Design and Simulation of Frequency-Selective Radome Together with a Monopole Antenna

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Abstract- In this paper, we present a novel axi-symmetric conical FSS radome at S-band and investigate the effect of the FSS radome located in close proximity of a monopole antenna. The strict periodic array of the novel FSS radome was indicated in detail, and the FSS radome together with a monopole antenna was simulated using the Ansoft software HFSS both at the pass and stop bands. The simulated results show that the novel FSS radome has a narrow band-pass response and is prospectively useful for out-of-band RCS control.

Index Terms- Frequency selective surfaces, FSS, Radome.

I. INTRODUCTION

Frequency selective surfaces (FSS) have attracted considerable attention in telecommunications, antenna design, and electromagnetic compatibility for several decades. The investigation of FSS has been the subject of much fruitful study [1-6]. They have been proposed to be used as polarizers, space filters, sub-reflectors in dual frequency antennas, and antenna radomes for radar cross section (RCS) control [3].

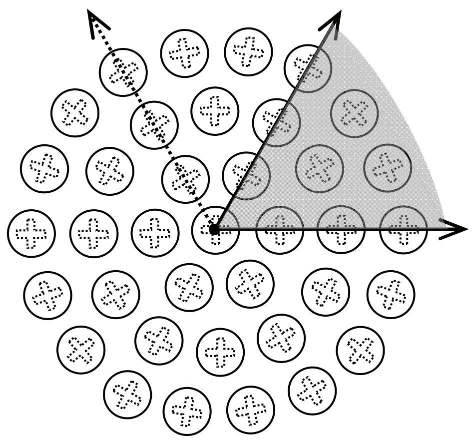
As a radome, the FSS is curved and has non-planar illumination. Because the FSS radome is often designed as a large structure, the approximate locally planar technique (LPT) method has been used to determine the scattering from a large FSS radome [4]. This LPT involves dividing the surface into a number of subarrays, each of which is assumed to be a segment of an infinite planar surface. The infinite FSS theory with plane wave illumination is applied to analyze each subarray.

In this paper, we propose a novel small FSS radome at S-band, which is mounted on sharp conical surface, and the strict periodic array of the FSS radome is indicated in detail. The FSS radome, together with a monopole antenna, is to be analyzed. Because the FSS radome is located in close proximity to a monopole antenna, and the whole structure is not too large and can be effectively simulated using the Ansoft software HFSS. The influence of the small FSS radome on the radiation of a monopole antenna is investigated by comparing the antenna radiation with the FSS radome present or not.

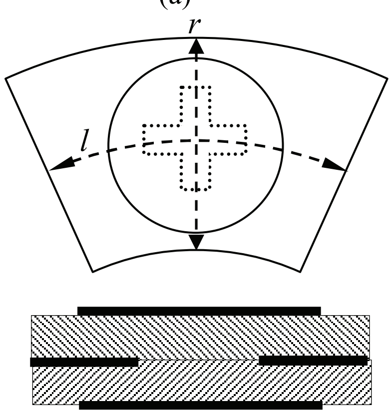
II. DESIGN

A FSS radome is a periodic array mounted on a curved surface. Firstly, we try to design the configuration of its unit cell. According to the narrow band-pass response of the known FSS based on the aperture coupled microstrip patches [5-6], its unit cell is chosen as two back-to-back circular patches laid on the surface of two dielectric slabs sharing a common ground plane, and one small crossed slot is set up on the ground plane to couple the fields from one patch to the other.

After the unit cell is chosen, the periodic array is established. For a miniature FSS radome, its curved surface has a much higher surface curvature, and a strict periodic array mounted on the sharply curved surface is difficult to construct. After much thought, we choose the FSS radome as a conical structure. This design is based on a novel axi-symmetric planar FSS. The geometry of the devised axi-symmetric planar FSS, as well as the chosen unit cell, are shown in Fig. 1.



(a)



(b)

Fig. 1. Geometry of an axi-symmetric planar FSS using aperture coupled patches. (a) Top view; (b) Unit Cells.

For the axi-symmetric planar FSS, the area of one unit cell is fan-shaped and its size is defined by two parameters, the length of the center arc l and the radius r, as shown in Fig. 1(b). To keep the axi-symmetry of the FSS, the ratio of the radius r to the center arc l shall be chosen as some fixed values, now we select it as:

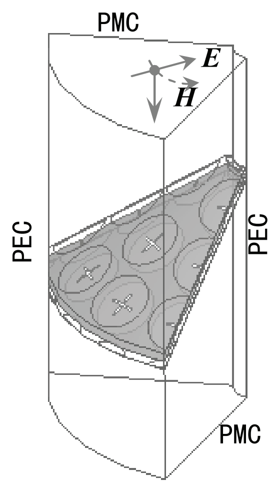
$$\frac{r}{l} = \frac{3}{\pi}.$$

In this way, the made-up FSS is just an axi-symmetric structure which is made up of six large pie slices, as shown in Fig. 1(a).

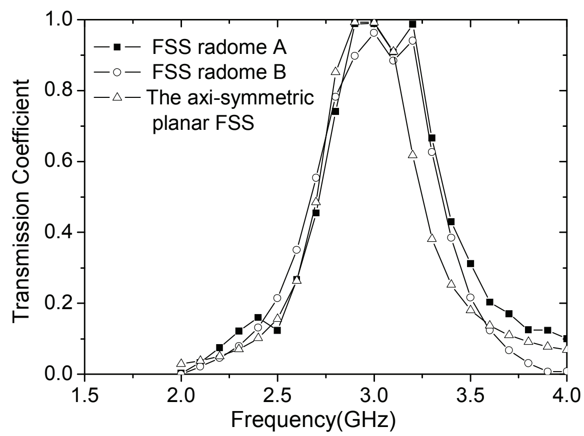
Now a novel axi-symmetric conical FSS radome can be constructed when one or two large pie slices of the axi-symmetric planar FSS are taken out and the left structure is circled around the center axis. When one large pie slice is taken out, the obtained FSS radome is named FSS radome A; when two large pie slices are taken out, a much sharper FSS radome B is obtained.

III. SIMULATED RESULTS

As an axi-symmetric structure, the small conical FSS radome can be simulated using the FDTD method in three-dimension cylindrical coordinates. We use Ansoft software HFSS to simulate it as a simple method.



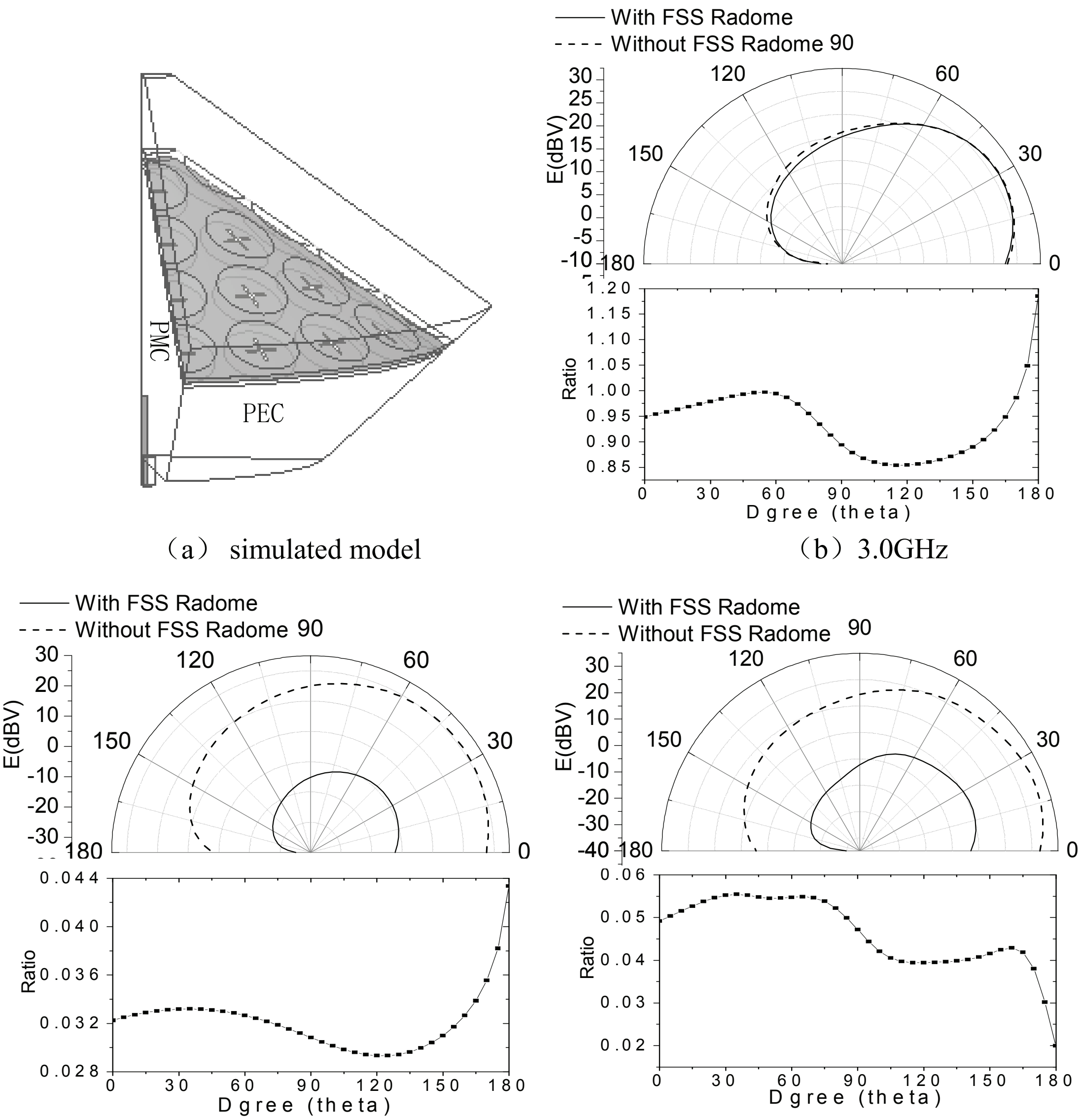
(a)



(b)

Fig. 2. Three dimensional simulated model of the FSS radome (a) and the simulated transmission coefficients (b).

After a series of simulations, we choose the structural parameters of the unit cell as follows: the radius of fan-shaped cell is r = 22.0*mm*, the radius of two



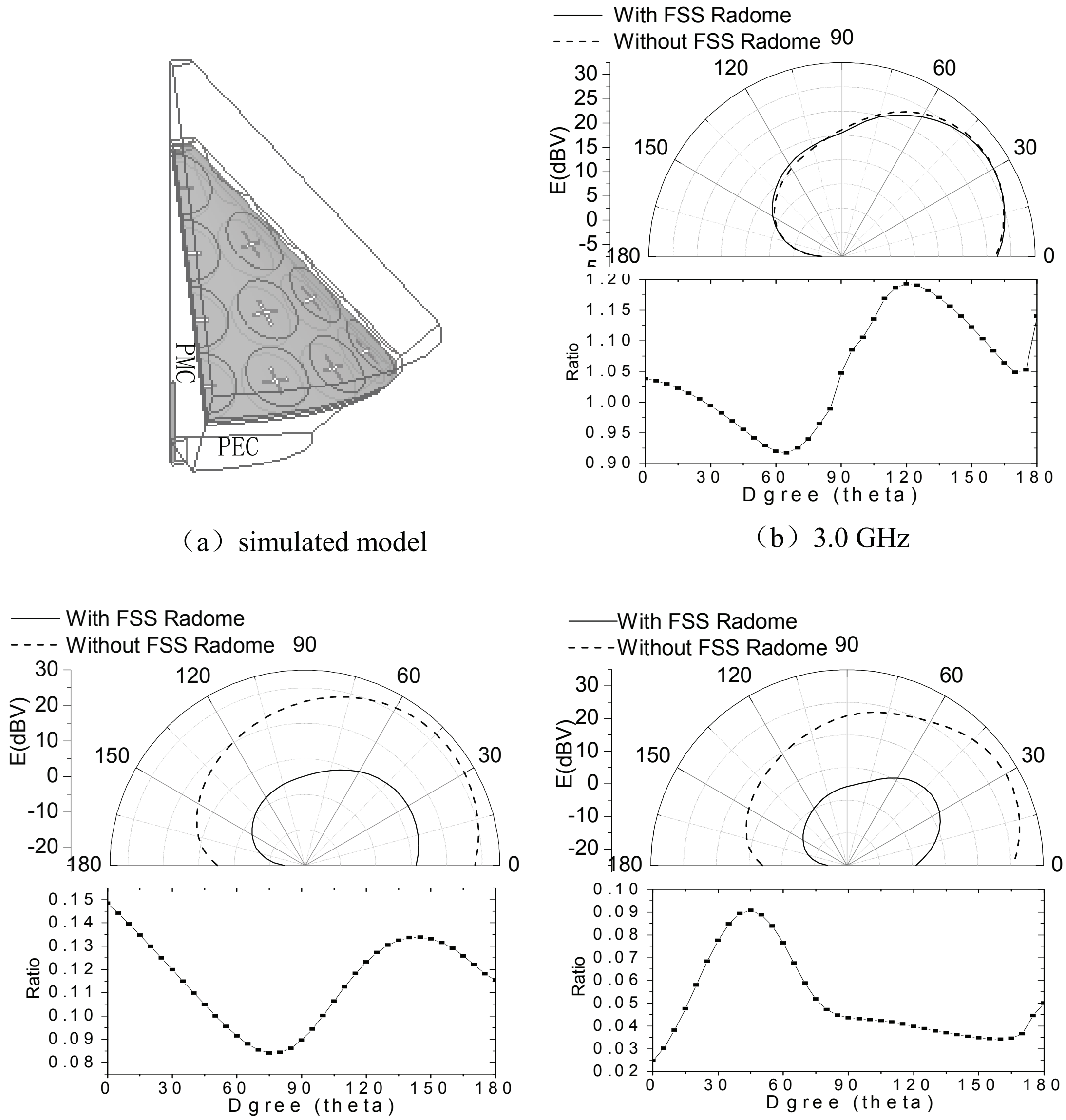
(c) 2.0GHz (d) 4.0GHz

Fig. 3. Three dimensional simulated model of the FSS radome A with a monopole antenna (a) and the simulated results at three frequencies3.0GHz (b),2.0GHz (c) and 4.0GHz (d).

back-to-back circular patches are all 10.0*mm*, the crossed slot on the ground plane contains two vertical rectangular gapes with the width 0.8*mm* and the length 9.0*mm*, the thickness of two dielectric slabs is 2.0*mm* and their dielectric constants are chosen as $\varepsilon_r = 6.0$.

The band-pass response of the conical FSS radome was analyzed first. According to its axi-symmetry, we pose the FSS radome into a large coaxial cable, and only choose one large pie slice as the simulated structure, as shown in Fig. 2(a). The analyzed transmission coefficients of the axi-symmetric planar FSS and the conical FSS radome are shown in Fig. 2(b). It is shown that the transmission coefficients have changed little when the axi-symmetric planar FSS was changed as the conical FSS radomes A and B. The desired narrow pass band response have been detected for all cases.

The conical FSS radome together with an antenna is simulated in succession. To keep the axi-symmetry of the whole structure, a monopole



（a）simulated model （b）3.0 GHz

（c）2.5GHz （d）4.0GHz

Fig. 4. Three dimensional simulated model of the FSS radome B with a monopole antenna (a) and the simulated results at the three frequencies 3.0GHz (b), 2.5GHz (c) and 4.0GHz (d).

antenna is selected and laid on the center axis of the conical FSS radome. In this way, we can separate one large pie slice from the whole structure using PMCs as the simulated structure.

Firstly, for the FSS radome A, the simulated structure is shown in Fig. 3(a). The radiation of the monopole antenna has been effectively simulated at three frequencies 2.0GHz, 3.0GHz, and 4.0GHz when the FSS radome A is presented or not. In the simulated results, these radiate electric fields in the middle longitudinal dissected plane of the simulated structure, as well as the ratio of the radiate fields in the presence of FSS radome A to that of the same antenna in the absence of the radome A, are shown in Fig. 3(b), (c) and (d).

At a frequency of 3.0 GHz which is in the pass band of the FSS radome A, the length of the monopole antenna is 25.0 mm. The data in Fig. 3(b) show that the FSS radome has little effect on the radiation of the monopole antenna, and the ratio is all close to 1.0 when the observation angle varies from 0 degrees to 180 degrees. While at frequencies of 2.0GHz and 4.0GHz, which are both in the stop band of the FSS radome A, the length of the monopole antenna is changed to 37.5 mm and 18.7 mm, respectively. The simulated results in Fig. 3(c) and (d) show that the radiation of the monopole antenna has been controlled in all directions because of the placement of the FSS radome A, as the ratio is reduced to -25~-35dB. It is verified that the FSS radome A has a desired band-pass response and will be prospectively useful for out-of-band RCS control.

Secondly, a similar process of simulations for the FSS radome B has been executed at the three frequencies: 2.5GHz, 3.0GHz, and 4.0GHz. The simulated structure and acquired results are shown in Fig. 4. According to the simulated results, the desired band-pass response of the FSS radome B has been effectively verified in the same way.

Finally, we combine the conical FSS radome A with a cylindrical FSS as a novel FSS radome. The unit cell of the cylindrical FSS is the same as that of the conical FSS. The longitudinal period is

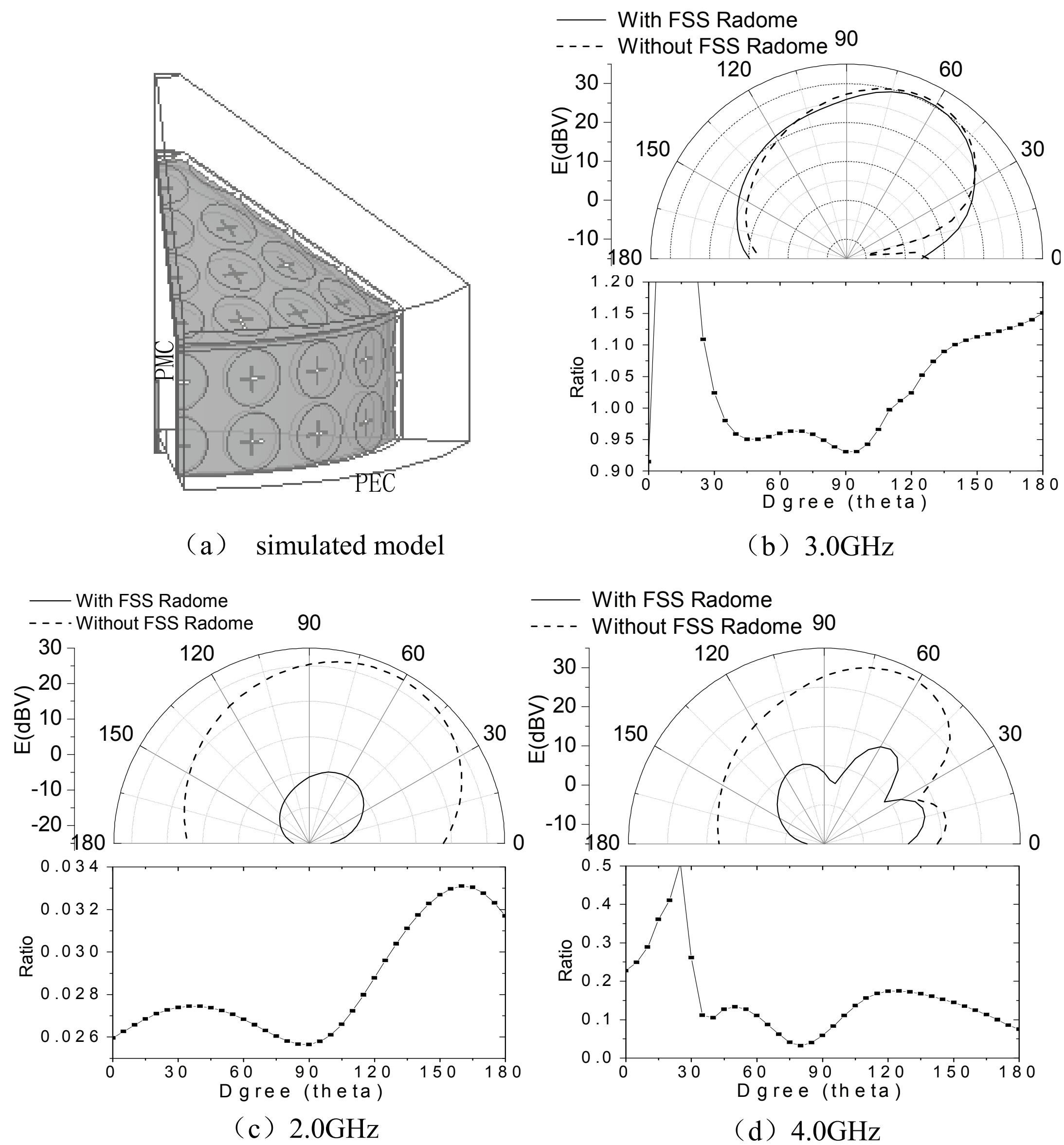


Fig. 5. Three dimensional simulated model of the novel FSS radome with a monopole antenna (a) and the simulated results at three frequencies3.0GHz (b), 2.0GHz (c) and 4.0GHz (d).

kept as 22.0mm, and the transverse period is changed to 24.9mm to keep the axi-symmetry of the whole structure. The simulated structure combined with the novel FSS radome with a monopole antenna is shown in Fig. 5(a), and the simulated results at three frequencies 3.0GHz, 2.0GHz, and 4.0GHz are shown in Fig. 5(b), (c) and (d), respectively. As the placement of the novel FSS radome, the data in Fig. 5(d) show that the reduction of the antenna radiation at 4.0GHz is relatively low in some directions, while the ratio is close to -20dB in most directions. The band-pass response of the FSS radome can still be seen.

IV. CONCLUSION

A novel axi-symmetric conical FSS radome was proposed in this paper. Its design was based on a novel axi-symmetric planar FSS, and its structure was described in detail. The effect of the proposed structure is effectively simulated with a monopole antenna using the Ansoft software HFSS. The simulated results showed that the novel FSS radome has a narrow band-pass response and is prospectively useful for out-of-band RCS control.

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