Compact Broadband Printed Monopole Antenna

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Abstract **─** A compact printed monopole antenna for broadband application is presented. The proposed antenna, having a total physical size of 21 × 6.5 mm consists of a patch fed by a coaxial line and an SMA connector as partial finite ground plane. The modified patch plane with a slot in its feed point helps to increase the impedance bandwidth of the proposed antenna. The optimal design may offer an ultra-wide impedance bandwidth from 2.56 GHz to 20 GHz. A prototype is fabricated and tested. The agreement between the simulated and measured results is quite good.

Index Terms **─** Compact printed monopole antenna and ultra-wideband.

I. INTRODUCTION

Recently ultra-wideband (UWB: 3.1 GHz – 10.6 GHz) technology has received much attention and has become the most promising candidate for future short-range high-speed data communications. Designing UWB antennas to match various applications such as the wireless personal area network (WPAN), wireless body area network (WBAN), indoor localization, biomedical imaging, and UWB array applications [1] is still a major challenge and has attracted the interest of many researchers [2, 3].

There are many requirements for the UWB antennas, such as low profile, radiation stability, and constant gain. To obtain these requirements, several compact antennas have been proposed for UWB applications in three dimensional [4], and planar form [5]. However, for miniaturizing the system size, the UWB antenna must be small enough as an internal antenna to be easily embedded in a portable device. In such miniaturized structures, to overcome the matching problem, someone has to make a special effort [6, 7].

In this paper, a compact and very simple printed monopole antenna with a matching slot has been proposed. To the authors' best knowledge, present suggestion is the smallest antenna that was reported yet. This antenna provides not only an ultra wide operating bandwidth for UWB systems, but also good impedance bandwidth from 2.56 GHz to 20 GHz with acceptable gain throughout the band. This broadband characteristic of the proposed monopole antenna is confirmed in the measurements. The antenna group delay and transmission characteristics are quite stable to satisfy broadband operation.

II. ANTENNA DESIGN, SIMULATION, AND FABRICATION

The geometry of the proposed UWB printed monopole antenna is shown in Fig. 1 (a), which occupies a compact size of only 21 (*L*) × 6.5 (*W*) × 0.762 mm. The fabricated antenna, printed on an RT5880 substrate with a dielectric constant of 2.2, is composed of a simply rectangular-shaped radiator, optimally etched lateral slot and fed by a 50 Ω coaxial line through an SMA connector. The designed antenna was successfully implemented as shown in Fig. 1(b). The length of the planar monopole was chosen to be 21 mm, which easily

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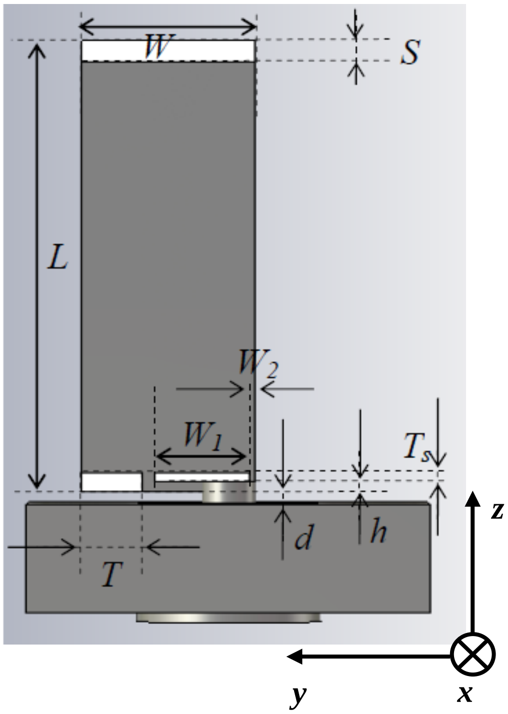
makes the obtained impedance bandwidth have a lower edge frequency f_L less than 2.56 GHz. The parameters of the feeding strips were also optimized to achieve a maximum impedance bandwidth.

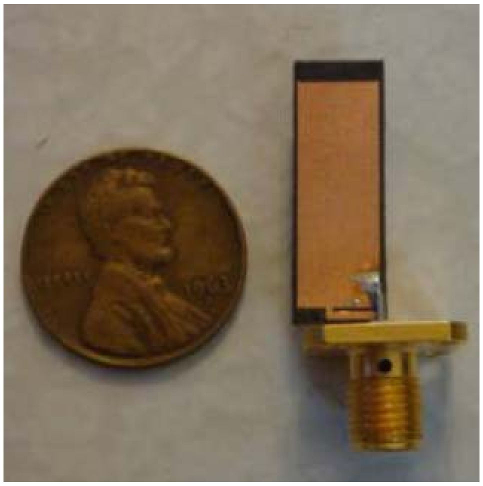
By adjusting "*d*", the coupling between the ground plane and the lower edge of the planar monopole is varied, which effectively introduces a variation in the input reactance of the antenna. Thus, impedance matching of the antenna can be fine-tuned, and optimized impedance bandwidth can be obtained for the antenna. The effects of slot and patch truncation have been shown in Fig. 2. The optimized antenna is capable of tuning from 2.56 GHz to 20 GHz providing an impedance bandwidth of about 7.8:1. Experimental results are also presented in Fig. 2. In this figure, we labeled the truncated slotted planar monopole antenna as Type I, while the slotted antenna is labeled as Type II (without truncation), and the antenna with nor the slot neither the truncation as Type III.

The measured results are in good agreement with those of the simulation. Despite its very small size, the proposed antenna has achieved wider bandwidth than the antennas reported in [3] and is able to tune over a wide bandwidth to cover the entire range 3.1 GHz to 10.6 GHz assigned for UWB applications. For UWB antenna systems, the group delay is a useful parameter to measure the variation of the phase response against frequency. The group delay of an antenna can be calculated from the derivative of the phase response of the transfer function with respect to frequency.

Figure 2 also shows the group delay results as calculated from the time domain responses, in CST Microwave Studio, which reveals less than 0.8 ns fluctuations in the group delay across the UWB, [8-10]. Apparently, smaller variations of the group delay occur for the truncated slotted antenna. It seems clearly that the slot is mainly affecting the impedance tuning condition while the patch truncation modifies the group delay response. Figure 3 shows the simulation results for the E- and H-planes radiation pattern at 3 GHz, 5 GHz, 10 GHz, 15 GHz, and 20GHz. It can be observed that the radiation pattern of the proposed antenna is monopole-like while the frequency is below 10 GHz and becomes broadside gradually in the higher frequencies. The measured co- and cross- components of the radiation pattern for some sample frequency only in E-plane for brevity are plotted in Fig. 4.



(a)



(b)

Fig. 1. (a) Antenna geometry and (b) photograph of measured antenna of dimensions: L = 21 mm, W= 6.5 mm, W_1 = 3.5 mm, W_2 = 0.25 mm, T = 2.25 mm, T_s = 0.4 mm, S = 0.5 mm, and d = 0.25 mm.

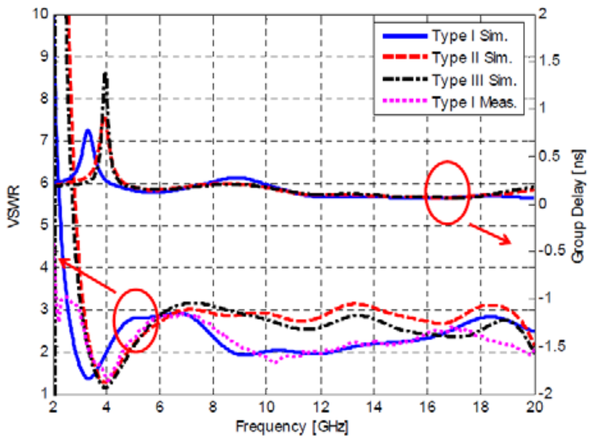
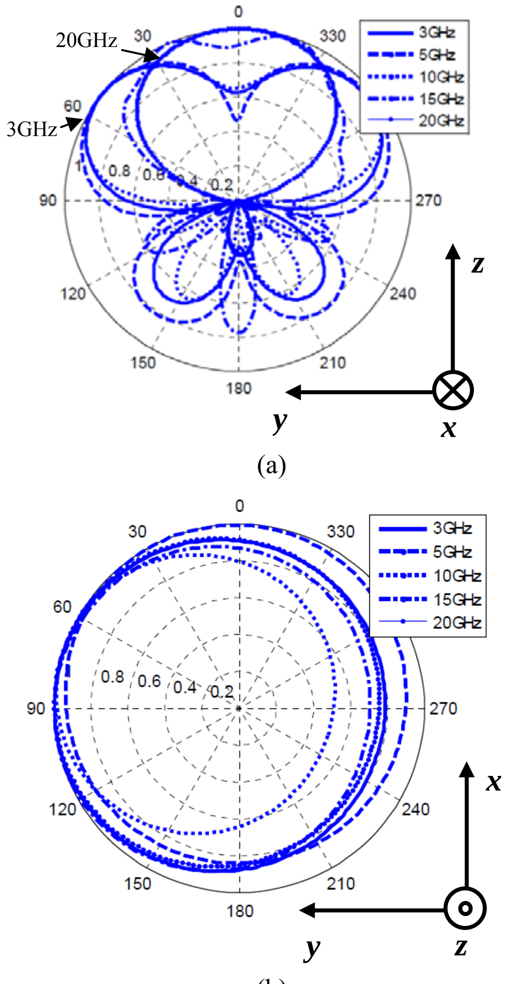


Fig. 2. Measured and simulated VSWR for both proposed and simulated antenna group delay.



(a)

(b)

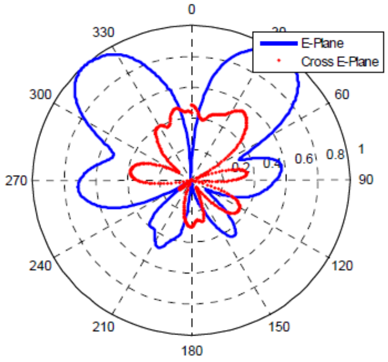
Fig. 3. Simulated normalized radiation patterns, (a) E-Plane and (b) H-Plane.

The measurements were made using a meter length of phase stable test cable. Moving a hand along this cable visibly perturbed the return loss display, indicating that the cable supported currents from the antenna. Current traveling from the ground down the feed cable is a very common phenomenon with monopole antenna designs. To achieve high levels of feed cable isolation in monopole-type designs, the use of current-choking techniques and careful placement of the feed cable connector have often been necessary. In commercial use, the antennas are normally operated connected directly to the transceiver PCB, and therefore the feed cable coupling is not an issue, [11].

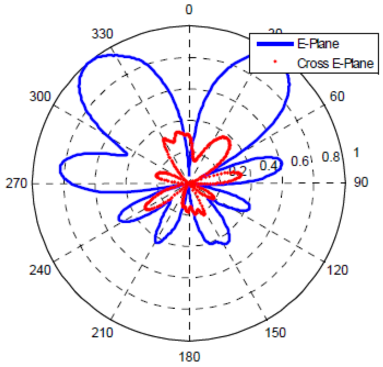
The radiation pattern looks like a doughnut, similar to a monopole pattern, at the first resonant frequency, as shown in Fig. 4 (a). At the second frequency, the pattern looks like a slightly pinched donut with the gain increase around $\theta=45^0$, Fig. 4 (b). Above the end of the standard UWB band and at the higher frequencies, the patterns are squashed in azimuth and humps form in the up-right directions (gain increasing), as shown in Figs. 4 (d) – 4 (e). The E-plane patterns have large back lobes and look like a doughnut or a slightly pinched doughnut at lower frequencies. With the increase of the frequency, the back lobes become smaller, splitting into many minor ones, while the front lobes start to form humps and notches.

It is also noticed that the patterns on the H-plane are almost omnidirectional at lower frequencies and become distorted at the end of the band. The asymmetry of the patterns for the E- and H-planes components is caused mainly by the asymmetrical feed configuration. Also, the severe asymmetry of the monopole causes degradation of the omnidirectional radiation patterns of the E-plane components in the azimuth plane, as shown in Fig. 4 (c). This degradation becomes worse when the operating frequency increases. As shown in Figs. 4 (a) – 4 (e), the measured radiation patterns are almost close to those obtained in the simulation (i.e., Fig. 3). This has verified the simulated radiation patterns. However, the measured E-plane pattern does not agree well with the simulation. This discrepancy seems to be due to an enhanced perturbing effect on the antenna performance caused by the feeding structure and cable at this frequency.

Moreover, from the comparison of the fabricated prototype to the simulated geometry of Fig. 1, it is clear that some of the asymmetry in the measured patterns as compared to the symmetry in the simulated patterns could be attributed to the offset in the ground plane afforded by the physical SMA connector. The ground plane in the simulation extends beyond the edge of the printed component of the antenna whereas the actual SMA stops at approximately the width of the slot (W_1).



(a)



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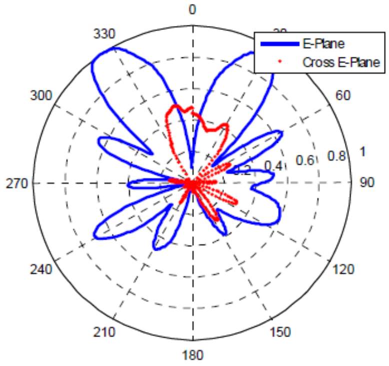
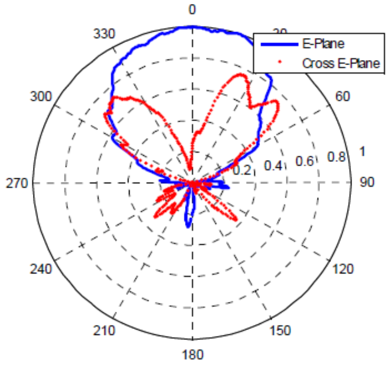
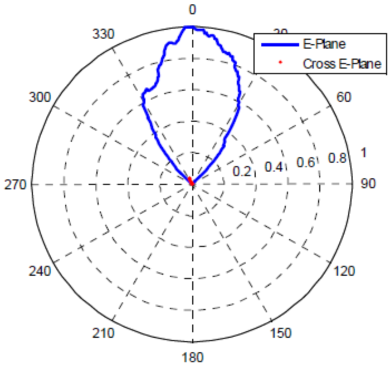


(c)



(d)



(e)

Fig. 4. Measured normalized E-plane radiation patterns at (a) 3 GHz, (b) 5 GHz, (c) 10 GHz, (d) 15 GHz, and (e) 20 GHz.

The transition of the radiation patterns from a simple doughnut pattern at the first resonance to the complicated patterns at higher harmonics indicates that this antenna must have gone through some major changes in its behavior; however, the antenna gain variation is less than 2 dB through the whole frequency band (simulation results at main lobe direction, $\theta = 60^0$), as shown in Fig. 5.

As it can be seen in Fig. 5, the antenna radiation gain is approximately flat at the antenna main lobe, while its variation is high in both azimuth and elevation angles. This behavior is due to much more uniform current distribution in the lower frequencies versus higher ones (see Fig. 6). In this figure, the poynting vector has been shown at 3 GHz, 5 GHz, 10 GHz, 15 GHz, and 20 GHz. This figure confirms the transition of the radiation patterns as described before.

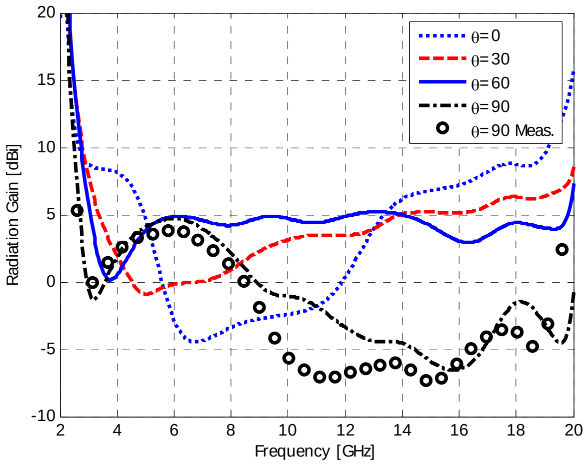
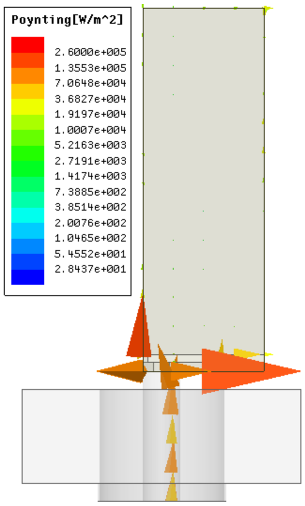
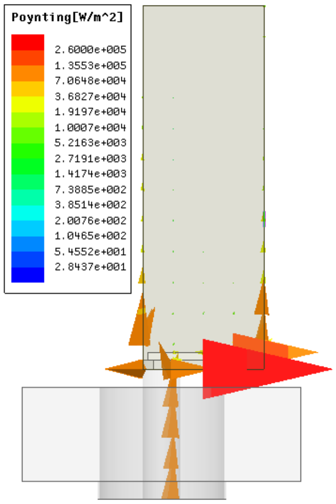


Fig. 5. Antenna gain at different elevation angles.



(a)



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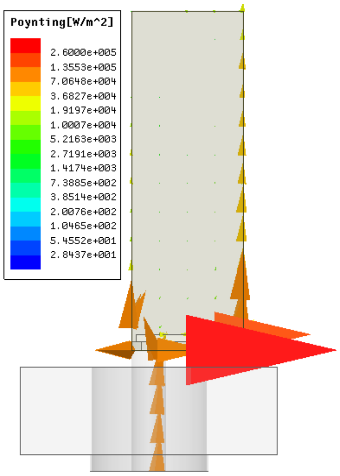

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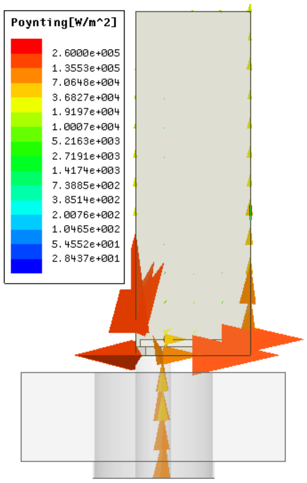

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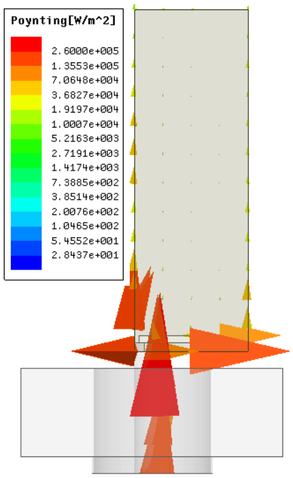

(e)

Fig. 6. Simulation results for normal pointing vector at (a) 3 GHz, (b) 5 GHz, (c) 10 GHz, (d) 15 GHz, and (e) 20 GHz.

III. CONCLUSION

A printed compact monopole antenna has been proposed and fabricated for broadband applications, while the antenna has a total size of 21 mm × 6.5 mm. The antenna composed of patch plane with etched slot on the bottom edge helps to increase the impedance bandwidth. It is observed from measurements that the proposed antenna with the optimally etched slot has achieved an impedance bandwidth of 17.0 GHz (2.56 GHz to 20 GHz), which covers the entire UWB band.

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