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A Compact Dual Band Implantable Antenna Based on Split-Ring Resonators with Meander Line Elements

Yunus Emre Yamac[1], S. Cumhur Basaran[2]
[1](Electronics and Communications Engineering, Yildiz Technical University, Turkey)
[2](Electrical and Electronics Engineering, Akdeniz University, Turkey)

ABSTRACT: *In this paper, a dual band implantable split-ring microstrip antenna which operates at MICS (Medical Implant Services) and ISM (Industrial, Scientific, and Medical) bands is proposed for biotelemetry applications. A miniaturized size of 9.5 mm × 9.5 mm × 1.27 mm was accomplished by using three split-ring resonators and meander lines elements on these resonators. A shorting pin appropriately placed between the patch and ground plane was used for the antenna miniaturization. In addition, three useful metallic paths between the rings provided fine frequency tuning. The proposed split-ring implantable antenna presents 23.5% and 9.3% bandwidth, -48 dB and -24 dB maximum gains, 407 W/kg and 403 W/kg maximum 1-g averaged SAR values at the respective bands. Return loss performance, radiation patterns and SAR values of the antenna design are presented in the paper.*

Keywords: *Dual band, ISM band, implant antenna, meander line elements, MICS band, micro strip, split-ring resonators*

I. INTRODUCTION

The implantable medical devices help improve the comfort of the patients at biomedical telemetry applications. The implant antenna is essential part of these systems and must be designed for obtaining robust communication link with an external unit. With a complete telemetry system monitoring some physiological parameters of the body (such as sugar level, body temperature etc.) can be accomplished [1]. Medical Implant Communication Services (MICS, between 402 to 405 MHz) is used for communication between implant and external unit [3]. ISM band is used for sending a wake-up signal from external unit. For using wake-up signal, the communication operates at certain intervals, so battery life-time can be improved [4]. Also, more batteries can be inserted in the implant device with obtaining more miniaturized antenna sizes [5]. In most studies antenna is inserted skin tissue and also stimulated in a tissue phantom model. The electrical parameters of biological tissue are dependent on frequency and temperature, so bandwidth of the antenna has to be increased for reliable communication at various body conditions. In addition, the implant antenna has to satisfy SAR (Specific Absorption Rate) requirements (1.6 W/kg on 1 g tissue and 2.0 W/kg on 10 g tissue).

Various methods have been used for miniaturization of the implant antenna. Most commonly method is PIFA by adding a shorting pin between ground and patch. Multi-layered structures, cavity slots, and various patch modifications are also used for miniaturization [6-10]. In addition, a conformal antenna design is utilized to have more compact implant device design. On the other hand, split-ring (SR) resonators are very good candidate for miniaturizing purpose. Because they can exhibit resonant behavior for wavelengths that are much larger than its size. Thus, SR based miniature antenna for WLAN applications have been reported recently in our previous study.

In this paper, we propose a compact dual-band implantable split-ring antenna for biotelemetry applications. We employed three additional elements for the design in this study different from the proposed antenna in [11-13]. One of them is superstrate material. It was chosen same material of the antenna substrate and it was used to isolate the antenna copper from the conductive human tissue. The other one is shorting pin. The pin was placed between top copper radiation layer and the ground plane of the antenna like PIFA design for miniaturization purpose. The third element is feeding structure. While microstrip or CPW feeding technique was used in [12-14], we used probe feeding technique for the design in this paper. As seen in Fig. 1, the radiating layer of the antenna has three concentric square split-ring resonators and three metallic pats appropriately placed between the rings. The proposed design provides a dual band performance at MICS band and ISM band with 23.5% and 9.3% bandwidths, respectively. It notes that the full-wave analysis of the proposed design was carried out using CST Microwave Studio which utilize the time-domain finite-integration technique. The simulated return loss, radiation pattern and SAR values at each respective frequency band are presented in this paper.

II. DUAL BAND IMPLANTABLE ANTENNA DESIGN

A. The Proposed Antenna Configuration

The proposed antenna configuration is depicted in Fig. 1 and design parameters are given in Table I. The electrical properties of RO3010 are ε_r=10.2 and tanδ=0.003. The superstrate prevents destructive effects of human tissues to the antenna and also, a better SAR performance is obtained by using superstrate material. A biocompatible insulation entails to prevent that the body see the implant antenna as an enemy [14]. As seen in Fig. 1(b), the antenna is simulated in a skin tissue phantom model that its electrical characteristics are ε_r=46.7, σ=0.69 at 402 MHz and εr=38.06, σ=1.44 at 2.45 GHz [15]. The design of the proposed antenna is simulated with CST Microwave Studio and the final optimized dimensions of the antenna and the the tissue model dimensions are given in Table 1.Several parametric studies were carried out to achieve desired antenna performance for tuning the resonant frequencies and return loss. As seen in Fig. 1, three path is placed between concentric SRs. Rogers 3010 is used as substrate and superstrate materials with 0.635 mm thicknesses. The dimensions of SRs, path positions, position of the shorting pin and feeding were optimized for desired results. A shorting pin is placed between the radiating layer and the ground plane.

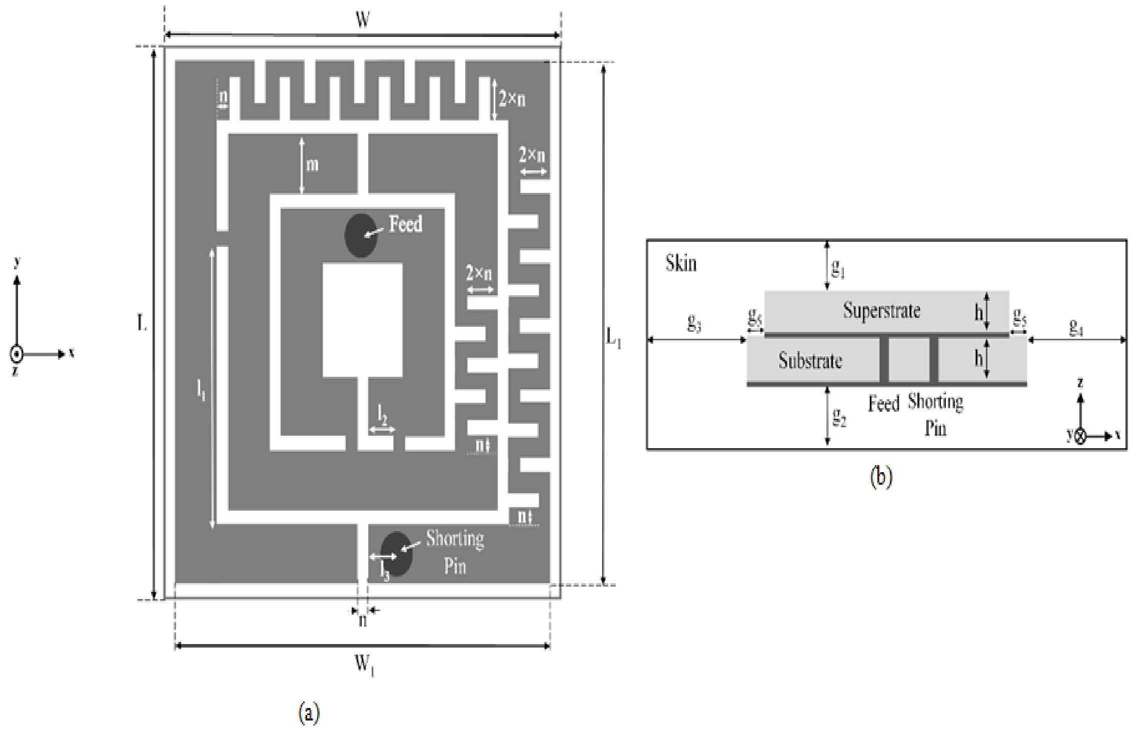


Fig. 1. The configuration of the proposed antenna: (a) Top view, (b) side view with skin tissue model.

Table 1. Detailed dimensions of the proposed antenna

Parameter	*Value*	*Parameter*	*Value*	*Parameter*	*Value*
L	9.5	l_1	4.8	g_1	40
W	9.5	l_2	0.8	g_2	40
L_1	9	l_3	0.67	g_3	3
W_1	9	m	1	g_4	3
h	0.635	n	0.27	g_5	0.25

B. Simulations Results

The proposed antenna as seen in Fig. 1 is simulated and return loss characteristic of the proposed antenna is given in Fig 2. From simulation results, impedance bandwidths of the antenna are 23.5% at MICS band (between 364 MHz to 461 MHz) and 9.3% at ISM band (between 2.32 GHz to 2.55 GHz). Also, radiation pattern performance of the antenna is given in Fig. 2. The maximum realized gains of the antenna are about -48 dB and -24 dB at each respective band. As seen in Fig. 3, an omnidirectional radiation is obtained for 402 MHz and 2.45 GHz.

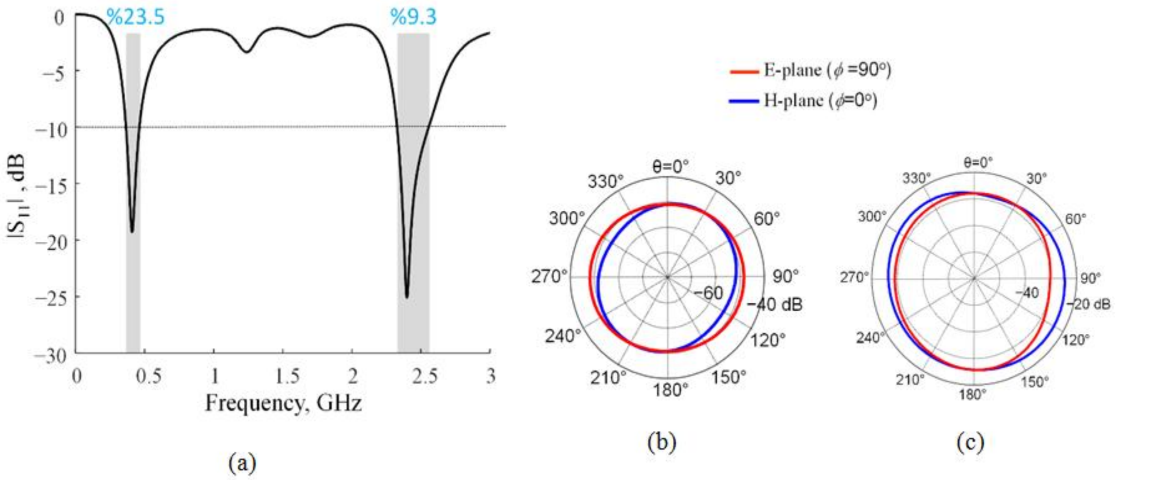
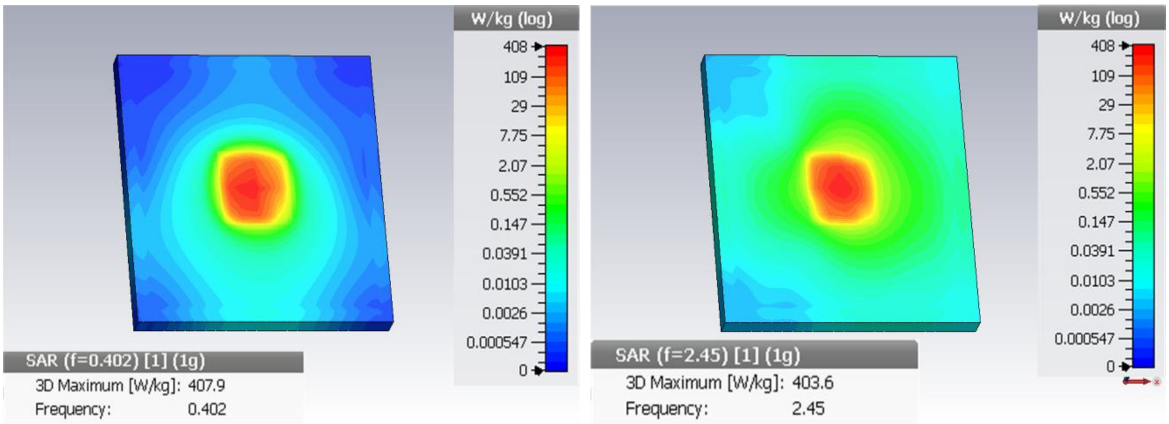


Fig. 2. Simulation results of the proposed antenna: (a) Return loss, (b) and (c) radiation patterns (f=402 MHz and 2.4 GHz, respectively)

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 were obtained as 407.9 W/kg at 402 MHz and 403 W/kg at 2.45 GHz as shown in Fig. 4. Therefore, the delivered power of the antenna input must be arranged to satisfy SAR regulations (1.6 W/kg) of ANSI/IEEE [16]. For 402 MHz and 2.45 GHz, maximum input powers should be 1.96 mW and 1.98 mW, respectively (as seen Table 2).

Table 2. Simulated maximum SAR and max input power

f [MHz]	*Max SAR (W/kg)*	*Max input power (mW)*
402	407.8	1.96
2405	0.635	1.98



(a) (b)

Fig. 3. SAR distribution in the skin tissue model, (a) *f*=402 MHz, (b) *f*=2.45 GHz.

III. CONCLUSION

In this paper, we have introduced a compact dual-band implantable split-ring antenna for biotelemetry applications. The miniaturization is vital important challenge in designing an implant antenna. The split-ring resonators were used for miniaturization purpose and miniature structure with 9.5 mm × 9.5 mm × 1.27 mm dimensions was obtained in the paper. The proposed design provides a dual band performance at 402 MHz MICS band and 2.4 GHz ISM bands. In addition, the antenna exhibits nearly omnidirectional radiation pattern characteristics for E and H-planes and acceptable SAR values at the respective frequency bands. All simulations were carried out by means of CST Microwave Studio Suite simulation program.

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