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SMALL SIZE EDGE-FED SIERPINSKI CARPET MICROSTRIP PATCH ANTENNAS

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Abstract—In this paper, we present a novel technique to reduce the size of edge-fed microstrip patch antenna. By etching the patch as the Sierpinski carpet, the resonant frequency can be lowered to lower values, and this property can be employed to reduce the size of the conventional patch antenna. The measurement results show, the patch achieved a maximum 33.9% size reduction by the edge-fed Sierpinski Carpet microstrip patch antenna (SCMPA) of the second iteration order, and other performances, such as return loss bandwidth and radiation patterns, were virtually unchanged.

1. INTRODUCTION

Aside from using high dielectric substrates [1], applying shorting techniques [2], and increasing the electrical length of the antenna by optimizing the shape [3], there are mainly two techniques to reduce the size of an edge-fed microstrip patch antenna. One is loading the edges of the patch with inductive elements [4, 5], and the other is inserting the capacitive elements into the patch [6, 7].

Koch fractal shapes have been applied to the edges of the patch to reduce the size of the antenna in [8–10], and the essence of this technique falls into the inductive loading at the patch edges. And until now, there has no reporting about the application of fractal theory to the technique of capacitive loading. In this paper, we propose a novel technique to apply fractal theory into this technique. By etching the patch as Sierpinski carpet of different iteration orders, the simulation results show the operating frequency of the antenna can be lowered to lower values, at the same time maintaining the bandwidth, radiation patterns comparable to that of a normal edge-fed microstrip patch antenna, and this property can be used to reduce the size of the patch antenna. The proposed method is verified by the measurement results.

2. SMALL SIZE EDGE-FED SCMPAS

2.1. Frequency Lowering Property of the SCMPAs

The Sierpinski carpet structure has been applied to antenna engineering widely [11, 12], as shown in Fig. 1, but until now, it has not been used to reduce the size of the edge-fed microstrip patch antenna.

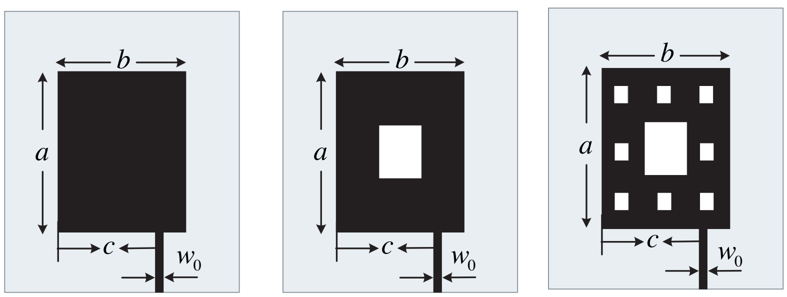


Figure 1. Schematics of the edge-fed Sierpinski carpet microstrip patch antennas of different iteration orders. S0: Zeroth iteration order, S1: First iteration order, S2: Second iteration order.

As can be seen from Fig. 1, the dropped little rectangular elements are inside the patch, thus these elements can be considered as capacitive elements. The whole structure of S1 and S2 are somewhat like the structures loaded by capacitive elements as reported in [6, 7], and this technique is expected to lower the operating frequency.

As soon as the center operating frequency ($f_0 = 1.8\,\text{GHz}$) and the substrate parameters ($er = 4.3$ and $h = 1\,\text{mm}$) given out, the design of the SCMPA can be accomplished easily. Firstly, the conventional edge-fed microstrip rectangular patch antenna can be designed followed the standard procedures given in [2]. Their optimum dimensions have been determined through the optimization process using FEM (finite element method)-based Ansoft HFSS version 10.0. Thus the physical parameters of the conventional edge-fed patch antenna can be arrived at $a = 60\,\text{mm}$, $b = 39.2\,\text{mm}$, $c = 26.8\,\text{mm}$, and $w_0 = 1.9\,\text{mm}$.

Secondly, the SCMPAs of different iteration orders can be designed by dropping elements on the patch as Sierpinski carpet, whose iteration factor is 1/3, without changing the physical parameters of the patch, as shown in Fig. 1. Because of the manufacturing tolerance, the iteration order is limited to 2.

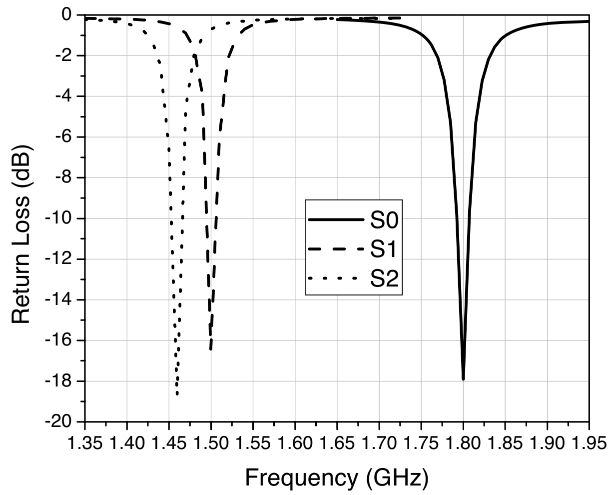


Figure 2. Simulated return losses of the designed edge-fed SCMPAs.

Fig. 2 shows the simulated return loss, and Fig. 3 shows the simulated radiation patterns, of the designed edge-fed SCMPAs of different iteration orders, respectively, using Ansoft HFSS version 10.0.

As expected by the authors, the center operating frequency of the designed SCMPAs of different iteration orders shifted to lower values as the iteration orders increased, as shown in Fig. 2. The center operating frequency of the conventional edge-fed rectangular patch antenna is 1.8 GHz, the edge-fed SCMPA of first iteration order is 1.5 GHz, and the edge-fed SCMPA of the second iteration order is 1.46 GHz. As also shown in Fig. 3, aside from a decreasing of the antenna gain, which is inevitable when the antenna size decreased, the radiation patterns of E-plane (phi $= 0°$) and H-plane (phi $= 90°$) of the designed SCMPAs of different iteration orders are comparable to each other.

From the above analysis, the frequency lowering property of the SCMPAs is shown clearly, and this property, as capacitive loading technique, can be used to reduce the size of the patch antennas.

2.2. Small Size Edge-Fed SCMPAs and Experiment Results

We designed the small size edge-fed SCMPAs at 1.8 GHz, using the substrate parameters given above. By optimizing the physical parameters (a, b, and c) of the SCMPAs of different iteration orders to make the resonant frequency centered at 1.8 GHz, the values of these parameters can be arrived successfully, which were as shown in Fig. 4.

The prototypes of the designed small size SCMPAs of different

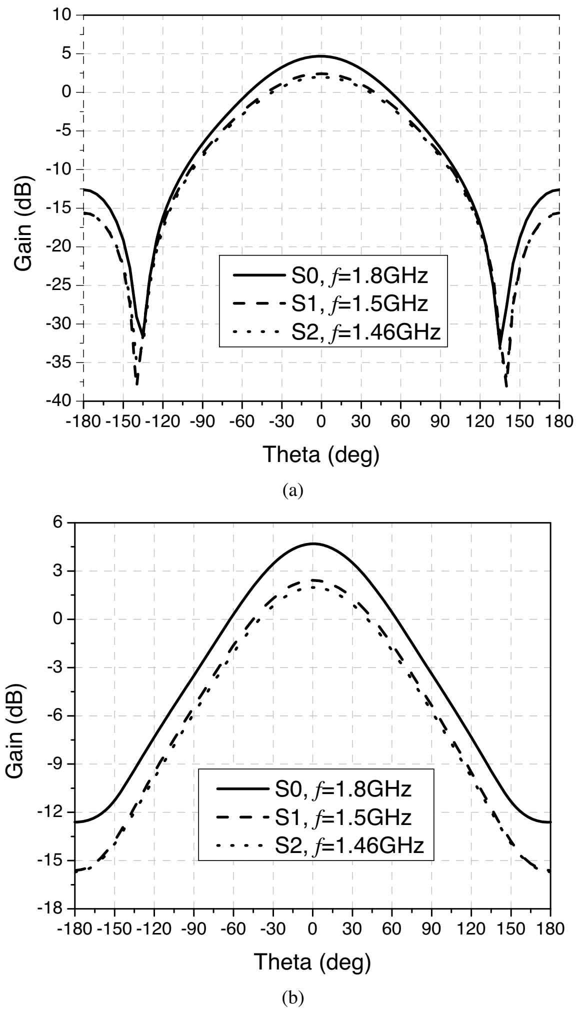


Figure 3. Simulated radiation patterns. (a) phi = 0 deg, (b) phi = 90 deg.

iteration orders were fabricated for experimental use, and Fig. 5 shows the photograph of the fabricated prototypes.

Fig. 6 shows the simulated and measured return losses, and Fig. 7 shows the simulated and measured radiation patterns, of the designed SCMPAs of different iteration orders.

As can be seen from Fig. 4 and Fig. 5, when resonated at same frequency, the size of the patch of SCMPA with the First iteration order

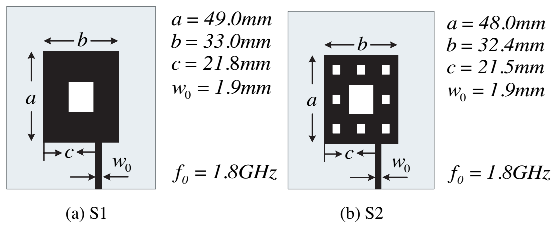


Figure 4. Schematics of designed edge-fed SCMPAs resonated at 1.8 GHz.

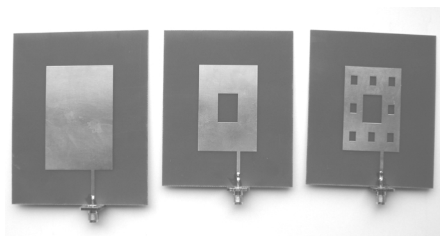


Figure 5. Photograph of the designed edge-fed SCMPAs resonated at 1.8 GHz.

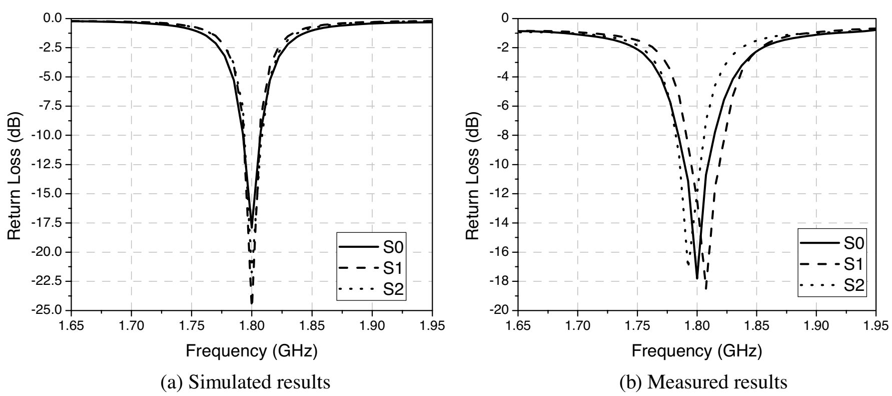
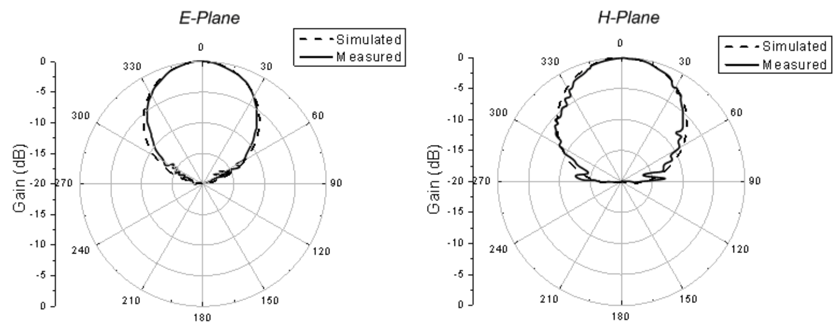
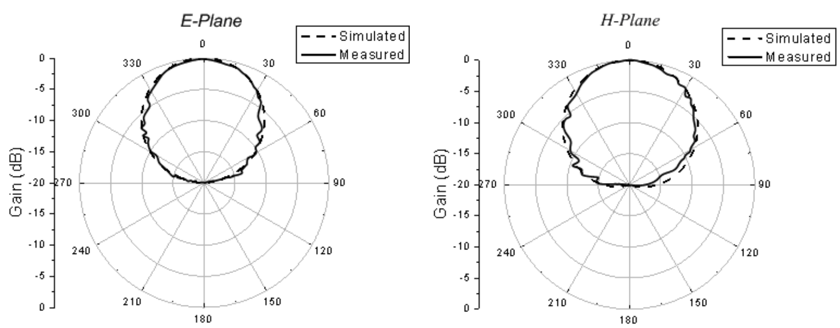


Figure 6. Return losses of the designed small size SCMPAs.

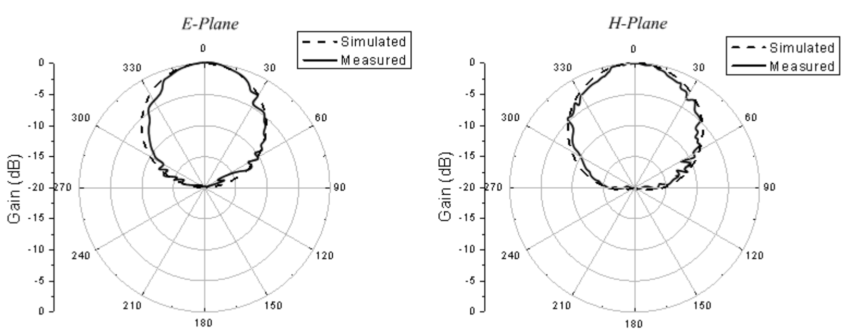
is 68.75% of the size of the patch of conventional patch antenna, thus achieved a 31.25% size reduction, and the size of the patch of SCMPA with the second iteration order is 66.1% of the size of the patch of the conventional patch antenna, thus achieved a 33.9% size reduction. And from these observations, it is expected that the resonant frequency of the SCMPAs with iteration orders higher than the second iteration



(a) S0



(b) S1



(c) S2

Figure 7. Radiation patterns of the designed small size edge-fed SCMPAs.

would remain almost constant.

As also can be seen from Fig. 6 and Fig. 7, the antenna performances such as the return loss bandwidth and the radiation patterns of the SCMPAs are virtually unchanged.

3. CONCLUSION

In this paper, based on the capacitive loading technique, the frequency lowering property of the edge-fed Sierpinski carpet microstrip antennas is studied. As expected by the authors, the edge-fed Sierpinski carpet microstrip antennas have lower resonant frequencies than the conventional patch antenna, and this property can by used to reduce the patch size of the antenna. When designed the edge-fed Sierpinski carpet microstrip antennas of different iteration orders at the same frequency, for Sierpinski carpet with 1/3 iteration factor, the size of the patch can be reduced to about 33.9% of the conventional counterpart without degrading the antenna performances, such as the return loss and radiation patterns. The essence of this size reduction technique is loading capacitive elements inside the patch, and to achieve a much greater reduction in antenna size, this technique can be used simultaneously with other size reduction techniques, such as inductive loading, using high dielectric constant substrate, shorting technique, etc.

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