Study of Radio Propagation for Wireless Body Area Network Communication in 2.4 GHz Band

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Abstract

This report investigates radio propagation for on-body wireless communications using three kinds of antennas optimized for the 2.4 GHz ISM Band. Transmission coefficients are measured and calculated when transmitting and receiving antennas are located in the vicinity of a dielectric circular cylinder.

Keywords : WBAN wireless body area network FDTD phantom

1. Introduction

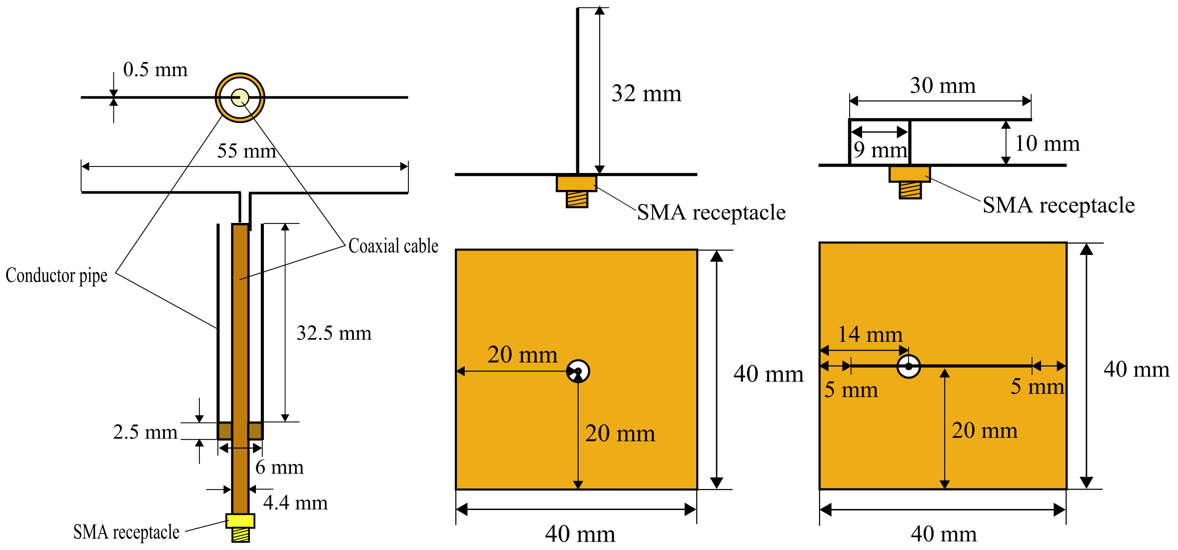
In recent years, wireless body area networks (WBAN) implemented using wearable devices that include a radio terminal placed on the body, have attached much attention [1]. Such networks have the potential to provide various ubiquitous services such as medical, health care, entertainment, security and so on. Because the antenna of the wearable device is placed close to the human body, the lossy human tissue influences the antenna characteristics and on-body radio propagation [2-4]. It is preferable that the antenna is small with a low profile for a practical wearable device. Moreover, the antenna should radiate an electric field vertically to the surface of human the body in order to use the creeping wave that propagates along the surface of the human body.

To clarify the radio propagation of WBAN communication, the transmission coefficient between the transmitting and receiving antennas in the vicinity of the human body is discussed experimentally and numerically. Three kinds of antennas, namely a monopole antenna, a dipole antenna and an inverted-F antenna are used for transmitting and receiving, and the dimensions of the antennas are optimized for the industrial, scientific and medical (ISM) band of 2.4-2.49 GHz. The transmission coefficients are measured when the same kind of antenna is used in the vicinity of a 2/3-muscle equivalent phantom body. Additionally, the transmission coefficients calculated by the FDTD method are compared with the experimental results.

2. Design of Antennas

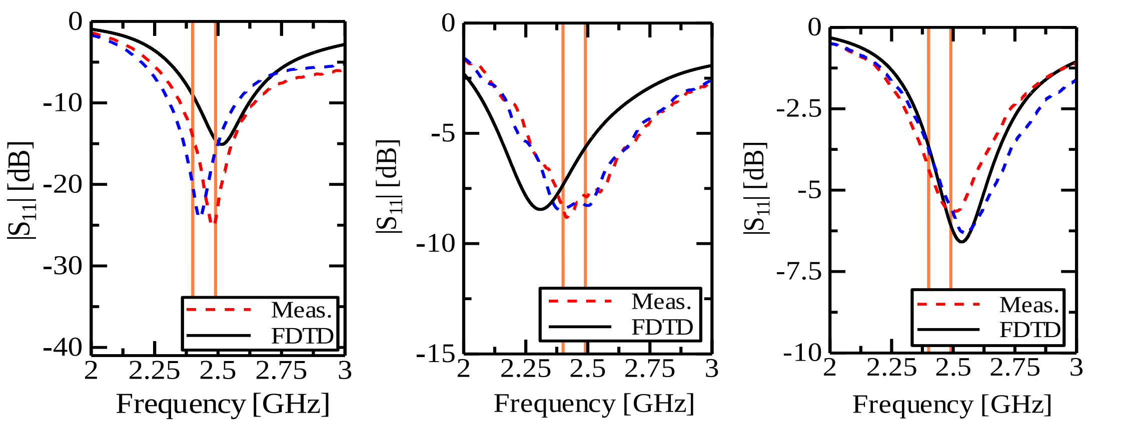
The geometry of the antennas is illustrated in Fig.1. A radiation element of the dipole antenna has a length of 55 mm and a diameter of 0.5 mm. A bazooka balun 35 mm long is used between the radiation elements and coaxial cable. The monopole antenna has a radiation element 32 mm, in length and a ground plane, with dimensions 40 × 40 mm^2. The inverted-F antenna is also on the ground plane and has the same dimensions as the monopole antenna. It is composed of a 30 mm radiation element, and feed and shorting pins,10 mm in length.

Fig. 2 shows the reflection coefficients of the three kinds of antennas in the vicinity of a dielectric circular cylinder modeled on the human arm. To consider the propagation characteristics of the wearable device attached to a human arm, we approximate the arm as a dielectric circular cylinder. The cylinder has a diameter of 55 mm, a length of 900 mm, relative permittivity of 52.7, relative permeability of 1, and conductivity of 1.73. The values of the electric constants are 2/3-human muscle at 2.45 GHz. The phantom body shaped circular cylinder used in the experiment is made from deionized water, agar, polyethylene powder, sodium chloride, TX-151, and dehydroacetic acid sodium salt. The distance between the surface of the cylinder and end of the radiation element or the ground plane is 3 mm. The reflection coefficient is measured the using Vector Network Analyzer E8364C from Agilent Technologies. Two experimental results are shown in each figure corresponding to the two antennas used for the transmission and the reception. The cause of the small disparity in the graphs is a fabrication error of the antennas. It can be seen that the measured resonance frequencies of the dipole and monopole antennas are in the ISM band, whereas that of the inverted-F antenna is shifted slightly from the ISM band.



(a) dipole antenna (b) monopole antenna (c) inverted-F antenna

Figure 1 : Structure of antenna.



(a) dipole antenna (b) monopole antenna (c) inverted-F antenna

Figure 2 : Reflection coefficient.

3. Transmission Coefficient

Fig. 3 shows the experimental setup for the measurement of the transmission coefficient. The distance between the transmitting and receiving antennas is 200mm. The distance between the surface of the cylinder and the end of the dipole antenna element or the ground plane of the monopole antenna and inverted-F antenna is 3 mm. The receiving antenna is successively located at azimuth angle of $\phi = 0°$, 90°, and 180°.

Fig. 4 shows the measured and simulated transmission coefficients when the receiving antenna is located at $\phi = 0°$. The maxima in the ISM band of the measured transmission coefficients of the dipole, monopole, and inverted-F antennas are -22.6 dB, -24.5 dB and -24.7 dB, respectively. It can be seen that the transmission coefficient of the dipole antenna is the highest of the three kinds of antennas, while those of monopole and inverted-F antennas are almost the same.

Fig. 5 shows the transmission coefficients when ϕ = 90°. The measured maxima in the ISM band of the transmission coefficients of the dipole, monopole, and inverted-F antennas are -26.8 dB, -31.4 dB, and -32.6 dB, respectively. Only for the inverted-F antenna is the difference between the maximum values for ϕ = 0° and 90° is greater than 7 dB.

Fig. 6 shows the transmission coefficients when ϕ = 180°. The maxima in the ISM band of the measured transmission coefficients of the dipole, monopole, and inverted-F antenna are -38.9 dB, -29.4 dB, and -29.5 dB, respectively. It is seen that the transmission coefficient of the dipole antenna decreases greatly. On the other hand, the transmission coefficients of the monopole and inverted-F antennas are greater than the obtained for ϕ = 90°. The reason seems to be that the ground plane acts as a radiation element.

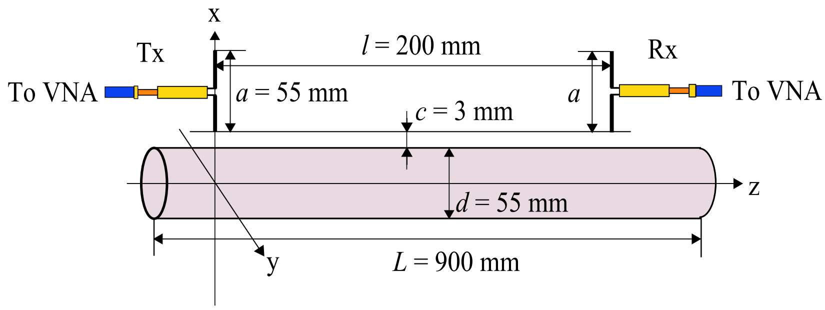
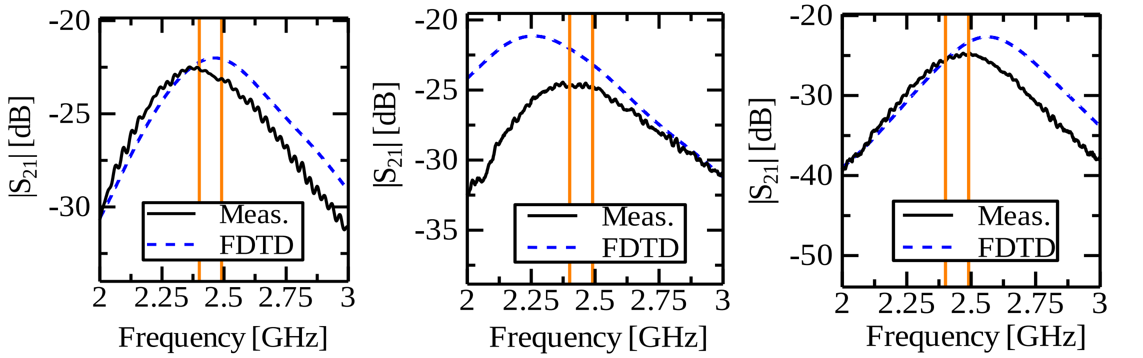
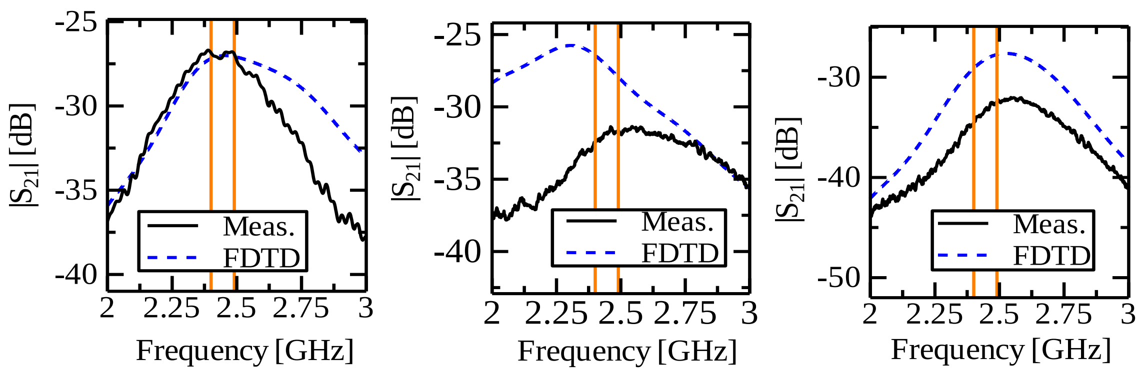


Figure 3 : Setup for the measurement.



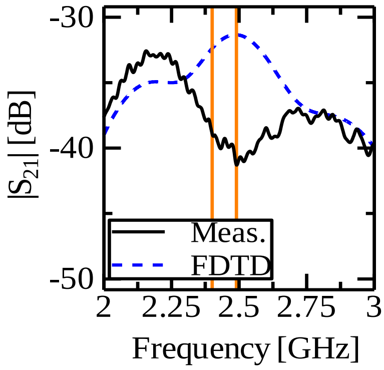
(a) dipole antenna (b) monopole antenna (c) inverted-F antenna

Figure 4 : Transmission Coefficient when receiving antenna is located at ϕ = 0°.

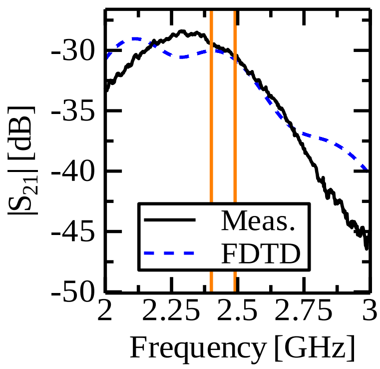


(a) dipole antenna (b) monopole antenna (c) inverted-F antenna

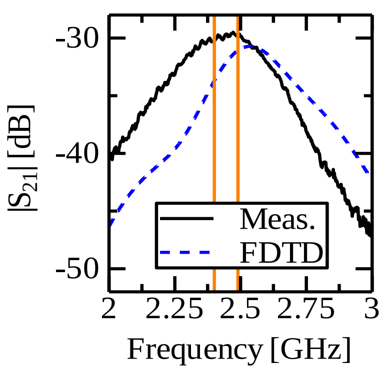
Figure 5 : Transmission Coefficient when receiving antenna is located at ϕ = 90°.



(a) dipole antenna



(b) monopole antenna



(c) inverted-F antenna

Figure 6 : Transmission Coefficient when receiving antenna is located at ϕ = 180°.

4. Conclusion

To clarify the radio propagation of WBAN communication, the transmission coefficients for three kinds of transmitting and receiving antennas in the vicinity of the dielectric circular cylinder were discussed experimentally and numerically. A monopole antenna, a dipole antenna and an inverted-F antenna were optimized for the 2.4 GHz ISM band. The results show that the decrease in transmission coefficients of the monopole and inverted-F antennas were smaller than that of the dipole antenna when the receiving antenna was located at ϕ = 180°.

References

[1] T. G. Zimmerman, "Personal area networks: Near-field intra-body communication," IBM Systems Journal, vol. 35, no. 3&4, pp. 609-617, 1996.

[2] Y. Hao, P. Hall, "On-Body Antennas and Propagation: Recent Development," IEICE Transactions on Communication, vol.E91-B, No. 6, pp.1682-1688, June 2008.

[3] M. Munoz, R. Foster, Y. Hao , "On-Body performance of Wireless Sensor Nodes using IEEE 802.15.4," European Conference on Antenna and Propagation (EuCAP) 2011, Rome, Italy, pp. 3946-3949, 2011.

[4] N. Chahat, M. Zhadobov, R. Sauleau1, and K. Ito, "A Compact Planar UWB Antenna for On-Body Communications" European Conference on Antenna and Propagation (EuCAP) 2011, Rome, Italy, pp. 3783-3786, 2011.

[5] Zhengyi Li, Kazuyuki Saito, Masaharu Takahashi, Koichi Ito, Yi Huang, "A Small Planar Inverted-F Antenna for Body-Centric Wireless Communications," International Symposium Antenna and Propagation, Macao, China, pp 86-89,2010