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# ELECTROMAGNETIC SHIELDING BY FREQUENCY SELECTIVE SURFACE

Syed Irfan Sohail and Mohammad Zarar
Research Centre for Applied Electromagnetics, Faculty of Electrical and Electronics Engineering, Universiti Tun Hussein Onn Malaysia, Parit Raja Batu Pahat Johor, Malaysia
E-Mail: Irfan@uthm.edu.my

**ABSTRACT**

This paper presents a dual-layer Frequency Selective Surface (FSS) that exhibits a significantly wide stop-band of 9.5 GHz in 4.91-14.41 GHz range. It demonstrates more than 35 to 45 dB attenuation that can be effectively used to shield X-band satellite signals and in other low-profile stop-band and shielding applications. The unit-cell generates significant 98.3 bandwidth percentage. The design consists of two symmetrical patterns printed over the surfaces of FR4 layers. Due to simple schematics, it bears a low fabrication cost.

**Keywords:** shielding, stop-band, attenuation.

## INTRODUCTION

Frequency selective surfaces (FSS) are periodic structures which are composed of one- or two-dimensional arrays of patch or slots, usually designed to exhibit a band-stop or band-pass response in the operating frequency. For more than four decades, these FSSs have been attractive options because of low-profile and comprehensive range of applications in antenna engineering, radars, wave-guide couplers, frequency absorbers, stop-band reflectors and in satellite communication systems etc. Unlike the traditional microwave filters, the frequency response of FSS is not only a function of its frequency, but also a function of the angle and polarizations of incident electromagnetic wave (Munk 2010), (Kiani 2006).

In past few years, the use of FSS in wireless communication networks for signal security, particularly in military applications, has increased to a considerable extent. For example, to isolate the two similar wireless networks of same frequency bands, operating within the same vicinity, the FSS can be used to reduce the signal interference. Generally, in low-profile applications, the conventional transmit/reflect FSS can be used as spatial filter onto the adjacent walls of a building to reflect the unwanted signals. As an example, in (Manicoba 2010) a dual-layer FSS was designed to absorb the Wireless Local Area Network (WLAN) 5.25 GHz signals and to transmit GSM mobile/cellular phone signals. This design helped in reducing the multipath reflections and other fading effects. In (Trindade 2010), a multi-layer geometry was attempted to get wide stop-band by cascading two or more FSS screens containing the Koch fractal elements. This design provided an increased -20 dB bandwidth, compared to the bandwidths that were obtained with single elements. Recently, a 2D periodic array of pre-fractal metal elements printed on the dielectric substrate has been proposed. It also showed stop-band characteristics but its bandwidth is a bit narrow (Hsing 2012). In (Kumar 2011), a double layer FSS was examined to obtain significant (40 dB) attenuation in the conventional SMPS enclosures. Most of these FSS have shown good stop-band characteristics and other features; however the phase of the reflection coefficient holds a key importance when such surfaces are used as wideband reflectors in antenna engineering applications. As in (Ranga 2011), a dual-layer FSS was designed for the gain enhancement of an antenna. This FSS shows low transmission coefficient and a linearly deceasing phase over ultra-wide band when two layers of FSS were separated by a small gap. In this configuration, the top FSS layer reflects the higher frequencies while bottom layer generates the lower frequency reflections. Due to constructive interference of the two wave components, excellent antenna gain enhancement was achieved with this design.

This paper presents a dual-layer stop-band FSS that exhibits wide 9.5 GHz stop-band in 4.91-14.41 GHz range. It provides over 35 to 45 dB attenuation and can be effectively used to shield X-band satellite signals and other unwanted signals that lie in its operating band. The unit-cell shows significant 98.3 bandwidth percentage and consists of two symmetric patterns over two layers of FR4.

## FSS UNIT-CELL SCHEMATIC

### Unit-cell design

Figure-1 shows the design of FSS unit-cell. The size of unit-cell is 15 by 15 mm in X- and Y-directions and the length and width of square-patch (outer-edge) "d" is 13 by 13 mm. There are four small square-slots, each of them have lengths and widths of 4 mm shown by "a" and "b". The cross-dipole width "c" is 1 mm and its height "h" is 9 mm. The width between substrate edge and square-patch "e" is 2 mm. The two substrates FR4 have same dielectric constants of 4.3 with thickness "t" of 1 mm and are separated by a small gap "g" of 6 mm from each other.

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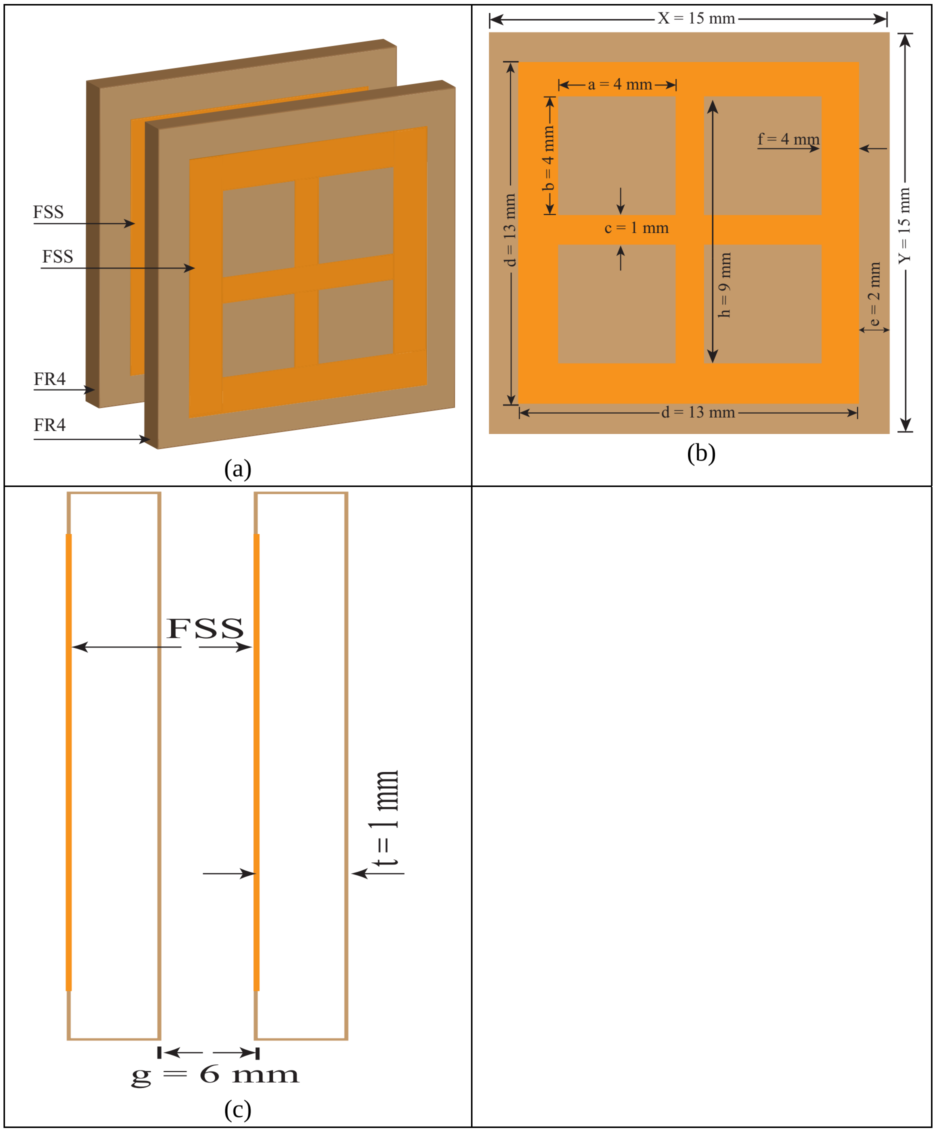


**Figure-1.** FSS unit-cell design; (a) Perspective view; (b) Front view; (c) Side view.

Table-1 summarizes all the design parameters of FSS unit-cell for ease of understanding.

**Table-1.** FSS unit-cell design parameters.

| **Parameters** | **X** | **Y** | **a** | **b** | **c** | **d** | **e** | **f** | **g** | **h** | **t** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Units (mm) | 15 | 15 | 4 | 4 | 1 | 13 | 2 | 4 | 6 | 9 | 1 |

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## RESULTS AND DISCUSSIONS

### Predicted results

The FSS unit-cell was simulated in CST Microwave Studio using periodic boundary conditions and Figure-2 presents the obtained stop-band response.

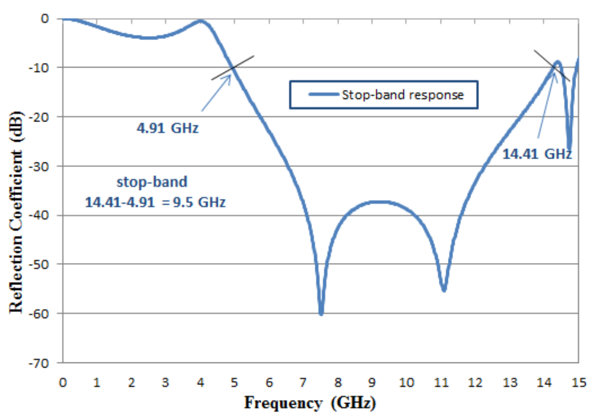


**Figure-2.** Stop-band response of FSS unit-cell.

It can be seen from the response that FSS exhibits a significant 9.5 GHz wide stop-band over a large band from 4.91-14.41 GHz. The optimum values of FSS element's dimension and gap between the substrate layers were selected that provided such a wide stop-band response. Since the gap between two substrates plays an important role so the whole structure was optimized in order to achieve wide band by suing two layers instead of one-layer. This optimization also demonstrated very high attenuation, achieved through this design, and is well over 35-40 dB. This stop-band attenuation can be effectively used to shield the X-band satellite signals (8-12 GHz) and in other low-profile reflectors and shielding applications where the unwanted signals can be isolated. The bandwidth percentage obtained here is 9.8 which is calculated by the following Equation (1):

$$\text{Bandwidth percentage} = \{(f_2-f_1)*2/(f_2+f_1)\}*100 \qquad (1)$$

Where $f_2$ is higher frequency and $f_1$ is lower frequency in the stop-band (4.91 to 14.41 GHz). In a further analysis, this FSS was thoroughly examined to analyze its performance characteristics in a detailed parametric study, by considering different parameters of its design, like; substrate thickness "t", gap "g" between two FR4 layers, variation in the dimensions of square-patch and varying the size of small square-slots etc. Later on, FSS unit-cell response was also compared with the response when the elements were patterned as Perfect Electric Conductor (PEC) with zero thickness approximation of PEC in the simulation.

### Parametric analysis

The following sections describe the analysis of FSS studied against each of the variable considered for its stop-band performance evaluation.

### Substrate thickness "t"

In first analysis, the thickness of substrate was varied from 1 mm to 2 mm in the increment of 0.5 mm and the corresponding response of FSS is presented in Figure-3. It can be seen from FSS response that when the substrate thickness is 1 mm, the stop-band bandwidth is 9.21 GHz. Upon increasing the thickness to 1.5 and to 2 mm, the bandwidths obtained are 8.8 GHz and 7.83 GHz respectively, which show a decreasing trend. However, the attenuation at varied thickness of substrate remains around 38 dB approximately.

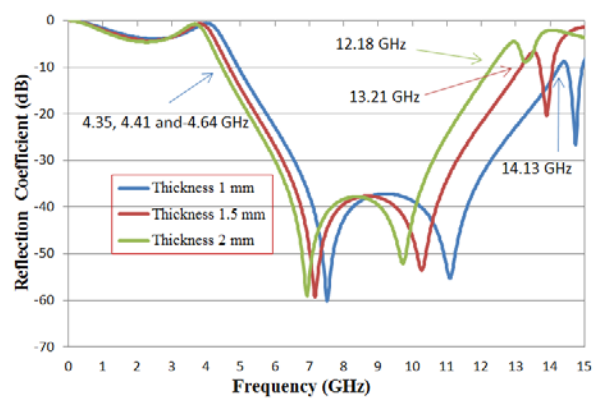


**Figure-3.** FSS response due to varying thickness of substrate.

### Gap "g" variation

In this analysis, transmission characteristics of FSS were obtained by varying the gap between substrate layers and are presented in Figure-4. It was found that the FSS bandwidth remains more or less same at the four different gaps. A slight shift occurs near the higher end stop-band frequency (14.41 GHz) and response eventually falls beneath 10 dB attenuation as indicated in the graph. In this case, the shielding strength at four gaps stretches between 28-35 dB, as compared to a constant attenuation observed in case of substrate thickness response.

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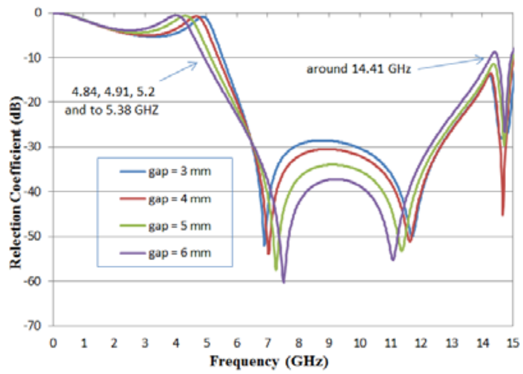


**Figure-4.** FSS response due to varying the gap between the substrate layers.

### Varying square-patch-outer edge

The FSS unit-cell was further investigated for its performance evaluation by varying the dimensions of the square-patch; the outer edge. It was varied from 12 mm to 13 and to 14 mm in length and width wise and the corresponding curves obtained with these variations are presented in Figure 5. It can be seen that a major shift takes place near the lower stop-band frequencies; 5.5, 4.9 and 3.8 GHz at 12, 13 and 14 mm dimensions of square-patch-edge respectively. However, the higher end frequencies do not vary largely. In addition to this the attenuation varies between 35-48 dB approximately for these three dimensions.

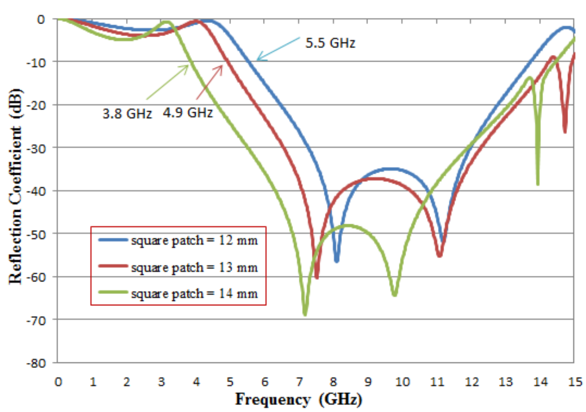


**Figure-5.** FSS response due to variable dimensions of outer square-patch-edge.

### Varying smaller-square-slots

In this analysis, the dimensions of small square-slots were varied from 4 mm to 3.5 and to 3 mm equally and the FSS response due to this variation is shown in Figure-6.

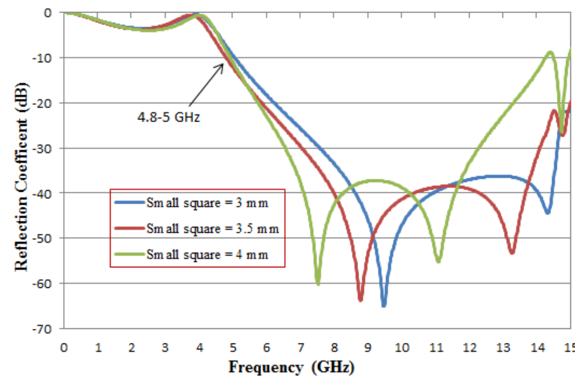


**Figure-6.** FSS response due to variable dimensions of small square-slots.

It can be observed from the response of FSS, that the lower end stop-band frequencies remain almost stationary around 4.8 to 5 GHz. However a major shift is found near higher end frequencies, in which each response had different inclination in its frequency value. Here, the FSS shielding bandwidths also shifts abruptly and the attenuation remains as close as to 38 dB at the three considered dimensions of small square-slots of FSS geometry.

### Response with PEC

The unit-cell was also tested to by patterning the conducting elements as PEC, Perfect Electric Conductor with zero thickness approximation and the FSS response was compared with those achieved with copper patterning elements. As can be seen in Figure 7 that response of two different types of conducting materials is almost similar to each other and FSS exhibits near similar stop-band of 9.5 GHz as well.

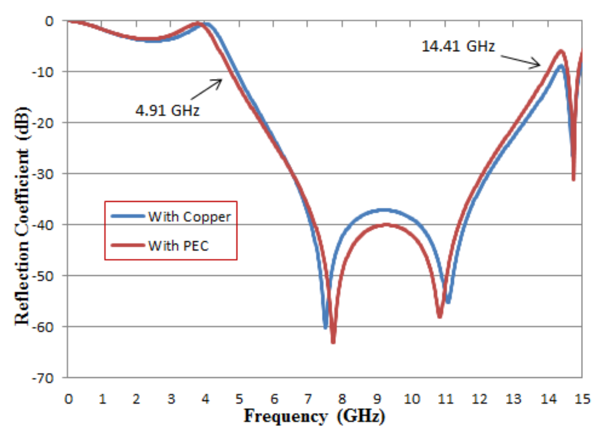


**Figure-7.** FSS response with PEC and copper based FSS elements.

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**Response with single layer**

Finally, the FSS with a single-layer substrate was examined to see its response. It was found that this single-layer design exhibited a narrow stop-band as shown in Figure 8 instead of a wide stop-band, achieved by a dual-layer design. Thus the dual-layer FSS has comparatively shown better stop-band characteristics than a single-layer FSS.

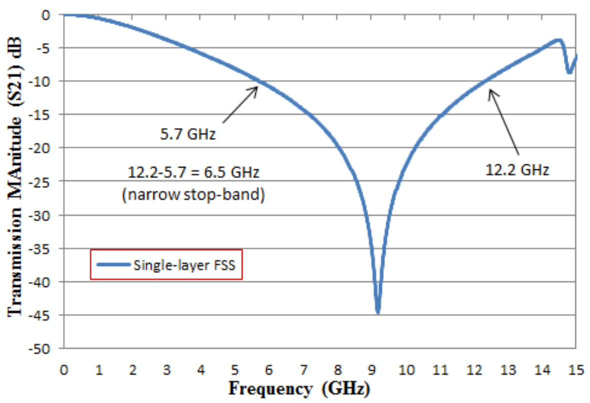


**Figure-8.** Transmission response of a single-layer FSS.

## CONCLUSIONS

A simple and effective dual-layer stop-band FSS was presented. It exhibits a significantly wide 9.5 GHz stop-band in 4.98-14.4 GHz band demonstrating strong 35-45 dB attenuation. This attenuation bandwidth can be used to effectively shield X-band (8-12 GHz) satellite signals and in other low-profile stop-band and shielding applications. The FSS shows significant 98.3 bandwidth percentage. Moreover, due to its design simplicity and only two layers, this FSS should bear low fabrication cost. The FSS prototype will be fabricated for measuring its practical response in the next phase.

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