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Evaluation of Partial Denture Management RFID System Using a Simple Phantom Model

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***Abstract*— We had proposed a 920MHz/5.02GHz dual-use RFID system to detect the existence of partial dentures for both in-body/out-body conditions. In this paper, the communication range has been measured for in-body RFID communication at 920MHz by using a simple phantom model. The partial denture with RFID has been placed at 3 different points in the oral cavity of the phantom model. Communication range of 200mm from the surface of phantom has been obtained for almost all around the phantom. Whereas, we have had no response from the RFID tag implanted in the denture at all position in the phantom at 5.02GHz. We've also confirmed the response from the RFID tag when the partial denture is placed out-body at 5.02GHz. These results show the feasibility to distinguish whether the partial denture with dual-use RFID tag is in-body or out-body.**

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

I. Introduction

With the development of passive RFID tags, RFID systems are increasingly being applied in medicine[1][2]. The same is true in the field of dentistry. In Japan, more than 89% of the elderly over the age of 75 use dentures, and about half of them use partial dentures. 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. Implantation of 2.4GHz RFID tag in a full denture was examined, but existing RFID tag can't be implanted in a partial denture (30 mm length). We proposed a miniaturized 5.02GHz RFID tag for partial denture[3]. We also showed this tag can be used as 920MHz RFID tag if the tag is placed inside of human body (in high dielectric medium)[3]. Therefore, we named this RFID system as in-body/out-body dual-use miniaturized RFID tag system.

In this paper, the dual-use RFID tag was implanted in a resin block that simulated a partial denture and in-body (oral cavity)/out-body operation is confirmed by measurement using simple phantom model.

II. Concept of Proposed System and Tag Design

A. Concept of Proposed System

Proposed partial denture management RFID system uses two different RF frequencies, 920MHz for in-body (in oral cavity) and 5.02GHz for out-body. When the partial denture with dual-use RFID tag is placed in the air (out-body), this tag operates at 5.02GHz. Since this tag is smaller than 2.45GHz RFID tag, it can be implanted in small partial denture. When the denture is placed in oral cavity (in-body), the tag operates at 920MHz because the permittivity of human body is greatly higher than the air. Fig.1 shows the composition of the entire communication system. For the in-body communication, the reader/writer is directly connected to the antenna without frequency converter to use 920MHz. For the out-body communication, the converter up-convert to 5.02GHz and down-convert to 920MHz for communication. The reader/writer is controlled and monitored by a personal computer.

B. Tag design

Figure 2 shows a photo of dual-use RFID tag embedded in a resin block. The size and medium of resin block simulate typical partial denture. The physical size of the tag is shown in Fig.3. The antenna can be miniaturized by setting the resonant frequency at 5.02 GHz for out-body use, therefore it can be implanted in a small partial denture. The red area is the Higgs-EC IC chip[4]. The black part is a 0.035 mm thickness antenna element made of copper film, and the

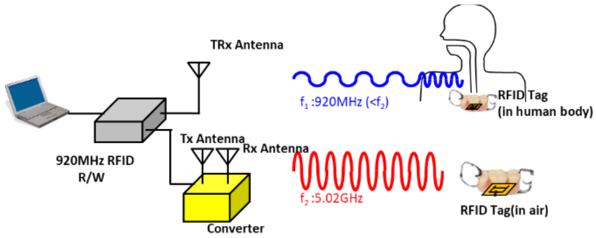


Fig.1 Composition of the system.

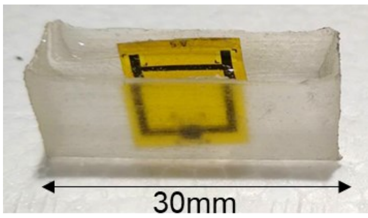


Fig.2 Photo of dual-use RFID tag embedded in resin block

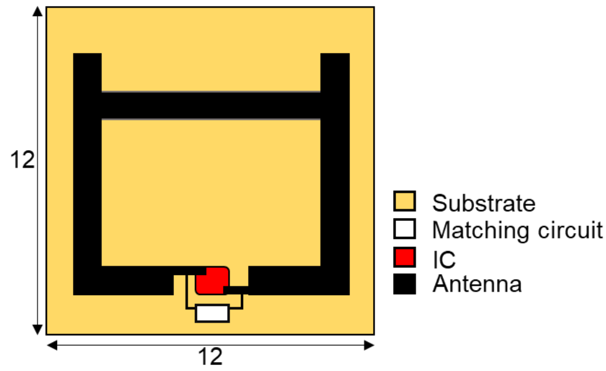


Fig.3 Structure of tag antenna. (Unit of length: mm)

yellow part is a 0.1 mm thickness FR-4 substrate. By adding a gamma matching circuit to the chip [5], this tag can be operated at 920 MHz for in-body use and at 5.02 GHz for out-body use.

III. Measurements

A. *Measurement of 920 MHz communication (in-body)*

Figure 4 shows an in-body environment model that simulates the shape of the human head. The model is filled with water to simulate the dielectric constant of the human body. RFID tag was placed inside the model as shown in Fig.5(b). It simulates a partial denture in the oral cavity. The measurement system is shown in Fig. 6. The 920 MHz reader/writer was used for the measurement. The UHF band monopole antenna(TRx) is directly connected to reader/writer. The monopole antenna was placed horizontally on the ground. The in-body environment model was placed opposite the monopole antenna. The transmit power at TRx antenna is set as 30dBm. The minimum received power of reader/writer is -60dBm. When reception becomes impossible, the L becomes the maximum communication distance. The maximum communication distance at each angle is measured by varying L and θ as shown in Fig. 6. A set of measurements was done for three tag positions: front teeth, left back teeth, and right back teeth, as shown in Fig.5(b).

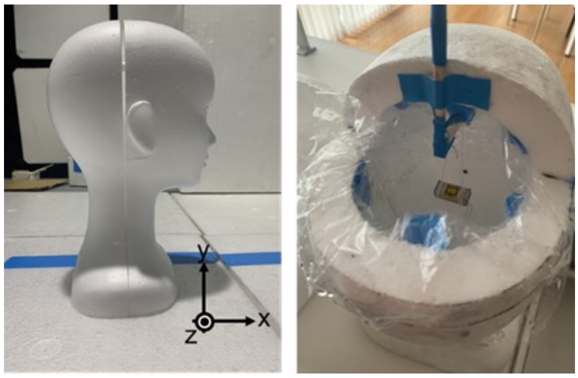
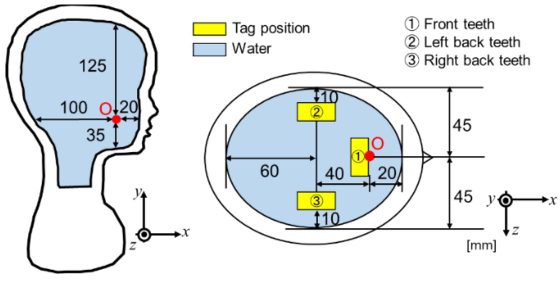


Fig.4 Photo of simple phantom model



(a) x-y Cross-section (b)x-z Cross-section

Fig.5 Cross sectional view of simple phantom model

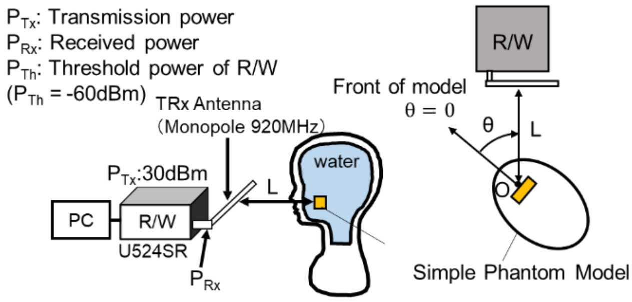


Fig.6 Measurement system of A (920MHz, in-body)

Figure 7 shows the measured communication range, plotting the maximum communication distance at each angle centered on the origin o, and provides an overview of the body environment model. When the RFID tag was attached to the front teeth, communication was possible over the entire circumference of the head. When the RFID tag was attached to the left back teeth, communication was possible over the entire circumference, and the communication range extended toward the right side of the head. When worn on the right back teeth, communication was possible over the entire circumference and the communication range extended toward the left side of the head. Regardless of the denture position, communication was possible over almost the entire circumference of the head, even when the antenna was 200 mm away from the head surface.

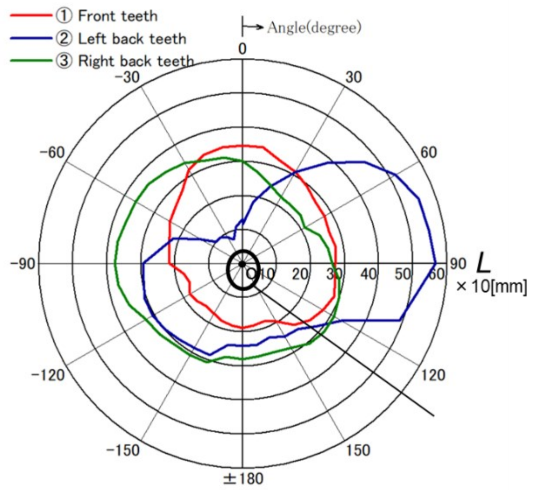


Fig.7 Communication range of A (920MHz, in-body)

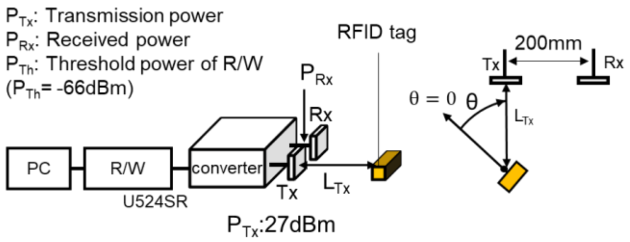


Fig.8 Measurement system of B (5.02GHz, out-body)

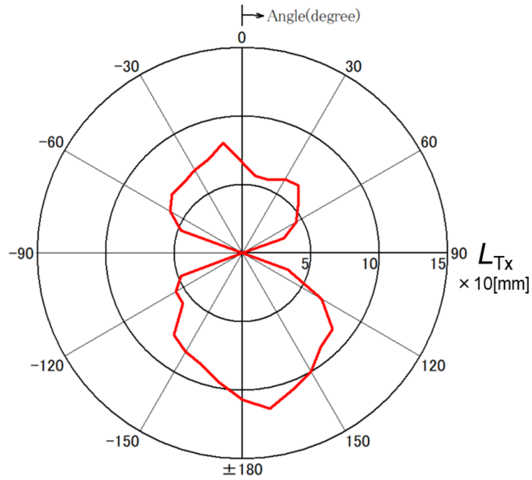


Fig.9 Communication range of B (5.02GHz, out-body)

B. *Measurement of 5.02 GHz communication (out-body)*

Figure 8 shows the measurement system for 5.02 GHz communication range in out-body environment. The frequency converter is connected between the R/W and the antennas. The frequency converter has two functions, up-convert 920MHz to 5.02GHz for Tx and down-convert 5.02GHz to 920MHz for Rx. Tx and Rx signals are separated in the converter. To ensure isolation between the Tx and Rx antennas, the patch antennas were placed 200 mm apart and in parallel. The transmit power P_{TX} is set to 27 dBm. Since the minimum received power at the reader/writer is -60 dBm and the down-conversion gain is 6dB, the minimum received power at Rx antenna is -66 dBm. The maximum communication distance at each angle is measured by varying L_{Tx} and θ. The RFID tag implanted in partial denture is placed on a foamed polystyrene block which simulates the air (out-body).

The measurement result are shown in Fig. 9. Although there is a radio insensitive zone in the communication range, the maximum communication distance of 100 mm was obtained. This result shows that the dual-use RFID tag implanted in partial denture can be found by 5.02GHz reader/writer if the denture is placed out-body.

C. *Measurement of 5.02 GHz communication (in-body)*

The measurement has been carried out by placing the tags in the simple phantom model using the same measurement system shown in Fig. 8. The transmit power from Tx antenna is 27 dBm. We tried to measure the communication range by changing L_{Tx} and θ. As a result, communication was impossible for any L and θ at 5.02GHz.

IV. Conclusion

In this paper, we have measured the communication range of dual-use RFID tag implanted in partial denture using simple phantom model. Measured in-body (in oral cavity) results at 920 MHz (in-body: in oral cavity) show 200mm communication range all around the phantom surface, whereas in-body communication is impossible at 5.02GHz. Measured out-body (in the air) result shows the maximum communication range of 100mm. These results show the feasibility to distinguish whether the dual-use RFID tag implanted in partial denture is in-body (in oral cavity) or out-body by using a dual-band (920MHz/5.02GHz) reader/writer.

Acknowledgment

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