POS1-45

Wearable Multi-band Antenna with Tuning Function for On-body and Off-body Communications

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1. Introduction

In the last few years, the research on body-centric wireless communications (BCWCs) is becoming very hot, because of numerous applications, such as, E-health systems, security agencies, and personal entertainment [1-2]. Especially, many researchers considered E-health systems as the biggest potential application with all kinds of wireless devices. The well-known requirements for wearable antennas in body-centric wireless communications area are compact size, light weight, low-profile, and lower specific absorption rate (SAR). Planar inverted-F antennas in [3-4] are good candidates for BCWCs, because the radiation toward the human body is reduced by using the large ground plane. However, their volume is still larger than our proposed antenna.

In our study, we proposed a wearable multi-band and low-profile planar inverted-F antenna (PIFA) with tuning function for on-body and off-body communications. In order to achieve multi-band operation, we used two branches in our antenna design. The longer branch for low frequency band (950-956 MHz), and the shorter branch with a varactor diode [5] embedded for high frequency bands. By supplying different DC voltages, the capacitance of the varactor diode can be controlled, therefore, the higher resonant frequency can be tuned without changing the dimension of the antenna. With this varactor diode, the proposed antenna can cover ISM band (2.40-2.48 GHz) and WiMAX (2.30-2.40 GHz). The radiation patterns of the proposed antenna in 950 MHz can be applied in on-body communications. Furthermore, the radiation patterns of WiMAX and ISM bands are relatively non-directional and are of no deep nulls in the half-sphere above the arm phantom. Therefore, the proposed antenna can be expected to be applied in on-body and off-body communications.

2. Antenna Design

The proposed antenna in our paper is shown in Fig. 1. In our antenna design, we used two substrate boards, both with a thickness of 0.8 mm and a relative permittivity of 2.17, and the distance between them is 4.4 mm. As a result, the height of the antenna is 6 mm. The lower substrate board has the area of 40×20 mm^2, and the ground plane is on the bottom layer of it, with the same area.

Since the proposed antenna is designed for BCWCs, in our study, an arm phantom (450 mm × 50 mm × 50 mm) with two-thirds muscle-equivalent electric properties is located close to the antenna. As shown in Fig. 2, the antenna is put 80 mm away from the end of the arm phantom, and the distance between the ground plane of the antenna and the surface of the arm phantom is set at 2 mm. In the beginning of simulation, we investigated three electric properties of the arm phantom at 950 MHz, 2.35, and 2.45 GHz, respectively (relative permittivity, 37.2 at 950 MHz, 35.8 at 2.35 GHz, and 35.2 at 2.45 GHz; conductivity, 0.65 S/m at 950 MHz, 1.15 S/m at 2.35 GHz, and 1.16 S/m at 2.45 GHz [6]). However, it is found that though the three electrical properties of the arm phantom are different, the simulated reflection coefficients are nearly the same. Therefore, in order to save the calculation time, we adopted only one kind of arm phantom (relative permittivity, 35.2； conductivity, 1.16 S/m) in the following simulation.

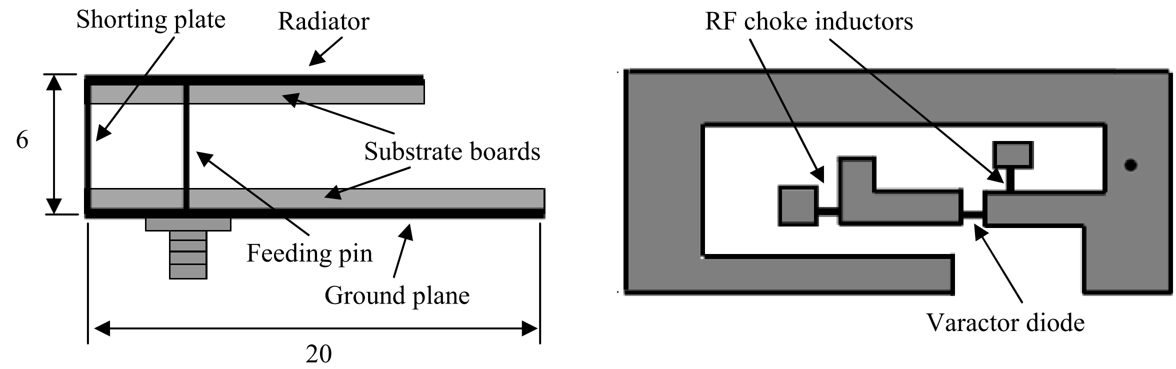


Figure 1: Structure of the proposed antenna (unit: mm).

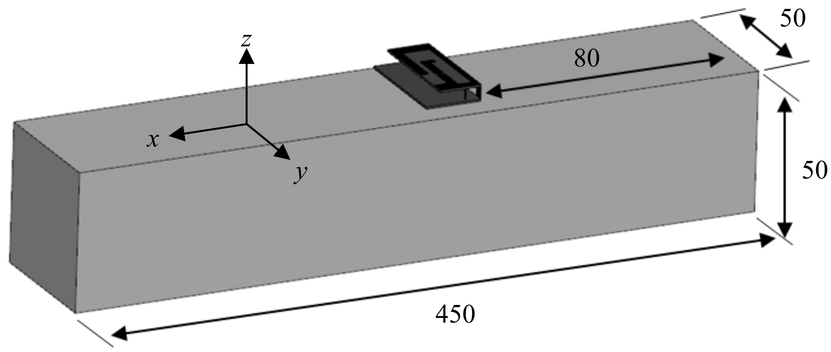


Figure 2: Antenna and the 2/3 muscle-equivalent phantom (unit: mm).

3. Experimental Results and Discussion

Fig. 3 (a) and (b) present the measured reflection coefficients of the proposed antenna with the arm phantom at different bias voltages (6 V and 14 V). From the results, the lower resonance frequency shifts slightly while the bias voltage is changed; the higher resonance frequency occurs from 2.27 to 2.50 GHz below -10 dB and the WiMAX (2.30-2.40 GHz) and ISM (2.40-2.48 GHz) can be covered while the bias is set 6 V and 14 V, as show in Fig. 10 (b). From the results, by increasing the voltage, the operation frequency band is shifted upward, which is because the capacitance of the varactor diode is reduced.

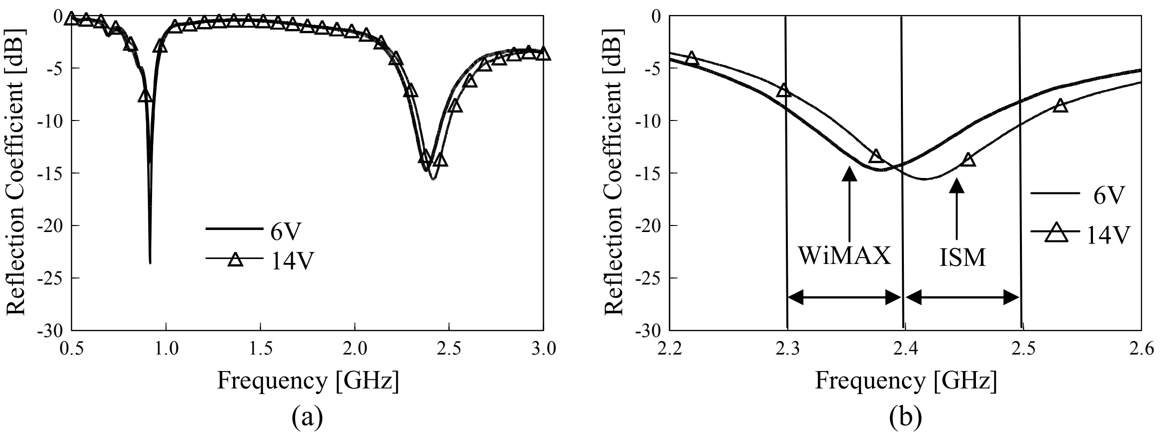
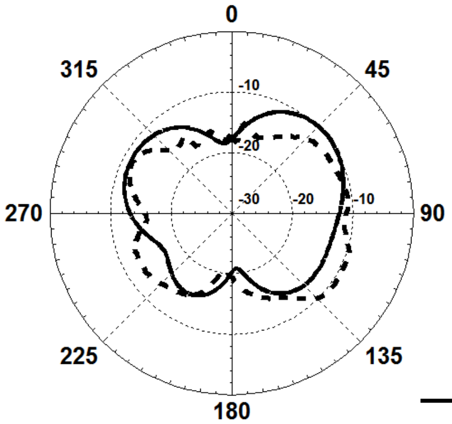
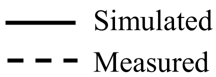


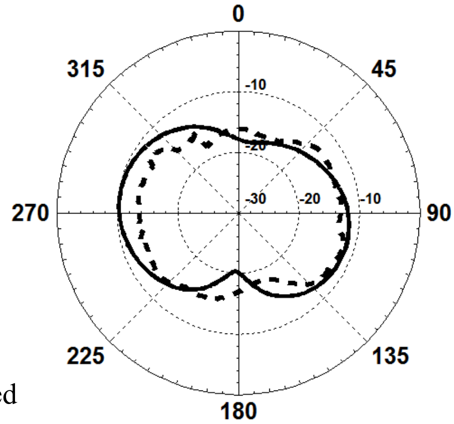
Figure 3: Measured reflection coefficients (a) 0.5-3 GHz and (b) 2.2-2.6 GHz.

The simulated and measured radiation patterns in the *xz* and *yz* planes at 950 MHz, 2.35 GHz and 2.45 GHz are shown in Fig. 4. From the results, the gain of the radiation patterns in the direction of 0 degree is decreased from the maximum gain at 950 MHz. However, the gain in horizontal direction (x-direction) is around -10 dBi, it can be applied in on-body communications. The radiation patterns for WiMAX and ISM bands are relatively omni-directional and are of no deep nulls in the half-sphere above the arm phantom with wide beam. Therefore, the proposed antenna is able to be applied in on-body and off-body communications in WiMAX and ISM bands. In addition, the measured radiation patterns are close to the simulated results, though there are some difference due to the coaxial cable and the DC lines. Fig. 5 presents the fabricated antenna with two DC lines and the proposed arm phantom in this paper.

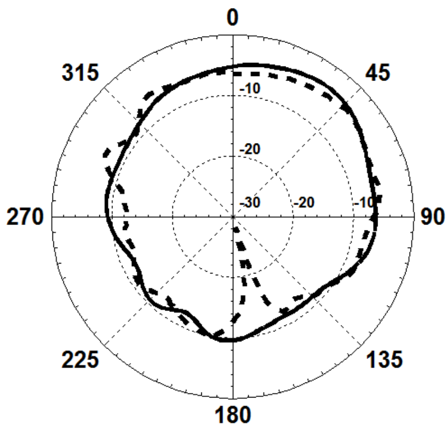


(a) 950 MHz in *xz* plane

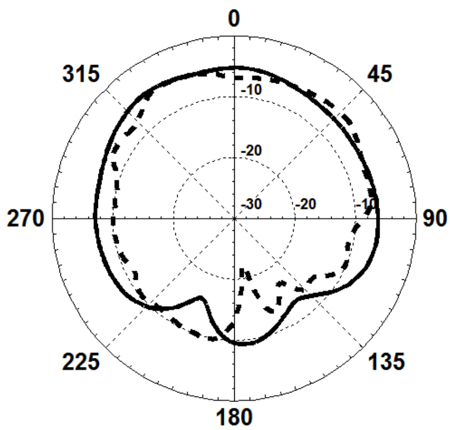




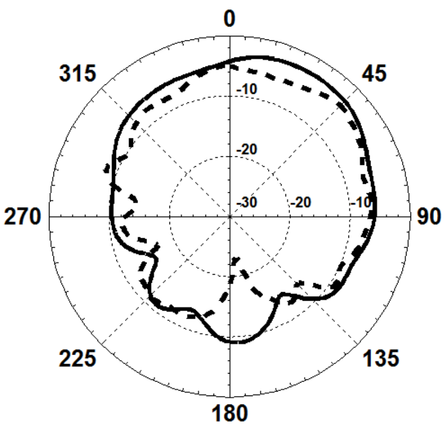
(b) 950 MHZ in *yz* plane



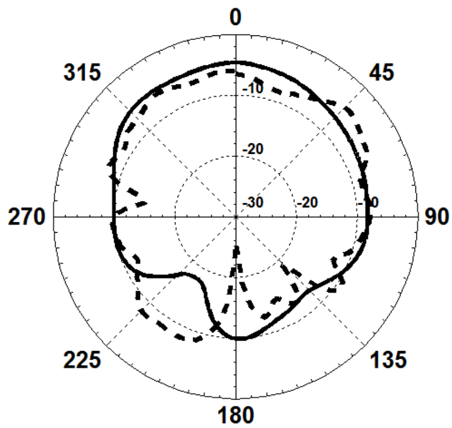
(c) 2.35 GHz in *xz* plane



(d) 2.35 GHz in *yz* plane

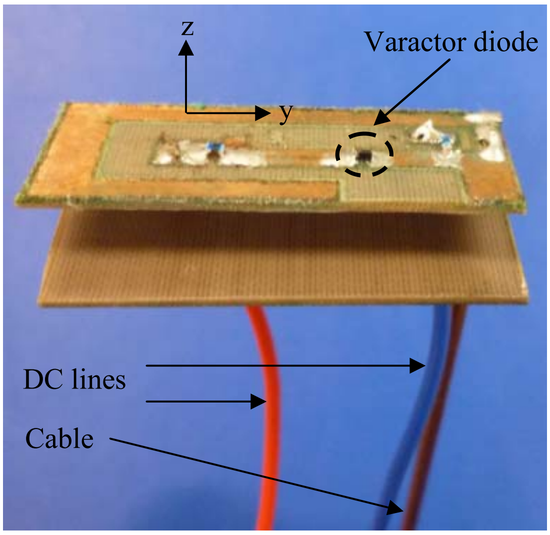


(e) 2.45 GHz in *xz* plane



(f) 2.45 GHz in *yz* plane

Figure 4: Simulated and measured radiation patterns.



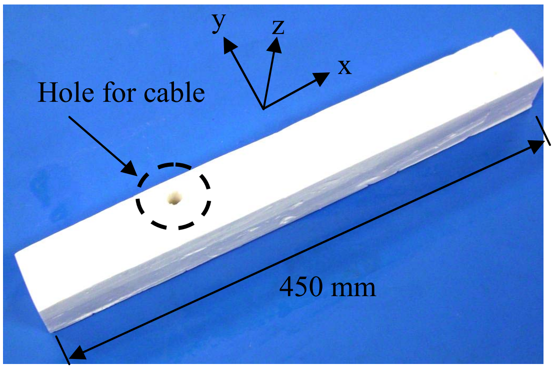


Figure 5: Prototype antenna and proposed 2/3 muscle-equivalent phantom.

4. Conclusions

The wearable multi-band antenna with tuning function for on-body and off-body communications is studied in this paper. It is a planar inverted-F antenna and there are two branches on the radiator: the longer branch low frequency band (950-956 MHz), and the shorter branch with a varactor diode embedded for high frequency bands. By supplying different DC voltages, the capacitance of the varactor diode varies, so the resonant frequency can be tuned without changing the dimension of the antenna. While the bias is set at 6 V and 14 V, WiMAX and ISM bands can be covered, respectively. In addition, the radiation patterns of the proposed antenna in 950 MHz, WiMAX and ISM bands are relatively omni-directional and are of no deep nulls in the half-sphere above the arm phantom. Therefore, the proposed antenna can be expected to be applied in on-body and off-body communications.

In the future, we will try to increase the tuning range of the antenna and use the chest phantom in our study.

References

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