Ultra-wideband slot antenna for wireless USB dongle applications

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An ultra-wideband (UWB) printed slot antenna, suitable for integration with the printed circuit board (PCB) of a wireless universal serial-bus (WUSB) dongle is presented. The design comprises a near-rectangular slot fed by a coplanar waveguide printed on a PCB of width 20 mm. The proposed design has a large bandwidth covering the 3.1–10.6 GHz UWB band, unaffected by the ground length, and omnidirectional radiation patterns. A linear phase response throughout the band further confirms its suitability for high-speed wireless connectivity.

Introduction: The universal serial-bus wireless (WUSB) combines the benefits of the USB with the convenience of wireless technology leading to data rates of 480 Mbit/s up to 3 m and of 110 Mbit/s up to 10 m [1]. The WUSB is one of the most promising applications of ultra-wideband (UWB) technology and among the first to be commercially available for short-range and high-speed wireless interfaces. WUSB dongles replace the USB cables and deliver instant UWB connectivity for a wide range of devices such as printers, hubs and external hard drives. The dongles employ an on-board UWB antenna on printed circuit boards (PCBs) typically of 23 × 70 mm^2 sizes. Along with miniaturised size and omnidirectional radiation patterns, dongle antennas should be flexible in design with ground independence [2]. A microstrip-fed monopole antenna with reduced ground plane effects [3] and a bended plate monopole antenna [4] are some of the designs reported for WUSB dongle applications.

The proposed antenna employs a near-rectangular slot which along with a tapered tuning stub exhibits a wide impedance bandwidth from 2.9 to 11 GHz. The width of the antenna is only 20 mm and is smaller than most of the slot antennas reported for UWB operations [5, 6]. Also, the antenna performance is observed to be unaffected by the PCB/ground length making the proposed design an ideal candidate for a WUSB dongle antenna. A coplanar waveguide (CPW) feed further ensures easy integration with the rest of the USB circuitry. The proposed antenna is successfully designed and experimentally verified. The antenna has excellent impedance matching, stable radiation patterns, and linear group delay over the entire UWB band along with good impulse response.

Antenna design: Fig. 1*a* shows the geometry of the proposed antenna and its optimised dimensions. The antenna consists of a CPW-fed tapered tuning stub along with a near-rectangular aperture etched out from the ground plane of a PCB. The CPW feed is designed for 50 Ω on FR4 substrate with $\varepsilon_r = 4.4$ and thickness $h = 1.6$ mm. Since the feed and the ground are on the same plane, a substrate with single-sided metallisation is used, making the antenna easy and cost-effective to manufacture.

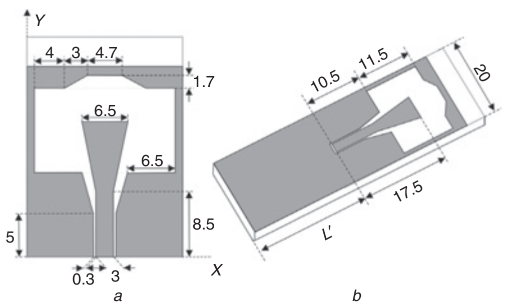

Fig. 1 *Proposed antenna*

a Geometry
b Integrated with WUSB dongle PCB

Results and discussion: The prototype of the proposed antenna design was fabricated and measured using a Rhode and Schwarz ZVB20 vector network analyser. The performance of the antenna was simulated using ANSOFT HFSS. The overall size of the proposed UWB antenna is compact (20 × 25 mm^2). However, while integrating the UWB antenna with the system ground plane of USB dongles as shown in Fig. 1*b*, the performance gets detuned as a result of using PCBs with various ground-plane lengths typically ranging at 70 mm. Hence, to assess the suitability of the proposed design for WUSB applications, the effect of the ground plane length on the antenna is studied and plotted in Fig. 2. It reveals a UWB behaviour with a 2:1 VSWR bandwidth from 2.9 to 11 GHz and a negligible variation in the matching and the impedance bandwidth of the antenna with PCB length, L'. The surface current distribution on the antenna integrated with the PCB of a USB dongle, plotted in Fig. 3, further confirms the ground length independence of the proposed design. It is observed that the majority of the electric currents are concentrated around the slot with very little current on the rest of the ground plane.

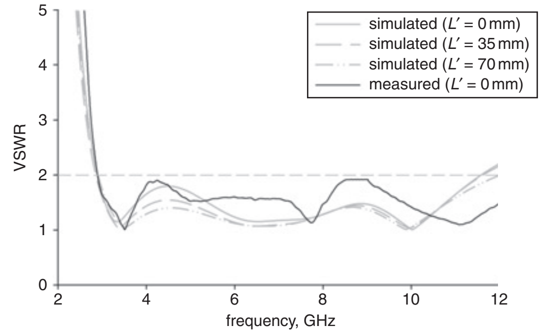

Fig. 2 *VSWR plot of antenna for different ground lengths*

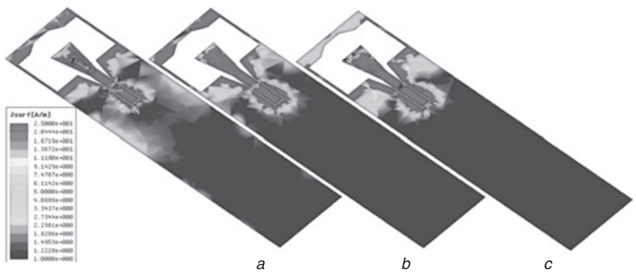

Fig. 3 *Surface current distribution on antenna integrated with PCB of USB dongle at 3.35, 6.5, 10 GHz*

a 3.35 GHz
b 6.5 GHz
c 10 GHz

The measured radiation patterns of the antenna in the X-Z and Y-Z planes for three different frequencies are shown in Fig. 4. The patterns are stable throughout the band and resemble that of a monopole in the H-plane (X-Z).

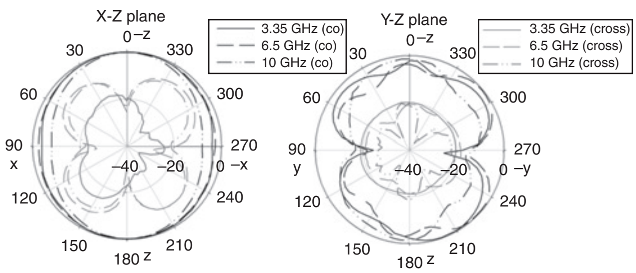

Fig. 4 *Measured radiation patterns of antenna*

The measured peak gain of the antenna is compared with the simulated one in Fig. 5*a*, which shows reasonable agreement with a peak gain above 2 dBi throughout the band. Measurement of group delay and S_{21} is performed by exciting two identical prototypes of the antennas kept in the far field for two orientations; face-to-face and side-by-side. A constant group delay and a fairly flat magnitude of S_{21} is observed, which ensures distortionless behaviour of the system when UWB pulses are transmitted and received. An exception at 9 GHz for the side-by-side orientation is owing to higher-order modes excited in the antenna which affects its radiated power along the ±X direction.

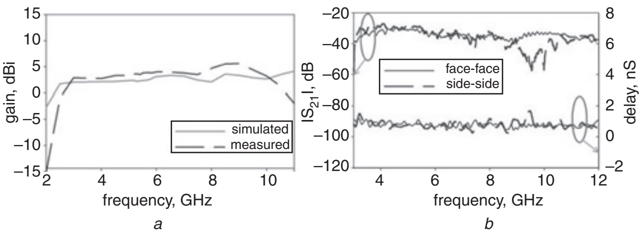

Fig. 5 *Measured peak gain and group delay and $|S_{21}|$ of antenna*

a Peak gain
b Group delay

Conclusion: A compact ultra-wideband slot antenna fed by a coplanar waveguide is proposed. The impedance bandwidth of the designed antenna ranges from 2.9 to 11 GHz. The antenna features all the desirable characteristics demanded by UWB communication systems such as adequate impedance bandwidth and stable radiation patterns throughout the ultra-wideband and a good time domain performance. In addition to compact size, the antenna is insensitive to ground plane length variations, making it suitable for WUSB dongle and mobile UWB applications.

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