Progress In Electromagnetics Research M, Vol. 2, 37–46, 2008

A BEVELED AND SLOT-LOADED PLANAR BOW-TIE ANTENNA FOR UWB APPLICATION

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Abstract—A novel planar bow-tie aperture antenna is proposed for ultra-wide band (UWB) application in this paper. Beveling technique is employed to increase the impedance bandwidth, and slot loading is introduced to improve the impedance matching. The measured impedance bandwidth is from 2.7 to 12 GHz for $S_{11} < -10$ dB, proving the effectiveness of these two techniques. The measured radiation patterns are relatively stable almost over the entire ultra-wide band of 3.1 to 10.6 GHz with low cross-polarization levels of at least -10 dB. Moreover, the proposed antenna maintains the advantages of ease of fabrication and relatively small electrical size.

1. INTRODUCTION

Ultra-wide band communication systems have recently attracted considerable research effort for their potential advantages of high data rate and low energy density. As one of the key components of an UWB system, antennas with ultra-wide impedance band and stable radiation patterns are required urgently. Many candidates are proposed and analyzed [1–23], such as circular disc monopole antenna [1], rectangular aperture antenna [2], tapered ring slot antenna [3], etc. Bow-tie antenna is a good candidate of UWB antennas for its well-known multi-band or wideband radiation performance [4]. A lot of these antennas are proposed in recent years [5–11]. But not all of them meet the demands of real UWB systems. The radiation patterns of the antenna in [5] are not stable over the entire operation band. The cross-polarization level of the antenna in [6] is high. The antenna in [7] is not easy to be integrated. The antenna in [8] has a wide impedance bandwidth while maintaining a simple structure and a small size. But only the radiation patterns at 5.6 GHz and 8.1 GHz are given in the paper. The impedance bandwidth of the antenna in [11] is widened the by adding two small sectors and changing sharp corners into round corners. However, the antenna does not operate in UWB band allocated by FCC. These antennas need improvements to be used in real UWB systems.

In this paper, a novel planar bow-tie aperture antenna is proposed. The commercial software Ansoft HFSS is employed for simulation. Beveling technique [14–17] is employed to increase the impedance bandwidth and slot loading [18–20] is introduced to improve the impedance matching. The proposed antenna is successfully fabricated. Experiments on the return loss and radiation patterns are carried out. The measured return loss is below -10 dB from 2.7 to 12 GHz. Both its E and H plane radiation patterns are relatively stable almost over the entire ultra-wide band of 3.1 to 10.6 GHz allocated by FCC with low cross-polarization levels of at least -10 dB, excelling the antennas in [5] and [6]. Due to the coplanar waveguide (CPW) feed, the proposed antenna preserves the advantages of convenience of impedance controlling and ease of integration. Meanwhile, the antenna keeps a relatively small electrical size of $0.85\lambda \times 0.5\lambda$ (λ is the wavelength at 3.1 GHz).

2. ANTENNA CONFIGURATION

The geometry of the proposed antenna is shown in Fig. 1. Unlike the conventional bow-tie antennas, each arm of the proposed antenna is extended with a triangular aperture to increase the bandwidth of the antenna. The sharp corners of the aperture are smoothed by adding appropriate triangle patches in order to mitigate the current reflection. Four narrow slots are cut to introduce reactance load and rectify the current distributions. A CPW-to-CPW transition is used to transform

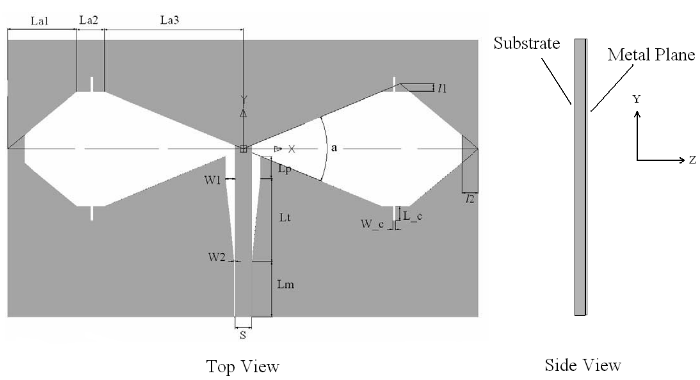


Figure 1. Geometry of the proposed antenna.

the input impedance of the antenna to 50 Ω. The antenna is realized on a substrate with $\varepsilon_r = 3$, $\tan\delta = 0.001$ and thickness $h = 1$ mm. The substrate does not obviously effect the antenna performance as the ground is absent. Table 1 lists the dimensions of the proposed antenna.

Table 1. Dimensions of the proposed antenna.

$La1$	25 mm	Lp	4 mm
$La2$	5 mm	Lt	15 mm
$La3$	12.5 mm	Lm	10 mm
$l1$	3 mm	α	45 deg
$l2$	3 mm	s	3 mm
$W1$	1.7 mm	W_c	0.5 mm
$W2$	0.2 mm	L_c	2.7 mm

3. DESIGN AND OPTIMIZATION PROCEDURES

The original type of bow-tie aperture antenna is shown in Fig. 2(a), denoted as Prototype I. A CPW-to-CPW transition feed is used for the convenience of impedance controlling and the ease of integration with other devices. As the center angle α and the length of bow-tie arms determine the lower limit of the operation frequencies [24], α and the total length of $La1$, $La2$ and $La3$ are chosen to make the antenna resonant at 3.1 GHz. The return loss is simulated and shown in Fig. 3. Unfortunately it crosses over the −10 dB line in the frequency bands of 5.3–6 GHz and 7.2–8.4 GHz.

To improve the impedance matching in the aforementioned frequency bands, beveling technique is employed. This technique is used to smooth the sharp corners of the structure in order to mitigate the reflection of the surface current, thus adjusting the antenna impedance and reducing the return loss. Triangle apertures are jointed with the bow-tie arms to smooth the sharp turnings of Prototype I. But the total length of the aperture remains the same. The modified antenna structure is shown in Fig. 2(b) and denoted as Prototype II. The simulated return loss is also given in Fig. 3. It is wonderfully reduced below −10 dB almost over the entire operation band of 3.1–10.6 GHz except at the frequencies around 5.8 GHz (5.6–6 GHz).

Similarly, the sharp corners of Prototype II are smoothed by adding appropriate triangle patches, as shown in Fig. 2(c). This antenna structure is denoted as Prototype III. The return loss is also simulated and given in Fig. 3. It meets the bandwidth requirement of UWB very well.

In order to make the return loss smaller, four narrow slots are cut

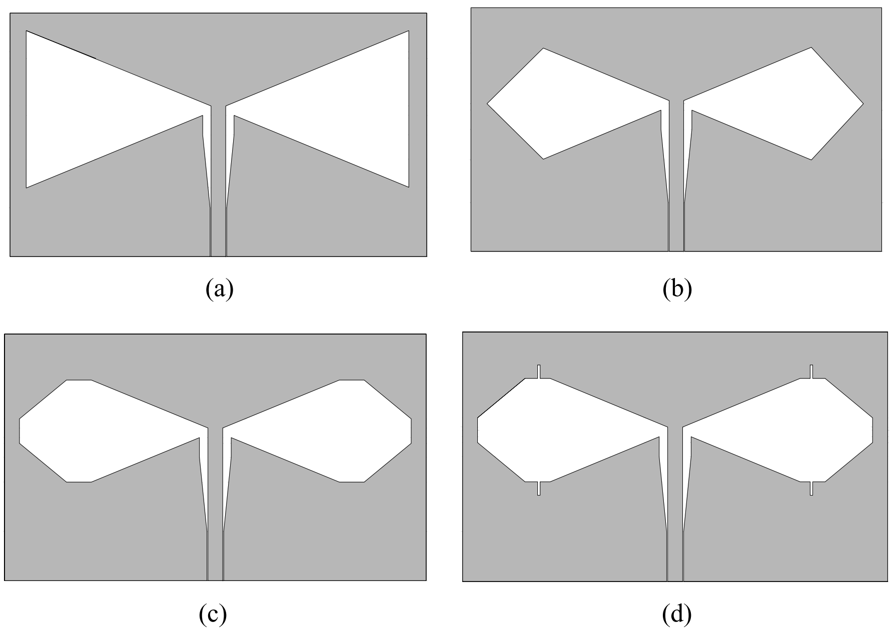


Figure 2. Different antenna structures. (a) Prototype I, (b) Prototype II, (c) Prototype III, and (d) proposed antenna.

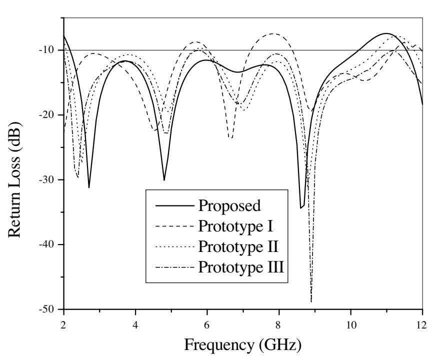


Figure 3. Return loss of different antenna structures.

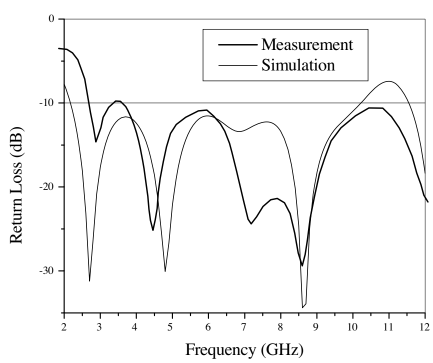


Figure 4. Measured and simulated return loss.

to introduce reactance loading as shown in Fig. 2(d). The simulation results prove that the slots benefit the impedance matching for −2 dB at most frequencies except the high frequencies above 10.4 GHz. Considering the dielectric loss at high frequencies, the measured return loss will be lower than the simulated result at the frequencies around 10.4 GHz. The experimental results shown in Section 4 validate this. The impedance bandwidth of the proposed antenna perfectly covers the band from 3.1 to 10.6 GHz.

4. MEASUREMENT RESULTS AND DISCUSSION

4.1. Impedance Bandwidth

The return loss of the proposed antenna is measured with Agilent N5230A and compared with the simulated result in Fig. 4. A good agreement is achieved. The −10 dB return loss impedance bandwidth successfully covers the entire UWB band of 3.1–10.6 GHz.

4.2. Field Distributions and Radiation Patterns

The radiation patterns at 3, 5, 7.5 and 10 GHz are measured inside an anechoic chamber and plotted in Figs. 5–8, respectively. They are very close to the radiation patterns of a traditional dipole, obviously due to the dipole-like bow-tie aperture.

As the radiation of an aperture antenna is decided by the field distribution in the aperture, the electric field distributions at different

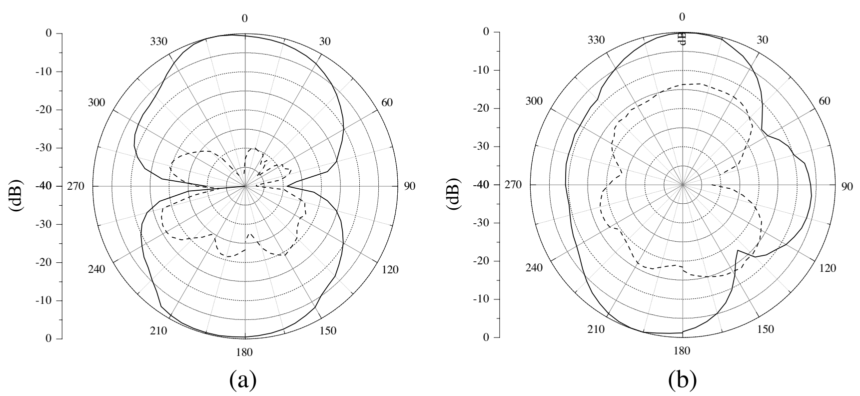
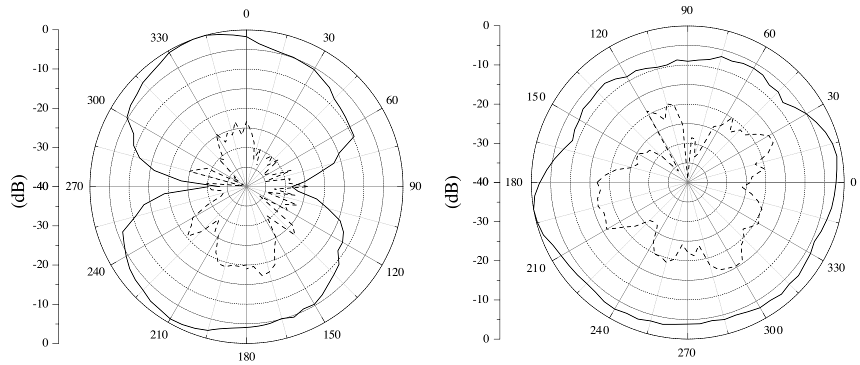
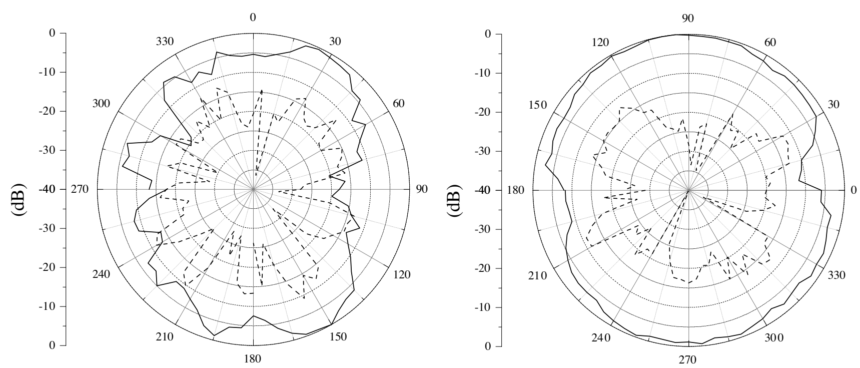


Figure 5. Measured co-(solid line) and cross-(dash line) polarization radiation patterns at 3 GHz. (a) E-plane (yz-plane) patterns, and (b) H-plane (xz-plane) patterns.



(a) (b)

Figure 6. Measured co-(solid line) and cross-(dash line) polarization radiation patterns at 5 GHz. (a) *E*-plane (*yz*-plane) patterns, and (b) *H*-plane (*xz*-plane) patterns.



(a) (b)

Figure 7. Measured co-(solid line) and cross-(dash line) polarization radiation patterns at 7.5 GHz. (a) *E*-plane (*yz*-plane) patterns, and (b) *H*-plane (*xz*-plane) patterns.

frequencies are shown in Fig. 9. The field distributions at 3 and 5 GHz are almost along the $+y$ and $-y$ directions respectively, so the cross-polarization levels are low at these frequencies. The E-plane (yz-plane) co-polarization patterns are bidirectional and H-plane (xz-plane) co-polarization pattern is omni-directional (3 GHz) or nearly omni-directional (5 GHz), like a traditional dipole. When the frequency rises to 7.5 GHz, the direction of the electrical field in the aperture

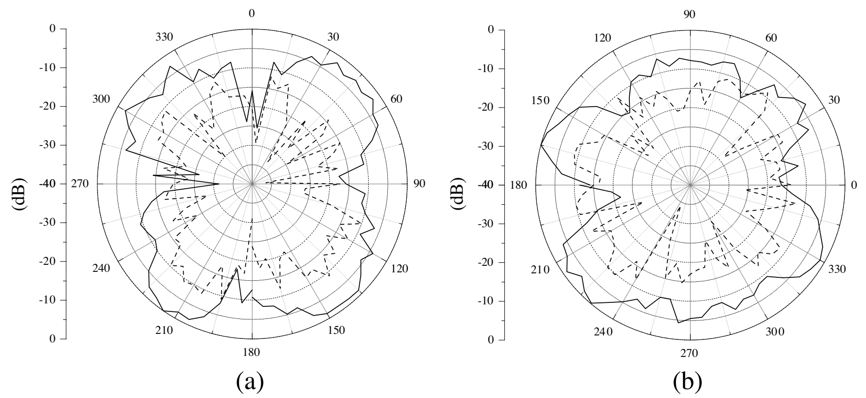


Figure 8. Measured co-(solid line) and cross-(dash line) polarization radiation patterns at 10 GHz. (a) E-plane (yz-plane) patterns, and (b) H-plane (xz-plane) patterns.

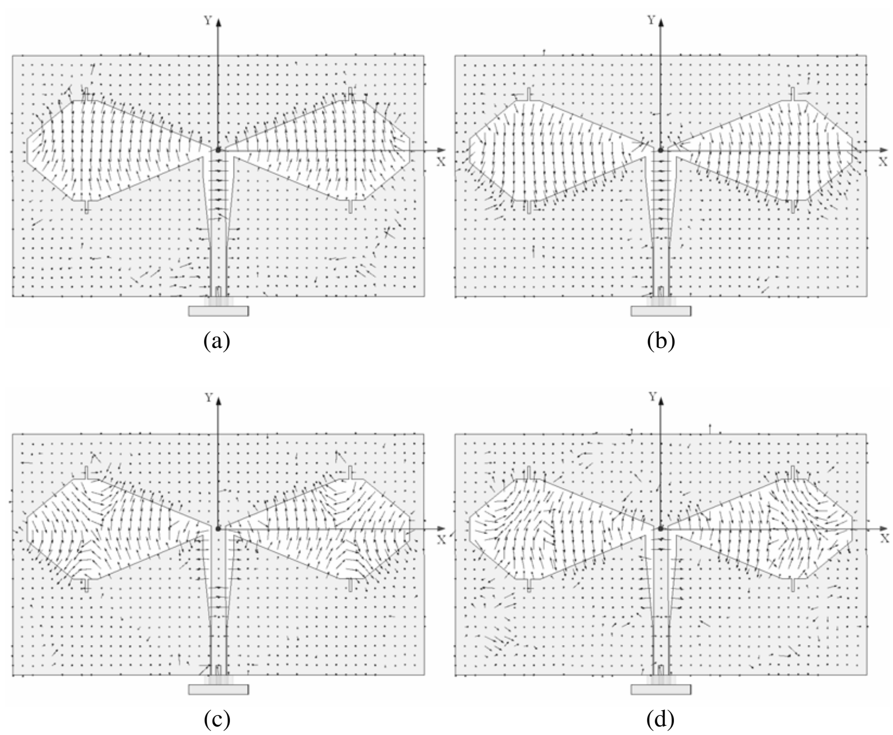


Figure 9. Electric field distributions at different frequencies. (a) 3 GHz, (b) 5 GHz, (c) 7.5 GHz, and (d) 10 GHz.

becomes complicated. As a result, the cross-polarization level rises and ripples appear in the E-plane (yz-plane) co-polarization pattern. But the H-plane (xz-plane) co-polarization pattern is still omni-directional. As the frequency increases to 10 GHz, the cross-polarization level becomes higher. The E-plane (yz-plane) co-polarization pattern is slightly split and the H-plane (xz-plane) co-polarization pattern becomes directional. As a conclusion, the radiation pattern of proposed antenna is almost stable in the operation band of 3.1–10.6 GHz.

5. CONCLUSIONS

This paper presents the optimization procedure of a novel CPW-fed bow-tie aperture antenna. Beveling technique is employed to increase the impedance width and slot loading is introduced to improve the impedance matching. The proposed antenna is fabricated and the measured results prove that these two techniques work well. The impedance bandwidth of the antenna totally covers the UWB band of 3.1–10.6 GHz. This successful experience is quite suggestive to the wide-band antenna designers. The measured E and H plane radiation patterns are stable almost over the entire operation band with the cross-polarization levels at least -10 dB lower than the co-polarization component. Besides, the proposed antenna preserves the advantages of ease of integration and small size.

ACKNOWLEDGMENT

This work was supported by the Hi-Tech Research and Development Program of China (No. 2006AA01Z275) the CRT Program of UESTC and the Youth Foundation of UESTC (No: L08010401JX0619).

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