Biological Effects of Microwave Radiation

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Introduction: Microwaves affect living systems directly at a low level of exposure. To study the real effects, modeling of heat transfer in human tissue is cooperated with the modeling of electromagnetics. RF module solves for Electromagnetic field distribution and SAR in Human body. Heat Transfer Model solves for temperature increase because of electromagnetic energy absorption.

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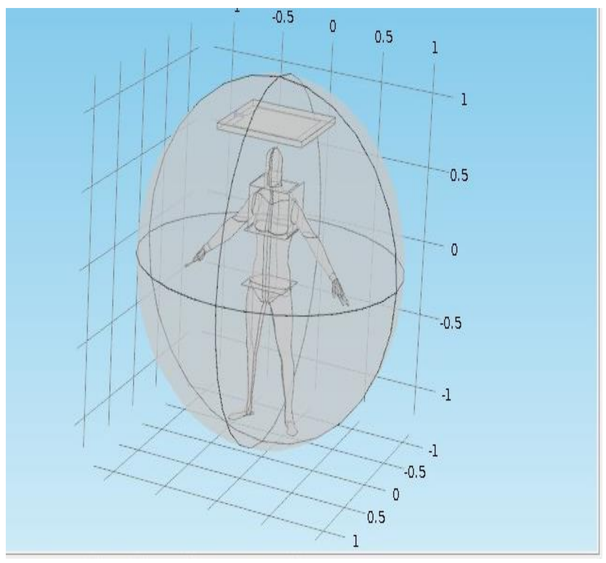

Figure 1. Model structure of human body with antenna

Computational Methods: Equation used for RF module :

$$\Delta \times \left(\frac{1}{\mu_r}\Delta \times E\right) - {k_0}^2\left(\varepsilon_r - j\frac{\sigma}{\omega\varepsilon_0}\right)E = 0$$

Equation used for Heat Transfer:

$$\frac{\rho C \partial T}{\partial t} = \nabla.(k\nabla T) + \rho_b C_b\, \omega_b (T_b - T) + Q_{met} + Q_{ext}$$

Conditions:

1.The perfect-electric-conductor boundary condition along the patches $n \times E = 0$.

2.Continuous boundary conditions along the interfaces of two different mediums, $n \times (E_1 - E_2) = 0$.

3.The outer sides of free space are considered as scattering boundary conditions to define absorbing boundaries.

4.The boundaries of the human body are considered as an insulated $n.(k\nabla T) = 0$.

5.The internal boundaries of human body are assumed as continuous boundaries $n.(k_1\nabla T_1 - k_2\nabla T_2) = 0$

Result: All the electrical properties of tissues are taken from Tables 1.

Electrical properties	value
Permittivity of substrate of patch antenna	5.23
Permittivity of brain	49.7
Conductivity of brain	0.59[S/m]
Mass density of brain	1.04e3[kg/m^3]
Heat capacity of blood	3639[J/(kg*K)]
Mass density of liver	1050[kg/m^3]
Mass density of blood	1000[kg/m^3]
Permittivity of skin	46.7
Permittivity of heart	66
Permittivity of skin	1010
Permittivity of liver	51.2
Permittivity of kidney	66.4
Conductivity of skin	0.69[S/m]
Conductivity of heart	0.97[S/m]
Conductivity of liver	0.65[S/m]
Conductivity of kidney	1.10[S/m]
Mass density of heart	1050[kg/m^3]
Mass density of kidney	1050[kg/m^3]

Table 1. elctrictic properties of tissue at 402 MHz

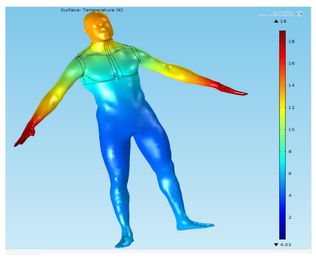

Figure 2

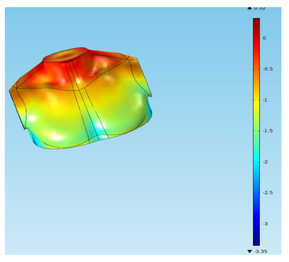

Figure 3

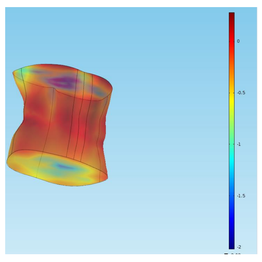

Figure 4

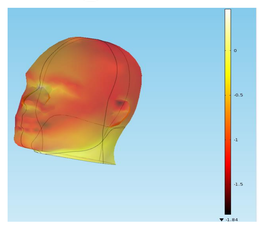

Figure 5

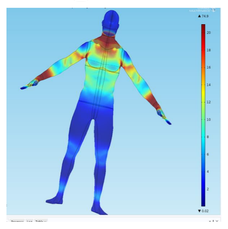

Figure 6

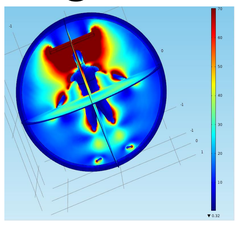

Figure 7

2.Increased Temperature variation **3**.SAR in heart
4.SAR in Lung **5**.SAR in head **6**.Temperature Gradient
7.Electric field in Human body

Conclusions: These results can be taken as a reference for better design of EM emitting devices and also for treatment of illness related to these radiations.

References:

1.André Vander Vorst, Arye Rosen, Youji Kotsuka, RF/Microwave Interaction with Biological Tissues. Hoboken, New Jersey: A John Wiley & Sons, Inc., 2006.
2.Kiran P. Singh, Nitish Kothari and Sanjana Choudhary, “Behavioural Change on EM Exposure and its Modelling,”

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