Design of a High Q Multifrequency Notch Filter with the Help of Frequency Selective Surface Having Square Spiral Patch Array

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ABSTRACT
This paper deals with the theortical investigation on high Q (80.50 approx) mutifrequency Notch type Frequency Selective Surface(FSS). The FSS is designed by cutting spiral slit into square shaped patch keeping same periodicity throughout. Compared to conventional square patch FSS the designed FSS can provide reduction in resonant frequency resulting in size reduction up to 95.20% with respect to 2.63GHz resonant frequency. The multiple (fourteen) resonating frequencies have been obtained with the help of this design. Theoretical investigations have been done by Ansoft Designer® software.

Keywords
Frequency Selective Surface, Method of Moment, Slit, Size Reduction, Resonating Frequency, Q factor, Notch Filter.

1. INTRODUCTION
In microwave engineering Frequency selective surfaces or dichroics can be regarded as filters of electromagnetic waves[1-4]. An array of periodic metallic patches on a substrate, or a conducting sheet periodically perforated with apertures, constitutes a frequency selective surface (FSS) to electromagnetic waves. Such structures have been well known in antenna theory for over half a century. They exhibit total reflection for patches and total transmission for apertures in the neighborhood of element resonance. The reflection and transmission band can be predicted theoretically by different methods viz. Finite Difference Time Domain method (FDTD), Finite Element Method (FEM) & Method of Moment (MOM).[5] The frequency selective properties of FSS are exploited to make a more efficient use of reflector antennas in satellite communication systems which results weight reduction of the satellite and increases its working life. The other application of FSS is to protect the Radar system using radome. FSS is also used in the domestic microwave oven Screen Window which blocks the microwave from coming out but passes the visible spectrum.

2. DESIGN
The reference patch is a two dimensional metallic copper patch of 20*20 mm^2 as shown in Figure 1. The patches are considered to be present on one side of a thin dielectric slab of glass PTFE having relative permittivity of 2.4 and thickness of 1.6mm. The dimensions are shown in the Figure 1.

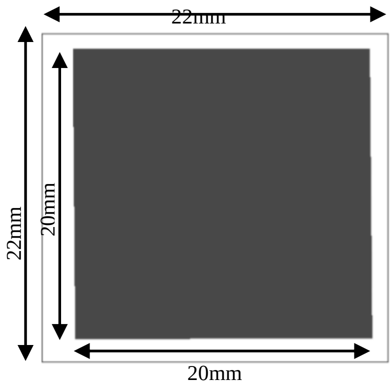

Figure 1: FSS with reference patch

Now we design the modified FSS array by cutting slit as shown in Figure 3. The line width of the slit is 0.5mm. The dimension of the unit cell of FSS is shown in Figure 2. The two dimensional array of patches with periodicity is taken 22 mm both in x and y-directions is shown in Figure 3.

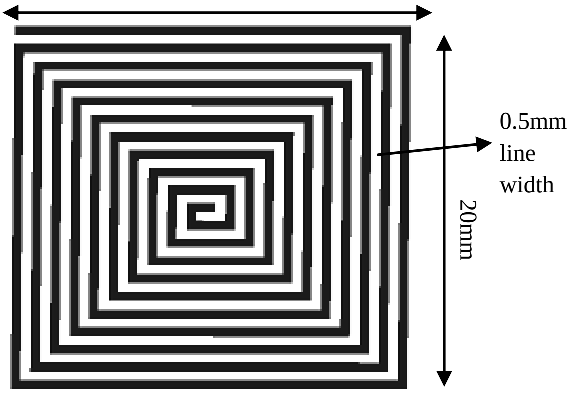

Figure.2: Unit cell of FSS with spiral slit

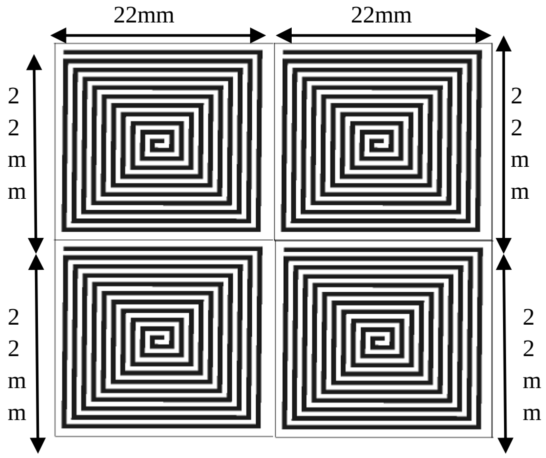

Figure3. Two dimensional array of patches with spiral slit

3. RESULTS & DISCUSSIONS

Computed transmission characteristics for reference patch [Figure 1] using Ansoft Designer® is plotted in Figure 4, which shows that the FSS resonates at 12GHz while considering the first frequency band.

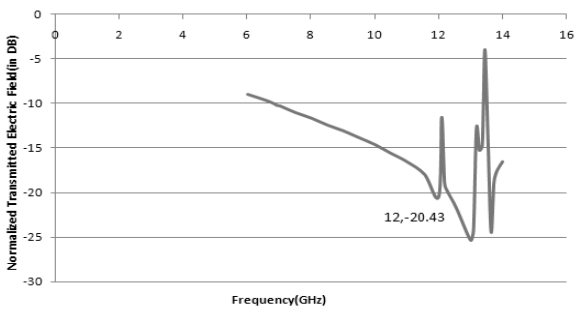

Figure4: Study of normalized transmitted electric field vs. frequency (corresponding to Figure1)

Computed transmission characteristics for proposed FSS [Figure.2] using Ansoft Designer® is plotted in Figure.5, which shows that the FSS resonates at 2.63 GHz while considering the first frequency band. Before designing the FSS with proposed grid, the first resonating frequency is obtained at 12GHz [Figure.4]. To obtain the resonating frequency at 2.63 GHz it would require the perimeter of the patch as 365.01 mm (approximately). The length of each side of the required patch is 91.25mm (approx). So the size reduction of $[(91.25^2-20^2)/91.25^2]=95.20\%$ (approx) has been achieved with the help of this proposed design.

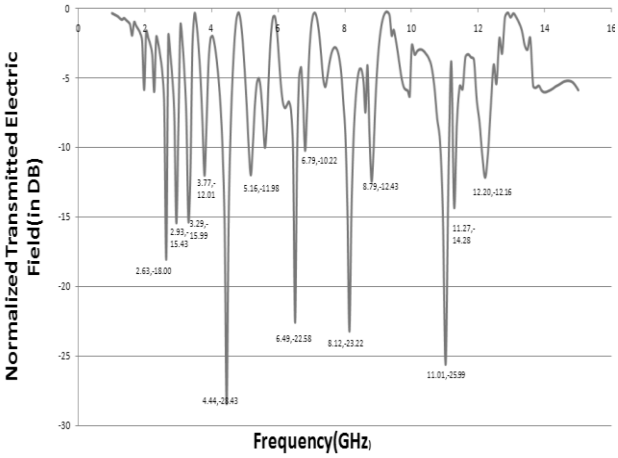

Figure5: Study of normalized transmitted electric field vs. frequency (corresponding to Figure 2)

Table 1: SUMMARIZED RESULTS

In the modified FSS multiple resonating frequencies have been obtained. The resonant frequencies with bandwidth and percentage bandwidth have been shown in tabular form.

Sl No	Design of FSS	Resonating Frequency in GHz	Transmission Gain (dB)	Bandwidth in GHz	Percentage bandwidth
1.	Patch without slit(Figure1)	12	-20.43	6.60	54.50%
2.	Patch with slit(Figure3)	2.63	-18.00	0.06	2.28%
		2.93	-15.43	0.08	2.73%
		3.29	-15.99	0.11	3.34%
		3.77	-12.01	0.10	2.65%
		4.44	-28.43	0.22	4.95%
		5.16	-11.98	0.12	2.32%
		5.59	-10.01	No band	No band
		6.49	-22.58	0.13	2.00%
		6.79	-10.22	No band	No band
		8.12	-23.22	0.20	2.46%
		8.79	-12.43	0.12	1.36%
		11.01	-25.99	0.27	2.45%
		11.27	-14.28	0.14	1.24%
		12.20	-12.16	0.19	1.55%

The Q factor and bandwidth of a filter is related by the following equation

$$Q=f_r/(f_1- f_2) \quad (1)$$

Where f_r is the resonating frequency and f_1 and f_2 are lower and higher cut-off frequencies respectively. Again,

$$BW=f_1-f_2 \quad (2)$$

Therefore the Q factor is inversely proportional with the bandwidth.

Calculations from the Table.1 show that minimum Q value obtained is 20.18 (approx) at 4.44 GHz while the stop-band with 11.27GHz resonant frequency has a maximum and large Q factor of 80.5 (approx). Again the design results a maximum bandwidth of 270MHz only. Therefore all the bands would provide a reliable selectivity over microwave range.

4. CONCLUSION

The main characteristic of the design is that it can be deployed as high Q notch filter with excellent selectivity for twelve -10dB stopbands within 15GHz. Moreover, calculation shows an achievement of huge compactness (95.20%) with respect to the reference patch [Figure.1]. This design is useful for different S, C, J, X & Ku-band applications in satellite communication & various microwave related communication purposes.

5. ACKNOWLEDGEMENT

This research work has been funded by D.S.T PURSE Project of University of Kalyani.

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