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A Novel Compact Broadband Antenna for LTE/WLAN/WiMAX Applications

Bei-Jun Wu and Quan-Yuan Feng*

Abstract—A compact wideband antenna consisting of a L-shaped radiating element which has a modified inverted-F structure and a C-shaped parasitic radiating element on the ground is proposed. Three resonant frequencies and a very wide operating band are obtained. A prototype of the proposed antenna has been constructed and experimentally studied. The measured results show that the operating bandwidth with 10 dB return loss is about 2.9 GHz (2.11–5.01 GHz), 81.46%, respectively, covering LTE2500 (2.5–2.69 GHz), 2.4 GHz WLAN and 2.5/3.5 GHz WiMAX bands. Furthermore, the antenna has a simple planar structure and small volume of only $30 \times 30 \times 1.6\,\mathrm{mm}^3$. Good radiation characteristics and acceptable peak gains are obtained over the operating bands.

1. INTRODUCTION

Recent developments in wireless communication have increased the demand for better antenna performance. A wireless communication antenna is required to cover a very wide frequency bandwidth or several frequency bands and is expected to be small in size and has high efficiency. For short- and long-range applications, many antennas [1–4] have been designed for the wireless local area network (WLAN) application in the 2.4 GHz (2.4–2.484 GHz)/5.2 GHz (5.15–5.35 GHz)/5.8 GHz (5.725–5.825 GHz) operating bands and the worldwide interoperability for microwave access (WiMAX) application in the 2.5 GHz (2.5–2.69 GHz)/3.5 GHz (3.3–3.8 GHz)/5.5 GHz (5.25–5.85 GHz) operating bands. Because of the advantages of low cost, easy integration, easy fabrication and omnidirectional radiation pattern, the printed monopole antenna has drawn much attention, and many shapes have been reported, such as G shape [5], L shape [6], E shape [7], C shape [8], etc. In [9–14], dual- or tri-band antennas have been achieved. An effective way to obtain wideband or additional resonant frequency is to add parasitic element just as in [15, 16]. But they also have the drawbacks of large size or complicated structures. Another way to obtain wideband or additional resonant frequency is to use defected ground, which is quite similar to adding parasitic element to the ground [17].

In this paper, a compact broadband antenna for LTE/WLAN/WiMAX applications is proposed. With a L-shaped radiating element which has a modified inverted-F structure and a C-shaped parasitic radiating element on the ground, the proposed antenna can generate three resonant frequencies at 2.28/3.44/4.92 GHz which are formed into one wide band (2.11–5.01 GHz) to cover LTE2500 (2.5–2.69 GHz), 2.4 GHz WLAN and 2.5/3.5 GHz WiMAX bands. The proposed antenna also shows good radiation characteristics with high efficiency and acceptable peak gains over the operating bands.

2. ANTENNA DESIGN

Figure 1 illustrates the geometry of the proposed broadband printed monopole antenna for WLAN/WiMAX application, together with a photograph of the fabricated antenna. The antenna

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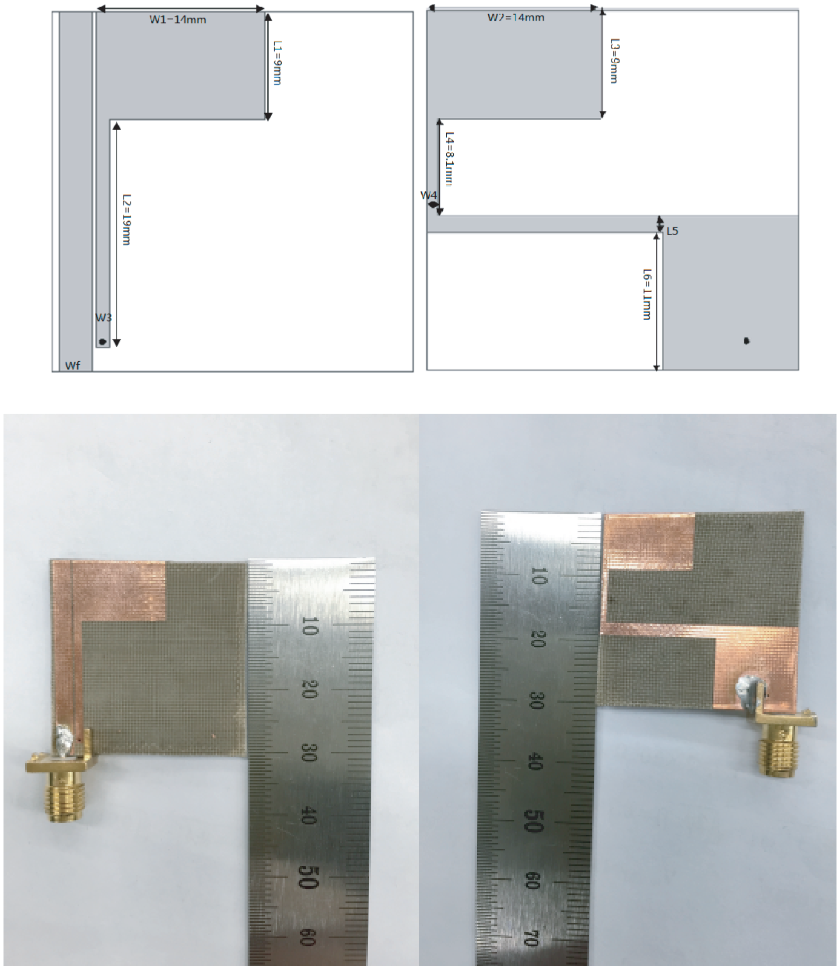
* Corresponding author: Quan-Yuan Feng (fengquanyuan@163.com).
The authors are with the College of Information Science and Technology, Southwest Jiaotong University, Chengdu, Sichuan 610031, China.



Front Back

Figure 1. Geometry of the proposed antenna and photograph of the fabricated antenna.

Table 1. Parameters of the proposed antenna.

W_f	W_1	W_3	L_1	L_2	W_2
2.7 mm	14 mm	1.2 mm	9 mm	19 mm	14 mm
L_3	L_4	W_4	L_5	L_6	r_{via}
9 mm	8.1 mm	1 mm	1.9 mm	11 mm	0.25 mm

consists of a L-shaped radiating element which has a modified inverted-F structure on top of the antenna and a C-shaped parasitic radiating element on the ground at the bottom. The 50 Ω CPW feeding mechanism has a signal strip width of $W_{\mathrm{f}} = 2.7$ mm and a gap distance of $S = 0.3$ mm between the signal strip and the L shape element which is coupled fed through the feed strip.

The proposed antenna is printed on a low-cost F4B substrate with thickness (h) of 1.6 mm, relative permittivity (ε_r) of 2.65, and loss tangent of 0.001. The volume of the proposed antenna is only $30 \times 30 \times 1.6\,\mathrm{mm}^3$.

3. EXPERIMENTAL RESULTS AND DISCUSSION

A fabricated prototype for the proposed broadband antenna has been experimentally studied, as depicted. The return loss is measured with Agilent E5071C ENA network analyzer (shown in Figure 2).

From the measured results, three distinct operating bandwidths with 10 dB return loss are about 2.9 GHz (2.11–5.01 GHz), corresponding to a bandwidth of 81.46% with respect to the center frequency, respectively. Good agreement between the simulation and measurement can be observed.

In order to further demonstrate the operation mechanism, surface current distributions on both sides of the proposed antenna at three resonant frequencies are simulated in HFSS and shown in Figure 3.

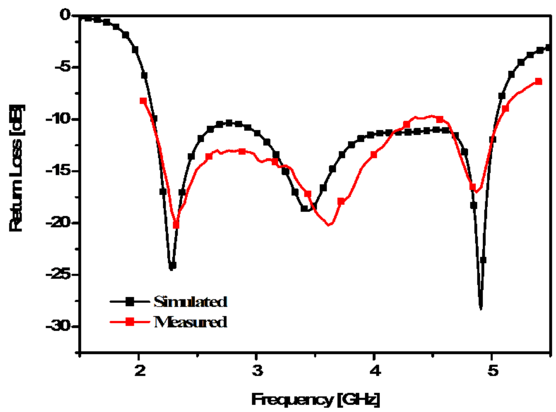
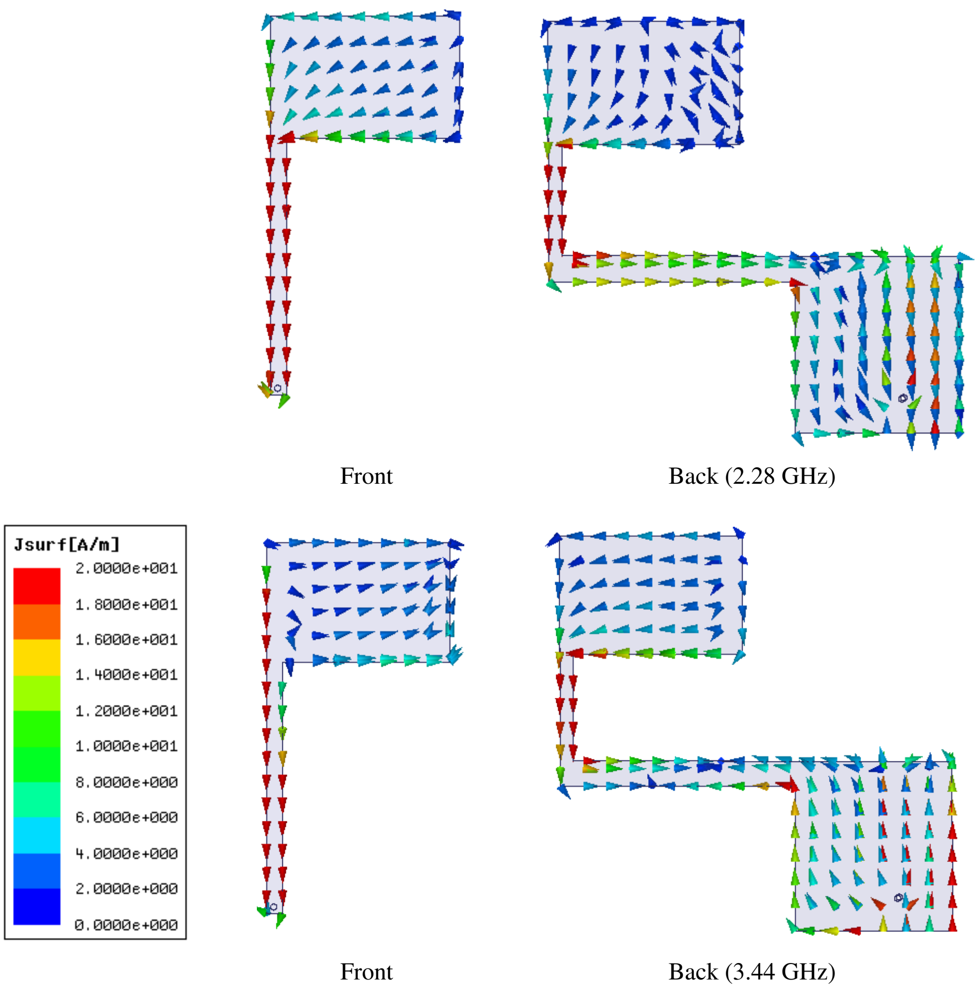


Figure 2. Measured and simulated return loss of the proposed antenna.



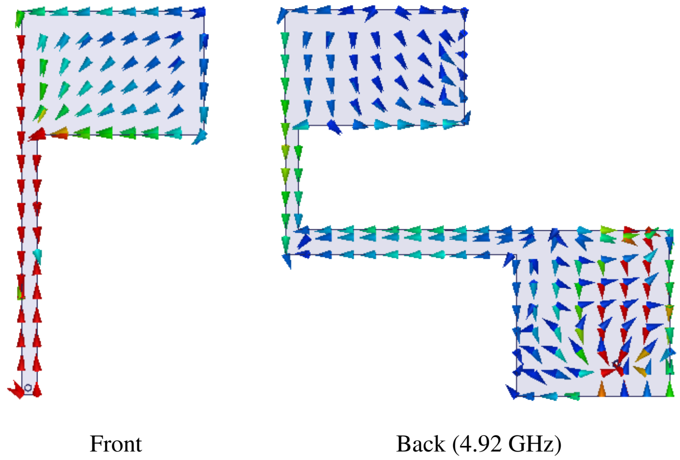


Figure 3. Simulated surface current distributions of the proposed antenna.

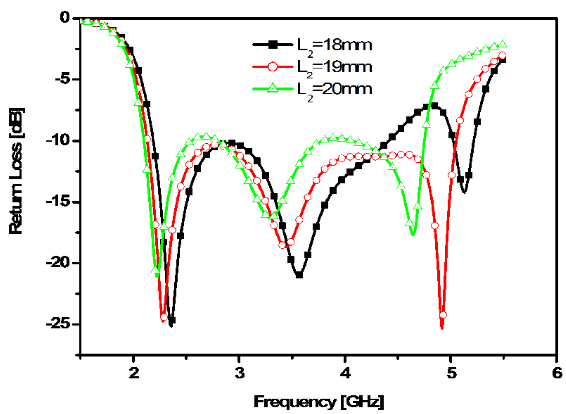


Figure 4. Simulated return loss of the proposed antenna with different L_2.

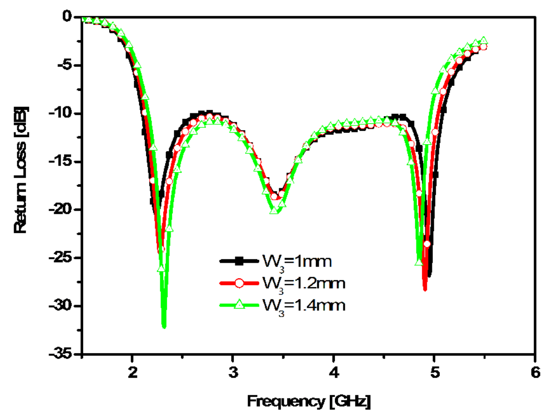


Figure 5. Simulated return loss of the proposed antenna with different W_3.

It can be clearly seen that the current has different distributions along the antenna in different bands. At 2.28 GHz, the surface current density is mainly concentrated on the L-shaped radiating elements with a modified inverted-F structure. So it's clear that the fundamental resonant mode at 2.28 GHz of the L-shaped radiating elements is excited. At the 3.44 GHz resonant frequency, the surface current is mainly concentrated at the parasitic C-shaped strip and radiation occurs mainly on it. Strong surface current distributions on part of the L-shaped radiating elements at 4.92 GHz are also seen, which demonstrates that another resonant mode on higher frequency of the L-shaped radiating element is excited.

The length L_2 of the L-shaped radiating element is a critical parameter to control the first and third resonant points, as shown in Figure 4. Clearly, with the increase of L_2, the resonant frequency will decrease, but it will also affect the impendence matching of higher frequency. So 19 mm was chosen for L_2 to achieve a good performance both in lower and higher frequency. In addition, the width of the L-shaped radiating element (W_3) also plays an important role in impedance matching condition, as shown in Figure 5. That was because the width affects directly the coupled fed between L-shaped element and the signal strip. Effects of the parasitic C-shaped strip width W_4 on resonant frequencies are also studied, as shown in Figure 6. Varying W_4 from 0.5 to 1.5 mm with an increment of 0.5 mm, the impendence match of the second resonant frequency is clearly seen to become better. However, it will affect the performance of the third resonant. According to this, the value of 1 mm for L_4 is therefore selected for the proposed antenna to search for appropriate resonant frequencies and optimal operating

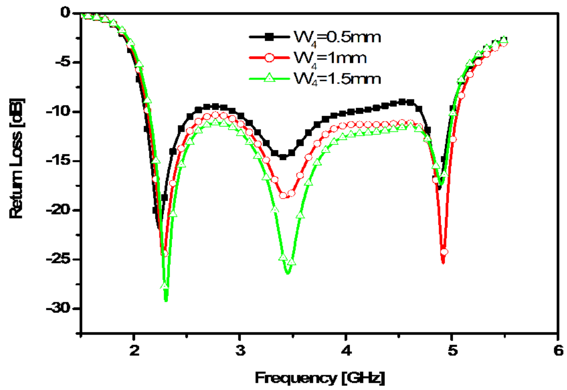
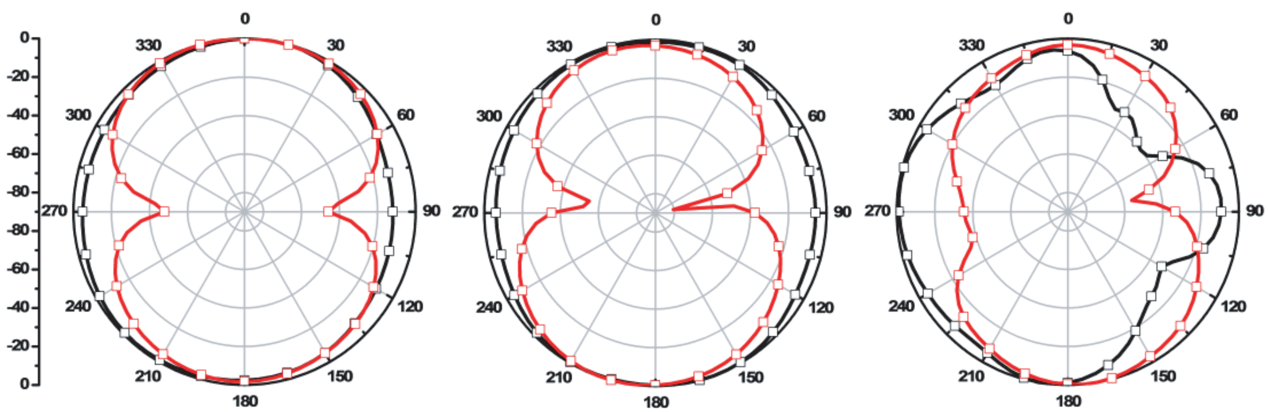
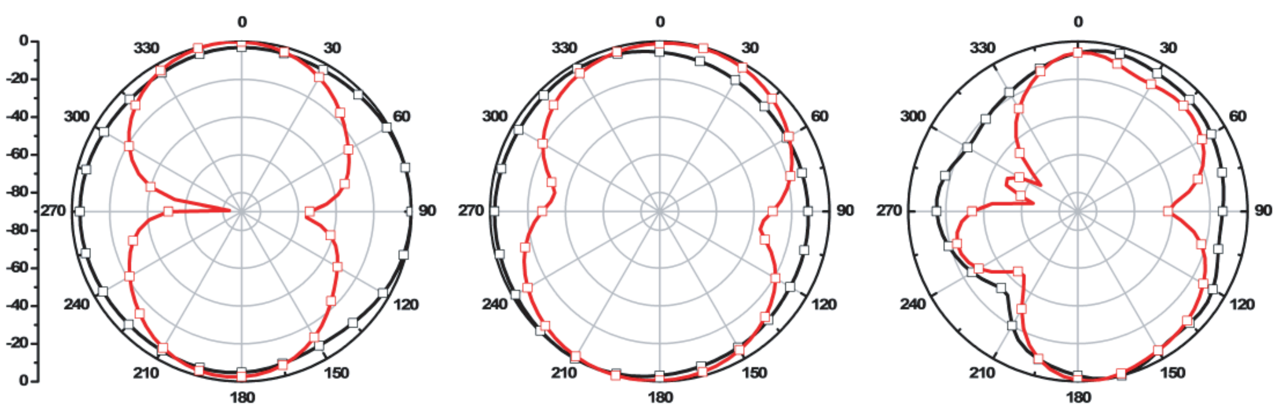


Figure 6. Simulated return loss of the proposed antenna with different W_4.

Figure 7. SATIMO near-field measurement system.



(a)



(b)

Figure 8. Measured normalized radiation patterns at 2.28, 3.44, and 4.92 GHz in (a) E-plane (x-z plane) and (b) H-plane (y-z plane).

bandwidths.

The radiation patterns of the proposed antenna were measured in a microwave anechoic chamber (SATIMO near-field measurement system shown in Figure 7). Figure 8 shows the measured and simulated far-field normalized radiation patterns including the vertical (E_θ) and horizontal (E_φ) polarization in the E-plane (x-z plane) and H-plane (y-z plane) of the proposed antenna. The obtained

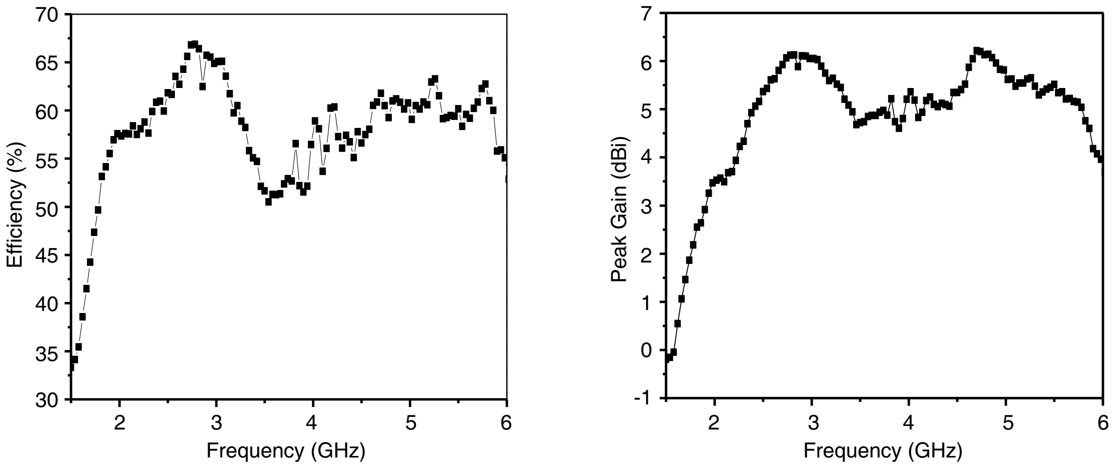


Figure 9. Measured efficiency and gain.

radiation patterns have bidirectional radiations in E-plane and nearly omni-directional radiations in H-plane in lower frequency. In general, stable radiation patterns within the operating bands are achieved. The measured gain and efficiency of the proposed antenna are depicted in Figure 9. The measured average gain is about 5.14 dBi and the average efficiency in operating band is about 58.7%, which still satisfy the requirement of some actual applications.

4. CONCLUSION

A compact broadband antenna with three resonant frequencies has been presented. By using a coupled fed L-shaped radiating element which has a modified inverted-F structure and a C-shaped parasitic radiating element on the ground, a wide operating band which can meet 2.4 GHz WLAN and 2.5/3.5 GHz WiMAX requirements is obtained, ranging from 2.11–5.01 GHz. The proposed antenna has the advantages of simple structure, easy fabrication, low cost, and compact size, showing good operating bandwidth, stable radiation patterns, and high efficiency and peak gain on operating band.

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