# A Frequency Selective Surface Design To Reduce The Interference Effect On Satellite Communication

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*Abstract*— **In this study, a sawtooth-shape scalable frequency selective surface structure (FSS) for X-band applications is presented. The proposed FSS structure intended to be used in shielding of X-band satellite communication systems to reduce the interference effect is specifically tuned to be operated in 10-12 GHz band and it is aimed to have a stable response at oblique incidence. The scalable design allows tuning the operating band up to scale factor of 0.6 without changing its dimensions. The structure is analyzed for commonly used dielectrics and design parameters. The performance of the design is simulated using CST Microwave Studio in terms of resonance frequency stability at oblique incidence and bandwidth. From the results, the design of the FSS has stable performance as a band-stop filter at oblique angle variations between 0° to 75° in TE and TM modes.**

*Keywords— frequency selective surface; oblique incidence; bandstop filter; stable performance; X-band; satellite communication*

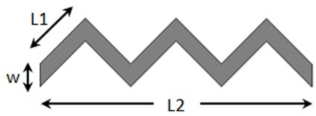
## I. INTRODUCTION

Frequency Selective surfaces (FSSs) formed by periodically interlacing the same patch or aperture conducting elements in either a one- or two-dimensional array are planar periodic structures that act as a filter for a plane wave arriving from any angle of incidence [1]. Due to their versatile functionality, since the 1960s FSSs have been increasingly used in the field of antenna design, radar and communications systems playing significant roles in both civilian and military purposes.

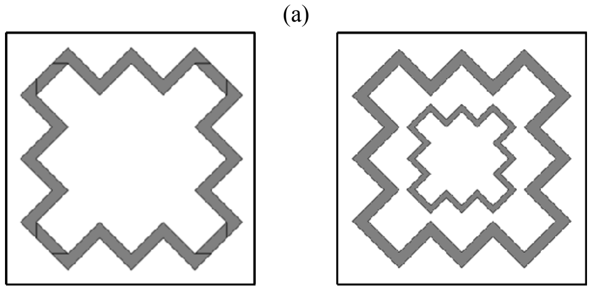
In recent years different forms and procedures have been proposed to realize FSS used in various stealth applications such as reducing the RF signature in low-observable platforms and shielding sensitive electronic devices from unwanted interference and jamming signals. Especially the increasing use of electromagnetic spectrum, which causes interference and frequency pollution, has revealed the necessity of taking additional measures in satellite communication systems as well as in all communication systems. Although the corrective action may be very complex if the interference is a combination of multiple sources, there are a number of possible countermeasures such as source elimination, grounding, filters and shielding [2].

Electromagnetic shielding of satellites, leading of these measures, is often expensive and causes major design engineering challenges. As stated in [3], the inner and outer structures of the satellites are well insulated with light conductive such as aluminum and carbon fiber reinforced plastic materials, but nevertheless the antennas are exposed to external interference effects and sensitive receivers are exposed to intra-system interference effects. The problems that may arise from these and similar causes adversely affect system performance in satellite. Due to its applicability to different surfaces and its ability to be produced with different materials, FSSs can be used to minimize or eliminate by filtering out-of-band signals. Especially the issues that studies focus on are as follows; preventing interference between radar and satellite communication antennas [4], interference control in indoor wireless environments [5], reduce coupling between antennas on satellites [3].

In this paper, a sawtooth-shape frequency selective surface structure filtering the band from 10 GHz to 12 GHz for shielding of X-band satellite communication systems has been presented. The proposed structure angularly stable up to 75° angle of incidence for both TE and TM modes. Moreover, the FSS structure's resonance frequency is able to adjust with adding scaled element without changing total structure dimensions which provides compactness.




(a)



(b) (c)

Fig. 1. (a) The basic geometry of element (b) Single element design (SED) (c) Scaled-element added design (SEAD)

## II. DESIGN AND ANALYSIS OF FSS STRUCTURE

Base part resembling sawtooth-shape of FSS structure (unit cells) is depicted in Fig. 1(a). The first step to be able to form FSS single element design (SED) shown in fig. 1(b), this base part is rotated *90°* symmetrically according to the origin to create three more new pieces and each pieces are combined.

Parameter values are given in Table I. Conductive FSS structure placed on one side of 0.3 mm height dielectric substrate with constitutive parameters of $\varepsilon_r=3$ and $\tan\delta=0.003$ (i.e. Arlon AD300). Parameter $L$ refers to the total length of the dielectric material. The total area of proposed FSS structure shown in Fig. 1(b and c) is 8 x 8 mm$^2$.

TABLE I. DIMENSIONS OF FSS ELEMENT

| **Parameters** | L | L1 | L2 | w | Scale Factor |
|---|---|---|---|---|---|
| | *mm* | | | | |
| **Values** | 8 | 1.41 | 7 | 0.5 | 0.5 |

Second step of composing the proposed FSS structure is to add a new scaled element on the same surface as shown fig. 1(c). Thanks to the new scalable design, the operating frequency of FSS structure is reduced by scale factor ranging from 0.1 to 0.6 without changing its dimensions. In this study *scale factor* is taken as 0.5. As it can be seen in Fig. 2., resonance frequency alter from 11.9 GHz to 10.9 GHz with scaled-element added design (SEAD) when the incident wave is parallel to surface normal ($\theta=0^\circ$).

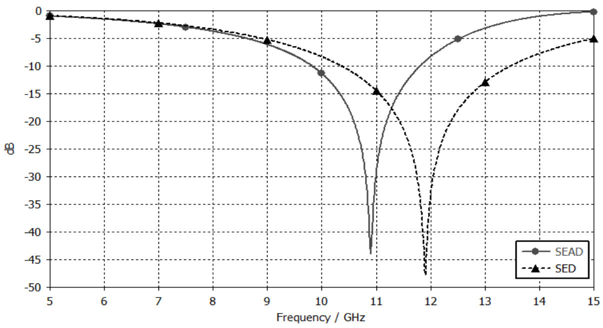



Fig. 2. Simulated S-parameters (S11) of single element design (SED) and scaled-element added design (SEAD) in TE mode at $\theta=0^\circ$

Fig. 3 shows that the proposed FSS is formed by a number of unit cells, which are placed periodically along the *x*-axis and *y*-axis directions.

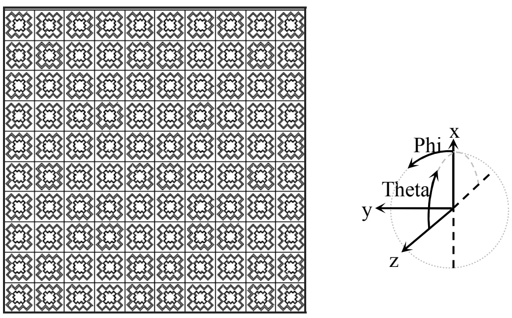
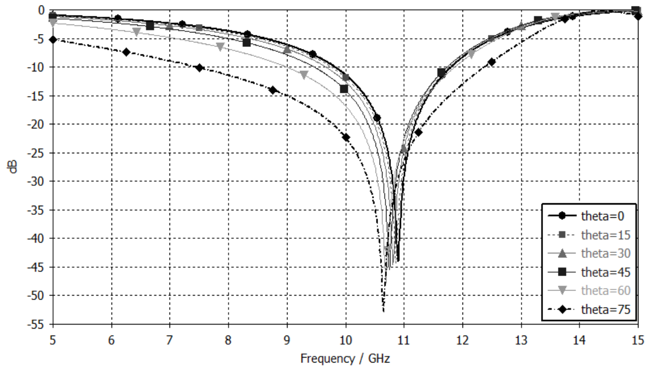


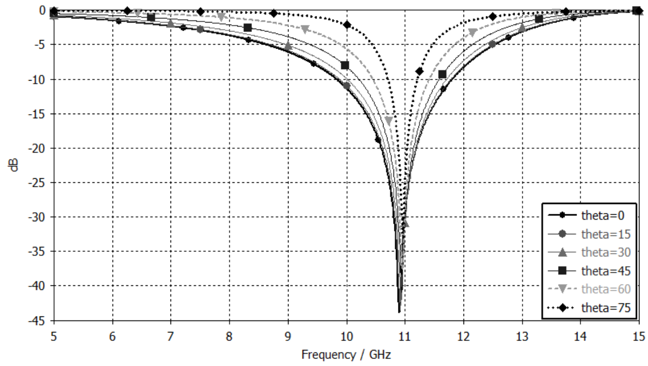

Fig. 3. Simulated 10x10 array view of the proposed design

## III. RESULTS AND DISCUSSION

The proposed FSS Structure is simulated with Computer Simulation Technology Microwave Studio (CST MWS) by applying unit cell boundary conditions in the x-axis and y-axis directions and setting up Floquet port excitations in the positive and negative z-directions. The transmission characteristics of proposed structure for oblique incidence are illustrated in Fig. 4. It can be observed that the stability of the resonance frequency with angle of incidence is provided between 0˚ to 75˚ and also that the -10 dB bandwidth broadens with the increase of the incident angles for TE mode, but for the TM mode bandwidth narrows in the given circumstance. The resonance frequency is 10.9 GHz and bandwidth is about 2 GHz for the normal incidence case.



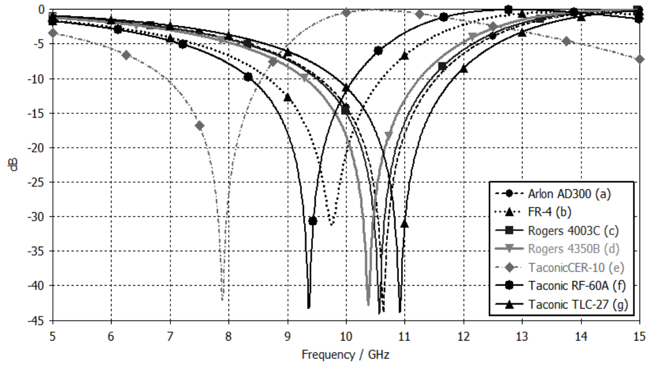

(a)



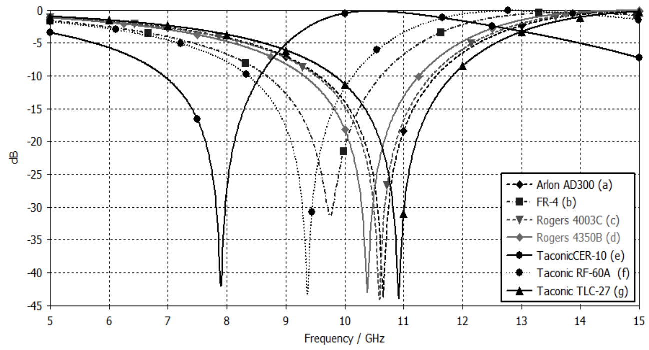

(b)

Fig. 4. Transmission Coefficient of the proposed FSS structure with different angle of incidence in (a) TE mode (b) TM mode

The structure is analyzed for two parameters. Firstly, off-the-shelf substrates having a similar thickness ($\Delta$) and different dielectric constant ($\varepsilon$) are examined. According to the results shown in Fig.5, the increase in $\varepsilon$ causes the decrease of the resonance frequency. Such as, the resonance frequency is 7.9 GHz for $\Delta=0.28$ and $\varepsilon=10.1$, while 10.4 GHz for $\Delta=0.338$ and $\varepsilon=3.48$. Secondly, the analyze result of the proposed FSS structure with different conductor width (w) is given in Table II. As it can be seen from Table II that the resonance frequency exhibits a constant response from 0.2 to 0.5 while decreases in the range of 0.5 to 0.9. If the bandwidth is considered, both of the -10 dB and -20 dB bandwidth increase as the width (w) increases.




(1)




(2)

Fig. 5. Transmission Coefficient of the proposed FSS structure using substrates having a similar thickness (Δ -mm) and different dielectric constant ($\varepsilon$) in (1) TE mode (2) TM mode [substrate code (Δ, $\varepsilon$) - a (0.381, 3); b (0.36, 4.3); c (0.305, 3.38); d (0.338, 3.48); e (0.28, 10.1); f (0.25, 6.15); g (0.37, 2.75)]

All these results show that a shift in resonance frequency can be obtained by varying the design parameters and adding scaled proposed unit cell single element. The parameter flexibility provides that the proposed FSS structure can operate at the desired frequency range. Such as, it can shows band-stop response in the 8-10 GHz frequency band by using Δ=0.25, ε =6.15, w=0.5 and scale factor=0.5 parameter values.

TABLE II. THE RESULTS OF USING DIFFERENT CONDUCTOR WIDTH (W) IN TE MODE.

| Parameter w (mm) | Bandwidth at -10 dB (GHz) | Bandwidth at -20 dB (GHz) | Resonance Frequency (GHz / dB) |
|---|---|---|---|
| **0.2** | 1.45 | 0.45 | 10.9 / -39 dB |
| **0.5** | 1.95 | 0.61 | 10.9 / -44 dB |
| **0.7** | 2.3 | 0.72 | 10.6 / -46 |
| **0.8** | 2.5 | 0.75 | 10.4 / -47 |
| **0.9** | 2.9 | 0.9 | 10 / -48.5 |

## IV. CONCLUSION

In this study, an FSS structure is proposed in order to improve the isolation of the X-band radiating system from other modules mounted on satellite. Considering the total weight, dimensions, manufacturing processes and costs, the design are aimed to be kept as simple as possible with a stable angle of incidence response to maintain the angular performance which is crucial for the most of the practical FSS structure applications. The results of the analysis show that the scalable design allows tuning the operating band up to scale factor without changing its dimensions which provides more compact designs at lower frequencies and parameter changes provide adjustable transmission characteristics such as resonance frequency and bandwidth. Moreover, The oblique incidence performance of proposed structure exhibits a stable transmission response up to 75˚ for both TE and TM modes.

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