A Quasi-hexagon Shaped Band-stop FSS in Wideband RCS Reduction

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Abstract— In this paper, a quasi-hexagon shaped band-stop frequency selective surface with a wideband RCS reduction is proposed. In terms of structural mode scattering, we design a kind of band-stop FSS as a substitute for the traditional metal reflection board grounded on a hexagon FSS prototype and the typical Koch fractal curve. Patch dipole antenna is used to confirm the validity of this method and the result of simulation shows that relative RCS of the patch antenna with metal ground, there is a considerable out-of-band RCS of the antenna with band-stop FSS ground plane about 11.3 dB reduction on average, and 27.3 dB reduction on 5.8 GHz.

1. INTRODUCTION

Frequency selective surface (FSS) is the free-space counterparts of microwave filters in a transmission line. FSS has been widely applied in microwave antenna, radar and satellite communications [1–3]. For example, FSS has been used traditionally in stealth technology for reducing the radar cross section (RCS) of communication and radar antennas as well as protecting receivers of such systems from interfering signals and jamming [4]. Over the years, a variety of FSS elements were introduced for band-pass and band-stop applications.

Band-stop FSS is from time to time used as antenna reflection ground [5] to improve the antenna gain [6] as well as reduce the out-ofband RCS. In this paper, an efficient design is present to achieve the traditional hexagon shaped band-stop FSS miniaturization, and effective harmonic suppression. By these excellent electromagnetic characteristics, our new quasi-hexagon shaped band-stop FSS can get great wideband RCS reduction.

2. DESIGN AND SIMULATED RESULTS

2.1. Structures Design

Figure 1(a) shows the traditional hexagon shaped band-stop FSS unit cell. The top layer consists of hexagon with length of l and width of w set in a periodic pattern, and the dielectric board consists of the F4B material with $\varepsilon_r = 2.45$, $\tan\sigma = 0.001$ and thickness 0.8 mm is used as the dielectric substrate. All metals in the FSS are made of copper with a conductivity $\sigma = 5.8 \times 10^7$ S/m. According to the particularity of hexagon, we target by the following way of fractal. Fig. 1(b) shows the first-order fractal structure, the method is from each vertex of hexagon, generate inside a bend line with the width of the hexagon. From first-order to second-order and the higher order fractal are adopts similar to the structure of the Koch curve method [7]. Second-order fractal structure is illustrated in Fig. 1(c).

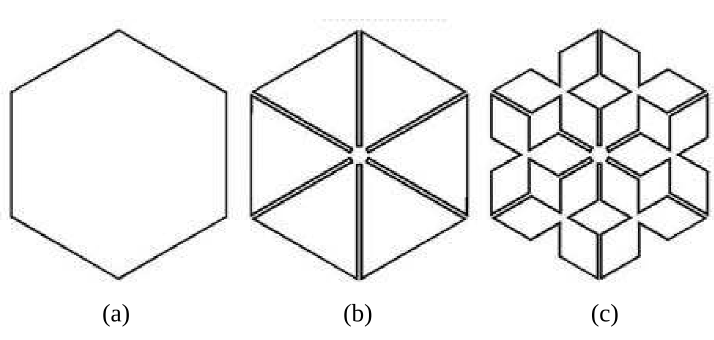


Figure 1: Structures of band-stop FSS unit: (a) traditional hexagon; (b) first-order fractal; (c) second-order fractal. ($l = 6$ mm, $w = 0.1$ mm).

2.2. Second-order Fractal Simulate and Analysis

We make full-wave simulations by using the commercial software HFSS. The simulation results of these three structures are shown in Fig. 2. for the normal incident, in which we observe the Transmission coefficient zeroes are 1 GHz, 2 GHz, 3 GHz. Compared with the traditional hexagon shaped band-stop FSS, the second-order fractal FSS with same length is almost 2 times miniaturization. These three structures have 2 times, 3.5 times, and 5 times respectively higher harmonic resonant frequency, which verify the second-order fractal FSS has effective harmonic suppression.

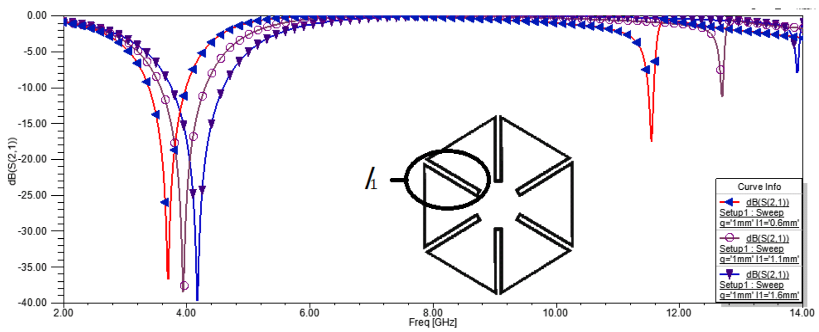
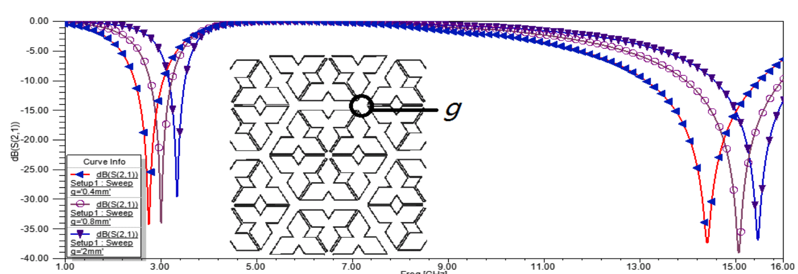


Figure 2: Simulations of the three structures FSS.

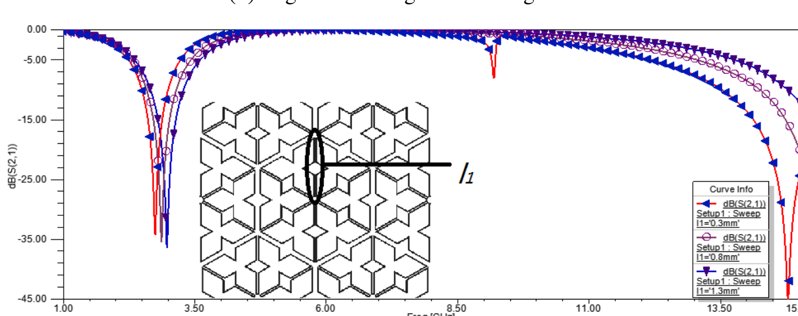
Figure 3 illustrates the simulation of the parameters of the design second-order fractal FSS including g unit interval, l_1 as the length of the bend line, l_2 as the length of Koch curve fractal line, and the gap width of the bend line. Fig. 3(a) shows the transmission coefficients with different g, in which we observe increasing the g increases the center frequency, a result of a larger capacity coupling. Fig. 3(b) and Fig. 3(d) show the transmission coefficients with different l_1 and l_2, in which we observe increasing the l_1 or l_2 decrease the center frequency for the larger electrical length. Fig. 3(d) shows the transmission coefficients with different g_1. It is worth mentioning that increasing the value of g_1, the higher harmonic resonant frequency in not monotonous changing subsequently.

2.3. RCS Simulate

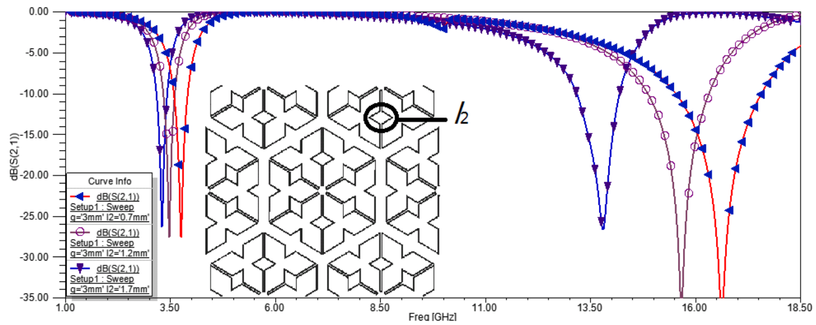
In order to verifying the RCS reduction of the new hexagon FSS, we design two working at the same frequency 2.9 GHz patch dipole antennas with metal ground and second-order fractal FSS ground. Through optimizing the parameters of the second-order fractal FSS, the simulation result is shown in Fig. 4, in which we observe the refraction index pole at 2.9 GHz and zero at 5.8 GHz.



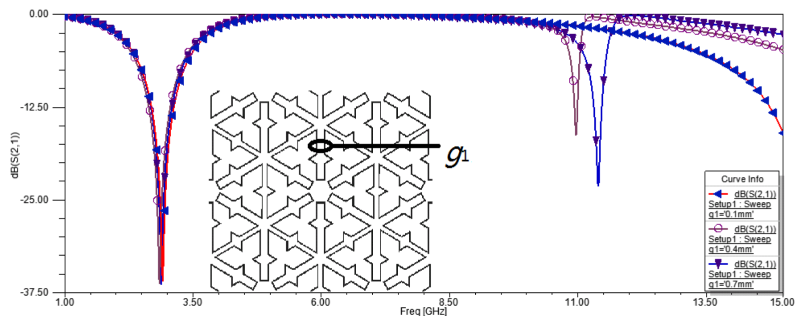
(a) ▲g=0.4mm ○g=0.8mm ▼g=2mm



(b) ▲l1=5.7mm ○l1=5.2mm ▼l1=4.7mm



(c) ▲l2=0.7mm ○l2=1.2mm ▼l3=1.7mm



(d) ▲g1=0.1mm ○g1=0.4mm ▼g1=0.7mm

Figure 3: Free-space simulations of second-order fractal band-stop FSS; (a) g; (d) l_1; (c) l_2; (d) g_1.

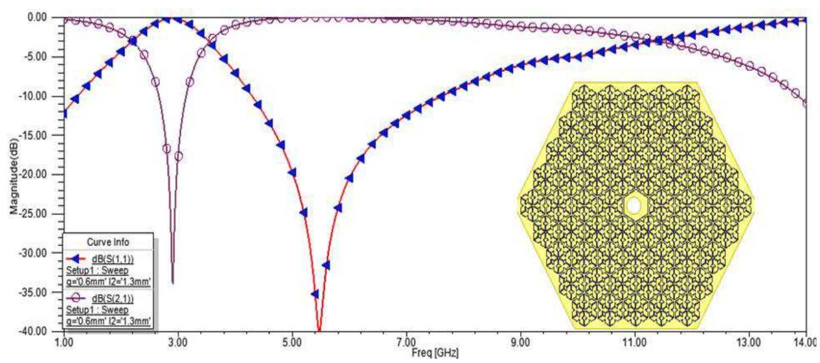


Figure 4: Free-space simulation of the second-order fractal band-stop FSS for the antenna ground.

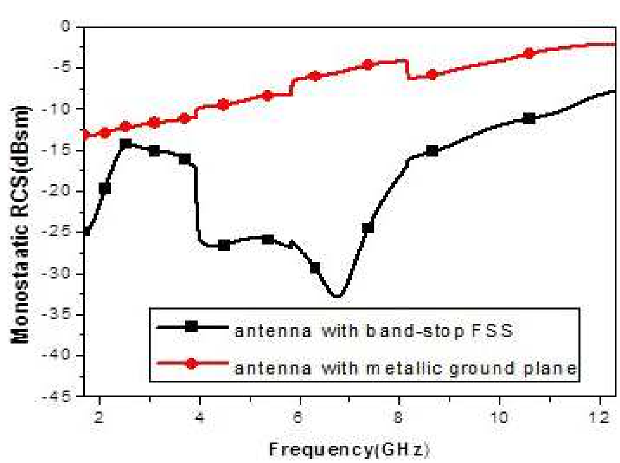


Figure 5: Simulation of RCS of the patch antenna with band-stop FSS and metal ground.

Fig. 5 illuminates the RCS of the antennas with metal ground and FSS ground, in which we observe comparing the antenna with metal ground, RCS of the antenna with FSS ground at out-of-band about 11.3 dB reduction on average from 1 GHz to 12 GHz, and the most reduction 27.3 dB at 5.8 GHz.

3. CONCLUSIONS

In this article, design of a quasi-hexagon shaped band-stop FSS in RCS reduction is presented. The quasi-hexagon structure is designed by a new fractal method, which effectively achieves the FSS miniaturization. The second-order fractal band-stop FSS has a great harmonic suppression, which effectively improve the RCS bandwidth.

ACKNOWLEDGMENT

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