Analysis of the HBC Path Loss Occurred in Arm-Waving Motion for Healthcare Monitoring

Roslina Binti Abdul Razak
Takushoku University
815-1 Tatemachi, Hachioji, Tokyo
193-0985, Japan
y2m313@st.takushoku-u.ac.jp

Takehiro Sugo
Takushoku University
815-1 Tatemachi, Hachioji, Tokyo
193-0985, Japan
y2m305@st.takushoku-u.ac.jp

Toshiyuki Maeyama
Takushoku University
815-1 Tatemachi, Hachioji, Tokyo
193-0985, Japan
tmaeyama@es.takushoku-u.ac.jp

ABSTRACT

Wireless body area networks (WBANs) used in conjunction with various types of biological sensors have shown promise as a means of supporting medical and healthcare services, and in recent years, the use of wearable devices that utilize the human body as a transmission channel has grown rapidly. However, the multipath environment encountered in daily life typically incurs a large path loss. In this paper, we examine the path loss occurring in the high frequency (HF) and ultrahigh frequency (UHF) bands in order to compare the efficiency and reliability of communication. As a preliminary effort, we extract the effects of arm movement on the performance of human body communication (HBC) systems by investigating the path loss occurring during arm waving, both with simulation software and experimentally in an anechoic chamber. Our results show that the HF band experiences lower path loss than does the UHF band. The experimental result shows a close agreement with the results of the simulation.

Categories and Subject Descriptors

Experimentation, Human Factors, Measurement

General Terms

Measurement, Design, Experimentation, Human Factors, Theory.

Keywords

HBC, human body communication systems, BAN, wireless, tele-healthcare.

1. INTRODUCTION

In recent years, there has been significant interest in and growth of wireless body area networks (WBANs) [1], which consist of sensor nodes worn on or implanted in a human body. WBANs can have a great deal of impact in personal healthcare, smart home, personal entertainment, and identification systems; however, personal area networks (PANs) currently inhabit a gap in relevant medical and communication regulations for some application environments, which has limited the ability to implement body area networks (BANs) [2].

As the population increases, the number of individuals requiring medical care or nursing has also grown rapidly, which in turn has increased demand for medical doctors and nurses. Critical care patients also require continuous monitoring of vital signs—such as oxygen saturation, heart rate (HR), and blood pressure—via single strip electrocardiography (ECG) and pulse oximetry (SpO_2) even when they are being transported [3]. By knowing the physiological changes undergone by patients in their daily lives or during transport, a preventive and early treatment strategy that makes transport safe and smooth can be supported. However, the bulkiness of currently used monitors makes them difficult to lift and transport, and as such monitors and equipment must frequently be wrapped around intravenous lines or other tubes, disconnections can easily occur. Furthermore, cases in which patients such as neonatal infants or the elderly must stay hospitalized for long monitoring periods can have negative effects on both the patients and their families.

There is, accordingly, ample need for an efficient and effective medical system utilizing comfortable, lightweight, and wearable communication equipment built upon low-cost, versatile, and reliable remote units. In order to provide high-quality medical support for patients in transit or at home, the application of medical information and communication technology (MICT) to medical roles has been assessed. The main roles of the MICT include [4]

- Collection and data transmission of various medical and healthcare data from vital sign sensors;
- High security and high reliability network formation for data delivery;
- Ranging and positioning using wireless technology to find the location of objectives.

Human body communication (HBC) systems [5] can provide short range communication between devices embedded within the human body with high reliability. As the path loss associated with the HBC is believed to be smaller than that of wireless spatial transmission, this method can be used to partially or fully perform the MICT roles described above, making HBC a promising technology for the support of medical and health care services.

This paper presents an analytical investigation of the path loss occurring over the surface of a human body during arm waving. Based on previous research [6], [7], a human model was

BODYNETS 2013, September 30-October 02, Boston, United States

DOI 10.4108/icst.bodynets.2013.253515

developed using finite-different time-domain (FDTD) simulation to investigate the impact of motion at frequencies of 30 MHz and 2.4 GHz. In order to validate the simulated path losses, these effects were experimentally measured at a frequency of 30 MHz in an anechoic chamber.

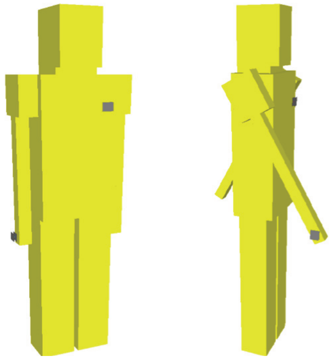
The rest of this paper is organized as follows. In Section 2, a simulation analysis and comparison of path loss results at different frequencies is provided. In Section 3, the measurement scenario is described and path loss results at 30 MHz are provided. In Section 4, a brief concluding discussion is given.

2. SIMULATION ANALYSIS

2.1 Simulation Model and Scenario

The human body was modeled using FDTD analysis at frequencies of 30 MHz and 2.4 GHZ. Figure 1 shows the human body model developed for this analysis within a 3500 × 3000 × 3100 mm test section (further details of this model construction are given in [8]). For the purposes of this evaluation, the permittivity of the human model was set to 300 and the conductivity was set to 0.35. The measurement system utilized two dipole electrodes [9]: a transmitter (Tx) mounted on the left side of the chest, and a receiver (Rx) mounted on the right wrist. Both the transmitter and receiver remained unmoved throughout the assessments.

For the purposes of this investigation, we set 0° as the position in which the arms are closest to the body, also known as the original position. The simulation started with the right arm of the model at a position of 90° upwards from the original position while the left arm was -30° (behind) the original position. A series of simulations were then performed in which the right arm moved downwards from 90° to -30° in increments of 10°, while the left arm remained static until the right arm reached 20° and then began moving upwards from -30° to 90°.



(a) 0° arm waving (b) 30° arm waving

Figure 1. Human body model.

2.2 Path Loss Results from Arm-Waving Effects at Frequencies of 30 MHz and 2.4 GHz

Figures 2 and 3 show the path losses caused by arm waving at frequencies of 30 MHz and 2.4 GHz, respectively. Here, the path loss is defined as the ratio of the transmitted to the received power, and α represents the angle of the right arm from the vertical (z-) axis, as explained previously in Section 2.1. It can be seen from Figure 2 that at 30 MHz, there is a relatively small path loss; this reaches a maximum of approximately 9 dB at $\alpha = 0$, corresponding to a reduction over the minimum path loss of approximately 4 dB. This reduction can be mainly attributed to the patterns of back-reflection of radio waves occurring when the arms are aligned with the abdomen, which results in the surface path loss.

The simulation results shown in Figure 3 correspond to the path loss caused by arm waving at 2.4 GHz. It can be seen from the figure that, as compared to the path loss at 30 MHz, there is a significant increase in the path loss. In this case, the path loss is maximum at $\alpha = -20°$, at which point the loss is more than 20 dB above the minimum value. We believe that, this reduction is probably caused by shadowing effects induced by the movement of the arms.

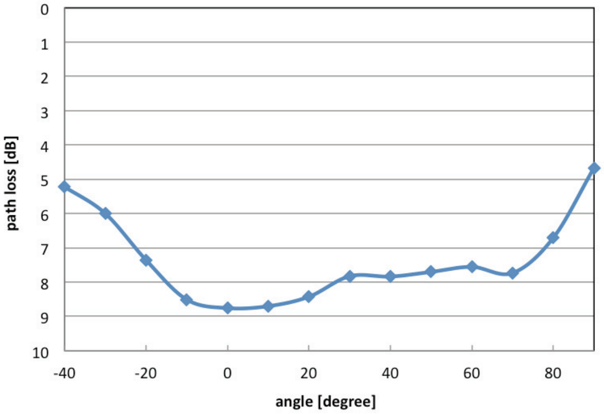


Figure 2. Path loss simulated at 30 MHz.

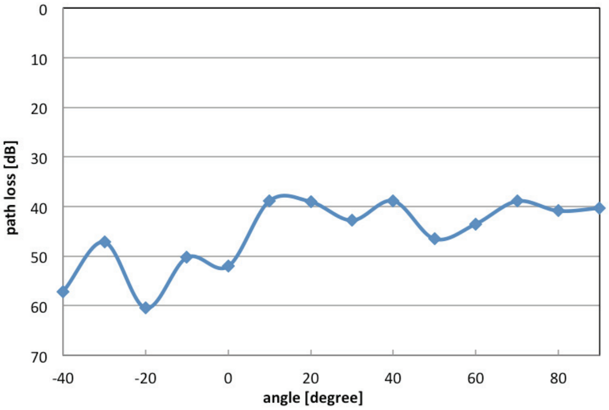


Figure 3. Path loss simulated at 2.4 GHz.

3. MEASUREMENT ANALYSIS

It is apparent from the data shown in Figures 2 and 3 that the path loss at 30 MHz is much smaller than that at 2.4 GHz. To corroborate these findings, measurements were conducted in an anechoic chamber.

3.1 Measurement Model and Scenario

The measurements were conducted in an anechoic chamber in order to avoid the reflection of waves from surrounding objects; although these may occur under realistic conditions, their presence would complicate the primary goal of this study of extracting the effects of arm movement on the performance of HBC systems.

Figure 4 shows the block diagram of experimental setup. A body-attached indicator with a frequency of 30 MHz was used to measure the path loss. The indicator was built into a small package (75 × 125 × 35 mm) and incorporated two indicators as a transmitter and a receiver. Figure 5 shows the external electrode [10]—a capacitance-type electrode structure with dimensions 33 × 38 × 1.6 mm. The measurements were conducted on a 24-year-old Chinese male (weight = 75 kg; height = 175 cm). During measurement, this human model would stand in a stationary position while moving his arms downwards from 90° to -30° in a manner mimicking the motion used in simulation analysis.

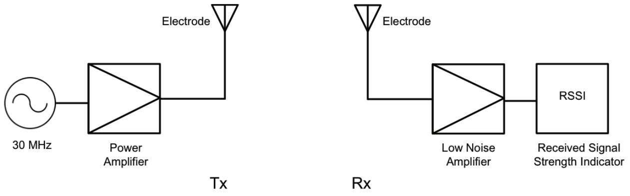


Figure 4. Block diagram of experimental setup.

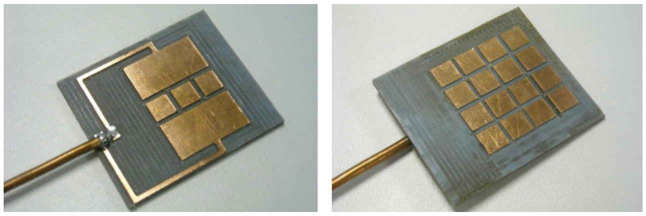


Figure 5. External electrode.

3.2 Path Loss Results caused by Arm-Waving Effects

Figure 6 shows the measured results of path loss owing to arm waving at a frequency of 30 MHz (the measured path loss shown includes antenna loss). It can be seen from the figure that there is a small increase in path loss similar to that seen in the simulation results in Figure 2. At $\alpha = -20$, the path loss is at a maximum value of approximately 9.4 dB, or approximately 4 dB greater than the minimum value. The path loss curves for the upward moving right arm differ slightly from the simulation results, most likely because the actual human body is composed of circular cylindrical shapes, while the simulation model was composed of rectangular solids. At 80°, the path loss becomes particularly small as there is a direct path between Tx and Rx at this position; at other angles, the path loss increases because the propagation path involves a surface path. Figure 6 shows that the antenna efficiency (the value of which takes path loss into account) increases with the frequency; however, the maximum value path loss occurs at 2.4 GHz, owing to the shadowing effect. Furthermore, the electrode has low radiation efficiency, and it can be seen from Figure 6 that if 60 dB is deducted from the path loss to compensate for this, the resulting loss distribution is approximately 5–9 dB, which is similar to the simulation results. The path loss can be calculated using the equations below:

From S_{11}, VSWR $\approx$ -60dB

Therefore,

RSSI - 60dB = Path Loss

Thus, the experimental results in Figure 6 can be seen to be in close agreement with the results of the simulation.

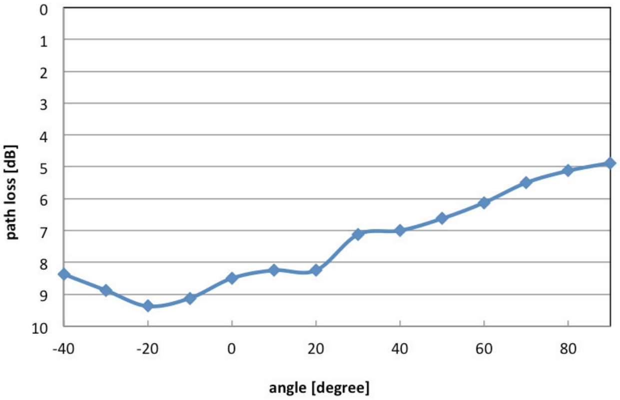


Figure 6. Path loss measured at 30 MHz.

4. CONCLUSION

The access points for sending health monitoring data to a hospital or a personal healthcare alert system would probably be mounted on the arms of a patient, and the ordinary movement of these could adversely affect the communication quality. We have correspondingly conducted several analyses to explore the path loss incurred by the arm-waving movement at differing monitoring frequencies. We determined through simulation that, in HBC, using the HF band produces a smaller reduction path than does the UHF band. Experimentally measured results also showed a high degree of agreement with the simulation results.

The relatively low path loss in the HF band indicates that communication at such frequencies could be facilitated through sensors mounted on virtually any part of the human body; in the 2.4 GHz band, however, the path loss is large enough to render useful communication difficult, irrespective of where the sensors are mounted.

The measurements in this study were conducted in an anechoic chamber; in our future work, it will be essential to analyze actual use scenarios in which an HBC system is characterized within a multipath environment.

5. ACKNOWLEDGMENTS

The authors acknowledge the support of the supervisor, laboratory members, and the valuable comments of the reviewers.

6. REFERENCES

[1] P. S. Hall and Y. Hao. *Antennas and propagation for body-centric wireless communication.* Artech House Publisher. ISBN 1-58053-493-7, 2006.

[2] IEEE802.15.6. DOI= http://www.ieee802.org/15/pub/TG6.html

[3] Australasian College for Emergency Medicine. *Minimum standards for transport of critically ill patients.* Emerg. Med. 15, 202–204, 2003.

[4] K. Y. Yazdandoost. *Channel model for body area network (BAN).* IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs), IEEE802.15-07-0943-00-0ban, November 2007.

[5] T. G. Zimmerman. *Personal Area Networks (PAN): Near-Field Intra-Body Communication*. M.S. thesis, MIT Media Laboratory, 1995.

[6] Y. Hao, P. S. Hall. *On-body antennas and propagation: Recent development.* IEEE Trans. Commun. 91, 6, 1682-1688, June 2008.

[7] N. Yamamoto, N. S., D. K., and K. Ogawa. 2011. *BAN communication quality assessments using an arm-waving dynamic phantom replicating the walking motion of a human.* In proceedings of the IEEE ICC 2011. June 2011.

[8] I. Kan, H., S., and T., Dec 2009. *Basic Characteristics of a Human-body Communication in Hz Band*. A・P2009-149, pp.41-45, IEICE technical report.

[9] K. Ito and N. Haga. F*requency Characteristics of Electric Field around the Human Body with a Low-Profile Monopole.* S-1-S-2, IEICE General Conference, March 2009.

[10] A. R. Roslina, I. Shinsuke, S. Takehiro, and M Toshiyuki. *A Study on Electrode Using Periodic Structure for HBC.* BS-7-3, IEICE General Conference, September 2012