Study on Dual Wide Band Frequency Selective Surface for Different Incident Angles

P. Samaddar, S. De, S. Sarkar, S. Biswas, D.C. Sarkar, P.P. Sarkar

Abstract: This paper deals with single layer Frequency selective surface (FSS) which acts as a double band reject filter. The two stop bands are really broad with percentage bandwidth of 26.67% and 14.53%. The maximum and minimum band separation for this proposed design is around 45 dB and frequency ratio is more than 1.9.This results are almost same for different incident angles.. This design is investigated theoretically by ANSOFT® Designer software and practically by standard microwave test bench and the both results show a good agreement.

Keywords: Frequency Selective Surface; Band reject filter, Band separation, Frequency ratio.

I. INTRODUCTION

For more than four decades, Frequency Selective Surfaces (FSSs) have been widely studied for their various applications in spatial microwave and optical filters. They are being used as polarized filters, sub reflectors, band-pass hybrid radomes for radar cross section (RCS) controlling [1-4]. These surfaces are periodic arrays of strip (dipole) on a dielectric slab or slot within a metallic screen, which behave as band stop or band pass filters, respectively. Several such grid geometries have been demonstrated, including arrays of annular and square rings, dipoles, tripoles, crosses, and Jerusalem crosses [5,6]. Ring slot frequency-selective surfaces (FSS) have been widely investigated in recent years [7-9]. In reference [8] they report a four-band FSS design for the NASA CRAF/CASSINI application, that use of multiple RF frequencies for science investigations and data communications links.

This paper presents some FSS designs which have square patch with concentric annular ring slots. Effort has been given to make a double band FSS which can stop C and Ku bands for different incident angles with good percentage bandwidth and high band separation. These bands are used in satellite communication and this microwave band stop filter can be used in this field. This paper actually introduces four designs, where every design is the modification of the previous design and the last (fourth design) one is the best among those and nearest to our requirement. The results for different incident angles are studied for this design.

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Every design is theoretically investigated by ANSOFT Designer / Nexxim v 2.2 software which uses method of Moment (MOM) process to calculate the results. To confirm the simulated result, the FSS is fabricated and experimentally tested. Every FSS is designed with dielectric (FR4, relative permittivity of 4.4 and 1.6mm thickness) and metal (copper).

II. DESIGN OF FSS

In this section four FSS designs are introduced with different number of concentric rings and circular slots. The first design has only one ring slot but the fourth has two rings and one circular slot. The size of the metallic square patches increases with the number of ring shaped slots. Single cells of the all four designs are shown in fig. 1. Though the number of rings is changed, the width of the ring and radius of circular slot are kept same as 1mm. By taking infinite array of these single cells (when the cells are kept 2mm apart in both vertical and horizontal direction) the result has been investigated by software. A small part of the fourth FSS is shown in Fig. 2. The periodicity in both horizontal and vertical direction for the first design is 8mm, for second design is 10mm, for third design is 12mm and for fourth design is 14 mm At the time of experiment a 12cm * 12cm (approximately) FSS having eight rows and eight columns is used. Figure 3 shows the fabricated FSS.

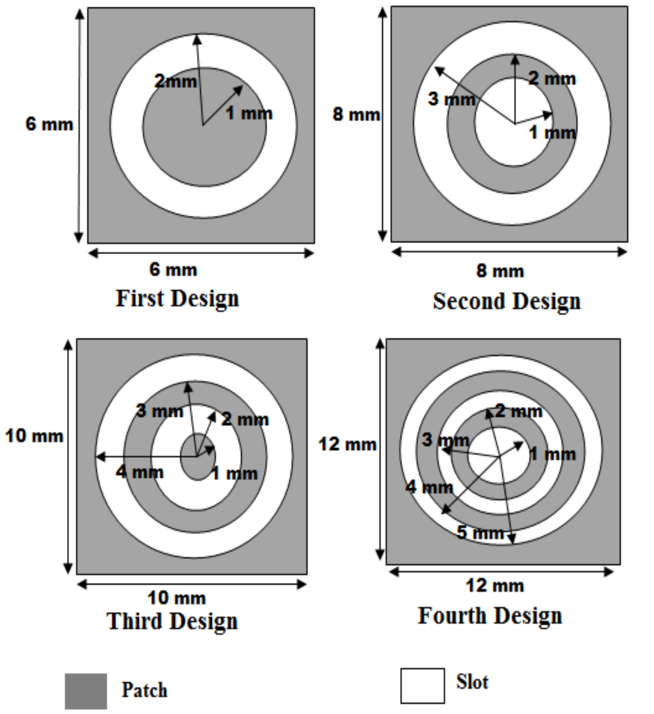


Fig. 1. Single Cells of the Four FSS

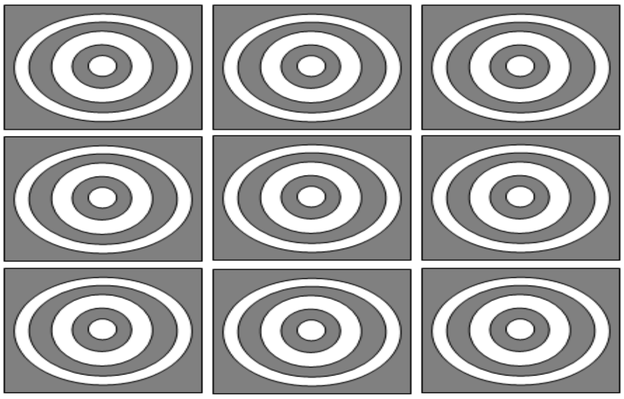


Fig. 2. FSS with Concentric Annular Slots (Fourth Design)

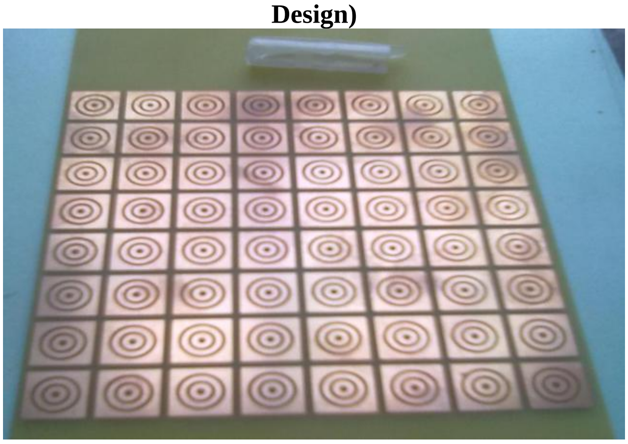
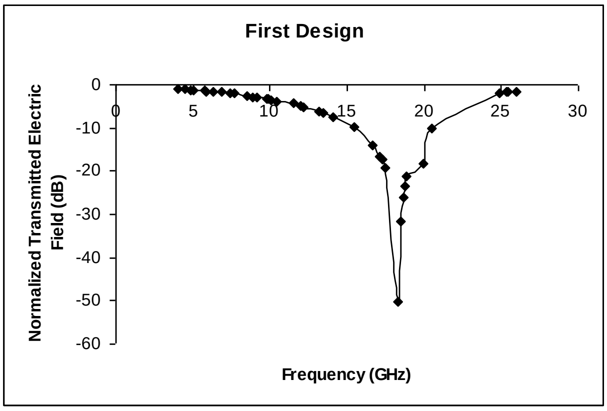


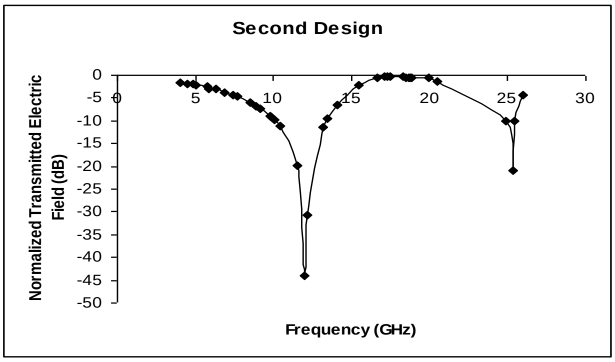
Fig.3. Fabricated FSS

III. RESULT

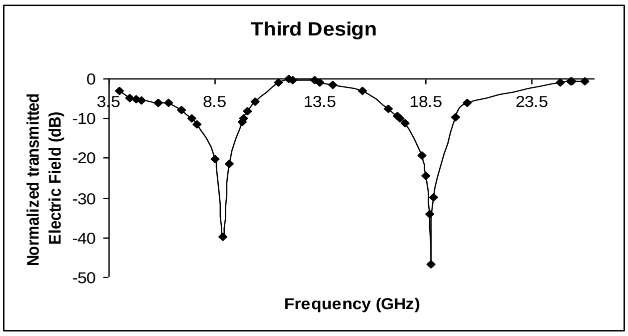
The simulated results for all the four designs are shown in table 1. A normalized electric field vs. frequency graph for all designs is shown in fig 4. By this graph it can be shown that bands are shifting left with every modification. The fourth design provides the best result, so it is fabricated and practically investigated. The response for different incident angle, starting from 0° to 60° with an interval of 10° is also investigated and shown in table 3. The practical investigation is done by standard microwave test bench. Agilent made microwave generator is connected to a transmitting horn. Receiving horn antenna is connected to an Agilent made power meter (model no E4418 B, EPM Series Power Meter) with sensor (model no E4412 A, E Series CW Power Sensor). The horn antennas and generators are changed for different frequencies bands like 4GHz – 6GHz, 6GHz - 8GHz, 8GHz - 12GHz etc. Both the practical and theoretical results for the fourth design are shown in the table 2 and transmission characteristic is shown in Fig.6.



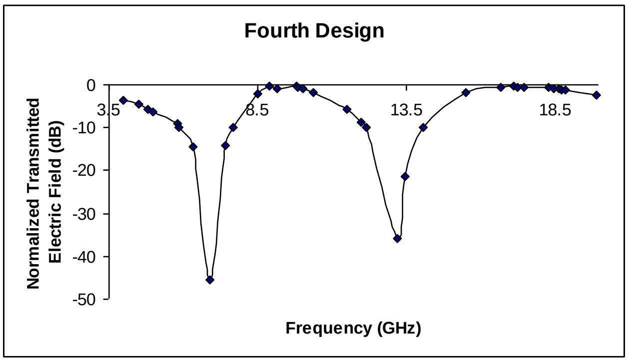
Graph for First Design



Graph for Second Design



Graph for Third Design



Graph for Fourth Design

Fig. 4 Normalized transmitted Electric field graph for four FSS

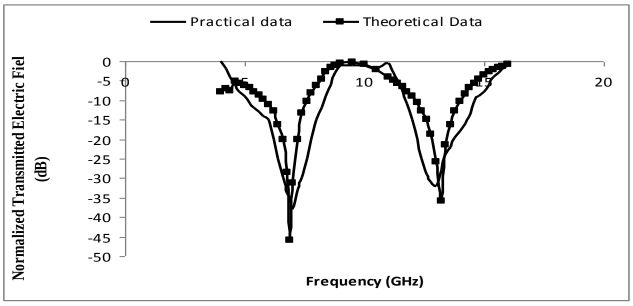


Fig 6. Normalized transmitted Electric field vs. frequency graph for fourth FSS (Simultaneously simulated and measured results)

Parameters / Name of FSS	Resonating Frequency (GHz)	Bandwidth (GHz)	Percentage Bandwidth
First Design	18.31	4.96	27.09
Second Design	12.01	3.41	28.39
	25.31	0.53	2.1
Third Design	8.9	2.44	27.42
	18.73	2.64	14.09
Fourth Design	6.9	1.84	26.67
	13.21	1.92	14.53

Table. 1. Simulated results for the four FSS designs

	Theoretical Results	Practical Results
Resonating Frequency (GHz)	6.9	7
	13.21	13
Bandwidth (GHz)	1.84	2.6
	1.92	2.8
Percentage Bandwidth	26.67	37.14
	14.53	21.54

Table 2. Theoretical and measured results for Fourth FSS

Incident Angle	First Band				Second Result			
	Theoretical Result		Practical Result		Theoretical Result		Practical Result	
	Resonating Fr. GHz	Bandwidth GHz	Resonating Fr GHz	Bandwidth GHz	Resonating Fr. GHz	Bandwidth GHz	Resonating Fr. GHz	Bandwidth GHz
0°	6.9	1.84	7	2.6	13.21	1.92	13	2.8
10°	7	1.91	7.1	2.5	13.16	1.81	13.2	2.7
20°	6.89	1.83	6.99	2.61	13.16	1.86	13.12	2.74
30°	6.89	1.8	7	2.5	13.17	1.84	13.2	2.8
40°	6.89	1.83	6.88	2.6	13.16	1.85	13.19	2.75
50°	6.89	1.78	6.9	2.55	13.16	1.83	13	2.8
60°	6.89	1.78	7	2.4	13.16	1.81	13.12	2.75

Table 3. Theoretical and measured results at different incident Angle for Fourth FSS

IV. CONCLUSION

Here dual band stop frequency selective structure has been designed. Both the bands are wide. The most important points to mention here are that the separation between transmission and reflection band is around 40 dB and the higher to lower frequency band ratio is 1.9. The novelty of the paper is that four goals (Broad band, multi band, good ratio between higher and lower band, good band separation) are achieved simultaneously in the design of a single layer FSS structure. Another important point is the independency of the structure with respect to the change in incident angles.

V. ACKNOWLEDGEMENT

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