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Novel hexaband folded meander-patch antenna for wireless USB dongles

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Abstract: This research proposes a new planar hexaband antenna for compact wireless USB dongles. A folded meander-patch and a monopole element are employed to generate multiple broadband resonances supporting WiBro, WLAN, Bluetooth, 2.5/3.5 GHz WiMAX, and S-DMB bands. This novel hexaband antenna, built into a compact USB dongle, measures only $10 \times 50 \times 1\, mm^3$. The measured 10 dB return loss bandwidths of the fabricated antenna are 21.1% (2.29-2.83 GHz), 11.6% (3.25-3.65 GHz), and 20.2% (5.13-6.28 GHz). The radiation efficiency and gain of the antenna are also tested in this study.

Keywords: wireless USB dongle, hexaband antenna, folded meander-patch

Classification: Microwave and millimeter wave devices, circuits, and systems

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1 Introduction

Based on the speed and security of wired universal serial bus (USB) technology, wireless USB was developed to simplify the use of various wireless services through digital handheld terminals [1]. This new wireless extension provides a high-speed data transmission rate of 480 Mbps (within a 3 m range), a speed equivalent to the current performance of wired USB 2.0. In conjunction with the rapid growth of compact digital devices employing a USB port, the need for a miniaturized USB dongle antenna capable of covering various wireless services has grown substantially. Various monopole type antennas have been designed to support multiple service bands such as UWB, WiBro, WLAN, Bluetooth, and S-DMB [2, 3, 4]. However, a hexaband wireless USB dongle antenna supporting the 3.5 GHz WiMAX band has yet to be reported. This study proposes a new hexaband antenna with a resonance of 3.5 GHz for wireless USB dongle applications. The proposed

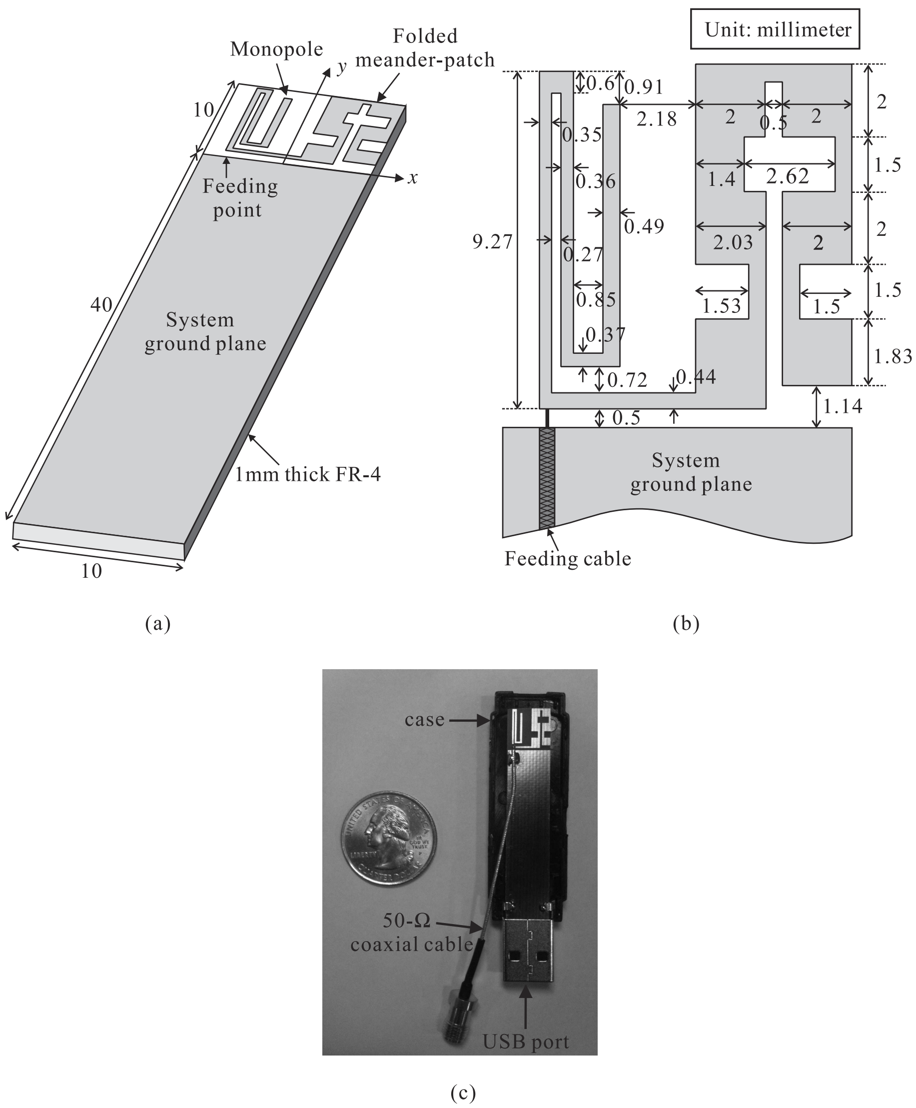

Fig. 1. (a) Geometry of the proposed antenna (b) optimized parameters of the radiating patch (c) photograph of the fabricated antenna.

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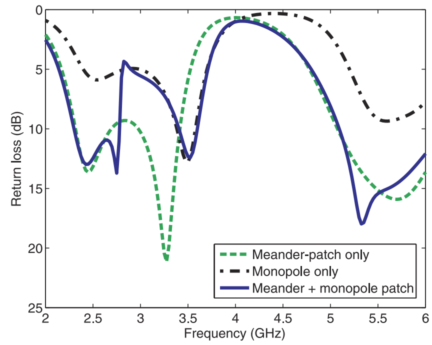
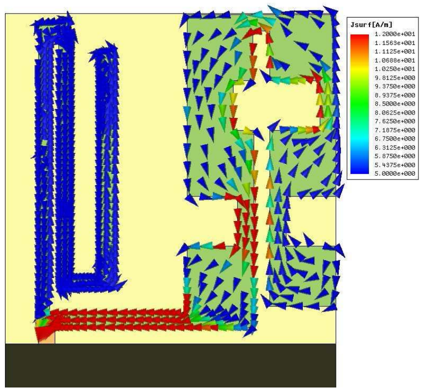
antenna is comprised of a folded meander-patch and a monopole element to achieve triple resonant band operation. The design and optimization of the antenna were completed using Ansoft HFSS [6] in conjunction with genetical swarm optimization (GSO), which was recently utilized in the design of a broadband polarization twist reflector [5]. Details of the antenna design, fabrication, and measurement results are discussed in the following sections.

2 Antenna design and optimization

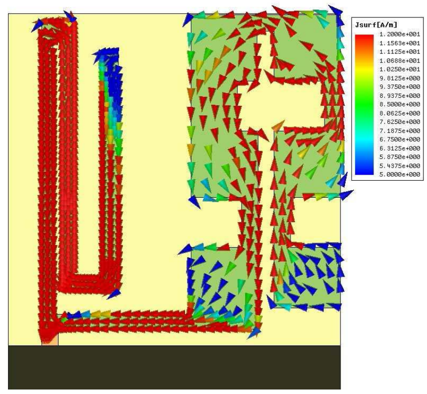
The proposed planar, multiband USB dongle antenna is illustrated in Fig. 1 (a). The main radiating patch, with dimensions of $10 \times 10\,mm^2$, con-



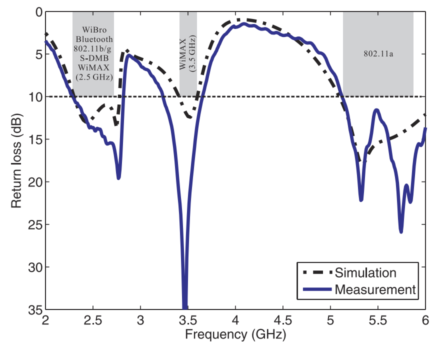
(a)



(b)



(c)



(d)

Fig. 2. (a) Simulated return losses of the antenna elements (b) simulated surface current distribution at 2.5 GHz (c) simulated surface current distribution at 3.5 GHz (d) measured and simulated return losses of the fabricated antenna.

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sists of a folded meander-patch and a monopole element. A system ground plane ($10 \times 40\,mm^2$) is located below the main radiation patch with both printed on the same plane of the substrate. A thin FR-4 substrate with a thickness of $1\,mm$ and a dielectric constant of $\epsilon_r = 4.6$ was used to fabricate the antenna. The antenna feed comes through a 50-Ω coaxial cable connected across the feeding point. The folded meander-patch was initially designed without a monopole element. Fig. 2 (a) shows the simulated return loss of the folded meander-patch. It was noted that this single folded meander-patch generates three different resonant frequencies, at 2.5 GHz, 3.3 GHz, and 5.6 GHz. A monopole element with a length of 24.5 mm (0.29λ at 3.5 GHz) was then added to the ungrounded section of the PCB to cover the 3.5 GHz WiMAX band. Moreover, as shown in Fig. 2 (a), this monopole attachment shifts the second resonant frequency (3.3 GHz) of the folded meander-patch to 2.75 GHz. A stagger-tuned, broadband resonance was therefore realized near the 2.5 GHz ISM band. Optimization based on the GSO algorithm was also conducted to determine the optimized dimensions of the radiating patches. In the optimization process, the following cost function was utilized:

$$\begin{aligned} Cost = & \sum_{f=2.3\,GHz}^{2.5\,GHz} \left| min\{0, RL(f) - 10\} \right| + \sum_{f=3.4\,GHz}^{3.6\,GHz} \left| min\{0, RL(f) - 10\} \right| \\ & + \sum_{f=5.1\,GHz}^{5.9\,GHz} \left| min\{0, RL(f) - 10\} \right| \end{aligned} \tag{1}$$

Here, $RL(f)$ is the simulated return loss (in dB) at the target frequency f. The finally optimized geometry of the radiating patch with the lowest cost value is shown in Fig. 1 (b). Figs. 2 (b) and 2 (c) illustrate the simulated surface current vectors of the optimized antenna at 2.5 GHz and 3.5 GHz. At the lower resonant frequency, the surface current is mainly distributed on the folded meander-patch, whereas the surface current is concentrated both on the folded meander-patch and monopole element at the higher resonant frequency.

3 Measured results

The optimized antenna based on the cost function (1) was fabricated to test the reflection and radiation performances in an RF anechoic chamber. A photograph of the fabricated antenna with a USB port embedded in the case is shown in Fig. 1 (c). Fig. 2 (d) illustrates the simulated and measured return losses of the fabricated antenna. The measured result is in good agreement with the result simulated using Ansoft HFSS. It was also found that the proposed antenna exhibits two broadband resonances (2.29-2.83 GHz and 5.13-6.28 GHz) and a narrow resonance (3.25-3.65 GHz), which together support hexaband wireless services that include the WiBro (2.3-2.4 GHz), Bluetooth (2.4-2.484 GHz), 2.5/3.5 GHz WiMAX (2.5-2.7 GHZ and 3.4-3.6 GHz), S-DMB (2.605-2.655 GHz) and 802.11b/g/a WLAN (2.4-2.485 GHz and 5.15-5.825 GHz) bands. Figs. 3 (a) and 3 (b) depict the measured gain patterns of the fabricated antenna on the two major cutting planes (the $x-z$ plane

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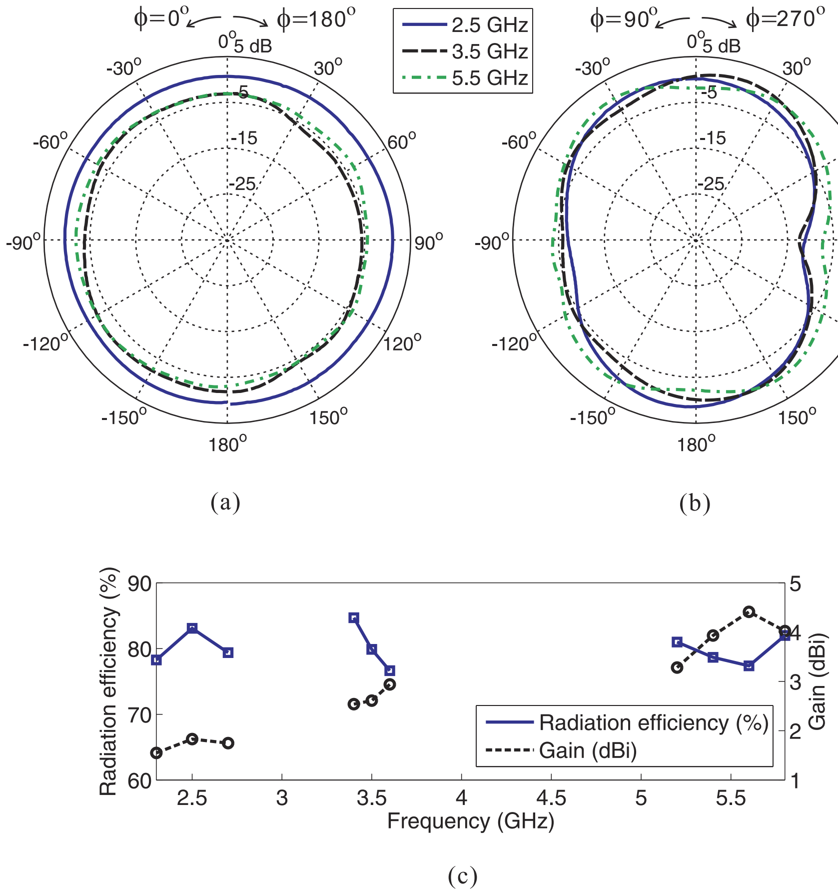

Fig. 3. (a) Measured gain patterns at $x-z$ plane (b) measured gain patterns at $y-z$ plane (c) measured total efficiency and peak gain.

and the $y-z$ plane) at 2.5 GHz, 3.5 GHz, and 5.5 GHz, respectively. It was noted that the measured patterns both at 2.5 GHz and 3.5 GHz are nearly omni-directional, whereas the radiation at 5.5 GHz is less omni-directional. The total radiation efficiency and peak gain of the fabricated antenna were also measured. These results are shown in Fig. 3 (c). The minimum efficiency was 76.6% at 3.6 GHz. The maximum peak gain of 4.4 dBi was achieved at 5.6 GHz.

4 Conclusion

A novel planar antenna employing a folded meander-patch and a monopole was proposed for multiband wireless USB applications. The proposed antenna was designed and optimized utilizing a stochastic GSO algorithm. The fabricated antenna exhibits triple resonance capability, making it able to cover at least six wireless service bands. The measured radiation characteristics also demonstrated the feasible performance level of the proposed antenna. Therefore, the antenna proposed in this research can be used in multiband, compact wireless USB dongle devices.

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