1P2-2

Proceedings of Symposium on Ultrasonic Electronics, Vol. 36 (2015)
5-7 November, 2015

Preliminary experimental channel modeling for airborne ultrasonic wave propagation of WBAN
WBAN のための空中超音波伝搬モデルに関する基礎的検討

Takahiro Aoyagi[1†], Marie Tabaru[2], and Kentaro Nakamura[2] ([1]Grad. School of Decision Sci. and Tech., Tokyo Inst. of Tech.; [2]P&I Lab. Tokyo Inst. of Tech.)
青柳貴洋 [1†], 田原麻梨江 [2], 中村健太郎 [2] ([1] 東工大院 社理工, [2] 東工大 精研)

1. Introduction

In recent years, with aging society especially in developed countries, information communication technologies for medicine and health care (MICT) gains great attention to reduce work loads of people who are in charge with these areas and to enhance their services. Wireless body area network (WBAN) is one of effective technology which can un-wire medical and health care equipments and services in medicine and health care. For wireless communications using electromagnetic wave and human body communications, a WBAN communication standard is published as IEEE802.15.6[1]. Meanwhile, ultrasound has been widely used to visualize internal body for medical diagnoses or treatments. Our research group studies on applications of airborne ultrasound for health care and medical use (e.g. [2]). However, there is a few research that utilizes airborne ultrasound on wireless body area network communications. To design a tele-communication system, a propagation channel model is necessary (e.g. [3]). In this report, a fundamental propagation characteristics of airborne ultrasound propagating on human body for WBAN communications is described.

2. Measurement of wave propagation of ultrasound on human body.

Fig. 1 shows the positions of ultrasonic transducers attached on human body. A subject of this measurement is a male of 163 cm height in tight thin long sleeve shirt and trousers. An ultrasonic transmitter (TX) is fixed on abdomen, and an ultrasonic microphone is fixed on eight position on body for individual measurement (1:ankle, 2:knee, 3:thigh, 4:waist, 5: chest, 6:hand, 7:elbow, 8:shoulder). An ultrasonic transducer (SPL Limited, UT1612MPR) is used as a transmitter. 40 kHz sinusoidal wave of 5.3 V peak-to-peak is input from a signal generator. The ultrasonic receiver is a microphone (ACO type 7118) with pre amplifier

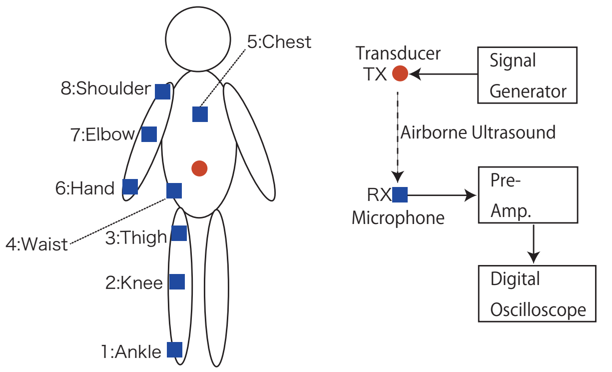

Fig. 1 Positions of ultrasonic transducers on human body (left) and signal flow (right).

(ACO type 4116) set at +20 dB. The output of the pre amplifier is connected to a digital oscilloscope and effective values of output voltage are recorded. **Table I** shows the distanced between transmitter and receivers. As shown in the figure, maximum distance is for leg (78 cm) and minimum distance is for waist and chest (18 cm). The average of distances is 36.8 cm. The measurement was conducted in a regular laboratory room of Suzukakedai campus of Tokyo Institute of Technology. Thus, there may be a lot of multi-path components reflected from walls, ceiling, floor, and equipment and furniture in the room.

Before measuring propagation characteristics on body, fundamental characteristics of the airborne ultrasound are measured. The received level in free space at the distance from 5 cm to 100 cm is

Table I Distance between TX and RX.

No.	Position	Distance to abdomen (TX) [cm]
0	Abdomen (TX)	0
1	Ankle	78
2	Knee	53
3	Thigh	36
4	Waist	18
5	Chest	18
6	Wrist	25
7	Elbow	29
8	Shoulder	37

---

aoyagi.t.aa@m.titech.ac.jp

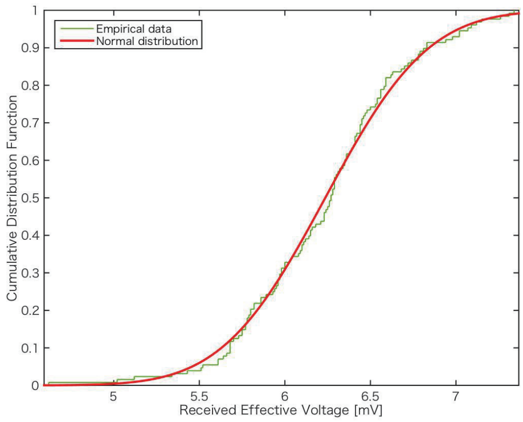

Fig. 3 Cumulative Distribution Function (CDF) of empirical and normal fitting of measured effective voltages.

estimated as −18.973 d + 54.256 [dBmV], where d is log10 of the distance between the transducer and the microphone in cm. −3 dB beam width of the transducer is around 70 deg.

First, to estimate the fluctuation of the measurements caused by multi-path components and other system errors, distribution of the received voltage is measured. The transducer and the microphone is set above 1.1 m from the floor. The distance between transducer (TX) and the microphone (RX) is set at 1 m. The received effective voltages on the oscilloscope are recorded 128 times in 5 minutes and 31 seconds. The received values distributes from 4.62 mV to 7.34 mV. The average of the measured voltage is 6.2 and the standard deviation is 0.47. **Fig. 3** shows the cumulative distribution function of measured received levels. The green line shows the empirical levels and the red line shows the fitting by normal function. As shown in the figure, normal function gives good fitting as strong line-of-sight components exist.

Fig. 4 and **Fig. 5** show the received levels of on body propagation measurements. Fig. 4 shows the result in case the direction of the microphone is set for upward for the positions 1, 2, 3, and 4, and is set for downward for the positions 5, 6, 7, and 8. The associated transmitter position is downward and upward respectively. For the Fig. 5, the transducer and the microphone are set on possible confronting direction. The horizontal axis shows the distance between the transducer and the microphone, and the vertical axis shows the received level. As shown in the Fig. 5, the received levels almost never change according to the distance, because the directive of the transmitter and the receiver is non-line-of-sight for most cases. And as shown in the Fig. 6, the received levels show strong

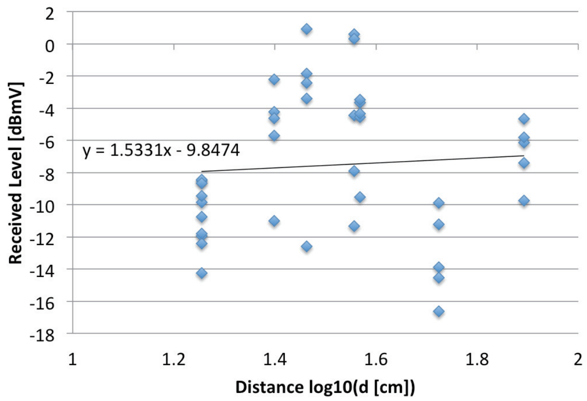

Fig. 4 Received levels of airborne ultrasound on human body (direction of the transducer and the microphone are fixed).

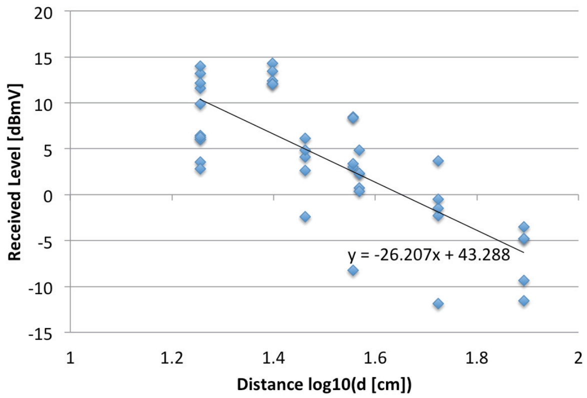

Fig. 5 Received levels of airborne ultrasound on human body (the transducer and the microphone are confronting).

dependency of the distance. This is because the transmitter and the receiver is set almost line-of-sight, so path-loss characteristics of a airborne ultrasound on body is obtained as in the formula in the figure.

3. Conclusion

In this paper, a fundamental measurement of airborne ultrasound propagation on human body for WBAN was reported. The further investigation and channel modeling for actual communication systems are left for further study.

References

1. https://standards.ieee.org/findstds/standard/802.15.6-2012.html
2. M. Tabaru et al.: IEICE Tech. Rep. MICT2014-44 (2014) 117.
3. N. Katayama et al.: IEICE Trans. Comm. **E92-B** (2009) 418.