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A Dual-band Antenna for Wireless USB Dongle Applications

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ABSTRACT: In this paper, the design of a dual-band antenna for universal-serial-bus (USB) dongle applications in the 2.4-GHz wireless-local-area network (WLAN) and 3.5-GHz Worldwide Interoperability for Microwave Access (WiMAX) systems is presented. The antenna consists of two folded inverted-F radiating elements. One inverted-F element generates a 2.45-GHz band for the WLAN band (2.4-2.484 GHz), and both inverted-F elements together resonate at around 3.5 GHz to generate a wide frequency band for the WiMAX system (3.3-3.8 GHz). The antenna is designed on a 25×70 mm² printed-circuit board (PCB), same size of an USB dongle PCB. For verification of simulation results, a prototype is fabricated and measured. Measured results show that the antenna has two impedance bandwidths, 2.39-2.5 GHz and 3.24-3.8 GHz, for the WLAN and WiMAX applications, respectively. The simulated and measured radiation patterns, efficiencies and gains of the antenna are all presented.

I. INTRODUCTION

The universal-serial-bus (USB) dongle introduced in recent years is becoming very popular in computer-associated devices for short-range wireless communications. A significant amount of study work on single-band antennas for USB dongle applications have been carried out. With the increasing demand for multiple services, it will be attractive to have a USB dongle integrated with a multiband antenna. So far, many studies on multiband antennas for USB dongles working in the wireless-local-area-network (WLAN) band have been reported. These included the monopole antennas [1-3], the spiral antennas [4], and the inverted-F antennas [5]. Recently, USB dongles integrated with an ultra-wideband (UWB) antenna have also been proposed as a multiple services solution [6-8]. In [9], it was also proposed to use a single antenna with two wide frequency bands, a lower band for the DCS1800 system operating from 1.71-1.88 GHz and a higher band for the WLAN system operating at 5 GHz, for USB dongle applications.

In this paper, the design of a dual-band planar antenna designed for USB dongle applications is presented. The antenna can operate in the 2.4-GHz WLAN (2.4-2.484 GHz) band and the 3.5-GHz WiMAX (3.3-3.8 GHz) band. The lower frequency band at around 2.45 GHz and the higher frequency band at 3.5 GHz are generated by using a folded inverted-F radiating element. Due to the narrowband characteristic of an inverted-F radiator, the higher band generated at 3.5 GHz is not wide enough for the Worldwide Interoperability for Microwave Access (WiMAX) system. To enhance the bandwidth, another folded inverted-F radiating element is used to generate a resonance at around 3.5 GHz. The antenna is studied and optimized using the EM simulation tool, CST. To evaluate the performance in a USB dongle, the antenna is fabricated on a Rogers substrate, 4350B, having a size of 25×70 mm², and measured. The measured results show that the antenna has the impedance bandwidths (S11 < -10 dB) from 2.39-2.5 GHz in the lower band and 3.24-3.81 GHz in the higher band. The radiation pattern is measured using the antenna measurement system, Satimo Starlab. Results show that the antenna has nearly omnidirectional radiation patterns in the two operating bands.

II. ANTENNA DESIGN

Figs. 1(a) and (b) show the geometry of the proposed antenna which was designed on a Rogers substrate, 4350B, having a size of $W \times L = 25 \times 70$ mm², about the size of the PCB used in a dongle. The substrate had a thickness of 0.8 mm, a relative permittivity of 3.5 and a loss tangent of 0.004. The antenna had a two-branch structure, branch $E_1$ and branch $E_2$, as shown in Fig. 1(a), occupying a total size of $25 \times 13$ mm². To achieve a compact size, branch $E_1$ consisted of two strips printed on the top and bottom sides, respectively, of the substrate, which are connected together using a via (indicated as "via2" in Figs. 1(a) and (b)). A short strip, indicated as "shortening element" in Fig. 1(a), was used to connect the radiator to the ground plane through a via (indicated as "via1" in Fig. 1(a)). As a result, branch $E_1$ and the shorting element formed a folded inverted-F radiator, which was designed to resonate at around 2.45 and 3.5 GHz. Similarly, branch $E_2$ and the shorting element formed another inverted-F radiator which was designed to generate a resonance at around 3.5 GHz to increase the bandwidth. A 50-Ω microstrip line with a width of $W_f$ was used for feeding the antenna. The antenna was optimized using the EM simulation tool, CST. The optimized dimensions were: $W=25$ mm, $L=70$ mm, $L_g=57$ mm, $L_1=2$ mm, $L_2=16$ mm, $L_3=9.5$ mm, $L_4=15.5$ mm, $L_5=5$ mm,
$L_6 = 8\text{ mm}, \ L_7 = 4.3\text{ mm}, \ W_1 = 2.5\text{ mm}, \ W_2 = 1.5\text{ mm}, \ W_3 = 2\text{ mm}, \ W_f = 1.8\text{ mm}, \ L_{f1} = 11.6\text{ mm}, \ L_{f2} = 25.6\text{ mm}, \ L_s = 6\text{ mm}$ and gap $= 0.2\text{ mm}$. With these dimensions, the antenna was fabricated on a Rogers substrate, 4350B, as shown in Fig. 1(c).

**III. SIMULATION AND MEASUREMENT**

Current distributions at the resonate frequencies of 2.45 and 3.5 GHz were used to study the operation of the antenna. At 2.45 GHz, Fig. 2(a) shows that the simulated current was mainly on branch $E_1$ which contributed to resonance. At 3.5 GHz, Fig. 2(b) shows that the current on both branches were quite large, thus both elements together contributed to resonance.

The simulated and measured $S_{11}$ are shown in Fig. 3, which shows a very good agreement. It can be seen that the antenna generated two frequency bands. The lower band had a bandwidth ($S_{11}<-10\text{ dB}$) of 110 MHz (from 2.39-2.5 GHz) which could be used for the WLAN system operating at 2.4 GHz. The higher band had a wider bandwidth of 570 MHz (from 3.24-3.81 GHz) which could be used for the WiMAX system operating at the 3.5 GHz.

**Fig. 1.** (a) Top view of proposed antenna, (b) layout of radiator, and (c) prototyped antenna

**Fig. 2.** Current distribution of antenna at (a) 2.45 GHz, and (b) 3.5 GHz.

**Fig. 3.** Simulated and measured $S_{11}$ of antenna.
The radiation characteristics of the antenna were measured using the antenna measurement system, Satimo Starlab. The simulated and measured radiation patterns in the x-z and x-y planes are shown in Fig. 4. It can be seen that the antenna had near-omnidirectional radiation patterns in both planes at 2.45 and 3.5 GHz.

The simulated and measured results on radiation efficiency and peak gain of the antenna are shown in Fig. 5. It can be seen that the simulation and measurement agreed very well at higher frequencies. However, there were large discrepancies between the measured and simulated results occurring at lower frequencies. These discrepancies were due to the effects of the feeding cable used in the antenna measurement system, as described in [10]. At the frequencies of 2.45 and 3.5 GHz, the measured efficiencies were 71.1% and 94.4%, respectively, with the corresponding measured gains of 2.5 and 3.4 dBi.

![Fig. 4. Simulated and measured radiation patterns in x-y and x-z planes at (a) 2.45, (b) 3.5 GHz.](image-url)
IV. CONCLUSIONS

The design of a dual-band antenna for USB dongle applications has been presented. The antenna has two bands operating in the 2.4- and 3.5-GHz bands for the WLAN and WiMAX systems, respectively, with near-omnidirectional radiation patterns. The antenna has a compact size of 25×70 mm² and consists of two folded inverted-F radiators. Results have shown that the antenna is a promising candidate for USB dongle applications.

REFERENCES