Internal Ultrawideband Monopole Antenna for Wireless USB Dongle Applications

Saou-Wen (Stephen) Su, *Member, IEEE*, Jui-Hung Chou, and Kin-Lu Wong, *Fellow, IEEE*

***Abstract*—A novel, ultrawideband (UWB) monopole antenna suitable to be mounted on the printed circuit board (PCB) of a wireless, universal, serial-bus (USB) dongle as an internal antenna is presented. The proposed antenna in the study is a U-shaped, metal-plate monopole antenna, easily fabricated from bending a simple metal plate onto a foam base of a compact size of $6 \times 11 \times 20\ \mathrm{mm}^3$. The antenna mainly comprises a pair of wide-ended radiating arms and a bevel-feed transition. When the antenna is mounted at the top portion of the PCB, one end of the radiating arm is also short-circuited to the system ground plane. With the proposed antenna structure, which can provide a very wide operating bandwidth of larger than 7.6 GHz, the antenna impedance bandwidth can easily cover the 3.1–10.6 GHz UWB band. Details of the antenna design are described, and experimental results of the constructed prototypes are presented and discussed.**

***Index Terms*—Antennas, internal antennas, ultrawideband (UWB) antennas, universal serial-bus (USB) dongle antennas.**

I. Introduction

FOR applications in consumer electronics (CE) or computer-associated devices in short-range, wireless, personal area-network (WPAN) communications [1], a combination of the wired, universal, serial-bus (USB), and ultrawideband (UWB) wireless technologies is needed and aims to provide instant UWB connectivity for a wide range of devices. Prepared for this scenario to arrive, the wireless USB Promoter Group [2] has been formed and proposes a high-data throughput with high-speed interconnect and low-power consumption for distances under 10 m [3]. The first, wireless-USB implementations will be most likely applied to USB dongles [4], which currently are widely used for plug-and-play capabilities in the catalog of multimedia CE and PC peripherals. In addition, numerous UWB antennas utilizing planar monopole antennas, in which the antenna is usually perpendicular to a large ground plane, have been successively reported thus far [5]–[15]. Due to the constraints of the dimensions of wireless USB dongles, this kind of conventional wideband antenna fails to meet the requirement for an internal antenna with a compact structure or a low profile for WPAN operation in the UWB band.

In this paper, a novel, internal-UWB antenna design for wireless USB-dongle applications is proposed. The proposed antenna [see Fig. 1(a)] is suitable to be mounted above the printed circuit board (PCB) of the wireless USB dongle, and shows a low profile of 6 mm from the front side of the PCB. The antenna is thus very promising to be embedded within the casing of the wireless USB dongle as an internal antenna. Furthermore, the proposed antenna in this study is capable of generating a very wide operating bandwidth (with the definition of 10-dB return loss) of larger than 7.6 GHz (approximately 2.98–10.61 GHz), which easily covers the UWB band of 3.1–10.6 GHz for WPAN communications. A design example of the proposed, internal-UWB monopole antenna for applications in wireless USB dongles is demonstrated. Details of the proposed design are described, and experimental results of a constructed prototype are presented. Effects of the system ground plane or PCB length of the wireless USB dongle on the antenna impedance bandwidth are also studied experimentally.

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II. Antenna Design

Fig. 1(a) shows the configuration of the proposed, internal-UWB antenna mounted on the top portion of the system ground plane or PCB of a wireless USB dongle. The system ground plane studied here is chosen to have dimensions of length L and width 20 mm, which are considered dimensions of some practical, wireless USB dongles. Note that the system ground plane does not cover the entire top portion of the PCB's back surface (a size of $6 \times 19\ \mathrm{mm}^2$ unoccupied). The proposed antenna can easily be constructed by bending a single metal plate (a 0.125-mm copper plate was used in the study), whose detailed dimensions are given in Fig. 1(b), onto a foam base of size $6 \times 11 \times 20\ \mathrm{mm}^3$.

The proposed antenna mainly comprises two portions: a pair of wide-ended radiating arms and a bevel-feed transition, which together form a U-shaped structure [see Fig. 1(b)]. The two radiating arms are also bent, following the bending of lines 1 and 2 as shown in Fig. 1(b), into a compact structure. In this case, the proposed antenna has a low profile of approximately 6 mm (about 0.06 wavelength of the desired lower edge frequency of the UWB band at 3.1 GHz) above the top portion of the system ground plane. Note that between bending line 2 and the top edge of the U-shaped metal plate are the wide-ended portions of the radiating arms. The width t of the widened radiating arms is adjusted for better impedance matching around the middle frequency band of the UWB operation. The related results will be elaborated more with the aid of Fig. 7 in the next section. Also, one of the wide-ended portions is further short-circuited at point B through a small square stub (size of $0.8 \times 1\ \mathrm{mm}^2$) soldered to a grounding strip (width 1 mm and length 6 mm) to the system ground plane on the back side of the PCB [see Fig. 1(a)]. This short-circuiting reduces the size of the planar monopole

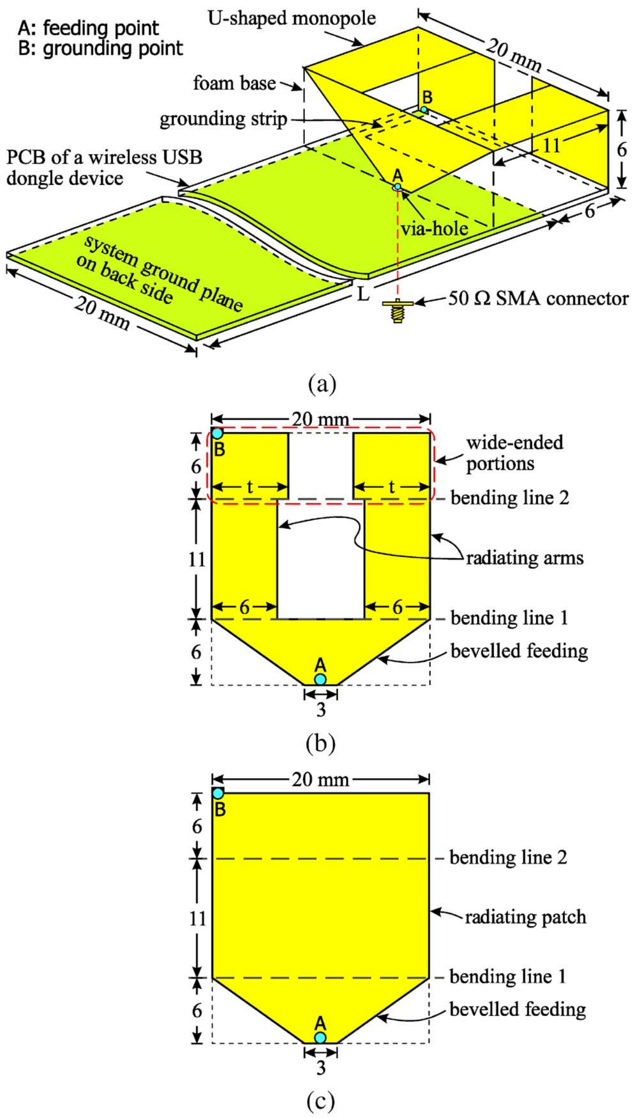

Fig. 1. (a) Configuration of the proposed, internal-UWB monopole antenna mounted on the PCB of a wireless USB dongle. (b) Detailed dimensions of the proposed antenna unbent into a planar structure of a U-shape. (c) Detailed dimensions of a corresponding simple planar monopole unbent into a planar structure.

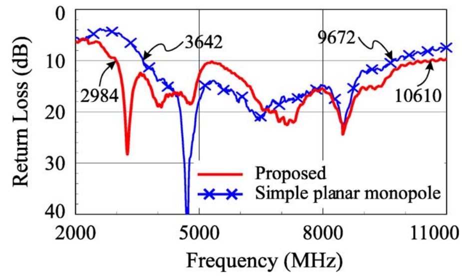

Fig. 2. Measured return loss for the constructed prototype with $L = 60$ mm, $t = 7$ mm and a corresponding simple planar monopole [the antenna in Fig. 1(c)].

antenna, due to a much lower resonant mode obtained, compared to the antenna reported in [9]. As for the portion of the bevel-feed transition, there are two symmetrical bevels (size of $6 \times 8.5\ \mathrm{mm}^2$) cut at the two lower corners which have proved helpful in enhancing the impedance matching for the upper frequencies within the bandwidth of interest [10].

Note that at the center of the bottom edge in the bevel-feed transition is the feed point (point A), which is connected to the central conductor (diameter 1.2 mm) of a 50 Ω SMA connector placed below a via-hole in the system ground plane for testing the constructed prototype of the proposed antenna in the experiment. For practical applications, one can also use a 50 Ω microstrip feed line printed on the front side of the PCB.

III. Experimental Results and Discussion

Based upon the design dimensions shown in Fig. 1(a) and (b), the proposed UWB monopole antenna was constructed and tested. The length of the system ground plane is first chosen to be 60 mm, which is a reasonable size of a practical wireless USB dongle. Note that, in Fig. 1(c), a corresponding simple planar monopole antenna with the same dimensions of the system ground plane and PCB are considered for comparison in the experimental study. Fig. 2 shows the measured return loss for the proposed constructed prototype and the corresponding simple planar monopole antenna. For the proposed constructed prototype, the measured impedance bandwidth, defined by a 10-dB return loss, reaches 7626 MHz (2984–10610 MHz) and thus easily covers the UWB operating frequency of 3.1–10.6 GHz. It is easily seen that the obtained impedance bandwidth of the proposed antenna is approximately 1.6 GHz larger than that of the simple planar monopole antenna (6030 versus 7626 MHz). The frequency ratio ($f_{\mathrm{U}}/f_{\mathrm{L}}$, in which f_{U} and f_{L} are the respective upper and lower edge frequencies of the 10-dB return loss impedance bandwidth) is also increased by a factor of approximately 1.3 (2.65 versus 3.55). With the use of a U-shaped metal plate, improved results are probably due to more-intensified, surface currents toward the top edge of the antenna and a more-uniform, surface current distribution in the two radiating arms, similar to the two-feed design studied in [15]. In this case, an enhanced impedance bandwidth can be obtained.

Radiation characteristics of the proposed antenna for frequencies across the UWB band were also studied. Fig. 3–5, show the measured radiation patterns at 3.1, 5.0, and 10.6 GHz for the proposed antenna, respectively; the antenna parameters are the same as studied in Fig. 2. From the measured results, comparable E_θ and E_ϕ components are seen. This characteristic allows signal reception and transmission for practical, wireless USB-antenna applications, because the indoor, wave-propagation environment for WPAN operation is usually complex. The measurements at the other operating frequencies over the operating band were also investigated, and the results showed similar radiation patterns as those plotted here. Fig. 6 presents the measured antenna gain and simulated radiation efficiency versus frequency. The antenna gain varies in a range of approximately 3.2–4.6 dBi for frequencies from 3.1 to 10.6 GHz in the UWB bandwidth. For the simulated, mismatch, radiation efficiency [16], it is found to exceed approximately 90% over the operating band. This good radiation efficiency is largely due to the use of the low-loss, low-permittivity foam base for the proposed UWB antenna, and partly because of the position of the antenna, half protruded from the top edge of the system ground plane.

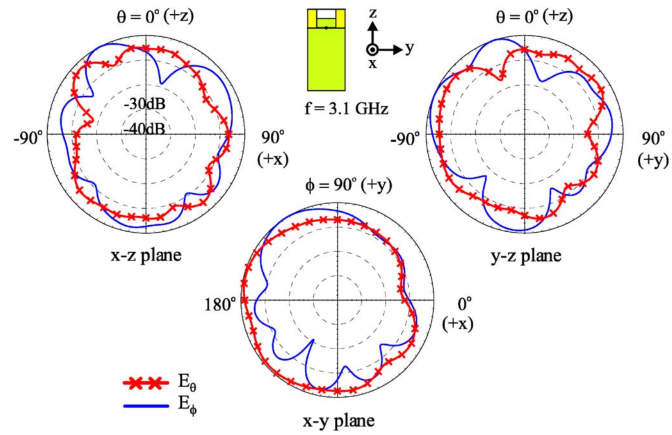

Fig. 3. Measured radiation patterns at 3.1 GHz for the constructed prototype studied in Fig. 2.

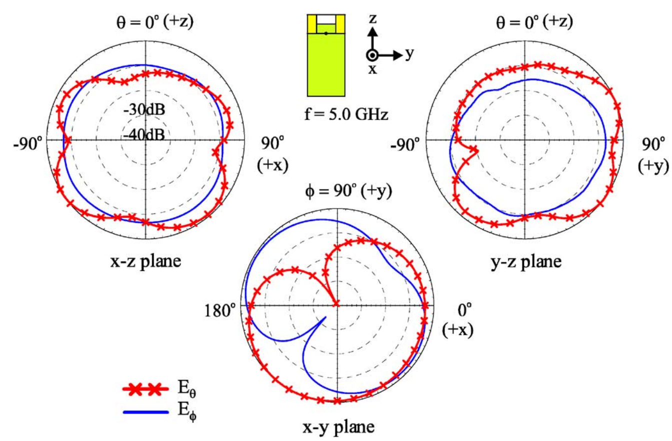

Fig. 4. Measured radiation patterns at 5 GHz for the constructed prototype studied in Fig. 2.

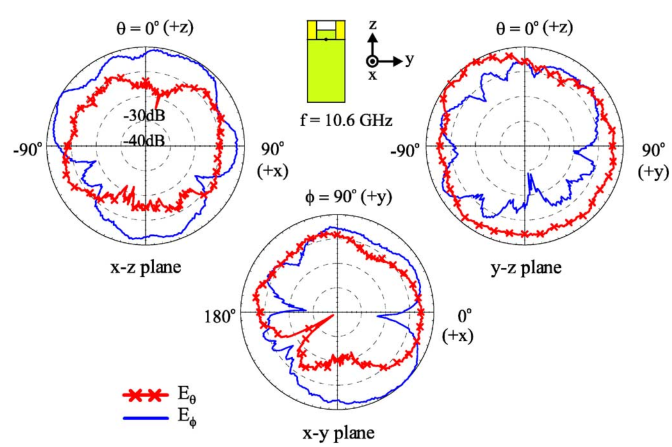

Fig. 5. Measured radiation patterns at 10.6 GHz for the constructed prototype studied in Fig. 2.

Experiments for analyzing the effects of the width t of the wide-ended portions of the radiating arms on the antenna impedance matching were conducted. Fig. 7 shows the measured return loss as a function of the width t varied from 6 to 8 mm (the other dimensions are the same as those in Fig. 2). It is seen that the variation in t largely affects the impedance

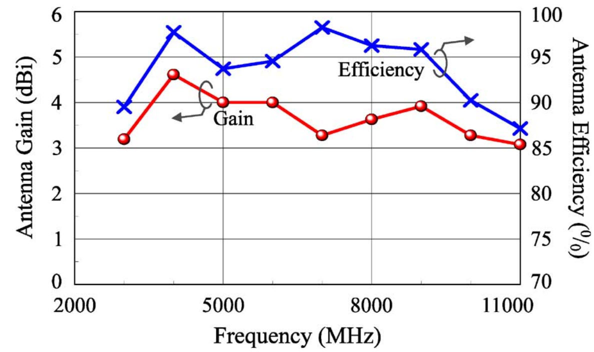

Fig. 6. Measured antenna gain and simulated radiation efficiency versus frequency for the constructed prototype studied in Fig. 2.

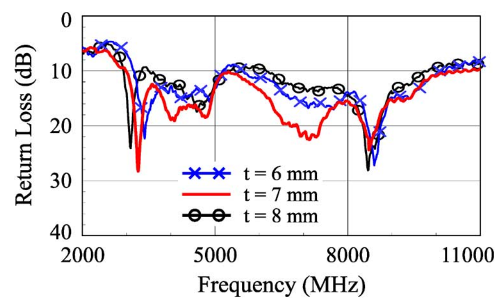

Fig. 7. Measured return loss as a function of the width t of the wide-ended portion of the radiating arm. Other parameters are the same as given in Fig. 2.

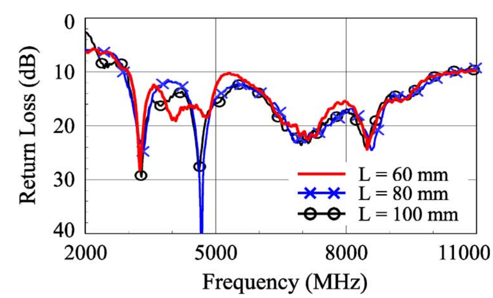

Fig. 8. Measured return loss as a function of the system ground-plane length L. Other parameters are the same as given in Fig. 2.

matching for frequencies between 5.0 and 6.5 GHz, and to some degree, affects the upper and lower edge frequencies, too. Also note that when the value of t is chosen to be 6 mm, the U-shaped metal plate monopole antenna has uniform radiating arms of width 6 mm. Furthermore, the effects of the system ground-plane length L on the antenna performance were also studied experimentally. The results of Fig. 8 show that the variations in the measured return loss are small, and the obtained impedance bandwidths remain almost the same. This characteristic indicates that the system ground-plane length does not significantly de-tune the antenna, and thus there is no need for re-matching as a result of using PCBs with various possible ground-plane lengths.

IV. Conclusion

A novel, internal monopole antenna suitable for UWB operation in a wireless USB dongle has been proposed. Prototypes of the proposed antenna have been successfully constructed and tested. The antenna is very easy to implement by bending a simple metal plate into a compact structure, and shows a very wide impedance bandwidth of approximately 7.6 GHz (approximately 3.0 to 10.6 GHz). Good radiation characteristics for the proposed antenna over the UWB band have also been obtained. Small ground-plane length effects on the antenna impedance bandwidth have also been observed. The proposed antenna is well suitable for internal, UWB-antenna applications in wireless USB dongles with various possible system ground-plane or PCB lengths.

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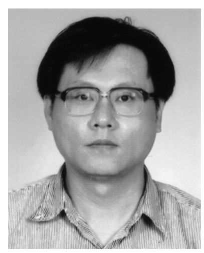

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