In-body/Out-body Dual-Use Miniaturized RFID Tag System Using 920MHz/5.02GHz Bands

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***Abstract*— This paper describes an in-body/out-body passive type RFID system by using a miniaturized tag antenna. The RFID tag is used for both in-body and out-body communications. In the out-body condition, the tag antenna is designed at operating frequency 5.02 GHz in order to shrink the tag size to about 2cm length. In the in-body condition, the operating frequency becomes lower than that in out-body condition due to the higher dielectric constant of surrounding medium (i.e. human body and liquid) of the antenna. From the EM simulation result, we found that this tag can be operated at 920 MHz-band which is commonly used in existing 920 MHz RFID system. Therefore, we decided to use existing 920 MHz RFID tag chip and fabricated the miniaturized RFID tag. Fabricated 2cm-class RFID tag performs dual-use characteristic for in-body/out-body conditions by using 5.02 GHz/920 MHz bands.**

Keywords*— *RFID, tag antenna, communication system.

I. Introduction

With the continuous development of passive-type RFID tags, more and more RFID systems have been applied to medical treatment. It has the ability to reduce malpractice and ameliorate the quality of life of the patients [1]. In dental care, more than 89% of elderly people over the age of 75 are using dentures in Japan, and about half of them use partial dentures [2]. Missing dentures is a very common problem for elderly people when using partial dentures. This research is trying to solve this problem by using novel RFID system by proposing a method to deal with the missing denture problem. The missing of the dentures is nothing more than two conditions, accidental swallowing or falling out of body due to lapse of memory. For in-body condition, several RFID antenna studies were carried out [3], which describe about implanted method. This paper proposes a dual-use miniaturized RFID tag system that can solve the missing dentures due to accidental swallowing or the falling out of the body with single tag antenna. In order to distinguish between the two conditions, different communication frequencies according to the place of the tag antenna (in-body or out-body) were used. In the in-body conditions, due to the high dielectric constant of surrounding medium, propagation loss in human body increases at high frequency range, we use low frequency for communication. In the out-body condition, the reader/writer is connected to the frequency converter to communicate at high frequency.

II. Concept of the System

The concept of dual-use RFID system is using different communication frequency for in-body and out-body communication with the same tag antenna. There is trade-off between antenna size and propagation loss of human body. Because of the antenna size is decreasing and the propagation loss is increasing as a function of the frequency. We use high frequency 5.02GHz to achieve small tag antenna for out-body communication. And we use low frequency 920MHz for in-body communication to achieve low propagation loss using same tag. Figure 1 shows the composition of the entire communication system. Same RFID tag is used for in-body/out-

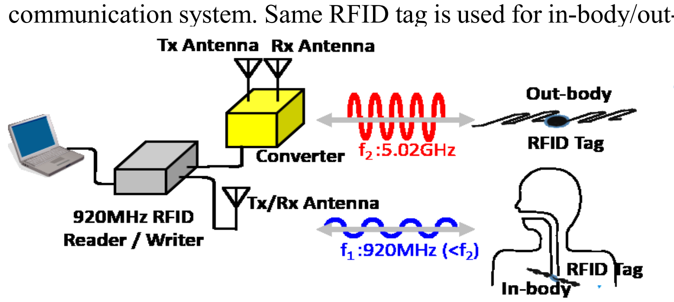


Fig.1 Composition of the system.

body communication using different frequency. For the in-body communication, the reader/writer is directly connected to the antenna without frequency converter to use f_1=920MHz. For the out-body communication, the converter up-convert to f_2=5.02GHz and down-convert to 920MHz for communication. The reader/writer is connected to the computer through the computer to control the output power of the reader/writer.

III. Reader/Writer and Converter Design

In this section the reader/writer and converter will be introduced. The U524SR of the 920MHz RFID reader/writer is used for in-body communication. The maximum transmit power is 30dBm. The internal structure of the frequency converter is shown in Fig. 2. The frequency converter has two functions, up-convert 920MHz to 5.02GHz for Tx and down-convert 5.02GHz to 920MHz for Rx. The RF circulator (RFCR2877) is used to achieve high Tx/Rx isolation and chip mixer (LTC5549) is used to achieve the frequency conversion with the 4.1GHz PLL. On-board filters are applied to decrease out-band spurious. The function of the converter is verified by experiment.

P_{TX} is antenna power of the in-/out-body communication. The output power of the reader/writer can be changed at the range of 15-30dBm. And, antenna power for in-body communication is too. The Tx gain and saturation power of the converter are 15dB and 30dBm, respectively. And the antenna power for the out-body communication is fixed as 30dBm. $P_{RX\text{-}min}$ is the minimum sensitivity of the Rx as input power of the reader /writer and frequency converter. The reader/writer can receive the minimum power of the signal of -60dBm. The Rx gain of the converter is 6dB, therefore, the $P_{RX\text{-}min}$ for out-body communication is -66dBm.

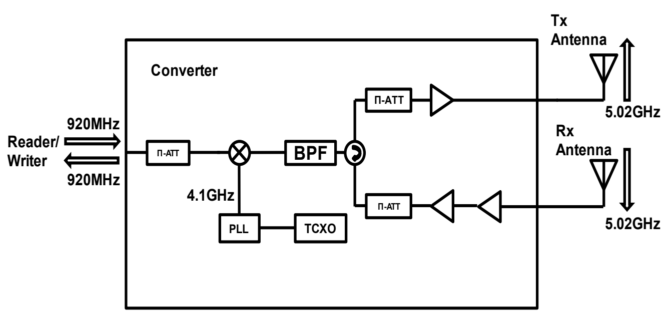


Fig.2 Block diagram of the converter

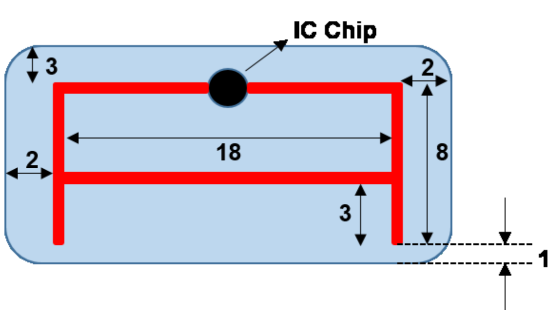
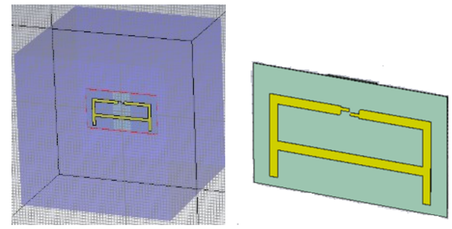


Fig.3 The structure of the tag antenna. (Unit of length: mm)



(a) In-body (b) Out-body

Fig.4 Simulation models of tag antenna

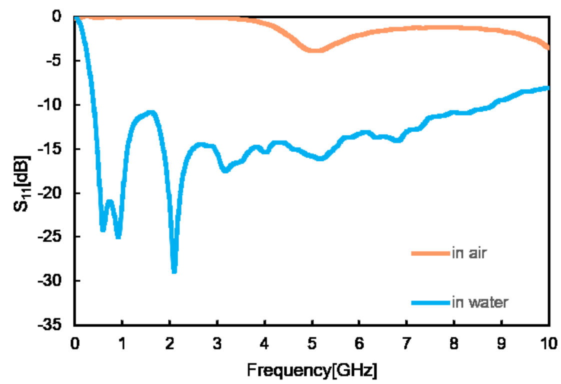


Fig.5 S_{11} of tag antenna by simulation

IV. Tag Design

A. Physical Structure

The physical size of the tag is shown in Fig.3. The black part is IC chip of Higgs-EC. The red part is antenna element using copper with the thickness of 0.018mm, the blue part is substrate using FR4 with the thickness of 0.1mm. On the reverse side of the substrate, a reinforcing plate using FR4 with the thickness of 0.4mm is being loaded.

B. Simulation

In this paper, CST MW-studio is used to simulate the communication of the tag antenna in the in-body and out-body conditions, and observe the resonant frequency by S_{11}. However, in this paper the impedance of the chip cannot be accurately measured especially at 5.02GHz, so source impedance is set to 50Ω in simulation for reference. Figure 4 shows the simulation models (a)in-body and (b)out-body, respectively. In the out-body conditions, the tag antenna is placed in the air with a relative dielectric constant of 1, while the conditions in the body is simulated with water. The relative dielectric constant value of water is 78 that is being shown in the CST. The size of the water model is a cube with a side length of 50 mm.

As shown in Fig.5, resonant frequency is about 5.02GHz in the air, and the return loss is about -3.8dB. In the case of water, the return loss is about -24 dB around 920MHz. The maximum antenna radiation gain is 2.4dBi in air and 3.1dBi in water. It can be seen from the simulation results that the tag antenna can have certainly communication effects in-body and out-body.

V. Experimental Results

Fabrication result of the antenna and tag is shown in Fig. 6. In order to conveniently operate the experiment, we sticked it to the acrylic plate. In order to avoid external interference and reflection, the entire experimental process was carried out in an anechoic chamber equipped with an absorbing material on the wall. The experimental method is that the tag reflects the radio wave emitted by the transmitting antenna (Tx) back to the receiving antenna (Rx) by backscattering method. The tag's ID and signal power are detected by reader/writer and displayed to control PC. The distance of the tag is changed to measure the P_{RX}. The distance is regarded as the maximum distance that the tag antenna can communicate. We experiment to detect the maximum communication distance of the tag antenna in both in-body and out-body conditions. The experiment is divided into two parts. The first part is the experiment of in-body condition as shown in Fig.7 (a). We put 15cm deep water into the 330×390×240 mm^3 plastic foam box with the thickness of 30mm. The UHF band monopole antenna(Tx/Rx) is directly connected to reader/writer. Considering the distance from the surface of the human body when the tag is in the human body, we place the tag 20mm from the inner surface of the plastic foam box, then measure the distance L_1. The second part is to place the tag antenna in the air for out-body communication. The frequency converter is connected to the reader/writer using the horn antenna BBHA9120B (1-10GHz) and measure the L_2 as shown in Fig.7 (b) with P_{TX} of 30dBm.

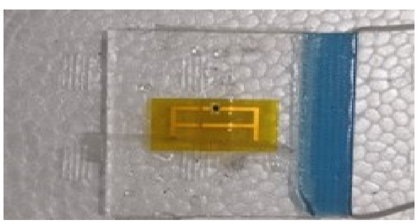
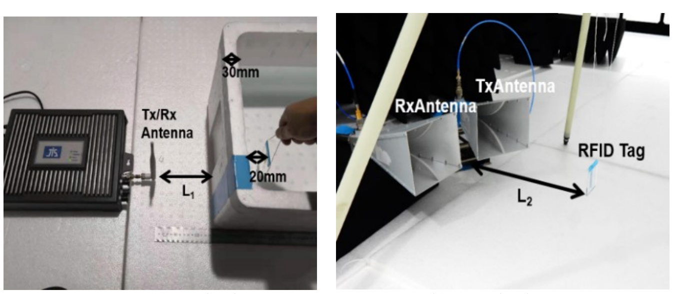


Fig.6 The tag on the acrylic plate



(a) In-body (b) Out-body

Fig.7 The experiment in Anechoic Chamber

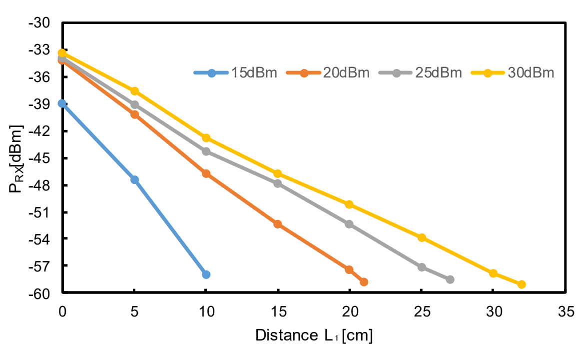


Fig.8 Communication distance and P_{RX} (change P_{TX} in water)

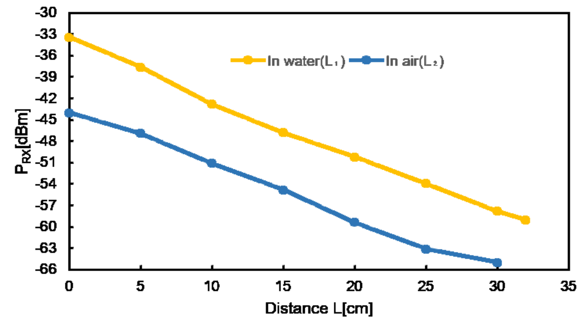


Fig.9 Communication distance and P_{RX}
(comparison of in water and in air when P_{TX} is 30dBm)

The results of the experiment are shown in Fig. 8. The relationship between P_{RX} and communication distance in the water is depicted. We set the output power of the reader/writer to 15dBm, the signal is no longer received when the tag antenna is 10 cm away from the monopole, and we change the output power of the reader/writer to 20dBm, then 25dBm, and 30dBm. The communication distance increases as well as the output power increases. In the air, we have to connect the reader/writer to the converter. Figure 9 shows the comparison of in water and in air when P_{TX} is 30dBm.Through the experimental results, it can be found that the tag antenna can communicate within a certain distance in different environments in-body and out-body. When the P_{TX} is set to 30dBm in both cases, the communication distance can reach about 30cm for out-body and 32cm for in-body.

VI. Conclusion

Miniaturization of antenna is a great concern to realize wireless communication RFID tag for medicine. In this paper, the operational frequency of in-body/out-body dual-use system is discussed by using a miniaturized tag antenna which can be implanted into partial dentures. Due to the difference of surrounding medium (mainly dielectric constant) of the tag antenna, the antenna can be operated at 920MHz (in-body) and at 5.02GHz (out-body). Simulation and experiment results show that the tag is able to communicate within dozens of centimeters in in-body/out-body conditions.

Acknowledgment

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