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A MINIATURIZED INTERNAL WIDEBAND ANTENNA FOR WIRELESS USB DONGLE APPLICATION

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Abstract—A miniaturized internal wideband antenna suitable for integration with the printed circuit board (PCB) of a wireless universal serial bus (WUSB) dongle is presented in this paper. The proposed antenna mainly consists of a folded metal plate with two sides beveled. By introducing a short-circuited pin connected to the system ground and etching a pair of slots in the bevel sides of the folded metal plate, a large impedance bandwidth from 2.4 GHz to more than 11 GHz is obtained, which easily covers the 2.4 GHz WLAN, WiMAX, S-DMB and UWB frequency bands. The effects of the short-circuited pin and the narrow slots on the impedance matching of the proposed antenna are investigated. The proposed antenna is easy to be fabricated by bending a sample metal plate due to its miniaturized geometry of $5 \times 12 \times 12.5\,\mathrm{mm}^3$. Details of the antenna design are described, and experimental results of the constructed prototypes are presented and discussed.

1. INTRODUCTION

With the development of the wireless communication technology, only a single digital device, which can provide multiple services such as high-quality multimedia broadcasting and wireless internet, are required in recent years. Providing good connection through plug-and-play function, a conventional universal serial bus (USB) is used to exchange data between most digital devices, including mobile phones, PDAs and laptops [1]. However, a major limitation of the USB technology is the presence of the cables. With the high speed wireless USB (WUSB), devices can be connected to the PC without cables. The

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WUSB is one of the most promising applications of ultra-wideband (UWB) technology. However, the antenna design for WUSB will be a challenging task due to the space constraint as well as the need to maintain good impedance and radiation performance across a broad operating bandwidth. Therefore, the numerous existing UWB antennas are too large in size to meet the requirements for internal antennas [2–6]. Recently, USB dongle antennas for WLAN [7, 8] and UWB [9–12] applications have been reported and investigated. However, these antennas cannot cover enough bandwidth for both the WLAN and UWB frequency bands with the limited sizes.

In this paper, a miniaturized folded internal wideband antenna is presented for wireless USB dongle application. The proposed antenna has a smaller size than the ones proposed in [9–11] and a lower profile than those in [9, 10]. In order to improve the impedance bandwidth with a miniaturized size, the proposed folded antenna has a pair of narrow slots etched in the folded antenna and a short-circuited pin connected to the system ground plane. With this compact structure, the proposed antenna provides a wide operational bandwidth covering the 2.4 GHz WLAN and UWB system bands. Thanks to its miniaturized size and low profile, the antenna is suitable to be mounted above the printed circuit board (PCB) of the WUSB dongle.

2. ANTENNA DESIGN

Figure 1 shows the geometry of the proposed miniaturized internal wideband antenna with a system ground plane for wireless USB dongle application. The antenna can be easily fabricated by bending a single 0.2 mm copper plate with two sides beveled. The terminals of the two folded sides are connected with each other by a piece of metal paper in the experiment. The folded wideband antenna is mounted on the front side of the substrate with relative dielectric constant $\varepsilon_r = 2.65$, thickness $h = 1.5\,\mathrm{mm}$, and total dimensions of $18 \times 40\,\mathrm{mm}^2$, which are suitable for most practical wireless USB dongles. It should be indicated that the system ground plane does not cover the entire back side of the substrate. In our design process, to improve the performance of the impedance matching over the wide bandwidth of interest, a pair of slots is etched in the bevel sides of the folded antenna and a short-circuited pin is placed under the proposed antenna and connected to the system ground plane with a grounding strip, as shown in Fig. 1. The antenna is fed by a $50\,\Omega$ round coaxial line connected to a SMA connector for testing the constructed prototype of the proposed antenna in the experiment.

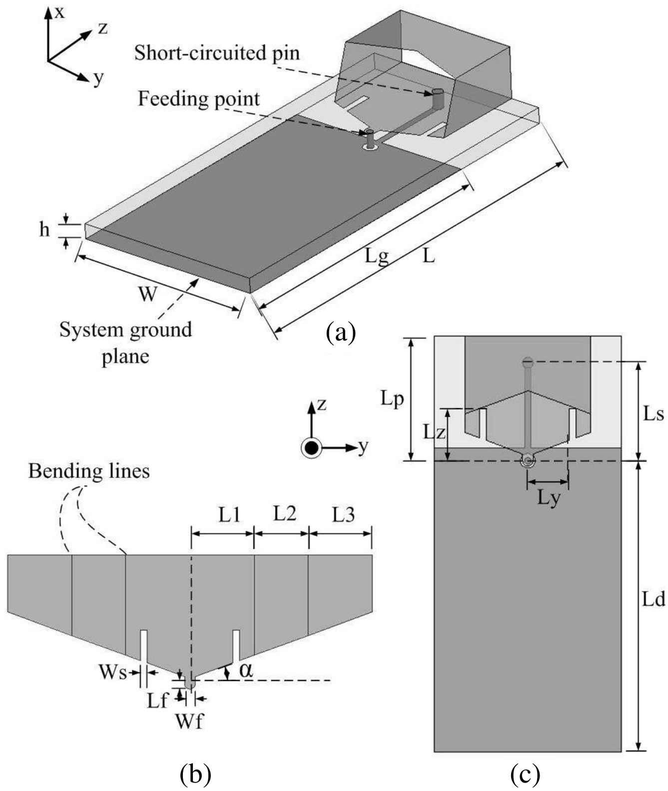

Figure 1. (a) Configuration of the proposed internal antenna mounted on the PCB of a wireless USB dongle. (b) Detailed dimensions of the unfolded internal antenna. (c) Top view of the proposed antenna.

The short-circuited pin plays significant roles in the impedance matching over the wide frequency band and the miniaturized size of the proposed antenna. Fig. 2 shows the effect of the short-circuited pin on the impedance matching. As can be seen from Fig. 2, with the presence of the short-circuited pin, the impedance bandwidth of the proposed antenna increased greatly and the low frequency edge of the operational band is reduced, compared to the curve without the short-circuited pin. Consequently, apart from enhancing the operational bandwidth, the shorted-circuited pin also reduces the size of the folded antenna, due to a much lower resonate mode is obtained. Furthermore, the position of the short-circuited pin L_s affects the impedance matching performance obviously as shown in Fig. 2.

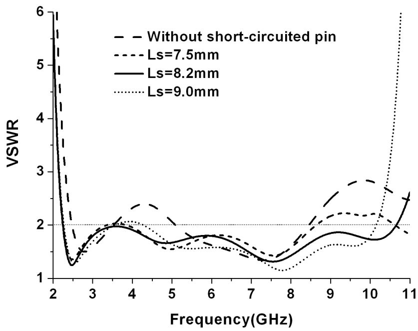

Figure 2. Effects of the short-circuited pin on the impedance matching characteristic.

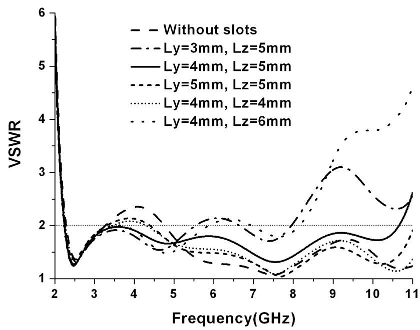

Figure 3. Effects of the narrow slots on the impedance matching characteristic.

(a) (b)

Figure 4. Photograph of the manufactured internal antenna. (a) Top view. (b) Bottom view.

The effect of the narrow slots in the bevel sides of the antenna on the impedance matching is illustrated in Fig. 3. It is evident from Fig. 3 that the impedance matching performance at the frequencies from 3.4 GHz to 4.7 GHz is improved by etching the slots in the bevel side as $L_y = 4$ mm and $L_z = 5$ mm. The effect of varying the length L_y and L_z are also shown in Fig. 3. The narrow slots have great influences on the impedance matching not only at the lower frequencies but also at the higher frequencies. In fact, the narrow slots are critical for implementing the wideband operation of the proposed antenna.

The electromagnetic software Ansoft HFSS is employed to perform the design and optimization processes. The final optimal parameters are shown as follows: $L = 40$ mm, $W = 18$ mm, $L_g = 29.2$ mm,

$L_d = 28\,\text{mm}$, $L_p = 12\,\text{mm}$, $L_s = 8.2\,\text{mm}$, $L_1 = 6\,\text{mm}$, $L_2 = 5\,\text{mm}$, $L_3 = 6\,\text{mm}$, $L_f = 1\,\text{mm}$, $W_f = 1\,\text{mm}$, $L_y = 4\,\text{mm}$, $L_z = 5\,\text{mm}$, $W_s = 0.6\,\text{mm}$, $\alpha = 20°$. The photograph of the manufactured internal wideband antenna for wireless USB dongle application is shown in Fig. 4.

3. MEASURED AND SIMULATED RESULTS

The proposed internal wideband antenna is measured by WILTRON3 7269A Vector Network Analyzer. Fig. 5 shows the simulated and measured VSWR of the proposed internal wideband antenna for wireless USB dongle application. It can be seen from Fig. 5 that the measured VSWR reasonably agrees with the simulated results with an acceptable frequency discrepancy, which may be caused by the SMA connector, the difference between the simulated and the measured environments and the tolerance in manufacturing. Fig. 5 reveals a sufficiently wideband behavior with a 2 : 1 VSWR bandwidth from 2.4 GHz to more than 11 GHz, satisfying the impedance matching requirement for WLAN (2.4–2.484 GHz and 5.15–5.825 GHz), WiMAX (3.5–3.7 GHz), S-DMB (2.605–2.655 GHz) and UWB (3.1–10.6 GHz) bands.

The far-field radiation characteristics of the proposed miniaturized internal wideband antenna for WUSB dongle application are also investigated. Fig. 6 shows the measured radiation patterns at the sampling frequencies of 2.4 GHz, 5 GHz and 8 GHz. As presented in Fig. 6, nearly omnidirectional radiation patterns in the x-y plane

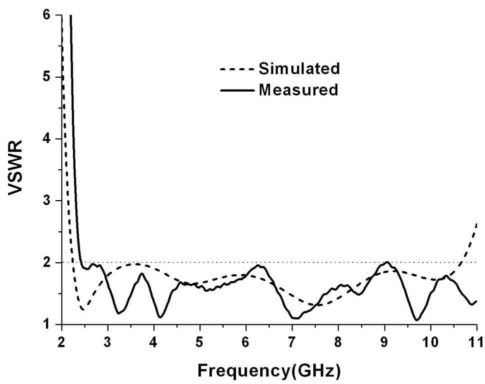

Figure 5. Measured VSWR of the proposed internal wideband antenna.

obtained at these frequencies. Fig. 7 shows the measured peak gain of the proposed folded internal wideband antenna. The antenna gain varies from 2.1 to 4.5 dBi over the whole operational band.

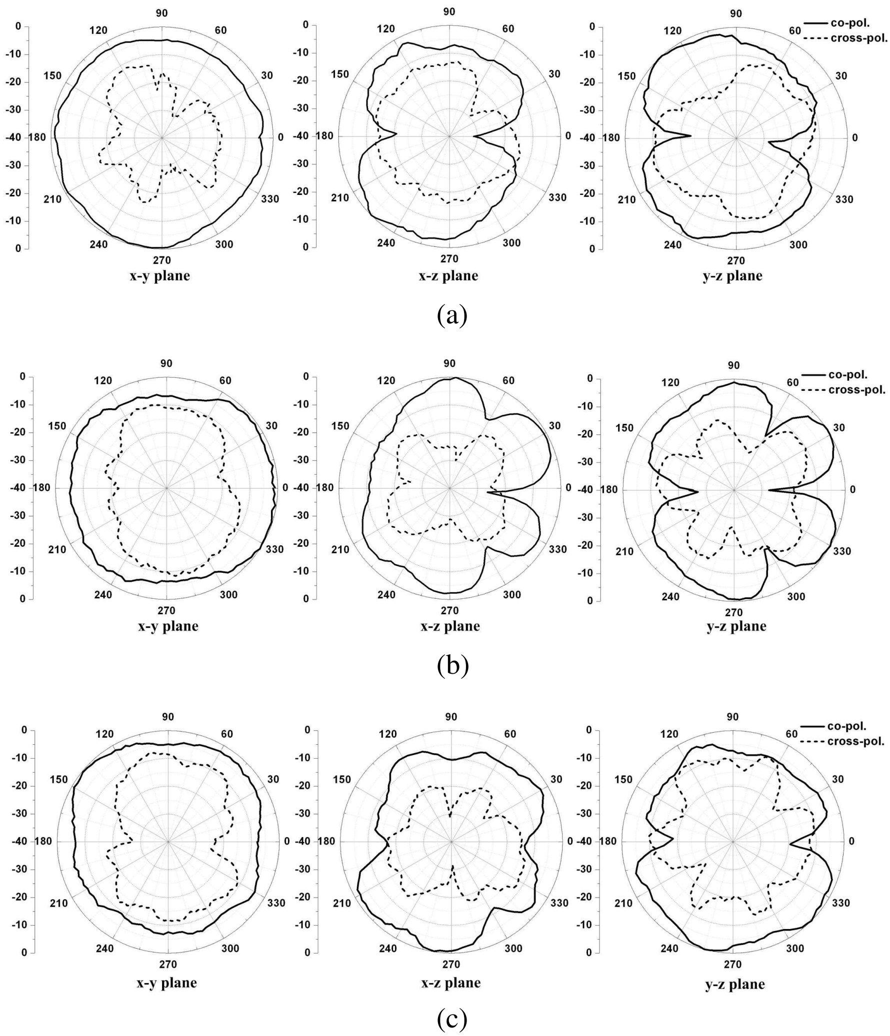

Figure 6. Measured radiation patterns: (a) 2.4 GHz, (b) 5 GHz, (c) 8 GHz.

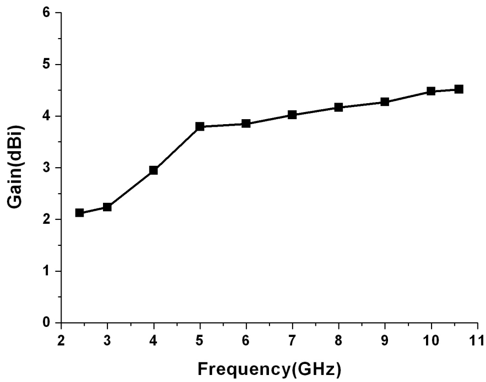

Figure 7. Measured peak antenna gain.

4. CONCLUSION

In this paper, a miniaturized internal wideband antenna for wireless USB dongle application is proposed. Prototypes of the proposed antenna have been successfully constructed and tested. The antenna is easily fabricated by bending a metal plate with two sides beveled. By employing two narrow slots and a short-circuited pin in the antenna design, the antenna shows a very wide impedance bandwidth of larger than 8.6 GHz (2.4 GHz–11 GHz), covering the 2.4 GHz WLAN, WiMAX, S-DMB and UWB system bands. Good radiation characteristics at 2.4 GHz, 5 GHz and 8 GHz for the proposed WUSB dongle antenna have also been obtained. Therefore, the proposed antenna could be a good candidate for future wireless applications since its size is small enough to satisfy the size constraints imposed on the USB dongle application.

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