Novel Shorted Meander-Line USB Dongle Antenna with a Compact Ground Plane

Seong Jae Jeong and Keum Cheol Hwang

This letter presents the design of a novel multiband USB dongle antenna with a compact ground plane. The radiating patch is composed of a modified meander-line monopole and a shorted loop to generate a dual-broadband resonance. The proposed antenna supports WiBro, Bluetooth, WLAN, WiMAX, and S-DMB services. The total dimensions of the fabricated antenna are 10 mm × 45 mm × 1 mm, the most compact size among multiband USB dongle antennas reported to date. The measured 10 dB reflection loss bandwidths are 20.8% (2.24 GHz to 2.76 GHz) and 20.2% (4.86 GHz to 5.95 GHz). The measured peak gain is 2.97 dBi, and efficiency is higher than 58%. In addition, the radiation pattern approximates an omnidirectional pattern.

Keywords: Wireless USB dongle, multiband antenna, meander-line, loop element.

I. Introduction

Wireless universal serial bus (WUSB), introduced from USB-IF, is a new wireless extension to USB that combines the speed and security of wired technology with the ease-of-use of wireless technology [1]. WUSB technology has been developed and adopted in many multimedia devices including laptops and PDAs for connection to various networked environments. Based on an easy plug-and-play function, WUSB provides high-speed data transmission rates of 110 Mbps (within a 10 m range) and 480 Mbps (within a 3 m range), the latter being equivalent to the current wired USB 2.0 performance. In conjunction with these developments, miniaturized antennas that can be incorporated into compact WUSB dongle devices are also required. They must meet size constraints and provide desirable levels of antenna performance. Although many multiband and broadband antennas have been successfully implemented for mobile handheld terminals [2]-[4], they are typically too large to be adopted in compact WUSB dongles. U-shaped monopole and folded monopole antennas, meanwhile, have been proposed for ultra-wideband and multiband USB dongle applications [5], [6].

The present study proposes a further miniaturized, multi-resonant antenna for wireless USB dongle applications. The radiating element of the proposed antenna consists of a modified meander-line and a shorted loop patch which together achieve dual-wideband resonance. The following sections describe the antenna design and discuss the measured antenna performance.

II. Antenna Simulation and Design

Figure 1 shows the configuration of the proposed multiband USB dongle antenna. The main antenna section is designed to fit into an area of 10 mm × 10 mm due to the space limitation of compact WUSB dongle devices. A rectangular system ground plane (10 mm × h mm) is placed below the radiating patch. The proposed antenna can be easily implemented using a single-sided metallization process because both the radiating patch and the ground plane are etched on the identical plane of the system circuit board (1.0 mm thick FR-4 substrate, ε_r=4.6, tanδ=0.025). The feeding of the antenna is conducted using 50 Ω coaxial cable, which is connected across the feeding point between the shorted loop patch and the system ground. The feeding point separates the main radiating patch into two sections: a loop-coupled meander-line patch and a shorted loop patch. A conventional meander-line element is attached on the upper portion of the rectangular loop element. This rectangular

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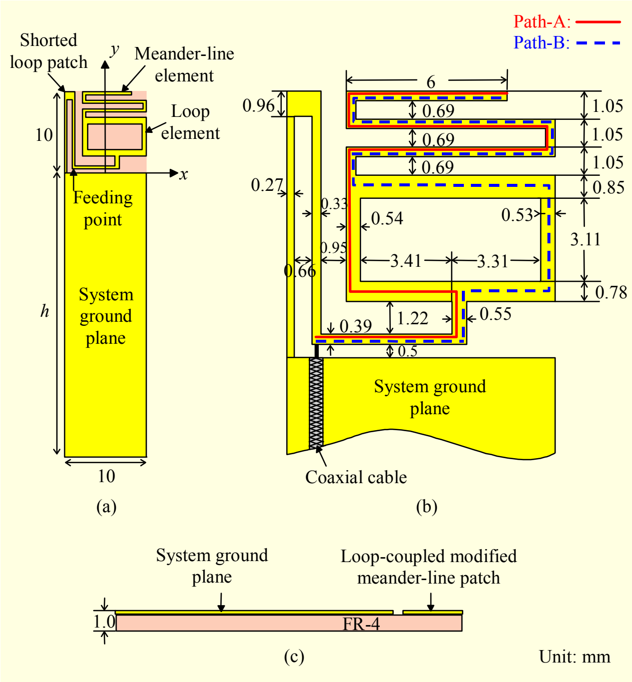

Fig. 1. Proposed antenna: (a) configuration of the proposed antenna, (b) detailed parameters of the radiating patch, and (c) side view.

loop element provides two slightly different electrical current paths (marked as Path-A and Path-B) from the feeding point to the end of the meander-line element. The loop-coupled meander-line patch was initially designed without a shorted loop patch. The detailed design parameters of the optimized antenna are illustrated in Fig. 1(b). The total lengths of Path-A and Path-B of the designed loop-coupled meander-line patch are about 37 mm (0.4λ at 3.5 GHz) and 43 mm (0.33λ at 2.3 GHz), respectively. Figure 2 shows the simulated reflection losses of the designed loop-coupled meander-line patch. We observed that the loop-coupled meander-line patch generates dual-resonant frequencies at 2.3 GHz and 3.5 GHz. Although the designed loop-coupled meander-line patch successfully exhibits a multi-resonant characteristic near the ISM frequency band, it does not provide a sufficient resonant bandwidth at the upper frequency band to cover the 802.11a WLAN service band (5.15 GHz to 5.825 GHz). Therefore, a shorted loop patch with a length of about 20 mm was added on the ungrounded portion of the circuit board to generate an additional resonance near the 5 GHz frequency band (see Fig. 2). Consistent with [7], the initial length of the shorted loop (L_{loop}) was determined as

$$L_{\text{loop}} = \frac{c}{f_{\text{r}}\sqrt{\varepsilon_{\text{r}}}} \quad , \qquad (1)$$

where c is the speed of light in a vacuum, and f_{r} is the resonant

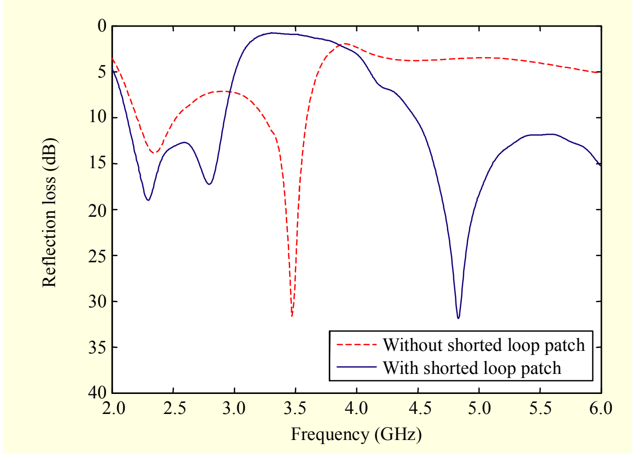

Fig. 2. Simulated reflection losses of loop-coupled meander-line patch with/without a shorted loop patch when h=40 mm.

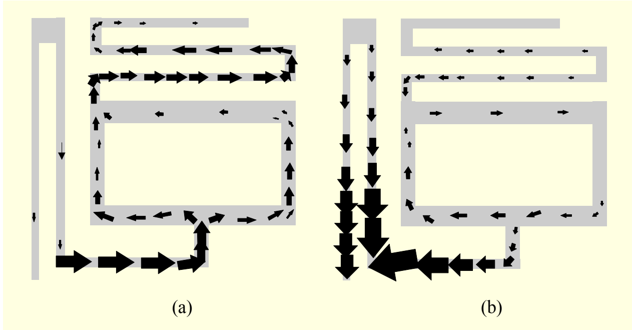

Fig. 3. Current distributions: (a) 2.3 GHz and (b) 5.5 GHz.

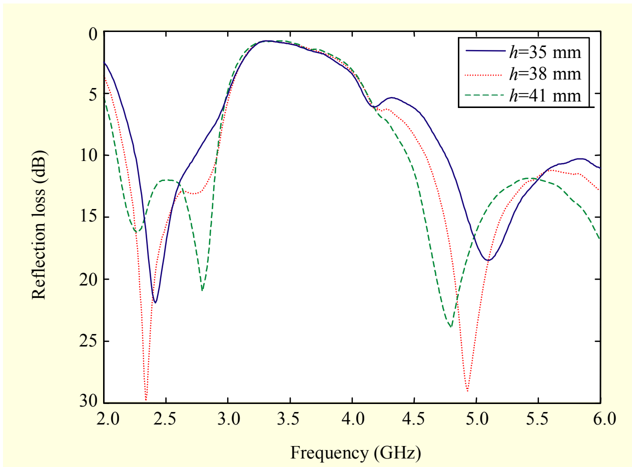

Fig. 4. Simulated reflection losses of the proposed antenna for various lengths of ground plane (h).

frequency of the shorted loop. In addition, as shown in Fig. 2, this attachment also shifts the second resonant frequency (3.5 GHz) of the loop-coupled meander-line to 2.8 GHz, thereby yielding a broadband stagger-tuned resonance at the lower resonance band. Current distributions shown in Fig. 3

also indicate the operation principle of the proposed antenna. Figure 4 illustrates the simulated reflection losses of the proposed antenna for various ground plane lengths (*h*) to validate the effect of the ground plane. Note that the other parameters correspond with those shown in Fig. 1(b). The figure demonstrates that increasing the length of the ground plane can enhance the bandwidth performances of both the lower and upper resonant bands. We also found that the proposed antenna exhibits sufficient bandwidths to cover WiBro, Bluetooth, WLAN, WiMAX, and S-DMB, even when employing a compact ground plane length of 35 mm. Therefore, a ground plane length of 35 mm was chosen for the design of the compact USB dongle antenna. The measured results of the optimized antenna are presented in section III.

III. Measured Results

Figure 5 shows a fabricated antenna with a plastic case for use as a WUSB dongle device. A 50 Ω semi-rigid coaxial cable was used to test the proposed antenna. The reflection loss was measured using an Agilent 8719A network analyzer. The measured results are in good agreement with the simulated

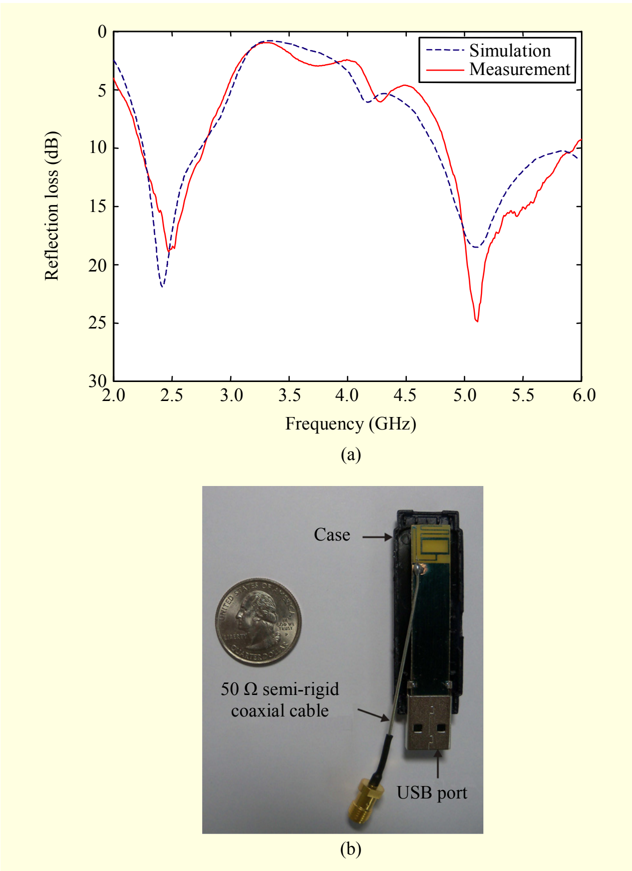

Fig. 5. (a) Simulated and measured reflection losses and (b) photograph of the fabricated antenna (*h*=35 mm).

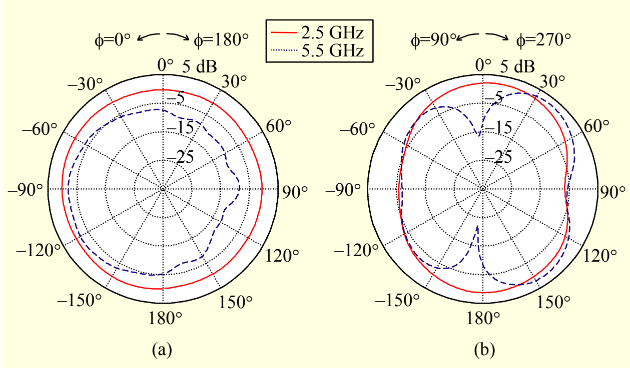

Fig. 6. Measured gain pattern of fabricated antenna (a) *x*-*z* plane and (b) *y*-*z* plane.

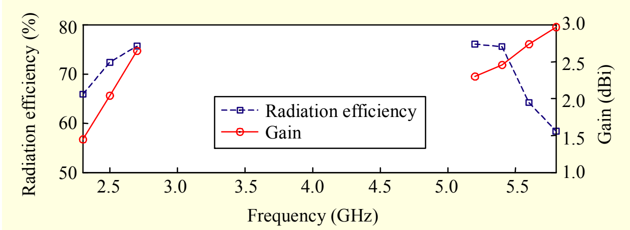

Fig. 7. Measured radiation efficiency and peak gain of fabricated antenna.

results using CST Microwave Studio. We also observed that the measured 10 dB reflection loss bandwidths of the lower band and upper band are 20.8% (2.24 GHz to 2.76 GHz) and 20.2% (4.86 GHz to 5.95 GHz), respectively. Therefore, the proposed compact WUSB antenna is shown to be capable of covering the WiBro (2.3 GHz to 2.4 GHz), Bluetooth (2.4 GHz to 2.484 GHz), WiMAX (2.5 GHz to 2.7 GHz), S-DMB (2.605 GHz to 2.655 GHz), and 802.11b/g/a WLAN (2.4 GHz to 2.485 GHz and 5.15 GHz to 5.825 GHz) bands. Figures 6(a) and 6(b) depict the measured gain patterns of the fabricated antenna of the two major cutting planes, *x*-*z* plane and *y*-*z* plane, respectively. The measured pattern at 2.5 GHz shows nearly omnidirectional characteristics, whereas the radiation at the 5.5 GHz is less omnidirectional. The measured radiation efficiency and peak gain are shown in Fig. 7. The total antenna efficiency is greater than 58% for all measured frequencies. The peak gain is 2.97 dBi at 5.8 GHz with gain variation of less than 1.52 dBi.

IV. Conclusion

We proposed a novel multiband antenna for compact wireless USB applications. A modified meander-line patch with a shorted loop element was employed to generate dual-broadband resonances. The simulated and measured results demonstrate that the proposed antenna can achieve sufficient bandwidth to cover WiBro, Bluetooth, WLAN, WiMAX, and S-DMB frequency bands. The proposed antenna has a suitable radiation pattern, efficiency, and gain for use as a WUSB dongle antenna capable of accessing various network services.

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