Wearable Planar Inverted-F Antenna (PIFA) at 2.45 GHz for On-Body Communications

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Abstract

In this paper, we proposed a compact wearable Planar Inverted-F Antenna (PIFA) with 2.45 GHz for Body-centric wireless communications. In order to investigate the performance of the range of the on-body communication systems, the path loss between the transmitted antenna and received antenna was discussed.

Keywords : Wearable, PIFA, Body-centric wireless communications, path loss

1. Introduction

In recent years, body-centric wireless communication received an increasing attention and became an active area of research because of there are widely applications such as E-health system, home care, military applications, sports training, security agencies, assistance to emergency services, fashion and entertainment, etc. In [1] spiral and serpentine microstrip antennas that can be used for communication with medical devices have been analyzed in the 402-405-MHz ranges. A dual-band textile antenna with EBG has been reported in [2]. By using two slits the dual-band operate at the 2.45 and 5 GHz can be achieved. The performance of a novel cavity slot antenna close to the human body for over body communications is presented in [3].

In this paper, we proposed a wearable antenna for on-body communications at 2.45 GHz, which is one of the ISM band and the frequency bandwidth available is from 2.4 to 2.48 GHz. This band is also used by a variety of computer equipment services, such as WiFi, Zigbee, WiMax and Bluetooth so are the microwave ovens.

2. Antenna and Arm Phantom Design

The proposed antenna is shown in figure 1. The size is 26mm × 26mm × 4mm (2.704 cm^3). In our design, a rectangular patch (20.5mm × 26mm) is mounted on the feeding pin and shorting pin. In order to improve the matching condition and adjust the resonant frequency, we used shorting plate in the corner of the rectangular patch and folded the ground plane. The height between the patch and the ground plane of the proposed antenna is 3.5 mm and the height of the folded ground plane is 4 mm. In our antenna, we used air as substrate. In previous study [4], by varying either the length or width of the ground plane affects the impedance bandwidth and resonant frequency of the antenna. In our technique, we folded the ground plane in order to control the resonant frequency and reduce the size of the antenna. In our research, we put the proposed antenna above the two-thirds muscle-equivalent arm phantom (dimension 50 mm × 50 mm × 300 mm; relative permittivity ε_r = 35.2；conductivity σ = 1.16 S/m). The proposed phantom is made by deionized water, agar, salt, polyethylene powder and TX-151. The proposed antenna is put 70 mm away from the end of the arm phantom and the space between antenna and the arm phantom is set to be 2 mm. Figure 2 shows the return loss of the proposed antenna in free space and with arm phantom. Compare with [3], the proposed antenna characteristic such as return loss when in close proximity to the phantom did not change strongly as in free space. Figure 3 and 4 present the simulated and measured results of reflection coefficient and radiation patterns. The measured bandwidth is 160 MHz from 2.36 to 2.52 GHz. From figure 4, in x-z plane, the average measured gain is -8.0 dBi and in y-z plane the average measured gain is -8.6 dBi. The measured maximum gain in y-z plane is -0.6 dBi which appears at 48 degree. Both simulated and measured results are in good agreement.

3. Path Loss for On-body Communications

Path loss is one of the most important factors in body area network. In order to model the path loss between the transmitted antenna and the received antenna, we use the Friis formula as follow:

$$\frac{P_r}{P_t}(d,h)_{dB} = P_0(h)_{dB} - n(h)\frac{d}{d_0}_{dB} \tag{1}$$

where P_r is received power and P_t is the transmitted power, d is the distance between the transmitted and received antennas, h is the distance between antenna and the face of phantom, P_0 is the is the path loss at a reference distance d_0, n is the path loss exponent at which the path loss increases with distance between the two antennas and always set to be 2 in free space. The path loss in our study is defined as both transmitted and received antennas have input impedance of 50 Ω and connected to a calibrated two ports network analyzer. In this section, we discuss path loss by different kinds of cases for on-body systems. Figure 5 shows these systems: (a) the transmitted and received antennas are in free space, (b) and (c) the transmitted and received antennas are located above the same face of the arm phantom and the distance d between the transmitted and received antennas and the gap h between antennas and the phantom is also discussed, (d) the position of the received antenna is fixed and discuss the path loss when transmitted antenna is rotated.

4. Results and Discussion

The experiment results of the setups in figure 5 are presented in this section. Figure 6 (a) shows the distance d between the transmitted and received antennas are 50 and 150 mm in free space. The simulated transmission coefficient for d = 50 and 150 mm at 2.45 GHz are -18.9 and -33.7 dB. The measured transmission coefficients for d= 50 and 150 mm at 2.45 GHz are -20.8 and -34.0 dB, respectively. Figure 6 (b) shows the simulated and measured results for both the transmitted and received antennas are above the phantom and the distance d between the two antennas are 100 mm. The simulated and measured transmission coefficient for d = 100 mm are -26.1 and -26.3 dB. From the Friis formula, the gap h between the antennas and the phantom is also one of the functions of path loss. Here we are going to discuss about the effect of varying the distance h between the antennas and the phantom on path loss. From figure 6 (c), when h＝0 and 15 mm, the simulated peak value of path loss are -26.8 and -22.8 dB and the measured peak value of path loss are -26.8 and -22.9 dB. The simulated and measured results for rotating the transmitted antenna are shown in figure 6 (d). When ϕ =90 and 180 degree, the simulated results are -26. 5 and -24.0 dB, the measured results are -26.5 and -23.7 dB. Due to ϕ =180 degree with strong coupling between the two antennas, therefore the performance of the path loss is better than other situations. From above mentioned results, the path loss in our study depends on the distance between the transmitter and the receiver strongly. The path loss increases as the distance increases.

4. Conclusion

In this paper, we proposed a compact wearable planar inverted-F antenna at 2.45 GHz for body-centric wireless communications. We investigated the path loss based on the on-body systems. The effect of distance between the transmitted and received antennas and the gap between the antennas and the phantom on path loss are also designed and analyzed. Both simulated and measured results are in good agreement. In the future work, we will discuss the path loss for different positions on the body and different postures.

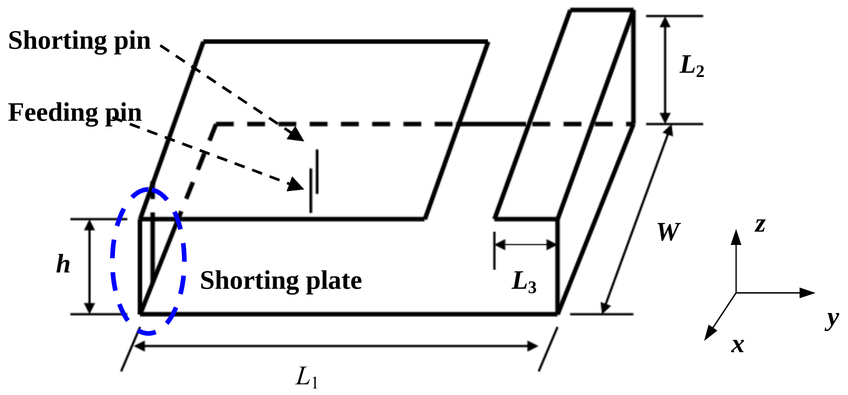


Fig. 1 Structure of the proposed antenna.

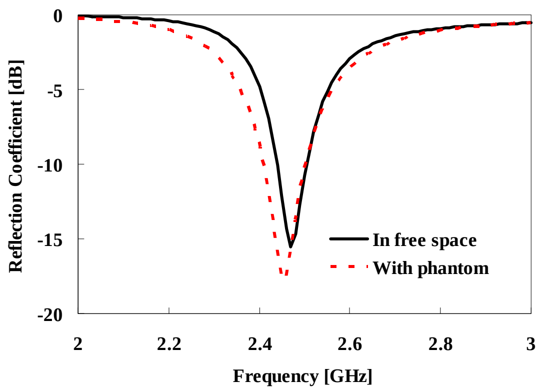


Fig. 2. Simulated reflection coefficients in free space and with phantom.

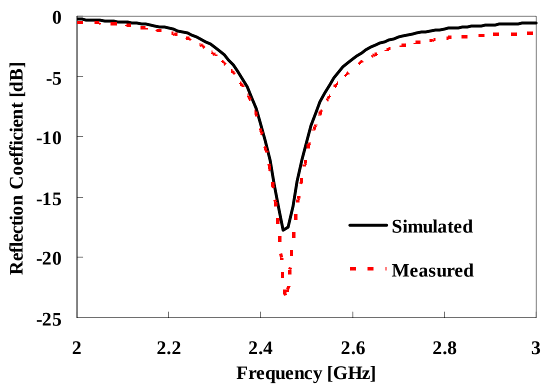
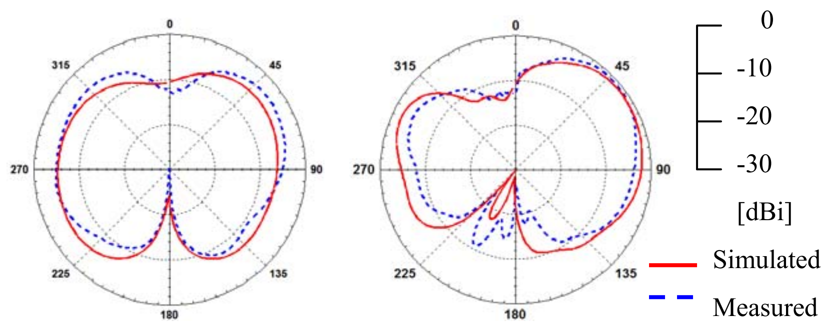


Fig. 3. Simulated and measured reflection coefficient.



(a) *x-z* plane (b) *y-z* plane

Fig. 4. Simulated and measured radiation pattern with phantom (a) *x-z* plane and (b) *y-z* plane.

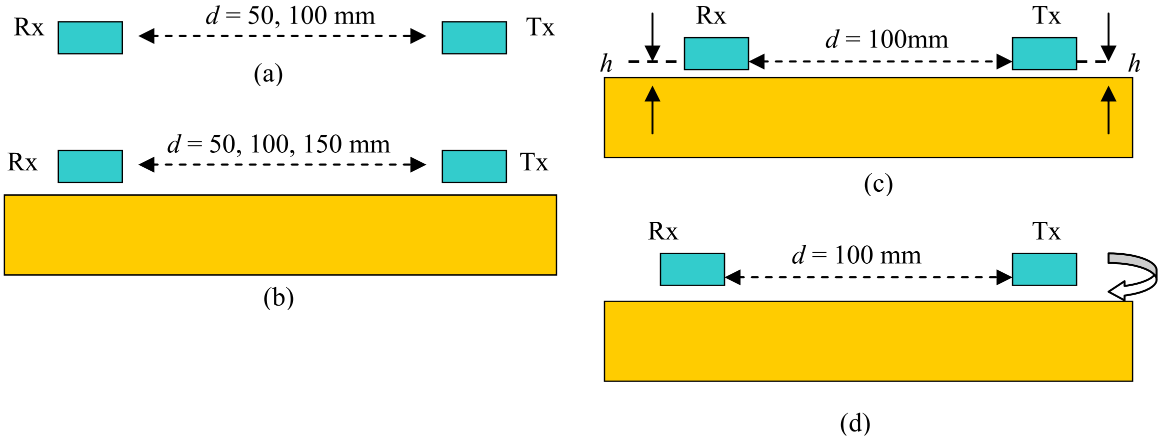


Fig. 5. The path loss setups (a) in free space, (b) varying the distance between the two antennas, (c) varying the gap between antennas and phantom, (d) rotate the transmitted antenna.

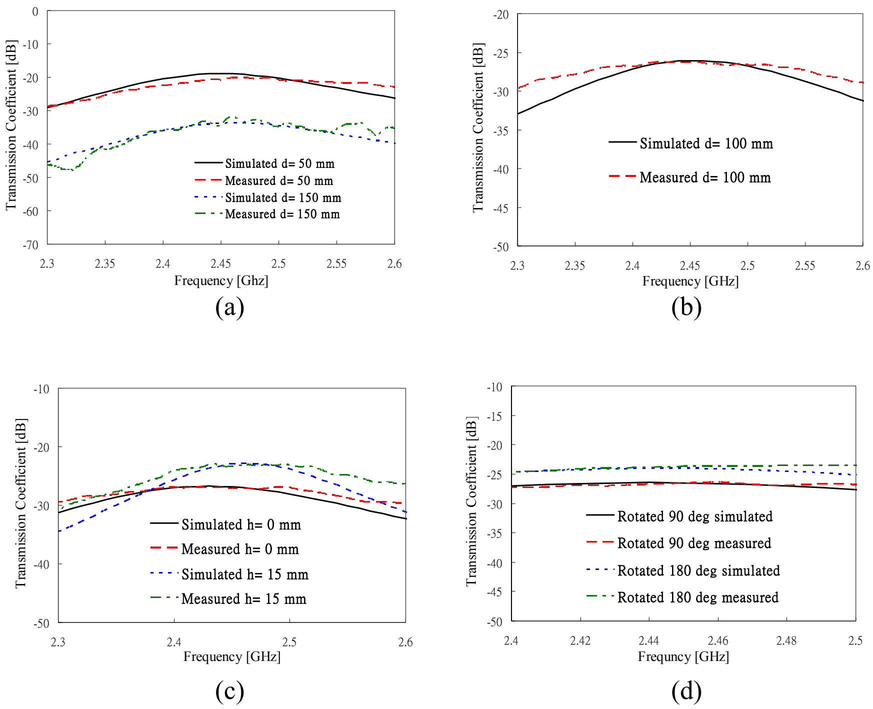


Fig. 6. Simulated and measured results of the path loss setups in figure 5. (a) in free space, (b) varying the distance between the two antennas, (c) varying the distance between the two antennas and the phantom (d) rotate the transmitted antenna

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