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A COMPACT MULTIBAND MONOPOLE ANTENNA FOR WLAN/WIMAX APPLICATIONS

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Abstract—A compact paw-shaped multiband monopole antenna for Wireless local area network (WLAN) and worldwide interoperability for microwave access (WiMAX) applications is presented. The proposed antenna is composed of a paw-shaped monopole element and a rectangular ground plane with simple configuration. This antenna can easily be fed by using a 50 ohm probe feed with SMA connector. By adjusting a few parameters of the three arms, the resonant frequencies can be easily tuned. The proposed antenna was analyzed and optimized to cover three bandwidths from 2.32 to 2.84, 3.39 to 4.34 and 5.11 to 5.91 GHz that for WLAN and WiMAX applications respectively, with the return loss of better than 10 dB. The performances of the antenna are demonstrated along with measured and simulated results. Moreover, simulated and experimental results with different parameters of the antenna are given.

1. INTRODUCTION

Due to the rapid development of the wireless communication over the last few decades, especially for the WLAN and WiMAX communications, a number of antenna designs have been proposed to be with dual- or multi-band performances to satisfy WiMAX (2.5–2.69 GHz, 3.4–3.69 GHz and 5.25–5.85 GHz) and WLAN (2.4–2.484 GHz, 5.15–5.35 GHz and 5.725–5.825 GHz) applications. However, the planar antenna still plays a key role in wireless communication system applications. The printed monopole antennas have many attractive features, such as simple structure, low profile, light weight and wide impedance bandwidth. Under this situation, various antennas are

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reported to achieve dual-band or multi-band operations in the literature, such as the G-shaped monopole antenna [1–3], the double T-shaped monopole antenna [4], the F-shaped monopole antenna [5], the L-shaped monopole antenna [6–8] and the triangle-shaped monopole antenna [9] etc.. As can be recognized, all of them can only support one application. There are also designs for both WLAN and WiMAX applications [10–17]. In [10–14], though the proposed monopole antennas have good characteristics for both WLAN and WiMAX applications, they are complicated in structures and large in size. The microstrip-fed circular disc monopole [15] can support tri-band operations, but with poor radiation patterns. The antennas in [16, 17] are small in size, but offer narrow impedance bandwidth characteristics in 2.4 GHz-band and 3.4 GHz-band.

In this paper, a novel compact tri-band printed antenna, which is suitable for WLAN and WiMAX applications, is proposed. Tri-band characteristics are achieved by using three branches of the paw-shaped strip. The three arms of the proposed antenna show a relatively independence, which makes the antenna easier to be adjusted so as to resonate at the desired frequencies. The performance of the antenna is verified by experimental data obtained from fabrication and measurement. The design of the proposed antenna is described in the second section. Moreover, experiments are conducted to investigate the influences of the geometry parameters on the positions of three bands. The results are discussed in Section 3.

2. ANTENNA DESIGN

Figure 1 illustrates the configuration of the proposed compact tri-band antenna, which is printed on an FR4 substrate with relative permittivity of 4.4, a loss tangent of 0.02 over the target frequency range, thickness of 1.6 mm and total size of $38 \times 30 \times 1.6\,\text{mm}^3$. In the simulation, an infinite substrate has been considered, while the finite ground plane is set to $30 \times 11\,\text{mm}^2$. The radiating element of the fabricated antenna consists of three arms (arm 1, arm 2, and arm 3). A $50\,\Omega$ microstrip line used to excite the antenna. It is obviously that arm 1 controls the resonance at 5.5 GHz, arm 2 determines the antenna resonance at 3.4 GHz and arm 3 controls the resonance at 2.4 GHz. The resonant lengths of the three arms can be calculated approximately by the following formulas:

$$L_{arm1} \approx (\pi \times \theta_1/180) \times (R_1 + W_1)/2 + L_1 + W_1/2 \tag{1}$$

$$L_{arm2} \approx L_2 + W_2 + S \tag{2}$$

$$L_{arm3} \approx (\pi \times \theta_3/180) \times (R_2 + W_2)/2 + L_2 + W_2/2 \tag{3}$$

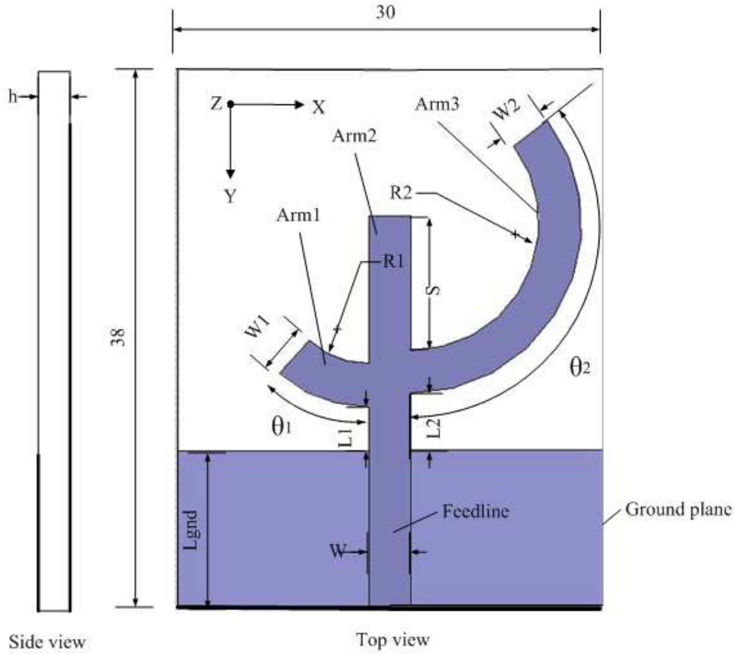


Figure 1. Configuration of the presented antenna (Unit: mm).

As given by [18], for a dielectric substrate of thickness h, microstrip line width is w and relative permittivity ε_r, the effective permittivity is:

$$\varepsilon_{re} \approx \frac{1}{2}\left[(\varepsilon_r+1)+(\varepsilon_r-1)\left(1+\frac{12h}{w}\right)\right]^{-\frac{1}{2}} \tag{4}$$

With $\varepsilon_r = 4.4$, $h = 1.6\,\text{mm}$ and $w = 3\,\text{mm}$ we can get $\varepsilon_{re} = 3.3249$.

Then we can get the guided wavelength λ_g by the following equation:

$$\lambda_g = \lambda_0/\sqrt{\varepsilon_{re}} = \frac{c_0}{f\sqrt{\varepsilon_{re}}} \tag{5}$$

The lengths of the three arms are set close to a quarter wave-length at 2.4 GHz, 3.4 GHz, and 5.5 GHz, respectively. So they can be calculated by the equations above. The original widths of the three arms need some fine tuning to get better impedance matching. Through the commercial software High Frequency Structure Simulator (HFSS), all the parameters are considered in the simulation. It is clear that every single design parameter affects not only one of the frequency bands, though the three arms show a relatively independence as their lengths are changed. All the optimized design parameters are depicted as shown in Table 1.

The manufactured antenna is shown in the Figure 2.

3. RESULTS AND ANALYSIS

By using Ansoft HFSS V12, The excited surface current distributions on the paw-shaped monopole at 2.4 GHz, 3.4 GHz and 5.5 GHz are presented, respectively in Figure 3. It is seen that three resonant modes are excited with the three arms, respectively. That means arm 1

parameters	values
W	3 mm
W_1	3.1 mm
W_2	3 mm
R_1	6.3 mm
R_2	9 mm
S	9.5 mm
L_{gnd}	11 mm
L_1	3 mm
L_2	4 mm
θ_1	42°
θ_2	127°

Table 1. Optimized parameters.

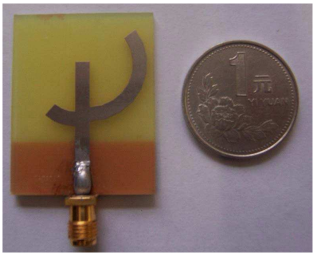
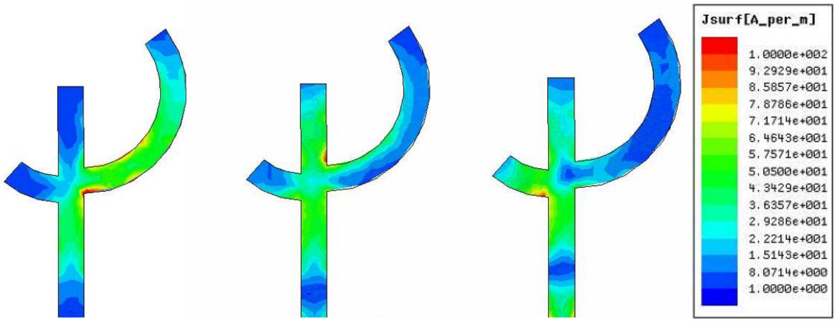


Figure 2. Photograph of the presented antenna.



(a) (b) (c)

Figure 3. The current distribution at (a) 2.4 GHz, (b) 3.4 GHz and (c) 5.5 GHz.

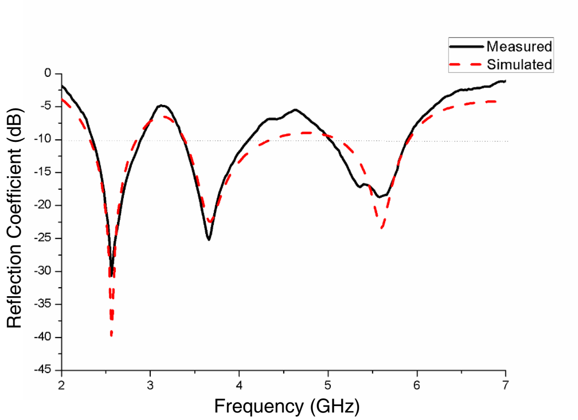


Figure 4. Measured and simulated reflection coefficient.

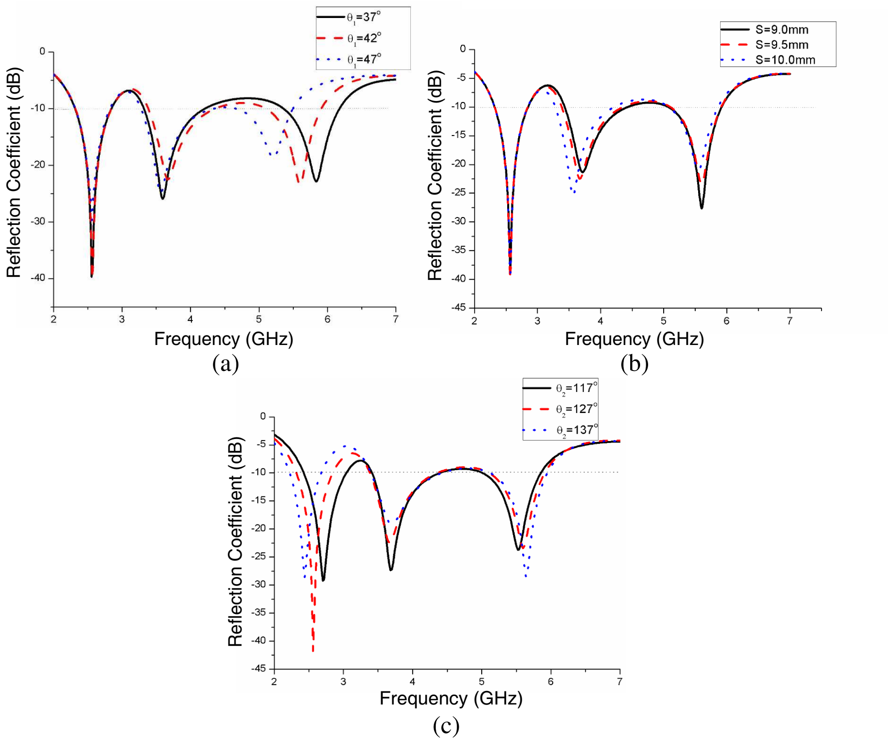


Figure 5. Simulated reflection coefficient curves with equivalent lengths of the three arms, (a) arm 1, (b) arm 2, (c) arm 3.

controls the 5.5 GHz resonance, arm 2 controls the 3.4 GHz resonance and arm 3 controls the 2.4 GHz resonance.

Figure 4 illustrates the reflection coefficient characteristics of the proposed tri-band antenna. It can be seen that, in the proposed antenna, the three resonant modes are excited around the 2.4, 3.4 and 5.5 GHz WLAN/WiMAX bands. The $S_{11} \leq -10\,\text{dB}$ bandwidth is about 520 MHz (2.32 $\sim$ 2.84 GHz) in the 2.4 GHz-band, 955 MHz (3.385 $\sim$ 24.34 GHz) in the 3.4 GHz-band and 800 MHz (5.11 $\sim$ 25.91 GHz) in the 5.5 GHz-band, which meets the bandwidth requirement for WLAN and WiMAX applications. As shown in this figure, a good agreement between the simulated and measured results is achieved. The tiny disagreement is mainly caused by the fabrication error and the environments of the measurement.

It can be seen from Figure 5(a) that, the high resonant frequency moves down as the angle of arm 1 is increased, but this can hardly affect the other resonant frequencies. Similarly, the middle and low

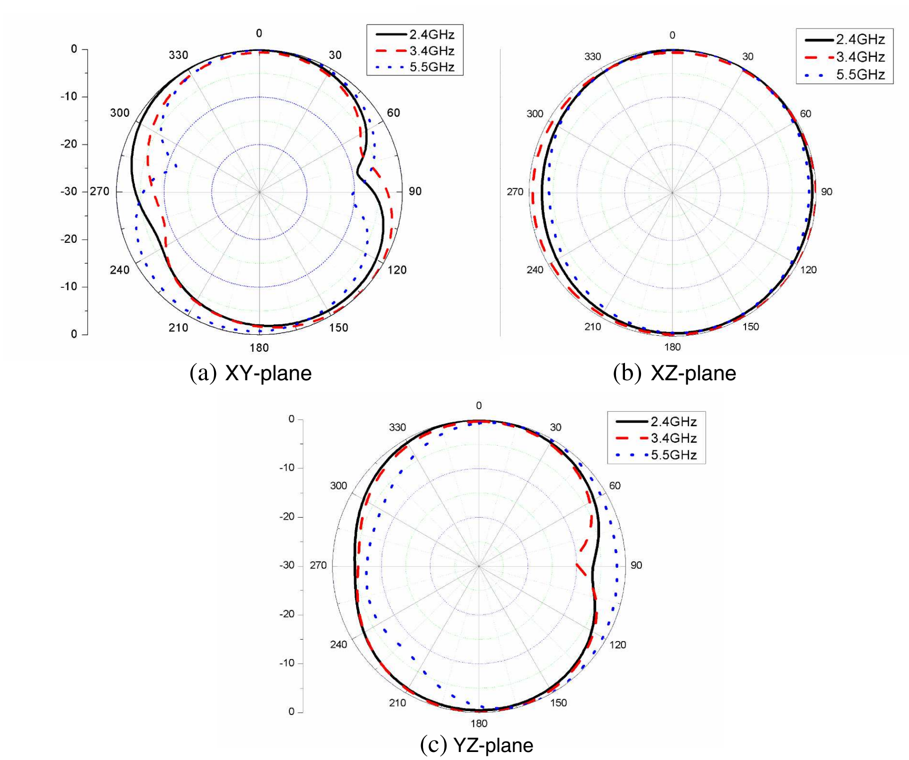


Figure 6. Radiation patterns of the presented antenna. (a) XY-plane. (b) XZ-plane. (c) YZ-plane.

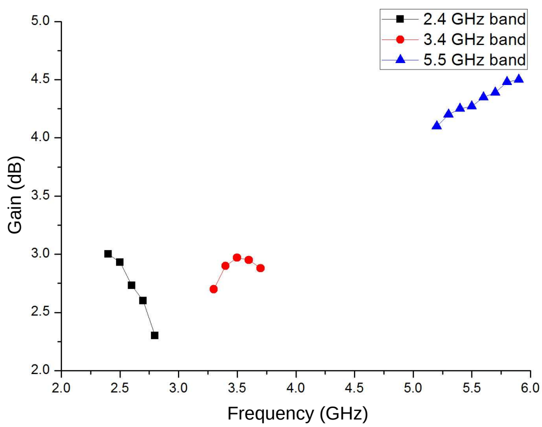


Figure 7. Peak gains of the proposed antenna.

frequencies move down as the equivalent lengths of arm 2 and arm 3 become larger, which indicates that the proposed antenna possesses a characteristic of relatively independence.

Figure 6 shows the far-field radiation patterns of the paw-shaped printed monopole antenna at three typical frequencies in the operation bands. The simulated results show that the radiation patterns of the antenna are bidirectional in XY-plane and YZ-plane and almost omnidirectional in XZ-plane. So the proposed antenna is responsible for using in the omnidirectional communication systems, such as WLAN and WiMAX. The simulated peak antenna gains against frequency are plotted in Figure 7. The results indicate the peak gains of the proposed antenna range approximately from 2.3 to 3 dB at 2.4–2.7 GHz, 2.7 to 3 dB at 3.4–3.7 GHz, and 4.1 to 4.7 dB at 5.2–5.9 GHz, respectively. The antenna exhibits stable gain across three operating bands, so it is suitable for the WLAN and WiMAX systems.

4. CONCLUSION

This paper presents the design of a printed monopole antenna for tri-band operation. This design is suitable for WLAN and WiMAX applications at 2.4 GHz, 3.4 GHz and 5.5 GHz bands. Results of simulated and measured reflection coefficient, impedance bandwidth, the radiation pattern at the operating frequencies and peak gains are obtained. The parameters of proposed design monopole elements are fully adjusted to get the best possible response for tri-band operations. The low-cost antenna is only $38 \times 30 \times 1.6\,\text{mm}^3$ in size, and easy to fabricate and integrate with the application-specific circuit.

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