Design of Dual-Mode Antenna at 21 MHz and 2.45 GHz for Medical Applications

Yuichiro Oya[1], Koichi Ito[1], and Kazuyuki Saito[1]
[1] Chiba University, 1-33 Yayoi-cho, Inage-ku, Chiba 263-8522, Japan

***Abstract* - In particular, personal healthcare is considered as the biggest potential application with all kinds of wearable wireless devices. In this paper, we propose a compact wearable dual-mode (on-body and off-body modes) antenna for personal healthcare systems. For on-body mode at 21 MHz, received voltage is analyzed, while for the off-body mode in the 2.45 GHz ISM band, reflection coefficient (S_{11}) and radiation patterns are studied with a high-resolution human model.**

***Index Terms* — Dual-mode, antenna, ISM band.**

I. Introduction

In recent years, body-centric wireless communications (BCWCs) have become a very active area of research because of their numerous applications in areas such as personal health care, smart homes, personal entertainment, and identification systems [1-2]. Especially many researchers considered remote health monitoring as the biggest potential applications with all kinds of wearable wireless devices. Thus these devices can be applied in on-body and off-body communications. In personal health-care systems, at least two modes of communication are required: on-body mode (collecting medical data) and off-body mode (exchanging data with outside networks). For on-body communications, the communication range is limited on the human body. Both wearable transmitter and receiver are mounted on the surface of the human body, and biophysical signal can be transmitted along the human body [3]. Off-body communications present the communication from the surface of the human body to a nearby external device. At least one antenna is located on the human body, and biophysical signal can be transmitted from the antenna on the human body to the external device [4], as shown in Fig.1. For example, the body signals can be detected and recorded in the on-body mode, and then the signals can be transmitted to external device in the off-body mode.

In this paper, we utilized the electrode and slit structures to develop a dual-mode (on-body and off-body modes) antenna for personal health care applications. In this study, on-body and off-body communications at 21 MHz and ISM band 2.45 GHz will be discussed with a high-resolution human model[5].

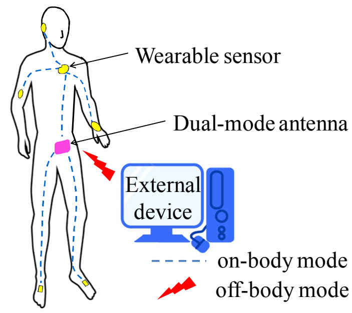


Fig. 1.Example of personal health-care systems.

II. Antenna Structure

Fig.2 presents the proposed dual-mode antenna. It consists of a feeding pin, a signal electrode and a radiator. In order to reduce the size and resonate in ISM band, two slits are embedded in the radiator. The size of the antenna is 30×25×4 mm^3. The length of the slit in the radiator is 18 mm in length and 2 mm in width. The height of the signal electrode is only 4 mm and the feeding pin is located in the signal electrode. This antenna works as a receiver in on-body mode (21 MHz) and a transmitter in off-body (2.45 GHz). In order to concern the equipment packaging, we placed a plastic (ε_r = 2.17) with 2 mm in thickness between the antenna and the human body, as shown in Fig.2.

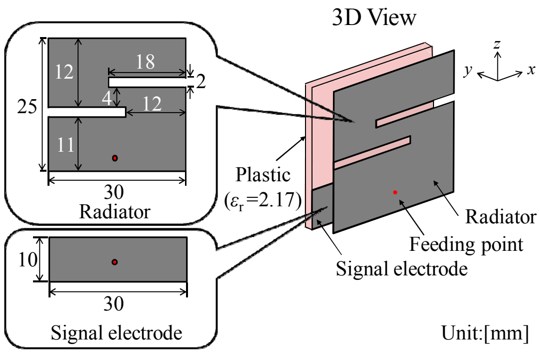


Fig. 2. Structure of the dual-mode antenna.

III. Results and Discussion

A. Off-body mode

In order to perform the off-body communications, we evaluated reflection coefficients changing the size of antenna and the length of the slit in the radiator. Fig.3 presents the simulated reflection coefficients when the antenna structure in Fig.2 works best in various examination. In addition as examples of the parameter studies, the results when the length of the slit was 16 and 17 mm were also presented in Fig.3. In the result of the proposed antenna, reflection coefficient at 2.45 GHz in ISM band was -11 dB. Therefore, the proposed antenna can transmit at 2.45 GHz for off-body mode because the proposed antenna was below -10 dB.

Fig.4 presents the simulated radiation patterns on the high-resolution human model. From the results, the radiation patterns in both planes are relatively omni-directional with no deep nulls in the half-sphere above the human body. Therefore, the proposed antenna is a good candidate for off-body communications. In addition, the weaker radiation toward the human body is due to the absorption by human body.

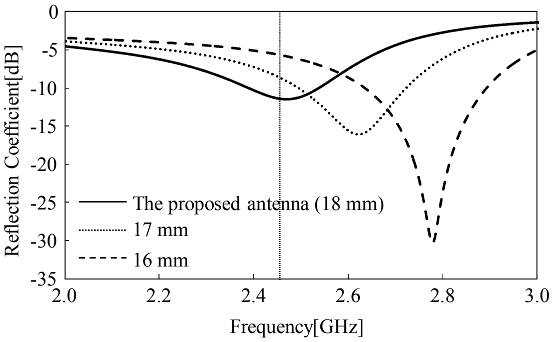


Fig. 3. Reflection coefficients.

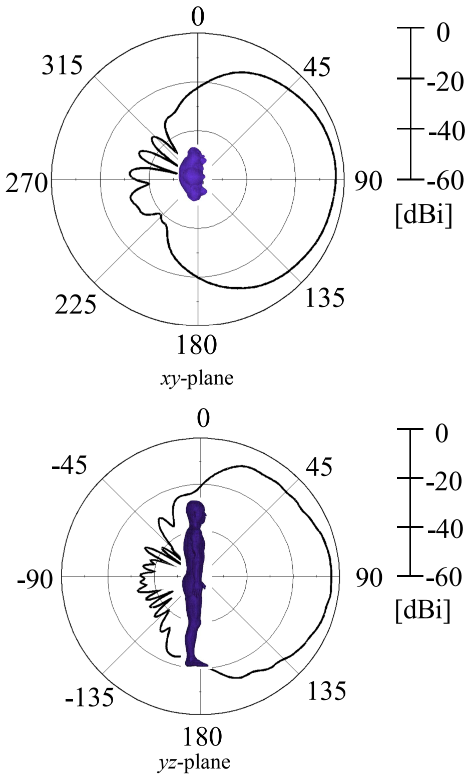
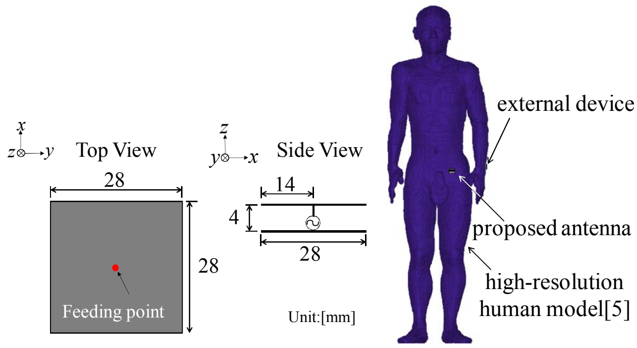


Fig. 4. Simulated radiation patterns at 2.45 GHz.

B. *On-body mode*

In previous section, we confirmed the proposed antenna can transmit at 2.45 GHz for off-body mode. Next, we evaluated possibility of transmitting at 21 MHz for on-body mode. The received voltage between the proposed antenna and the external device is studied. The size and height of the external device is 28×28 mm^2 and 4 mm, as shown in Fig.5.(a). The proposed antenna is attached to the waist while external device is attached to the left hand in Fig.5.(b). The voltage of the transmitted antenna is 1 Vp-p. From the simulated results, received voltage is -95 dB. In reference [6], the lowest received voltage of antenna for only on-body mode was -100 dB in similar situation, however, the antenna for only on-body mode was able to transmit. In comparison with this result, the proposed antenna is better. Therefore, the proposed antenna can transmit at 21 MHz for on-body mode.



(a). external device. (b). attached point.

Fig. 5.Analytical model.

IV. Conclusion

In this paper, we proposed a compact wearable dual-mode (on-body and off-body modes) antenna for personal health care systems. In order to verify the antenna, received voltage at 21 MHz, reflection coefficient and radiation patterns in the 2.45 GHz are discussed. From the results, the proposed dual-mode antenna can be applied in on-body and off-body communications for medical applications.

In the future, we will try to use whole body phantom to evaluate the performance of the wearable antenna.

Acknowledgment

Authors would like to thank Dr. Chia-Hsien Lin, graduated from our laboratory in Chiba University for his useful comments.

References

[1] P. S. Hall and Y. Hao, Antennas and Propagation for Body-Centric Wireless Communications. Norwood, MA: Artech House, 2012.

[2] M. Hamalainen, A. Taparugssanagorn, J. Iinatti, and R. Kohno, "Exploitation of wireless technology in remote care processes," IEICE Trans. Commun., vol. E92-B, no.2, pp. 373-378, Feb. 2009.

[3] K. Fujii, M. Takahashi, K. Ito, K. Hachisuka, Y. Terauchi, Y. Kishi, K. Sasaki and K. Itao, "Study on the transmission mechanism for wearable device using the human body as a transmission channel, " IEICE Trans. Commun., vol.E88-B, no. 6, pp. 2401-2410, June 2005.

[4] A. Tronquo, H. Rogier, C. Hertleer and L. Van Langenhove, "Robust planar textile antenna for wireless body LANs operating in 2.45 GHz ISM band, " Electron. Lett., vol. 42, issue 3, pp. 142-143, 2006.

[5] T. Nagaoka, S. Watanabe, K. Sakurai, E. Kunieda, S. Watanabe, M. Taki and Y. Yamanaka, "Development of Realistic High-Resolution Whole-Body Voxel Models of Japanese Adult Male and Female of Average Height and Weight, and Application of Models to Radio-Frequency Electromagnetic-Field Dosimetry " Physics in Medicine and Biology, Vol.49, pp.1-15, 2004.

[6] Y. Oya, K. Ito, M. Takahashi, and K. Saito, "Received voltage analysis of wearable sensor for home medical care," Proceedings of the 2013 IEICE Society conference, p.179, Fukuoka, Japan, Sep. 2013.