*Progress In Electromagnetics Research Letters, Vol. 25, 77–85, 2011*

# A COMPACT COPLANAR WAVEGUIDE FED WIDE TAPERED SLOT ULTRA-WIDEBAND ANTENNA

**P. Fei*, Y.-C. Jiao, Y. Ding, and F.-S. Zhang**

National Key Laboratory of Science and Technology on Antennas and Microwaves, Xidian University, Xi'an, Shaanxi 710071, China

**Abstract**—A novel coplanar waveguide (CPW) fed wide tapered slot antenna (WTSA) is presented in this paper. A wideband CPW-to-wide slotline (WSL) transition is employed to feed the antenna. The corrugated edge structure and broken line tapered profile are also applied in this design to achieve wideband performance, as well as maintain compact size. A prototype of the antenna is fabricated. The measured results indicate that the antenna is a good candidate for UWB detection and imaging applications.

## 1. INTRODUCTION

In recent years, ultra-wideband (UWB) technology has drawn much attention in both academic and industrial fields. One of the key issues in UWB system is to design suitable antennas that are capable of working in the desired frequency band. Many types of omnidirectional monopole antennas have been developed for short range communication [1–4]. However, in medical and military fields, for the detection applications, directional antennas are more advantageous.

Tapered slot antenna (TSA), which is first known as Vivaldi antenna in 1979 [5], is still one of the most widely used kind of end-fire wideband antennas. Compared with other kinds of antennas, the TSAs have wideband performance, moderate directivity, planer structure and low profile. Apart from the conventional linear and exponential TSAs, various TSAs with different tapered profiles, such as parabolic profile, Fermi profile and logarithmically profile, are subsequently proposed [6–8]. It is also worth to mention that several UWB TSAs and TSA arrays have been developed recently for the application in through wall imaging and biomedical detection, etc. [9, 10].

*Received 2 June 2011, Accepted 11 July 2011, Scheduled 18 July 2011*
* Corresponding author: Peng Fei (pfei@mail.xidian.edu.cn).

In this paper, a novel CPW-fed WTSA with UWB performance is presented. By employing a novel wideband CPW-to-WSL transition, the antenna is with pure single-planar configuration, which is preferable for the MMIC applications. According to the design criteria of conventional tapered slot antennas in [11], the bandwidth of TSA is generally proportional to their length and aperture. Therefore, the antenna becomes bulky when UWB performance is desired. In this design, the corrugated edge structure is implemented to minimize the size of the antenna. The electrical size of the designed antenna is $0.35\lambda \times 0.30\lambda$($\lambda$ as the vacuum wavelength operating at the lowest working frequency), smaller than the sizes in the published works [12] ($0.52\lambda \times 0.52\lambda$), [13] ($0.43\lambda \times 0.40\lambda$), [14] ($0.47\lambda \times 0.40\lambda$) and [15] ($0.36\lambda \times 0.36\lambda$). A spline composed of elliptical line and straight line is applied as the tapered profile to maintain good impedance matching in the desired frequency band.

The remainder of this paper is organized as follows: the design procedure is addressed in Section 2; in Section 3, the experimental results are illustrated and discussed; finally, a conclusion is given in Section 4.

## 2. ANTENNA DESIGN

Figure 1 shows the geometries of the proposed antennas named A1, A2 and A3. All the antennas are designed on the FR4 substrates with relative dielectric constant $\varepsilon_r = 4.4$, loss tangent $\tan\delta = 0.02$ and thickness $h = 1\,\text{mm}$. The dimensions of the substrates are all set to be $35\,\text{mm} \times 30\,\text{mm}$. A1 shown in Figure 1(a) is the original UWB WTSA. The CPW-to-WSL transition applied here is inspired by [16]. In [16], the rectangular stub works as a phase shifter, supplying a 180° phase delay to guarantee the in-phase characteristic at the end of the delay slotline. In our design, however, the rectangular stub is alternated with a fan-shaped one for the purpose of better impedance matching and less radiation loss. In the radiation part, elliptical tapered profile is employed to smooth the field variation from the transition part. High Frequency Structure Simulator (HFSS) is used to predict the behavior of the antenna. The simulated return loss performance is shown in Figure 2. The better than 10 dB return loss band extends from 4.3 GHz to 11.0 GHz. The lower limitation agrees with the prediction in [11]; the higher limitation, on the other hand, is limited by the nature of CPW-to-WSL transition.

In order to extend the operating frequency band of the antenna as well as keep the compact size, corrugated edge structure are introduced in A2. As shown in Figure 1(b), three pairs of slots are horizontally

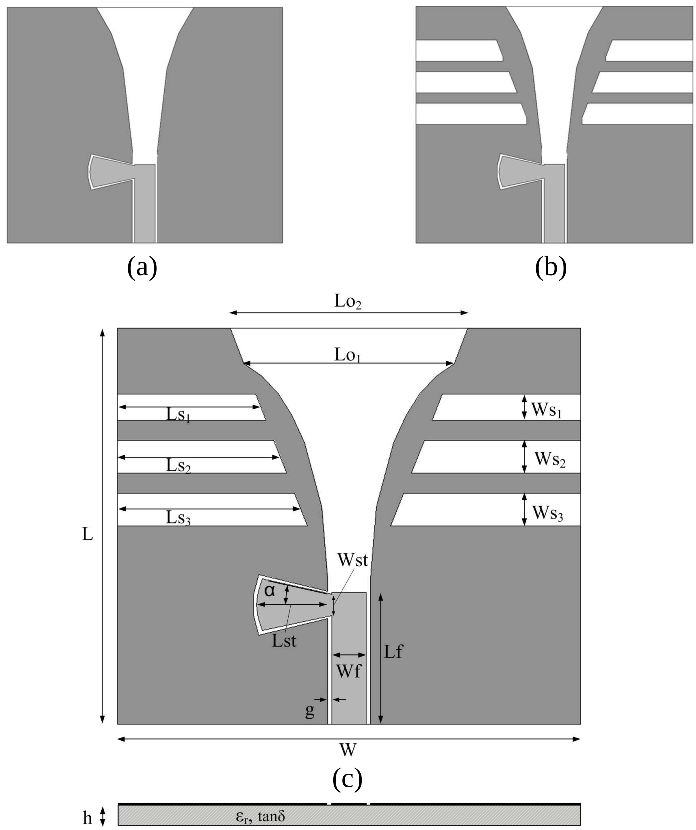


**Figure 1.** The geometry of the proposed antennas. (a) A1; (b) A2; (c) A3.

loaded on the outer side of the antenna arms. The lengths of the slots are chosen to be approximately a sixth of the 4 GHz wavelength in the free space. Furthermore, these slots are designed with different length in order to decrease the influence on the flare slot. The slots are used to change the current flow on the arms. By introducing the slots, the current path on the arms are lengthened, which equals to the enlargement of antenna aperture. Apart from that, the etched slots will also introduce additional resonance mode at corresponding frequencies. It is predictable that the lower end of the working band will be extended. Figure 2 shows the return loss performance of A2. It is clear that compared with the performance of A1, the low end band cutoff of A2 is shifted from 4.3 GHz to around 3 GHz. However, the introduction

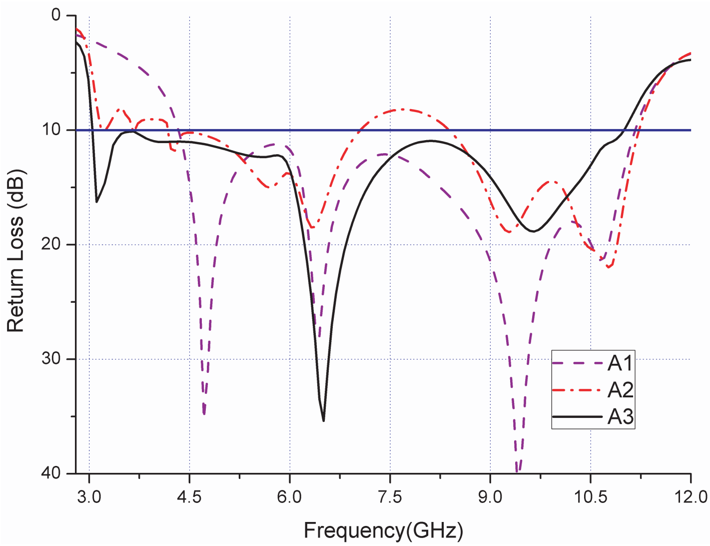


**Figure 2.** The return loss performance of A1, A2 and A3.

of slots also degrades the impedance matching. Mismatching behaviors are observable around the frequencies of 3.5 GHz and 8 GHz.

To further improve the impedance matching performance, the profile of the antenna is tried to be modified. After several attempts, the hybrid broken line profile composed of elliptical line and straight line is proved effective and is applied in A3. Figure 1(c) shows the geometry of A3. Figure 2 shows the return loss performance of A3. As illustrated in Figure 2, compared with that of A2, the return loss performance of A3 is improved in most of the operating frequency band, except a bandwidth loss of about 0.2 GHz in the high end cutoff. After fine tuning and optimization, the final optimal dimension values are obtained as follows: $W = 35\,\mathrm{mm}$, $L = 30\,\mathrm{mm}$, $Ws_1 = 2\,\mathrm{mm}$, $Ws_2 = 2.5\,\mathrm{mm}$, $Ws_3 = 2.5\,\mathrm{mm}$, $Ls_1 = 10\,\mathrm{mm}$, $Ls_2 = 11.2\,\mathrm{mm}$, $Ls_3 = 12.7\,\mathrm{mm}$, $Lo_1 = 15.9\,\mathrm{mm}$, $Lo_2 = 18\,\mathrm{mm}$, $Wst = 1.6\,\mathrm{mm}$, $Lst = 6\,\mathrm{mm}$, $Wf = 2.6\,\mathrm{mm}$, $Lf = 10\,\mathrm{mm}$, $g = 0.3\,\mathrm{mm}$, $\alpha = 12.8^\circ$.

## 3. RESULTS AND DISCUSSIONS

In order to validate the proposed design procedure, a prototype of A3 is fabricated as shown in Figure 3. A SMA connector is used to feed the antenna. The comparison between the simulated and measured return losses of A3 is illustrated in Figure 4. As demonstrated in this figure,

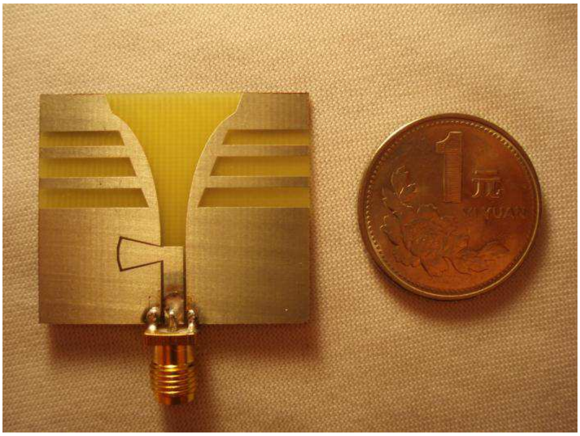


**Figure 3.** Photograph of the proposed antenna.

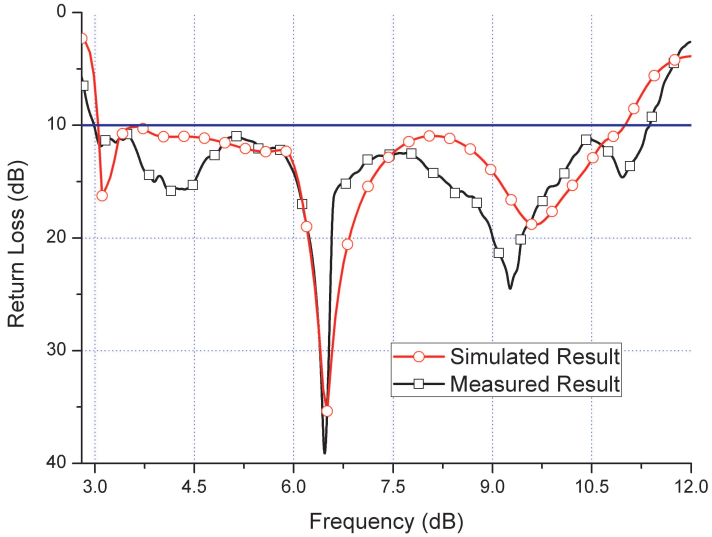


**Figure 4.** The simulated and measured return loss performance of the proposed antenna.

the measured operating band in term of better than 10 dB return loss is achieved over 3.0 GHz to 11.4 GHz. The simulated and measured results show agreed tendency in the low end and high end cut off. The differences between the two curves may be attributed to the inaccurate simulation, the irregular soldering or the inappropriate quality of the

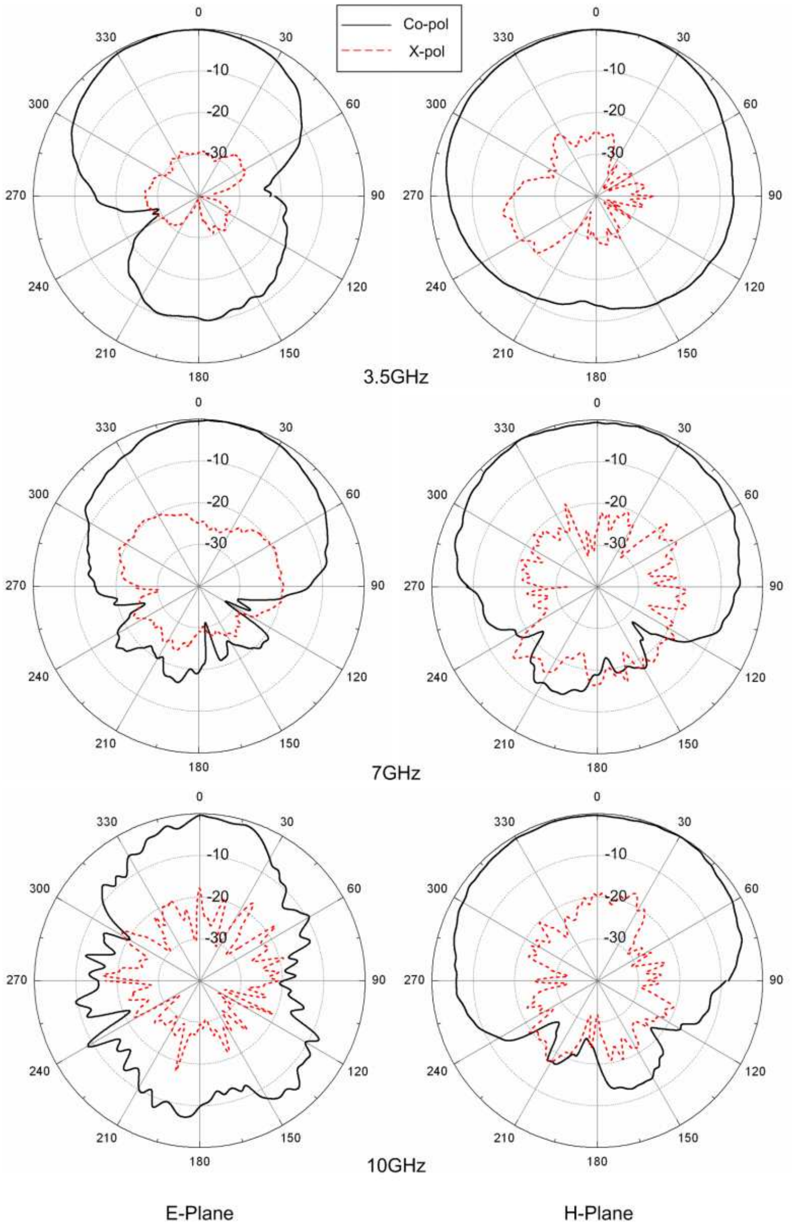


**Figure 5.** $E$-plane and $H$-plane radiation patterns of the proposed antenna at 3.5 GHz, 7 GHz and 10 GHz. (unit: dB).

microwave substrate.

The measured radiation patterns at 3.5 GHz, 7 GHz and 10 GHz are shown in Figure 5. It is obviously from the figure that the cross-polarization levels are all below $-18$ dB. The antenna shows good end-fire radiation property in the entire band. Generally, the $E$-plane patterns show narrower HPBW while the $H$-plane patterns exhibit better stability, which is reasonably in accordance with the nature of TSA. Besides, the antenna shows better than 10 dB front-back ratio at the measured frequencies except the little degraded performance in the 10 GHz $E$-plane pattern.

Figure 6 plots the realized gain variation versus frequency. According to the figure, the realized gain achieves the peak value of 7.4 dB as frequency increases to 9 GHz, and drops after that. The decline of the gain in high frequencies is possibly due to the dielectric loss and the surface-wave propagation along the antenna.

The time domain characteristic of the fabricated antenna is also tested. Two prototypes are positioned side by side with a distance 30 cm and the group delay is measured by a VNA. As shown in Figure 7, preferred stable group delay performance is observable with a variation less than $\pm 1.2$ ns in the desired band, indicating that a transmitted signal will not be seriously distorted by the proposed antenna.

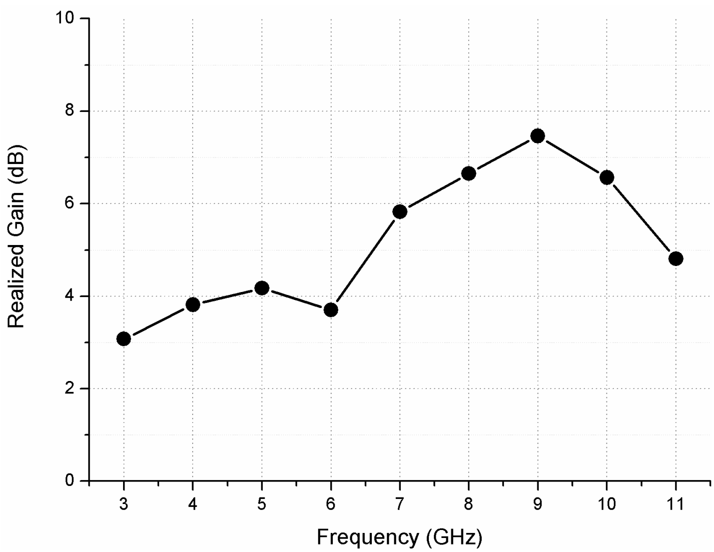


**Figure 6.** Realized gain variation versus frequency.

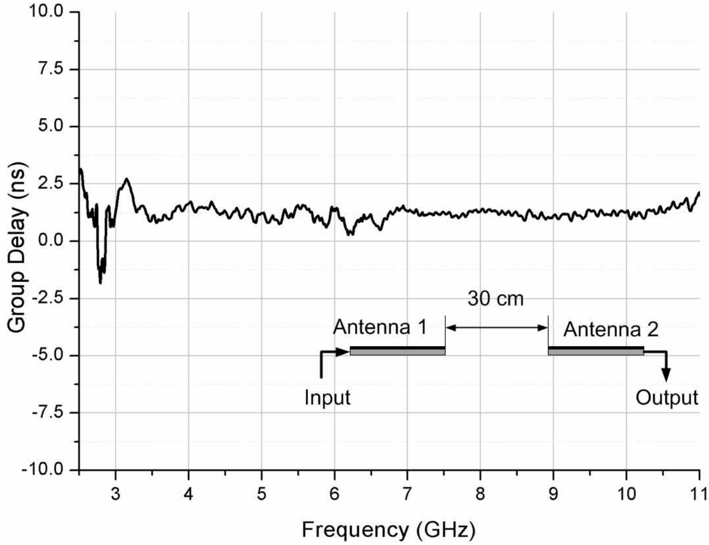


**Figure 7.** Group delay performance of the fabricated antenna.

## 4. CONCLUSION

In this paper, a compact CPW-fed wide tapered slot UWB antenna is designed. The antenna is investigated numerically and experimentally for its impedance matching properties, radiation performances and time domain characteristics. The results demonstrate that the proposed antenna has wide operating band, reliable directional radiation characteristics, moderate gain and small signal transmission distortion. All this properties make it a good candidate for UWB detection and imaging applications.

## REFERENCES


1. Zaker, R. and A. Abdipour, "A very compact ultra wideband printed omnidirectional monopole antenna," *IEEE Antennas Wireless Propagat. Lett.*, Vol. 9, 471–473, 2010.
2. Lin, S., R.-N. Cai, G.-L. Huang, and J.-X. Wang, "A miniature UWB semi-circle monopole printed antenna," *Progress In Electromagnetics Research Letters*, Vol. 23, 157–163, 2011.
3. Liu, J., S. Zhong, and K. P. Esselle, "A printed elliptical monopole antenna with modified feeding structure for bandwidth enhancement," *IEEE Trans. Antennas Propag.*, Vol. 59, No. 2, 667–670, Feb. 2011.

4. Yang, X.-S. and J.-H. Dou, "Planar multi-trapezoidal ultra-wideband antenna and its parametric analysis," *Progress In Electromagnetics Research Letters*, Vol. 12, 49–58, 2009.
5. Gibson, P. J., "The Vivaldi aerial," *Proc. 9th Eur. Microwave Conf.*, 101–105, Brighton, U.K., Jun. 1979.
6. Mokraoui, A. and R. Aksas, "Scattered field improvement of tapered slot antenna using a parabolic-shaped slot," *Microw. and Opt. Technol. Lett.*, Vol. 44, No. 4, 331–334, 2005.
7. Sugawara, S., Y. Maita, K. Adachi, K. Mori, and K. Mizuno, "A mm-wave tapered slot antenna with improved radiation pattern," *IEEE MTT Int. Microwave Symp.*, 959–962, Denver, CO, Jun. 1997.
8. Wang, N.-B., Y.-C. Jiao, Y. Song, L. Zhang, and F. S. Zhang, "A microstrip-fed logarithmically tapered slot antenna for wideband applications," *Journal of Electromagnetic Waves and Applications*, Vol. 23, No. 10, 1335–1344, 2009.
9. Yang, Y., Y. Wang, and A. E. Fathy, "Design of compact Vivaldi antenna arrays for UWB see through wall applications," *Progress In Electromagnetics Research*, Vol. 82, 401–418, 2008.
10. Lazaro, A., R. Villarino, and D. Girbau, "Design of tapered slot Vivaldi antenna for UWB breast cancer detection," *Microw. and Opt. Technol. Lett.*, Vol. 53, No. 3, 639–643, 2011.
11. Yngvesson, K. S., "The tapered slot antenna — A new integrated element for millimeter-wave application," *IEEE Trans. Microw. Theory Tech.*, Vol. 37, No. 2, 365–374, Feb. 1989.
12. Abbosh, A. M., H. K. Kan, and M. E. Bialkowski, "Design of compact directive Ultra wideband antipodal antenna," *Microw. and Opt. Technol. Lett.*, Vol. 48, No. 12, 2448–2450, 2006.
13. Hood, A. Z., T. Karacolak, and E. Topsakal, "A small antipodal Vivaldi antenna for ultra wide-band applications," *IEEE Antennas Wireless Propagat. Lett.*, Vol. 7, 656–660, 2008
14. Song, Y., Y. C. Jiao, T. L. Zhang, G. Zhao, and F. S. Zhang, "Small tapered slot antenna with a band-notched function for wireless applications," *Progress In Electromagnetics Research Letters*, Vol. 10, 97–105, 2009.
15. Wang, Y., A. Bakar, and M. Bialkowski, "Reduced-size UWB uniplanar tapered slot antennas without and with corrugations," *Microw. and Opt. Technol. Lett.*, Vol. 53, No. 4, 830–836, 2011.
16. Kim, H. and C. W. Jung, "Ultra-wideband end fire directional tapered slot antenna using CPW to wide-slot transition," *Electron. Lett.*, Vol. 46, No. 17, 1183–1185, 2010.