Compact CPW-Fed Planar Monopole Antenna with Triple-Band Operation for WLAN/WiMAX Applications

Ping Wang[1,2], Guang-Jun Wen[1], and Yongjun Huang[1]

[1] Centre for RFIC and System Technology
School of Communication and Information Engineering
University of Electronic Science and Technology of China, Chengdu 611731, China
wangpingcqz@163.com, wgj@uestc.edu.cn, yongjunh@uestc.edu.cn

[2] College of Electronic and Information Engineering
Chongqing Three Gorges University, Chongqing 404000, China

Abstract **─** In this paper, we propose a compact coplanar waveguide (CPW) feed planar printed monopole antenna for WLAN/WiMAX applications. By employing two different types of structures-L-shaped slot and I-shaped notched slots, three distinct frequency bands with -10dB reflection coefficient, which correspond to 2.4GHz-2.6GHz, 3.4GHz-3.85GHz and the other at 4.9GHz-5.89GHz, can be achieved to covering 2.4/5.2/5.8 GHz WLAN and 2.5/3.4/5.5 WiMAX. Also, the antenna has a small size of 30mm×23mm, and can provide excellent property, including low profile, moderate gain, approximate omnidirectioal radiation pattern, which prove that the antenna is a good candidate for WLAN/WiMAX applications.

Index Terms **─** Triple-band antenna, L-shaped slot, I-shaped slot, WLAN/WiMAX.

I. INTRODUCTION

Due to the rapid development of modern wireless communication systems technique, the research activity of the multiple or broad bands operation and miniaturized size for current antenna has become one of a highly competitive topic and is growing stupendously. In [1] and [2], the planer monopole antennas can achieve broad bandwidth, but have a large size, especially a large ground plane (250mm×250mm), whose configuration do not meet the miniaturization requirements of radio-frequency (RF) units[3]. However, planar printed microstrip antenna may be a better candidate due to their attractive features, such as ease of fabrication, low profile, small size, ease of integrating with active devices and nearly omnidirectional radiation characteristics, and so on. In order to satisfy the wireless local area network (WLAN) standards of 2.4–2.484 GHz (IEEE 802.11b/g)/5.15–5.825 GHz (IEEE 802.11a) and the worldwide interoperability for microwave access (WiMAX) standards of 2.5–2.69 GHz/3.4–3.69 GHz/5.25–5.85 GHz [4] simultaneously, many microstrip printed antennas have been widely studied [5-9]. In [5], a pair of parasitic strips is introduced to reach an operating bandwidth of 4290 MHz (～108.7%), and the antenna has a dimension of 61×51.5mm^2. A trapezoidal ground [6] and a parasitic U-shaped open stub [7] are also used to the design of the antenna for the WLAN/WiMAX applications. Only by varying the slot's construction, width, and length, the feed point's position and the CPW-fed gap, another compact dual-/multiband antenna have been shown in [8]. A CPW-fed dual-wideband antenna formed by a triangular monopole and a U-shaped monopole is obtained, which occupies a small size and obtain good dipole-like radiation characteristics [9]. However, most of them have large dimensions and do not pay attention on the interference suppression, because there are many other existing narrowband services such as C-band satellite communications that have occupied some licensed frequency bands, which may result in lower performance of interference suppression. To avoid the problem, several novel antennas with three separated resonate frequency are reported in literatures [4, 10-15], which have good impendence bandwidth and radiation pattern, but these antennas have also

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either large size or insufficient frequency restriction.

In this letter, a distinct triple-band resonate antenna for WLAN/WiMAX applications is proposed. By inserting three I-shaped notched slots and an L-shaped slit on radiation patch, along with introducing symmetrical L-shaped couple slot on ground plane which had been proven to be useful to produce resonant mode [16], three separated resonant frequency bands can be easily obtained. Compared to those designs shown in the open literature, the antenna has not only better performance of interference suppression, but also smaller size. Details of the antenna design are described, and prototypes of the proposed antenna have been constructed and tested. The simulated and measured results about impedance bandwidth, radiation pattern, and gain are discussed in detail in the next sections.

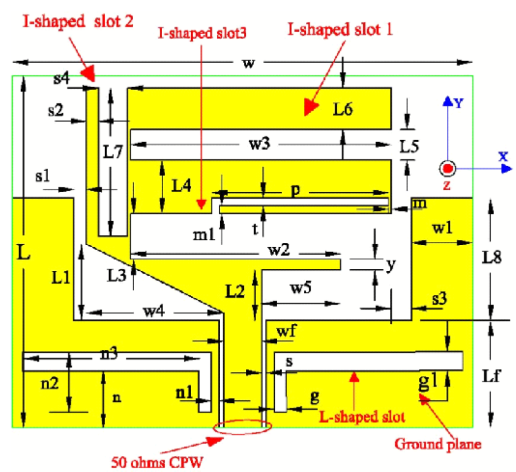
II. ANTENNA CONFIGURATION

Geometrical configuration of the proposed antenna for WLAN/WiMAX applications is shown in Fig. 1(a). The antenna is printed on FR-4 substrate of thickness 1mm, with the dielectric constant of 4.4 and a loss tangent of 0.02, and fed by a 50Ω CPW transmission line. In this design, two equal L-shaped ground planes, each comprising two different sections which are 32mm^2 and 94.15mm^2, are situated symmetrically on each side of the CPW line. In order to produce resonate at 5.65GHz, a pair of L-shaped slots is etched into ground plane, which broaden the higher frequency range. On the other hand, three I-shaped notched slots are also inserted into radiation patch, which controls the lower operating band (2.4/2.5GHz) and medium frequency band (3.4GHz). Furthermore, a horizontal L-shaped slit of width t and length p+m1 is inserted into radiation patch to improve impendence bandwidth. This arrangement was found to be effective in obtaining an appropriate impedance bandwidth of the antenna, and the performance results are demonstrated in the following section.

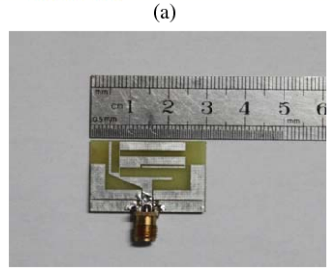
In the proposed antenna configuration, the use of two horizontal I-shaped slots and a vertical I-shaped slot on radiation patch produce three different surface current paths, and by properly tuning two different horizontal spacing of s1 and s3 from the patch to the side ground planes, a dual-resonance mode can be excited on lower frequency, a resonate mode produced in medium frequency and other resonate mode happened on higher frequency, respectively. Note that the ground-plane dimensions can also affect the resonant frequencies and operating bandwidths of the two operating bands. Thus, the ground-plane dimensions should also be taken into account in determining the proper parameters for the proposed design to achieve the desired triple-band operation.

Table 1: Parameter values of the fabricated antenna. (Dimensions in mm)

Parameter	*w*	*w1*	*w2*	*w3*	*w4*	*w5*	*L*
Value	30	4	13.7	17	8.95	5.15	23
Parameter	L1	L2	L3	L4	L5	L6	L7
Value	5	3.3	3	3.5	2	2.7	9.7
Parameter	L8	Lf	n	n1	n2	n3	g
Value	8	7	3.7	0.5	3	11.5	0.8
Parameter	g1	wf	s	s1	s2	s3	s4
Value	0.3	2.5	0.3	0.8	0.8	1.3	1.9
Parameter	m	m1	p	t	y		
Value	0.2	0.5	11.5	0.5	0.7		



(a)



(b)

Fig. 1. (a) Geometry of the proposed antenna, (b) Photograph of the proposed antenna.

The proper parameters can be obtained with the aid of the commercially available software Ansoft

HFSS version 13 (high-frequency structure simulator), and a 50Ω-SMA connector is connected to the end of the CPW-feed mechanism serves as antenna port. Parameter values of the proposed antenna are summarized in Table 1. Moreover, a photograph of the fabricated antenna with triple-band characteristic is shown in Fig. 1.

III. EXPERIMENTAL RESULTS AND DISCUSSION

The proposed antenna is implemented and tested using an Agilent N5230A series vector network analyzer. Fig. 2 describes the simulated and experimental reflection coefficient against the frequency, which shows good agreement. The simulated and the experimental below 10-dB bandwidths range from 2.4–2.62 GHz/2.4–2.6 GHz(8.76%/8%), from3.37-3.74GHz/3.4-3.85GHz (10.4%/12.4%)and from 5.04–5.75GHz/4.9–5.89GHz (13.2%/18.4％), which shows a minor frequency shift owing to the error of substrate parameters of the FR-4 substrate and tolerance in manufacturing. It is also observed that best resonant frequencies happened in 2.46GHz, 2.56GHz, 3.56GHz, 5.25GHz and 5.65GHz. The Smith chart and the simulated input impedance of the proposed antenna shown in Fig. 3 and Fig. 4 further illustrate the excellent impedance matching of the proposed triple-band antenna, respectively.

To further insight into the physical behavior of the antenna, the simulated current distributions of the proposed antenna at different resonate frequencies are presented in Fig. 5. We can see that

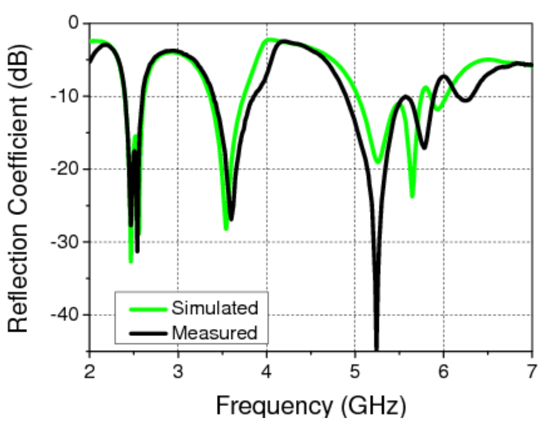


Fig. 2. Simulated and measured reflection coefficient of the proposed antenna.

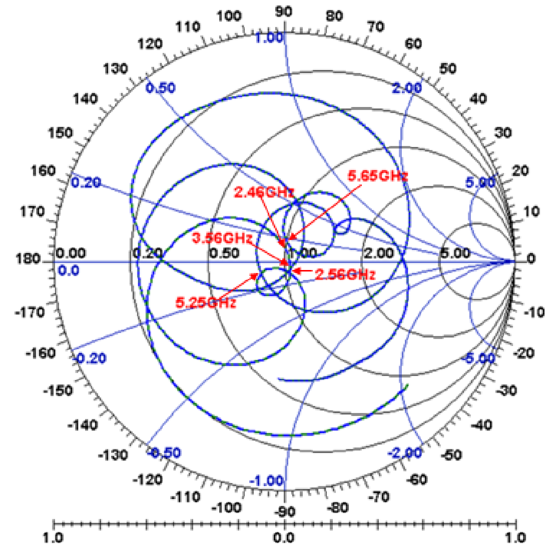


Fig. 3. Simulated input impedance on Smith chart for the proposed antenna.

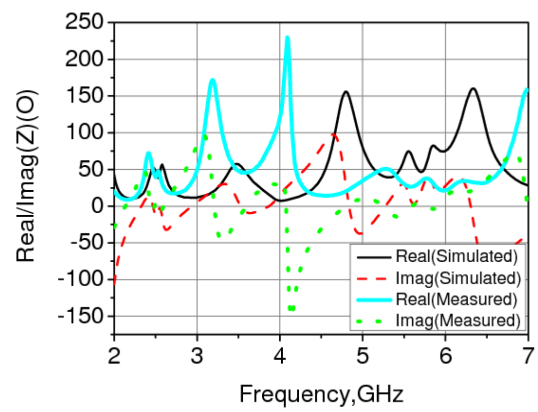


Fig. 4. Simulated and measured impedance of the antenna.

notched slot 1 provide a low resonate frequency (2.56GHz) shown in Fig. 5 (b), moreover, notched slot 2 and CPW control the flow direction of current in 2.46GHz and 3.56GHz. Meanwhile, in the high frequency (5.25GHz) the unfolded arm provide a resonate mode, and a pair of loaded L-shaped slots with length of about $\lambda/2$ provide the another resonate mode(5.65GHz), which broaden the higher frequency bandwidth.

Figure 6 presents the frequency response of reflection coefficient for the proposed antenna without different slots embedment. In the case without notched slot 1, second resonate mode is not effectively excited at lower resonance frequency range, and other frequency ranges have no effects. Similarly, when removing a pair of L-shaped slots on the ground plane, a worse frequency response was achieved in higher frequency range, but in other two frequency bands it was invariable. It is also observed that existence of the notched slot 2 not only can largely affect impedance matching to the lower band and the medium band, but also seriously change the excitation of the upper-band resonant modes. It clearly indicates that these results are similar with that achieved from simulated current distributions in Fig. 5.

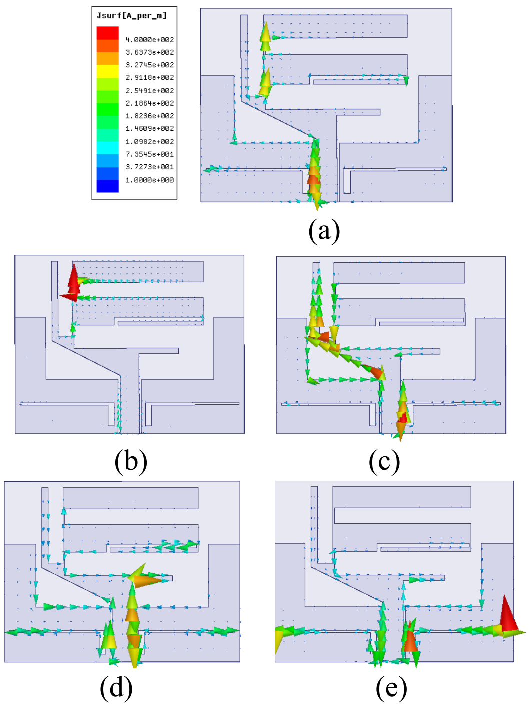


Fig. 5. Simulation surface current in (a) 2.46GHz, (b) 2.56GHz, (c) 3.56GHz, (d) 5.25GHz, (e) 5.65GHz.

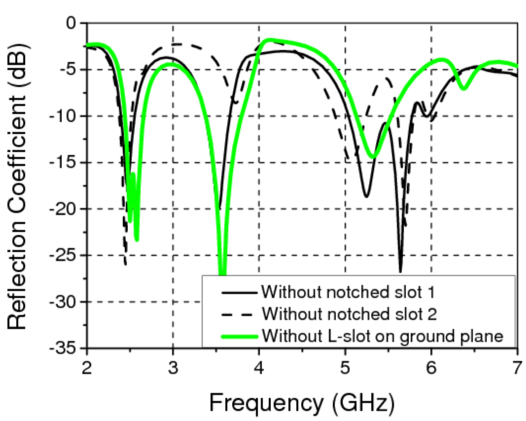


Fig. 6. The effect of notched slots to the proposed antenna's resonant modes.

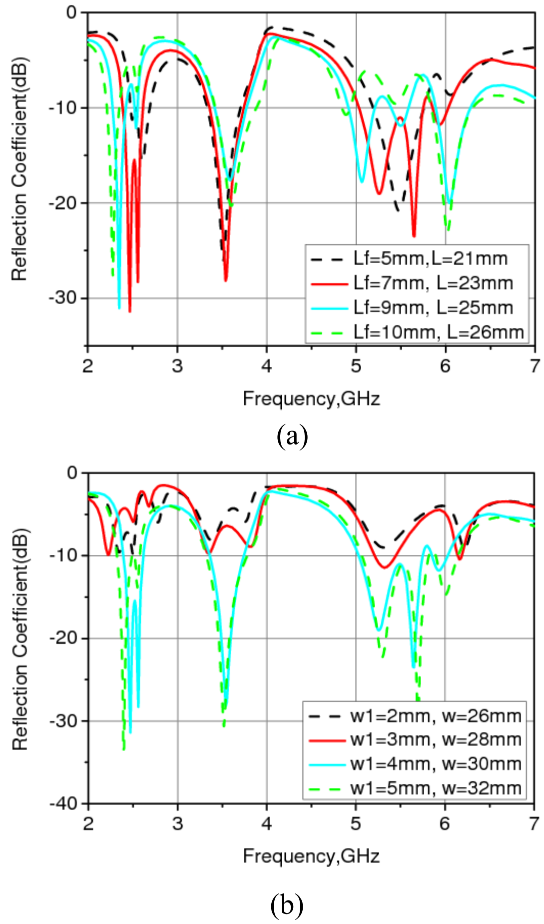


Fig. 7. The effect of the ground plane size on the antenna performance.

The simulated reflection coefficient curves with different ground plane widths (w) and lengths (Lf) are exhibited in Fig. 7. It is clearly seen that when w and Lf are changed, they can significantly increase or decrease the impedance bandwidth of the antenna. It is also noticed that the length of the ground plane affects the impedance matching more significantly at lower frequencies than at higher frequencies as shown in Fig. 7(a), and in Fig. 7(b) the reflection coefficient curves vary significantly and exhibit various shapes for the four different ground plane widths. To have a wider impedance bandwidth, the length and width of ground plane need to be well optimized and the extracted optimum parameter values are w=30mm and Lf=7mm.

Radiation characteristics are also considered. The simulated and measured radiation patterns of the proposed antenna in xz-plane and yz-plane for both E_Φ and E_θ at 2.46GHz, 3.56GHz and

5.25GHz (resonate frequencies) are shown in Fig. 8, respectively. From the results, the radiation patterns in the xz- and yz-planes, as expected, are all very dipole-like radiation. The electric field E_θ keeps always eight-shaped radiation pattern and the electric field E_Φ holds nearly omnidirectional radiation pattern in xz-plane and yz-plane. It is also observed that the antenna has more vertical current (y-axis) shown in Fig. 5 (d) at higher frequency, so the radiation pattern is similar with dipole-like radiation along y-axis. Fig. 9 shows the peak gains and radiation efficiency across the three operating frequency bands. It should be observed that for the operating band of 2.4–2.7 GHz, the peak gain of the antenna varies from 1dB to 2.05dB, and the radiation efficiency obtains the lowest value of 70% in centre frequency. For the medium band, the antenna has relatively small gain and radiation efficiency variation, the peak gain is 2.14dB, and the radiation efficiency varies around 83%.

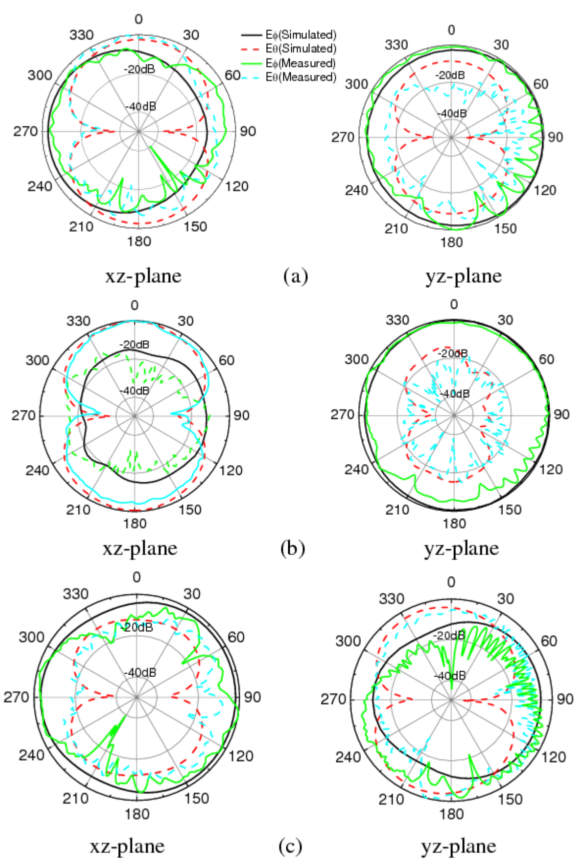


Fig. 8. Simulated and measured radiation patterns for the proposed antenna at (a) 2.46GHz, (b) 3.56GHz and (c) 5.25GHz in xz-plane and yz-plane, respectively.

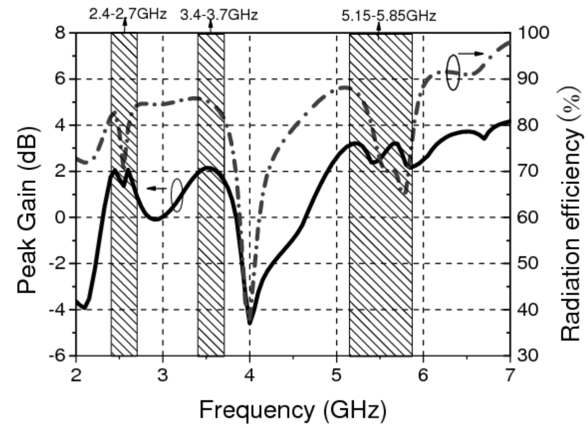


Fig. 9. Peak gain and radiation efficiency of the proposed antenna.

The peak gain in the higher operating band of 5.15–5.85 GHz is also stable, which varies from 2.15dB to 3.2dB, however, the radiation efficiency drop to 65% in 5.75GHz. The low radiation efficiency may be high loss in FR-4 substrate (a loss tangent of 0.02), which results in a decrease in gain and radiation efficiency as shown in Fig. 9. But then the gain of the proposed antenna within the operating bands satisfies the requirement of some wireless communication terminals.

IV. CONCLUSION

In this paper, a novel CPW-fed monopole antenna is proposed for WLAN/WiMAX applications. The proposed antenna has good performance of interference suppression, excellent radiation patterns, excellent resonance character and small size. The measured results illustrate that the obtained impedance bandwidths are about 8% (2.4GHz-2.6GHz), 12.4% (3.4GHz-3.85GHz) and 18.4 % (4.9GHz-5.89GHz), good enough for WLAN and WiMAX applications. This indicates that the proposed antenna is well suited for WLAN/WiMAX portable units and mobile handsets.

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Ping Wang was born in Chongqing, China, in 1981. He received his B.S. in physics from Western Chongqing University of China in 2005 and the M.S degree in theoretical physics from Chongqing University, Chongqing, in 2008. Currently, he is working toward the Ph.D. degree in University of Electronic Science and Technology of China (UESTC). His current research interests include patch antennas, wideband antennas, and arrays.

Guangjun Wen was born in Sichuan, China, in 1964. He received his M.S. and Ph.D from Chongqing University of China in 1995 and from University of Electronic Science and Technology of China in 1998, respectively. He is currently a professor and doctor supervisor at University of Electronic Science and Technology of China. His research and industrial experience covers a broad spectrum of electromagnetics, including RF, Microwave, Millimeter wave Integrated Circuits and Systems design for Wireless Communication, Navigation, Identification, Mobile TV applications, RFIC/MMIC/MMMIC device modeling, System on Chip (SoC) and System in Package (SiC) Design, RF/Microwave/Millimeter wave Power source Design, "The Internet of things" devices and system, RFID system and networks, antennas, as well as, model of electromagnetic metamaterial and its application in microwave engineering area.

Yongjun Huang was born in Sichuan, China, in 1985. He received his B.S. in Mathematics from NeiJiang Normal University of China in 2007 and M. S. in Communication Engineering from University of Electronic Science and Technology of China in 2010. His dissertation work and research activities are electromagnetic metamaterial and its application in microwave engineering area, FDTD analysis for the model and RCS characteristic of metamaterials.