SAR Reduction of the Implanted Meandered Antenna with Two Novel Antennas

S. M. T. Mirrahimi, A. Keshtkar, and A. R. Bayat

***Abstract*—One of the safety important limitations in the designing of the implanted antennas is the specific absorption rate (SAR). With respect to application of ANSI SAR limitation it should be 1.6 (W/Kg) for one gram (1-g) of tissue. In this paper a method have been used to reduce the SAR value. First, we utilized a meandered implanted antenna and simulated by using finite difference time domain (FDTD) method and then by using the Non-uniform Width Radiator method we proposed two novel implanted antennas which are better than the first meandered antenna in the aspect of SAR limitation also they can be used in the frequency band (402-405MHz) of the medical implant communications service (MICS).**

***Index Terms*—Biological tissue, implanted antennas, specific absorption rate (SAR).**

I. INTRODUCTION

Implanted antennas are used in hyperthermia and biotelemetry applications. They are embedded in the human or animal body to medical therapy and diagnosis diseases. In contrast to a multitude of researches related to hyperthermia, studies for biotelemetry applications have not been widely reported. In the former researches the implanted antennas transmits vital information such as temperature, blood pressure, cardiac beat rate and continuous Glucose monitoring to the external equipment. Therefore, the implanted antennas and devices has an important role in the human life. Until now there are different type of antennas used as implanted antennas such as dipole, loop, Microstrip, Cavity Slot antennas and so on[1],[2]. Some frequency bands dedicated to the medical applications. One of that is the frequency band (402-405 MHz) of medical implant communications service (MICS) and some other one is the industrial-scientific-medical (ISM) band (2.4-2.48 GHz) which are recommended by the European Radiocommunications Committee (ERC) for ultra-low-power active medical implants[3].

A. Specific Absorption Rate

In addition to frequency considerations an important parameter in the designing of the implanted antennas of the biomedical systems is the specific absorption rate (SAR).

It determines the rate at which energy is absorbed by the human body when exposed to an electromagnetic field. The SAR is defined as the time derivative of the incremental energy dW absorbed by or dissipated in an incremental mass dm contained in a volume element dV of a given density ρ:

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$$SAR = \left(\frac{d}{dt}\right)\left(\frac{dW}{dm}\right) = \left(\frac{d}{dt}\right)\left[\frac{dW}{\rho(dV)}\right] \quad (1)$$

Or, using the Poynting vector theorem for sinusoidal varying electromagnetic fields:

$$SAR = \left(\frac{\sigma}{2\rho}\right)|\bar{E}_i|^2 \quad (2)$$

where $\bar{E}_i$ is the peak value of the internal electric field (in volts per meter), the σ is conductivity of the tissue and the ρ is the mass density of the tissue.[4].

In the U.s., the ANSI SAR limitation for general public is limited by the FCC to 1.6 W/kg over one gram (1-g) of tissue [5]. This value can be controlled by decreasing the input power delivered to the antenna but, in this paper the reduction of the SAR is achieved by using 1w normalized power. There are a number of research works in the cell phones to reduce the SAR parameter by different methods. In some research works this reduction is achieved by using meta-materials [6].In the other research the effect of RF sheets in reducing the Electromagnetic absorption has reported [7]. The RF shield has also used in implanted antenna applications to reduce the SAR in human head model[8].Beside of using the RF shield and meta-material there is another method by changing the structure of the radiators in which it causes to reduces the SAR parameter[9].

B. Antenna Configuration

In this paper, it has been used the meandered antenna in the MICS frequency band (402-405 MHz) [1]. This structure consists of four rectangular strips (15 mm × 3.8 mm) which are electrically connected to one another with three connection strips. Fig. 1 shows the structure of the meandered antenna.

The radiator is located between substrate and superstrate dielectric layers (thickness=2.5mm, dielectric constant ε_r=10.2). The superstrate protect the neighboring tissues surrounding the implanted antenna it acts as a buffer between the metal radiator and human tissue by reducing the RF power at the location of lossy human tissues. The superstrate also assists the antenna to well matched to 50 Ω through decreasing effects of the high conductive biological tissues. A grounding pin also is used in this implanted antenna to achieve smaller dimension than the other type of the implanted antennas [3].

The antenna is embedded in two different biological models represented in Fig. 2 to compare the accuracy of the results when embedded in a real biological model. The first model is homogenous biological tissue model (ε_r=46.7, conductivity, σ=0.69 S/m, mass density, ρ=1.0 g/cm^3 at 402 MHz). The properties of the second model which is the 3-layered model is shown in the table.I [3]. Another reason of using the implanted antenna in the second model is because of the pacemakers and implantable cardioverter defibrillators

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are normally placed between the skin and muscle tissues in the upper human chest[10].

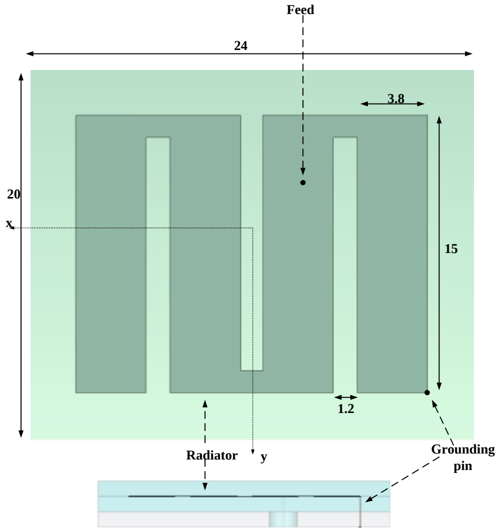


Fig. 1. Antenna configuration.

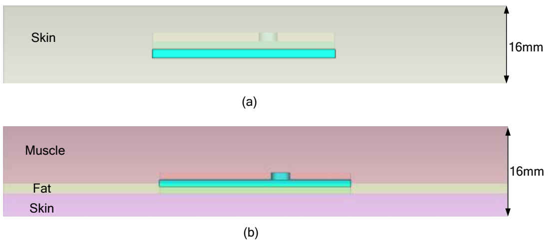


Fig. 2. Two different biological tissue models. (a)homogenous skin tissue. (b)3-layered tissue model.

TABLE I: ELECTRICAL PROPERTIES OF THE BIOLOGICAL 3-LAYRED TISSUE MODEL[3]

Tissue	ρ (g/cm^3)	σ (S/m)	ε_r
Skin	1.01	0.69	46.7
Fat	0.92	0.08	11.6
Muscle	1.0599	0.7972	57.1

II. BASIC MEANDERED IMPLANTED ANTENNA

In the two different tissue models the antenna is located at 4mm from the bottoms of the tissue models and the performance of the antenna is calculated by the finite-difference time-domain (FDTD) method in the each of two models. As it has been shown in Fig. 3, it shows that the return loss of the meandered antenna in the each of two different models are approximately similar, in fact because of changing in the tissue model we encountered with some shift in resonate frequency but it still resonates at MICS frequency band, therefore for the rest of our simulations the simple homogenous skin tissue has been used. By using the simple model of tissue in Fig. 2(a) , The impedance matching and SAR characteristic of the meandered antenna in the simple skin tissue has shown in Fig. 3. The simulated results of this antenna shows good return-loss around the MICS frequency band. Also the SAR distribution of this antenna is equal 236(W/kg) that is higher than the ANSI SAR limitation which is 1.6(W/kg) for 1-g of tissue and has shown in Fig. 4

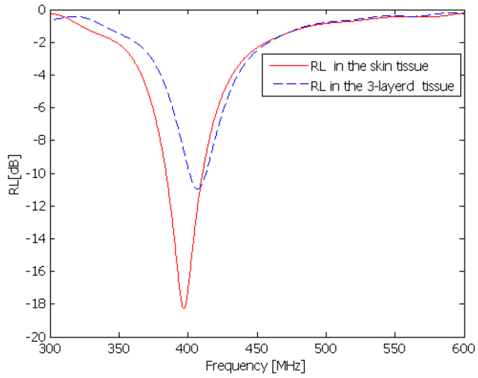


Fig. 3. Simulated return loss for antenna in two different biological tissues.

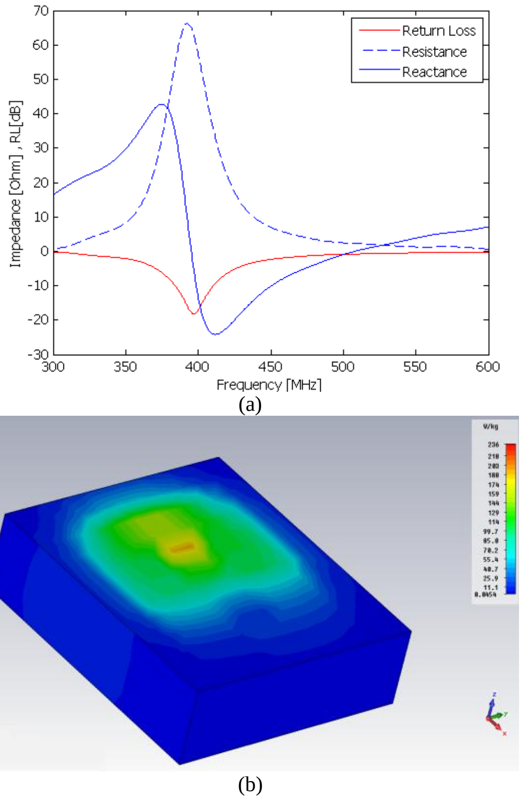


Fig. 4. Impedance matching and SAR characteristics of the meandered antenna in the simple skin tissue model.

III. PROPOSED NOVEL MODIFIED IMPLANTED ANTENNAS

In this paper by using the represented method in [9],has been tried to reduced the 1-g peak SAR value by changing the radiator structure in the meandered antenna. It has been proposed two novel types of antennas as shown in Fig. 5. In the first proposed antenna the dimension of the radiator has been changed so that instead of using four strip in the Fig. 1 only two strips with non-uniform radiators has been used which were electrically connected together with a strip. The radiator width at the shorting pin is 5mm and in the other part of it is 12mm width. Also the gap between these two segments is 2mm as shown in Fig. 5(a). In the second proposed antenna has been used four strips with non-uniform radiator as shown in Fig. 5(b). The width of the radiator in the location of the shorting pin is 3mm, the gap distance between two near strips is 1.5mm and the width of the second strip is 4.75mm the two other strips in this antenna are the same as the first and the second strips.

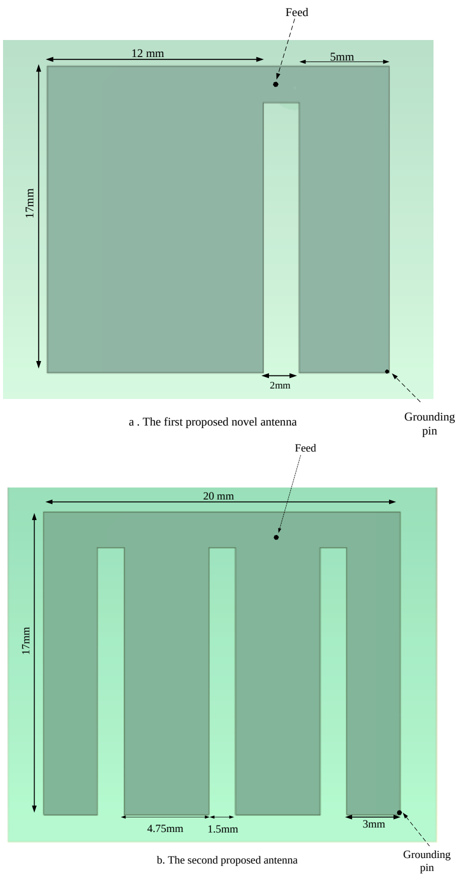
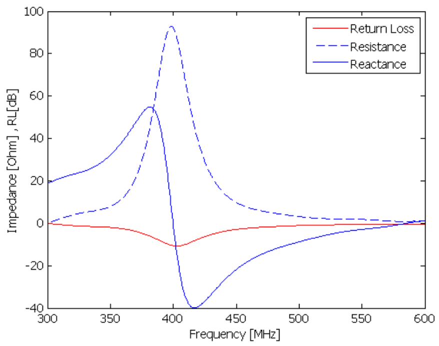
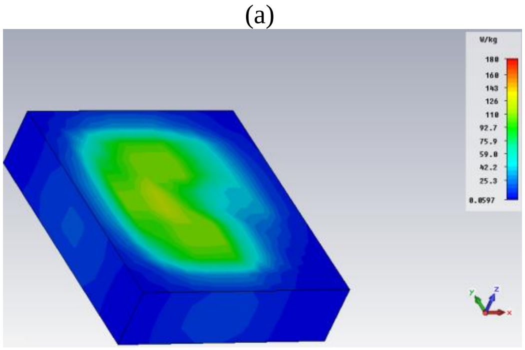


Fig. 5. Two novel proposed structures to SAR reduction.

The simulated results of the first proposed antenna has shown in the Fig.6. As shown in this figure, the impedance matching characteristics of this antenna shows good return-loss around the MICS frequency band and the SAR distribution of this antenna is equal 180(W/kg) which is better than the meandered antenna and so it's radiated power is 73µW which is more better than the meandered antenna.



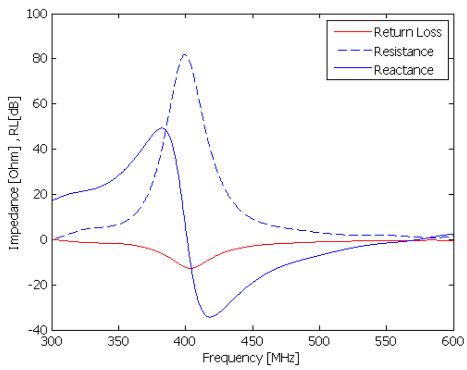
(a)



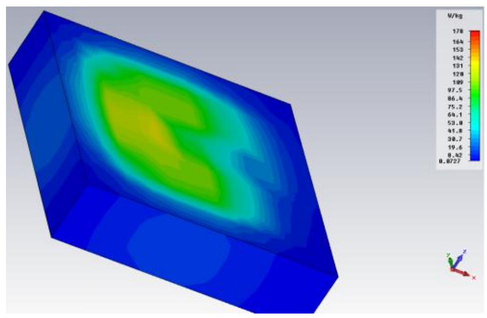
(b)

Fig. 6. (a). Impedance matching (b). SAR characteristics of the first proposed antenna in the simple skin tissue model.

Fig. 7 shows the simulated results of the second proposed antenna as shown in this figure the return-loss is around the MICS frequency band, which is suitable to medical applications also the SAR distribution of this antenna is equal 178(W/kg) which is much more better than the meandered antenna and the first one. The radiated power of the second proposed antenna is 78µW which is much better than the meandered antenna and the first one. The Table II shows the improvement characteristics of the meandered antenna with two novel proposed antennas as shown in this table the second proposed antenna is much better than meandered and the first one in the aspects of SAR reduction and improving the radiated power.



(a)



(b)

Fig. 7. (a). Impedance matching (b). SAR characteristics of the second proposed antenna in the simple skin tissue model.

TABLE II: IMPROVEMENT CHARACTERISTIC OF THE MEANDERED ANTENNA WITH TWO NOVEL PROPOSED ANTENNAS

	meandered antenna	The first proposed antenna	The second proposed antenna
1-g peak SAR first model (W/kg)	236	180	178
Radiated Power (µW)	43	73	78

IV. CONCLUSIONS

In this paper by using the non-uniform width radiator it have been proposed two novel antennas that suitable in (MICS) frequency band (402-405MHz) which is our desired. The radiation characteristic of the antennas evaluated in terms of the 1-g SAR and the radiated power is of our interest too. The 1-g SAR of the first proposed antenna reduced to 180W/kg and it's radiated power increased to 73µW. In the second proposed antenna the 1-g SAR is 178W/kg and the radiated power is 78µW when delivered power is equal 1W.

As shown in the table II the second proposed antenna is much more better than the first one. In the future research works improvement in the radiation characteristic, 1-g SAR distribution and it's radiated power, will be explained with much more detailes.

REFERENCES

[1] Y. Rahmat-Samii and J. kim, "Implanted antennas in medical wireless communications," *Morgan and Claypool*, 2006, pp. 45-69.

[2] W. Xia, "Perfornabces of an implanted cavity slot antenna embedded in the human arm," *IEEE Transactions on Antennas and Propagation,* vol. 57, no. 4, pp. 894 – 899, 2009.

[3] Y. Rahmat-Samii and J. kim, "Impanted antennas inside a human body: simulation, design, and characterizations," *IEEE Transactions on Microwave Theory and Techniques*, vol. 52, pp. 1934-1943, 2004.

[4] A. V. Vorst, A. Rosen, and Y. Kotsuka, "RF/microwave interaction with biological tissues," *Wiley*, 2006, pp. 23-29.

[5] "IEEE recommended practice for measurements and computations of radio frequency electromagnetic fields with respect to human exposure to such fields,100kHz to 300 GHz," *IEEE standard C95.3-2002,* 2002

[6] S. S. Karthikeyan *et al.*, "Reduction of specific absorption rate in human tissues using split ring resonators," *Applied Electromagnetics Conference (AEMC)*, 2009

[7] J. Wang, O. Fujiwara, and T. Takagi, "Effects of ferrite sheet attachment oportable telephone in reducing electromagnetic absorption in human head," *Electromagnetic Compatibility, 1999 IEEE International Symposium* on vol. 2, pp. 822 – 825, 1999

[8] L. K. Ragha and M. S. Bhatia, "evaluation of sar reduction in implanted spherical head model using RF shield," *India Conference (INDICON), Annual IEEE* 2009.

[9] Y. Rahmat-Samii and J. kim, "SAR reduction of implanted planar inverted F antennas with non-uniform width radiator," *Antennas and Propagation Society International Symposium, IEEE*, 2006.

[10] D. Wessels, "Impanteble pacemakers and defibrillators: Device overview and EMI considerations," *IEEE Electromagnetic Compatibility Int.Symp.*, vol. 2, pp. 911-915, 2002.

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