A Compact Tri-Band Monopole Antenna for WLAN and WiMAX Applications

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Abstract- **A compact tri-band planar monopole antenna is proposed in this paper that employs reactive loading and a defected ground plane structure. This proposed antenna operates in two modes. The first resonance exhibits a dipolar mode over the lower WiFi band of 2.40– 2.485 GHz and the upper WiFi band of 5.15 - 5.70 GHz. The second resonance has a monopolar mode over the WiMAX band at 3.30–3.70 GHz. Full-wave analysis shows that the currents of these two modes are orthogonal to each other, resulting in orthogonal radiation patterns in their far field. The defected ground, formed by appropriately cutting a spiral-shaped slot out of one of the CPW (Coplanar Waveguide) ground planes, leads to the second resonance.**

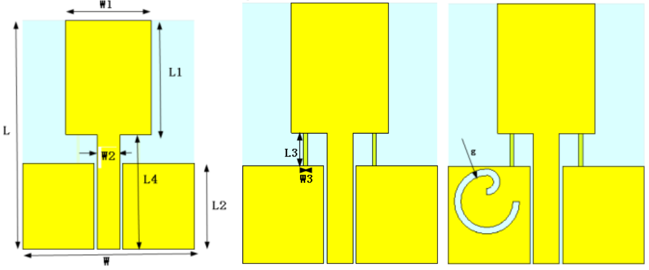
I. INTRODUCTION

The planar monopole is attractive for WLAN antenna design because it has a low profile, broadband, multiband operation. The traditional approach is to use multi-branched strips in order to achieve multiband operation [1], which generally leads to a large volume or requires a large ground plane. Alternatively, the concept of the frequency-reconfigurable multiband antenna [2] has been proposed to develop multiband monopole antennas for WiFi and WiMAX applications [3]. Recently the idea of creating a multiband defected-ground-plane monopole antenna was presented in [4]. And the concept of using slots within printed monopole designs has been investigated by other authors, who have focused on creating a band-reject filtering property in their antennas. For example, in [5] the slots were cut out of the radiating element, while in [6] a single slot was etched out of the ground plane. But these antennas require the use of some vias or many lumped-element components.

In this paper, a compact multiband antenna is proposed. It is easy to fabricate and at a very reasonable cost, thus making it ideal for using in WLAN devices. The resulting defected ground plane creates two orthogonal polarizations and three additional resonances in the input impedance of the antenna, whose locations can be adjusted according to the size and position of the slot. In this work a more detailed explanation of the antenna operation is outlined.

II. ANTENNA DESIGN

The proposed antenna consists of a printed rectangle monopole antenna that has a spiral-shaped slot etched out of its ground plane and bake side with two copper bar loadings, which is shown in Fig. 1. A coplanar waveguide feed is also used. The width of microstrip line (W_2=4mm, L_4=20mm) is determined so that the impedance can be set to 50Ohm. The antenna is designed on a FR4 substrate with height h=1mm, ε=4.0+i0.064. A rectangular patch is chosen as the monopole radiation element. The parameters of the constructed antenna are as follows: L=40mm, W=40mm, L_1=20mm, W_1=15mm, L_2 =15mm, W_2=4mm, g=1mm, L_3=6.5mm, W_3=0.6mm, W_s=7mm. The distance between ground and strip is 0.42mm.



(a) (b) (c)

Figure 1. The schematic of the three antenna models. (a) Model 1: conversional monopole antenna. (b) Model 2: dual-band monopole antenna with copper bar loadings. (c) Model 3: tri-band monopole antenna with copper bar loading and a defected ground plane.

III. SIMULATION RESULTS AND DISCUSSIONS

Fig. 2 depicts the simulated S11 parameter based on the standard Finite Difference Time Domain (FDTD) method for three antenna models which have same dimensions. Model 1 is a conversional monopole antenna. Model 2 is a dual-band monopole antenna with two copper bar loadings. And Model 3 is the proposed tri-band monopole antenna with two copper bar loadings and a defected ground plane. As clearly observed from Fig. 2, proposed antenna exhibits a bandwidth of 1100MHz for the lower WiFi band from 1.90 GHz to3.0GHz and a bandwidth from 4.60GHz to 5.70GHz for the higher WiFi band. It also has a bandwidth of 400MHz for the WiMAX band from 3.30GHz to 3.7GHz. Since the operating frequency of the initial design (Model 1) is out of the range of interest for existing WLAN applications, different approaches using copper bar loadings and a defected ground are pursued to create the corresponding second and third resonances at a lower frequency range in order to meet the WLAN specifications.

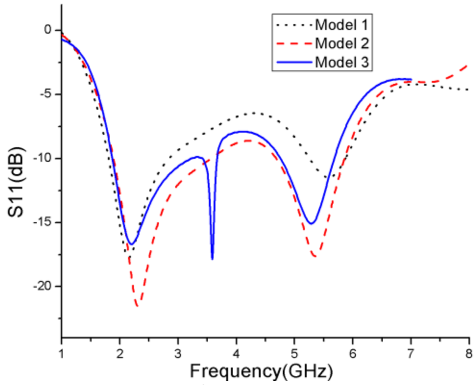
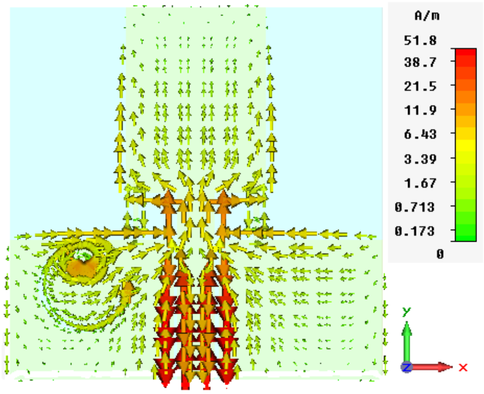
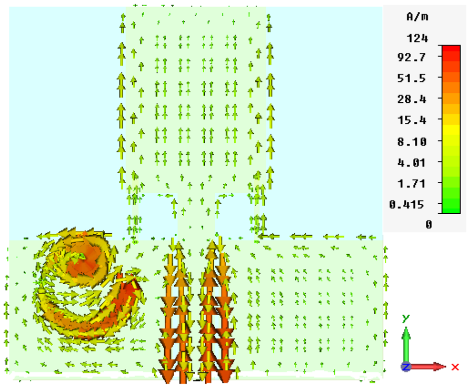


Figure 2. Simulated S11 for Model 1, Model2 and Model 3.

The dual-mode operation mechanism of the Model 3 will be discussed in this section. It can be explained by considering the current distribution on the copper at each of the resonant frequencies, as shown in Fig. 3. These figures were sketched from the surface current distributions. At 5.3GHz, the copper bar loadings was adjusted so that the surface current along the monopole and the bottom thin inductive strip were out of phase. Thus, at this frequency the copper bar loading was used to create a folded monopole, similar to the four-arm folded monopole in [7]. The y-direction currents contribute to radiate, as shown in Fig. 3(a). And at this frequency the currents along the top edges of the two ground planes are out of phase. Therefore, these currents do not contribute to any radiation. At 3.68 GHz, the antenna no longer acts as a folded monopole along the y-axis, but as a dipole oriented along the x-axis. This is a result of the in-phase currents along the top edges of both the ground plane sections (as shown in Fig. 3(b)) which render the ground plane as the main radiating element at this frequency. As can be seen in Fig. 3, there is a strong concentration of the currents along the spiral-shaped slot on the left ground plane. The slot forces the current to wrap around it and thus creates an alternate path for the current on the left ground plane, whose length is approximately at its resonance. It is also noted from Fig. 5 (we will discuss later) that the spiral-shaped slot does not significantly affect the balanced CPW mode, since it is placed far enough away from the CPW.



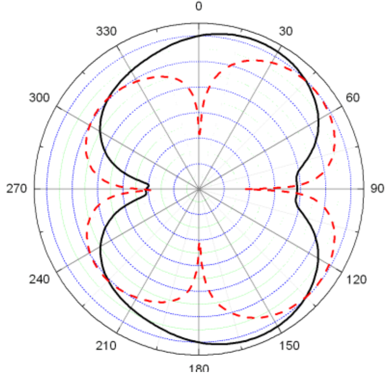
(a)



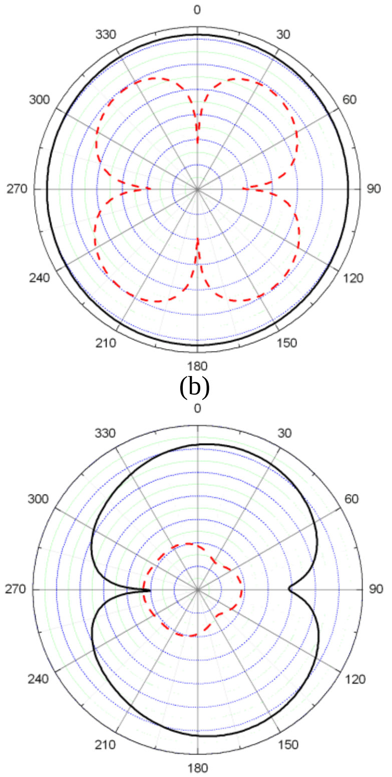
(b)

Figure 3. Simulated surface current distribution on the copper of the Model 3 at the resonant frequencies of 5.3GHz and 3.68 GHz. (a) Folded monopole mode at 5.30 GHz, (b) Dipole mode at 3.68GHz.

The simulated radiation patterns for the proposed tri-band monopole antenna are plotted in Fig. 4 and Fig. 5 for the three principle planes at the frequencies of 5.30GHz and3.68GHz. Fig.4 shows the radiation patterns at 5.30 GHz for the E-plane (xy-plane and yz-plane) and the H-plane (xz-plane). The fact that the antenna exhibits radiation patterns with a horizontal y-directed linear E-field polarization, verifies that the antenna operates in a folded monopole mode around 5.30GHz, due to the y-directed anti-phase currents along the monopole and the thin vertical inductive strip, as shown in Fig. 3(a). The x-directed currents along the thin horizontal inductive strip have a contribution to the cross polarization in the yz-plane. It can also be seen that at this frequency, the slot on the left ground has a minimum contribution to the radiation since the currents are dominated by the y-directed along the monopole. At this frequency, the simulated radiation efficiency is 98.38%. Fig. 4 shows the radiation patterns. At 3.68 GHz, since the spiral-shaped slot which is cut out of the left ground plane results in meandered currents along both the y-direction and the x-direction, which have independent contributions to the radiation. It is observed from Fig. 5 that the antenna exhibits two linear electric fields that are orthogonally polarized in both the y and x directions. In fact, at3.68GHz the width of the ground plane, or equivalently the length of the radiating edge, is approximately equal to $\lambda_g/2$. The simulated radiation efficiency at this frequency is 86.3%.



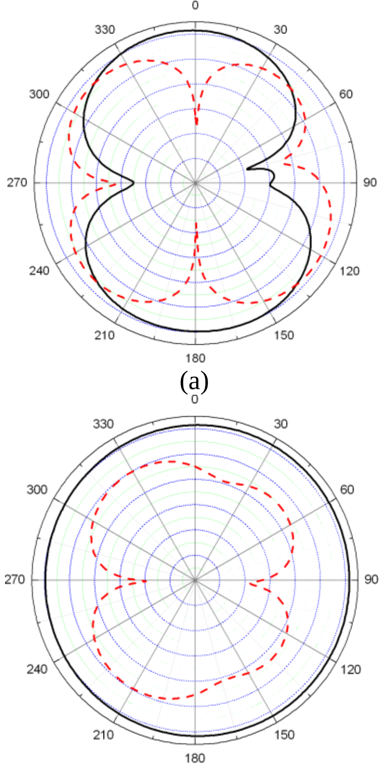
(a)



(b)

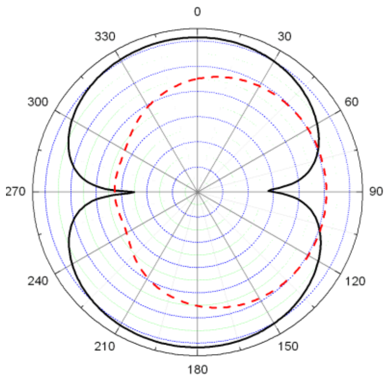
(c)

Figure 4. Simulated radiation patterns for the tri-band monopole antenna at 5.30GHz. Solid black line: simulated co-polarization, dash-dot red line: simulated cross-polarization. (a) xy-plane. (b) xz-plane. (c)yz-plane.



(a)

(b)



(c)

Figure 5.Simulated radiation patterns for the tri-band monopole antenna at3.68GHz. Solid black line: simulated co-polarization, dash-dot red line: simulated cross-polarization. (a) xy-plane. (b) xz-plane. (c)yz-plane.

IV. CONCLUSION

A compact and broadband antenna has been presented, which employs copper bar loadings on a conventional printed monopole design in order to create a dual-mode antenna. It was demonstrated that the addition of the copper bar loadings allows the antenna to be modeled as a short folded monopole at 5.30 GHz while the loading enables the entire top edge of the ground plane to radiate at 3.68 GHz. Thus, the copper bar loaded antenna achieves orthogonal pattern diversity in both the 3.3-3.7GHz WiMAX and 5.15-5.70GHz WiFi bands. Additionally, the antenna maintains a very high efficiency in both the bands of interest. It is therefore well suited for MIMO diversity systems for emerging WLAN applications.

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