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Bandwidth-Enhanced Double-Slot TSA with Y-Shaped Corrugated Edges

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Abstract—In this paper, a novel bandwidth-enhanced ultra-wideband (UWB) tapered slot antenna, with Y-shaped corrugated edges, is proposed. In the double-slot structure, the two slots are separated by a V-shaped metal surface with straight edges, which is beneficial for improving the directivity of the antenna. Meanwhile, an exponential Y-shaped corrugated edge is designed. This novel corrugated edge not only can improve the impedance bandwidth of the antenna by extending the path of the current, but also can enhance the directivity by concentrating the energy near the tapered slot. The proposed antenna provides 167% fractional bandwidth from 2.5 GHz to 28 GHz. The gain of the antenna is more than 10 dB from 3.5 GHz to 25 GHz and more than 8 dB in the whole operating band.

1. INTRODUCTION

In recent years, with the rapid development of wireless communication systems, broadband and high gain have become two important factors in the design of UWB antennas [1–3]. Tapered slot antenna (TSA) is one of the best antennas used in ultra-wideband technology, which was first proposed by Hines et al. in 1953 [4], and it is widely used in radio astronomy, ground penetrating radar, ultra-wideband communication, ultra-wideband imaging and other fields [5–7]. TSA has the advantages of simple structure, easy processing and good port matching. Its profile usually has the following forms: exponentially tapered slot (ETSA), linearly tapered slot (LTSA) and constant width slot (CWSA) [8]. CWSA has the highest gain and narrowest beam, but its side-lobe level is also the highest. ETSA has minimum side-lobe level, but the gain and directivity of a conventional ETSA are low.

In a conventional TSA, in order to ensure that the standing wave energy in the slot line is effectively radiated out, a certain extra width is required outside the tapered slot. The use of corrugated edges can help to reduce the antenna size. Paper [9] analyses various corrugated edges and finds that rectangle corrugated edges are the best. Other methods such as designing a new feed network [10] or changing the tapered slot structure [11] can also improve the bandwidth. However, the improvement of the bandwidth is limited. Using an array of ETSA [12] is a conventional way to improve the gain and obtain high directivity, but it is costly and complicated. Other methods such as using conductor strip gratings [13] or a photonic band gap structure [14] are also complicated because of the need to optimise the parameters of the metal strips and holes. Paper [15] proposes a double-slot Vivaldi antenna. Its impedance bandwidth is significantly improved, and the fractional bandwidth of the antenna reaches 142%. But the bandwidth of the gain more than 10 dB is only from 5 GHz to 15 GHz. The paper [16] is based on double-slot Vivaldi antenna, adding zero index materials to improve the directivity, which is not only complicated, but the improvement of the gain embodied only in 5–9 GHz.

In this paper, a bandwidth-enhanced ultra-wideband (UWB) tapered slot antenna, with Y-shaped corrugated edges, is proposed. On the one hand, the impedance bandwidth is improved by extending the path of the current. On the other hand, the directivity of the antenna is enhanced by concentrating

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the energy near the tapered slot. The proposed antenna provides 167% fractional bandwidth from 2.5 GHz to 28 GHz. The gain of the proposed antenna is more than 10 dB from 3.5 GHz to 25 GHz and more than 8 dB at the whole operating band.

2. ANTENNA DESIGN AND SIMULATION

The configurations of a conventional TSA and a double-slot TSA without Y-shaped corrugated edge are shown in Figure 1(a). The configurations of the proposed antenna and T-junction power divider are shown in Figure 1(b). By using the double-slot structure, the gain and directivity of the double-slot TSA is significantly improved compared to the single-slot TSA [15]. With the Y-shaped corrugated edges, the path of the surface current is extended. And the Y-shaped corrugated edges make the surface current near the tapered slot, which is beneficial for improving the gain of the antenna. The Y-shaped corrugated edges use exponential curve to expand, which is beneficial for concentrating the energy. The curve function of the Y-shaped corrugated edges is obtained as follows:

$$y = \frac{W}{4} + 0.25 * \exp\left(In\left(\frac{W}{0.5}\right) * \frac{x}{L}\right) /2\ ) \tag{1}$$

The substrates used here are F4B with 2.65 permittivity, 0.5 mm thickness, and 0.003 loss tangent.

The two slots of the antenna are excited in uniform amplitude and phase by a T-junction power divider. Figure 2(a) shows the geometry of a conventional T-junction power divider. The discontinuity

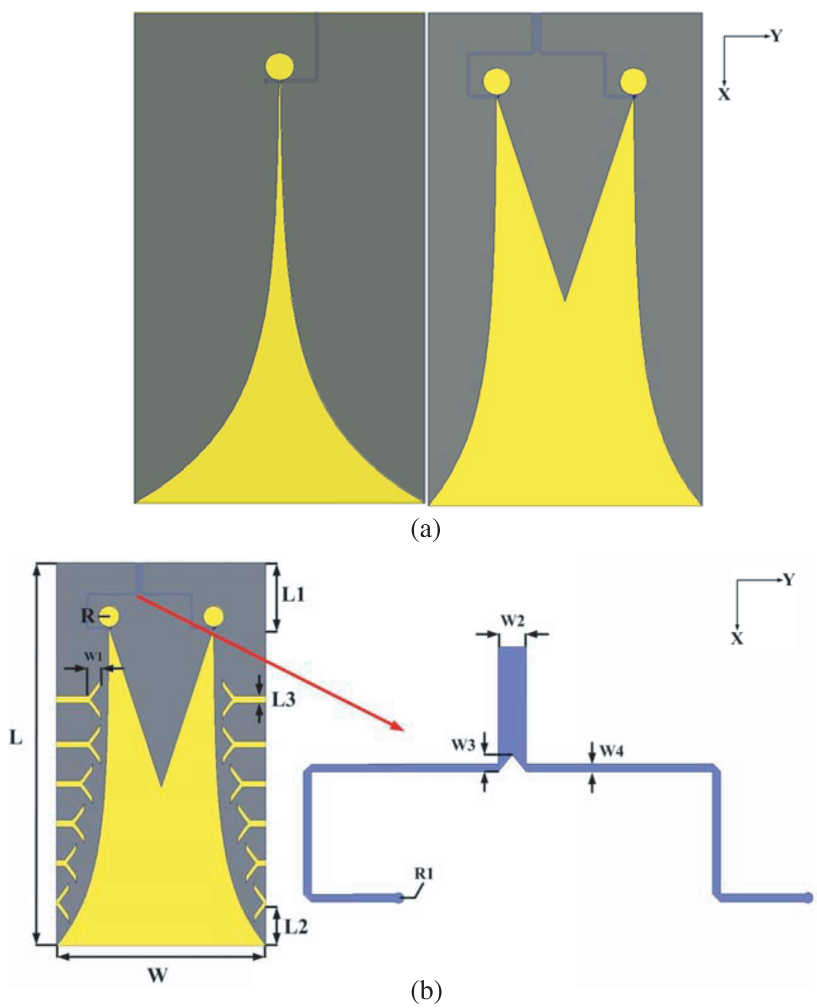


Figure 1. Geometry of the proposed antenna and T-junction power divider.

of this structure is severe, which can produce the stray field or high modes in the power distribution. The V-shaped slot of the power divider can relieve this problem. Figure 3 shows the comparison of the reflection coefficient, and the reflected energy of the input-port is reduced with the use of the V-shaped slot. Figure 4 shows the amplitude and phase unbalance of the two T-junction power dividers. It can be seen that the proposed T-junction power divider has better consistency of the amplitude and phase.

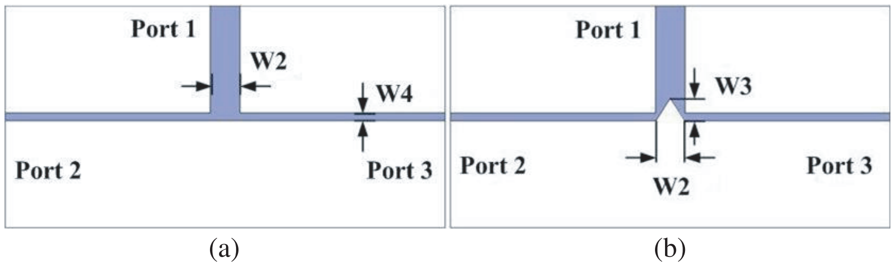


Figure 2. Geometry of the T-junction power divider. (a) Conventional, (b) with V-shaped slot.

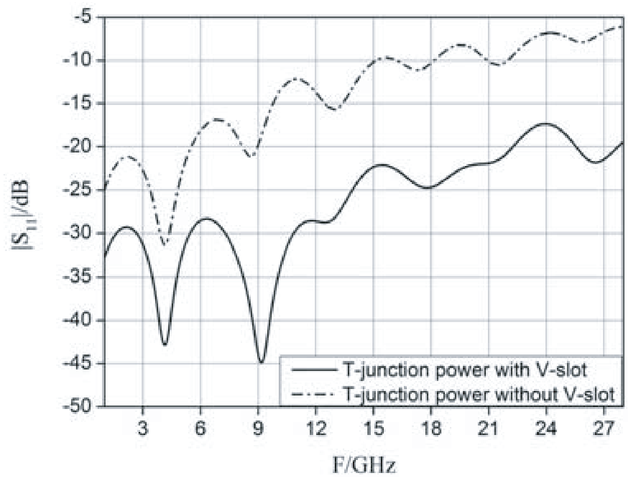


Figure 3. Comparison of the simulated reflection coefficient.

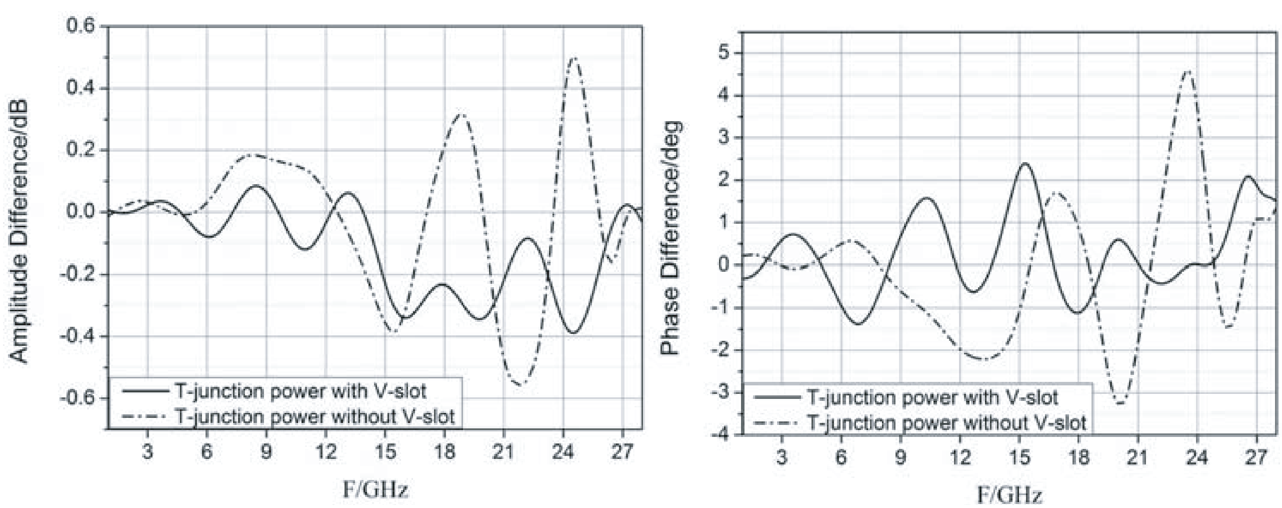


Figure 4. Amplitude and phase difference.

Table 1. Optimized parameter values of the proposed antenna (mm).

W	$W1$	$W2$	$W3$	$W4$	L	$L1$	$L2$	$L3$	R	$R1$
80	5	2.73	1.675	0.75	145	25	15	2.5	4	0.5

The terminal short circuit of the microstrip in the transition from microstrip to tapered slot line is realized by using metal via holes. This direct short-circuit method not only has the wide conversion bandwidth mentioned in paper [17], but also can avoid a large amount of surface wave excited by circular or sector open-stub at high frequency band. The detailed parameter values are shown in Table 1.

Figure 5 shows the simulated reflection coefficient of the proposed TSA, the double-slot TSA without Y-shaped corrugated edge and the conventional TSA. The reflection coefficient is simulated by ANSYS 17.0. Seen from the results, the proposed antenna provides 167% fractional bandwidth from 2.5 Hz to 28 GHz, which is the widest among them. In Figure 6, the gain of the proposed antenna is more than 10 dB from 3.5 GHz to 25 GHz and more than 8 dB at the whole operating band.

Figure 7 shows the comparison of radiation patterns between the proposed antenna and conventional

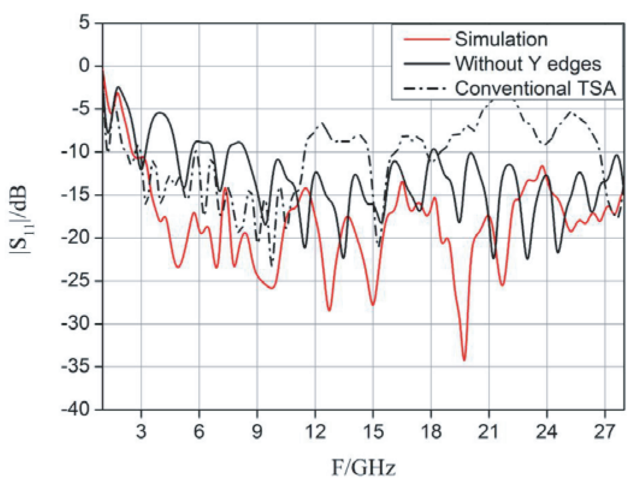


Figure 5. Comparison of the simulated reflection coefficient.

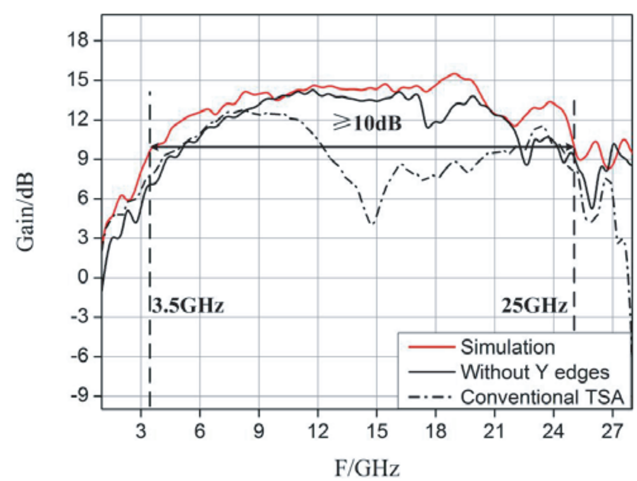
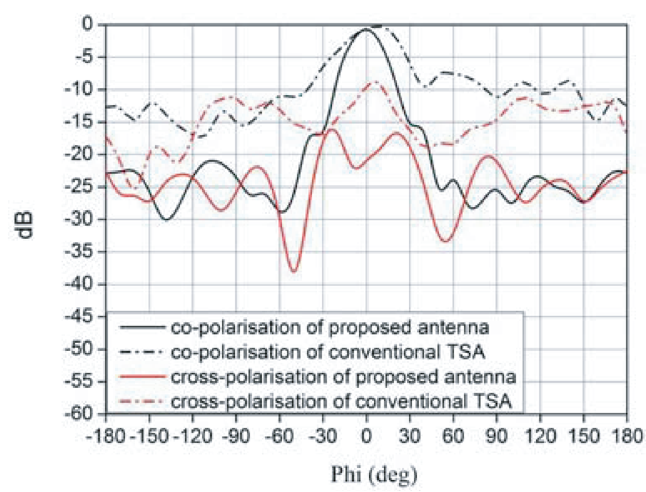
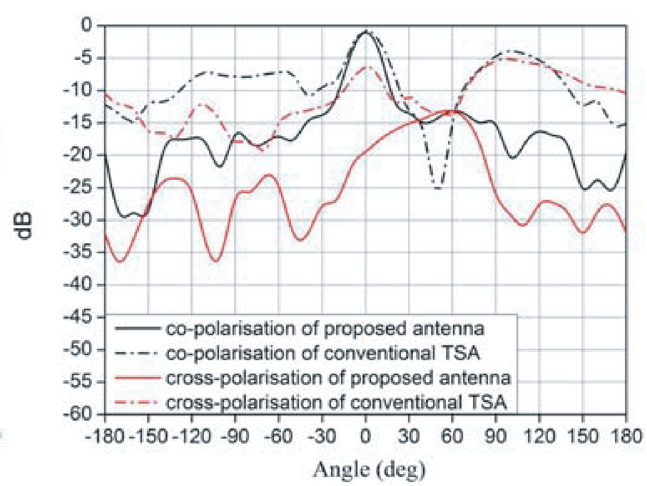


Figure 6. Comparison of the gain.



(a)



(b)

Figure 7. Comparison of the radiation patterns at 15 GHz. (a) E-plane, (b) H-plane.

TSA in the E- and H-planes at the center frequency. The co-polarisation and cross-polarisation of the proposed antenna are better than that of the conventional TSA. Seen from Figure 8, the power loss of the double-slot TSA without Y-shaped corrugated edge at outer edge is more severe than that of the proposed antenna. In Figure 9, the aperture field of the proposed TSA is closer to plane wave than that of the conventional TSA.

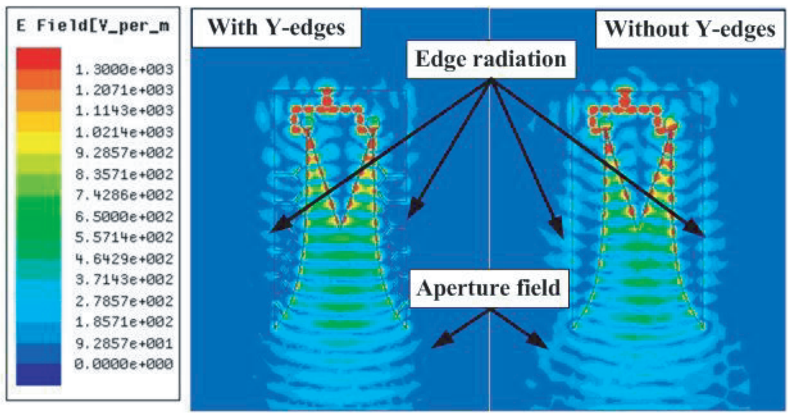


Figure 8. Simulated E-field distributions across slot apertures of antennas at 15 GHz.

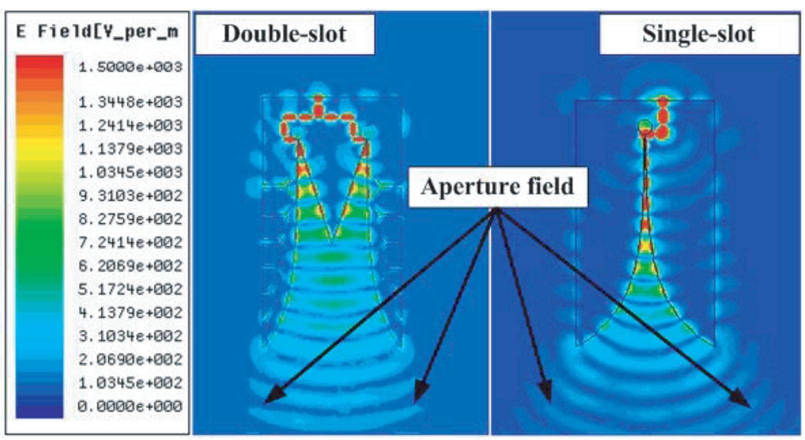
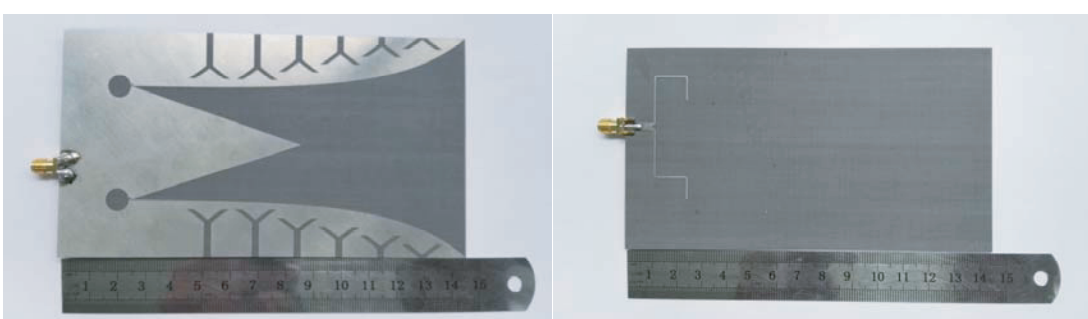


Figure 9. Simulated E-field distributions across slot apertures of antennas at 10 GHz.



(a) (b)

Figure 10. The fabricated prototype of the proposed antenna. (a) Top view, (b) bottom view.

3. MEASUREMENT OF THE ANTENNA

Figure 10 shows the top and bottom views of the fabricated antenna. The reflection coefficient is measured by AV3672C Vector Network Analyzer. The measurement of the antenna in the microwave anechoic chamber is shown in Figure 11. The comparison of simulation and measurement results of the proposed antenna is depicted in Figure 12 and Figure 13. Seen from the results, the measured results agree well with the simulated ones. The directivity of the antenna is pretty good. Figure 14 shows

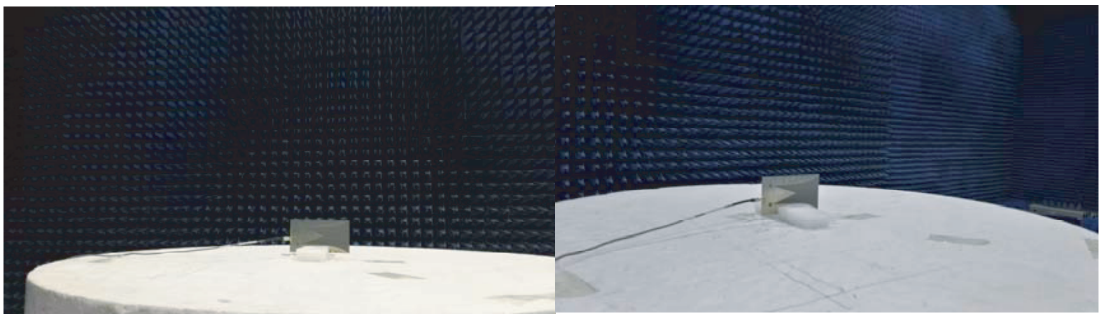


Figure 11. Measurement of the antenna in the microwave anechoic chamber.

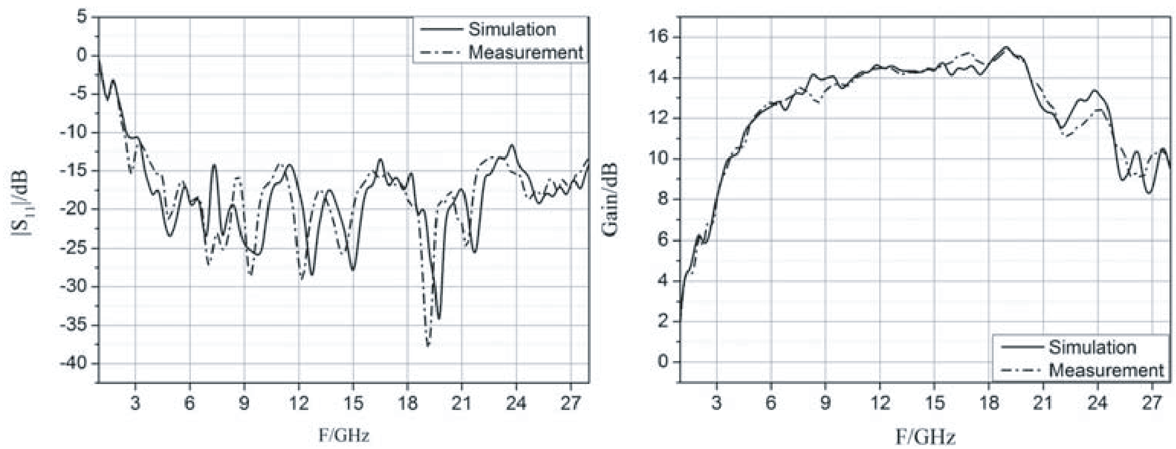
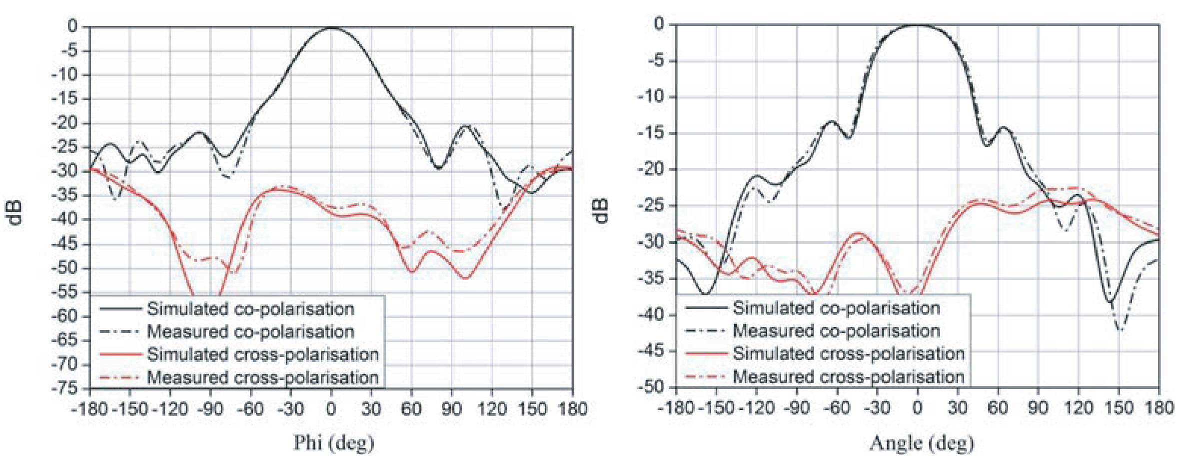


Figure 12. The Measurement and simulation of the reflection coefficient and the gain.



(a) (b)

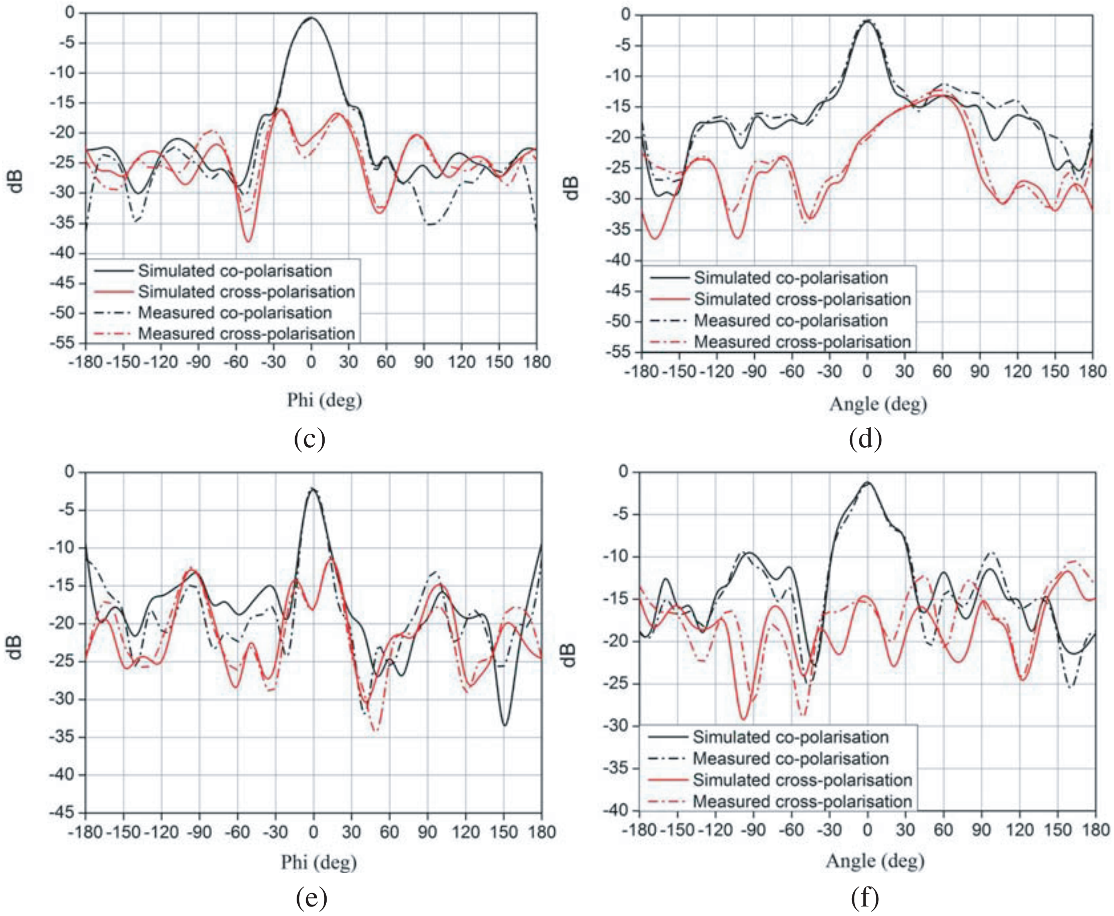


Figure 13. The measurement and simulation of the radiation patterns. (a) E-plane at 5 GHz, (b) H-plane at 5 GHz, (c) E-plane at 15 GHz, (d) H-plane at 15 GHz, (e) E-plane at 25 GHz, (f) H-plane at 25 GHz.

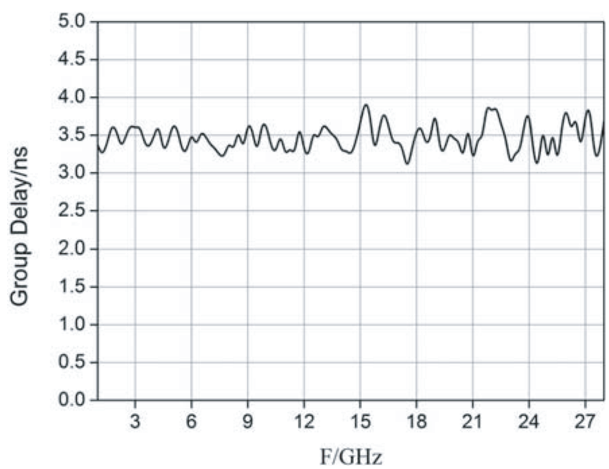


Figure 14. Measured group delay of the proposed antenna.

the measured group delay of two identical antennas which are placed face to face. The group delay is around 3.5 ns in the working band with its variation less than 0.5 ns. The small variation indicates that the antenna cannot cause serious distortion in the pulse signal transmission.

4. CONCLUSION

In this paper, a new type of double-slot TSA with exponential Y-shaped corrugated edge is proposed. The antenna is excited by a T-junction power divider. The proposed antenna provides 167% fractional bandwidth from 2.5 GHz to 28 GHz. The gain of the proposed antenna is more than 10 dB from 3.5 GHz to 25 GHz and more than 8 dB at the whole operating band. This antenna has the broad application prospect and practical values at the UWB technology field.

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