Design of Denture Implanted RFID Tag Antennas

Junyi XU† Hiroyasu SATO† and Qiang CHEN†

†Graduate School of Engineering, Tohoku University, Sendai, Japan

E-mail: xu-j@ecei.tohoku.ac.jp

Abstract Design of denture implanted RFID tag antennas in the UHF band is performed. The input impedance of the antennas in the human body phantom are measured with changing the antenna structure and are compared with the simulated values by using the frequency dependent FDTD method. The conjugate matching condition between the antennas and the RFID chip are demonstrated.

Keyword RFID; denture; designed antenna; HBEL; Resin

1. Introduction

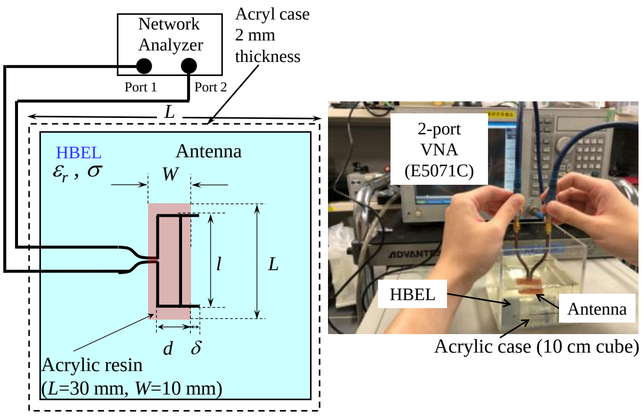
Radio Frequency Identification (RFID) [1], a kind of wireless communication technology, is widely used all over the world, which can identify specific target and read/write related data without any mechanical or optical contact between the system and the target.

Compared with other RFID tags working in the UHF band used for metal or dielectric bodies [1], the RFID tags in-body are more challenging. In this research, a RFID tag implanted in the denture is developed for the detection of wandering elderly persons.

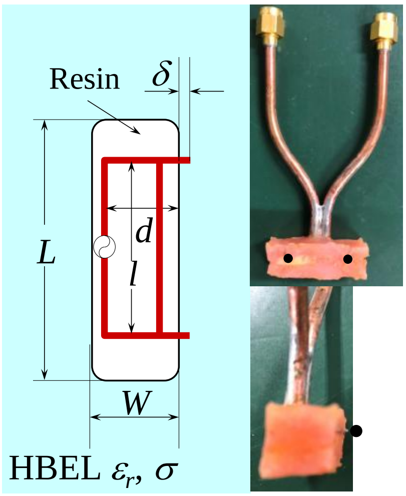
In this paper, the design of RFID tag antennas in the denture is presented. The successful design on the input impedance of RFID tag antenna in the human body phantom and the conjugate matching condition between developed the antenna and the RFID chip are demonstrated.

2. Experiment Setup

The experiment setup is shown in Fig. 1. In Fig. 1(a), the chip impedance in broadband frequency range is measured by S-parameter method using 2-port VNA (Agilent E5071C). Because of the small size of the chip, a JIG is necessary. In Fig. 1(b), a designed antenna with the length l covered by the acrylic resin is placed at the center of the acrylic case. A bending dipole with a loop surrounding used as the design. The bending part of the dipole with the length of $d+\delta$=8 mm is fixed. The two ends of dipole was exposed outside the resin with the length of δ=1 mm [3]. As a phantom of denture, the self-curing acrylic resin which is actually used as material of dentures was used. Size of a denture phantom are with the length L=30 mm, the width W=10 mm. As a phantom in the mouth, the human body equivalent liquid (HBEL) produced by SPEAG having the complex permittivity of the muscle is filled in a cubical acrylic case [2]. The complex permittivity of the acrylic resin and HBEL were measured by using the coaxial probe method. Measured relative permittivity of acrylic resin was around ε_r =2. At 920 MHz, the relative permittivity of HBEL was almost ε_r =60 and the conductivity of HBEL is about 0.7 S/m. In order to obtain the input impedance in broadband frequency range, the S-parameter method [2] with 2-port VNA (Agilent E5071C) was used.



(a)Measurement of antenna impedance



(b) Model of antenna

Fig.1. Experiment setup.

3. Results

Fig. 2 shows the input impedance $Z_a=R_a+jX_a$ of antenna slightly exposed and full covered. The resistance of antenna full covered is almost zero, which is hardly impossible to realize the impedance matching. On the other hand, if two ends of the antenna are slighty exposed into the outside environment, the range appears where the resistance is big enough to realize the impedance matching. Then it is the only thing to realize impedance matching in adjusting the length *l*.

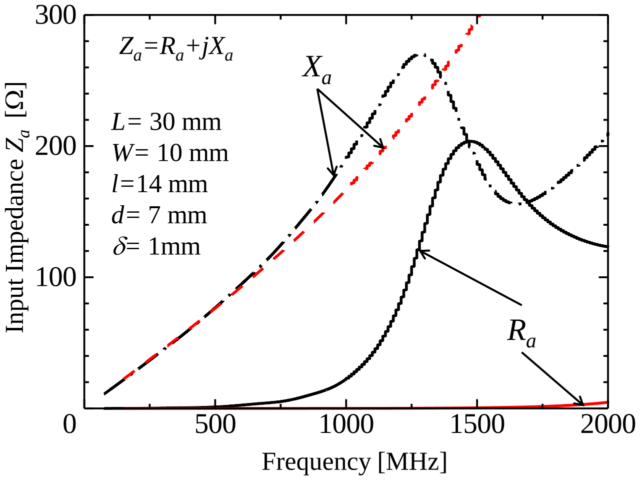


Fig. 2 Input impedance of antenna slightly exposed and full covered

Fig. 3 shows the input impedance $Z_a=R_a+jX_a$ of designed antenna with changing the length *l* from 10 mm to 22 mm. It can be observed that when the length *l* changed from 10 mm to 22 mm, the resonant frequency decreased. When the frequency is lower enough the resistance of the designed antenna was quite small values and the large reactance around j140 Ω was observed. This impedance performance can be used into impedance matching with RFID chip.

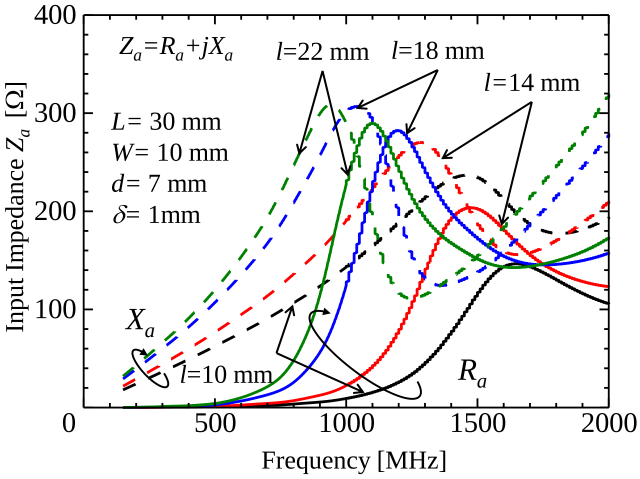


Fig. 3 Antenna impedance with different *l*

Fig. 4 shows the input impedance of simulation value and experiment value. As a result, the resonant frequency is almost the same as simulation value, which means it is possible to realize the same performance as simulation into real product. As for the reason why the value of experiment is a little bit different from simulation value, it is not clear yet. One of the possible reason can be related to quality factor Q.

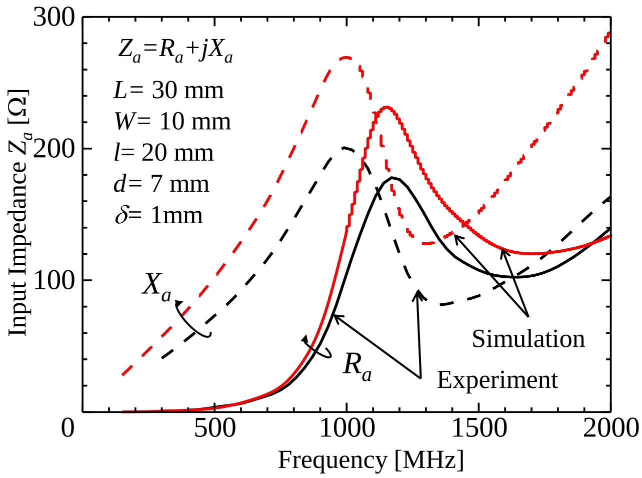


Fig. 4 Antenna input impedance of simulation and experiment

It is noted from Fig. 3 that it is available decreasing the length *l* for higher resonant frequency, lower resistance and higher reactance if necessary. The reverse is also true. For different cases of impedance matching with RFID chips, it is possible to tune the size of antenna in order to meet the requirement of matching.

Fig. 6 and Fig. 7 show an example of impedance matching which includes chip impedance $Z_c=R_c+jX_c$ of Impinj Monza 4, antenna input impedance $Z_a=R_a+jX_a$ when l=10 mm and the absolute value of power wave reflection coefficient $|\Gamma|$. The power wave reflection coefficient Γ [5] is given by

$$\Gamma = \frac{Z_a^* - Z_c}{Z_a + Z_c} \quad (3)$$

It can be observed from Fig. 6 that at around 930MHz, the chip impedance is almost conjugate matching with the input impedance of antenna when *l* is 10 mm. And Fig. 7 shows that the absolute value of power wave reflection coefficient $|\Gamma|$= -9.3 dB is realized at 930 MHz when the length l=10 mm and after precise tuning successful design of RFID tag antenna will be realized.

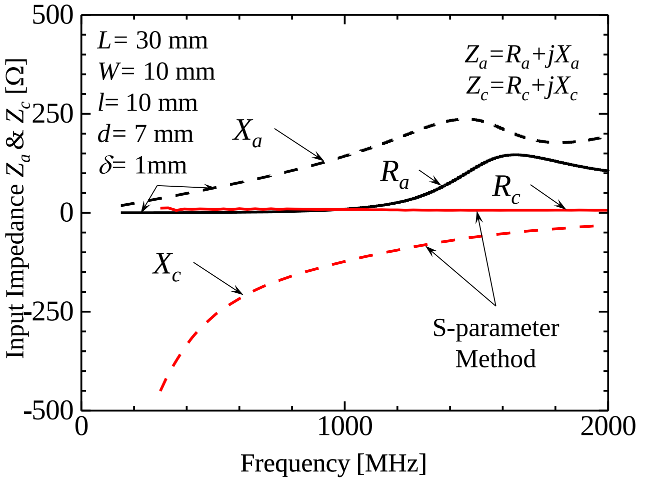


Fig. 5 Input impedance of Monza 4 and antenna with length of l=10 mm

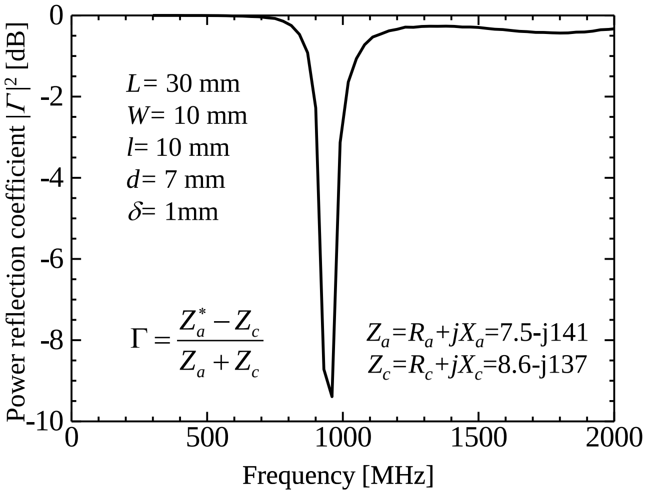


Fig. 6 Power wave reflection coefficient $|\Gamma|$ between Monza 4 and antenna with length of l=10 mm

4. Conclusion

In this paper, design of denture implanted RFID tag antennas in the UHF band is performed. The input impedance of the antennas in the human body phantom is measured with changing the antenna structure and is compared with the simulated values by using the frequency dependent FDTD method. As an example, the conjugate matching condition between the antennas and the RFID chip are demonstrated. Also, if better performance is required, precise tuning of antenna is possible with the method above.

5. Acknowledgment

This work was partly supported by COI STREAM (Center of Innovation Science and Technology based Radical Innovation and Entrepreneurship Program).

6. References

[1]K. h. Chen, Q. Chen and K. Sawaya, "Closely located RFID tag antennas on high dielectric objects," 2016 International Symposium on Antennas and Propagation (ISAP), Okinawa, 2016, pp. 998-999.

[2]H. Sato, Y. Li, and Q. Chen, “Measurement of dipole antenna in deionized water,” in Proc. International Symposium on Antennas and Propagation (ISAP 2015), S3.8.7, pp. 618-620, Tasmania, Australia, Nov. 2015.

[3]H. Sato, N. Fujii, Q. Chen, N. Ishii, M. Takahashi, R. Suga, K. Uesaka and H. Yoshida, "Dipole Antenna With Sheath-Cover for Seawater Use," 2017 International Symposium on Antennas and Propagation (ISAP 2017), 1376, pp.1-2, 30 Oct.- 2 Nov. 2017, Phuket, Thailand.

[4]H. Sato, Q. Chen, "Slightly Exposed Capsule Dipole Antenna in Lossy Liquid," in Proceedings of the 2018 IEICE Society Conference, B-1-114, Kanazawa, Japan.

[5]K. Kurokawa, "Power Waves and the Scattering Matrix," in IEEE Transactions on Microwave Theory and Techniques, vol. 13, no. 2, pp. 194-202, March 1965.