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Integration of Resonant Coil and Antenna for Wireless Power Transfer and Data Telemetry

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***Abstract* – In this study, the Rx resonant coil for the wireless power transfer (WPT) operating at 13.56 MHz is integrated with the antenna for the medical communications service (MICS) band communications. They shares the PCB area of a narrow bar-type shape; the coil has outer current path of the substrate and the meandered planar inverted-F antenna (PIFA) is designed to be located inside the coil. To verify the potentials of the proposed structure, a prototype is fabricated and tested in air and in vitro. The power transfer efficiency (PTE) of about 20% at 15 mm distance and antenna gain of roughly -40 dBi are obtained.**

***Index Terms* — Antenna, MICS, wireless power transfer, WPT, biomedical implant device, inductive link.**

I. INTRODUCTION

Recently, with growing interests in U-health care, study on the biomedical implant devices, such as capsule endoscope, pacemaker, ECG recorder, neuro-stimulator, and retinal implant, have recently drawn high attention. For wireless communications with implanted units, the Medical Implant Communication Service (MICS) band (402-405 MHz) is recommended by the Federal Communications Commission (FCC). Implantable antenna operates in human/animal body and ensures the wireless communications, therefore, many researches on the antenna design for the requirements have also been carried out [1]-[2].

The electric components of the implanted devices need a power source. Conventional biomedical implant devices have been supplied with electric power by an internal primary cell, which should be unfortunately replaced through a surgery with a discharge cycle. The wireless power transfer (WPT) is considered a noticeable alternative [3].

The WPT resonator and implantable antenna should be located on the outward surface of the implanted device. In additional, they operate in-body environment, consequently, are required to be miniaturized. In this study, integration of the resonator and antenna on a common substrate is proposed. The frequency bands for the designed WPT and wireless communications are 13.56 MHz and MICS band, respectively. Their potentials for the applications are verified by simulations and will be demonstrated by experiments.

II. INTEGRATION OF THE MICS BAND ANTENNA WITH THE RX RESONATOR

The integration of the MICS band antenna and the Rx resonator has a narrow bar-type shape for easy injection with a guider such as the hypodermic syringe. The integration size is determined to 30 mm x 5 mm which is identical to the developing wireless communication and WPT modules.

A. Design of the Tx and Rx Coils

The goal of the coil design is to provide the maximized Q-factor. The resonance is achieved by selecting the suitable capacitance according to the inductance of the coil. Therefore, the resonant coil design is followed by the antenna design, and integration is completed after a little iteration.

As shown on Fig. 1 and 2, the Rx coil has multilayer and multi-turns structure, while the Tx coil has sing layer and multi-turns structure. The coil patterns are printed on 0.8 mm-thick (h_{sub}) FR-4 substrates, and 0.5 mm-thick (h_{quartz}) quartz superstrate covers the structures to preserve their biocompability and robustness. The quartz superstrate has been used for the packaging material of the implant device.

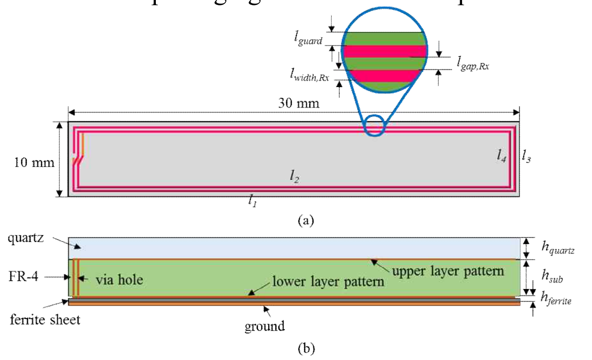


Fig. 1. Geometry of the designed resonant Rx coil: (a) top and (b) side

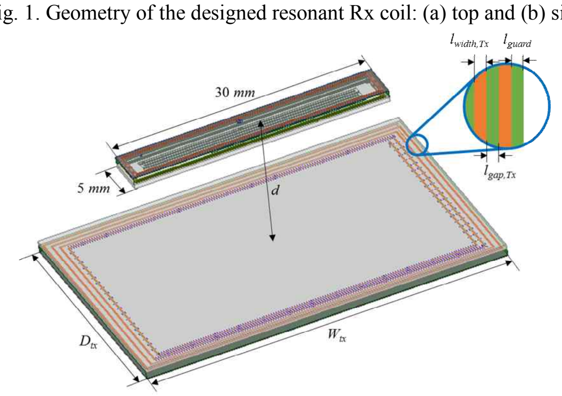


Fig. 2. Geometry and comparison of the designed Tx coil and Rx coil

The large inner radius of a coil tends to increase the mutual inductance. Therefore, the line width ($l_{width,Rx}$) and the gap ($l_{gap,Rx}$) between lines have minimum values, 0.15 mm and 0.13 mm, respectively. The printed patterns are 0.3 mm (l_{guard}) apart from the edge of PCB. The number of turns and layers are optimized using high frequency structural simulator (HFSS) of Ansys Corporation.

According to [4], if the radius of Rx coil and distance between Rx and Tx coils are known, the radius of Tx coil having maximum mutual inductance is determined. In our case, the distance (d) between coils is set to 15 mm. Therefore, the depth (D_{tx}) and width (W_{tx}) of Tx coil are 42.4 mm and 30.4 mm, respectively. The parameters of Tx coil are also optimized and the Tx coil has single layer and four turns. The line width ($l_{width,tx}$) and the gap ($l_{gap,tx}$) are 0.35 mm and 0.6 mm, respectively.

B. Design of the MICS Band Antenna

In our structure, the space for the MICS band antenna is only inner area of coil, about 28 mm x 3 mm. To design the small antenna, the meandered planar inverted-F antennas (PIFA) structure is used. In comparison with usual substrate materials for the implantable antenna, the FR-4 have relatively low permittivity, μ_r = 4.4. However, the ferrite sheet for shielding magnetic field by the coils have high permeability. Its relative permeability is 131 at 13.56 MHz and 31 at 400 MHz. Therefore, the ferrite sheet with high permeability allows to reduce the effective wavelength on the PCB. As a result, the meandered PIFA can be effectively minimized. Due to bottom ground, in addition, the antenna gain increase and the back lobe decrease.

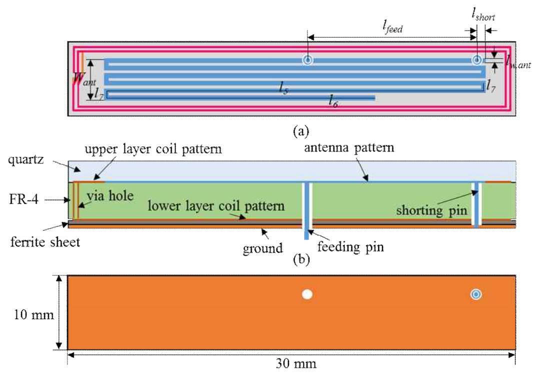


Fig. 3. Geometry of the proposed antenna: (a) top, (b) side, and (c) bottom

III. Simulations, Prototype, and Experiment Results

As it can be observed from Fig. 4, the prototype consists of the bottom circuit module and top pattern module. The connection between two modules is realized and fixed by an 6 pins connector.

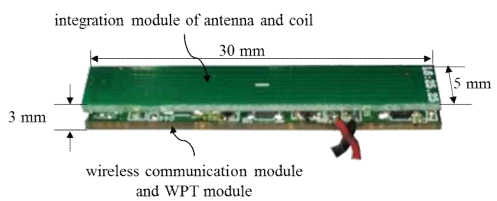
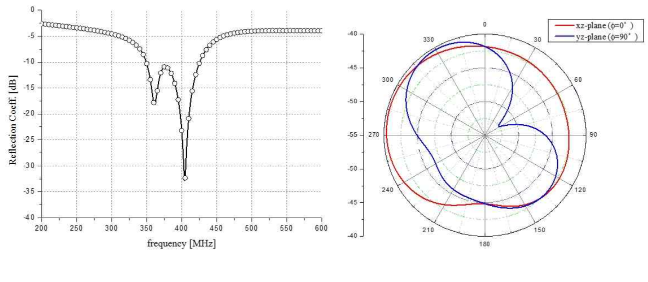


Fig. 4. Fabricated prototype

The simulated reflection coefficient of the proposed meandered PIFA antenna in the skin tissue model is presented in Fig. 5(a), and the gain radiation patterns in the xz- and yz-plane are shown in Fig. 5 (b).



(a) (b)

Fig. 5. Simulation results of the MICS antenna: (a) reflection coefficient frequency response and (b) far-field gain radiation patterns

At resonance frequency, 13.56 MHz, the simulated and measured Rx coil parameters are presented in Table I. The measured results are in good agreement with the simulations. When the distance between the coils is 15 mm, the power transfer efficiency (PTE) is achieved about 20%.

TABLE I

Rx coil Parameters and PTE

Rx coil	*simulation*	*experiment*
L, nH	595.2	605.6
R, Ω	2.59	2.1
Q	19.6	24.57
k	0.034	0.035
η, %	19%	21%

IV. Conclusion

In this paper, the integration of the WPT coil and MICS antenna with narrow bar-type shape are investigated. The proposed structure can be suitable for biomedical implant devices inserting into the subcutaneous tissue such as ECG recorder and pacemaker.

Acknowledgment

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