Design of wide band Microstrip-line-fed antenna with circular polarization at ISM band for biomedical applications

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Abstract

In this paper, a new wide band Micro strip antenna for implantable biomedical application in the frequency of ISM (industrial, scientific and medical) band (2.4–2.48 GHz) is presented. The total size of the proposed antenna is 20×20 mm^2 with the thickness of 1 mm , and this antenna is embedded in FR4 substrate with dielectric constant of 4.4. The antenna parameters show good results such as lower return loss, perfect impedance matching, and better gain. The 3-dB axial ratio bandwidth is 2.2GHZ(from 1.2 -3.4 GHz) that is broader than the other conventional antennas. The proposed antenna possesses the return loss of -29 dB at 2.4GHz. Thus the proposed antenna can be employed for several implantable applications.

Keywords: Wide band Microstrip antenna,ISM band biomedical applications , circular polarization Phantom model

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1.Introduction

Applications of implantable antennas is inbody and onbody communication systems are noticeable these days[1]. The possibility of collecting vital data of a body such as blood pressure, sugar and heartbeat or reprogramming of implanted set through wireless communication made them unique. Even a wireless endoscopy is possible using these systems. Compared with the conventional endoscopy method, wireless tablet endoscopy affords a direct study of the entire small intestine and does not require any sedation [2].

These medical fields have been discussed since 2004 and have reduced the need for operations.

These antennas are applied in many fields such as implantable medicine, excitation of nerve system and when communication is needed in medical applications. For example when it is needed to inform the doctor in emergency situations or when implantable devices such as pacemakers or implantable drug releasers need reprograming without a new surgery. Finding location of patients with Alzheimer's disease or recognition of people by these implantable devices using wireless connection (for example, instead of using debit cards in purchases) are other applications of these devices. All these applications need suitable antennas to connect the implanted devices to information center.

Patch designs are preferred for implantable antenna design, because of their flexibility in conformability and shape. These implante antennas will be placed inside a complex lossy environment which is another complication[3]. Implantable antennas must be biocompatible in

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order to safeguard patient safety and to prevent rejection of the implant. To characterize the human body as a medium for radio frequency wave propagation, the electrical properties of the body tissues should be known for the frequency of interest.

Circularly polarized antennas have been widely used in wireless communication applications such as global positioning system, ISM, radio-frequency identification (RFID) system and radar, since they can enhance the signal reception with flexible orientation. Because the transmitter and the receiver are not fixed or their operation is variable with weather conditions, circular polarization (CP) is desired to prevent the effects of displacement and path loss of the antennas[4,5,6]. Therefore, designing a compact antenna with circular polarization is an essential challenge. In this paper, a wideband circularly polarized monopole antenna is proposed using microstrip feed shaped line. The antenna is designed for implantable biomedical application in the frequency range of 2.4–2.48 GHz ISM (industrial, scientific and medical) band and the total size of the antenna is about 20 mm ×20 mm with 1 mm thickness.

Design and analysis of a novel compact square monopole antenna are proposed with human phantom models such as muscle, fat and skin along with its relative dielectric permittivity, electrical conductivity and some of the parameters such as gain, return loss, radiation pattern are measured.

2. Antenna design

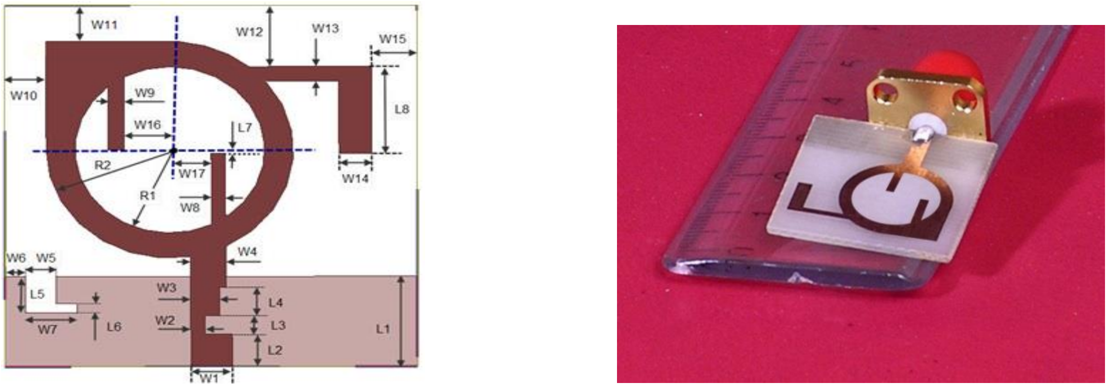
Fig.1 demonstrates the configuration of the proposed antenna. The resonant frequency of proposed antenna is 2.4 GHz. The basic configuration of the proposed antenna is fed by a strip line and was printed on one side of a 1mm thick FR4 substrate that was used herein, with a 4.4 relative permittivity, whereas the other side of the substrate was printed on a ground plane. In this design, the total size of the substrate is 20mm×20mm. An inverted L-shaped slot with dimension of 2.5×2 mm^2 are created in the ground plane of the antenna to improve its impedance matching. By creating the L-shaped arm with dimension of 5.9×4.8 mm^2 sticking to the circle and two rectangular-shaped arm in the empty circle we have better impedance matching and axial ratio. The main goal of the design is to create circular polarization in ISM band. Therefore, the main challenge in the design procedure focuses on how the circular-shaped radiator improve the impedance matching and axial ratio of the antenna. By adjusting the dimensions of the L-shaped slot and circular-shaped radiator, circular polarization can be created in the 1.2-3.4 GHz frequency band. Dimensions of the proposed antenna are given in Table 1. Design of parametric model for skin, fat and muscle is done as per their relative dielectric constant of human tissues [7,8] which is shown in Table 2. And the thickness of human tissues is shown in Table 3 [9,10]. The proposed antenna with phantom model is demonstrated in Fig. 2.

3. Results and discussion

The antenna parameters such as return loss, radiation pattern, Surface current distribution , and gain, are measured from HFSS (High Frequency Structure Simulator). The parameters of the antenna measured at human body phantom model as shown in Fig. 2.

3.1. Return loss

Fig. 3 illustrates the simulation result of return loss of about -29 dB at 2.4 GHz which is lower than the other conventional antennas and it is suitable for biomedical application.



(a) (b)

Figure.1 Structure of the proposed antenna (a) schematic, (b) top view of fabricated antenna

Figure. 2 Phantom model

Table 1 Dimensions of proposed antenna

R_1	4.5mm	L_8	4.5mm
R_2	6mm	W_{13}	0.8mm
W_1	2mm	W_{14}	1.6mm
W_2	0.7mm	W_{15}	2.2mm
W_3	1.4mm	W_{16}	2.2mm
W_4	1.7mm	W_{17}	2mm
W_5	1.5mm	L_1	5mm
W_6	1mm	L_2	1.8mm
W_7	2.5mm	L_3	1mm
W_8	0.7mm	L_4	1.5mm
W_9	0.8mm	L_5	2mm
W_{10}	2mm	L_6	0.5mm
W_{11}	2mm	L_7	0.2mm
W_{12}	3.4mm		

Table 2 Electrical properties of human tissues.

Tissue	Permittivity	Conductivity
Skin	$\varepsilon_r = 38$	$\sigma = 1.46$
Fat	$\varepsilon_r = 5.28$	$\sigma = 0.10$
Muscle	$\varepsilon_r = 52.7$	$\sigma = 1.73$

Table 3 Thickness of each phantom layer.

Human tissue	Thickness
Skin	4mm
Fat	4mm
Antenna	1mm
Muscle	8mm

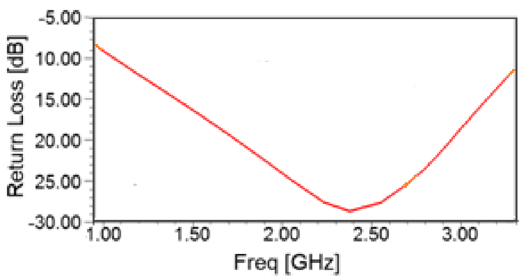


Fig. 3 Return loss characteristics of proposed antenn

3.2. Gain

The variations of antenna gain with frequency are shown in Fig. 5. It is clear from Fig. 4, antenna gain shows peaks at -6dB for frequency 2.4 GHz. The antenna gain is negative because the antenna is embedded into human tissue, not in free space.

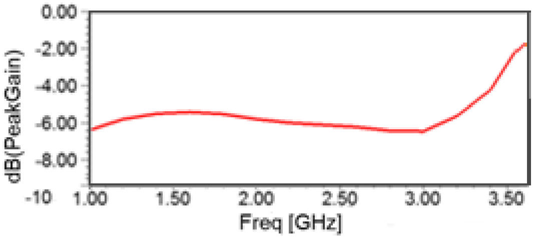


Fig .4 Antenna gain variations corresponding to frequency

3.3 Radiation pattern

Fig. 5 shows the LHCP/RHCP plot at 2.4 GHz. This radiation pattern is obtained at the E-plane (YZ-plane) and H-plane(XZ-plane) of the proposed antenna at ISM band . It is more clearly observed at frequencies well inside the CP band(circular polarization), that the antenna displays left handed circular polarization over much of the upper half space(Z > 0) and right handed circular polarization over much of the lower half space (Z < 0, below the antenna).

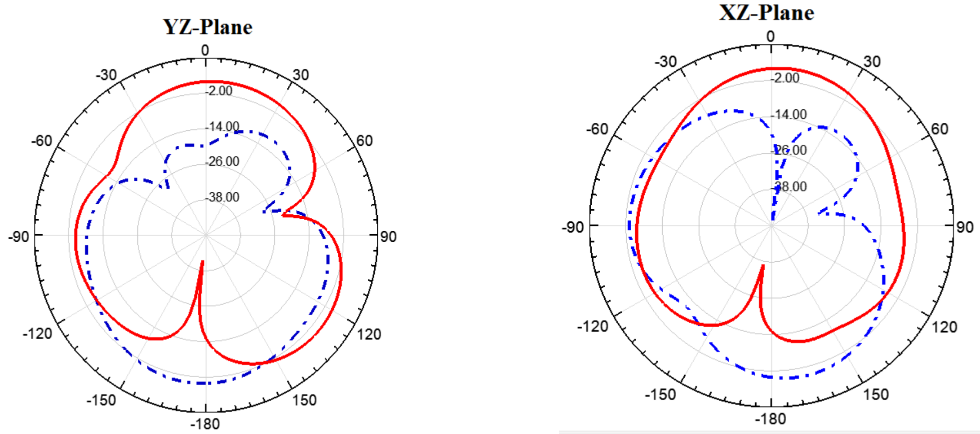


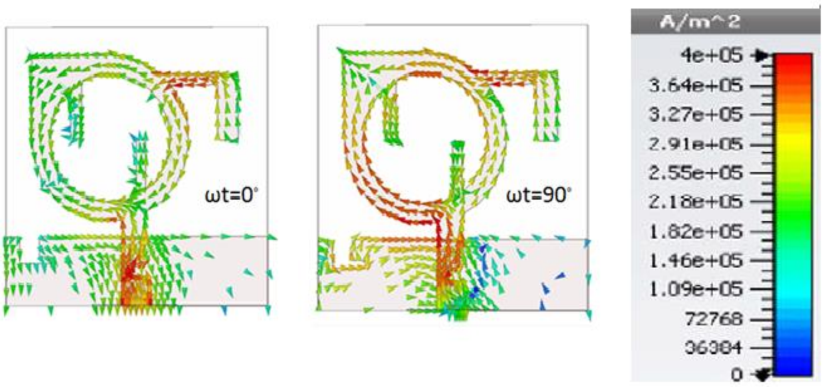
Figure .5 LHCP/RHCP plot for the the proposed antenna at 2.4 GHz.
Simulated LHCP
Simulated RHCP

3.4. Current distribution

Surface current distributions on Antenna at 2.4GHz at 0°, 90° phases are depicted in Figure 6.

3.5 Axial ratio

The measured axialratio results for the antenna are presented in Fig7. The antenna has a wide 3-dB AR bandwidth from 1.2 to 3.4 GHz.



(a) (b)

Figure 6. Surface current distribution at 2.4GHz. (a) 0◦ (b) 90 ◦

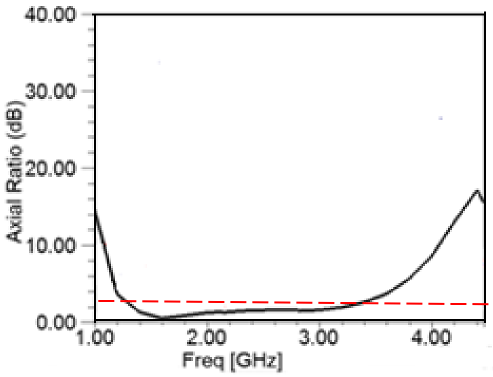


Fig.7 Simulated axial ratio of the proposed antenna

4. The effect of changing the thickness of the fat tissue

The fat tissue in different areas of the body has different thicknesses and varies from person to person. The electromagnetic properties of fat from the muscle and the skin are very different and its conductivity is very different. Therefore, the thickness of the fat layer can affect the characteristics of the implanted antenna. The variations of antenna return loss by changing the thickness of the fat tissue are shown in Fig.8.as seen in low thickness ,the return loss of preposed antenna have more desirable values.

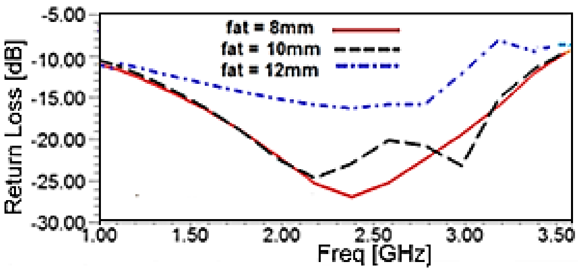


Fig.8 Return loss of proposed antenna by changing the thickness of the fat tissue

Conclusions

A low-profile, low-cost, wideband, circularly polarized antenna, has been proposed and studied. The antenna exhibits wideband circularly polarized radiation. The proposed antenna is designed for ISM band (2.4–2.48 GHz). A axial ratio bandwidth of 80% ranging from 1.2 GHz to 3.4GHz has been achieved . The proposed antenna possesses the return loss of -29 dB at 2.4GHz. Thus this antenna is a suitable candidate for the field of biomedical engineering applications.

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