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A NOVEL ULTRA-WIDEBAND BOW-TIE SLOT ANTENNA IN WIRELESS COMMUNICATION SYSTEMS

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Abstract—A novel ultra-wideband bow-tie slot antenna fed by CPW is proposed in this paper. This antenna has been demonstrated to provide an UWB with return loss less than −10 dB from 9.5 GHz to 22.4 GHz. The bandwidth is up to 80%, which is quite better than the traditional bow-tie slot antenna. Simulated and measured results are presented.

1. INTRODUCTION

Recently, ultra-wideband (UWB) technique has become one of the most fascinating technologies in indoor communications. It has the merits of high speed transmission rate, lower power consumption and simple hardware configuration over conventional wireless communication systems. So the antenna designed for UWB signal is one of the main challenges, especially when low-cost, geometrically small and radio efficient structures are required for typical applications.

The bow-tie slot antenna is a broadband design conventionally used in many communication applications [1, 6]. To enhance the bandwidth of CPW-fed bow-tie slot antenna, some techniques have been proposed, including the use of a tapered metal stub to achieve impedance matching [1], the use of inductive coupling [2, 6], and the adjustment of slot flare angle to enhance bandwidth [3, 4].

In this paper, by adding two small sectors to the bow-tie slot and changing the ordinary sharp corners to round corners, the bandwidth is enhanced largely to 80%. The proposed antenna can provide BW for most part of X-band (9.5 $\sim$ 12.4 GHz), part of K-band (18.0 $\sim$ 22.4 GHz) and the whole Ku-band (12.4 $\sim$ 18 GHz). Compared to the one [3], bandwidth increase more than twice. The numerical analysis is performed with the Ansoft High-frequency Structure simulator (HFSS), which is based on the finite element method. And the measurement results are conducted to verity this novel antenna by HP8510 vector network analyzer. Details of the proposed slot antenna designs are described. Simulated and measured results of impedance bandwidth and the radiation characteristics are given and discussed in this paper.

2. ANTENNA DESIGN

The proposed antenna with round corners and two small sectors is compared with two other types — without round corners and without round corners and small sectors, as Fig. 1. Fig. 1(c) is a bow-tie slot antenna with two small sectors and round corners, (b) without round corners, and (a) without round corners and small sectors. The proposed antenna is printed on a 0.5 mm thickness substrate with $\varepsilon_r = 4.9$. A thin film copper metallization of thickness 0.002 mm is carried out. The slot has a flare angle of 90 deg and arm length $a = 10$ mm. The dimensions of the two sector stubs are expressed by $a1 = 3.8$ mm and $h1 = 1.5$ mm. The characteristic impedance of the CPW line is $50\,\Omega$ with $kx = 1$ mm center conductor width and $f0 = 0.35$ mm gap width. Radius of the turning sites of the slots and small sector stubs are $r1 = 3$ mm and $r2 = 0.8$ mm. The junctions of the feed gaps and slots are also employed round corners, and radius are separately $r3 = 0.3$ mm and $r4 = 0.4$ mm.

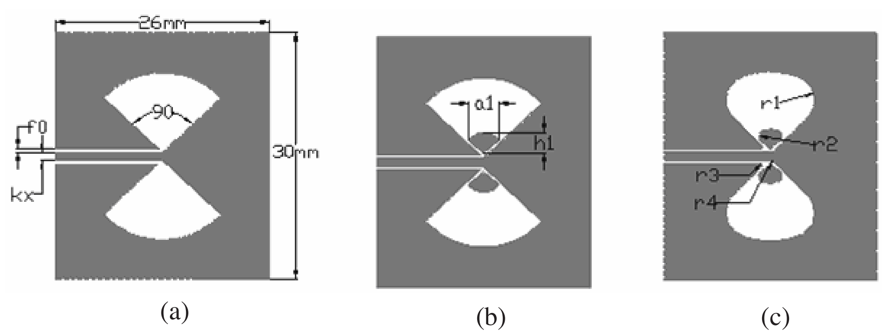


Figure 1. Configuration of the proposed antenna: (a) without round corner and small sectors (b) without round corners (c) with round corners and two small sectors.

3. RESULTS AND DISCUSSION

The small sector stubs play an important role in increasing the bandwidth. By using small sector stubs, the current is strengthened along the edges of the slots, which enhance the electric field distribution on the wide slot. As a result, compared to Fig. 1(a), the bandwidth of Fig. 1(b) is vastly improved from 25% to 56%.

Radius of round corners of the two small sector stubs is also a factor influencing the performance of the antenna effectively. Fig. 2 shows the relationship between $r2$ and the bandwidth. The lower edges of bandwidth kept static basically while the higher edges rises rapidly, but the return loss deteriorates over the whole band with increase of $r2$.

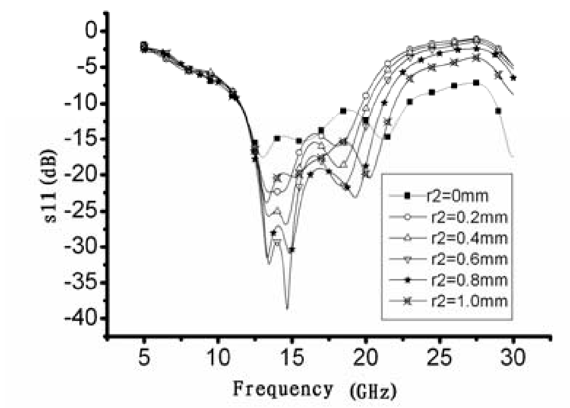


Figure 2. Simulated s parameters of different $r2$.

The round corners of slots also change the current along every edge of the slots. Without round corners, the current of the proposed antenna is mainly distributed in middle body of every edge. Using round corners, the current of the whole slot becomes homogeneous and the current also appears in the turning sites, which results that the lower frequency for $s11 < -10$ is kept static basically, but the higher frequency performance is improved obviously as shown in Fig. 3.

From above analysis, we can see that the existence of round corners enhances the return loss greatly, which is already applied in [7]. Because the current reflection reduces at the edge of round corners, which changes the current distribution on the antenna radiation surface. The smooth edge with round corners reduces the feed current reflection, and it changes the current distribution on antenna's surface,

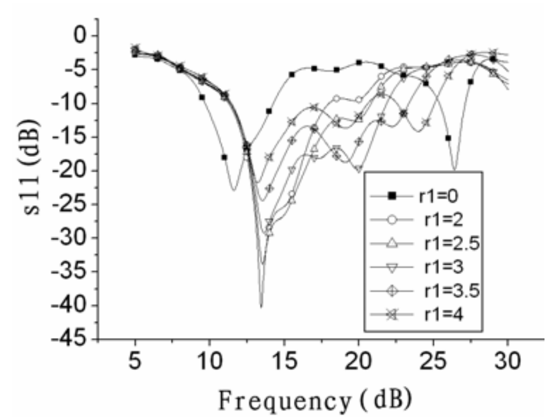


Figure 3. Simulated s parameters of different $r1$.

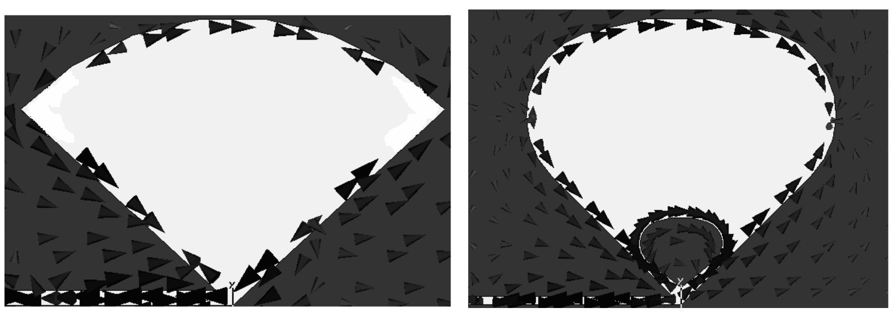


Figure 4. The current distribution with and without small sectors and round corners.

which influences antenna's performance straightway. The current distribution with and without sector stubs is shown in Fig. 4.

The center conductor and gap width determine the matching between the feed-line and the antenna. So the operating bandwidth of the proposed antenna is critically dependent on the center conductor width kx and gap width $f0$ of the CPW line. We separately show the different real part of input impedance with various values of kx and $f0$. For this reason, selecting $kx = 1\,\text{mm}$ and $f0 = 0.35\,\text{mm}$ so as to obtain a good matching. The results are shown in Fig. 5.

The junctions of the feed gaps and slots are also modified with round corners, as a result, the bandwidth has been improved from 65% to 80%. By sweeping parameter, $r3 = 0.3$, $r4 = 0.4$ are determined. The result is shown in Fig. 6.

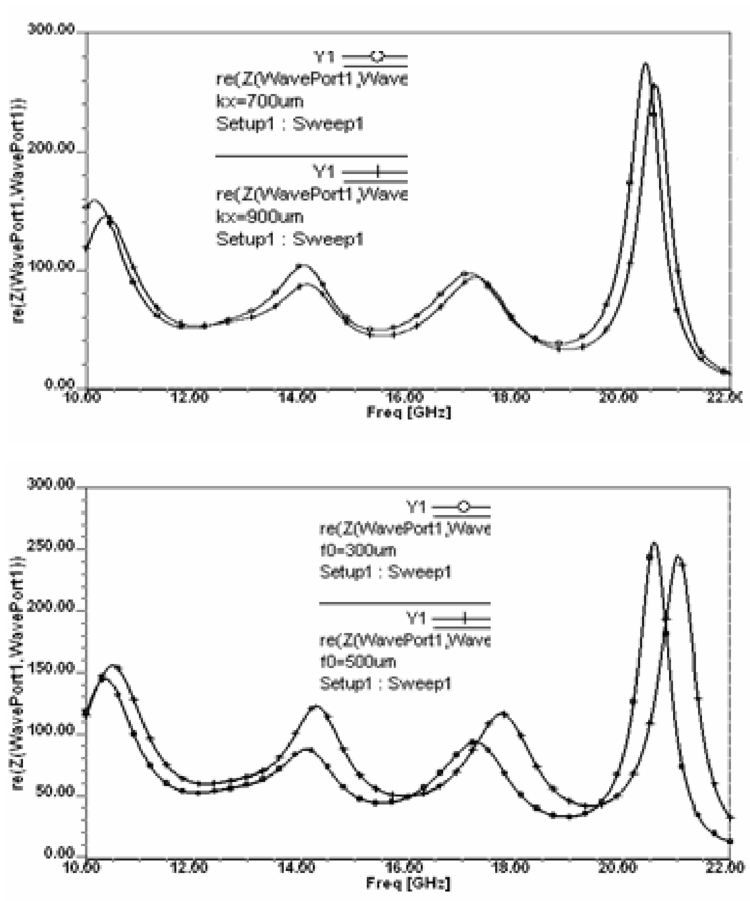


Figure 5. Real part of input impedance when $kx = 0.9\,\mathrm{mm}$, $f0 = 0.3\,\mathrm{mm}$, $0.5\,\mathrm{mm}$ and $f0 = 0.3\,\mathrm{mm}$, $kx = 0.7\,\mathrm{mm}$, $0.9\,\mathrm{mm}$.

Adding multiple round corners to the primary structure, the current distribution along the slots and the electrical fields on the slots are changed, which makes it easier to match the antenna over a very large frequency band. The obtained impedance bandwidth of 80% is superior to the antenna [3]. The measured data and the simulated ones of the proposed antenna are present in Fig. 7. According to the measured results, the measured reflection coefficient is large than the simulated at some frequency points. The deviation between theory and experiment is partially due to the fabrication imperfections and the uncertainties in substrate thickness and the dielectric constant. Also, the SMA connector and the degree of space wave diffraction at

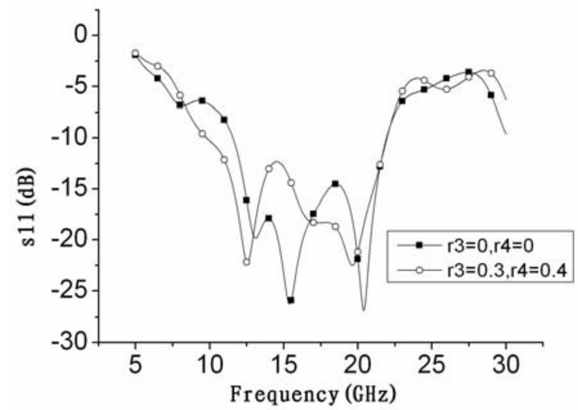


Figure 6. The different bandwidth before and after the junctions of the feed gaps and slots employing round corners.

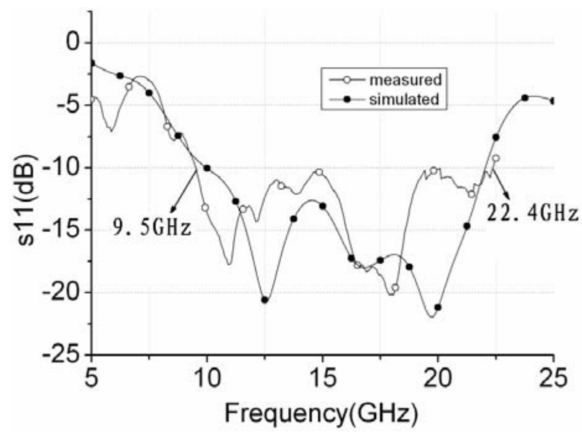
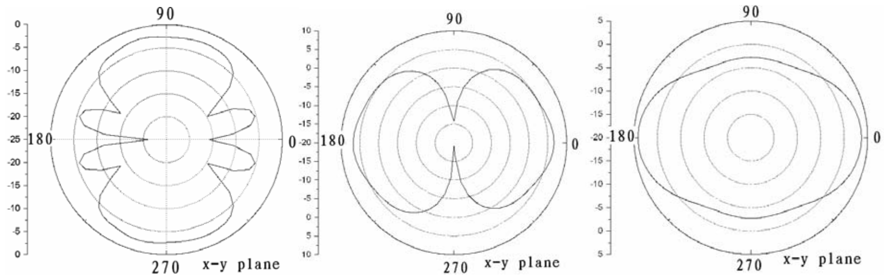


Figure 7. Measured and simulated s11 of the proposed antenna.

the operating frequencies influence the appearance of the return loss.

The profile modification of the proposed antenna does not change the inherent radiation patterns, which are also similar to the monopole antenna. The radiation patterns in three orthogonal planes of center frequency 15.95 GHz are illustrated in Fig. 8.



(a) (b) (c)

Figure 8. Radiation patterns at center frequency 15.95 GHz in three orthogonal planes (a) x-y plane (b) x-z plane (c) y-z plane.

4. CONCLUSIONS

In this paper, a modified bow-tie slot antenna fed by CPW is presented and experimented. This design demonstrates a wider impedance bandwidth (80%) than that of the traditional CPW-fed bow-tie slot antenna. These are greatly due to adding two small sectors and changing sharp corners into round corners. The radiation patterns of the antenna are similar to the dipole antenna, and remain broadside and bidirectional. In addition, compared to the antenna [3], the proposed antenna is printed on a rectangle substrate which is processed easily, and the size of slots decreases for sharp corners changing into round corners. So the antenna is suitable for the wireless communication systems.

ACKNOWLEDGMENT

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