METACHIRAL MODEL FOR HUMAN HEAD RADIATED BY MICROWAVES AND MAGNETIC FIELD EMITTED FROM CELLULAR PHONES

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Abstract

A mathematical numerical method (Finite-Difference Time-Domain FDTD) for a microwave signal emitted by a cellular phone, propagating in a human head model is presented. The different biological tissues are characterized by the Born-Fedorov formalism. The results on a 2-Dim human head model show the evolution of the specific absorption rate, (SAR coefficient), in function of input power, antenna impedance and electromagnetic parameters of layer tissues. The spatial peak specific absorption rate (SAR) is sensitive to the magnetic-chiral factor, which is important in the brain metamaterial layer. For GSM/PCN phones extremely low frequency real pulsed magnetic fields are added to the model as they travel right through the whole of the user's head (in the order of 10 to 60 milligauss). The more important conclusion of our work is that the head absorption, is bigger that the results for a classical model. The hot spots are produced due to the combination of microwave and the magnetic field produced by the phone´s battery.
Also, we investigate the relationship between the brain's meta chiral effect and the localized peak SARs (specific absorption rate) inside our model. The FDTD method was used to compute the SARs inside the MRI based head models consisting of various tissues for 0.9 and 1.8 GHz microwave. The localized peak SAR reaches maximum inside the head for over five tissues including skin, fat, muscle, bone, and brain.
The results show the evolution of the specific absorption rate, (SAR coefficient), as function battery's magnetic field and meta-chiral factor.
Key Words: Maxwell equations, metachirality, FDTD, SAR

Resumen.

Se presenta un modelo electrodinámico constituido por un fluido de bioplasma con capas metaquirales, el cual permite representar la estructura interna de la cabeza humana y analizar su comportamiento cuando es radiada por campos electromagnéticos de microondas en el espectro de la telefonía celular. Como técnica numérica se utilizó el de las diferencias finitas en el dominio del tiempo, FDTD, la cual permite simular, primeramente, los campos electromagnéticos deducidos de las ecuaciones de Maxwell y en seguida simular la tasa de absorción específica, SAR. Los resultados obtenidos muestran el comportamiento del coeficiente SAR en función de la potencia de entrada, de la impedancia de la antena, del factor de metaquiralidad y del campo magnético producido por la corriente de la bateria. La conclusión más importante de nuestro trabajo es que, al haber considerado el factor metaquiral combinado con efectos de campo magnético de baja frecuencia en el modelo de fluido propuesto, la absorción en la cabeza humana, producto de los campos electromagnéticos emitidos por los teléfonos celulares, es hasta un 100% mas elevada que en el modelo clásico. obtenida por otras simulaciones de diferentes autores En los modelos clásicos la tasa de absorción es en torno de 1-1.5 mwatt/gr, en los cuales sólo se considera la permeabilidad, la permitividad y la conductvidad eléctrica del tejido biológico.

Descriptores: Ecuaciones de Maxwell; Metaquiralidad; FDTD; SAR

1. INTRODUCTION

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 cellular phones as a major communication link. This growth has raised the research on the effects of microwave interaction with biological tissues and the level of interference on electronic equipment. Government, industry and university researchers are attempting to assess the risk, if any, of the communication revolution and determine if need exists for the establishment of new regulations.

Many scientists consider an acceptable level of magnetic fields, to be less than 200 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 cellular phone. When a cellular phone is held to the user's head, it emits low frequency magnetic field of 1000 to 6000 nT, which together microwave fields can penetrate exposed tissues and induce energy absorption [1]. 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 [2] [3] 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. Two of the most important are the frequency-domain method of moments [4] and the finite-difference time-domain (FDTD) algorithm [5] [6] [7] [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 [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.

2. BIOLOGICAL AND ELECTRODINAMICS POINT OF VIEW.

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 chiral-electrodynamics 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 10 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 Born-Fedorov constitutive equations are

$$\boldsymbol{D} = \varepsilon\left(\boldsymbol{E} + \beta\nabla\times\boldsymbol{E}\right) \tag{1}$$

$$\boldsymbol{B} = \mu\left(\boldsymbol{H} + \beta\nabla\times\boldsymbol{H}\right) + \boldsymbol{B_0} \tag{2}$$

where ε, μ, and β are the dielectric permittivity, magnetic permeability, chiral pseudoscalar respectively. Here, the magnetic field $\boldsymbol{B_o}$ of the battery is included. [1, 4]. Following [9], .for a linear, isotropic, nondispersive and metachiral loss media we can relate D and B. If it is assumed that the medium is isotropic, non-permeable and non dispersive, the Cartesian field components of Maxwell equations are like

$$\frac{\partial H_z}{\partial t} = \frac{1}{\mu}\left(\frac{\partial E_x}{\partial y} - \frac{\partial E_y}{\partial x}\right) + \beta\omega\left(k_x H_y - k_y H_x\right) - \frac{2B_{0z}\omega_0}{\mu} \tag{3}$$

$$\frac{\partial E_z}{\partial t} = \frac{1}{\varepsilon}\left(\frac{\partial H_y}{\partial x} - \frac{\partial H_x}{\partial y}\right) + \beta\omega\left(k_x E_y - k_y E_x\right) - \frac{\sigma}{\varepsilon} E_z \tag{4}$$

And so on, where $\omega = 2\pi f$, $k_x = 2\pi/\lambda_x$ and $k_y = 2\pi/\lambda_y$. Here σ is the conductivity and ω_o represents the low frequency of the magnetic field $\boldsymbol{B_0}$, with. $\omega_o t \le 1$

3. DISCRETIZATION BY FDTD

The FDTD method (Finite Difference Time Domain) initially proposed by Yee is commonly used in the resolution of Maxwell equations [16]. 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 [11]. Using the Yee basic algorithm notation, the equations are transformed to [17]:

$$\begin{aligned} H_z\Big|_{i,j+1}^{n+1} = H_z\Big|_{i,j+1}^{n} &+ C_{ay}\left(E_x\Big|_{i,j+3/2}^{n+1/2} - E_x\Big|_{i,j+1/2}^{n+1/2}\right) - C_{ax}\left(E_y\Big|_{i+1/2,j+1}^{n+1/2} - E_y\Big|_{i-1/2,j+1}^{n+1/2}\right) + C_{qx}\, H_y\Big|_{i,j+1}^{n+1/2} \\ &- C_{qy}\, H_x\Big|_{i,j+1}^{n+1/2} - \frac{2B_{0z}\omega_0}{\mu} \end{aligned} \tag{5}$$

$$\begin{aligned} E_z\Big|_{i-1/2,j+1/2}^{n+1/2} &= D_a\Big|_{i-1/2,j+1/2} E_z\Big|_{i-1/2,j+1/2}^{n+1/2} + D_{bx}\Big|_{i-1/2,j+1/2}\left(H_y\Big|_{i,j+1/2}^{n} - H_y\Big|_{i-1,j+1/2}^{n}\right) \\ &- D_{ay}\Big|_{i-1/2,j+1/2}\left(H_x\Big|_{i+1/2,j+1}^{n} - H_x\Big|_{i+1/2,j}^{n}\right) + D_{qx}\, E_y\Big|_{i-1/2,j+1/2}^{n-1/2} - D_{qy}\, E_x\Big|_{i-1/2,j+1/2}^{n-1/2} \end{aligned} \tag{6}$$

And so on, where

$$C_{ay} = \frac{\Delta t}{\mu_0 \Delta y}\ ; \quad C_{ax} = \frac{\Delta t}{\mu_0 \Delta x}\ ; \quad C_{qy} = \beta\omega k_y \Delta t + \frac{2B_{0x}\omega_0}{H_0 \mu}\Delta t\ ;$$

$$C_{qx} = \beta\omega k_x \Delta t + \frac{2B_{0y}\omega_0}{H_0\mu}\Delta t, \ldots . f(\beta, B_0\omega_0) = \beta + \frac{2B_{0x}\omega_0}{H_0\omega\mu}$$

$$D_a\Big|_{i,j} = \frac{2\varepsilon_{i,j} - \sigma_{i,j}\Delta t}{2\varepsilon_{i,j} + \sigma_{i,j}\Delta t}\ ; \quad D_{by}\Big|_{i,j} = \frac{2\Delta t/\Delta y}{2\varepsilon_{i,j} + \sigma_{i,j}}\ ; \quad D_{bx}\Big|_{i,j} = \frac{2\Delta t/\Delta x}{2\varepsilon_{i,j} + \sigma_{i,j}}$$

$$D_{qy} = \left(\beta\omega k_y \Delta t\right) \Big/ \left(1 + \frac{\sigma_{i,j}\Delta t}{2\varepsilon_{i,j}}\right)\ ; \quad D_{qx} = \left(\beta\omega k_x \Delta t\right) \Big/ \left(1 + \frac{\sigma_{i,j}\Delta t}{2\varepsilon_{i,j}}\right)$$

Above a grid point in space is defined as (i, j, k) with coordinates (iΔx, jΔy, kΔz) where Δx=Δy=Δz=Δ is the cubic cell size and Δt 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 4-7Δ 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].

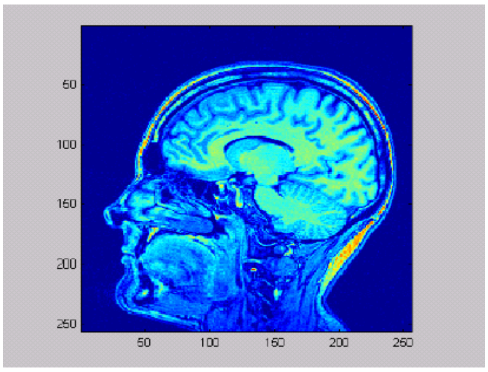
$$SAR_{i,j}(\beta, B_0\omega_0) = \frac{\sigma_{i,j}\, E_T^2\big|_{i,j}}{2\rho_{i,j}} \qquad (7)$$

Where:

$$E_T\big|_{i,j}(\beta, B_0\omega_0) = \sqrt{\frac{1}{n}\sum_{1}^{n} E_y^2\Big|_{i,j}^{n} + E_x^2\Big|_{i,j}^{n} + E_z^2\Big|_{i,j}^{n}}$$

4. **SAR SIMULATION.**

Using the linear FDTD algorithm with chirality and magnetic field, obtained from eq. (5) and (6), some simulations for the microwave spectrum are made. The human head model is based in magnetic resonance image, as shown in Figs. 1 and 2. The model was constructed with 64,000 cubic cells. The total number, counted from the bottom of the head, of layers used in this model was 50. The 12^{th} and 34^{th} layers, digitalized from respective MRI images (matrix of 80x80), are shown in Fig. 3a and 3b, respectively. Both the dielectric constant and the conductivity of the brain were obtained from literature [8] [17]. 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, where a set of equivalent resistors *Ra* of 40, 120 and 180 ohms were assumed at the center gap of the equivalent dipole antenna. As transmitted power we used the GSM system power: 0.25, 2 and 3.56 W. Following the equation $P = V^2 / 2R_a$, the voltage across the center gap of the equivalent antenna was calculated as a function of *Ra*. The main considerations made to develop the simulation runs are: 1) The frequency used was 900 MHz, 2) The cellular phone antenna produces an isotropic signal; we assumed that a plane wave propagates from the center of the antenna, and 3) 4 types of tissues (skin, bone, blood and brain) are considered.



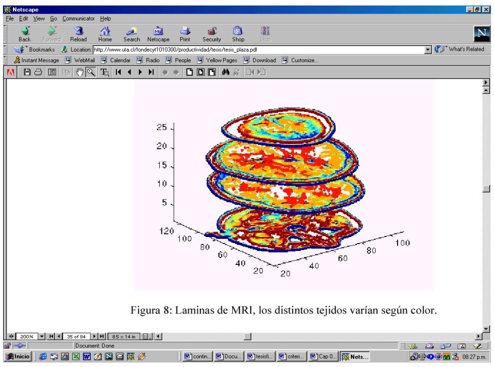


Fig. 1: The tissues are identified according to colors. **Fig. 2:** Transverse cuts sheets of MRI.

Fig. 3a: Layer 12^{th}

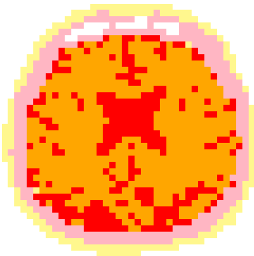


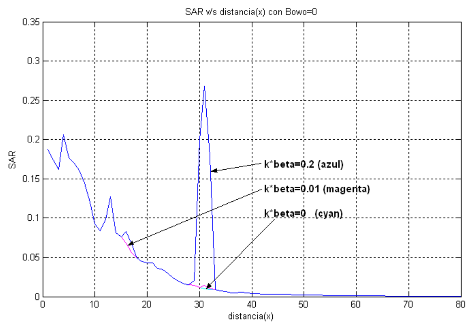
Fig. 3a: Layer 34^{th}

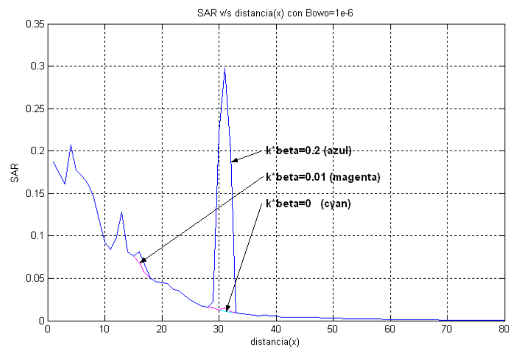
TISSUE	MEDIUM
Air	0
Skin	1
Bone	2
Brain	3
Blood	4
Muscle (eyes)	5
Optic Nerve	6
Muscle (temporal)	7
Iris	8
Eyes	9

Table 1

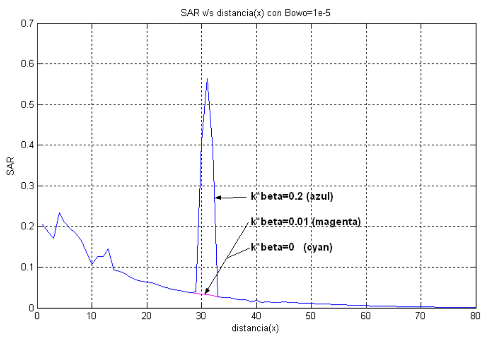
5. ANALYSIS OF RESULTS

The simulation results, for layers 12 and 34, are shows in the Figs 4 – 7, where the SAR variation as found moving inside head is presented. Figs 4a - 4d represents the variation of the maximum SAR, in the 12th layer, as a function of the inner head distance for a fixed value of magnetic field and the chiral factor is parameter. The form of the response of SAR, in these figures, decresase very quickly due to the wave absorption by the different mediums of the head, but it observed too that the SAR has a impulsive response (hot point) between cells Nº 30-32. Like this hot point is due to the magneto and chiral factor is null for kβ=0 and Boωo=0 (Figs. 4a-4d). The hot point peak magnitude increase, due only the chiral factor, almost 6 times for kβ=0.1 and 13 times for kβ=0.2 (Fig. 4a). In considering both factors (kβ and Boωo), the increase of hot point peak magnitude may be very large, thus in Fig. 4c the increase is 2 times for Boωo=10e-5 and kβ=0.1 or kβ=0.2. For Boωo=10e-4 the increase is 12 times for kβ=0.1 or kβ=0.2.

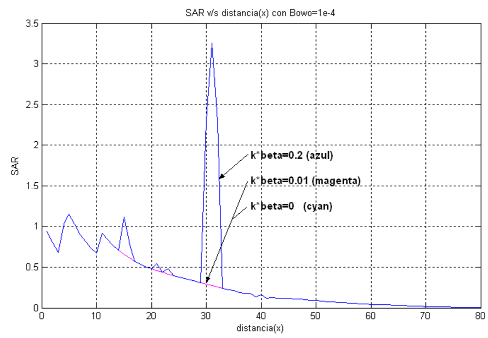




(a)
(b)



(c)



(d)

Fig. 4 Variation of the maximum SAR, for 12th layer, as a function of the inner head distance and the magnetochiral factor.

Fig. 5 represent the variation of the maximum SAR, in the 12th layer, for a fixed value of chiral factor and the magnetic field is parameter, and it observed a normal variation of SAR for null chiral factor and maximum magnetic field of 1e-4 (Figs. 5a-5b). The Fig. 5c shows the joint effect of magnetic field and chiral factor in the peak value of hot point, beginning for a chiral factor of kβ=0.2 and magnetic field of Boωo≤1e-5. In the last figure it observed too a maximum peak of SAR of 3.2 W/kg for Boωo=1e-4. The sistematic simulations, similar to those the Figs. 5a to 5c, it permett to obtain the graphic of Fig. 5d, where it observed the maximum SAR variation v/s chiral factor for different values of magnetic field.
Fig. 6 represent the variation of the maximum SAR, in the 34th layer, for a fixed value of magnetic field and the chiral factor is parameter. It observed a normal variation of SAR for low values of chiral and magnetic factor (kβ≤0.2 and Boωo≤1e-6 in Figs. 6a-6b). For higher values of magneto-chiral factor it observed a decrease riplle response of SAR (Figs. 6c-6d with 0.2<kβ≤0.6 and 1e-5 <Boωo≤1e-4).
The same results of Figs. 6 are obtenued when the chiral factor is constant and the magnetic field the is a parameter and are shows in Figs. 7a-7c and the Fig. 7d it observed the maximum SAR variation v/s chiral factor for different values of magnetic field.

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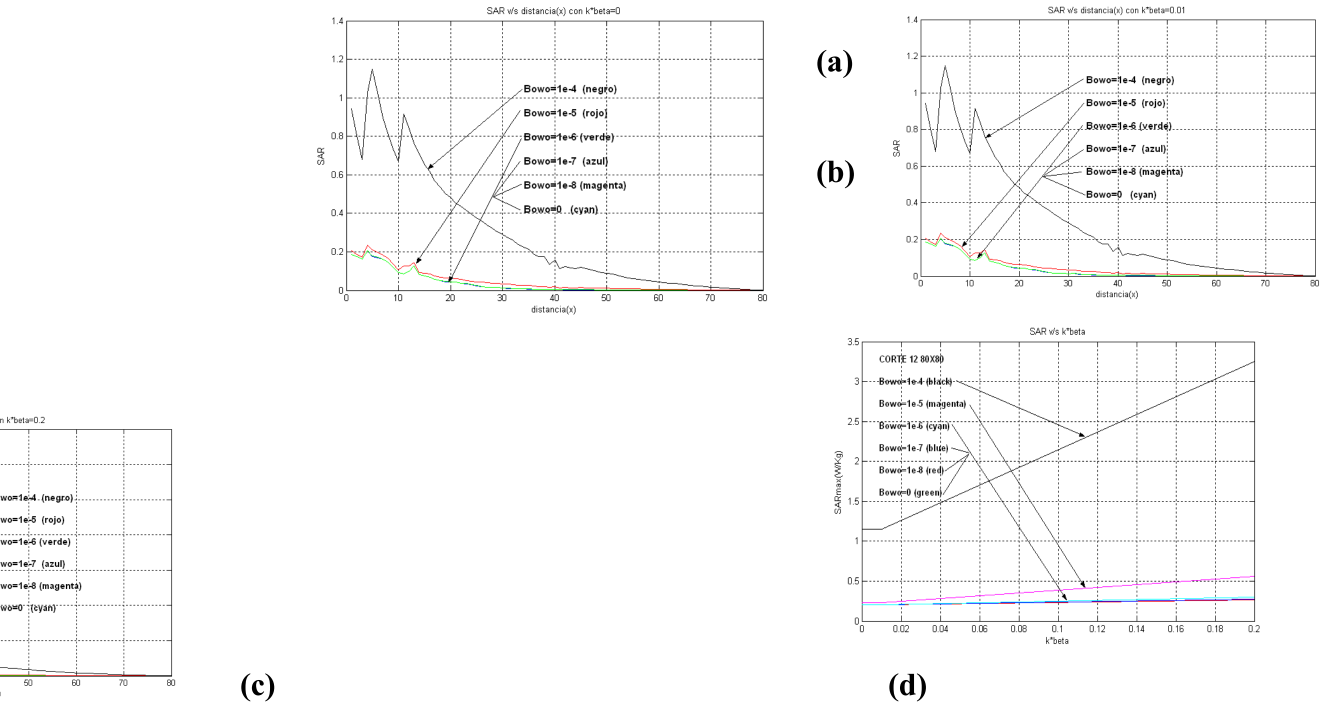
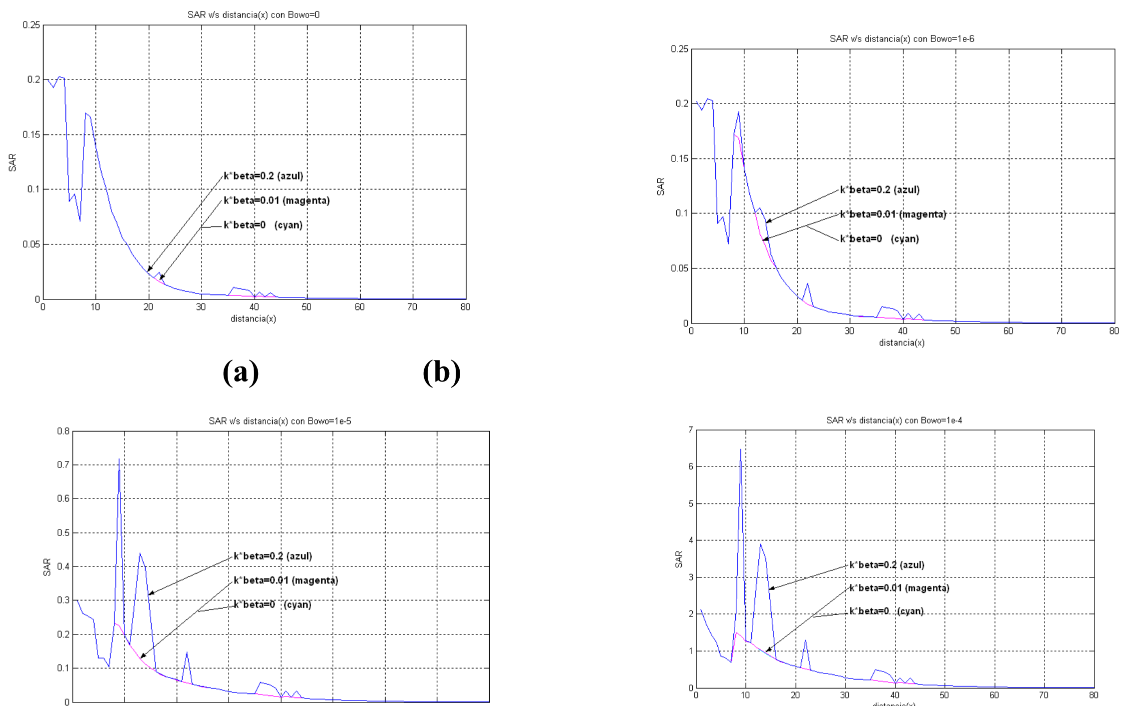


(a) (b) (c) (d)

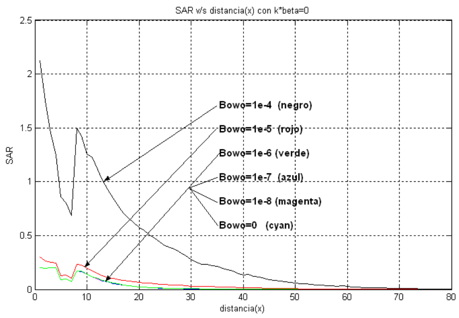
Fig. 5 Maximum SAR, for 12th layer, as a function of the inner head distance and the magnetochiral factor (Figs 5a-5c). Fig. 5d shows the maximum SAR v/s chiral factor different values of magnetic field.



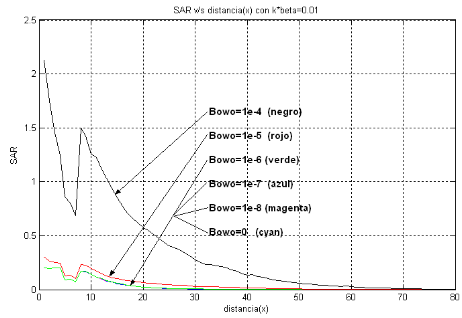
(a) (b)

(c) **(d)**

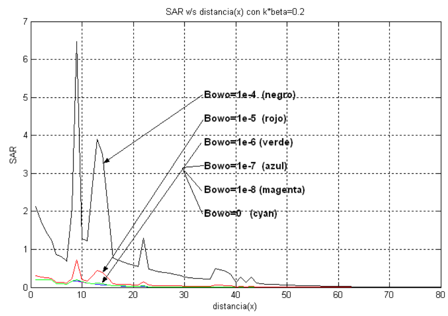
Fig. 6 Maximum SAR, for 34th layer, as a function of the inner head distance and the magnetochiral factor.



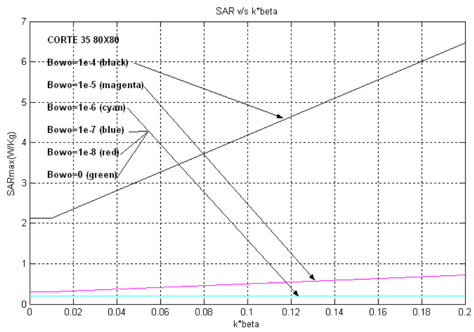
(a)



(b)



(c)



(d)

Fig. 7 Maximum SAR, for 34th layer, as a function of the inner head distance and the magnetochiral factor.

The results obtained with the magneto-chiral bioplasmatic model, in the determination of the magnitude and the distribution of the SAR coefficient (Figs. 4-7), are similar to those obtained by others authors [19]-[20] using different models than the one shown in this work, only in the case which $k\beta=0$ and $B\omega o=0$. It was demonstrate that the effect of the presence of magnetic and chiral factors is to augment the absorption of microwave of cellular telephones and, principally, enable the hot point appearing in the 12th layer case.

6. 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). 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 exact 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 12th and 34th layers. The results also show the evolution of the specific absorption rate, (SAR coefficient), as function of input power, antenna impedance, battery's magnetic field and meta-chiral factor. The more importants conclusion of our work are: 1) with the magneto-chiral electrodynamics model the head absorption of microwave fields, produced by cellular phones, is bigger that the results obtained for classical models, and 2) in the case of 12th layer is verified the existence of hot point, whose magnitude depend of magnetic field intensity and the medium chirality.

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