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Multilayered Implantable Antenna Design for Biotelemetry Communication

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ABSTRACT In this paper, a multilayered implantable antenna for MICS band biotelemetry applications is introduced. The proposed antenna has a fairly compact design with three layers. The primary radiator of the antenna consists of split-ring elements providing miniaturization. The antenna exhibits uniform radiation pattern for both *E* and *H*-plane and acceptable gain performance at desired frequency band. Analysis and design of the antenna was carried out using CST Microwave Studio and the results were validated by means of ANSYS HFSS simulator.

Keywords: Antenna design, Implantable, MICS band, Biotelemetry

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1. INTRODUCTION

Recently, there is a growing research activity on short-range wireless biotelemetry applications in treating human diseases and monitoring various physiological parameters. Pacemaker communication, body temperature, respiratory rate, blood sugar, oxygen content of blood monitoring and endoscopy are just a few examples of the applications. Thanks to the biotelemetry, the physiological signals are wirelessly transceived between implantable medical devices and exterior equipment. In addition, for the communication between an implanted system and exterior monitoring or control equipment, wireless links are essential for the whole biotelemetry system. A typical biotelemetry system comprises a biosensor appropriate for the particular signals to be monitored, battery, a transmitter and an antenna. Among all the components necessary for implanted telemetry applications, the antenna plays a key role in obtaining robust communication network as well as in miniaturization of the whole device [2-5]. Besides, the difficulties in achievement of an optimum design by optimizing simultaneously the basic parameters such as its structure in compliance with the body physiology, electrically of dimensions, bandwidth, radiation efficiency and Specific Absorption Rate (SAR) values increase the significance and value of designing such an antenna at a higher level.

Communication Services (MICS, 402.0–405.0 MHz) is the most commonly used for the biotelemetry system [1]. The spectrum of 3 MHz allows for 10 channels (a bandwidth of 300 KHz each) to support simultaneous operation of multiple implantable medical devices in the same area, and to limit interference from the co-located Meteorological Aids Service band (401-406 MHz). Nevertheless, Industrial, Scientific and Medical (ISM, 2.4-2.84 GHz) band is also used for biomedical telemetry systems. Implant Communication Services is used for communication between implant and external unit. ISM band is used for sending a wake-up signal from external unit. For wake-up signal, the communication operates at certain intervals, so battery life can be improved. Also, more batteries can be inserted in the implant device with obtaining more miniaturized antenna.

In authors' earlier works, a split-ring (SR) [6] as well as a complementary split-ring [7] based novel implantable antenna designs were proposed. In current study, we employed a multilayer structure inspired by the antenna design reported in [8] in order to achieve a smaller antenna configuration as compared to the designs developed in [6, 7]. The radiating top layer of the antenna is composed of three concentric square SR elements as shown in Figure 1. The proposed antenna with novel configuration provides a single band performance at 400 MHz MICS band. The full-wave analysis of the proposed design was carried out using CST Microwave Studio, utilizing the time-domain finite-integration technique. Besides, Ansoft HFSS based simulation results was also introduced and presented to have cross-comparison for the return loss

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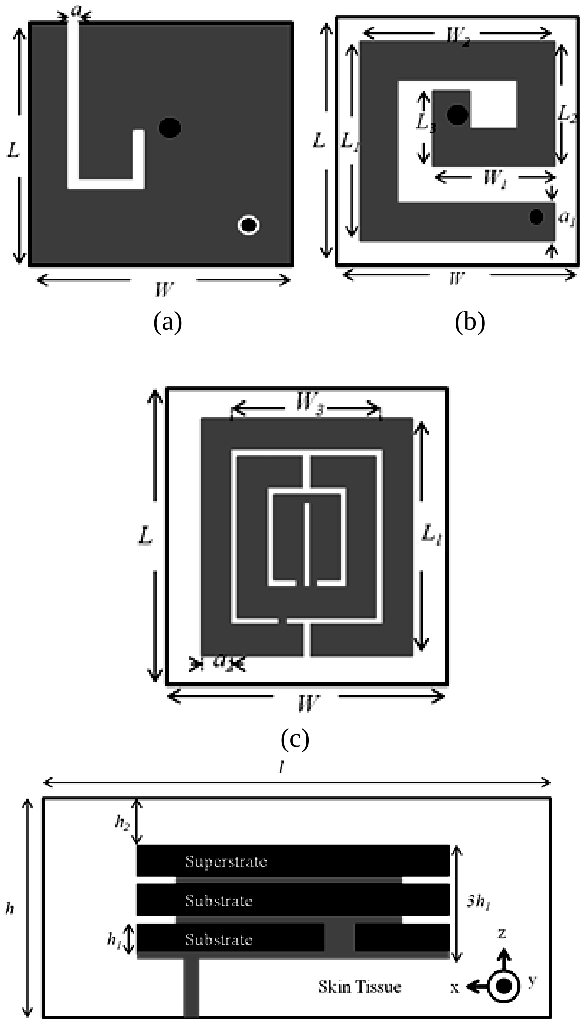
characteristics of the proposed antenna. In this paper, the simulated return loss, radiation pattern and SAR values at the respective frequency band are presented.

2. ANTENNA DESIGN

The designed antenna has dimensions of 10×10×2.01 mm in three layer configuration. It is of outmost importance and desire to have minimum dimensions for the antenna when its implantation is taken into consideration. The frequency value that the antenna operates is the MICS (402-405 MHz) band allocated for biomedical applications. The proposed antenna consists of three layers. The bottom part of the substrate structure is used as the ground plane, and part there is a patch as the first radiation element on the top part. Above the second substrate is another second radiation element in the structure. Above all these layers, there is a top layer material. These structures, called superstrate as shown in Figure 1 (d), are made of the same material as the other two substrate structures. The purpose of their use is to gain a high directionality to the antennas and to allow them to radiate at a wide band gap [8]. The design has a short pin structure that connects the ground layer and the first radiation structure. The purpose of this short-circuiting pin is to reduce the antenna size by half, as well as to reduce the antenna's resonance frequency by half. Rogers RO3010 material was used as the substrate in the antenna design. The dielectric constant of Rogers RO3010 material is $\varepsilon_r = 10.2$. Three layers of RO3010 material were used in the design. In the design of the antenna, a slit is opened in the ground layer to reduce the resonance frequency in addition to make a sharp adjustment in resonance frequency values. The final dimensions of the antenna are recorded as follows (all in millimeters): L=W=10, a = 0.3, a_1 = 1.5, a_2 = 1, L_1 = 8, L_2 = 5, L_3 = 3, W_1 = 5, W_2 = 8, W_3 = 5.5, l = 1.30, h = 12, h_1 = 0.67, h_2 = 5. The layers of the designed antenna are shown in Figure 1. The size of the ground layer is 10×10 mm. The circular structure seen almost in the middle of the Figure 1 (a) indicates the location of the short-circuit pin. The other circle structure in the lower right part indicates the position of the coaxial feed structure. Above the ground layer, there is the first substrate structure with the first radiation structure. The substrate layer is 10×10 mm while the first layer of radiation on it is 8×8 mm in size. In Figure 1 (b), there is a meander line parasitic patch providing enhancement of antenna bandwidth. In the second layer of the antenna shown in Figure 1 (c), three concentric SR elements are used for primary radiators of the antenna. The substrate structure on the second patch layer is 10×10 mm in size. The size of the patch with SR structure is 8×7.5 mm. SR structures are preferred in this design because they reduce the resonance frequency. A square patch joint was made with the outermost ring physically touching the ring immediately inside, with a radius of 0.3 mm and allowing for precise frequency adjustments. These patches, especially used in fine frequency adjustments, help the antenna to radiate to the desired frequency. Changes can be made to the frequencies at which the antenna enters the resonance by changing its location. As shown in Figure 1, the transmission paths in this layer are 0.5 mm thinner than the transmission paths in the first layer. The reason for this is to increase the number of rings in the interior and reduce the spacing between them by bringing the rings together. Narrowing the paths between the rings allows us to obtain high capacitance values and also allows us to reduce the resonance frequency.



(d)

Fig. 1. Configuration of the proposed antenna with its design parameters; (a) Ground plane, (b) Lower radiation layer, (c) Upper radiation layer, (d) Side view of the antenna

3. EXPERIMENTAL RESULTS

In this study, we have mainly used the commercially available CST Microwave Studio during the design stage, due to its speed advantage. The High Frequency Structure Simulator (HFSS, a FEM based full-wave analysis tool with dissimilar modeling capabilities) was also employed to compare the results obtained from the CST. In particular, the truncation schemes differ in each simulator. As a result, some discrepancies in the HFSS and CST simulation results were observed. As it can be seen in Figure 2, the antenna provides a single band performance at frequency of 400 MHz with 40.44 MHz band width. Moreover, radiation patterns in the MICS band of the antenna are shown in Figure 3. As seen the antenna exhibits uniform radiation pattern in the both *zx* and *zy* -plane at the respective band.

Additionally, we simulated the proposed antenna in the skin tissue model to obtain 1-g averaged SAR values at respective frequency bands. For standard CST input power, maximum SAR values are obtain as 287.1 W/kg at 400 MHz as shown in Figure 4. Therefore, the delivered power of the antenna input must be arranged to satisfy SAR regulations (2 W/kg) of IEEE. For 402

MHz, maximum input power has to be lower than 5.57 mW.

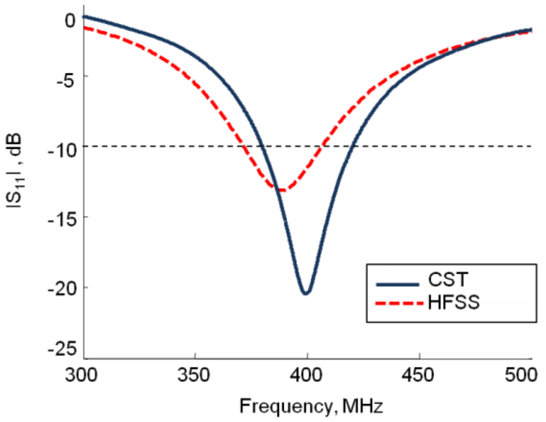


Fig. 2. Comparison of return loss performance of the antenna (CST vs. HFSS softwares)

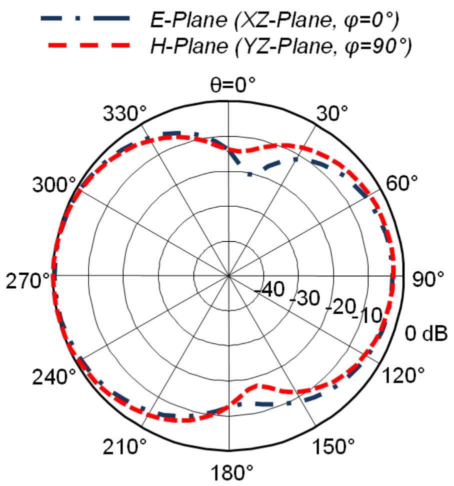


Fig. 3. Farfield realized radiation pattern *E*-plane and *H*-plane for the proposed antenna at 400 MHz

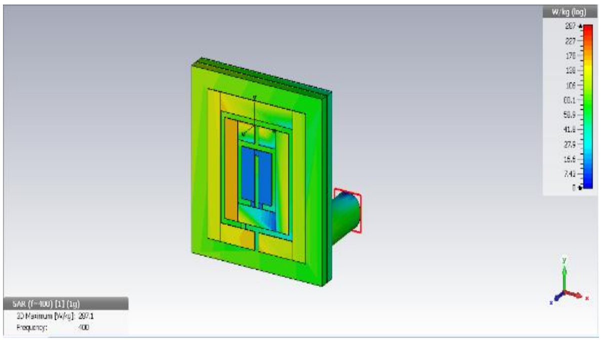


Fig. 4. SAR distribution in the skin tissue model for 400 MHz

4. CONCLUSION

We presented a novel multilayered implantable antenna for MICS band applications. In order to keep the antenna size small, a split-ring based radiator with a shorting pin is used. The antenna is excited by a coaxial probe feed and provides a single band operation about 400 MHz. The antenna exhibits nearly uniform radiation patterns and the SAR values of the antenna satisfy the standard safety guidelines in the band.

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Biographies

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