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Microwave Signal in a Magneto-Chiral Media

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Abstract: A numerical method for a microwave signal emitted by a smart phone, propagating in a magneto-chiral media, characterized by an extended Born-Fedorov formalism, is presented. It is shown that the use of a cell model, combined with a real model of the human head, derived from the magnetic resonance of images allows a good determination of the near fields induced in the head when the brain chirality and the battery magnetic field are considered together. The results on a 2-dim human head model show the evolution of the specific absorption rate (SAR coefficient) and the spatial peak specific absorption rate which are sensitives to the magneto-chiral factor, which is important in the brain layer. For smart phones, extremely low frequency real pulsed magnetic fields (in the order of 10 to 60 miligauss) are added to the model through the whole of the user's head. The more important conclusion of our work is that the head absorption is bigger than the results for a classical model without the magneto-chiral effect. Hot spots are produced due to the combination of microwave and the magnetic field produced by the smart phone´s operation. The FDTD method was used to compute the SARs inside the MRI based head models consisting of various tissues for 5 GHz. As a result, we found that in the head model having more than four kinds of tissue, the localized peak SAR as hot spots reaches maximum inside the head for over five tissues including skin, bone, blood, muscle and brain cells.

Key words: Maxwell equations · Magneto-chirality · FDTD · SAR

INTRODUCTION

There has been a flood of activity in the scientific community to assess the possibility that smart phone users may be putting themselves at higher risk for cancer. A number of studies have been published that investigate the association between the RF radiation emitted by smart phones and cancer and a handful of the epidemiological and experimental studies have been examined in this paper. On the whole, these studies have provided little reason for believing that cellular phones cause cancer. The long-term effects of cellular phone use have not been adequately evaluated due to the young age of the technology, however, there has been no concrete indication of adverse effects so far. The absence of ionizing radiation and the low energy levels associated with cell phones make it improbable that these gadgets are capable of being carcinogenic. Despite this strong negative indication, it is important that research into the science of cell phone radiation be continued so that the safety of this technology can be further confirmed to the public. In recent years there has been a continuing explosion in the growth of microwave and radio frequency communications, particularly a dramatic acceleration in the use of smart phones as a major communication link. This growth has raised the research on the effects of microwave interaction with biological tissues.

During operation, a smart phone sends data in short 15/26-ms packets [1]. As a consequence, the current flow from the battery to the transmitter is not constant, but varies according to the data packet structure of the protocol. This pulsed battery current gives rise to a magnetic field around the phone. In a conducting material, like human tissues, this pulsed magnetic field induces currents. These currents have recently been studied [2, 3] in order to assess the exposure of the human head to the magnetic field. In this paper, the exposure assessment calculations are extended with a more detailed head model where the microwave signal is considered in a magnetized environment and in this situation we discuss

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the possibility of higher risk for head cancer. Many scientists consider an acceptable level of magnetic fields, to be less than 200 nano Tesla, nT. Imprudent levels of EMFs to be from 200 nT to 700nT and dangerous levels of EMFs to be greater than 700 nT. Although these are the acceptable limits, many appliances that people use everyday exceed these limits, especially the smart or cellular phone. When a smart phone is held to the user's head, it emits low frequency magnetic field of 1000 to 6000 nT, which together with microwave fields can penetrate exposed tissues and induce energy absorption [1-3]. Even though a lot of work has been done, there is still no complete assessed knowledge about this process. However, there is a general agreement about the relevance of the correct evaluation of the mechanisms of interaction between EM fields and biological systems.

Several calculation techniques have been used by many researchers in order to evaluate the interaction between human head and mobile phone antennas. One of the most important is the finite-difference time-domain (FDTD) algorithm [4-8]. These analysis range from simple models of human head, such as homogeneous sphere to heterogeneous anatomically correct models based on magnetic resonance imaging. To address the problem and on the basis of our previous experience on chiral waves [9-14], a procedure to determine the absorption of RF waves emitted by cellular phones is presented, consisting of the following three main steps: 1) evaluation of the electromagnetic fields distribution inside the biological target, 2) modeling of human head and 3) SAR simulation by including magneto-chirality effects.

Chiral Head Model: To characterize the microwave absorption by the brain tissue, radiated by cellular phones, it is assumed that the brain tissue media is chiral. This chiral effect is due to a microscopic mechanism where the typical cell membrane of brain is a fluid bilipid layer with a lot big chiral protein molecules embedded in it. Every protein molecule is polar and will tend to align itself with an electric field and often helical rotate in its socket, so any volume of brain tissue must have a lot of cells bearing protein molecules that happen to resonate at its rotation frequency. Recent studies on DNA have shown that large electron flows are possible with the stacked base pairs of the double helix and a collective interaction of large ionic ensembles where the electromagnetic field is assumed in aqueous solutions of amino acids. Also when the twisted DNA molecule is a right-handed helix is transcribed into RNA, the DNA molecule can be unwound; another report says that signaling inside neurons can have two twists. Also, experimentally an intrinsic electric-field ion cyclotron resonance in biomolecules and microwave assisted hydrolysis of chain molecules was found [9].

Here we propose the hypothesis that all these features can be explained in a unified manner, namely the magneto-chiral model, where the bioplasma is divided into two very thin layers separated by a permeable membrane, having cylindrical microtubules or helical structures. The dimmers α and β can exist in two different geometric configurations which correspond to the electric polarization states of dimmers, whose helicoidal structure can be right (R) or left (L). Then since the protein medium is chiral, an electromagnetic wave in this medium necessarily will rotate its polarization plane in accordance with the dominant biological structure. Preliminary calculus show that the medium frequencies are between 5 and 20 GHz (microwave radiation). The eigenfrequencies, for typical proteins become between 10 GHz -12 GHz and for cluster DNA molecules the interval is between 1 GHz to 12 GHz. These frequencies are typical for microwave radiation. Accordingly with the above discussion, we consider the brain tissue as a chiral bioplasma immersed in a low magnetic field, characterized by a global chirality factor, T, so the extended Born-Fedorov constitutive equations are $\boldsymbol{B} = \mu\,(\boldsymbol{H} + T\nabla \times \boldsymbol{H}) + \boldsymbol{B}_0\,(t)$, $\boldsymbol{D} = \varepsilon\,(\boldsymbol{E} + T\nabla \times \boldsymbol{E})$ and:

$$D_{x,y,z} = \varepsilon_0\varepsilon_r E_{x,y,z} + \varepsilon_0\varepsilon_r T\left[\partial E_{z,x,y} / \partial y,z,x - \partial E_{y,z,x} / \partial z,x,y\right],$$
$$B_{x,y,z} = \mu_0 H_{x,y,z} + \mu_0 T\left[\partial H_{z,x,y} / \partial y,z,x - \partial H_{y,z,x} / \partial z,x,y\right] + B_{ox,oy,oz},$$

and so on, where, $\varepsilon\mu$ and T are the dielectric permittivity, magnetic permeability, chiral pseudoscalar, respectively. Here the magnetic field $B_0\,(t)$ of the battery and from a magnetized environment are included. Following [9-14] for a linear, isotropic, non dispersive and chiral media we can relate D and B. It is assumed that the medium is isotropic, non-permeable and non dispersive.

Discretization by FDTD: The FDTD method (Finite Difference Time Domain) initially proposed by Yee is commonly used in the resolution of Maxwell equations [15]. It has the advantages that it is not necessary to derive the wave equation of the system in order to solve the field vectors and it operates in the time domain which allows analysis of transient phenomena. Through the FDTD method the discretization of above equations is performed by considering the partial derivative approximations made by Mur [9]. Using the Yee basic algorithm notation and following [12] the Maxwell equations are transformed to:

$$\partial H_z / \partial t = 1/\mu\left(\partial E_x / \partial y - \partial E_y / \partial x\right) + T\omega\left(k_x H_y - k_y H_x\right) - 2B_{0z}\omega_0 / \mu,$$
$$\partial E_z / \partial t = 1/\varepsilon\left(\partial H_y / \partial x - \partial H_x / \partial y\right) + T\omega\left(k_x E_y - k_y E_x\right) - \sigma E_z / \varepsilon,$$

and so on, where $\omega = 2\pi f$, $k_x = 2\pi/\lambda_x$ and k_y. Here σ is the conductivity and ω_0 represents the low frequency of the magnetic field $\boldsymbol{B_0}$, with ω. Similar equations are founded for the other components$_0$ $t \leq 1$.

Above a grid point in space is defined as (i, j, k) with coordinates (i?x, j?y, k?z) where ?x = ?y = ?z = ? is the cubic cell size and ?t is the time increment. An important problem encountered in solving the time domain electromagnetic-field equation, by FDTD method is the absorbing boundary conditions. In our formulation, the second order approximation of Mur is used for the near-field irradiation problems. The outer absorbing cells are placed at a distance of 4-6? on all sides of the human head model. After calculation of the induced chiral electric field by the FDTD method, the local specific absorption rate SAR, is calculated as [5]:

$$SAR_{i,j}(\beta) = \sigma_{i,j}\, E_T^2\Big|_{i,j} / 2\rho_{i,j} \qquad (1)$$

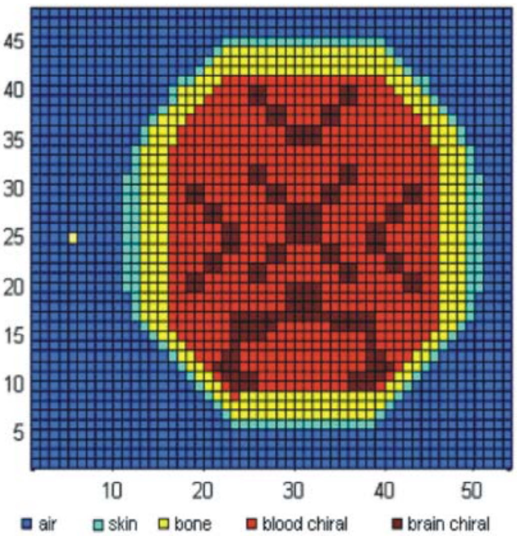
where $\beta = T + 2B_{0x}\ \omega_0 / H_0\omega\mu$ and:

$$E_T\Big|_{i,j}(\beta) = \sqrt{(1/n)\sum_{1}^{n} E_y^2\Big|_{i,j}^{n} + E_x^2\Big|_{i,j}^{n} + E_z^2\Big|_{i,j}^{n}} \qquad (2)$$

SAR Simulation: Using the linear FDTD algorithm with chirality and magnetic field, obtained from (1) and (2), some simulations for the microwave spectrum are made. The human head model is based in magnetic resonance image. The model was constructed with 345, 600 cubic cells. The total number, counted from the bottom of the head, of layers used in this model was 54. Here we choose the 34th layer because there are great concentrations of brain tissue. The 34th layer is digitalized from a respective MRI image (matrix of 80 x 80), are shown in Fig. 1 of ref [9]. Both the dielectric constant and the conductivity of the brain were obtained from literature [8, 16]. The calculations were made with an initial sinusoidal time varying electric field.

To analyze the effects of cellular phones radiation we considered the ANSI/IEEE C95.1 standard, where the parameters of concern with respect to human health are the rate at which a user absorbs electromagnetic energy, is the SAR. In order to find the power density in the area close to an active cellular phone, the radiation source of the cellular phone was modeled by an equivalent dipole antenna. The main considerations made to develop the simulation runs are: 1) The frequency used was 5.000 MHz and 2) For the 34th layer 4 types of tissues (skin, bone, blood and brain) are considered.

Analysis of Results: The simulation results, for layer 34, are shown in the Figs. 2 and 3, where the SAR variation as found moving inside head is presented. The distance between the antenna and the head was assumed to be 2.0 cm, the Figs. 2a and 2b represent the variation of the local SAR as a function of the inner head distance for a fixed value of the magnetic field and the chiral factor is a parameter. Under the following power conditions (0.25 and 1.0 W), the values of the magnetic factor, $B_0\omega_0$, produced by the current battery are 10^{-5} and 10^{-4} approximately. A normal variation of SAR for low values of chiral and magnetic factor was observed k $\beta \leq 0.1$ and $\beta_0\ \omega_0 \leq 10^{-6}$, can be compared with the numerical SAR of [8] and the measured and computed SAR values of [18]. The form of the response of SAR, in these figures, decrease very quickly due to the wave absorption by the different mediums of the head, but it is observed too that the SAR has an impulsive response (hot points) in several cells inside the head. Like these hot points are due to the magneto-chiral effects, they are null for k$\beta = 0$ and $B_0\omega_0 = 0$. The combination of chiral effect of the brain layer and the effect of the magnetic field makes that the SAR increases. In considering both factors ($k\beta$ and $B_0\omega_0$), the increase of hot point peak magnitude may be very large, thus in Fig. 2a the increase is 2 times for $B_0\omega_0 = 10^{-5}$ and $k\beta = 0.2$. For $B_0\omega_0 = 10^{-4}$ the increase is 12 times for $k\beta = 0.2$.



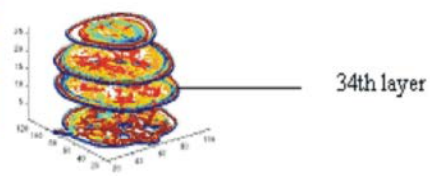
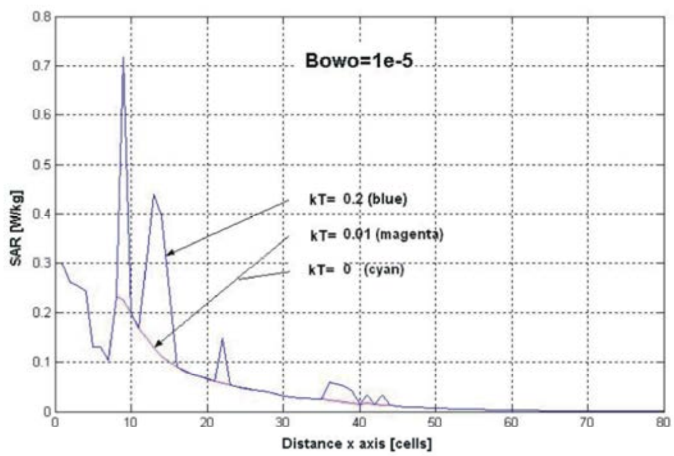
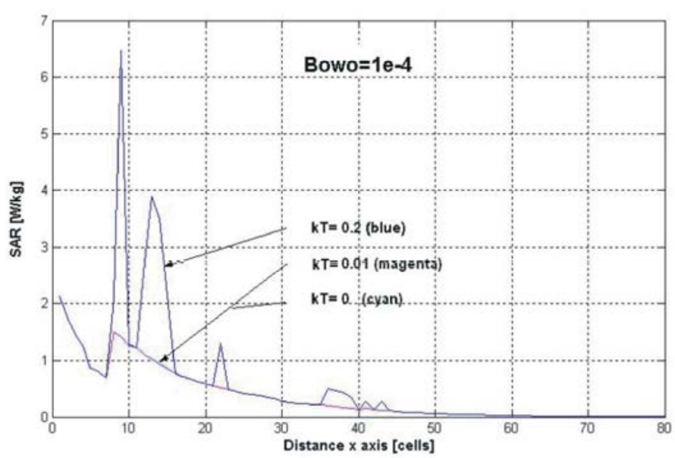


Fig. 1a: The 34th discretized layer, Fig. 1b: Position of the 34th layer in the whole brain

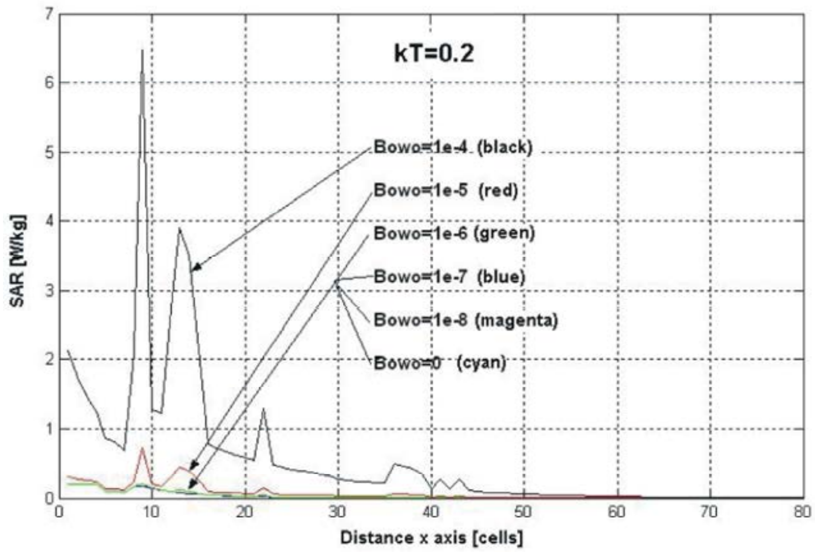


(a)

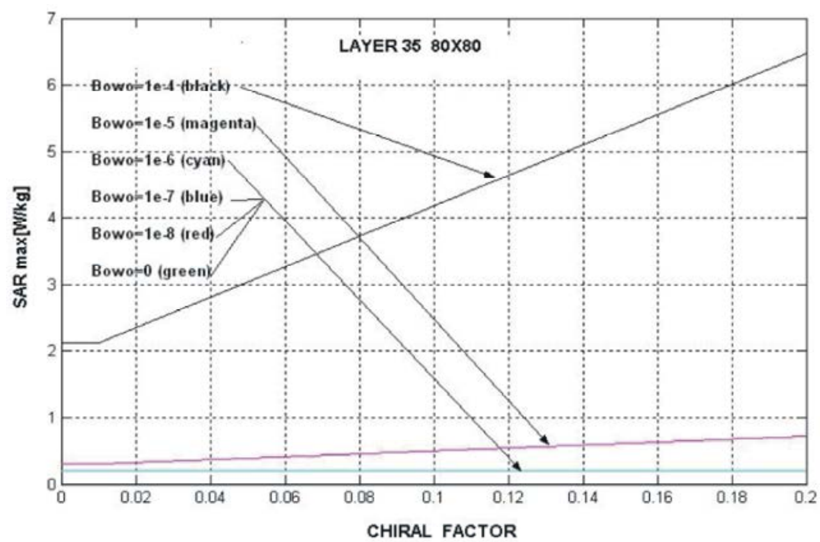


(b)

Fig. 2: Maximum SAR, for 34th layer, as a function of the inner head distance having as parameter the $B_0\omega_0$ factor and $k\beta$ = constant



(a)



(b)

Fig. 3: Maximum SAR, for 34th layer, as a function of the inner head distance having as parameter the chiral factor and $B_0\omega_0 = cte$.

For higher values of the magneto-chiral factor an increase in ripple response (hot spans) of SAR (Figs. 2a and 2b with $0.2< k\beta \leq 0.6$ and $10^{-5}<\beta_0\omega_0 \leq 10^{-4}$) was observed. The profile of local SAR across the layered head model is similar to Fig. 6 of [4]. Similar results are obtained when the chiral factor is constant and the magnetic field is taked into account as parameter and are showing in Figs. 3a and 3b. A synthesis of systematic simulations are observed in Fig. 3b, where the maximum SAR variation v/s chiral factor for different values of magnetic field is shown. In this figure we may conclude that there is a threshold starting in $k\,\beta \geq 0.1$ and Boωo $\geq$1e-4.

The results obtained with the magneto-chiral model, in the determination of the magnitude and the distribution of the SAR coefficient, Figs. 2 and 3, are similar to those obtained by others authors [17, 18] using different models than the one shown in this work, only in the case which $k\beta = 0$ and $\beta_0\omega_0 = 0$. It was demonstrate that the effect of the presence of magnetic-Faraday and chiral factors is to augment the absorption of microwave of cellular telephones and, principally, enable the hot points appearing in the 34^{th} layer case. For higher values of the magneto-chiral factor a increase in ripple response (hot spans) of SAR (Figs. 3a and 3b with $0.2 < k\beta \leq 0.6$ and $10^{-5} < \beta_0\omega_0 \leq 10^{-4}$) was observed. The profile of local SAR across the layered head model is similar to Fig. 6 of [4]. In this case it is possible to have a higher risk for head cancer.

CONCLUSIONS

A bioplasmatic magneto-chiral model of the human head has been presented that allows determination and evaluation of the absorption induced by the radiation of cellular phone. Electromagnetic fields radiated were determined firstly by means of the FDTD technique and then the specific absorption coefficient (SAR) was calculated. It is shown that the use of a cell model, combined with a real model of the human head, derived from the magnetic resonance of images allows a good determination of the near fields induced in the head when the brain chirality and the battery magnetic field are considered. The simulations are made for the 34^{th} layer. The results show the evolution of the specific absorption rate, (SAR coefficient), as a function of battery's magnetic field and chiral factor. The more important conclusions of our work are: 1) with the magneto-chiral model, the head absorption of microwave fields, produced by smart phones, is bigger that the results obtained for classical models and 2) in the case of 34^{th} layer is verified the existence of hot spots, whose magnitude depend of magnetic field intensity and the brain chirality. This hot spot can generate a higher risk for head cancer when we consider the long-term effects of microwaves of cellular or smart phone.

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