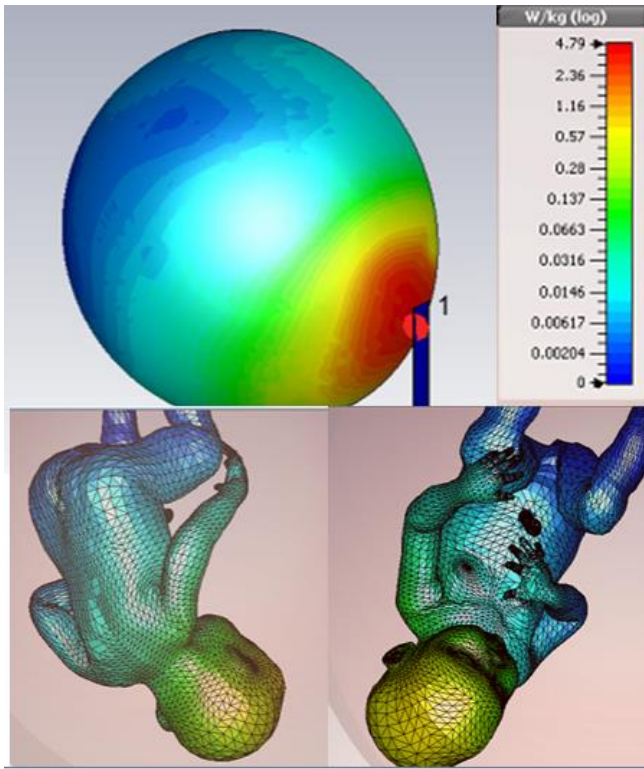


Fig. 10. Example of model of fetus in uterus with planar monopole antenna

Results of simulations are displayed in the Table II. As it is shown, there are the significant differences between the two cases - AustinWoman model and model of fetus. The maximal SAR value for 10g of tissue is 14,2 W/kg with Austinwoman model in 10mm distance from human skin to source of EMF (mobile phone/planar monopole antenna-900MHz). The lowest value 1,27 W/kg of tissue SAR for 10g is for using model of fetus in 10mm distance from human skin tissue to source of EMF (dipole antenna -2,4 GHz) and both values are by open space conditions. In addition to evaluating the overall SAR value, as in previous simulations, we created a line on which we evaluated the SAR in the selected area as part of postprocessing. For the model of fetus, we chose the head of the fetus model.

TABLE II. RESULTS OF SIMULATIONS FOR MAXIMAL VALUE OF SAR IN MODEL OF FETUS AND AUSTINWOMAN MODEL DEPENDS ON DIFFERENT FREQUENCIES [24]

Frequency	Maximal value of SAR [W/kg]			
	GSM 900 MHz	UMTS 2100 MHz	LTE 2600 MHz	Dipole-2450 MHz
Austin woman	14,2	12,4	11,7	6,27
Model of fetus	4,79	2,43	2,02	1,27
Frequency	Maximal value in the line of SAR [W/kg]			
	GSM 900 MHz	UMTS 2100 MHz	LTE 2600 MHz	Dipole-2450 MHz
Austin woman	0,0019	6×10^{-6}	5×10^{-6}	$2,5 \times 10^{-6}$
Model of fetus	0,45	0,015	0,012	0,001

IV. CONCLUSION

In this paper, the study of the electromagnetic energy absorption changes caused to the two models by pregnancy by different antennas and frequencies were proposed. The near-field exposure results from have shown that the SAR values vary for the antenna type and pregnant model type, where is the antenna placed 10mm from models.

In some cases of our simulation scenarios, the SAR values results are not within the limits for public radio-frequency EMF field exposure by ICNRIP. However, it could be caused setting the specific parameters of our simulations – such as dielectric parameters of materials, number of voxels, boundary conditions in each space and types of using models. On the other hand, the cases presented in this paper, represent a risk for long-term exposure of human body, especially of fetus by pregnancy, to EMF.

In this article we want to show differences between two models of human body in pregnancy and differences by specific frequencies and antennas types. Our investigation shows, that higher SAR value is by higher resolution model - AustinWoman, model in first trimester of pregnancy, and by frequency 900MHz for monopole antenna. In first trimester of pregnancy is fetus the most sensitive for negative influences from environment and not enough safety is not recommended. Therefore, a woman at this stage of pregnancy should be particularly protected and the limits of SAR should be respected.

ACKNOWLEDGMENT

This work has been supported from project n. APVV-14-0519, „Smart textiles and clothing for mobile monitoring of human vital functions “

REFERENCES

- [1] GUL, A., CELEBI, H., UGRAS, S. 2009. The effects of microwave emitted by cellular phones on ovarian follicles in rats. Arch Gynecol Obstet. 2009; 280(5): 729–33.
- [2] ROSHANGAR, L., HAMDI, B. A., KHAKI, A. A., RAD, J. S., SOLEIMANI-RAD, S. 2014. Effect of low-frequency electromagnetic field exposure on oocyte differentiation and follicular development. Adv Biomed Res. 2014; 3: 76
- [3] MAILHES, JB., YOUNG, D., MARINO, A. A., LONDON, SN. 1997. Electromagnetic fields enhance chemically-induced hyperploidy in mammalian oocytes. Mutagenesis. 1997; 12(5): 347–51.
- [4] PANAGOPOULOS, D.J., CHAVDOULA, E.D., NEZIS I.P., MARGARITIS, L.H. 2007. Cell death induced by GSM 900-MHz and DCS 1800-MHz mobile telephony radiation. Mutat Res. 2007; 626(1–2): 69–78.
- [5] FEDOROV, A.I., WEISMAN, N.I., NEMOVA, E.F., MAMRASHEV, A.A., NIKOLAIEV, N.A. 2013. Terahertz radiation influence on number and development dynamics of offspring F1 of fruit fly females under stress. Biofizika. 2013; 58(6): 1043–50.
- [6] WDOWIAK, A., WDOWIAK, A. 2015. Comparing antioxidant enzyme levels in follicular fluid in ICSI-treated patients. GynecolObstetFertil. 2015; 43(7–8): 515–21.
- [7] GUNEY, M., OZGUNER, F., ORAL, B., KARAHAN, N., MUNGAN, T. 2007. 900 MHz radiofrequency-induced histopathologic changes and oxidative stress in rat endometrium: protection by vitamins E and C. Toxicol Ind Health. 2007; 23(7): 411–20.
- [8] EN 62209-1:2006. “Human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices – Human models, instrumentation, and procedures – Part 1: Procedure to determine the SAR for hand-held devices used in close proximity of the ear (frequency range of 300 MHz to 3GHz)”, 2006.

- [9] Smondrk, M., Benova, M., Psenakova, Z. "Evaluation of SAR in human body model comprising of metallic implant". In 2018 *Elektro. IEEE*, May 2018
- [10] MASSEY, J. W., YILMAZ, A. E. 2016. AustinMan and AustinWoman: High-fidelity, anatomical voxel models developed from the VHP color images. in Proc. 38th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (IEEE EMBC), Orlando, FL, Aug. 2016.
- [11] BELRHITI, L., RIOUCH, F., TRIBAK, A., TERHAZ, J., SANCHEZ, A. M. 2017. Investigation of Dosimetry in Four Human Head Models for Planar Monopole Antenna with a Coupling Feed for LTE/WWAN/WLAN Internal Mobile Phone. [Online] 27.4.2017 [Cit 10.4.219] Dostupné na internete:<http://www.scielo.br/scielo.php?script=sci_arttext&pid=S2179-10742017000200494>
- [12] DUHAINI, I. 2016. The effects of electromagnetic fields on human health. [Online] September 2016 [Cit. 7.3.2019] Dostupné na internete:<<https://www.sciencedirect.com/science/article/pii/S1120179716308766>>
- [13] BERNARDI, P., CAVAGNARO, M., PISA, S., PIUZZI, E. 2003. Specific Absorption Rate and Temperature Elevation in a Subject Exposed in the Far-Field of Radio-Frequency Sources Operating in the 10–900-MHz Range. In: IEEE Transaction on Biomedical Engineering. March 2003;50(3):295-303
- [14] BALOGH, L. 2004. Non-Thermal Effects Mobile Phones at Biological Objects. In: Advances in Electrical and Electronic Engineering. September-December 2003;2(3-4):46-49
- [15] Salah, I.Y., Yazen, A.Khalil. "High Resolution Numerical Modelling of In-Vehicle Mobile Cars". *International Journal of Electromagnetics and Applications* 2015, 5(1):66-72
- [16] Dominguez, H., Raizer, A. and Carpes, W.P., Jr. "Electromagnetic fields radiated by a cellular phone in close proximity to metallic walls", *IEEE Trans Magn* 38 (2002), 793-796
- [17] Mydlova, J., Benova, M., Psenáková, Z., Smondrk, M. "Evaluation of Specific Absorption Rate in SAM Head Phantom with Cochlear Implant with and Without Hand Model Near PIFA Antenna". *Advances in Intelligent Systems and Computing*, Springer Nature Switzerland AG 2019, ISBN 978-3-030-23761-5
- [18] Mydlova, J., Benova, M., Stefancova, V., Pitlova, E. "Assessment of SAR in human body model with the cochlear implant inside a railway vehicle." Proc. of the 13th Int. Scientific Conference on Sustainable, Modern and Safe Transport, Transportation Research Procedia
- [19] Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields, ICNIRP GUIDELINES. Health Physics , April 1998, Volume 74, Number 4
- [20] Gombárska, D.; Smetana, M.; Janousek, L.: High-Frequency Electromagnetic Field Measurement Inside Personal Vehicle Within Urban Environment In: MEASUREMENT 2019 [print] : proceedings of the 12th international conference. - 1. vyd. - Bratislava: Ústav merania, 2019. - ISBN 978-80-972629-2-1
- [21] J. Misek, J. Vojtek, M. Veternik, M. Kohan, V. Jakusova, G. Spanikova, I. Belyaev, J. Jakus. New radiofrequency exposure system with real telecommunication signals. In: Advances in Electrical and Electronic Engineering. Vol. 16, No. 1 (2018), pp. 101-107
- [22] Jakušová, V. 2009. Ultrafialové žiarenie a mobilná komunikácia: Fyzikálne vlastnosti, biologické účinky a ochrana zdravia. 1. vyd. Bratislava: Samosato, 2009. 97 s. ISBN 978-80-89464-00-5
- [23] Kopani M., Filova B., Sevcik P., Kosnac D., Misek J., Polak S., Kohan M., Major J., Zdimalova M., Jakus J. Iron deposition in rabbit cerebellum after exposure to generated and mobile GSM electromagnetic fields. Bratisl Med J, 2017, 118(10):575-579
- [24] Lauková, T.: Vyhodnotenie vplyvov elektromagnetických polí na plod v maternici , Diplomová práca 2018, UNIZA, Žilina, EDIS