Progress In Electromagnetics Research Letters, Vol. 16, 61–68, 2010

A NOVEL TRI-BAND PRINTED MONOPOLE ANTENNA WITH AN ETCHED ∩-SHAPED SLOT AND A PARASITIC RING RESONATOR FOR WLAN AND WIMAX APPLICATIONS

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Abstract—A novel tri-band printed monopole antenna with an etched ∩-shaped slot and a parasitic ring resonator is proposed for satisfying wireless local area network (WLAN) and worldwide interoperability for microwave access (WiMAX) applications simultaneously. The proposed antenna comprises a rectangular radiation patch with an arc-shaped edge and an embedded ∩-shaped slot on the top and a parasitic ring resonator on the opposite side. The measured results show that the impedance bandwidths of the proposed antenna, defined by voltage standing wave ratio (VSWR) $\leq$ 1.5, are 350 MHz (2370–2720 MHz), 680 MHz (3390–4070 MHz) and 1080 MHz (4920–6000 MHz), which cover the required bandwidths for both WLAN (2400–2480 MHz, 5150–5350 MHz, 5725–5825 MHz) and WiMAX (2500–2690 MHz, 3400–3690 MHz, 5250–5850 MHz) applications. Furthermore, good monopole-like radiation characteristics with moderate peak gains are obtained over the operating bands.

1. INTRODUCTION

In modern wireless communication systems, the multiband antenna has become one of the most important circuit elements and attracted much interest [1]. To satisfy the IEEE 802.11 WLAN standards in the 2.4/5.2/5.8 GHz operating bands and the WiMAX standards in the 2.5/3.5/5.5 GHz bands, multiband antennas with simple structure and superior radiation performance are required. In recent years,

Received 15 June 2010, Accepted 15 July 2010, Scheduled 22 July 2010
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many dual wideband and tri-band printed monopole antennas for WLAN/WiMAX applications have been studied and proposed in [1–11]. However, additional band pass filters are required to be added into the system to avoid frequency collision and minimize interference when these antennas in [1–10] are used, because they have very wide frequency coverage, covering many existing narrowband services such as 3G mobile communications and S/C-band satellite communications. Though the antenna proposed in [11] has three distinct operating bands for WLAN and WiMAX, it's very large in size the same as the antennas in [2, 10], and much complex in structure as well as the antennas in [4, 5] and [8–10]. In addition, high performance modern communication systems have much stricter requirement for the VSWR of the antenna and the VSWR less than 1.5 over the operating band(s) will be the latest development tendency in antenna design.

In this paper, a novel tri-band printed monopole antenna with an etched ∩-shaped slot on the radiation patch and a parasitic ring resonator on the bottom side for WLAN/WiMAX applications is presented. Three distinct bandwidths that meet the requirements for the WLAN/WiMAX standards can be obtained by adjusting the length of the slot and the radius of the ring resonator to eliminate two undesired bands. The ∩-shaped slot and ring resonator play the roles as filters. Details of the antenna design and parameter study are presented and discussed as following.

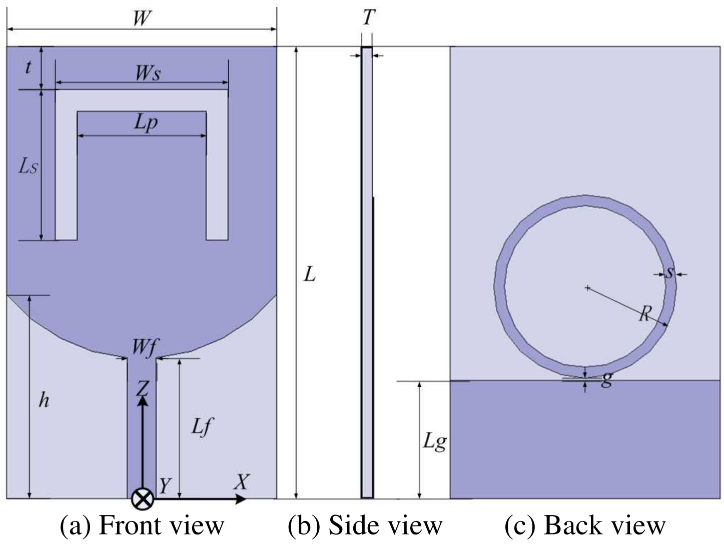


Figure 1. Geometry of the proposed antenna.

2. ANTENNA DESIGN

The geometry of the proposed antenna is shown in Figure 1. The antenna is designed and fabricated on a substrate with dielectric constant of 2.65, thickness of 1.0 mm, and total area of $42 \times 25\,\text{mm}^2$. A rectangular radiation patch with an arc-shaped edge and fed by a 50-Ω microstrip line, is printed on the top side of the substrate. A ∩-shaped slot, which comprises a horizontal and two vertical slots, is etched on the radiation patch. The lengths of the horizontal and vertical slot are Ws and L_S, respectively. A rectangular ground with the size of $25 \times 11\,\text{mm}^2$ and a parasitic ring resonator are printed on the bottom side of the substrate. The outer radius of the parasitic ring resonator is R and the gap between the ground and ring resonator is g. By varying the values of L_S and R, two appropriate notched bands can be generated for rejecting the undesired bands. The required numerical analysis and proper geometrical parameters of the proposed antenna are studied with the aid of Ansoft High Frequency Structure Simulator (HFSS) software, and the optimum design parameters are shown in Table 1. A prototype of the proposed antenna is fabricated according to the aforementioned design results, as shown in Figure 2.

Table 1. Optimal parameters of the antenna prototype.

Parameter	L	W	L_s	W_s	L_f	W_f	t
Value/mm	42	25	14	16	13	2.7	4
Parameter	L_p	h	T	L_g	g	R	s
Value/mm	12	19	1	11	0.2	8.5	1

Figure 2. Prototype of the proposed antenna.

3. RESULTS AND DISCUSSION

The prototype of the proposed antenna has been constructed and experimentally studied. With the help of the Ansoft HFSS and WILTRON37269A vector network analyzer, the simulated and measured VSWR curves are shown in Figure 3. From the measured results it can be observed that the impedance bandwidths (VSWR $\leq$ 1.5) of the fabricated antenna are 350 MHz (2370–2720 MHz), 680 MHz (3390–4070 MHz), and 1080 MHz (4920–6000 MHz), which cover the required bandwidths for both WLAN and WiMAX applications. The discrepancy in VSWR between the simulated and measured results, mostly attributed to the tolerance in the relative dielectric constant

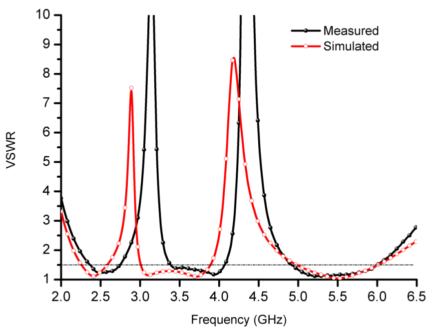


Figure 3. Simulated and measured VSWR of the proposed antenna (L_S = 14 mm, R = 8.5 mm).

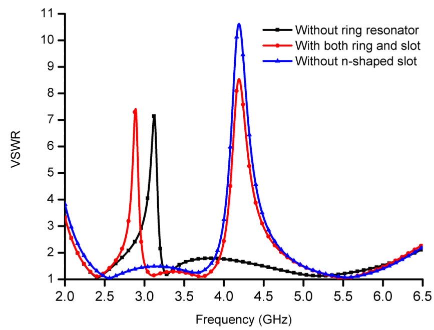


Figure 4. Simulated VSWR of the proposed antenna with/without ring or slot.

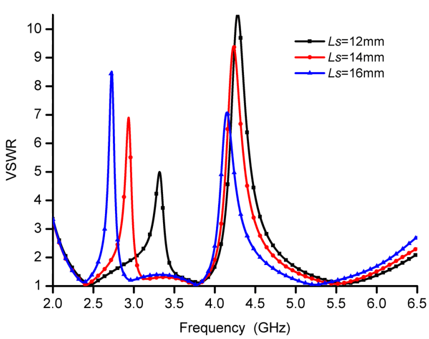


Figure 5. Simulated VSWR for different values of L_S (R = 8.5 mm).

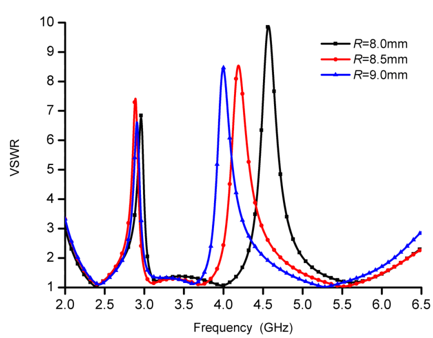
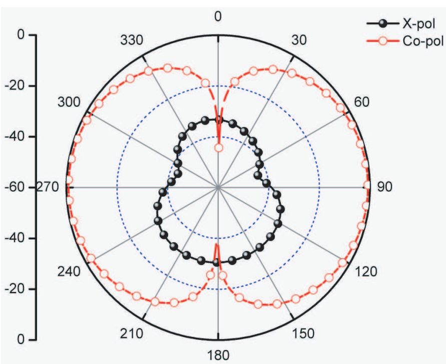


Figure 6. Simulated VSWR for different values of R (L_S = 14 mm).

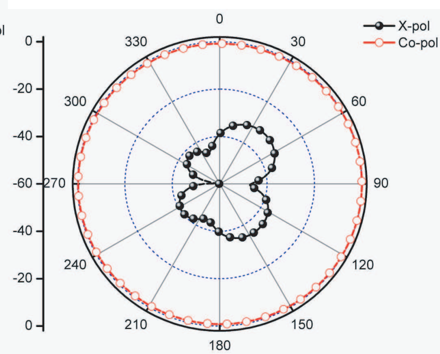
and the loss tangent $\tan\delta$ of the substrate, manufacture and test environment, is tolerable.

To demonstrate the effect of the ∩-shaped slot and the ring resonator on generating the lower and higher notched bands, Figure 4 presents the comparison of the simulated VSWR curves for the antenna in the case with the ∩-shaped slot only (without the ring resonator), the case with the ring resonator only (without ∩-shaped slot), and the case with both the ∩-shaped slot and the ring resonator. It can be seen that, when the ∩-shaped slot is employed only, the notched band whose center frequency guided wavelength equals the length of the whole slot (twice the length of vertical slot plus the length of horizontal slot) is obtained. Similarly, when the ring resonator is presented only, the notched band whose center frequency guided wavelength equals the ring's perimeter can be excited [12].

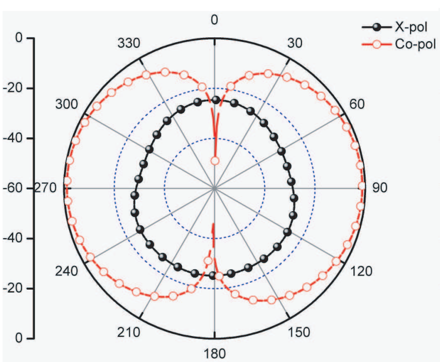
Figures 5 and 6 show the VSWR curves for the proposed antenna with various parameters of L_S and R. In Figure 5, as the length of



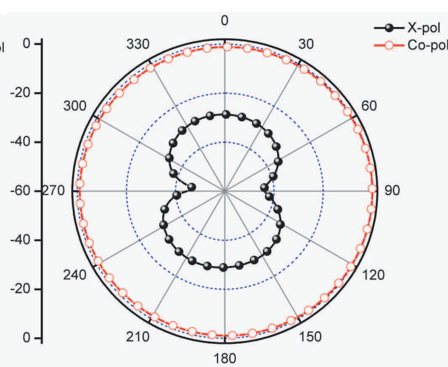
2.45GHz E-plane (y-z plane)



2.45GHz H-plane (x-y plane)



3.5GHz E-plane (y-z plane)



3.5GHz H-plane (x-y plane)

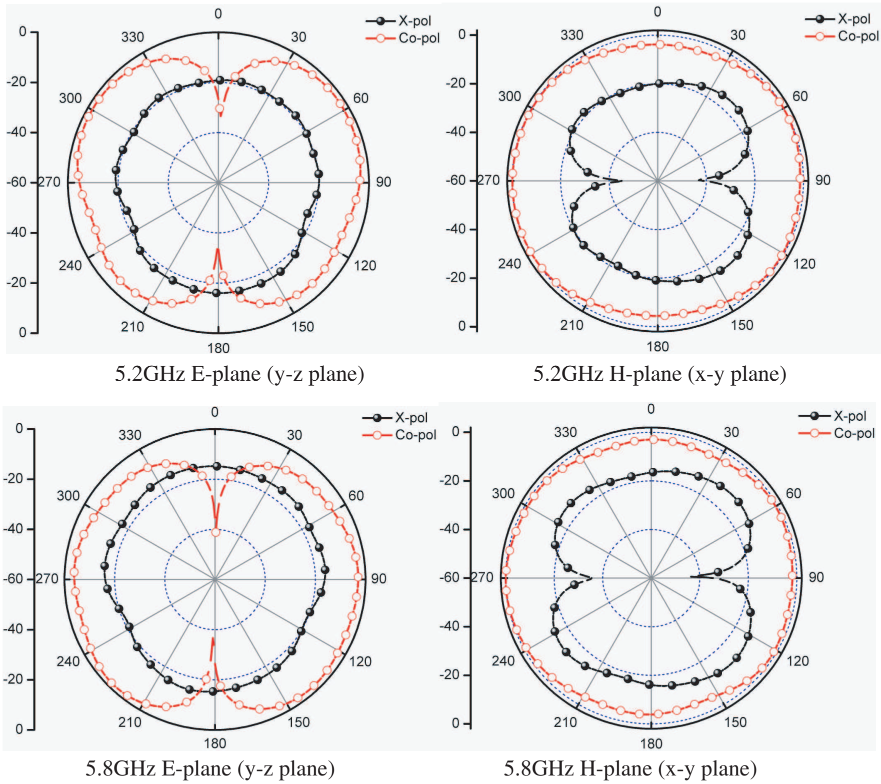


Figure 7. Measured far-field radiation patterns of the proposed antenna.

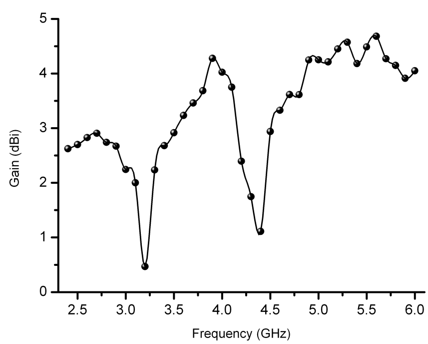


Figure 8. Measured peak gains of the proposed antenna.

the vertical slot increases, the lower rejected band decreases since the center frequency guided wavelength of the rejected band equals the length of the whole slot, and the optimum result is obtained when L_S is varied to 14 mm. The higher rejected band decreases with the increasement of R since its center frequency guided wavelength equals the ring's perimeter, and the optimum result is obtained when R varies to be 8.5 mm, shown in Figure 6.

The measured E-plane and H-plane radiation patterns for the proposed antenna at 2.45, 3.5, 5.2 and 5.8 GHz are shown in Figure 7. It can be seen that, the radiation patterns are bi-directional in the E-plane (y-z plane) and almost omni-directional in the H-plane (x-y plane), which indicate a good monopole-like radiation characteristics over the operating bands.

The measured peak antenna gains against frequency are plotted in Figure 8. The gains are from 2.65 to 2.93 dBi within the 2.4–2.7 GHz band, from 2.69 to 3.49 dBi within the 3.4–3.7 GHz band and from 4.50 to 4.22 dBi within the 5.2–5.9 GHz band. Obviously, the small variations of less than 1 dB in each of the operation bands show that the peak gains of the proposed antenna are moderate. On the other hand, the peak gains in the rejected band decline sharply, such as it's less than 0.5 dBi at 3.2 GHz and 1.1 dBi at 4.4 GHz, because part of the input power is reflected.

4. CONCLUSION

A novel tri-band printed monopole antenna with an etched ∩-shaped slot on the radiation patch and a parasitic ring resonator on the back-side of the radiation patch for WLAN/WiMAX applications has been designed, manufactured and measured successfully. The measured results demonstrate that ∩-shaped slot and parasitic ring resonator generate two undesired bands and by properly tuning the length of the slot and the radius of the ring resonator, three distinct bandwidths that meet the requirements for WLAN and WiMAX standards are obtained. The proposed antenna also has good monopole-like radiation characteristics with moderate gains over the operating bands, which makes it an excellent candidate for the WLAN and WiMAX applications.

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