Progress In Electromagnetics Research Letters, Vol. 40, 61–69, 2013

A COMPACT TRIPLE-BAND FORK-SHAPED ANTENNA FOR WLAN/WIMAX APPLICATIONS

Liang Xu*, **Zheng Yu Xin, and Jun He**

Research Institute of Electronic Science and Technology, University of Electronic Science and Technology of China, Chengdu 611731, China

Abstract—A novel triple-frequency fork-shaped antenna for WLAN/WiMAX applications is proposed and investigated in this paper. The presented antenna is simply composed of three radiating elements viz. Stub1, Stub2, Stub3. By adjusting the lengths of the three stubs, three desired resonant frequencies can be achieved and adjusted independently. Experimental results show that the antenna impedance bandwidths for $S_{11} \leq -10\,\mathrm{dB}$ are 2.4–2.65 GHz, 3.3–4.05 GHz, and 5–5.98 GHz, covering the 2.4/5.2/5.8 GHz WLAN bands and 2.5/3.5/5.5 GHz WiMAX bands. Furthermore, nearly omnidirectional radiation patterns over the operating bands have been obtained.

1. INTRODUCTION

The increasing demands for wireless connectivity necessitates a single antenna to cover several allocated wireless frequency bands. It is a significant issue in communication systems to miniature the antenna while providing good performance over the bands. Due to the widespread popularity of portable wireless devices, the demand for low-cost, low- profile, multi-band, and easy manufacture antennas has been accelerated in the last decades. Wireless local area network (WLAN) and worldwide interoperability for microwave access (WiMAX) have been widely applied to mobile devices such as laptops and 4G smartphones. There are many reported antenna designs for wireless systems, but the most are single-band or dual-band [1–5]. One simple way to cover all frequency bands is using wideband antennas. However, when these antennas are used in WLAN and WiMAX systems, additional band pass filters are required to avoid collision and

Received 2 April 2013, Accepted 8 May 2013, Scheduled 12 May 2013

* Corresponding author: Liang Xu (LiangXu_UESTC@163.com).

minimize frequency interference because their wide operating bands cover many existing narrowband services, like UMTS (1920 $\sim$ 2170) and some satellite communications bands. There are a few designs to operate over all four wireless frequency bands [6–10]. In most cases, the antennas have large overall size and complicated structure which are not suitable for the portable wireless terminals with limited space. In [11], a square-slot antenna with symmetrical L-strips is presented for WLAN and WiMAX applications, but the three resonant frequencies can not be tuned independently.

In this paper, a simple structure fork-shaped antenna for WLAN/WiMAX applications is proposed. The antenna is formed by three Stubs and rectangle ground plane. By adjusting the length and width of the three Stubs, three resonant frequencies can be obtained and tuned independently. Measured results show that the proposed antenna is able to operate in triple-band and cover the 2.4/5.2/5.8 GHz WLAN bands and 2.5/3.5/5.5 GHz WiMAX bands. Details of the antenna design and simulated results as well as measured results are carefully examined and discussed.

2. ANTENNA DESIGN

Figure 1 shows the geometry of the triple-band antenna, which is printed on a 20 mm $\times$ 37 mm Rogers 4350 substrate of thickness 0.508 mm, permittivity 3.48, and loss tangent 0.004. The antenna is formed by a fork-shaped radiator and rectangle ground plane. In order to miniaturize the size of the antenna for application of the portable devices, a 50 Ω CPW-fed line is used to excite the printed monopole antenna. The width of the CPW feed line is 1.55 mm. The dimensions of the proposed antenna are optimized and shown in Table 1.

Table 1. Parameters of the proposed antenna (see Figure 1).

Parameter	L_1	L_2	L_3	L_4	L_5	W_1	W_2	g	h
Value (mm)	18.5	11	9.5	3.3	10.7	7.225	9.125	2	0.508

The commercially available software Ansoft HFSS V13 is carried out to perform the design and optimization process. Figure 2 shows the evolution of the proposed antenna and corresponding simulated reflection coefficient. It begins with the design of Antenna #1, which consists of an inverted L-shaped Stub1 and a CPW feed line. As illustrated in Figure 2(b), the first resonant mode at about 2.55 GHz

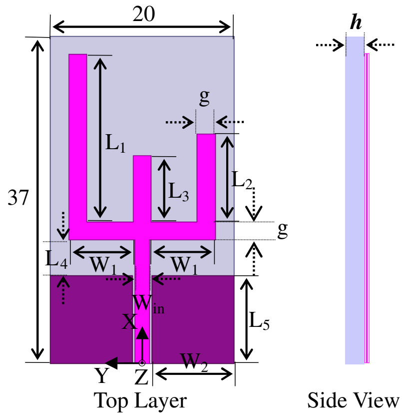


Figure 1. Geometry of the proposed triple-band fork-shaped antenna (unit: millimeters).

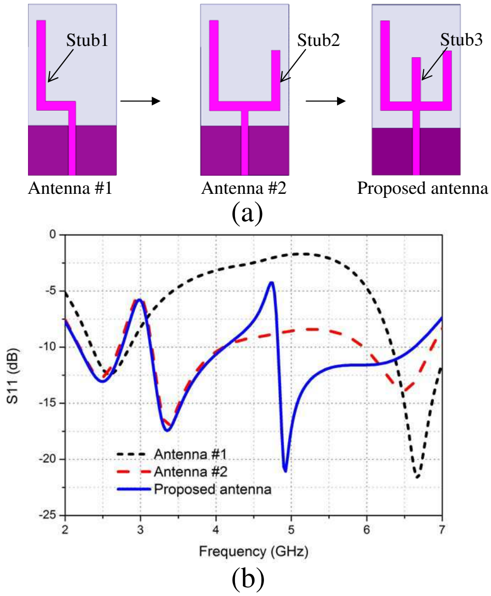


Figure 2. (a) Evolution of the proposed triple-band antenna. (b) Its corresponding simulated reflection coefficient.

is generated by Antenna #1 and it covers the operating band from 2.39–2.79 GHz. Then an inverted L-shaped Stub2 extends from the CPW feed line is employed to generate the second resonant mode at about 3.35 GHz. By extending a rectangle stub from the CPW feed line, the third resonant mode at about 4.95 GHz can be achieved and the triple-band antenna for WLAN/WiMAX applications is obtained. It is found that the performance of the first and second working band is not affected by the appearance of the third working band.

The effects of the design parameters on the antenna performance are plotted in Figure 3. Figure 3(a) shows the simulated reflection coefficient when the length of the L_1 changes. By tuning the length of L_1, the total length of Stub1 varies. It is seen that the increase in L_1 decreases the resonant frequency of the band and vice versa. So, by changing the length of the stub, the related frequency will be changed, while has slight effect on the other band. As shown in Figure 3(d), L_4 (the gap between the radiating patch and the ground plane) could affect the performance of the triple-band antenna. It is apparent that the input reflection coefficient of the proposed antenna with $L_4 = 3.3$ mm is better than that $L_4 = 2.3$ mm and $L_4 = 2.8$ mm.

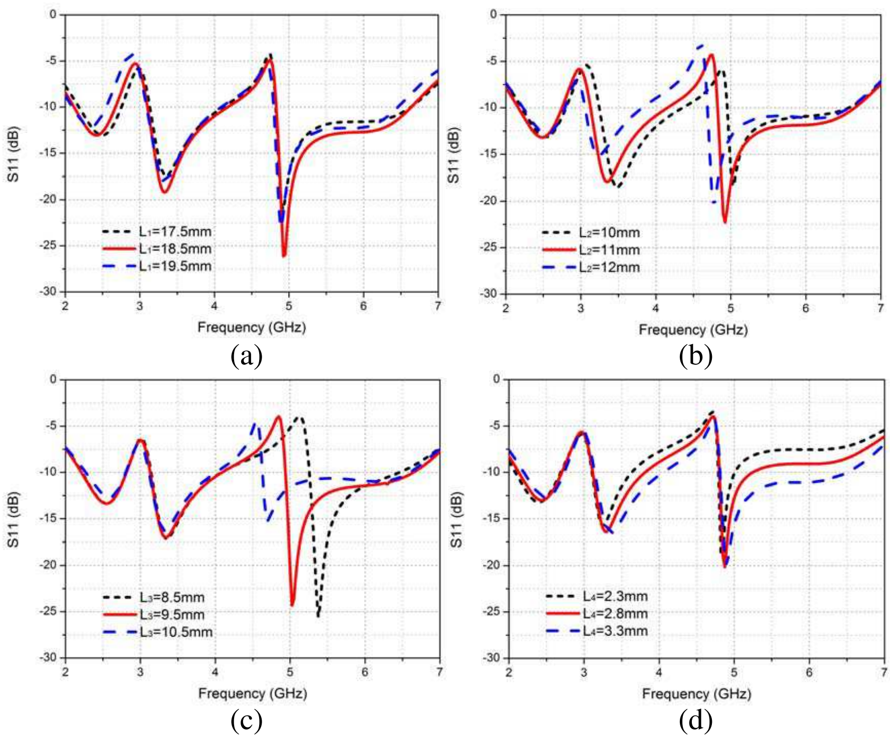
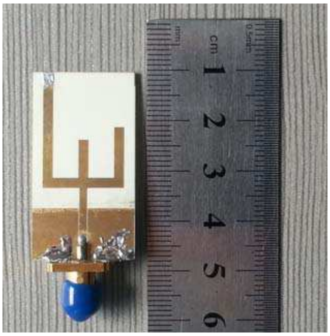


Figure 3. The simulated reflection coefficient of the proposed antenna with (a) varied L_1, (b) varied L_2, (c) varied L_3, (d) varied L_4.

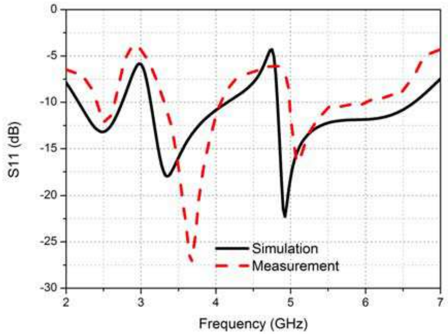
3. RESULTS AND DISCUSSION

Based on the optimal dimensions listed in Table 1, a prototype of the triple-band fork-shaped antenna is fabricated and experimentally investigated. Figure 4(a) shows a photograph of the fabricated antenna. Its performance was measured in an Anechoic Chamber with an Agilent E8362C. For the convenience of comparison, the measured and simulated results of the proposed antenna are plotted in Figure 4(b) and listed in Table 2. The measured impedance bandwidths for $S_{11} \leq -10$ dB are about 250 MHz (2.40–2.65 GHz) resonated at 2.50 GHz, 705 MHz (3.3–4.05 GHz) resonated at 3.6 GHz, and 980 MHz (5.00–5.98 GHz) resonated at 5.1 GHz, which can fulfill both the WLAN bands (2.4–2.485 GHz, 5.15–5.35 GHz, and 5.725–5.825 GHz) and the WiMAX bands (2.5–2.69 GHz, 3.4–3.69 GHz, and 5.25–5.85 GHz). As described in Figure 4(b), the measurement result agrees well with the simulation result.

In order to better understand the antenna behavior, the current distributions of the dual-band antenna at frequencies of 2.45 GHz,



(a)



(b)

Figure 4. (a) Photograph of the fabricated triple-band fork-shaped antenna. (b) Measured and simulated reflection coefficient of the proposed antenna.

Table 2. Measured and simulated impedance bandwidths of the proposed triple-band antenna.

	First resonant mode		Second resonant mode		Third resonant mode	
	$f1$ (GHz)	BW (GHz)	$f2$ (GHz)	BW (GHz)	$f3$ (GHz)	BW (GHz)
Measured	2.50	2.40–2.65	3.6	3.3–4.05	5.1	5.00–5.98
Simulated	2.45	2.17–2.75	3.35	3.15–4.10	4.83	4.95–6.60

3.5 GHz and 5.5 GHz are simulated and shown respectively in Figures 5(a)–(c). It can be clearly seen from the figure that the current distribution at three resonant frequencies is different. For the first resonant mode (at 2.45 GHz band), a large surface current density is observed along the Stub1, whereas for the second (3.5 GHz band) and third (5.5 GHz band) resonant modes, the current distribution becomes more concentrated along the Stub2 and Stub3 respectively. However, they also have a common feature that large current is concentrated along the CPW feed line.

The simulated E-plane (XOZ) and H-plane (YOZ) radiation patterns at 2.45, 3.5 and 5.5 GHz are normalized and shown in

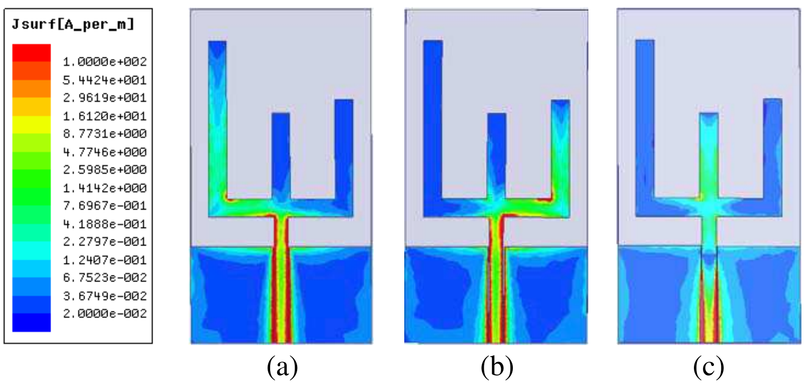
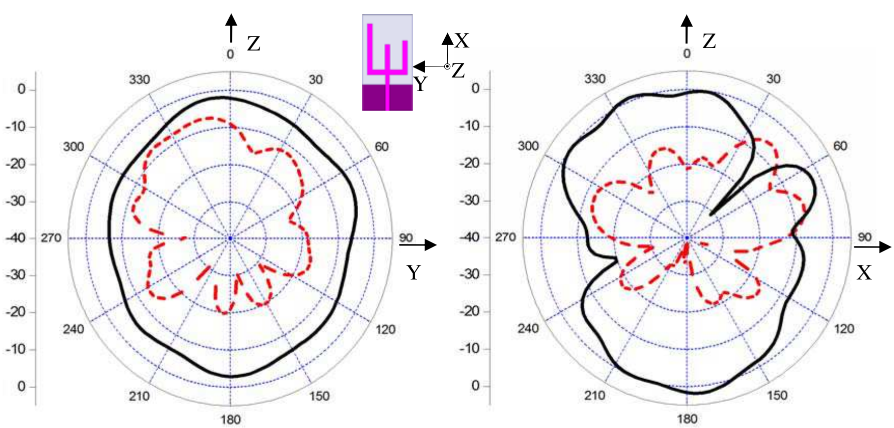


Figure 5. Simulated surface current distribution of the proposed antenna. (a) 2.45 GHz. (b) 3.5 GHz. (c) 5.5 GHz.



(a)

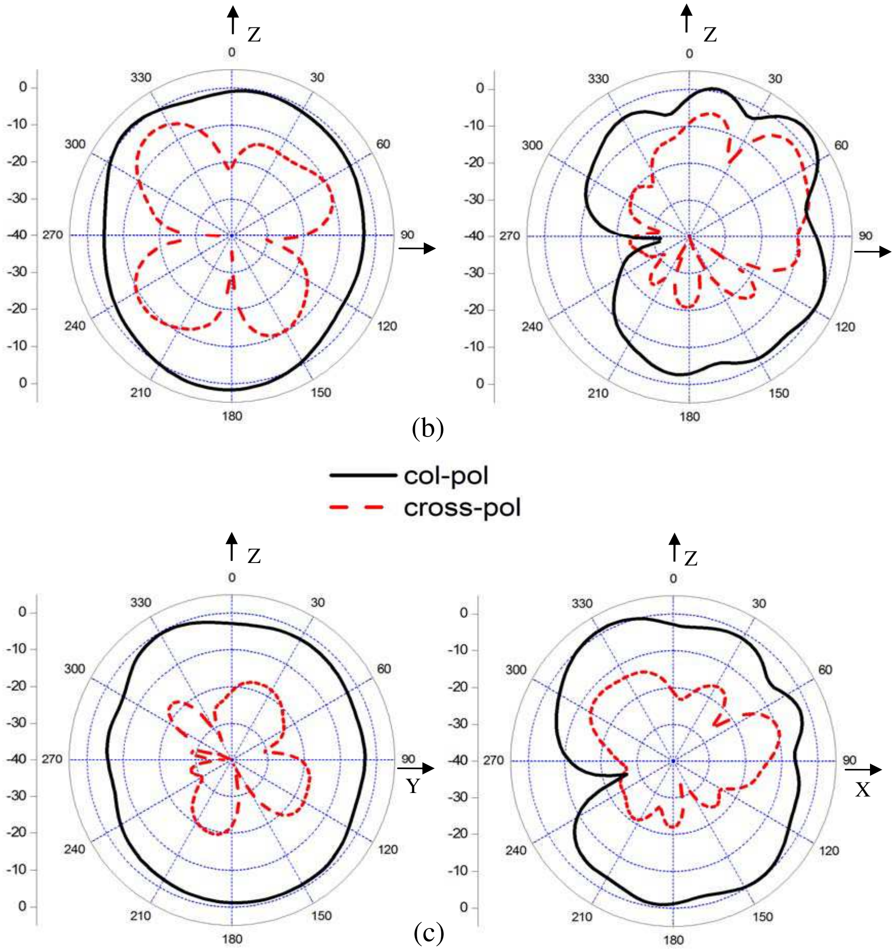


Figure 6. Simulated radiation patterns for the proposed antenna at (a) 2.4 GHz, (b) 3.5 GHz, and (c) 5.5 GHz.

Figure 6. The proposed antenna has nearly omnidirectional radiation characteristic in the H-plane and figure-eight radiation pattern in the E-plane over the three bands.

4. CONCLUSION

A simple structure CPW-fed antenna for triple-frequency operations is proposed with simulated and measured results. The antenna has a simple fabricated structure and compact size of $20\,\mathrm{mm} \times 37\,\mathrm{mm}$. By employing three separate resonant Stubs, the three working bands can be achieved successfully and tuned flexibly. The antenna prototype has been fabricated and measured. The measured result shows that the impedance bandwidths are 2.4–2.65, 3.3–4.05, and 5–5.98 GHz, which cover the 2.4/5.2/5.8 GHz WLAN bands and 2.5/3.5/5.5 GHz WiMAX bands. In addition, the antenna shows good radiation characteristics across the whole working band. Consequently, the proposed antenna is suitable for portable wireless terminals.

ACKNOWLEDGMENT

This work is supported by the Fundamental Research Funds for the Central Universities of China (No. ZYGX2010J117).

REFERENCES

1. Wu, Y.-J., B.-H. Sun, J.-F. Li, and Q.-Z. Liu, "Triple-band omni-directional antenna for WLAN applications," *Progress In Electromagnetic Research*, Vol. 76, 477–484, 2007.
2. Lee, C.-T., S.-W. Su, and F.-S. Chang, "A compact, planar plate-type antenna for 2.4/5.2/5.8-GHz tri-band WLAN operation," *Progress In Electromagnetic Research Letters*, Vol. 26, 125–134, 2011.
3. Gao, X., H. Zhong, Z. Zhang, Z. Feng, and M. F. Iskander, "Low-profile planar tripolarization antenna for WLAN communications," *IEEE Antennas and Wireless Propagation Letters*, Vol. 9, 83–86, 2010.
4. Zaker, R., C. Ghobadi, and J. Nourinia, "A compact microstrip-fed two-step tapered monopole antenna for UWB and WLAN applications," *Progress In Electromagnetic Research*, Vol. 77, 137–148, 2007.
5. Chu, Q.-X. and L.-H. Ye, "Design of compact dual-wideband antenna with assembled monopoles," *IEEE Transactions on Antennas and Propagation*, Vol. 58, No. 12, 4063–4066, 2010.
6. Ren, F.-C., F.-S. Zhang, J.-H. Bao, B. Chen, and Y.-C. Jiao, "Compact triple-frequency slot antenna for WLAN/WiMAX operations," *Progress In Electromagnetic Research Letters*, Vol. 26, 21–30, 2011.
7. Xie, J.-J., Y.-Z. Yin, J. Wang, and S.-L. Pan, "A novel tri-band circular alot patch antenna with an EBG structure for WLAN/WiMAX applications," *Journal of Electromagnetic Waves and Applications*, Vol. 26, No. 4, 493–502, 2012.

8. Wang, T., Y.-Z. Yin, J. Yang, Y.-L. Zhang, and J.-J. Xie "Compact triple-band antenna using defected ground structure for WLAN/WiMAX applications," *Progress In Electromagnetic Research Letters*, Vol. 35, 155–164, 2012.
9. Li, H. H., X. Q. Mou, Z. Ji, H. Yu, Y. Li, and L. Jiang, "Miniature RFID tri-band CPW-fed antenna optimised using ISPO algorithm," *Electronics Letters*, Vol. 47, 161–162, 2011.
10. Pei, J., A.-G. Wang, S. Gao, and W. Leng, "Miniaturized triple-band antenna with a defected ground plane for WLAN/WiMAX applications," *IEEE Antennas and Wireless Propagation Letters*, Vol. 10, 298–301, 2011.
11. Hu, W., Y.-Z. Yin, P. Fei, and X. Yang, "Compact triband square-slot antenna with symmetrical L-strips for WLAN/WiMAX applications," *IEEE Antennas and Wireless Propagation Letters*, Vol. 10, 462–465, 2011.
12. Mehdipour, A., A. R. Sebak, C. W. Trueman, and T. A. Denidni, "Compact multiband planar antenna for 2.4/3.5/5.2/5.8-GHz wireless applications," *IEEE Antennas and Wireless Propagation Letters*, Vol. 11, 144–147, 2012.