Proceedings of the 3rd World Congress on Electrical Engineering and Computer Systems and Science (EECSS'17)
Budapest, Hungary – August 16 – 17, 2016
Paper No. ICBES 110
DOI: 10.11159/icbes16.110

Computer-based Thermal Analysis of Brain Exposed to Near-Gigahertz Electromagnetic Field

Ugur Sorgucu[1], Deniz Aktas[1], Ibrahim Develi[2]
[1]Bartin University
Faculty of Engineering, Bartin University, Bartın, Turkey
sorgucu@bartin.edu.tr; denizaktas@bartin.edu.tr
[2]Erciyes University
Faculty of Engineering, Erciyes University, Kayseri, Turkey
develi@erciyes.edu.tr

Abstract - In the last century, interactions between Electro Magnetic Fields (EMF) and biological systems have been studied by many disciplines. One of the most common methods is the use of computer simulations to investigate the effects of EMF on biological systems. Nearly all frequency bands and tissue types were studied in previous researches; the focus of recent researches has been on the communication frequency area and brain tissue. Accordingly, communication frequency area and brain tissue are modelled in the current study for different cases. As one of the most commonly used frequencies in cellular communication the different strengths of EMF at 900 MHz were evaluated and the resulting thermal effect on the human brain was investigated using a software package. As a result, remarkable temperature changes were obtained under different electromagnetic strengths.

Keywords: Thermal Effect of Electromagnetic Field, 900 MHz, Abaqus Thermal Modelling, Finite Elements Method (FEM).

1. Introduction

Direct or indirect exposure of billions of people to EMF has drawn the interest and attention of the scientific world to the possible related health risks. As a result of the rapid spread of communication devices in the last decades, more focus has been placed on the issue of EMF exposure. However, exposure to EMF is a general expression which describes all frequency bands. Therefore, the spreading frequency of the EMF is crucial, during the investigation of the thermal effect of EMF on biological tissues. Since, the propagation of EMF in the biological tissues and the effects on tissues are directly associated with spreading frequency [1, 2].

Possible harmful effects of the EMF due to increase in the number of mobile phone subscribers have attracted the attention of not only scientific world but also public interest [3]. At this point, revealing the physical and biochemical effects of EMF exposure mechanism plays an important role in the elimination of public concern. Therefore, international organizations specified standards about exposure to EMF [4-6].

Numerous researches have been carried out on the possible harmful effects of EMF. However, humans cannot be used as subjects of these works, because of academic ethics. Indeed, as it is indicated in the study of [7], there is a need for structures that simulate human tissues or computer simulations. In this regard, the most common utilized tools are computer programs. Several advantages can be obtained by using computer programs. Computer programs provide an opportunity to numerous variations without cost; also multiple numbers of analyses can be concluded within shorter periods.

There are a few important points to be noted while analyses are carried out with computer simulations. These are the spreading frequency, strength of EMF, exposure duration and the properties of the material to be affected. In this study the effect of EMF is investigated for 900 MHz frequency and different strengths. 900 MHz is selected for its common worldwide use as a second generation communication frequency. Another important issue is the selection of tissue exposed to EMF. In this study, brain tissue is selected for investigation of EMF effect. Since, the highest rates of exposure takes place in the head region.

2. Modelling of the Mobile Phone Effect on Brain Tissue

In this study, the assessment of the temperature distribution through the brain tissue was obtained by using a finite element Abaqus software package. Abaqus is a powerful software in the analysis of heating, mechanic and, electromagnetic situations and etc. A mobile phone, modelled as a heat flux source, was applied to brain tissue. The brain tissue was designed as a half sphere to easily monitor the effect of the EMF. The designed simulation environment is presented in Figure 1.

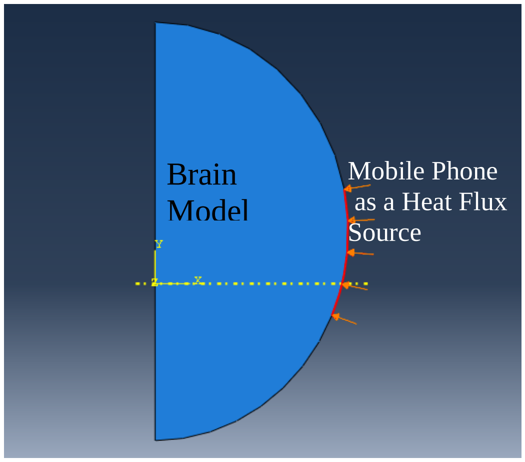


Fig 1: Designed Simulation Environment.

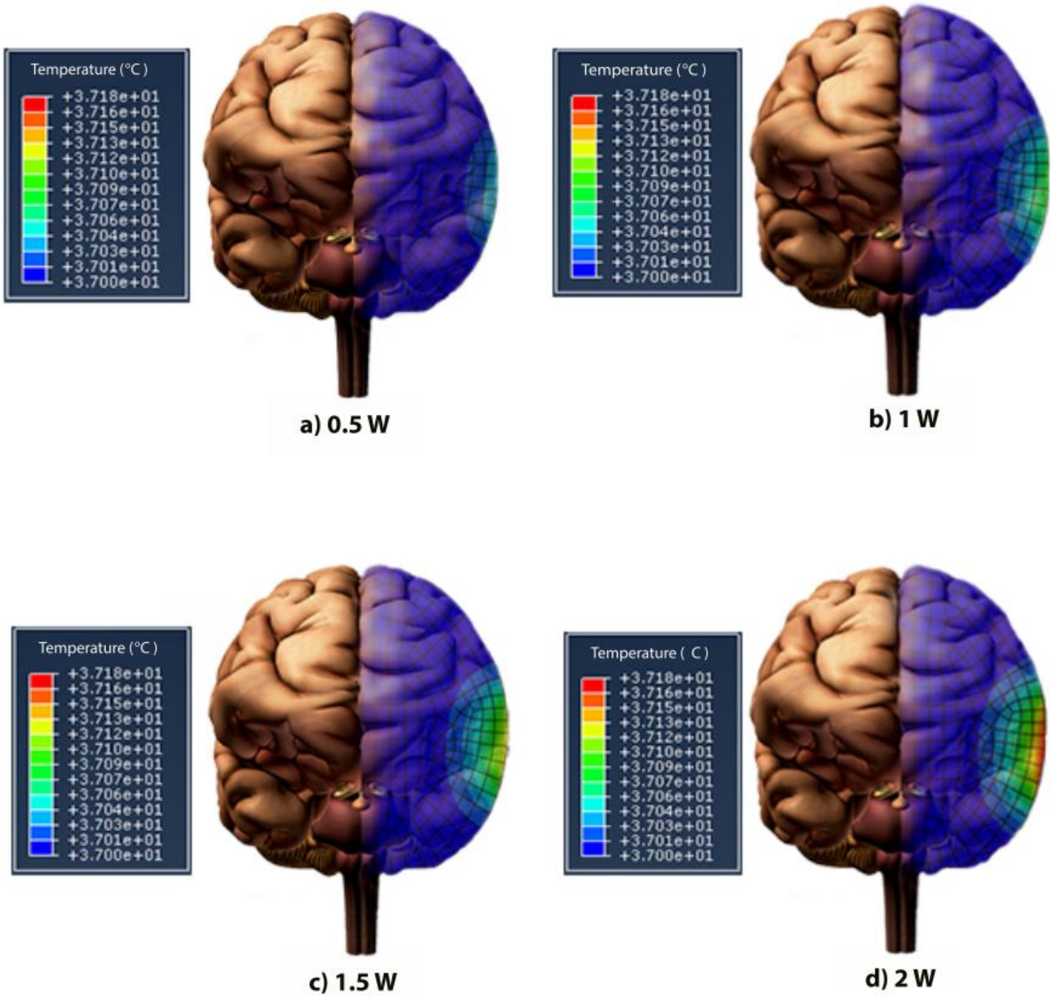
As seen in Figure 1, mobile phone was modelled as a heat source in the Abaqus and the brain was modelled as a half sphere. Brain was modelled by some coefficients which were used in previous researches [8]. The coefficients related with the brain tissue are as follows:

ρb : density of the brain tissue (kg m-3) = 1038,
Cp : specific heat of the brain tissue (J kg-1 °C-1) = 3650,
Ti : initial temperature of the brain tissue = 37 °C,
κt : thermal conductivity of the brain tissue (W m-1 °C-1)

As known from literature, mobile phones can emit peak powers of 2 W, but mean outputs of mobile phones are approximately 125 mW at 900 MHz frequency, due to the reasons such as time division multiplexing (duty factor 1/8) [9]. However, in the scope of this study, mobile phone is considered as a heat flux source; therefore power density of the mobile phone was taken into consideration. The power density which is produced by mobile phone can be calculated using the Seybold's study [10].

Antenna output power of the commercially available mobile phones varies from 0.5 W to 2 W. The power density formula of [11] can be used in order to calculate the power density of the antenna output power. In this study, the output powers of 0.5 W, 1 W, 1.5 W and 2 W were used, respectively. Then, their power densities were found depending on the [11], 1.35275 W/m2, 2.7055 W/m2, 4.05825 W/m2, 5.411 W/m2, respectively. Brain which was modelled with specified coefficients were exposed to different power densities for the duration of 1800 second (30 minutes) and observed temperature distributions are presented in Figure 2.

As seen in Figure 2, maximum temperature rise in brain was obtained as about 0.18 °C for exposure of 1800 seconds to mobile phone which emitted power of 2 W. Maximum temperature rise was obtained in the closest area to mobile phone and almost no rise in temperature was observed beyond distance of average 40 mm. The results obtained in this study are in a good agreement with the [11]. Most of the mobile phones available in the markets broadcast about 1W EMF. The phone, which has 1W output power, causes about 0.09 °C temperature rise. This amount of temperature rise is good news for many mobile phone users. Figure 2 shows the results of exposure to 900 MHz EMF for the duration of 1800 seconds. However, in Figure 2, no information is given about the temperature change within 1800 seconds. Accordingly, the temperature change during the brain- phone interface for the region subject to the maximum temperature distribution is presented in Figure 3.



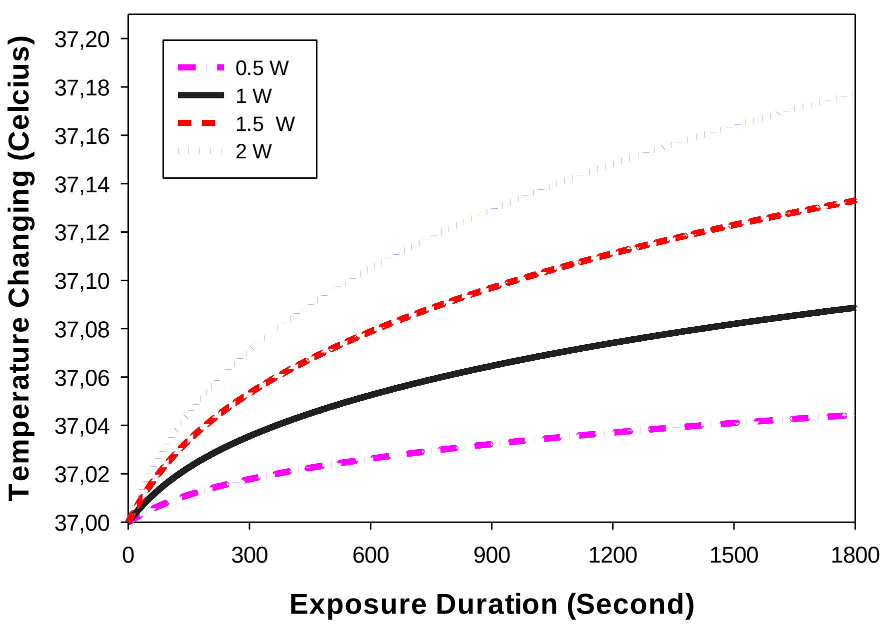


Fig 3: Temperature changing in the brain under different exposure conditions.

As seen in Figure 3, the maximum temperature rise was observed during the exposure to 2W. Although the exposure duration to EMF was long enough, observed maximum temperature was about 0.18 ^{o}C. The results are in a good agreement with the authors' previous experimental research [12]. Perfusion characteristics of the human body can be corresponded with the exponential behaviour of the temperature rise in the brain. It should be also noted that significant portion of the observed maximum temperature was obtained within the first 900 seconds. As seen in Figure 3, the duration of the phone call is crucial for human health. Indeed, the temperature rise within the first 300 seconds occurs at a higher rate than the temperature rise within the last 300 seconds. It must be noted that the first 300 seconds is crucial for most of the calls send within this period.

3. Conclusion

In this study, thermal effect of EMF is modelled for different conditions, which is rather new in modelling of the thermal effect of EMF. Indeed, there is no tool for modelling the EMF as a magnetic field source. Therefore, in this study EMF is considered as a heat flux source. As remarked in the paper, considering the EMF as a heat flux source is a new viewpoint. Afterwards, it is applied to brain tissue which is electrically specified and temperature changes were observed. 0.18 ^{o}C maximum temperature rise was observed under exposure to 2 W electromagnetic power for the duration of 1800 second. The simulation results are also in an agreement with the experimental and analytical studies which are cited in the paper.

References

[1] O. P. Gandhi, "Use of the Finite-Difference Time-Domain Method for Calculating EM absorption in Man Model," *IEEE Transaction on Biomedical*, vol. 35, no. 3, pp.179-186, 1998.

[2] K. Y. E. Wasife and A. Y. A. Batniji, "EMF in Tissue- Equivalent Liquids for Different Frequencies by Means of Flux Density," *International Journal of Innovative Research in Science, Engineering and Technology*, vol. 2, no. 2. pp. 479-484, 2013.

[3] B. Sanou and ITU (The International Telecommunication Union), "ICT Facts and Figures," Geneva, Switzerland, 2014.

[4] Federal Communications Commission Office of Engineering & Technology, *Questions and Answers about Biological Effects and Potential Hazards of Radiofrequency EMF*. OET Bulletin 56, Fourth Edition, August 1999.

[5] ICNIRP Guidelines, "Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic and EMF (up to 300 GHz)," *Health Physics*, vol. 74, no. 4, pp. 494–522, 1998.

[6] IEEE, "IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency EMF, 3 kHz to 300 GHz," C95.1, 1999.

[7] U. Sorgucu, I. Develi, and S. Ozen, "How to Prepare Head Tissue-Equivalent Liquids for SAR Calculations, Dosimetry and Hyperthermia Researches at 900 and 1800 MHZ GSM Frequencies," *Radiation Protection Dosimetry*, 2015.

[8] W. Teerapot, S. Srisawatdhisukul, and P. Rattanadecho, "Specific Absorption Rate and Temperature Distributions in Human Head Subjected to Mobile Phone Radiation at Different Frequencies," *International Journal of Heat and Mass Transfer*, vol. 55, no. 1, pp. 347-359, 2012.

[9] D. H. Gultekin, L. Moeller, "NMR Imaging of Cell Phone Radiation Absorption in Brain Tissue," in *Proceedings of the National Academy of Sciences*, vol 110, no 1, pp. 58-63, 2013.

[10] J. S. Seybold, *Introduction to RF Propagation*, First Edition. New Jersey: John Wiley & Sons, Inc., 2005.

[11] A. H. Sallomi, "A Theoretical Approach for SAR Calculation in Human Head Exposed to RF Signals," *Journal of Engineering and Development*, vol. 16, no.4, pp. 304-313, 2012.

[12] I. Develi and U. Sorgucu, "Prediction of Temperature Distribution in Human BEL Exposed to 900 MHZ Mobile Phone Radiation Using ANFIS," *Applied Soft Computing*, vol. 37, pp 1029–1036, 2015.