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Metalik Ortopedik İmplantlı Vücutta Elektromanyetik Alanlara Maruziyetin İncelenmesi

Investigation of the Exposure to Electromagnetic Fields in the Body with Metallic Orthopedic Implant

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Özetçe— **Bu çalışmada özellikle endüstriyel alanlarda kullanılan kablosuz iletişim sistemlerinin, implant bulunan insan vücudu üzerindeki etkileri incelenmiştir. Çalışmada insan vücudunun elektriksel özellikleri dikkate alınarak oluşturulan bir model üzerinde, ilgilenilen dokuda özgül soğurma oranı (SAR) değişimleri belirlendi. Günümüzde, radyo frekans dalgalarına maruziyet, bu cihazların kullanımının hızla yaygınlaşmasına paralel olarak daha fazla artmaktadır. Kontrolsüz maruz kalmanın canlı organizmalar üzerindeki zararlı etkilerinin olduğunu bildiren birçok çalışma vardır. Bu çalışmada, insan modelinin yakınına bir düzlem dalga kaynağı yerleştirilmiştir. Ortalama SAR kütlesi 10 gram olarak alınmıştır. Simülayonlarda, 900 MHz, 1800 MHz ve 2450 MHz çalışma frekansları için elektrik alan değerleri sırasıyla 41.25 V / m, 58.33 V / m ve 61 V / m (ICNIRP tarafından belirlenen radyasyon limitleri) olarak alınmıştır. Elde edilen simülasyon sonuçlarına göre implantlı kolda SAR değerlerinin 1800 ve 2450 MHz frekanslarında implantlı olmayan modele göre arttığı, ayrıca frekans değerinin azalmasıyla SAR farkının azaldığı gözlemlenmiştir.**

Anahtar Kelimeler — Electromanyetik Alan Maruziyeti, Özgül Soğurma Oranı, Metalik Ortopedik İmplantlar

Abstract—**In this study, especially the effects of wireless communication systems used in industrial areas on human body with implant were investigated. The specific absorption rate (SAR) changes on a model considering the electrical properties of the human body in the study were determined in the tissue of interest. Nowadays, radio frequency waves are increasingly exposed in parallel with the rapid spread of the use of these devices. There are many studies reporting that harmful effects of this uncontrolled exposure on living organisms are present. In this study, a plane wave source was placed near the human model. Average SAR mass was taken as 10 grams. In the simulations, the electric field values for the 900 MHz, 1800 MHz and 2450 MHz operating frequencies were taken as 41.25 V/m, 58.33 V/m and 61 V/m respectively (the radiation limits set by ICNIRP for public exposure). According to the obtained simulation results, it was observed that the SAR values were increased in the arm with implant at the 1800 and 2450 MHz frequencies compared to the non-implanted model, and it was also observed that as the frequency value decreased.**

Keywords — Electromagnetic Field Exposure, Specific Absorption Rate, Metallic Orthopedic Implants

I. INTRODUCTION

There are a lot of people carrying metal items in their bodies. These items may comprise medical implants, including orthopedic plates, screws, wires and rods. It is well known that metallic materials interact strongly with electromagnetic fields [1]. Implants, in particular orthopedic implants, may have various possible dimensions as well as complex shapes depending on clinical requirements. For example, an orthopedic implant may be of different lengths depending on the size required for the patient [2]. Feng, David X et al. evaluate the MRI safety for 39 commonly used medical implants at 7.0 T. In referred this study, chosen metallic implants were tested for

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magnetic field interactions, radiofrequency-induced heating and artefacts using standardized testing techniques [3]. In [4], the researchers present characterization of through-the-body UHF-RFID (860–960 MHz) links for passive tags implanted into human limbs [4].

In [5], numerical methods and modelling were used to estimate the effect of a passive, metallic superficial implant on a mobile phone electromagnetic field and especially its absorption in tissues in the near field.

The dosimetry of exposure to radio frequency electromagnetic fields of mobile phones is generally based on the SAR, which is the electromagnetic energy absorbed in tissues per unit mass and time [5]. In [6], the authors investigate RF induced heating on cornea passive metallic implants at 1.5 T and 3.0 T [6]. In [1], the researchers investigates the effect of electromagnetic waves on eight different orthopedic medical devices were explored on six human cadavers [1]. In [7], the authors present an example of how numerical electromagnetic and thermal modelling can be used to specify whether scattered RF fields around metallic implants in workers [7]. In [8], the researchers present a novel mechanistic model and computational approximation for electromagnetic safety evaluations of electrically short implants [8].

Well-known associations have defined the SAR limits. Thus, electromagnetic hazards for specified frequency can be pretended. SAR limit values defined by ICNIRP and IEEE is 4 W/kg for limb (for 10 gr average tissue) [9,10].

In this study, the effects of communication instruments and wireless systems on the body of people carrying metallic implants were investigated. The specific absorption rate (SAR) changes on a model taken into account the electrical properties of the human body were determined in the tissue of interest. It is aimed to determine the SAR changes of different frequencies emitted by wireless communication devices on human body with and without implant.

II. MATERIALS AND METHODS

Specific absorption rate (SAR) is known as absorbed electromagnetic energy in any biological tissue. SAR causes increase of heat in induced tissue. SAR depends on frequency, dielectric constant of the tissue and many of environmental and personal parameters.

With the developing technology, SAR levels have been determined by using SAR probes. In addition, phantom modeling and numerical calculations have been used to examine SAR levels. In phantom modeling, the electrical equivalent of the human body is created and measured in laboratory conditions. The formulations that is used for the numerical SAR calculations is given in Equation 1.

$$SAR = \frac{dW/dt}{\rho} = \frac{Q_{ext}}{\rho} = \frac{\sigma|\mathbf{E}|^2}{\rho} = \omega\varepsilon_0\varepsilon''\frac{|\mathbf{E}|^2}{\rho} \qquad (1)$$

where ε_0 and ε'' represent permittivity of free space and imaginary part of complex permittivity, respectively. ρ is the biological tissue density (kg/m3). ω is an angular frequency. t represents the time (s) and |**E**| is the amplitude of the electric field (V/m).

According to Equation 1, electrical field value on tissue, electrical conductivity of tissue and tissue density must be known in order to SAR calculation. In Equation 2, knowledge of the temperature change in tissue is sufficient information for the SAR calculation.

$$SAR = C\frac{dT}{dt} \qquad (2)$$

where C is defined as tissue specific heat capacity, dT/dt is the temperature increase in tissue [11].

SAR analyzes have been carried out through the finite integration technique (FIT) based simulation software called. Gridding process is applied as a finite integration technique like finite difference time domain (FDTD) method. However, unlike the other techniques, FIT uses integral form of Maxwell's equations [12]. In this study, the human model which is used in simulations has been consisted of voxels. Voxel is defined as the smallest unit of the three dimensional objects. Resolution of one voxel for human model is defined as 8×8×8 mm. A sample human body model is shown in figure 1.

Figure 1. Human body model [13,15]

Dielectric properties of biological structures might be obtained through complex permittivity measurement at desired frequency [14]. In this way, interaction between the incident electromagnetic wave and living tissue can be explained.

$$\varepsilon^* = \varepsilon' - j\varepsilon'' \qquad (2)$$

Where, j is the $\sqrt{-1}$, ε^* represents the complex permittivity and ε' defines the real part of the complex permittivity.

$$\sigma = \omega\varepsilon_0\varepsilon'' \qquad (3)$$

Dielectric properties of some biological tissues [11, 14] used in this paper is given in Table 1.

TABLE I . Electrical properties of some biological tissues.

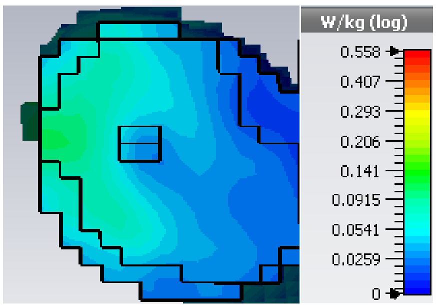
	900 MHz		1800 MHz		2450 MHz	
Tissue	ε'	σ (S/m)	ε'	σ (S/m)	ε'	σ (S/m)
Skin	41.4	0.867	38.8	1.184	38.00	1.464
Fat	5.46	0.051	5.34	0.078	5.28	0.104
Muscle	55.95	0.969	54.44	1.389	53.57	1.810

III. SIMULATION RESULTS

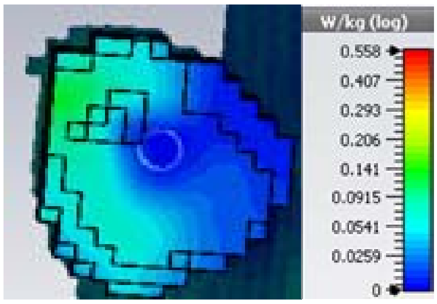
In the simulations, the plane wave source has been located at the near the human model. The average SAR mass has been taken as 10 gr. Limit value for 900 MHz was 41.25 V/m determined by the ICNIRP for the electric field. As the limit value for 1800 MHz, the ICNIRP value for the electric field is 58.33 V/m, and, the limit value is 61 V/m for 2450 MHz.

Fig. 2a, Fig. 3a, Fig. 4a shows the changes in the SAR occurring on a horizontal cross-section taken from the human model at frequencies 2450 MHz, 1800 MHz and 900 MHz respectively.

Fig. 2b, Fig. 3b, Fig. 4b shows the SAR changes on a horizontal cross section taken in the case of an implant in the arm in the human model at frequencies of 2450 MHz, 1800 MHz and 900MHz, respectively. In table 2, maximum induced SAR values for 10 gr average tissue is given.

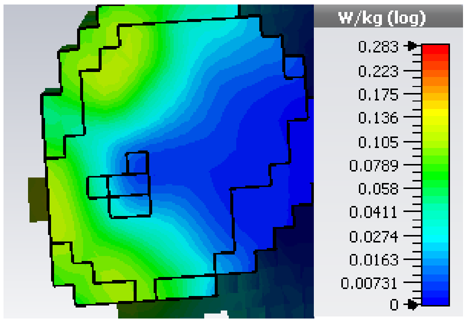


(a)

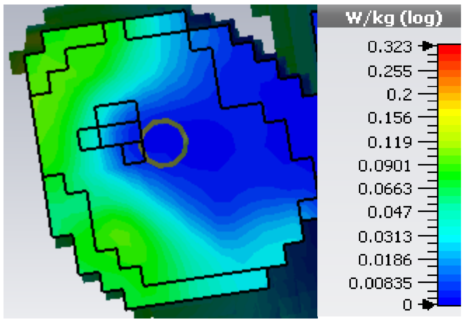


(b)

Figure.2. SAR distributions on horizontal cross-section at 900 MHz for a) non-implanted human arm and b) implanted human arm.

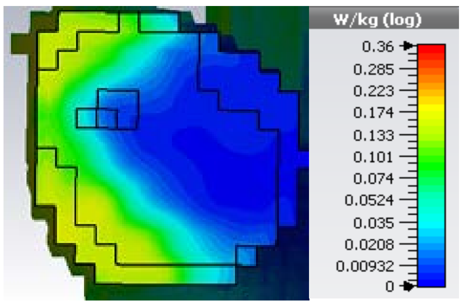


(a)

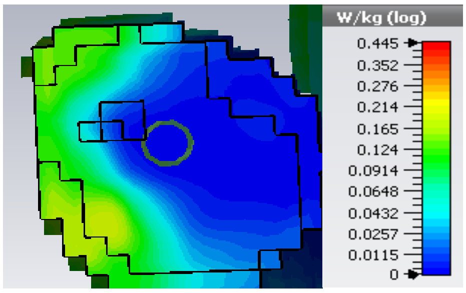


(b)

Figure.3. SAR distributions on horizontal cross-section at 1800 MHz for a) non-implanted human arm and b) implanted human arm.



(a)



(b)

Figure.4. SAR distributions on horizontal cross-section at 2450 MHz for a) non-implanted human arm and b) implanted human arm.

TABLE II. Maximum induced SAR for 10 gr average tissue (W/kg)

Frequency	*non-implanted (SAR)*	*implanted (SAR)*
900 MHz	0.558 W/kg	0.558 W/kg
1800 MHz	0.283 W/kg	0.323 W/kg
2450 MHz	0.36 W/kg	0.445 W/kg

According to obtained results shown in table 2, induced SAR values were increased in the arm with implant for 1800 and 2450 MHz operating frequencies compared to the non-implanted case. Considering that the body tissue needs to be absorbed at a certain power per kilogram of tissue for a certain temperature increase, it is obvious that the implanted condition will also cause temperature increase in the tissue concerned.

IV. CONCLUSIONS

The implants with a simple geometry can be simulated in a homogeneous phantom or a computational human model [16]. In this study, SAR variations for different frequencies have been investigated according to both implanted and non-implanted condition in the voxel based human arm model. Simulations have been performed for 900, 1800 and 2450 MHz frequencies. Obtained simulation results have showed that the SAR values were increased in the arm with implant at the 1800 and 2450 MHz frequencies compared to the non-implanted case. With this method, for different body parts and for different orthopedic implants, the SAR changes in the region of interest can be investigated.

In the literature, the effects of implants on heat and SAR exchange were investigated mostly in MRI environment. Considering the increasing exposure of electromagnetic fields at different frequencies day by day, the importance of determining the effects of implants with different geometric shape and different materials on the human body will also increase.

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