ENG ZOR Antenna for Implantable Biomedical Service

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Abstract

An epsilon negative (ENG) zeroth-order resonance (ZOR) antenna for medical implant communication system (MICS) is proposed. Owing to the fact that a ZOR antenna can be realized in compact size if the shunt capacitance and shunt inductance are large enough, the electrical size of the proposed antenna is only 0.020 λ_0 x 0.017 λ_0 x 0.002 λ_0 (λ_0: the wavelength at the center frequency of MICS band) including the ground plane. Moreover, the return loss property of the proposed antenna is very insensitive to the permittivity and size of the human body model.

Keywords: Antennas, Epsilon Negative Metamaterial, Medical Implant Communication Service, Zeroth-Order Resonance

1. Introduction

Recently, the implantable biomedical system draws much attention in medical therapy. While the implantable in-body communication system uses medical implant communication service (MICS) band (402 MHz – 405 MHz) [1], it is exceptionally difficult to design a compact antenna for MICS band due to its low frequency. Compact spiral and serpentine antennas for MICS band were proposed in [2], but they had narrow bandwidth. Since human body is highly variable medium, a narrow band antenna is not suitable as an implantable antenna.

In this paper, we propose an antenna for implantable biomedical service system using epsilon negative (ENG) zeroth-order resonance (ZOR). Because an ENG ZOR is independent on its physical size, the proposed antenna has excessively compact size. Also, the impedance matching of the proposed antenna is hardly affected by the human body model. The insensitiveness of the antenna is demonstrated using numerical simulations for various cases.

2. Antenna Design

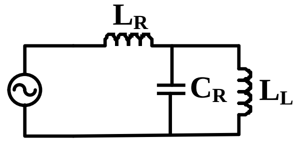
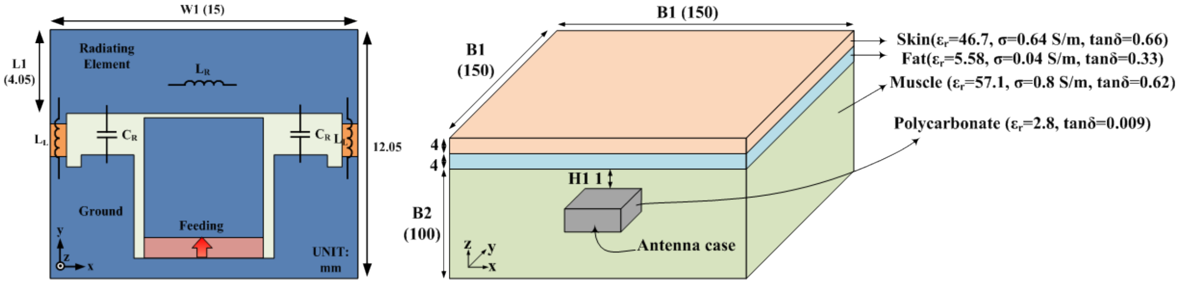


Figure 1: Equivalent circuit model of the ENG ZOR antenna.

Fig. 1 shows the equivalent circuit model of an ENG ZOR antenna. An ENG ZOR antenna can be realized by adding a shunt inductor (L_L) to a conventional patch antenna [3]. The resonance frequency of the ENG ZOR antenna is

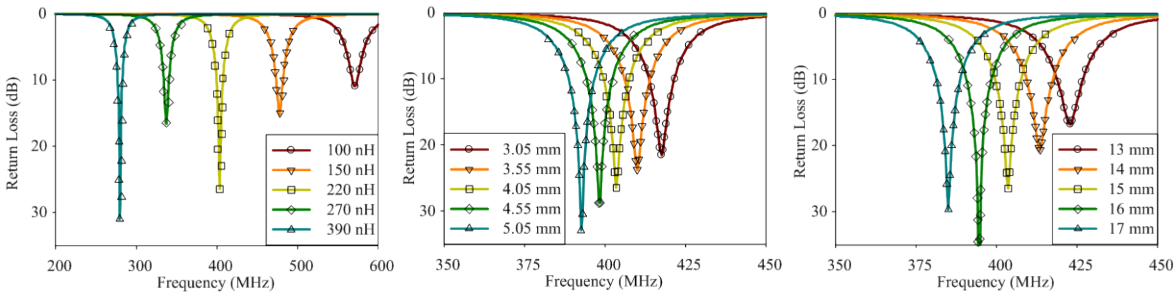
$$\omega_0 = \omega_{sh} = \frac{1}{\sqrt{C_R L_L}}. \quad (1)$$

Since the ZOR frequency is theoretically independent on the physical length of an antenna, a ZOR antenna can be realized in very compact size [4]. In addition, the ZOR frequency can be controlled by changing the shunt inductance.



(a) Layout of the proposed antenna (b) Human body model for the proposed antenna

Figure 2: Configuration of the proposed antenna for implantable medical service.



(a) (b) (c)

Figure 3: Simulated return loss characteristics of the proposed antenna for (a) various chip inductance values, (b) various lengths (L1) and (c) various widths (W1) of the radiating element.

Fig. 2(a) depicts the layout of the proposed antenna. The proposed antenna is implemented on a FR-4 substrate (ε_r=4.4, tanδ=0.02, thickness=1.6 mm) and fed by a coplanar waveguide transmission line. The gap between the radiating element and the ground plane gives rise to the shunt capacitance (C_R) and the series inductance (L_R) is owing to the line inductance of the radiating element. In addition, the shunt inductor (L_L) is implemented by using a Murata 1608 series chip inductor of 220 nH between the radiating element and the ground plane [5]. The chip inductor as a shunt inductor is an advantageous method for an ENG ZOR antenna because it provides large inductance with very compact size. For the sake of the large inductance of the chip inductor, the proposed ENG ZOR antenna can be extremely compact.

Fig. 2(b) shows the human body model for the proposed antenna. The human body model is composed of three layers: skin (150 mm x 150 mm x 4 mm), fat (150 mm x 150 mm x 4 mm), and muscle layers (150 mm x 150 mm x 100 mm). The proposed antenna is enclosed by a polycarbonate case positioned at 1 mm below the fat layer. The polycarbonate case has the size of 15.55 mm x 17 mm x 8.6 mm and the thickness of 1 mm.

Fig. 3(a) shows the return loss characteristics of the proposed antenna for various chip inductance values. Since the ZOR frequency is inversely proportional to the square root of L_L as described in (1), the resonance frequency of the proposed antenna is decreased as L_L increases. However, since the chip inductor manufacturers provide discrete values of chip inductance, fine tuning of the resonance frequency can be performed by optimizing the size of radiating element. Fig. 3(b) and (c) show the return loss characteristics of the proposed antenna for various radiating element sizes. The larger the radiating element, the lower the resonance frequency is. Thus the impedance matching over the MICS band can be achieved by changing the chip inductance value and the radiating element size.

3. Results

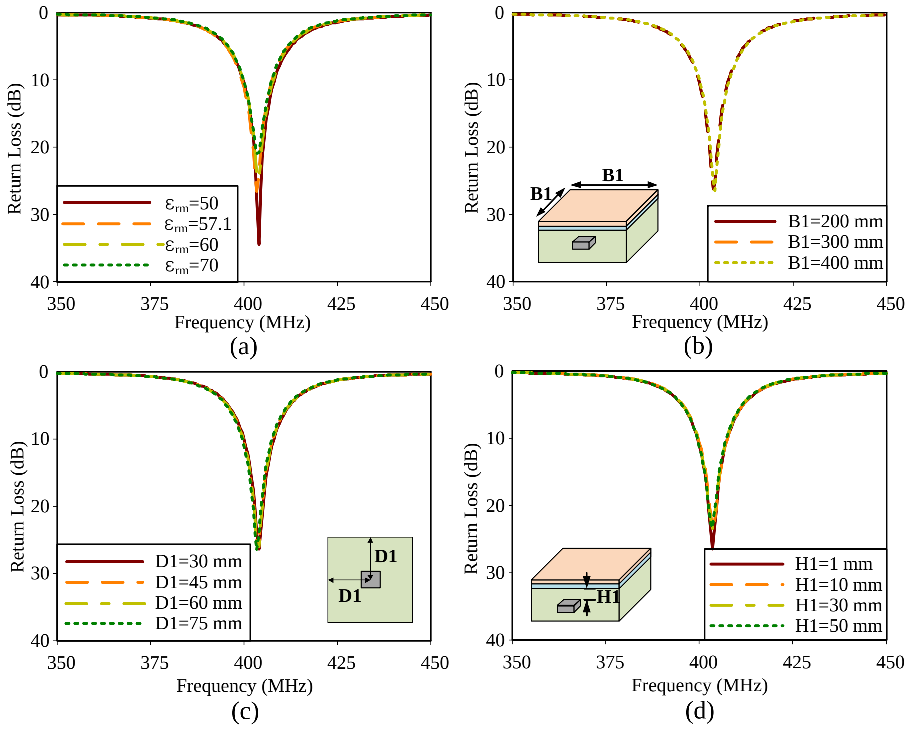


Figure 4: Simulated return loss properties for various (a) relative permittivity of the muscle layer (ε_{rm}), (b) body model sizes (B1), and (c) horizontal (D1) and (d) vertical positions (H1) of the antenna in the body model.

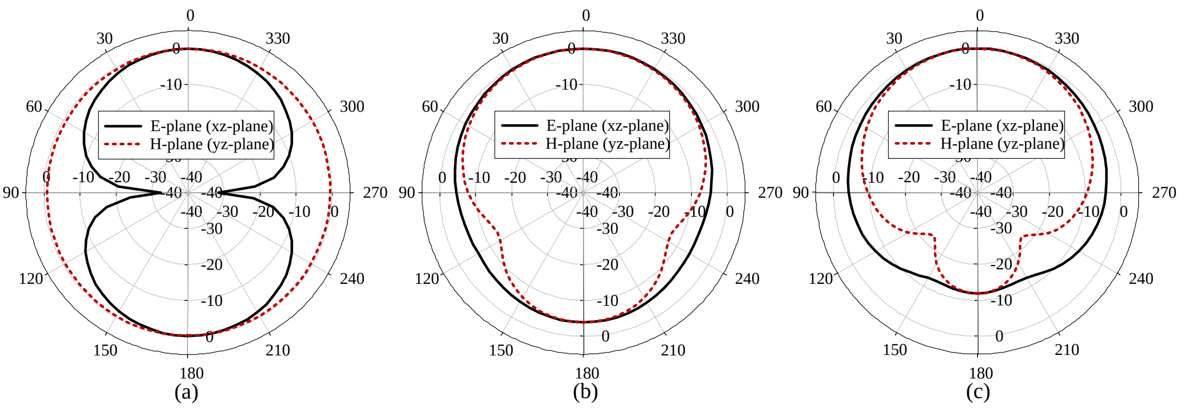


Figure 5: Simulated radiation patterns of the proposed antenna (a) in the air, (b) in 150 mm x 150 mm x 100 mm human body model, and (c) in 400 mm x 400 mm x 150 mm human body model.

Fig. 4 shows the return loss properties of the proposed antenna for various human body models. The return loss of the proposed antenna was higher than 15 dB over the MICS band and the 10 dB return loss bandwidth was 8 MHz (2.0%). Also, the return loss property of the proposed antenna did not change when the relative permittivity of the muscle layer and the body model size changes as shown in Fig. 4(a) and (b). Furthermore, the variation of the antenna position in the human body model did not cause the impedance matching problem as shown in Fig. 4(c) and (d). The results shown in Fig. 4 reveal that the impedance matching characteristic of the proposed antenna was nearly independent on the human body model. This insensitiveness property is very beneficial for implantable antenna as each person has different body size, thickness, composition, and relative permittivity. Therefore, the proposed antenna can be implanted in human body for any position and any person.

Fig. 5 shows the normalized radiation patterns of the proposed antenna in various mediums. Although the proposed antenna has dipolar pattern in the air as shown in Fig. 5(a), the radiation pattern was monopolar in the body due to the loss of human body as shown in Fig. 5 (b) and (c). The peak gains of the proposed antenna were -23 dBi, -36 dBi, and -34 dBi in the air, in 150 mm x 150 mm x 100 mm, and 400 mm x 400 mm x 150 mm human body models, respectively. The poor gain of the proposed antenna was caused by extremely compact size of the antenna not by the chip inductor. The higher gain can be achieved if we increase the size of ground plane.

4. Conclusion

An implantable ENG ZOR antenna for biomedical application was proposed. The proposed antenna includes chip inductors for the ENG ZOR with compact size. The size of the proposed antenna is only 15 mm x 12.05 mm x 1.6 mm (0.020 λ_0 x 0.017 λ_0 x 0.002 λ_0). The impedance matching over the MICS band was attained by choosing the appropriate chip inductor value and adjusting the size of radiating element. The proposed antenna was insensitive to the variation in human body model. The radiation pattern of the proposed antenna in human body model was monopolar due to the loss of human body. We are convinced that the proposed antenna can be a good candidate for compact biomedical implant devices.

References

[1] FCC Rules and Regulations 47 CFR Part 95.

[2] P. Soontornpipit, C. M. Furse, and Y. C. Chung, “Design of Implantable Microstrip Antenna for Communication With Medical Implants,” IEEE Trans. on Micw. Theory and Tech., vol. 52, no. 8, pp. 1944-1951, 2004.

[3] J. H. Park, Y. H. Ryu, J. G. Lee, and J. H. Lee, “Epsilon Negative Zeroth-Order Resonator Antenna,” IEEE Trans. on Antennas and Propag., vol. 55, no. 12, pp. 3710-3712, 2007.

[4] A. Sanada, M. Kimura, I. Awai, C. Caloz, and T. Itoh, “A planar zeroth-order resonator antenna using a left-handed transmission line,” Proc. 34th European Microw. Conference, Amsterdam, vol. 3, pp. 1341-1344, 2004.

[5] [Online]. Available: http://www.murata.com.

Acknowledgments

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