A Novel Substrate Integrated Waveguide Back-cavity Antenna with Bow-tie Shaped Slot

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Abstract— As substrate integrated waveguide cavity-backed antenna with narrow rectangular slot always be narrow banded, a novel cavity-backed antenna with bow-tie shaped slot is proposed. Bow-tie shaped slot is integrated on the SIW cavity to wide the bandwidth. Design and simulation process are also given in this paper, the key parameters affecting the performance of antenna is studied, and test sample is fabricated and tested. Test results show that 3.96% relative bandwidth and 4.9 dBi gain are obtained at the antenna center frequency 5.3 GHz. The simulation results coincide well with simulated results, verify the validity of the designing.

1. INTRODUCTION

The development of communication system has led designers to pursue light, low profile, easy manufactured and integrated antennas [1]. Thus, the technology of printed patch antenna is favored and admired. But, the traditional printed patch antenna has great transmission loss. In recent years, substrate integrated waveguide (SIW) is developed and has became a research hotspot, and these researches springing up [2–6].

SIW is a new type of guided wave structure as a good alternate when the antenna being designed required light and easy integrated as traditional metal waveguide is no longer suitable. As a new and good wave transmission structure, SIW is especially suitable to form slot antenna, and a lot articles about this is published [7–10], using SIW structure to form a backed-cavity is also a research hotspot in recent years [11, 12]. Backed-cavity slot antenna based on SIW formed a resonant cavity behind the antenna makes it can filter the interference signal out of work frequency band, this nature greatly improve the performance of the receiver and reduce the size of circuit.

Reference [11] proposed a backed-cavity antenna with narrow gap, and has obtained the good radiation effect, but the working frequency band is limited, only 1.32% relative bandwidth.

In this letter, in order to design a low profile narrowband omni-directional antenna using in short range wireless communication system, a novel SIW backed-cavity antenna with bow-tie shaped slot is proposed and analyzed. The backed-cavity structure is formed by SIW theory to filter out unwanted frequencies and bow-tie shaped slot is used to produce the omnidirectional pattern. Compared to the reference [11], the proposed antenna bandwidth reached 3.96%. The detailed design and simulation process are given in this paper, key parameters affecting the performance of antenna is studied, and the test results is also given and analyzed.

2. DESIGN AND SIMULATION

The topology of the antenna proposed is shown in Fig. 1. Antenna is designed using ARLON substrate ($\varepsilon_r = 2.2$ and 1 mm thickness). Cavity is designed based on the classic theory of rectangular waveguide cavity and it is formed by a series of mental through-hole with 0.3 mm radius and 1 mm distance, the radius and distance value satisfy the rule of SIW structure design [13]. The cavity works at its first TE_{101} mode. A cavity works at TE_{mnl} can be determined by following formulas:

$$a = \frac{c}{f_c \times 2 \times \varepsilon_r} \tag{1}$$

$$\beta_{mn} = \sqrt{k^2 - \left(\frac{m\pi}{a}\right)^2 - \left(\frac{n\pi}{h}\right)^2} \tag{2}$$

$$k = \omega\sqrt{\mu\varepsilon} \tag{3}$$

$$\lambda_g = \frac{2\pi}{\beta_{mn}} \tag{4}$$

$$b = l\frac{\lambda_g}{2} \tag{5}$$

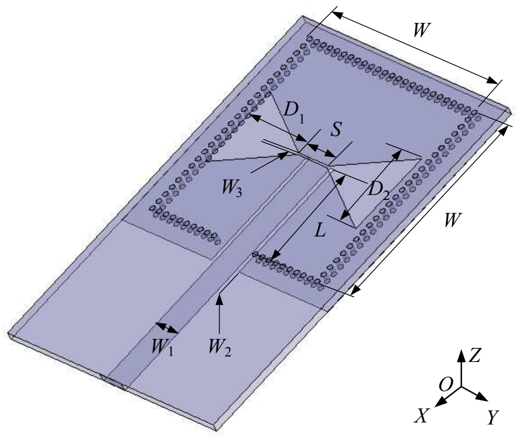

Figure 1: Topology of the antenna.

In the formulas, a, b, h represent the width, length, and height of cavity, respectively.

The coplanar waveguide (CPW) transition structure is used to improve the coupling degree between the external micro-strip and the cavity. The radiation slot is formed by a pair of symmetrical triangles connected by a narrow gap; the narrow gap is overlapped with the end of CPW structure end which is helpful to improve the radiation performance of the bow-tie slot.

The center frequency of the antenna is general decided by the size of cavity, but the shape of the triangle is an important factor of the radiation performance of antenna, tuning the value of D_1 and D_2 can change the center frequency of the antenna and get best radiation performance.

Using HFSS 11 to modeling and simulate. Fig. 2 and Fig. 3 show the affection characteristics according to the variation of D_1 and D_2, respectively. The value of D_1 and D_2 show direct ratio with the center frequency of antenna. Based on the character, micro-tuning of the center frequency in engineering is realized, which makes design much easier.

In order to test the radiation performance of the antenna proposed, a test piece with center frequency 5.29 GHz is researched. The dimensions of antenna are shown in Table 1.

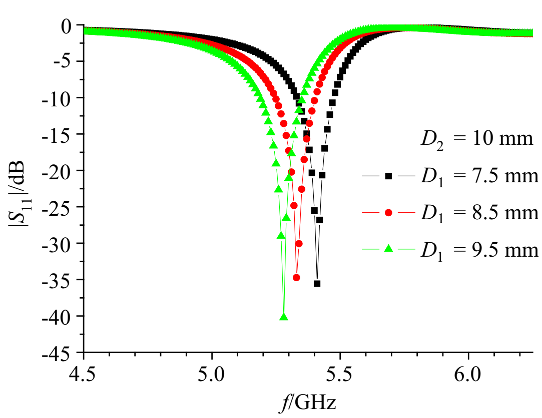

Figure 2: Matching characteristics according to the variation of D_1.

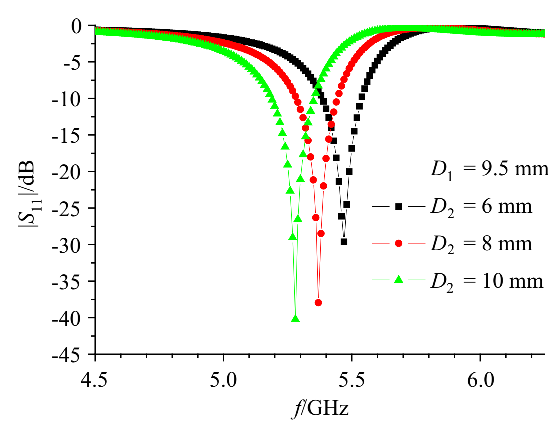

Figure 3: Matching characteristics according to the variation of D_2.

Table 1: Dimensions of antenna.

W	W_1	W_2	W_3
24 mm	3.1 mm	0.5 mm	0.2 mm
S	D_1	D_2	L
1 mm	1 mm	22 mm	12.5 mm

3. EXPERIMENT RESULTS AND ANALYSIS

Figure 4 shows the manufactured antenna, (a) is the top photography and (b) is the bottom photography. SMA is utilized in connecting the antenna under test with the experiment equipment. The return loss curves are shown in Fig. 5 It is shown in the figure that the return loss is more than 10 dB in the frequency scope of 5.16 GHz–5.37 GHz.

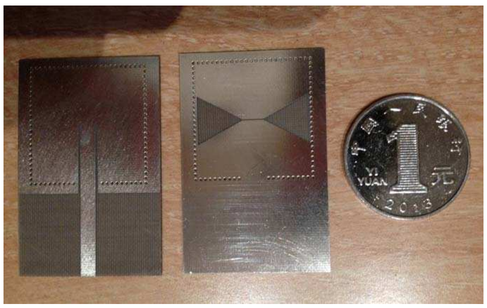

Figure 4: Test structure of antenna.

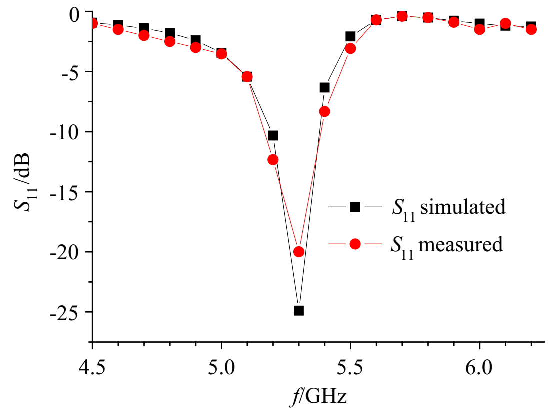

Figure 5: Simulated and measured return loss of antenna.

Simulated and measured far-filed antenna radiation patterns are shown in Fig. 6. Fig. 6(a) for E-plane, where 4.9 dBi Gain and 84° half-power beam width is obtained, the cross-polarization is lower than -48 dB. Fig. 6(b) shows the measurement results of H-plane, where also a 4.9 dBi best Gain is obtained, and cross-polarization radiation is not so good as E-plane, lower than -19 dB. The measured results show good agreement with simulated ones.

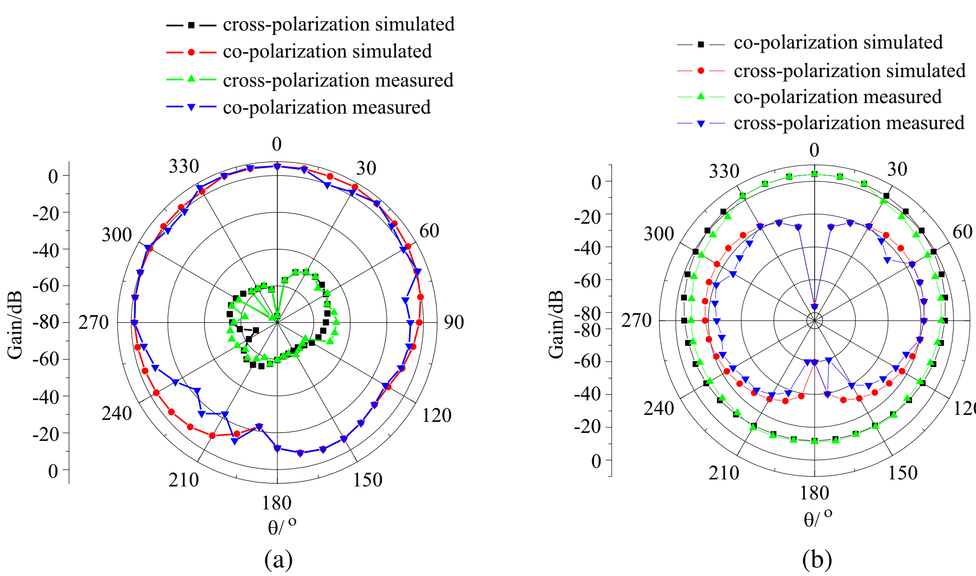

Figure 6: Measured and simulated directivity diagram. (a) E-plane. (b) H-plane.

4. CONCLUSION

In this paper, a SIW backed-cavity antenna with bow-tie shaped aperture is proposed and designed, key parameters of the antenna are studied. By integrating bow-tie shaped aperture, the antenna obtain wider bandwidth than the narrow rectangular slot antenna, but the radiation pattern of the antenna is reduced, thus the antenna is suitable for the communication system which require covering wider scope. Finally, the antenna is fabricated and tested. The measured results and simulation results are in good agreement, verify the validity of the design.

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