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# Study of 5.8 GHz Band-Stop Frequency Selective Surface (FSS)

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**Abstract:** This paper presents the study of 5.8 GHz frequency selective surface (FSS) acts as a band stop to eliminate unwanted radiation signal at 5.8GHz. The FSS was designed using computer simulation technology (CST) Microwave Studio software. The paper shows the comparison of square loop, octagon loop and hexagon loop of Band stop FSS (BSFSS) performance at 5.8 GHz. Besides, the BSFSS design using four different type of dielectric substrate such as FR-4, TLY-5, Roger RT5870 and Roger RT5880 were compared. The results obviously show that the Rogers RY5880 has the attenuation -44.72 dB. The fabricated FSS were measured by using free space technique with two horn antennas connected to performance network analyzer (PNA). The measured and simulated results were compared. The results show that the square loop FSS structure have the better attenuation -26.76 dB (simulated) and -38.34 dB (measured) at 5.8 GHz.

**Keywords:** FSS, bandstop, attenuation

## 1. Introduction

The growth of wireless technology, the concern towards its security attracted greatly attention [1], [2]. Uncontrolled electromagnetic wave from a device might degrade the other to another device performance. This uncontrolled electromagnetic wave defines as electromagnetic interference or unwanted signal. Electromagnetic interference may cause failure of electronic devices in susceptible environment. Therefore, many researchers have study on the frequency selective surface (FSS) due to its widespread applications in the fields of spatial filter, radar, and microwave absorber [3]– [5]. Therefore, many research of FSS are listed in the literature for shielding application. The band stop FSS (BSFSS) can act as a shielding wall to save the wireless devices from getting damaged from the interferences [6]. In FSS design, there are few factor which effects the frequency response such as substrate thickness, substrate dielectric, its geometry, the spacing between the elements, slot size, and etc. [7] – [9].

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In this paper, square loop, octagon loop and hexagon loop of Band stop FSS (BSFSS) performance at 5.8 GHz were investigated. The performance of BSFSS with various dielectric substrate were compared. The CST MW studio is used as a simulation tool to design and simulated the return loss (S11) and insertion loss (S21) of the BSFSS.

## 2. Experimental

The Fig, 1 and Fig. 2 show the fabricated square and octagon design FSS. The FSS structure measured by using A pair of horn antennas (Model: A-INFO LB-187-10, 3.95 GHz-5.85 GHz). One of the horn antenna acts as a transmitter and another one acts as receiver as shown in Fig. 3. The transmitter horn antenna transmits the signal propagate through the FSS structure and receiver horn antenna receive the signal pass through the FSS. For free space far field measurement, the distance between the two horn antennas were 335 mm and the FSS will be placed at the middle of two horn antennas shown in Fig. 4. The measured results (S-parameter) of MUTs were shown in the Network Analyzer.

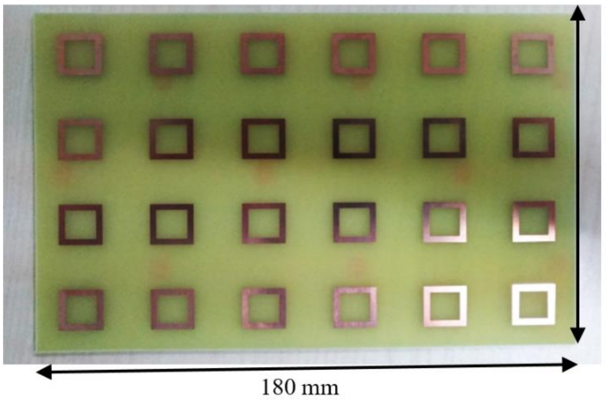


**Fig. 1 - Completed square design FSS structure (MUT)**

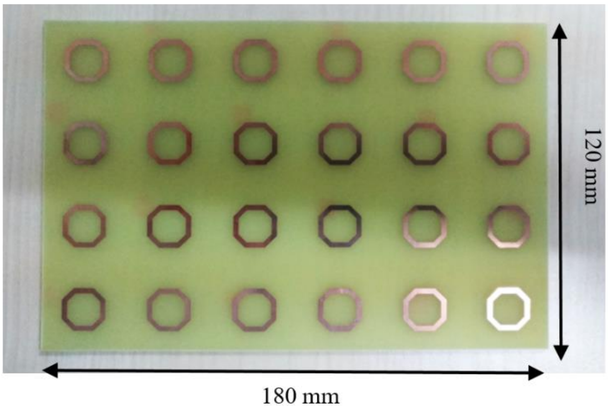


**Fig. 2 - Completed octagon design FSS structure (MUT)**

**Fig. 3 - Horn antennas (Model: A-INFO LB-187-10, 3.95 -5.85 GHz)**

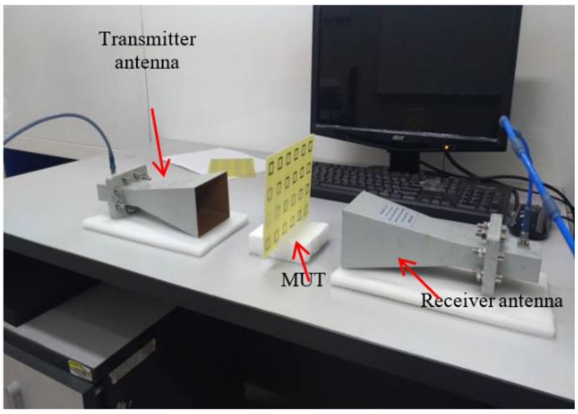


**Fig. 4 - Measurement set-up with square array FSS structure.**

The free space technique is contact-free, less restrictive and non-destructive on MUT (Material Under Test) thickness or even shape, as long as the probing beam can be guaranteed to pass through a uniform thickness of homogenous MUT. Moreover, as long as the latter condition can be met, it is also suitable for the non-solid dielectric material characterization such as liquids or powder material which cannot maintain the uniform thickness condition without the addition of a container and are the primary focus of this work. For the free space technique, the MUT does not have to match the waveguide cross section, easier to guarantee uniform sample distribution, contained appropriately and can measured liquid.

The inaccuracies in dielectric measurements using free space methods are mainly due to the diffraction effects from the edge of the sample and signal leakage from the whole test environment, if not taken in an isolated environment, spurious signal interference. However, the standing waves in the test environment between the antennas and the multiple surfaces of the MUT and which cannot be completely calibrated out. Free space measurement is consisting of two horn antennas, one acts as transmitter and another acts as receiver. After that, the horn antennas are connected to the network analyzer. The VNA must be calibrated before starting the measurement. Then, put the MUT between the middle of the two horn antennas. After the measurement setup, observe the S-parameters with MUT and without MUT [10]. Fig. 5 shows the Free space measurement setup.

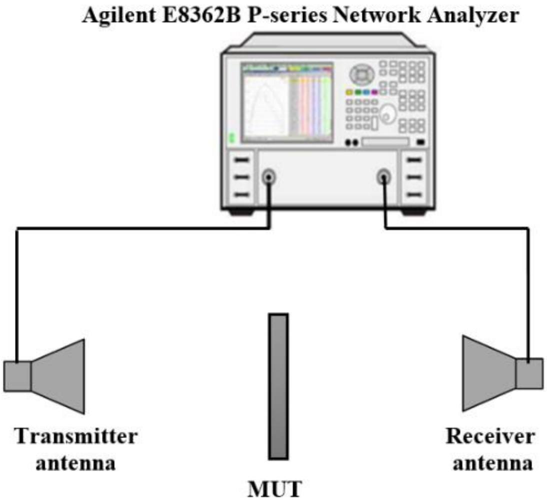


**Fig. 5 - Free space measurement setup**

## 3. Results and Discussions

### 3.1 Different Design Comparison

Fig. 6 and Fig. 7 show the Octagon and Hexagon design of FSS structure. Table 1 shows the shape of design effects the S-parameter results. From the observation, square design of FSS structure has better result of $S_{11}$ and $S_{21}$ compare to hexagon and octagon design. At 5.8 GHz, the $S_{11}$ value of square design is approximate to 0 dB, it means the return loss is high. The smaller of $S_{21}$ value, the lower absorptivity at receiver and can act as a good attenuator.

Therefore, the square design is the highest attenuation compare to hexagon and octagon design. Octagon has the second best performance and continues by hexagon among the three different design.

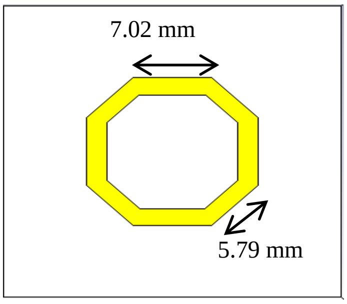


**Fig. 6 - Octagon design of FSS**

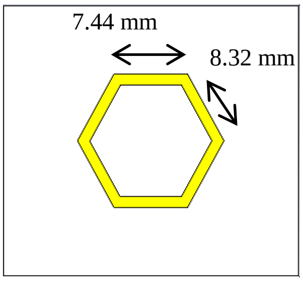


**Fig. 7 - Hexagon design of FSS**

**Table 1 - S-Parameter results of FSS with different design**

| Type of FSS | Frequency (GHz) | $S_{11}$ (dB) | $S_{21}$ (dB) |
|---|---|---|---|
| Hexagon | 5.80 | -0.66 | -23.25 |
| Octagon | 5.80 | -0.582 | -24.46 |
| Square | 5.80 | -0.44 | -26.76 |

## 3.2 Square Loop FSS Parametric Study

In this section, the comparison of various length, x and width, w effect the frequency response and S-parameters of BSFSS. A FR-4 substrate with thickness 1.6 mm and dielectric constant 4.4 was used design the BSFSS. The parameter of square design FSS structure shown in Figure 8. Table 2 shows length, x effects the frequency and S-parameters. Figure 9 (a) and (b) show that the length, x increases, the frequency shift to lower frequency. From the results show that the $S_{11}$ and $S_{21}$ values are slightly changed from -1.00 dB to -0.41 dB and -20 dB and -28 dB, respectively. This shows that the gap between copper and substrate affect the S-parameter results of FSS structure.

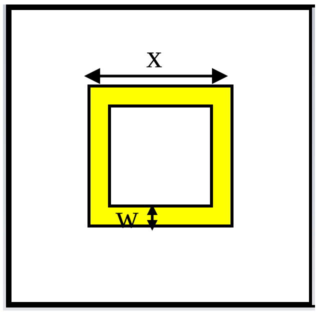
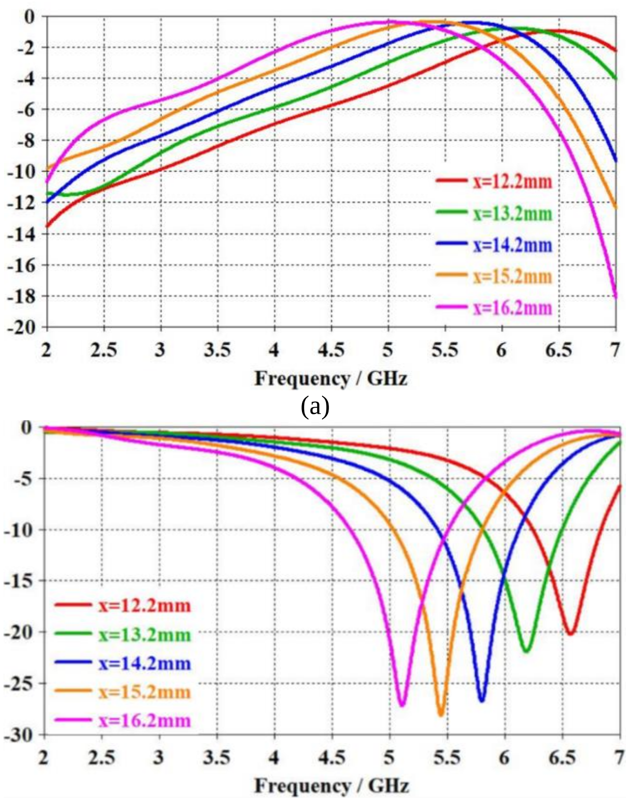


**Fig. 8 - Parameter of square loop FSS**



(a)

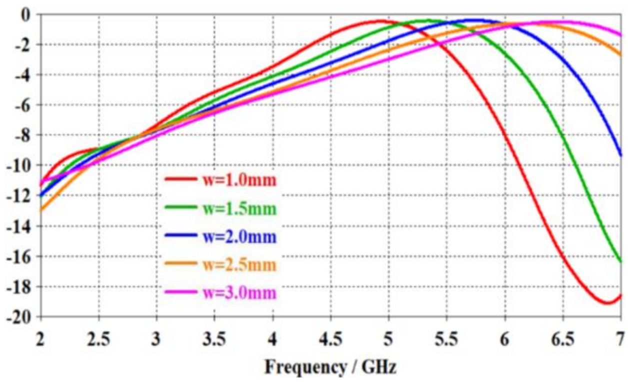
(b)

**Fig. 9 - S-parameter result of FSS square loop with various length, x; (a) S11 and (b) S21.**

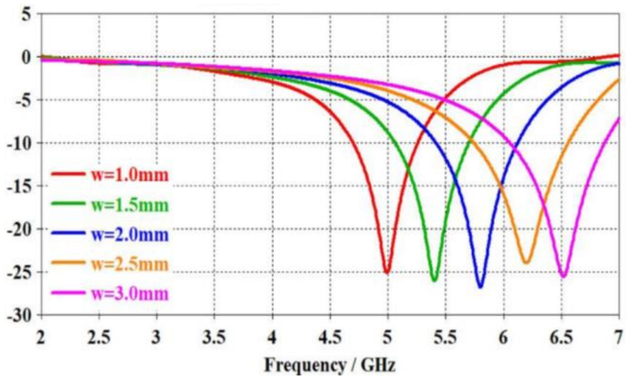
**Table 2 - Parameter, x effects the result of FSS structure.**

| Length, x (mm) | Frequency (GHZ) | $S_{11}$ (dB) | $S_{21}$ (dB) |
|---|---|---|---|
| 12.2 | 6.57 | -1.00 | -20.21 |
| 13.2 | 6.19 | -0.81 | -21.91 |
| 14.2 | 5.80 | -0.44 | -26.76 |
| 15.2 | 5.45 | -0.37 | -28.12 |
| 16.2 | 5.11 | -0.41 | -27.17 |

Table 3 shows the parameter, w effects the frequency and S-parameter results. Figure 10 (a) and (b) show the S-parameter shift to higher frequency when increasing the width, w of the square loop FSS. From the observation, when the width, w increases, the frequency will be increases. The $S_{11}$ values change variation between -0.40 dB and -0.65 dB and the $S_{21}$ values change variation between -25 dB and -27 dB. This shows that the gap between copper and substrate affects the S-parameter results of FSS structure.



(a)



(b)

**Fig. 10 - S-parameter result of FSS square loop with various width, w; (a) S11 and (b) S21.**

**Table 3 - Parameter, w effects the result of FSS structure.**

| Width, w (mm) | Frequency (GHZ) | $S_{11}$ (dB) | $S_{21}$ (dB) |
|---|---|---|---|
| 1.0 | 4.99 | -0.52 | -25.15 |
| 1.5 | 5.40 | -0.47 | -26.09 |
| 2.0 | 5.80 | -0.44 | -26.76 |
| 2.5 | 6.20 | -0.63 | -24.00 |
| 3.0 | 6.52 | -0.53 | -25.56 |

### 3.3 Simulation Results of Array Square Loop FSS

The number of loop of FSS structure can increased and the number of loop does not affect the S-parameter result or performance. The design is depending on structure's size, shape of design and substrate of FSS. After attach the FSS structure, the result of $S_{21}$ become smaller, this is because the FSS structure has tries to eliminate the frequency at 5.8 GHz. The absorptivity of square design FSS structure higher than octagon FSS structure since the $S_{21}$ value of square design FSS structure smaller than octagon FSS structure. The obtained results from the simulation shows that the array of square loop will not affect the S-parameter results. All the S-parameter results are shown in Figure 11 and Table 4. From the results, obviously shows the characteristic of the square loop FSS is acts as a bandstop filter. The $S_{11}$ and $S_{21}$ values remains at -0.44 dB and -26.77 dB, respectively.

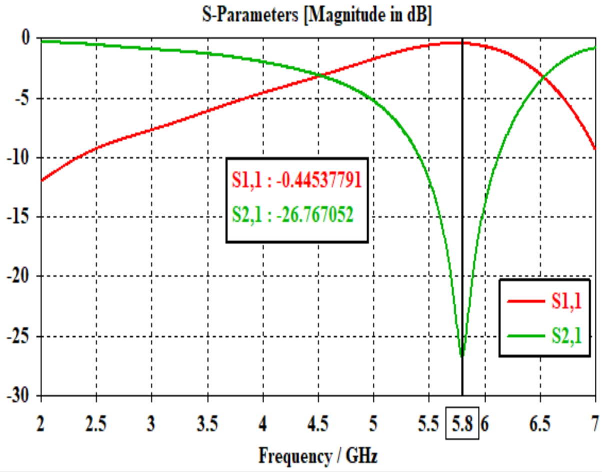


**Fig. 11 - S-parameter Results of Array Square Loop FSS**

**Table 4 - Comparison of S-parameter results of FSS with various number of square loop.**

| Parameter | $S_{11}$ (dB) | $S_{21}$ (dB) |
|---|---|---|
| 1 square loop | -0.44 | -26.76 |
| 2 square loops | -0.44 | -26.77 |
| 4 square loops | -0.44 | -26.77 |
| 9 square loops | -0.44 | -26.77 |
| 16 square loops | -0.44 | -26.77 |
| 24 square loops | -0.44 | -26.77 |

## 3.4 Simulation Results of FSS with Various Dielectric Substrate

Table 5 shows different of dielectric substrate effect the S-parameter results. From the observation, $S_{11}$ value of Rogers RT5880 is nearest to 0 and means that the return loss is the smallest whereas FR-4 has largest return loss among the dielectric substrates. $S_{21}$ value of Rogers RT5880 is the smallest and means that its absorptivity is the highest and FR-4’s absorptivity is the smallest among the all. This is because Rogers RT5880 has a smaller dielectric constant and thickness, it is 2.2 and 0.787 mm respectively. From the results, we can conclude that the dielectric substrate with smaller dielectric constant and thickness will have better result of S-parameter.

## 3.5 S-parameter Measurement Results

From the observation, the measurement results in Table 6 show the FSS structure performed well. The S11 is -31.61 dB and the S21 is -0.29 dB when without attach the FSS result of attach octagon design FSS structure is -19.82 dB and its S21’s result is -35.04 dB. The FSS structure tries to solve the 5.8 GHz signal frequency and don’t want let it pass through. From the observation, after attach the square design FSS structure and octagon FSS, the $S_{11}$ value increase 10.67 dB and 11.78 dB respectively. The value of $S_{21}$ with attach square loop design FSS structure decrease 38.05 dB and value of $S_{21}$ with attach octagon design FSS structure decrease 34.75 dB.

**Table 5 - S-parameter results of FSS square loop design with various dielectric substrate at 5.8 GHz**

| Dielectric Substrate | Dielectric constant | Thickness (mm) | $S_{11}$ (dB) | $S_{21}$ (dB) |
|---|---|---|---|---|
| FR-4 | 4.4 | 1.6 | -0.44 | -26.77 |
| Rogers RT5870 | 2.33 | 1.575 | -0.14 | -31.06 |
| Rogers RT5880 | 2.2 | 0.79 | -0.05 | -44.72 |
| TLY-5 | 2.2 | 1.5738 | -0.67 | -39.66 |

**Table 6 - S-parameter result of measurement**

| Measurement condition | Frequency (GHz) | $S_{11}$ (dB) | $S_{21}$ (dB) |
|---|---|---|---|
| Without attach square design FSS structure | 5.8 | -31.61 | -0.29 |
| With attach square design FSS structure | 5.8 | -20.12 | -38.34 |
| With attach octagon design FSS structure | 5.8 | -19.82 | -35.04 |

## 4. Conclusions

In the conclusions, the three different FSS design have been designed and compared. The octagon and square FSS have been fabricated and measured. The simulated results of FSS structure were simulated in an ideal free space measurement with CST-MWS boundary condition setting. Therefore, the measured results of S-parameter show slightly different compare with the simulated results might due to free space measurement path loss such as free space loss, interference signal from environment. The results show that the hexagon, octagon, and square FSS able to eliminate the interference frequency at 5.8 GHz. As a results, the FSS structure is one of the technique which can use to eliminate the interferences or unwanted signal without using any external power.

## Acknowledgement

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