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Computational Modeling and Numerical Analysis of the Effects of Cell Phones at 1800 MHz frequency

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Abstract

In this paper, the computational model of a human head is designed, composed of three geometries that correspond to the brain, skull and skin respectively is designed. Then, using a numerical analysis software thermal effects produced by a cell phone are simulated.

To simulate a patch antenna is used to generate an electromagnetic field at 833 MHz frequency. Through numerical analysis, the temperature distribution and specific absorption rate (SAR) are calculated by the finite element (FEM) method.

Keywords: Cell phone, human head, electromagnetic field, SAR, FEM.

1. Introduction

Cell phones emit radio frequency waves, a form of non ionizing electromagnetic radiation that can be absorbed by the devices closest to these tissues.

Due to the increase in the number of subscribers to mobile phone services, today there has been a concern about the possible existence of negative effects on the electromagnetic fields produced by cell phones. However, it is not known whether exposure to these devices affect health of people.

In the 80's and 90's, scientists around the world conducted studies to determine the potential effects of electromagnetic emissions.

These investigations allowed the determination of acceptable levels below which no risk is guaranteed by the use of cell phones. Figure 1 shows the number of cell phone subscriptions from 2001 to 2014.

The SAR is defined as the maximum power absorbed by living tissue. Governments have set standards not to exceed the SAR levels and avoid risks to human health. Maximum levels are 1.6 W / kg for the US and 2W / kg for Europe [1].

These values are used for frequencies between 100 kHz and 100 GHz (non-ionizing radiation particularly from cellular phones).

The electromagnetic fields emitted by modern GSM phones have a maximum power of 1 to 2 W, while other digital cellular technologies have powers under 1 W. These levels are generally regarded as safe by international regulatory authorities [2].

The risk of cancer due to cellular telephony, became important following a lawsuit in May 1993 in the United States. In the case, the plaintiff argued that cell phone use was the cause of the generation of a brain tumor at his wife. This claim was disproved due to lack of evidence [3].

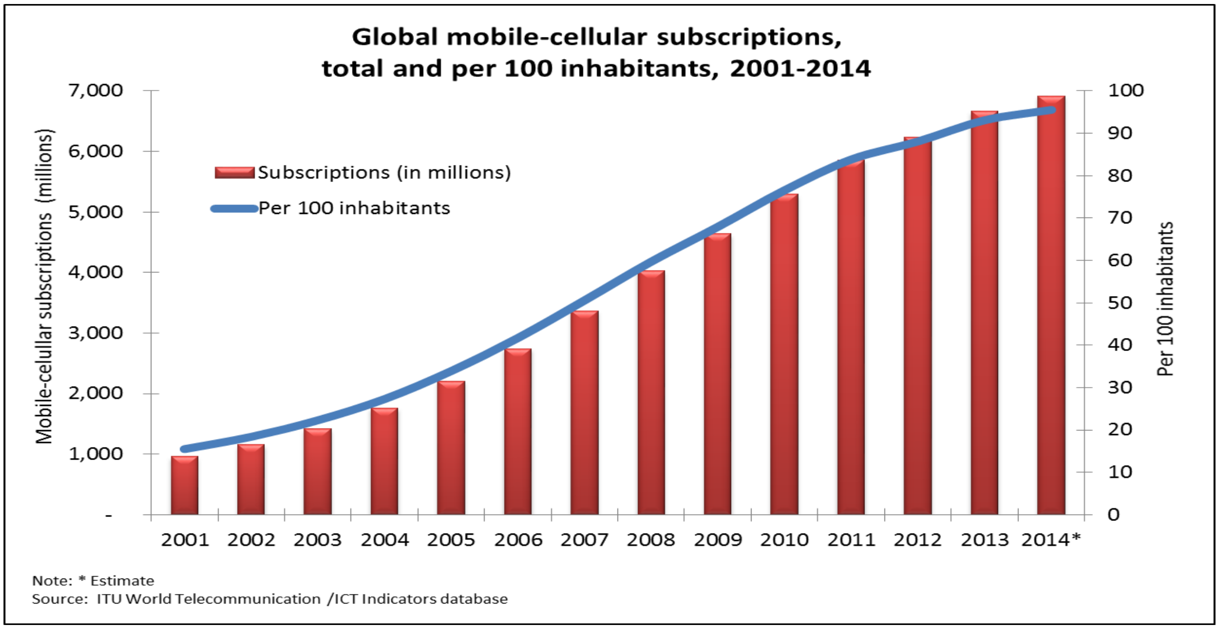

Fig. 1. Subscriptions to mobile phones (data source: International Telecommunication Union, 2014).

From that date, there have been scientific and epidemiological studies to validate the existence of negative effects on cell phone.

2. Methodology

The energy of the electromagnetic waves that cell phones produce is absorbed by the human head. Then, this energy is dissipated as heat causing a temperature increase in biological tissues.

Due to the ethical conditions of prolonged human exposure to electromagnetic fields, in this research project it is decided to use the computer model of a human head for the study.

The study on the thermal effects produced by the cell phone is determined by the vector Helmholtz equation and the equation of Bio warming. This system of equations is solved by numerical analysis by the finite element method using the software $COMSOL^{TM}$ $Multiphysics$.

2.1 Computational model (human head)

The typical approach of a computer-aided design (CAD) uses vector geometry, surfaces and solids for describing a volume entities. However, there is no CAD description available for a wide range of complex geometries such as biological structures.

Currently, there are a variety of software that can generate volumes of high quality through images from some medical imaging equipment such as the computer tomography (CT) and magnetic resonance (MR) among others.

The geometry of the human head was made based on medical images obtained in a tomographic study. Figure 2 shows the tomographic study and computational model.

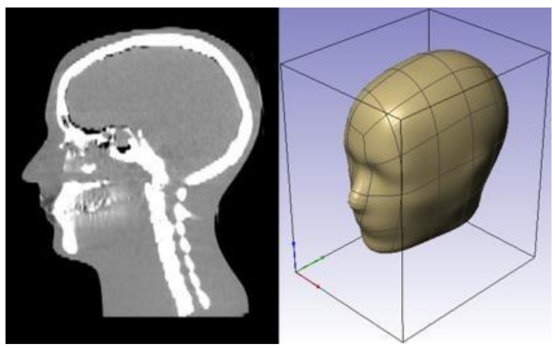

Fig. 2. a) Tomographic Study. b) Human head geometry

2.2 Numeric Analysis (FEM)

The finite element method is one of the most used techniques for solving partial differential equations of applied mathematics engineering.

The main objective of this method is to replace some unknown function in the domain, change by a set of shaped elements defined but unknown amplitude [4].

The computational implementation of FEM analysis is performed generally by three basic units: the pre-processing, processing and post-processing. In Figure 3 the operations in each unit are summarized.

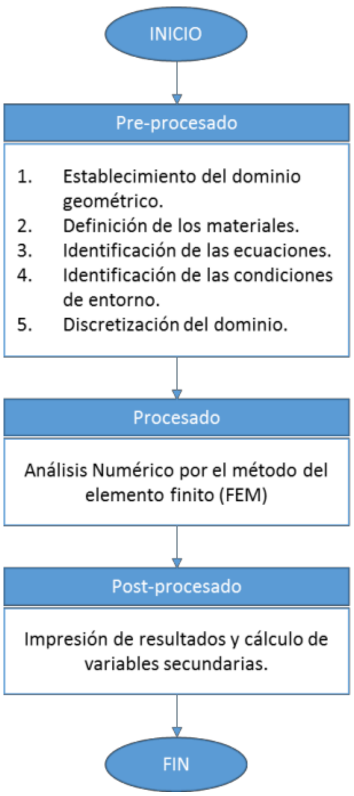

Fig. 3. FEM Computational Analysis

2.3 Creating the geometric domain

The model of the human head is exported to numerical analysis software. Then the model of the patch antenna is positioned on the left side of the head. Finally, these two geometries are encapsulated in an area that simulates the air where electromagnetic waves propagate. Figure 4 shows the geometric domain.

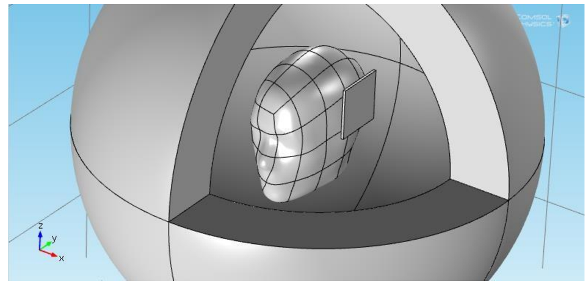

Fig. 4. Geometric Domain

2.4 Definition of materials

The computer model of the human head is composed of three geometries corresponding to the brain, skull and skin respectively. Figure 5 shown these geometries.

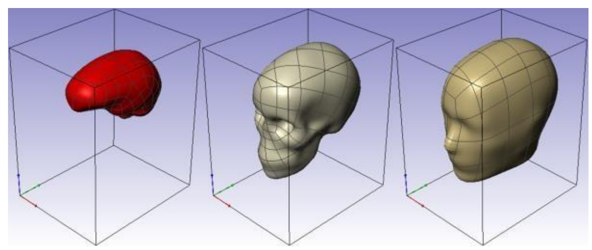

Fig. 5. Human Head Geometries

Each geometry is assigned the dielectric and thermal properties depending on the tissue they represent. Table 1 show these values.

Table 1. Dielectric and thermal properties (data source: ITIS Foundation, 2015).

	Brain	Skull	Skin
Electric conductivity	1.23 S/m	0.136 S/m	0.845 S/m
Relative electric permittivity	49.9	12.5	41.8
Density	1046 kg/m^3	1908 kg/m^3	1109 kg/m^3
Thermal conductivity	0.51 $W/m \cdot °C$	0.32 $W/m \cdot °C$	0.37 $W/m \cdot °C$
Thermal capacity	3630 $J/kg \cdot °C$	1313 $J/kg \cdot °C$	3391 $J/kg \cdot °C$

2.5 Equations identification

Depending on the physical nature of the study will lead to the state variables associated with the problem. The state variables are interrelated by constitutive equations representing a physical law in particular.

2.5.1 Electromagnetic analysis equation

Maxwell's equations allow us to describe the propagation of electromagnetic waves in space [5]. To electrodynamic problems, these equations are simplified by the vector Helmholtz equation shown below:

$$\nabla X \frac{1}{\mu_r} \nabla X E - k_0^2 \varepsilon_r E = 0 \tag{1}$$

E represents the electric field (V/m), μ_r, the relative electric permeably, ε_r the electric relative permissively and k0 the wavenumber of free space (m^{-1}).

2.5.2 Thermal analysis equation

Bio-heating processes in living tissue are influenced by the blood perfusion through the vascular network. Pennes proposed a model to describe the effects of metabolism and blood perfusion in an energy balance within the tissue [6]. These two effects are incorporated into the bio-heating equation shown below:

$$\rho C \frac{\delta T}{\delta t} = \nabla(k\nabla T) + Q_{bio} + Q_{ext} \tag{2}$$

ρ is the tissue density (kg/m^3), C is the thermal tissue capacity (J/kg°C), k is the thermal tissue conductivity (W/m°C), T is the Temperature (°C), Q_{bio} is the biological heat source and Q_{ext} is the external heat source.

The biological heat source is determinated by the next equation:

$$Q_{bio} = \rho_b C_b w_b (T_b - T) + Q_{ext} \tag{3}$$

$\rho_b C_b w_b$ (T_b-T) is the blood perfusion and Q_{met} is the thermal metabolic source.

2.5.3 SAR analysis equation

The SAR can be calculated by the next equation [6]:

$$SAR = \frac{\sigma}{\rho} |E|^2 \tag{4}$$

E represents the electric field (V/m), σ is the electric conductivity (S/m) and ρ the tissue density (kg/m^3).

2.6 Environmental conditions identification

Environmental conditions allow us to define how it should behave the problem under certain circumstances.

2.6.1 Electromagnetic conditions analysis

Electromagnetic fields must satisfy the equation of Maxwell in each tissue and its boundaries [7]. The condition that must be in environment interface two tissues is:

$$(E_A - E_B) * n = 0 \tag{5}$$

Where n is a normal vector and (E_A – E_B) is the difference between tissue (V/m).

The geometric domain of free space has a boundary condition, which allows electromagnetic waves to pass through the domain without reflection. This condition is defined by the following equation:

$$n * \left(\nabla * (E + E_b)\right) - \left(jk + \frac{1}{r}\right) n * (E * n) = 0 \tag{6}$$

n is a normal vector, E is the electric field (V/m), j and E_b are the incident plain wave (V/m) and k is the wave number (m^{-1}).

Patch antenna plates must function as a perfect conductor [7]. Therefore, the condition of a perfect conductor environment is defined as:

$$n * E = 0 \tag{7}$$

At the bottom of the patch antenna, a port is placed between the two plates to generate the magnetic field from a voltage differential [7]. The condition for generating the electromagnetic field is:

$$Z_{in} = \frac{V_1}{I_1} \tag{8}$$

Where Z_{in} is the input impedance (Ω), V_1 the voltage between the plates (V) and I_1 the current (A).

2.6.2 Environment conditions for thermal analysis.

The thermal insulation condition delimits the heat flow at the edges of the human head [7]. This condition is given by the following equation:

$$n * (k\nabla T) = 0 \tag{9}$$

Where n is a normal vector, k is the tissue thermal conductivity (W/m°C) and T is the Temperature (°C).

2.7 Discretization domain

Discretization process it is known as meshing and involves subdividing geometry into a number of small elements. The most used in FEM analysis elements are lines in one dimension, two-dimensional triangles and tetrahedrons in three dimensions.

According Kuhlemeyer and Lysmer (1973), the characteristic wavelength of the medium is important in determining an accurate numerical model on dynamic analysis. The size of the element should be less than 1/8 to 1/10 of the wavelength.

The domain discretization was performed using tetrahedral elements in the geometry of the human head and the patch antenna. In the geometry of the sphere triangular elements they were used. Figure 6 show the discretization of the domain.

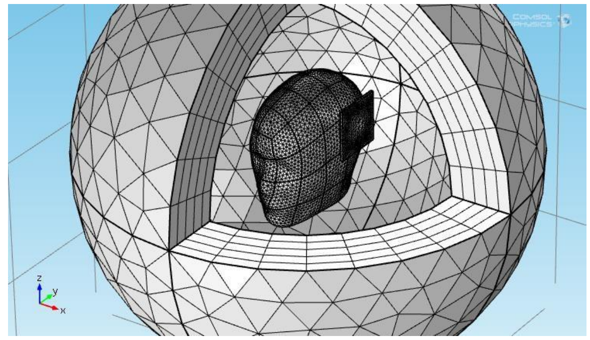

Fig. 6. Domain Discretization

3. Results and discussion

An initial condition of 0 ℃ in the temperature of the human head is established. For the generation of electromagnetic field values of 45.5 V and 75 Ω they were used in the port of the patch antenna.

Figure 7 shows the temperature distribution in the computational model of the human head exposed to an electromagnetic field with an 833 MHz frequency.

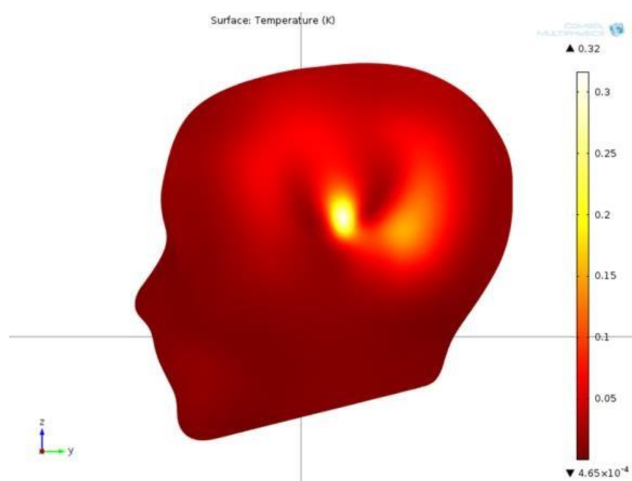

Fig. 7. Temperature Distribution

Figure 8 shows the SAR distribution in the computational model of the human brain exposed to an electromagnetic field with a frequency of 835 MHz.

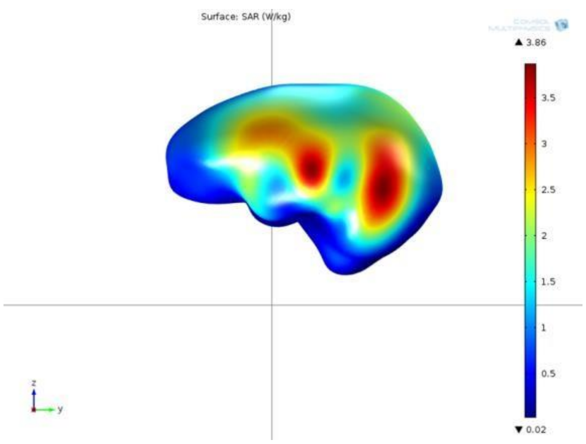

Fig. 8. SAR Distribution

4. Conclusions

Studies on electromagnetic effects in humans are limited, therefore the results of this research project show that the implementation of a computational model and numerical analysis are useful tools for determining thermal effects produced by cell phones.

In the simulation, the maximum SAR levels were recorded in the regions closest to the port patch antenna where the electromagnetic field is generated brain.

A large power is used to generate the electromagnetic field. It is for this reason that SAR levels obtained in numerical analysis exceeded the limits set by the rules. However, the realization of this study opens a pattern in the generation of future studies where own powers of a cell phone is used.

References

[1] A. A. Omar, "Complex image solution of SAR inside a human head illuminated by finite-length dipole," *Progress In Electromagnetics Research B,* vol. Vol. 24, pp. 223-239, 2010.

[2] C. T. Vini G. Khurana, Michael Kundi, Lennart Hardell, Michael Carlberg, "Cell phones and brain tumors: a review including the long-term epidemiologic data," *Surgical Neurology,* vol. Vol. 72, pp. 205-215, 2009.

[3] S. F. D., "Telefonía móvil (celular) y salud humana," *Revista Médica Universitaria. Facultad de Ciencias Médicas - UNCuyo,* vol. Vol. 3, 2007.

[4] A. D. B. Tirupathi R. Chandrupatla, *Introducción al estudio del elemento finito en ingeniería*. México, D.F.: Pearson Prentice Hall, 1999.

[5] D. Davidson, *Computational electromagnetics for RF and microwave engineering*. Cambridge, UK.: Cambridge University Press, 2005.

[6] E. G. Moros, *Physics of thermal therapy fundamentals and clinical applications*. EUA: CRC Press, 2013.

[7] P. R. Teerapot Wessapan, "Specific absorption rate and temperature increase in human eye subjected to electromagnetic fields at 900 MHz," *Journal of Heat Transfer,* vol. Vol. 134, September 2012.