Experimental Study of Polarization and Frequency Diversity Antenna in Different Positions of Indoor Environments

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Abstract: In this paper, the diversity gain of polarization and frequency diversity of antennas in three different indoor environments is investigated. This paper will show a diversity experiment and the results of diversity gains in different positions of the same indoor environment, and the diversity gains of narrowband and broadband frequency range are also measured.

Keyword: polarization diversity, frequency diversity, indoor environment

1. Introduction

In recent years, Body-centric wireless communication devices, such as on-body sensor for healthcare applications are desired and studied by many researchers. For high quality communication, antenna diversity technique such as polarization diversity and frequency diversity are very important.

Considered about the portability and the electric wave toward to human body, antennas in body-centric wireless communications, such as on-body sensor, are supposed to be small enough to be wearable and have low radiation power. However, since the limit of antenna size and radiation power, in practical application body-centric wireless communication has a problem of high attenuation in complex environment. To overcome the attenuation of wearable antennas, technique of polarization diversity and frequency diversity is introduced. By placing transmitting antennas in different polarizations, and sweeping transmitting frequency in a wideband, variety signals of different received powers can be observed. By selecting the best signal in all frequencies and polarizations, a critical improvement of diversity gain can be obtained.

This paper is organized as follow. Section 2 describes a polarization and frequency diversity experiment and the experiment setup in a room. Transmitting antennas will be set in 3 different positions (A, B, C) of the same room. In section 3, the results of spectrogram, received power and cumulative probability of 3 positions are performed. Finally, conclusions are given in Section 4

2. Experimental setup

In Fig.1, the communication system of this experiment is performed. A 4-Port Vector Network Analyzer (Agilent N5224A) was used to measure received power as S21: vertically polarized levels, S43: horizontally polarized levels, in a frequency range of 2.4 GHz to 2.5 GHz, including Bluetooth® [1] frequency range. A power splitter was used and whose output ports were connected to receivers Port 2 and Port 4. In order to simulate the multipath fading environment, vertically polarized patch antenna (Rx. V) was rotated in the horizontally and the vertically direction using a rotating table as shown in Fig. 2.

Fig.2 and Fig.3 show the experimental environment and the human equivalent phantom. The experiment is performed in a 9 m length and 14 m width room. In order to evaluate the transmitting diversity, vertically polarized (Tx.V) and horizontally polarized (Tx.H) transmitting patch antennas were placed on the surface of a human equivalent-phantom (SPARG) with height of 1.4m. A vertically polarized receiving patch antenna (Rx.V) was placed on a rotating table in different positions of the room named A, B and C. As shown in Fig.2, A is the place in the room with distance of 5m from the transmitting diversity antennas on human equivalent-phantom. Position B is at the outside of the room beside the door with the door closed. C is in the side room with some obstacles between the transmitting diversity antennas and receiving patch antenna.

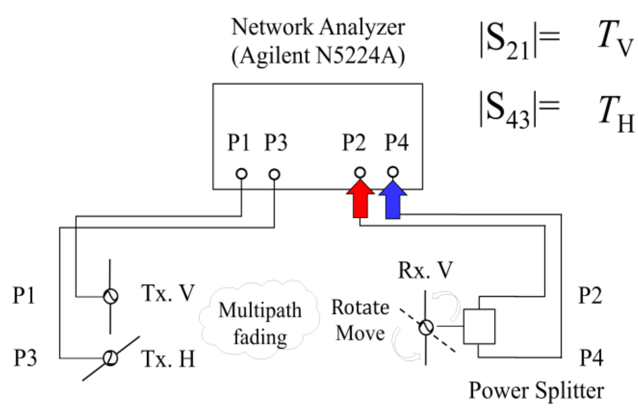

Fig.1 Communication system

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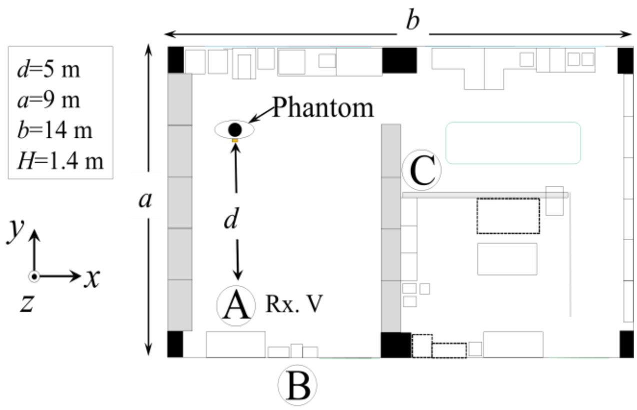


Fig.2 Experimental environment

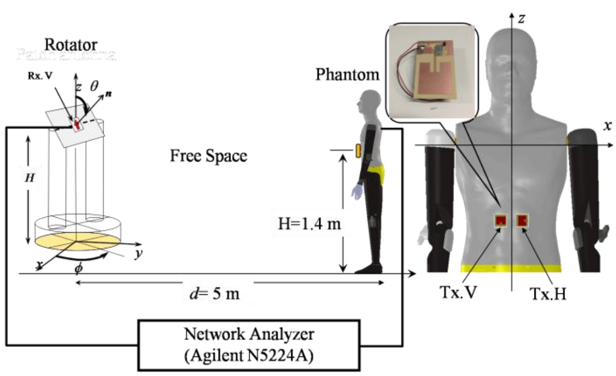
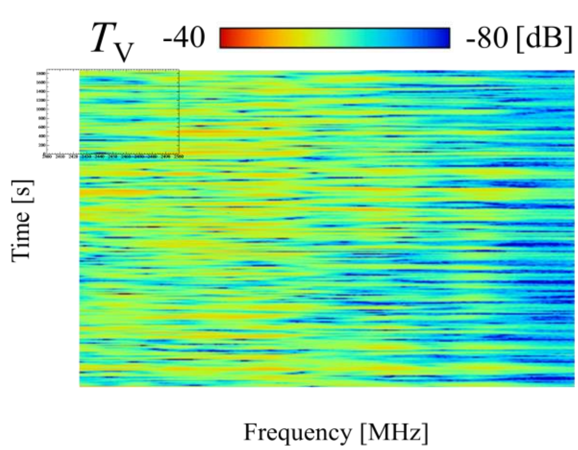


Fig.3 Phantom and rotator

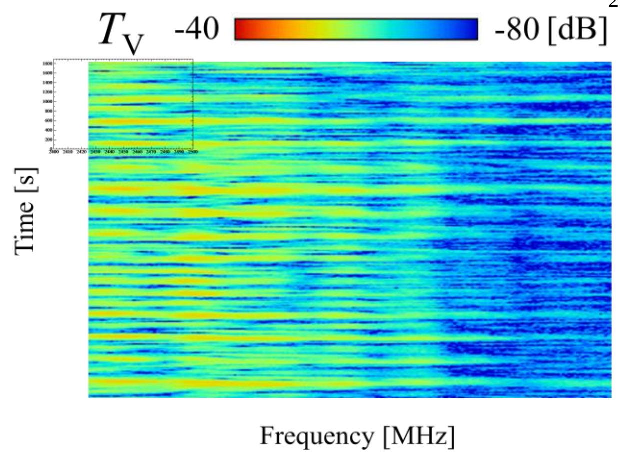
3. Results of experiment

3.1 Spectrograms

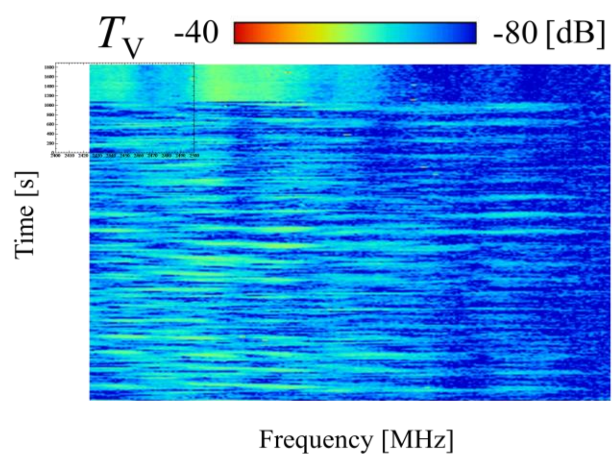
The spectrograms of receiving signals Tx.V of frequency range from 2.4 GHz to 2.5 GHz in positions A, B and C are presented in Fig.4, where (a), (b) and (c) are related to positions A, B and C.



(a)



(b)



(c)

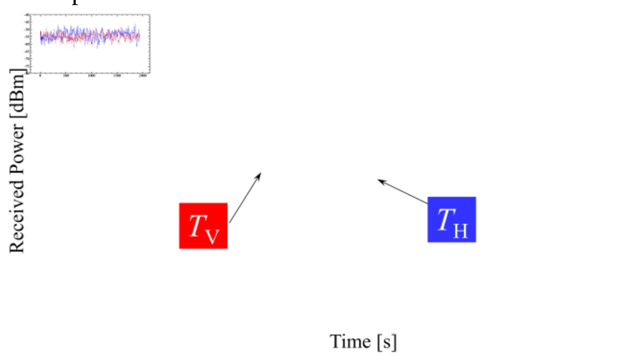
Fig.4 Spectrograms of receiving powers Tx.V at position A, B and C.

Only the spectrograms of Tx.V are demonstrated here, for there are no critical differences in figures between Tx.V and Tx.H especially in indoor environment. As shown in Fig.4(a), when receiving antenna was placed in position A, where rotating table and receiving antenna straightly face to the transmitting antennas, the intensity of received power is relatively stronger since there are no obstacles between transmitting and receiving antennas. As to Fig.4(b) and (c), receiving antennas being side position C and outside position B, it is obvious that strong attenuations due to the multipath effect can be observed especially in the bandwidth from 2.45 GHz to 2.5 GHz.

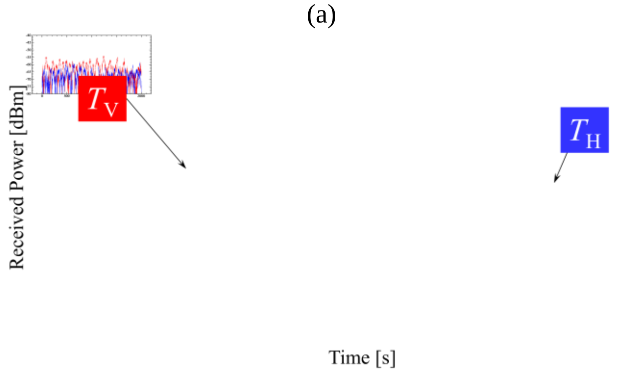
3.2 Received power

To demonstrate the relationships between Tx.V and Tx.H, the received powers of Tx.V and Tx.H at all three positions are performed in Fig.5.

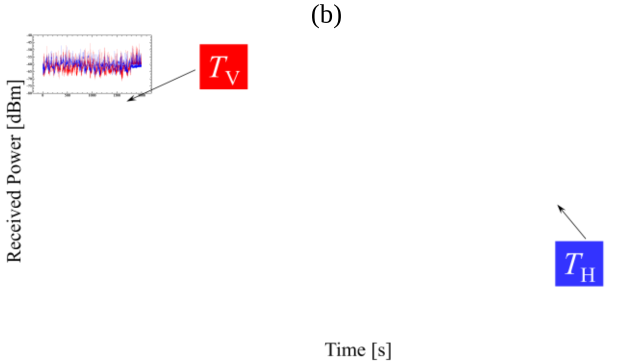
In Fig.5, it can be observed that in all three cases, the amplitude of received powers of both Tx.V and Tx.H are fluctuating intensively and rapidly. Fig.5(a) shows the received power at position A, the average received power of both Tx.V and Tx.H are about -55 dBm. And at position B, since the receiving antenna is at outside of the room with the door closed, the received powers are under -60 dBm at most time. The received powers at position C are generally a bit stronger than the received power at position B but weaker than that at position A, for it is not completely isolated between transmitting and receiving antennas. When compare Tx.V with Tx.H in each case, it is obvious that the received powers of Tx.V and Tx.H are almost at the same level due to the multipath effect.



(a)



(b)



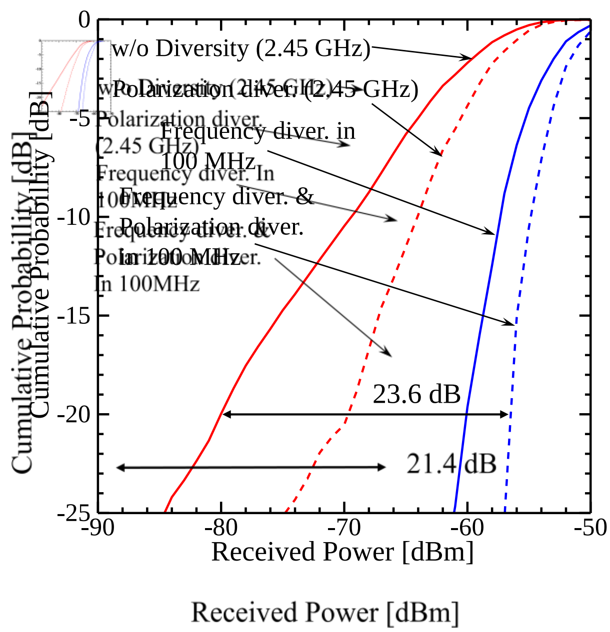
(c)

Fig.5 Relationships of received power between Tx.V and Tx.H at position A, B and C.

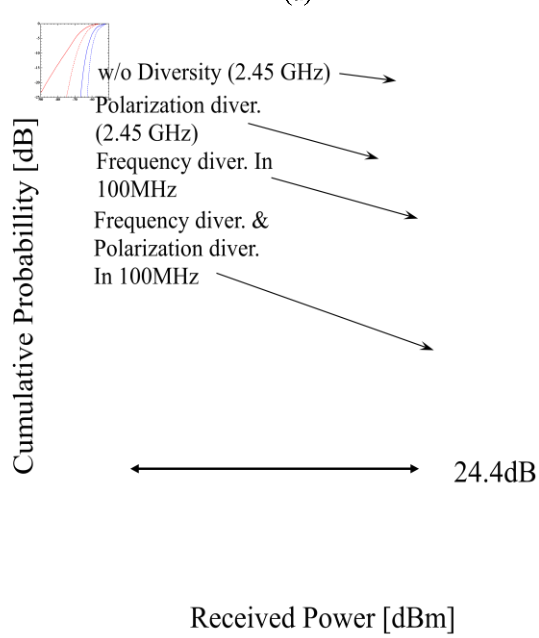
3.3 CDF results

In order to demonstrate the diversity gains from polarization diversity and frequency diversity, Fig.6 shows the cumulative distribution function (CDF) results of three cases of the experiment. According to the results in 3.2 that the received powers of Tx.V and Tx.H are almost at the same level, only the CDFs of Tx.V are presented here.

The diversity gain is evaluated at the cumulative probability of -20 dB (1%). From Fig.6, it can be observed that without diversity, the received powers are relatively low in all three cases, and with either polarization diversity (At 2.45 GHz) or frequency diversity (2.4 GHz – 2.5 GHz), apparently improvements can be observed. When frequency diversity and polarization diversity are both applied, diversity gains of 23.6 dB, 24.4 dB and 21.4 dB can be obtained at position A, B and C.



(a)



(b)

(c)

Fig.6 Cumulative probability of Tx.V at position A, B and C.

4. Conclusion

The experimental evaluation of polarization diversity and frequency diversity in different indoor environments were performed. It is found that the receiving levels of Tx.V and Tx.H are pretty close to each other due to the multipath effect, and quite large diversity gains about 23 dB in average are realized in Bluetooth® frequency band when both the polarization diversity and the frequency diversity is applied.

Reference

[1] The Bluetooth® word mark and logos are registered trademarks owned by Bluetooth SIG, Inc.