

Insole Antenna System For Detection of Elderly Wanderers

Hiroyasu Sato ^{1*}, Kodai Sato ¹, Kazuhiro Suzuki ², and Qiang Chen ¹

¹ Department of Communications Engineering, Graduate School of Engineering, Tohoku University, Sendai, Japan

² Life Laboratory Inc., Sendai, Japan

*email: hiroyasu.sato.b1@tohoku.ac.jp

Abstract - In this paper, an insole antenna system composed of a transmitting insole antenna with a Bluetooth module driven by a DC-power generated by stepping on a piezoelectric element is proposed. The insole antenna is attached to the space of the arch of the insole to reduce the influence of the human body on the antenna characteristics. Propagation analysis by Two-wave model and experimental evaluation of received power are presented. It is demonstrated that the received power can be increased by increasing the height of receiving antenna.

Keywords — Insole Antenna, Elderly wanderers, Battery-less

I. INTRODUCTION

A detection system to find elderly wanderers is desired in recent years. To realize those systems, it is necessary to attach a tag antenna on-body of wanderers always wears. As an example, RFID tags with antennas inserted into dentures are being researched [1-3]. When detecting wanderers over long distances of 100 m using Bluetooth, an antenna design with high radiation efficiency and a battery to drive the Bluetooth module are required.

In this study, we propose a battery-less insole antenna system in which an antenna is attached to the insole of a shoe and drives a Bluetooth module by generating DC-power using a piezoelectric element. Propagation analysis by Two-wave model and measured received power distribution along a road with changing height of a receiving antenna are evaluated.

II. INSOLE ANTENNA STRUCTURE

The proposed insole bowtie monopole antenna is shown in Fig. 1. The advantage of the foot as a position of antenna is that it can generate DC-power using a piezoelectric element to drive a Bluetooth module and radio waves can be transmitted without a power source. Also, it is possible to avoid the decrease of antenna efficiency by selecting the arch of the foot as the antenna position, no contact with the human body. The Bluetooth board acts as the ground plane of the bowtie monopole antenna and can be placed in the space of the arch. The disadvantage of an insole antenna is the reduction in received power caused by its low height, which will be discussed in the next section.

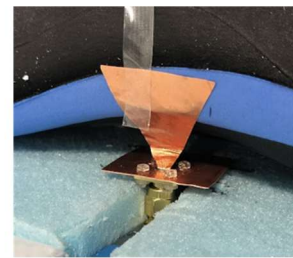
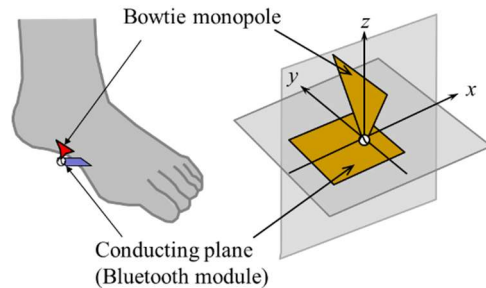


Figure 1. Insole bowtie monopole antenna.

III. ANALYSIS AND EXPERIMENT

Two-wave analysis model are shown in Fig. 2 where an insole antenna is used as the transmitting antenna, and a patch antenna is used as the receiving antenna. The heights of the insole antenna and the receiving patch antenna are h_T and h_R , respectively.

Fig. 3 shows the calculated results of the received power using the Two-wave model when $(h_T, h_R) = (1 \text{ m}, 1 \text{ m})$ and $(h_T, h_R) = (2 \text{ cm}, 1 \text{ m})$. The gain of the transmitting and receiving antennas in the calculation was set as 0 dBi. The crossover point (or break point) d_c is provided as

$$d_c = 4\pi h_T h_R / \lambda \quad (1)$$

where the power attenuation switches from -2nd power of the distance to -4th power of the distance at d_c . When the height of the transmitting antenna decreases from $h_T = 1 \text{ m}$ to $h_T = 2 \text{ cm}$, cross over point changes from $d_c = 103 \text{ m}$ to $d_c = 2 \text{ m}$ and the propagation loss increases significantly as the distance increases. Decrease of received power are 34 dB at a distance of $d = 100 \text{ m}$.

In order to increase the received power, the height of received antenna h_R are increased. Fig. 4 shows the calculated results of the received power using the Two-wave model when h_T is fixed as 2 cm and h_R is changed as 1 m, 3

m, and 10 m. The received power at $d=100$ m were increased 20 dB by increasing the height of the receiving antenna from $h_R=1$ m to $h_R=10$ m.

The above analytical results were verified by outdoor experiments. An asphalt road was used as shown in Fig. 5. The polarization of both the transmitting and receiving antennas was vertical. A patch antenna was used as the receiving antenna, and the received power was measured by a spectrum analyzer. The insole antenna are set on a robot moving with velocity v [m/s]. Height of the insole antenna h_T was fixed as 2 cm. Measured received power with changing distance d were shown in Fig. 6 when the height of the receiving patch antenna is $h_R=33$ cm, 71.5 cm, and 3 m. The increase of received power at $d=30$ m was 17 dB when the height of the receiving antenna h_R changes from 33 cm to 6.89 m. These results demonstrate that even if the height of the insole antenna is small, the propagation loss can be reduced by increasing the height of the receiving antenna.

IV. CONCLUSION

An insole antenna system for detecting eldary wanderers has been proposed and experimentally evaluated the radio wave propagation characteristics. It is found that the received power can be significantly improved by increasing the height of the receiving antenna.

ACKNOWLEDGMENT

This research was partly supported by METI R&D Support Program for Growth-oriented Technology SMEs Grant Number JPJ005698.

REFERENCES

- [1] J. Xu, H. Sato, M. Motoyoshi, N. Suematsu, K. Yasui and Q. Chen, "A low-loss and compact uhf rfid tag antenna for implanted denture," IEEE Journal of Radio Frequency Identification, vol.6, pp. 1-7, 2022.
- [2] J. Xu, H. Sato, and Q. Chen, "Design of Denture Implanted RFID Tag Antennas," Proc. AWPT2018, SA-4-P03, Nov. 2018.
- [3] J. Xu, H. Sato, M. Motohashi, N. Suematsu, H. Kanetaka, K. Yasu and Q. Chen, "Development of Denture Implanted RFID Tag Antennas," Proc. iWEM2018, POS.2.15, Aug. 2018.

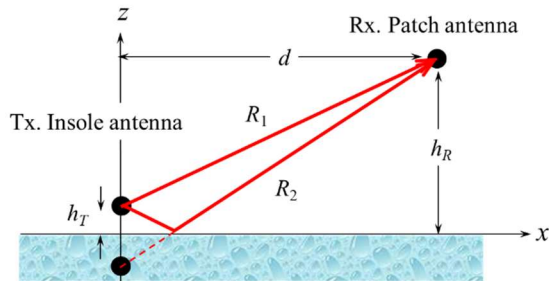


Figure 2. Two-wave analysis model.

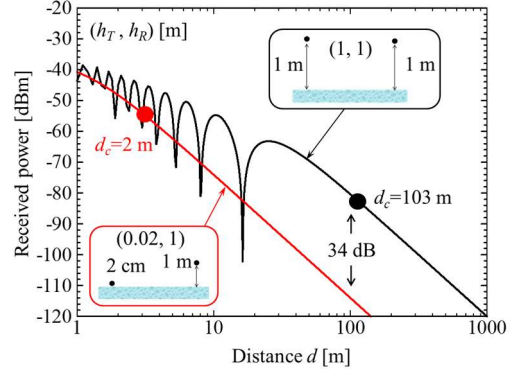


Figure 3. Calculated received power using Two-wave model when $h_T=2$ cm, 1 m.

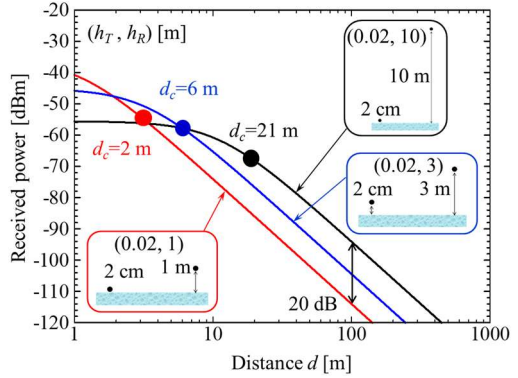


Figure 4. Calculated results of received power using Two-wave model when $h_R=1$ m, 3 m and 10 m.

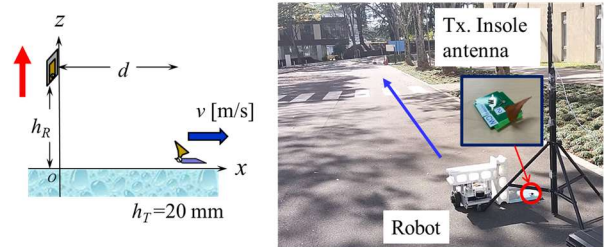


Figure 5. Outdoor experiments at asphalt road.

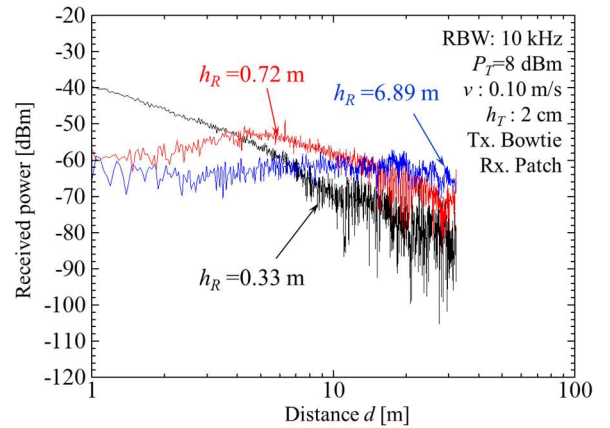


Figure 6. Measured received power with changing distance d when $h_R=0.33$ m, 0.72 m and 6.89 m.