Design of Two Multiband Frequency Selective Surfaces with Novel Shaped Slots on Circular Patch

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ABSTRACT
Frequency Selective Surfaces (FSS) with two novel designs have been presented in this paper. Both the designs are based on the slots cut on the reference circular patch resulting in multiple resonating frequencies (3 bands in case of the first design & 4 bands in case of the second one within 20GHz). Size reductions of 61.1% & 81.5% have been achieved respectively in the two proposed designs. The resonating frequencies of the first band are obtained at 5.8GHz & 4GHz respectively. Investigation is done on patch without slot & then patch with the specific slots mentioned earlier. A comparative study has also been carried out with respect to the reference patch with radius of 12 mm & the FSSs with two novel designed slot cut on the reference patch. The FSSs with these particular designs will work as a band stop filter in microwave range radio communication. ANSOFT® software has been used for designing & theoretical findings.

Keywords
Frequency Selective Surface, Method of Moment, Slot, Size Reduction, Resonating Frequency

I.INTRODUCTION
A Frequency Selective Surface (FSS) is comprised of an infinite array of periodically arranged metallic patch or aperture elements that exhibit total reflection or transmission of microwaves, respectively, in the neighbourhood of the element resonance [1]. Frequency selective surfaces, which are a type of metamaterial, have been studied for a long time due to their many properties[2]. Frequency selective surfaces (FSSs), working as a spatial filter, is typically used in high performance radomes for radars & communication antennas over the years for both commercial & military applications [3-5]. It offers low profile and ease of manufacturing, which provide a great advantage over traditional spatial filters [6]. But limitations of frequency selective surfaces are narrow bandwidth & high resonating frequencies. On the other hand, FSS structures with lower resonating frequencies lead to larger size.

Generally theoretical analysis of the surfaces are done by three methods. Finite Difference Time Domain method (FDTD), Finite Element Method (FEM) & Method of Moment (MOM). Ansoft is the software which works based on method of moment. This procedure is most complicated but the accuracy is the highest. Here in our study, proposed FSS structures have been theoretically analyzed by Ansoft Designer®.

II.DESIGN
The reference patch is a circular metallic copper patch of radius of 12 mm[fig.1] fabricated on a

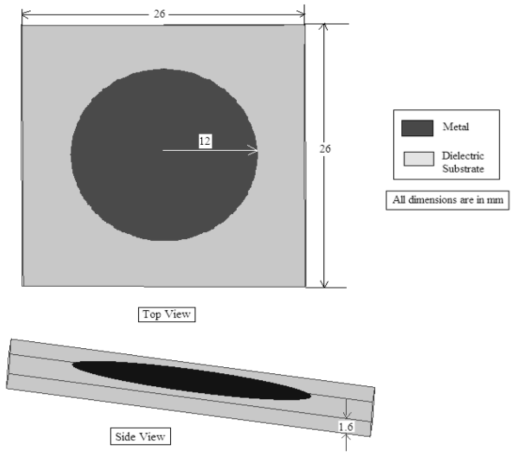

Fig.1: FSS with reference patch (unit cell)

dielectric slab. In this study the dielectric slab is glass PTFE having relative permittivity of 2.4 & thickness of 1.6 mm. The substrate dimension for a single cell is 26mmX26mm. A 2-dimensional array of these cells is considered for this study & is simulated accordingly.

The first proposed design [Fig2] is obtained by cutting four triangular slots from the reference patch. These triangles are isosceles triangles & are having completely same parameters. The four vertices,

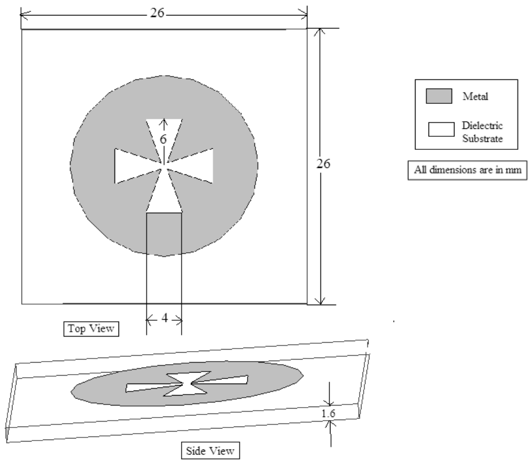

Fig.2: FSS with proposed first design (unit cell)

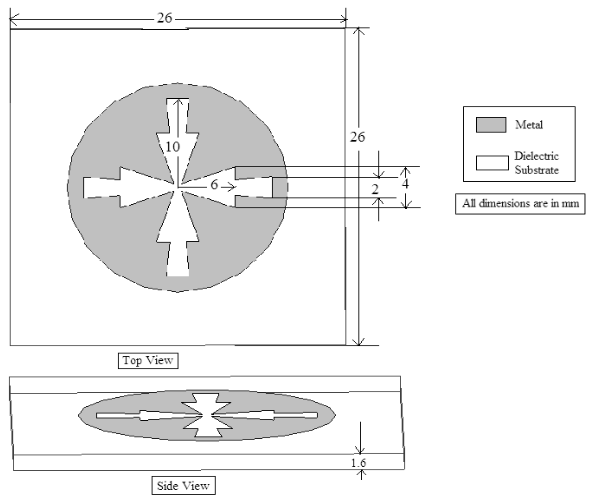

Fig.3: FSS with proposed second design (unit cell)

situated opposite to the bases of the triangles, coincide at the centre of the circular patch. The height & length of the base of the isosceles triangles are 6mm & 4mm respectively.

The above mentioned slot is modified further to obtain another novel shaped design of the slot. In the modified design [fig3] a second isosceles triangle is being merged on the previous triangle (keeping the vertices opposite to the bases as common point of the two triangles) & an arrow shaped slot is formed. The height & length of the base of the isosceles triangle, merged on the previous one, is 10mm & 2mm respectively.

III.RESULTS

Computed transmission characteristics for proposed FSS [fig.2] using Ansoft is plotted in Fig.5, which shows that the FSS resonates at 5.8 GHz while considering the first frequency band. Before designing the FSS with proposed grid, the first resonating frequency is obtained at 9.3GHz [fig.4]. To obtain the resonating frequency at 5.8 GHz it would require the patch of radius of 19.24 mm approximately. So a size reduction of [π*(19.242-122)/(π*19.242)]=61.1% (approx.) has been achieved with the help of this proposed design.

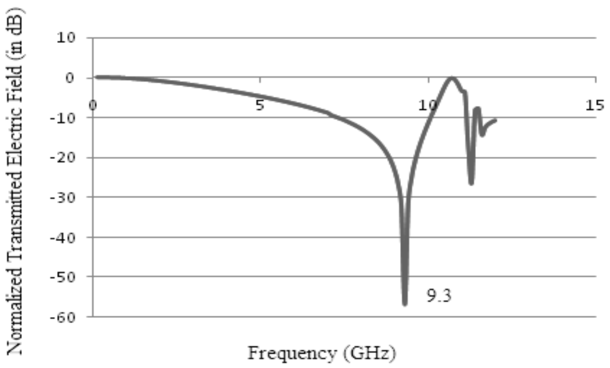

Fig 4: Study of normalized transmitted electric field vs. frequency (corresponding to Fig.1)

Fig.4 shows normalized transmitted electric field plotted vs. frequency of the reference patch & the plot exhibits that the only resonating frequency, within 10GHz, is at 9.3 GHz.

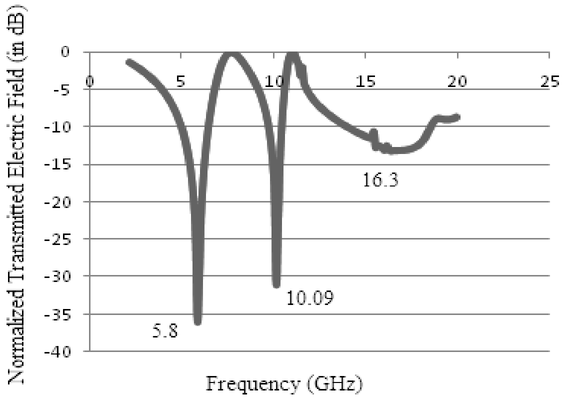

Fig. 5: Study of normalized transmitted electric field vs. frequency (corresponding to Fig.2)

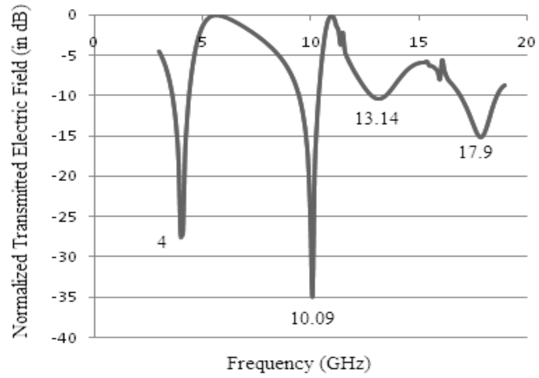

Fig.6: Study of normalized transmitted electric field vs. frequency (corresponding to Fig.3)

Comparative study between fig. 4 & fig. 5 shows that resonating frequency of the frequency selective surface (FSS) is shifted from 9.3 GHz to 5.8 GHz after designing the patch with proposed grid-shaped slot. Along with the large size reduction of 61.1% multiband is obtained with resonating frequencies being at 5.8GHz, 10.09GHz & 16.3GHz with bandwidth of 22.93%, 7.43% & 27.61% respectively. Especially the third band is a broadband, stretched up to 4.5GHz, which is enormous for an FSS.

Table 1: SUMMARIZED RESULTS

		Resonating Frequencies (GHz)	Lower cut-off frequency at -10dB(GHz)	Upper cut-off frequency at -10dB(GHz)	Bandwidth in GHz(% Bandwidth)	Size Reduction (%)
Patch without slot(Fig.1)		9.3	7.25	10.09	2.84(30.5)	----
Patch with slot(Fig.2)	Band 1	5.8	4.94	6.41	1.47(22.93)	61.1
	Band 2	10.09	9.67	10.42	0.75(7.43)	
	Band 3	16.3	13.99	18.49	4.50(27.61)	
Patch with slot(Fig. 3)	Band 1	4.00	3.62	4.39	0.77(19.25)	81.5
	Band 2	10.09	9.47	10.41	0.94(9.32)	
	Band 3	13.14	12.81	13.51	0.7(5.33)	
	Band 4	17.9	16.94	18.66	1.72(9.61)	

In case of the second proposed design the first resonating frequency is obtained at 4GHz. Calculations show that to resonate at 4GHz the patch radius required is 27.9mm approx. Therefore in this case the size reduction obtained is [π*(27.92-122)/(π*27.92)]=81.5% (approx.). This design gives four frequency bands considering less than -10dB transmission gain within 20GHz range, i.e. one band extra compared to the previous design & the resonating frequencies are obtained at 4GHz, 10.09GHz, 13.14GHz & 17.9GHz with bandwidth of 19.25%, 9.32%, 5.33% & 9.61% respectively.

The results are summarized in the Table 1.

IV.CONCLUSION

Both the designs can be deployed as bandstop filter in microwave range communication. In both the designs, a huge compactness is achieved (61.1% & 81.5% respectively). Both the designs result multiple resonating frequencies, while in the first design there are two broad-bands (-10dB stopbands) also with 22.93% & 27.61% bandwidth. Frequency Selective Surface with more than one operating frequencies is required where it is needed to stop the signals at different bands of frequencies. Therefore a single component fulfils the requirement of separate spatial filters with single stop-band and reduces the complexity of the system [7].
While the first design can be applied for different C, X & Ku-band applications like satellite communication etc., the second design will be useful for various S, C, X & Ku-band communication purposes.

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