A NOVEL COMPACT FREQUENCY SELECTIVE SURFACE USING K AND Ka BAND FOR SATELLITE APPLICATIONS

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***Abstract*— A single layer novel compact frequency selective surface which is used in reflector antenna is designed and simulated. The proposed unit cell reflects electromagnetic waves in k and ka band with maximum reflection occurring at 22.62 GHz and 35.44 GHz respectively. The designed FSS find its application in satellite communication. A crossed dipole structure in center and two-legged structure in corners and square loop in each quadrant makes the FSS unit cell structure. The FSS is designed with oblique incident angle for TE and TM polarization with the return loss 0.3 dB in 22.62 GHz and less than 0.5 dB in 35.44 GHz. The proposed work shows frequency independence against oblique angle of incidence. The simulated result from CST microwave studio is compared with other similar works.**

1.INTRODUCTION

Frequency selective surface, also called spatial filter modify the electromagnetic wave incident on surface, providing transmission or reflection characteristics at certain desired frequency. The modification is done in amplitude or phase of the EM incident wave. FSS is designed by periodic arrays of metallic element placed on dielectric substrate [5]. A single layer triband transmissive/reflective frequency selective surface is designed with incident angle up to 80°and also shows polarization stability. Controllable passband in X-band and reflect band in ku and ka band was proposed in [3]. FSS unit cell is designed using two symmetric pattern of metallic fractal lines printed on single layer with dimension of 7×7 mm2 with Centre frequency of 4.05GHz and 5.30GHz with polarization and angle independency [4]. The three-layer broad band polarization FSS is realized with low transmission co-efficient and act as excellent ripple free band pass filter by using k and ka band [6]. A multi-layer FSS structure is adopted by coupling of capacitive and inductive surface to realize the angular stability [5]. A frequency selective surface can transmit or reflect the electromagnetic waves in accordance with desired range of frequencies. The reflection and transmission of the electromagnetic wave depends upon angle of incidence, polarization, and dielectric material that is used. In this paper the FSS acting as sub-reflector antenna that is designed to be reflective layer for k and ka feed. For element single layer design, the prime cost is low and process of fabrication is easy. Stable performance is achieved for different polarization and incident electromagnetic waves which increase the communication capacity of the antenna in the satellite communication system. The proposed design is to give maximum reflection at 22.62GHz and 35.44 GHz. This paper is categorized as follow. Section II illustrates the design and structure of the proposed unit cell. Simulated results are demonstrated in section III. Comparative study is done in section IV. Conclusion of the proposed work is given in section V.

2.DESIGN AND STRUCTURE OF UNIT CELL

The proposed FSS unit cell design is s symmetric structure with cross dipole and a square loop. The designed unit cell has a dimension 4mm × 4mm with thickness 0.5mm. The FSS unit cell is designed with cross dipole at the Centre, a two-legged shape structure at corner and a square loop in each quadrant. The FSS unit cell is made to reflect electromagnetic waves in k and ka band. The copper annealed patch is placed on a single layer FR4 substrate with tangent loss 0.02 and permittivity ε_r =4.4.

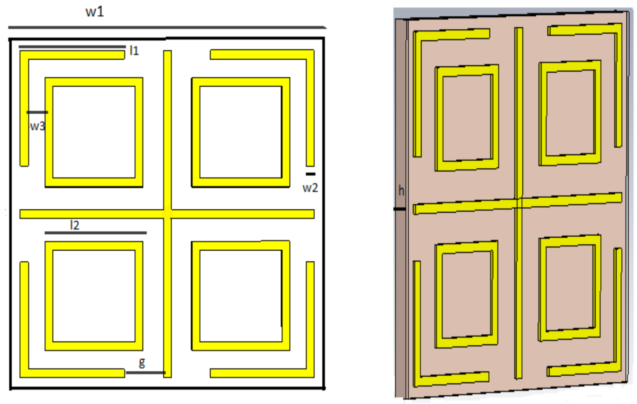

Figure 1(a, b): Geometry of FSS element

The parameter of the designed FSS unit cell is shown in Table I. The parameter h and g denote the thickness and the element spacing of FSS unit cell respectively.

TABLE I
PARAMETER VALUES OF FSS

Parameter	Values(mm)
h	0.5
g	0.5
l1	1.32
l2	1.25
w1	4.0
w2	0.1
w3	0.23

Firstly, the FSS is designed using a cross dipole. This structure has the worst stability with variation in incident angle. The reason behind this is when a vertically polarized wave hits the dipole, the dipole resonates irrespective of the incident angle. If the direction of the incident wave is oblique to the broadside of the dipole, the dipole will not resonate effectively depending on the incident angle. That's why the desired resonance frequency is not obtained with this structure. Hence the structure is further improved by adding a square loop in each quadrant. The square loop structure resonates when half of the loop length is a multiple of one full wavelength which results in dielectric effect which leads to frequency stabilization. Even though the desired frequency is not reached. Finally, a two-legged structure is added at corners to get the desired frequency.

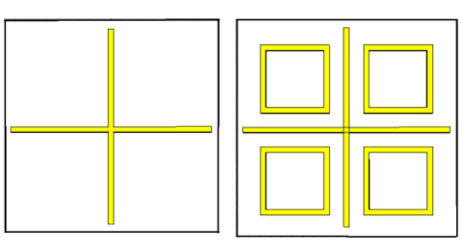

Figure 2a: **Figure 2b:**

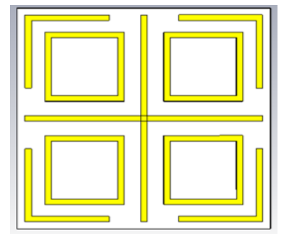

Figure 2c:

The design process is demonstrated step by step. Firstly, a crossed dipole is designed which is shown in figure 2a. The evaluated result from figure 3a shows reflection characteristic appear at 23GHz. The desired frequency is 35GHz which is not reached. Hence the structure is improved by adding a square loop in each quadrant as shown in figure 2b. But still desired frequency is not achieved which is shown in figure 3b. Further improvising the structure by adding a two-legged structure in corners yields the desired frequency. The maximum reflection occurs at 23GHz and 35GHz.The figure 2c shows the final design and figure 3c shows the corresponding result.

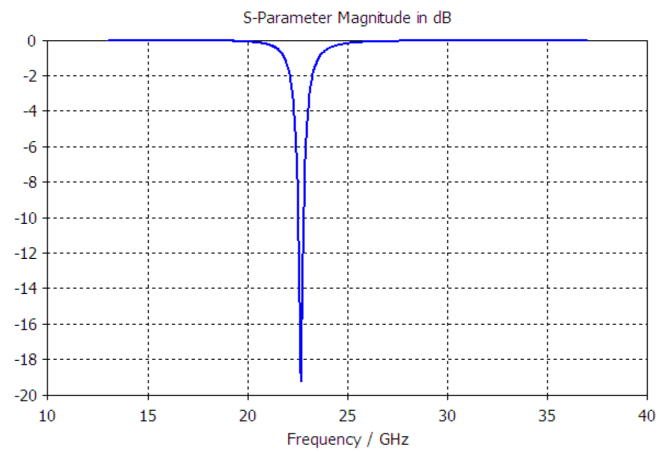

Figure 3a: S_{11} frequency for the first design stage of the patch cell, for incident angle 0°.

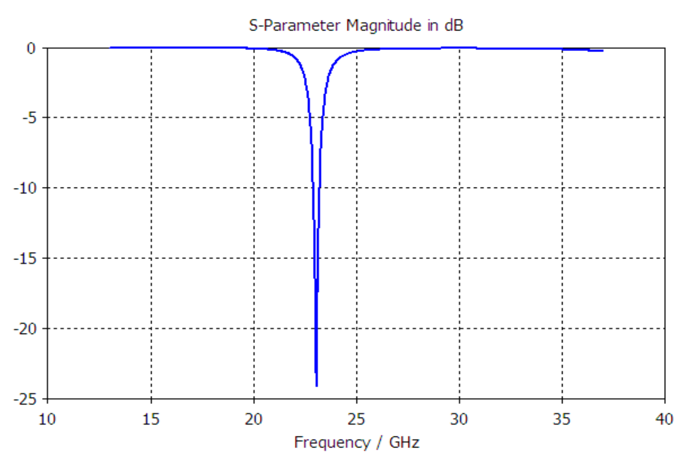

Figure 3b: S_{11} frequency for the second design stage of

the patch cell, for incident angle 0°.

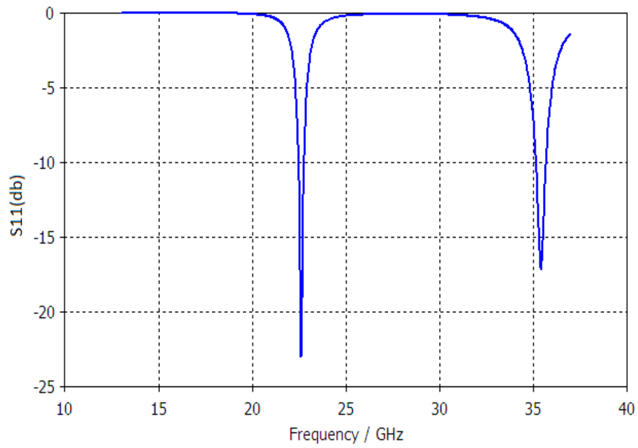

Figure 3c: S_{11} frequency for the third design stage of the patch cell, for incident angle 0°.

3.SIMULATION AND RESULT

For analyzing and optimizing the FSS geometry design using periodic boundary condition and floquet port CST microwave studio is used. The design is simulated for different angle ranging from 0° to 60°.This is shown in figure 4a. From the figure it is observed that the reflection co-efficient is below -10dB.The transmission co-efficient for the designed FSS is also obtained and it is shown in the figure 5.

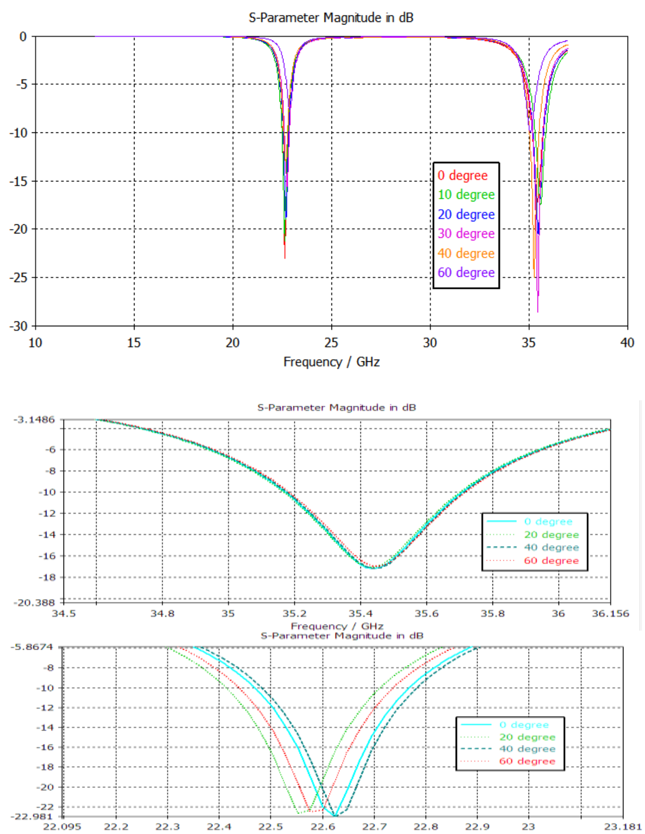

Figure 4(a, b, c): S_{11} frequency for the proposed FSS geometry, for incident angle ɵ =0°, ɵ =20°, ɵ=40°, ɵ =60°

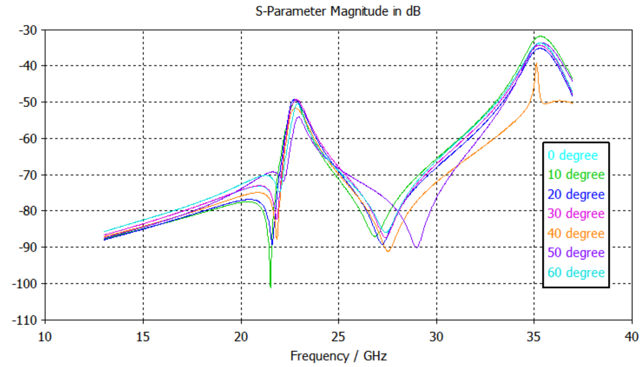

Figure 5: S_{21} frequency for the proposed FSS geometry, for incident angle ɵ =0°, ɵ =20°, ɵ=40°, ɵ =60°

The reflection co-efficient for TM and TE polarization is determined in figure 6. From the figure it is understood that designed FSS structure shows frequency stability against different oblique angle of incidence for TE and TM polarization.

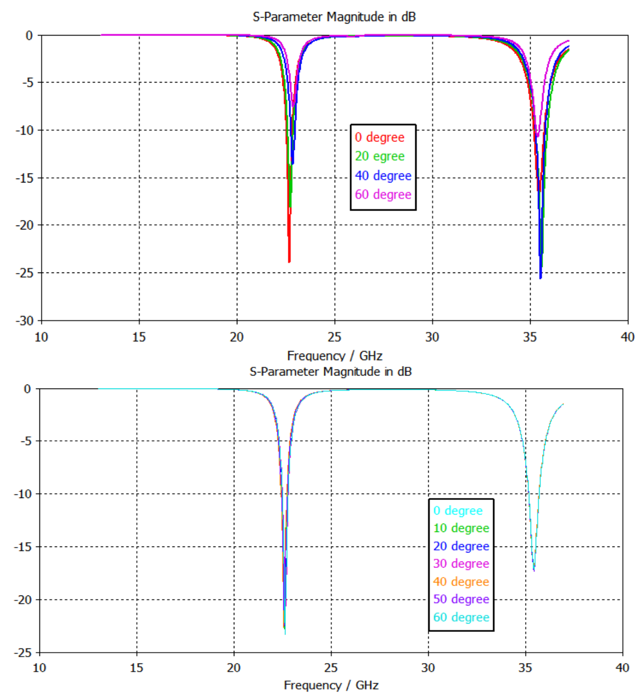

Figure 6(a, b): S_{11} frequency for TE and TM polarization, for incident angle ɵ =0°, ɵ =20°, ɵ=40°, ɵ =60°

From the figure 4a, it is observed that reflection coefficient parameter increases with increase in the incident angle for TE polarization. The reflection loss is observed as 0.3 dB in 22.62GHz when the wave incident is from 0° to 60°. While the bandwidth at 22.62GHz for the wave incident at 0° is

TABLE II Table comparison of the proposed FSS with similar FSS

Articles	Unit cell design(mm^2)	Number of operating bands	Number of substrate layer	Operating frequency band	polarization	Angle range
[3]	5×5×0.508	3	1	X, Ku, Ka	Dual	0°-80°
[4]	7×7×1.6	2	1	C	Dual	0°-60°
[5]	2.2×2.2×0.5	1	7	Ka	Dual	0°-60°
[2]	6×6×11.5	1	5	Ku	Dual	60°
[1]	4×4×1	2	1	Ku, Ka	Dual	60°
This work	4×4×0.5	2	1	K, Ka	Dual	0°-60°

4.6%. Further increase in the incident angle results in increase in bandwidth percentage. On the other hand, the reflection loss is observed less than 0.5 dB in 35.44 GHz when the wave incident is from 0° to 60°.While the bandwidth at 35.44 GHz for the wave incident at 0° is 4.99%. The proposed FSS design provides good result for oblique angle of incidence in TE and TM polarization modes.

4.COMPARITIVE STUDY

To compare the proposed design with other similar works a comparative table is made. The comparison highlights the advantage of proposed design over other designs. From the table II, it is seen that the designed FSS unit cell is compact in size when compared with other works. The unit cell design, number of operating bands, number of substrate layer, operating frequency, polarization and angle range of the proposed work is compared with other similar works.

5.CONCLUSION

A single layer FSS with frequency stability for different angle of incidence up to 60° in TE and TM polarization modes is designed. The proposed design shows maximum reflection at 22.62 GHz for k band 35.44 GHz for ka band. The designed FSS structure is compact in nature and shows frequency stability for different oblique angle of incidence. The proposed design finds its application in satellite communication because of its frequency coverage.

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