Compact Triple-Band Monopole Antenna for WLAN/WiMAX-Band USB Dongle Applications

Ya Wei Shi, Ling Xiong, and Meng Gang Chen

A miniaturized triple-band antenna suitable for wireless USB dongle applications is proposed and investigated in this paper. The presented antenna, simply consisting of a circular-arc-shaped stub, an L-shaped stub, a microstrip feed line, and a rectangular ground plane has a compact size of 16 mm × 38.5 mm and is capable of generating three separate resonant modes with very good impedance matching. The measurement results show that the antenna has several impedance bandwidths for S11 ≤ –10 dB of 260 MHz (2.24 GHz to 2.5 GHz), 320 MHz (3.4 GHz to 3.72 GHz), and 990 MHz (5.1 GHz to 6.09 GHz), which can be applied to both 2.4/5.2/5.8 GHz WLAN bands and 3.5/5.5 GHz WiMAX bands. Moreover, nearly-omni-directional radiation patterns and stable gain across the operating bands can be obtained.

Keywords: Triple-band antenna, USB dongle, WLAN, WiMAX.

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I. Introduction

With the rapid development of personal wireless communications, the standards of wireless local area network (WLAN) and Worldwide Interoperability for Microwave Access (WiMAX) have been widely applied to portable devices such as PDAs, laptops, and 3G smartphones. Almost all of these devices have adopted some USB ports for data exchanges and access to multiple wireless applications through wireless USB dongle devices. To implement the applications of wireless USB dongles, miniaturized antennas with multiple working bands that can be incorporated into compact USB dongles are needed. Various multiband antennas (including microstrip-fed, CPW-fed, and slot antenna) that can support WLAN, WiMAX, or WLAN/WiMAX applications have been reported for mobile terminals [1]–[7]. However, these antennas are not suitable for compact USB dongle devices owing to their large size.

The study of small antennas fit for USB dongles of a compact size has become an interesting topic. Few antennas have been designed for multiband USB dongle applications [8]–[13]. In [8], a printed meander-line antenna is proposed for USB dongle devices, but it can only cover a 2.4 GHz WLAN band and is 60 mm × 20 mm including the ground plane. Dual-band antennas for USB dongle applications are presented in [9]–[11], but it is a pity that these antennas can't cover the 3.5 GHz WiMAX band. In [12], an antenna with triple-band characteristics is obtained by connecting the metal patterns that are implemented in the upper and lower sides of the substrate through vias. It has a compact size of 15mm × 40 mm but can't cover the 5.15 GHz to 5.35 GHz WLAN band. A triple-band antenna for WLAN/WiMAX applications with three simple circular-arc-shaped strips has been investigated in [13]. It can cover the 2.4/5.5/5.8 GHz WLAN bands and 2.5/3.5/5.5 GHz WiMAX bands; while, the third frequency band from 4.96 GHz to 5.96 GHz does not have a very good impedance matching condition.

In this paper, a multi-resonant microstrip-fed antenna is proposed for wireless USB dongle applications. Compared to conventional multi-resonant antennas, the presented antenna has a much simpler structure, occupies less volume, and is easy to fabricate. By adjusting the geometries and sizes of the L-shaped stub and circular-arc-shaped stub, three separated good impedance bandwidths that can be applied to both the 2.4/5.2/5.8 GHz WLAN bands and the 3.5/5.5 GHz WiMAX bands are achieved. The measurements agree well with the simulations. The dimensions of the fabricated antenna are 16 mm × 38.5 mm, which makes it convenient for compact USB dongle devices. The thickness of the antenna is 1 mm. Moreover, the antenna has good radiation patterns and stable gains across the three working bands.

II. Antenna Design

1. Antenna Configuration

The configuration of the triple-band monopole antenna is shown in Fig. 1(a). Figure 1(b) displays the photograph of the fabricated antenna. The circular-arc-shaped stub, L-shaped stub, and a 50 Ω microstrip line are printed on top of the FR4 substrate (relative dielectric constant of 4.4 and thickness of 1 mm), and a ground plane is printed on the other side of the substrate. The width of the circular-arc-shaped stub is 2.8 mm and that of the L-shaped stub is 2 mm. The design and optimization process of the proposed antenna is carried out by the commercially available software Ansoft HFSS V12. The main parameters of the antenna are as follows: $w = 16$ mm, $w1 = 8$ mm, $w2 = 4.5$ mm, $wd = 1.9$ mm, $L = 38.5$ mm, $l1 = 15$ mm, $h1 = 2.5$ mm, $h2 = 6.5$ mm, $x1 = 3.55$ mm, and $r1 = 8$ mm.

Figures 2(a) and 2(b) present the design evolution of the proposed antenna and its corresponding simulated S-parameters. The design starts from Antenna #1, which only consists of a circular-arc-shaped stub and a microstrip feed line. It can be seen from Fig. 2(b) that a dual-band antenna that can cover 2.2 GHz to 2.45 GHz (resonant at 2.32 GHz) and 4.97 GHz to 5.7 GHz (resonant at 4.97 GHz) is obtained. The frequency band resonant at 3.6 GHz is generated by adding an L-shaped stub to the circular-arc-shaped stub (Antenna #2). Then, the impedance bandwidths of Antenna #2 are 2.13 GHz to 2.3 GHz centered at 2.21 GHz, 3.4 GHz to 3.92 GHz centered at 3.6 GHz, and 4.67 GHz to 5.6 GHz centered at 4.95 GHz. Though a triple-band operating characteristic is achieved, the first and third bands are not desired for the 2.4/5.8 GHz WLAN band. By reducing the length of the circular-arc-shaped stub, the first and third resonant modes shift to higher frequencies and a triple-band antenna suitable for WLAN/WiMAX applications is then achieved.

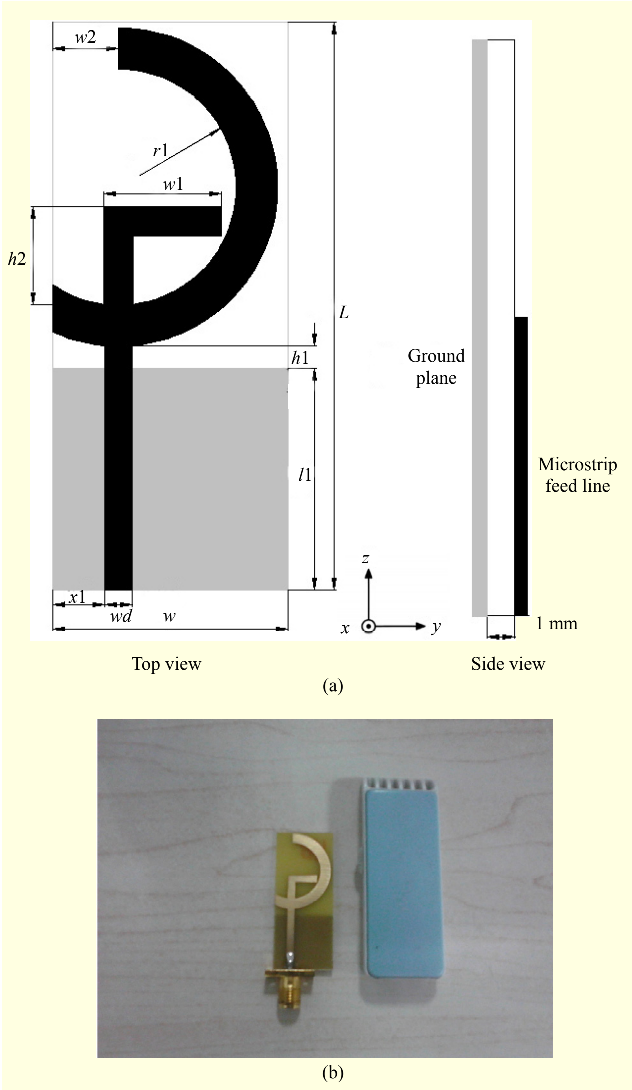

Fig. 1. (a) Configuration of proposed antenna and (b) photograph of fabricated antenna.

2. Current Distribution

To further study the property of the proposed antenna, the simulated surface current distribution at 2.4 GHz, 3.6 GHz, and 5.4 GHz are illustrated in Fig. 3. It can be clearly seen from the figure that three different resonant modes at different positions of the antenna are excited. In Figs. 3(a) and 3(c), strong surface current follows along the circular-arc-shaped stub, which indicates that the circular-arc-shaped stub generates the first resonant mode of 2.4 GHz and third resonant mode of 5.4 GHz.

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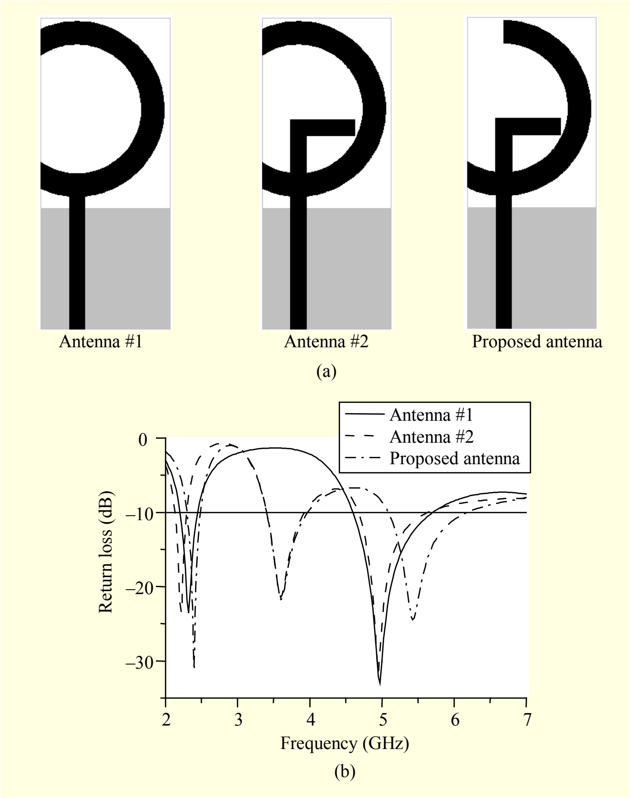

Fig. 2. (a) Evolution of proposed triple-band wide-slot antenna and (b) its corresponding simulated return losses.

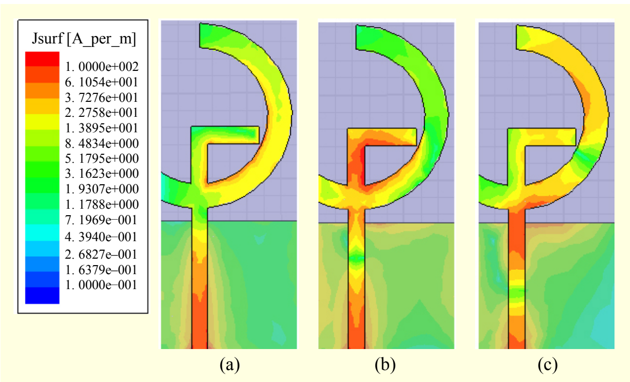

Fig. 3. Simulated surface current distribution of proposed antenna: (a) 2.4 GHz, (b) 3.6 GHz, and (c) 5.4 GHz.

For the second resonant mode, at 3.6 GHz, large surface current density is observed along the L-shaped stub.

3. Parameter Analysis

Based on the above analysis, the parameters that most affect the antenna performance are studied in Fig. 4. Figure 4(a) shows the simulated S-parameters when the whole length of the circular-arc-shaped stub changes. With an increase to $w2$, the length of the circular-arc-shaped stub decreases, and the first and third resonant modes shift to higher frequencies; the second resonant mode is not affected. Figure 4(b) plots the simulated S-parameters by changing the height of the L-shaped stub ($h2$). The whole length of the L-shaped stub increases with an increase in $h2$. It can be clearly seen that the second resonant mode shifts to a lower frequency with the increase to $h2$. It is a pity that the first and third resonant modes are also affected. Because of the different $h2$, the distance between the circular-arc-shaped stub and L-shaped stub changes, which makes the mutual coupling of the two stubs also vary.

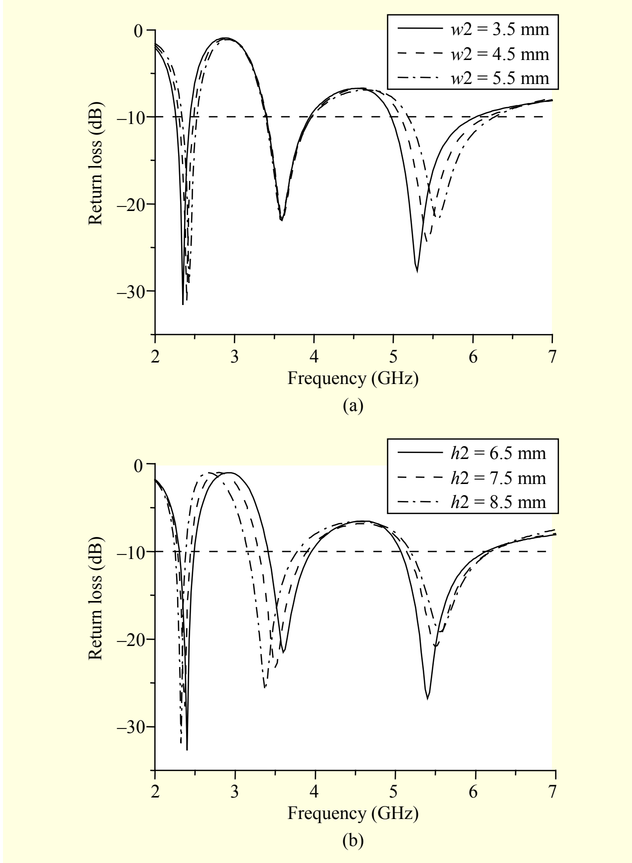

Fig. 4. Simulated S-parameters of proposed antenna: (a) when $w2$ changes and (b) when $h2$ changes.

III. Experimental Results and Discussion

1. Impedance Performance

A prototype of the triple-band monopole antenna is designed, fabricated, and tested by the Agilent E8363B vector network analyzer. The measured result versus the simulated one is shown in Fig. 5. The measured impedance bandwidths for $S11 \le -10$ dB are about 260 MHz (2.24 GHz to 2.5 GHz) resonant at 2.42 GHz, 320 MHz (3.4 GHz to 3.72 GHz) resonant at 3.54 GHz, and 990 MHz (5.1 GHz to 6.09 GHz) resonant at

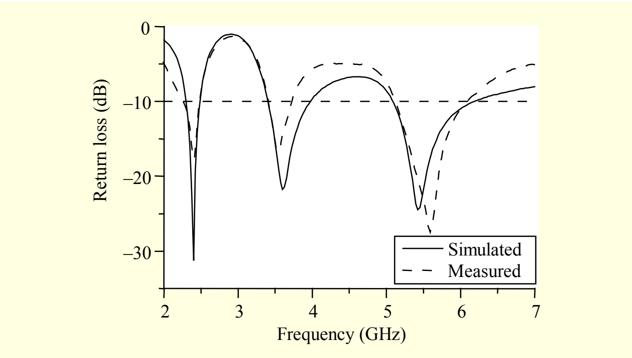

Fig. 5. Measured and simulated S-parameters of proposed antenna.

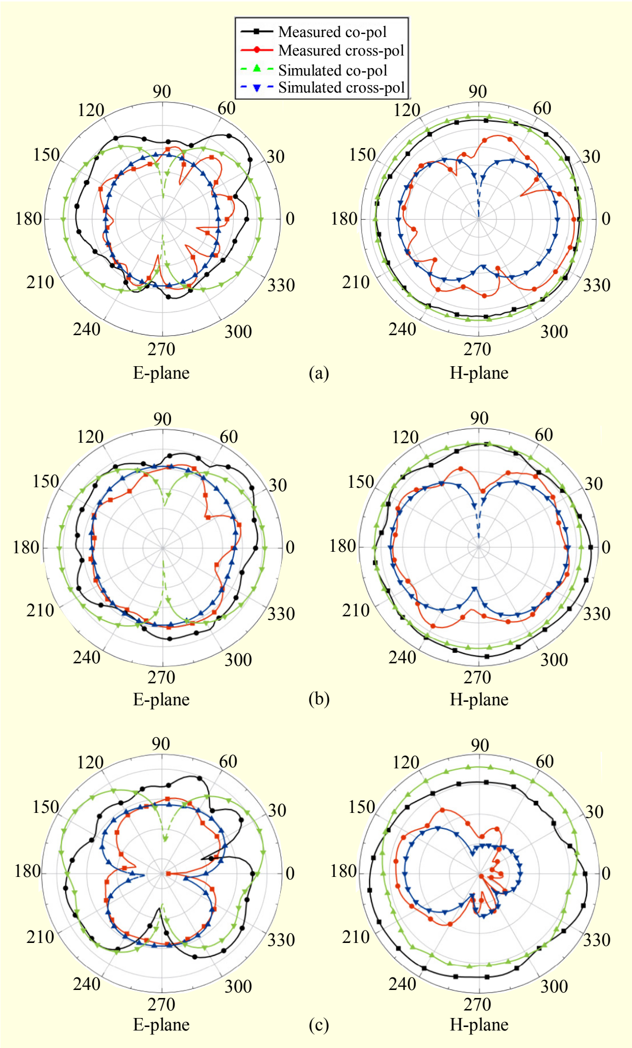

Fig. 6. Measured and simulated radiation patterns of proposed antenna: (a) 2.4 GHz, (b) 3.5 GHz, and (c) 5.5 GHz.

5.57 GHz, which are able to cover the 2.4/5.2/5.8 GHz WLAN bands and 3.5/5.5 GHz WiMAX bands. Obviously, the measured result shows good agreement with the simulated

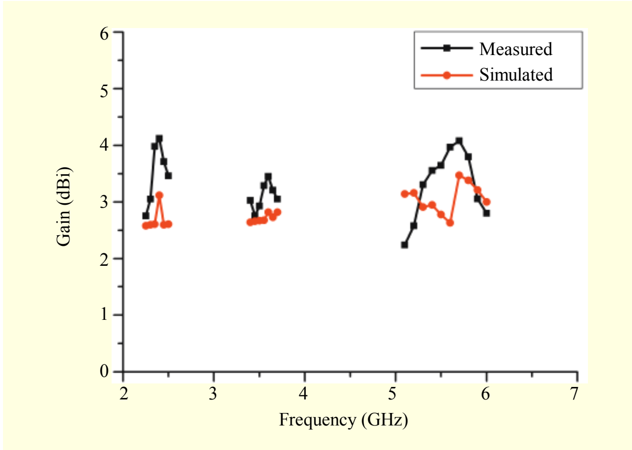

Fig. 7. Measured and simulated gains of proposed antenna.

one except for some discrepancy at the second operating frequencies. This may be caused by fabrication tolerance or the unstable dielectric constant of the substrate.

2. Radiation Performance

Figure 6 shows the normalized simulated and measured E-plane and H-plane radiation patterns at 2.4 GHz, 3.5 GHz, and 5.5 GHz. It can be seen that monopole-like radiation patterns in the E-plane with nearly-omnidirectional radiation patterns in the H-plane are observed. However, the radiation patterns display higher directivity with the increasing frequency. The simulated and measured gain of the antenna is plotted in Fig. 7. As shown in Fig. 7, over the 2.4 GHz operation band, the measured antenna gain is varied from 2.75 dBi to 4.12 dBi. For the medium band resonant at 3.5 GHz, the measured antenna gain is about 2.75 dBi to 3.45 dBi. At the higher band from 5.1 GHz to 6 GHz, the measured gain of the antenna changes from 2.24 dBi to 4.08 dBi. The simulation result seems to agree well with the measured one with a difference of less than 1 dBi.

IV. Conclusion

A compact triple-band monopole antenna for wireless USB dongle applications has been presented in this study. Three separate frequency bands are obtained by printing an L-shaped stub and a circular-arc-shaped stub on the substrate to become the radiation patch of the antenna. Measured and simulated results show that the antenna is not only simple and compact in structure, but that it also has good characteristics in impedance matching and radiation performance for operating at the 2.4/5.2/5.8 GHz WLAN bands and the 3.5/5.5 GHz WiMAX bands. Therefore, the proposed antenna is appropriate for internal multi-frequency applications in a compact wireless USB dongle device.

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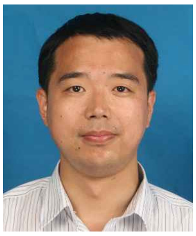

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