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DESIGN OF A FRACTAL DUAL-POLARIZED APERTURE COUPLED MICROSTRIP ANTENNA

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Abstract—In this paper, a fractal dual-polarized aperture-coupled microstrip antenna is presented. The proposed antenna adopts 1st Minkowski fractal patch and is fed by the aperture-coupled structure with H-shaped and H-shaped loaded capacitance. The size of Minkowski fractal patch is reduced by 20% compared with a square patch. Results show that the T/R isolation is better than 35 dB, improved by 2 dB compared with the double H-shaped slots. The gain is more than 8 dB, and the front-back ratio is greater than 20 dB in the operating frequency range. Both simulated and experimental results are in good agreement.

1. INTRODUCTION

With the rapid development of wireless communications, more and more attention has been focused on antennas with high gain and low cost, among which smart antennas and retrodirective arrays are two good candidates. The retrodirective array responds automatically to the incident wave direction by transmitting a signal back to an interrogator's direction [1–4]. However, this type of array needs a large number of antenna elements.

In order to reduce the number of elements, the dual-polarized antenna is adopted as the element of retrodirective array. As the dual-polarized antenna can provide polarization diversity, reduce multipath fading of received signals and increase the transmit-receive (T/R) isolation [5, 6].

The dual-polarized antenna has several kinds of feeding structures. The first type is the coplanar structure, including corner-feeding and

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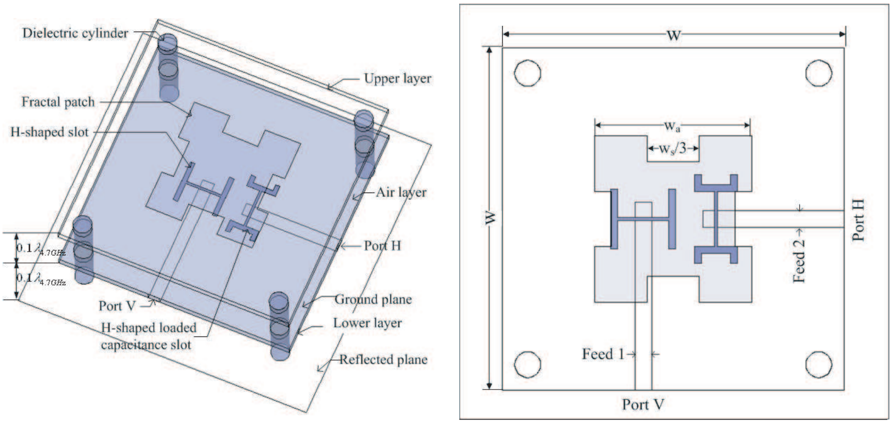
edge-feeding forms [5, 7, 8]. This feeding form causes a bad isolation so that it only fits for the special situation. The second type is aperture-coupled structure, which achieves high isolation by cutting C- or H-shaped slot on the ground plane [9, 10]. The third type is the combination of the coplanar and aperture-coupled structure, which produces high isolation and pure polarization. However, it is difficult to use this type in the design of antenna arrays due to the feed lines on different layers [11].

In this paper, a 1st Minkowski fractal dual-polarized microstrip antenna is proposed as the element of the retrodirective array, which is fed by the aperture-coupled structure [12]. The operating frequency range of the antenna is 4.4 GHz $\sim$ 5 GHz. The measured results show good agreement with the simulated ones.

2. ANTENNA DESIGN

Figure 1 shows the structure of the Minkowski fractal dual-polarized microstrip antenna. The antenna consists of two dielectric substrate layers each with a thickness of $h = 1$ and sizes of $40 \times 40\,\text{mm}^2$. The upper substrate uses the PTFE material with a permittivity of 2.65. The Minkowski fractal patch is inverted on the upper substrate protected from the external environment conditions. The lower substrate is the FR4 material with a permittivity of 4.4. The



(a) (b)

Figure 1. Structure of the proposed antenna. (a) Side view, (b) vertical view.

ground plane is located on the top side of the lower layer on which two orthogonal apertures are etched. The microstrip feed lines are put on the opposite side of the lower layer, produced from the input ports V and H, respectively. Power is coupled to the patch radiator from the feed lines via the aperture-coupled structure. The microstrip feed lines with open stubs are tuned by changing the parameters X_t and H_t. For enhancing the front-to-back ratio of the proposed antenna, a reflector plane is used below the lower dielectric substrate; the distance between which is about 0.1λ at 4.7 GHz.

There is an air layer ($h_1 = 0.1\lambda$ at 4.7 GHz) between the two dielectric layers, as shown in Figure 1, which is introduced to broaden the impedance bandwidth by reducing the average relative dielectric constant. The multilayer structure realizes the broadband resonator performance of the radiation patch.

The 1st Minkowski fractal structure changes the current distribution on the radiation patch ($w_a = 16.8$ mm, $w_s = w_a/3$), as shown in Figure 2. The current twists and turns along the surface of the fractal conductor, which is different from the current distribution over the traditional rectangular conducting patch. Thus the resonant frequency of the antenna decreases as the electrical length of the patch increases, and the antenna size is reduced by 20% compared with the conventional square patch.

The H-shaped loaded capacitance aperture-coupled structure is used to increase the distance between the two apertures, as shown in Figure 3. It is good to improve the T/R isolation. The H-shaped aperture is defined by parameters, $X_a = 7$ mm, $X_b = 0.5$ mm, $X_c = 6$ mm, $X_d = 0.2$ mm. And the following parameters determine the H-shaped loaded capacitance slot: $Y_a = 5$ mm, $Y_b = 0.8$ mm, $Y_c = 6$ mm, $Y_d = 0.2$ mm, $T_c = 1.1$ mm. The values of the microstrip

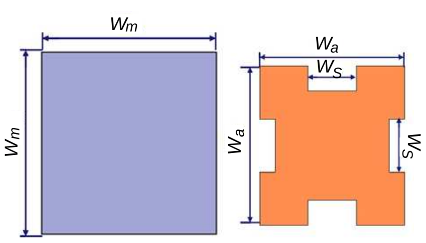


Figure 2. Structure of the conventional square patch and the Minkowski fractal patch ($w_m = 21$ mm, $w_a = 16.8$ mm).

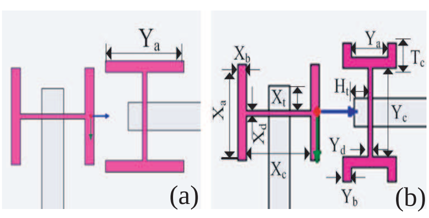


Figure 3. The aperture-coupled structures. (a) Double H-shaped slots, (b) H-shaped and H-shaped loaded capacitance slots.

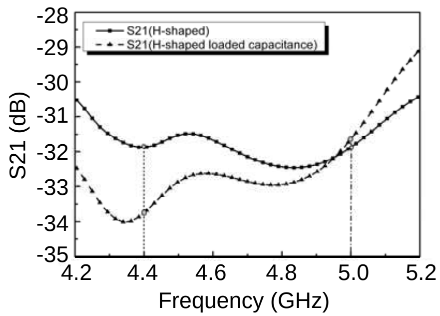
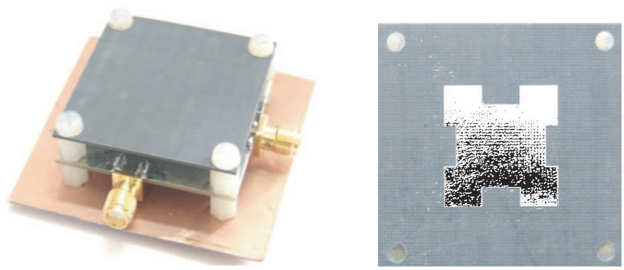


Figure 4. The T/R isolation with H-shaped slot ($Y_a = 7.2\,\mathrm{mm}$, $T_c = 0\,\mathrm{mm}$) and H-shaped loaded capacitance slot ($Y_a = 5\,\mathrm{mm}$, $T_c = 1.1\,\mathrm{mm}$) at the same length.



(a) (b)

Figure 5. The fabricated antenna. (a) Side view, (b) the 1st Minkowski fractal patch.

feed lines with open stubs are $X_t = 2\,\mathrm{mm}$ and $H_t = 3.5\,\mathrm{mm}$.

Figure 4 depicts that the H-shaped loaded capacitance slot makes the T/R isolation increase by about 2 dB, compared with the H-shaped slot in 4.4 GHz $\sim$ 5 GHz. It shows that the H-shaped loaded capacitance slot can effectively reduce the coupling of the two ports.

3. EXPERIMENT AND RESULTS

The proposed antenna is constructed and simulated by Ansoft HFSS 11. According to the proposed antenna, the fractal dual-polarized antenna is shown in Figure 5. The antenna is measured with a vector network analyzer Agilent N5230A.

Figure 6 shows the simulated and measured results of the two

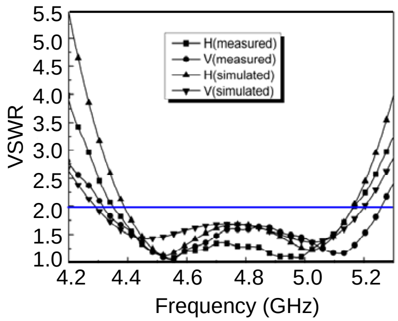


Figure 6. Simulated and measured VSWR of the proposed antenna.

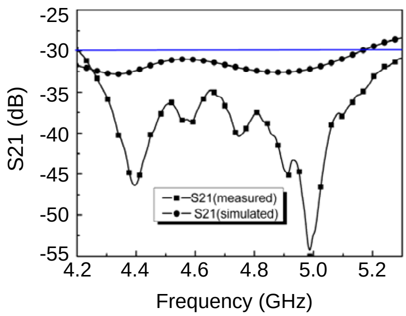


Figure 7. Simulated and measured T/R isolation.

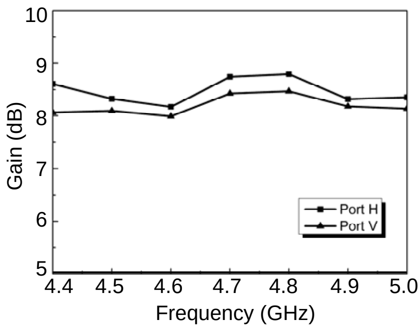
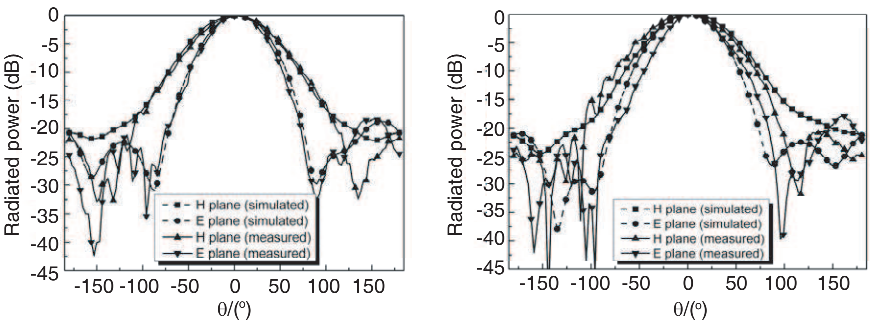


Figure 8. Measured gain of the proposed antenna.

orthogonal ports. The simulated impedance bandwidth at port H is 4.82 GHz $\sim$ 5.168 GHz (VSWR < 2), and the relative impedance bandwidth achieves 16.8%. For port V, the simulated relative impedance bandwidth is 19.7% (from 4.270 GHz to 5.203 GHz). The measured relative impedance bandwidth at ports H and V achieve 17.6% and 20.5%, respectively. It shows that the results of the measurement are in good agreement with those of simulation. And the test curve shifts slightly, which is caused by the uneven distribution of dielectric constant and measuring environment.

The simulated and measured isolation between two ports are shown in Figure 7. The T/R isolation is better than 35 dB over the operating frequency range. The results show that the high isolation of two ports satisfies the engineering requirements.

Figure 8 shows the measured gain of the proposed antenna. The gain of the antenna is greater than 8 dB in the operating frequency



(a) (b)

Figure 9. Simulated and measured radiation patterns of the proposed antenna (a) port H, (b) port V.

range.

As shown in Figure 9, the far field radiation patterns are studied in E and H planes by exciting each port at 4.7 GHz. From the comparison of the simulated and measured results, it is observed that the measured radiation patterns are similar to the simulated results, and the front-back ratio is greater than 20 dB. The radiation pattern in the H plane of port V presents some corrugations when measured, as a result of the measurement condition influence.

4. CONCLUSION

A fractal dual-polarized microstrip antenna is presented as the element of a retrodirective array. The antenna size is reduced by 20% using 1st Minkowski fractal radiation patch, and the T/R isolation is improved by 2 dB with the H-shaped loaded capacitance and H-shaped slots (Compared with double H-shaped slots). The results show that the relative impedance bandwidths (VSWR < 2) achieve 17.6% and 20.5% respectively. The gain of the antenna is greater than 8 dB, and the front-back ratio is greater than 20 dB. The T/R isolation is better than 35 dB in the operating frequency range. Thus, it is feasible to utilize the proposed fractal dual-polarized microstrip antenna as the element of the retrodirective array.

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