Performance of An Implanted Tag Antenna in Human Body

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***Abstract*- RFID system is a growing technology for various applications such as logistics management and automatic object identification, and medicine management. In recent years, it is suggested to combine with in-body wireless communications to reduce medical error and improve quality of live (QOL) of patient. In this paper, we designed the tag antenna which integrates with an integrated circuit (IC) chip of 9.3 – *j*55.2 Ω. The antenna is embedded into the three-layered human arm phantom and the performance is simulated by finite-difference time-domain (FDTD) method. In addition, by use of the handy reader, the maximum read range of 1.3 cm of the proposed antenna can be reached, that is approaching the theoretical value of 1.7 cm by the link budget.**

I. INTRODUCTION

RFID system is a growing technology and useful for various applications such as logistics management and automatic object identification, and medicine management. In recent years, it is suggested to combine with in-body wireless communications to reduce medical error and improve quality of live (QOL) of patient [1] in the hospital.

In addition, the in-body technology is being used in medical application, where cardiac pacemaker is implanted in the human body to provide the electrical impulse to the human heart in asystole caused a ventricular contraction. Besides, microchip implant use identifying integrated circuits for tagging and tracking of animal [2]. Today, in-body wireless communication is suggested to be applied to deliver the information of human body such as temperature, blood pressure, and cardiac rate [3] in the hospital. Therefore, if RFID system combines with in-body wireless communication that will be a great benefit to the medical application. However, the human body is a complex environment that is not attractive for wireless signals because of the mutual influence between the human body and the implanted antennas. Moreover, antenna muse be small and thin because the implanted device is embedded in the human body. Previous study describes that the antenna performance is attenuated by the loss of the human body [4].

Nowadays, many reports focusing on the low frequency (LF, 30–300KHz) and the high frequency (HF, 3–30 MHz) [3] have been presented, because the attenuation from the human body is not strong. However, these systems are limited by drawbacks of short communication range and low data rates; moreover, the design of small size antenna in a limited implantable environment is a challenge. The medical implanted communication service (MICS) has been suggested to be used for in-body wireless communication. However, the physical antenna size is still large for embedding antenna into human body. Therefore, the industry-science-medical (ISM) band of 2.4 GHz is a suitable candidate due to the high data rates and reduction of the antenna size. Some references regarding these issues have been published; for instance, The planar inverted-F antennas (PIFA)-like structure on a substrate with high dielectric loss and a cavity slot antenna design have been proposed [5]–[7]. Moreover, The relationship between the RF transmission and the human body for link budget was proposed in references [8] and [9].

In this report, we proposed an implanted tag antenna which combines with a IC chip (μ-chip). In order to match the conjugate impedance of $9.3 - j55.2\ \Omega$, the loop structure is adopted in the antenna design. Moreover, the proposed antenna is coated by a glass coating of 16.75 mm × 5 mm × 2 mm to avoid touching human tissue and keep antenna working for a long time. The antenna is embedded into the three-layered arm phantom and the antenna performance is simulated by FDTD method. The maximum read range of the proposed antenna is measured by the handy reader.

II. ANTENNA STRUCTURE AND HUMAN ARM MODEL

Fig. 1 (a) illustrates the configuration of the proposed antenna which is designed to match the conjugate impedance of $9.3 - j55.2\ \Omega$ by the adopting loop structure. The antenna size is 15.75 mm (L) × 4 mm (W). The glass coating ($\varepsilon_r = 5.0$) is introduced to cover the proposed antenna for reducing influence from the human body. Therefore, the whole size of the proposed antenna will become 16.75 mm × 5 mm × 2 mm.

Figs. 2 shows the human arm phantom which is used to represent a realistic human arm. The phantom of 150 mm × 60 mm × 60 mm is composed of a skin ($\varepsilon_r = 38.0$, $\sigma = 1.5$ S/m), a fat ($\varepsilon_r = 5.3$ $\sigma = 0.1$ S/m) and a muscle ($\varepsilon_r = 52.7$, $\sigma = 1.7$ S/m) at 2.45 GHz [10]. The thicknesses of each tissue in the three-layered phantom are 2, 4, and 54 mm, respectively. Moreover, the proposed antenna is embedded into the fat of the phantom with a depth of 3 mm from surface of skin, since the loss of fat is less than at the skin and muscle layers.

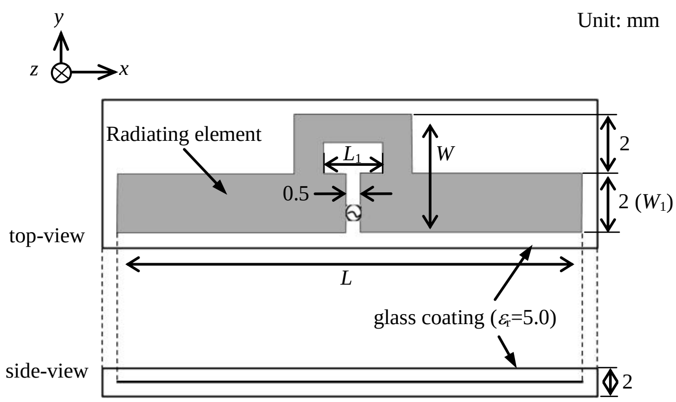
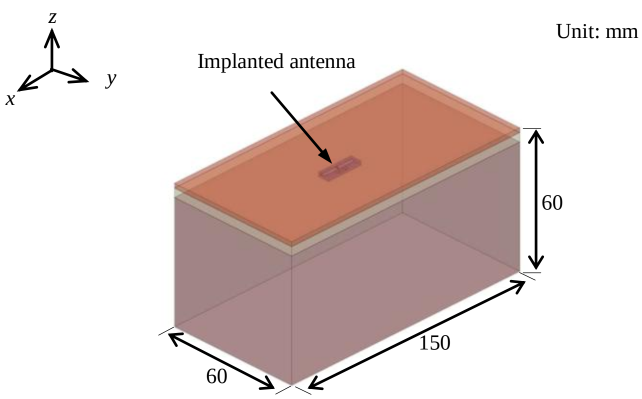
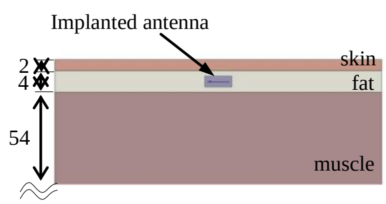


Figure 1. Antenna structure with glass coating.



(a) Over-view.



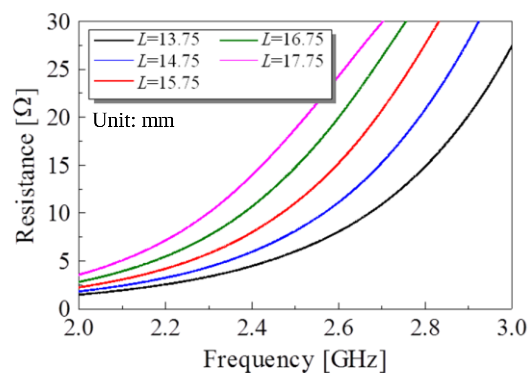
(b) Cross-view.

Figure 2. Human arm phantom.

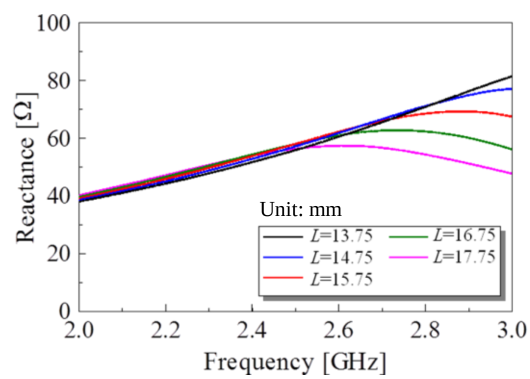
III. Result and Discussion

Since the loop structure is added for improving the impedance matching, the effect on antenna performance is investigated by varying the parameters of loop structure L, L_1 and W_1 (position of the feeding point). The simulated results are shown in Figs. 3 (a)−(f). In Figs. 3 (a) and (b), it is found that when the L is changed from 13.75 mm to 17.75 mm, the resistance is changed from 5.2 Ω to 16.3 Ω at the desired frequency of 2.45 GHz but the reactance does not changed. From the Figs. 3 (c) and (d), simulated result describes that varying parameter of L_1 not only causes resistance to be increased but also changes the reactance. Thus, when L_1 equals to 2.0 mm, the good impedance matching can be obtained. From the results of Fig. 3 (e) and (f), the input impedance can be fin tuned to achieve good impedance matching by varying the parameter W_1 from 0.0 mm to 2.0 mm. Therefore, when these parameters of the L, L_1 and W_1 are set to be 15.75 mm, 2 mm and 1.5 mm, respectively, the input impedance of the proposed antenna can easily match the conjugate impedance of $9.3 - j55.2$ Ω.

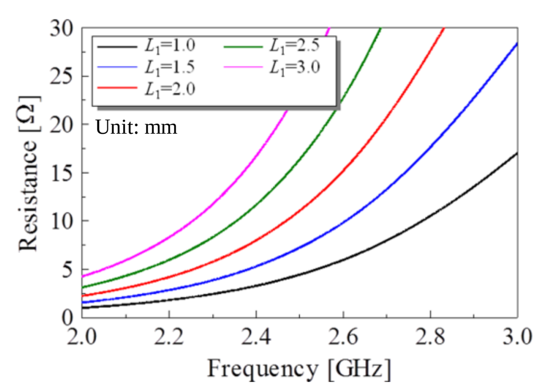
Fig. 4 shows the simulated and measured input impedances. As the result, it is found that the measured result of $9.5 + j55.1$ Ω which is approaching to the IC chip of $9.3 - j55.2$ Ω. Moreover, it also shows a good agreement with simulated result.



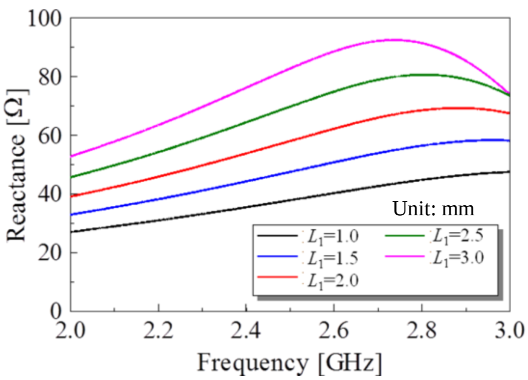
(a) Resistance of parameter L. (L_1=2 , W_1=1.5)



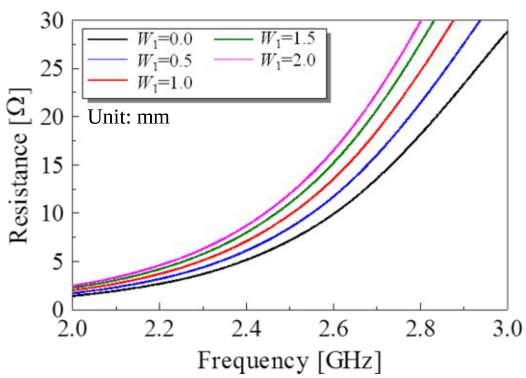
(b) Reactance of parameter L. (L_1=2 , W_1=1.5)



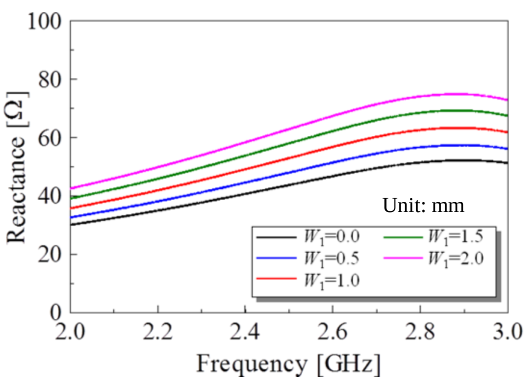
(c) Resistance of parameter L_1. (L=15.75 , W_1=1.5)



(d) Reactance of parameter L_1. (L=15.75 , W_1=1.5)



(e) Resistance of parameter W_1. (L=15.75 , L_1=2)



(f) Reactance of parameter W_1. (L=15.75 , L_1=2)

Figure 3. Impedance characteristics of the proposed antenna.

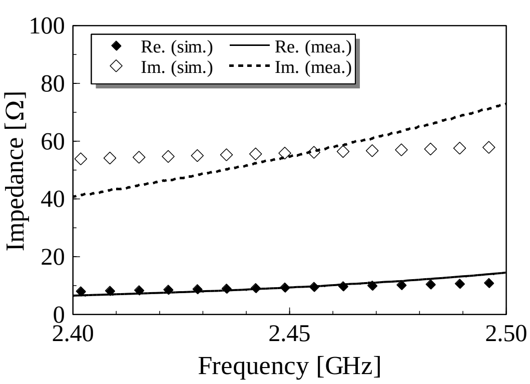
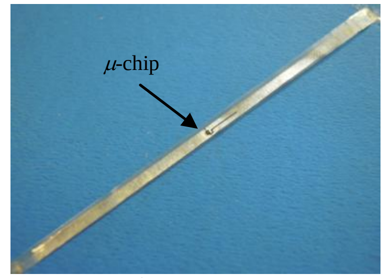
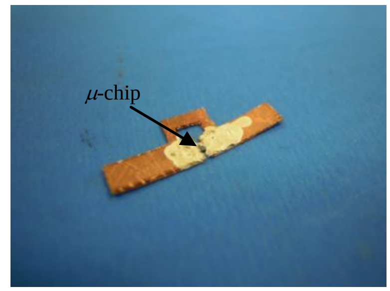


Figure 4. Simulated and measured input impedances.



(a) Reference tag antenna.



(b) Fabricated antenna

(c) Measurement setup

Figure 5. Reference antenna, fabricated antenna and the measurement setup.

IV. Link Budget and Measurement

Figs. 5 show the reference antenna, fabricated prototype antenna and a handy reader. In order to validate the design, we measured the maximum read rage of the proposed antenna by a handy reader. Before the measurement, we can calculate the theoretical value of the maximum read range by the friis transmission formulas:

$$r = \frac{\lambda}{4\pi}\sqrt{\frac{P_t G_t G_r}{P_r}} \qquad (1)$$

In measurement setup of Fig. 5 (c), the reader is an R001M (Sekonic Company) with the output power of 10 mW/MHz. Due to the Bandwidth of 20 MHz, the transmission power P_t by the reader is 200 mW. The minimum threshold power P_r is 2.2 mW [11]. G_r is the gain of the tag antenna (-15.7 dBi). G_r is the gain of the reader. The gain of the reader can be calculated as follows. Fig 5 (a) shows the reference tag antenna [12] which is designed to combine with a μ-chip. The antenna gain of 2.3 dBi presents in free-space and the maximum reader range of 14 cm can be detected by a handy reader under the measurement. Therefore, by Eq. (1), the gain of the handy reader of 1.25 dBi can be obtained. According to above discussion, the theoretical value of the maximum read range *r* of an implanted tag antenna is 1.7 cm. From the measured result, the maximum read range of the proposed antenna is approximately 1.3 cm between the proposed antenna and a handy reader. Moreover, it is very approaching the theoretical value of 1.7 cm.

V. CONCLUSIONS

An implanted tag antenna is proposed and realized for in-body wireless communication. The result shows that the antenna can match the conjugate impedance of $9.3 - j55.2\ \Omega$ very well, even though antenna is embedded in human arm. Moreover, the measured result confirmed the reliability of the simulated result. In addition, we also confirmed that the measured maximum read range of tag antenna is 1.3 cm which approaches the theoretical value of 1.7 cm.

REFERENCES

[1] P. S. Hall, Y. Hao, Antennas and propagation for body-centric wireless communications, Artech House, Boston, MA, 2006.

[2] Positive ID web site : http://www.postiveidcorp.com/

[3] A. Sani, M.Rajab, R. Foster, and Y. Hao, "Antennas and Propagation of Implanted RFIDs for Pervasive Healthcare Applications," *Proceedings of the IEEE*, Vol. 98, No. 9, pp. 1648-1655, Sep. 2010.

[4] H. Y. Lin, M. Takahashi, K. Saito, and K. Ito, "Performances of Implantable Folded Dipole Antenna for In-Body Wireless Communication," *IEEE Trans. Antennas Propag.*, vol.61, no.3, pp.1363-1370, Mar. 2013.

[5] Merli, F.; Bolomey, L.; Zurcher, J.-F.; Meurville, E.; Skrivervik, A.K., "Versatility and tunability of an implantable antenna for telemedicine," Antennas and Propagation (EUCAP), page(s): 2487-2491, Apr. 2011

[6] W. Xia, K. Saito, M. Takahashi, and K. Ito, "Performances of an Implanted Cavity Slot Antenna Embedded in the Human Arm," *IEEE Trans. Antennas Propag.*, vol. 57, no. 4, pp. 894–899, Apr. 2009.

[7] K. Kawaski, M. Takahashi, K. Saito, and K. ITO, "Design of planar antenna for small implantable devices," *International Symposium on Antennas and Propagation* (ISAP 2012), pp.1264-1267, Nagoya, Japan, Oct. 2012.

[8] W. G. Scanlon, J. B. Burns and N. E. Evans, "Radiowave Propagation from a Tissue-Implanted Source at 418 MHz and 916.5 MHz," *IEEE Trans. Bio. Eng.*, vol. 47, no. 4, pp. 527–534, Apr. 2000.

[9] T. S. P. See, X. Qing, Z. N. Chen, C. K. Goh, and T. M. Chiam, "RF Transmission In/Through the Human Body at 915 MHz," *Antennas and Propagation Society International symposium (SPSURSI)*, pp. 1–4, Apr. 2010.

[10] Dielectric Properties of Body Tissues (IFAC), http://niremf.ifac.cnr.it/tissprop/

[11] M. USAMI, et al, "The μ-chip: An Ultra-Small 2.45 GHz RFID Chip for Ubiquitous Recognition Applications," *IEICE Trans. Electron.*, Vol. B86-C, No. 4, pp. 521-528, 2003.

[12] Daisuke OCHI, Masaharu TAKAHASHI, Koichi ITO, Kouichi UESAKA, and Aya OHMAE, "Performances of the wrist band type RFID antenna," *Proceedings of the 2006 IEICE general conference*, p.71, Kanazawa, Sep. 2006.