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# Design of Double Layer Frequency Selective Surface with Almost Flat Pass Band and Sharp Roll Off

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**Abstract**

This paper presents aperture type frequency selective surface (FSS) with tripole and annular ring shaped element. Different designs are investigated to accomplish sharp roll off, flat band, polarization and incident angle independent frequency response. Finally annular ring FSS exhibits sharp roll off (maximum 27 dB/GHz), almost flat response, polarization (at 0º and 90º) and incident angle independent characteristic. The designs are scaled to achieve predetermined pass band frequency._ Simulated results are verified by measured data. Final structure shows nearly-flat band pass property from 3 GHz to 4 GHz. Practical measurements are done by standard microwave test bench. The simulated and measured results are in good parity.

**Keywords:** Frequency Selective Surface, aperture, Roll off, Polarization, Incident angle.

## INTRODUCTION

Frequency selective surfaces have been extensively studied for their useful applications in radar cross section (RCS) as radomes, sub reflector in multi frequency system and so on [1-5]. Generally FSS is two dimensional periodic array of different shapes either printed on a dielectric slab or etched out within a metallic plate placed on a dielectric slab. Theses structure shows electromagnetic wave filtering property. But these conventional structures generally cannot fulfil the requirements like wide band, sharp roll off in different polarizations simultaneously. These are very important characteristics for real life use of these devices. Recently different researchers are trying to overcome such problems with substrate integrated waveguide (SIW), different types of three dimensional designs based on microstrip geometry etc [3-7]. But these designs are very complicated and the thickness of the structure is increased for some of them.

Different structures (like dipole, rectangular, circular, hexagonal, tripole, ring etc.) are investigated and it is noticed that tripole and ring structures are most suitable to achieve sharp roll off [8]. So in this paper double layer tripole and ring shaped band pass FSSs are presented and they exhibit more than 1 GHz bandwidth with sharp roll off (minimum 10 dB/ GHz) and almost polarization independent characteristic. The designs are simulated by FEKO software. Practically fabricated FSS is measured by standard microwave test bench. Simulated and measured results are in good parity.

Several research papers describe theoretical analysis about wave propagation through FSS. By these techniques transmission and reflection characteristics can be calculated for a particular structure. When a particular transmission characteristic is needed to be achieved, these methods cannot be used to evaluate the specific structural dimension of a unit FSS cell. This paper uses scaling method to make an FSS resonate at a desired frequency range. These final designs are verified by simulated and practical model.

## FSS DESIGN

For band pass application aperture type FSS is investigated. Different types of slot elements like dipole, circular, square, square ring, hexagonal, hexagonal loop, Jerusalem cross, annular ring, tripoles are investigated with a goal to achieve sharp roll off and polarization independent property [8]. Annular ring and tripoles showed maximum advantage. To make the FSS even more selective microwave filter multilayer concept is introduced [1]. Then tripole FSS is found to be more suitable. However both multilayer tripole and ring FSSs are investigated and presented in this paper.

First tripole FSS is designed with arm length 5mm, width 2 mm and periodicity 16.5 mm as shown in Fig. 1 (a). Annular ring FSS is designed with outer radius 7 mm and inner radius 6 mm; periodicity is taken 16 mm as shown in Fig. 1 (b). The FSS with tripole slot resonates at $f_{T1}$ frequency and FSS with ring slot resonates at $f_{R1}$. To make it resonate at $f_{T2}$ or $f_{R2}$ frequency, dimension of the total structure is scaled with the factor of $f_{T1}/f_{T2}$ for tripole FSS and $f_{R1}/f_{R2}$ for annular ring FSS. Fig. 2 shows the modified FSSs after scaling. As the width of the dielectric is fixed due to limitation of fabrication, the width is kept same for both FSSs and dielectric constant is 2.8 considering local availability of the material. Dielectric used in this case is acrylic sheet [9]. Other factors like arm length, width, radius and periodicity are scaled by $f_{T1}/f_{T2}$ and $f_{R1}/f_{R2}$ factor. The dimensions are shown in Table I. Each FSS is fabricated using laser cutting technology [9] and experimentally tested by standard microwave test branch.

Both the FSSs are investigated whether they are polarizations and incident angles independent or not. Ring slotted FSS is more suitable in this respect. To achieve sharp roll off and flat top frequency response double layer concept is adopted [1]. Same type of aperture element with same dimension is printed on both side of the dielectric. This double layer annular ring type FSS is also fabricated and measured practically.

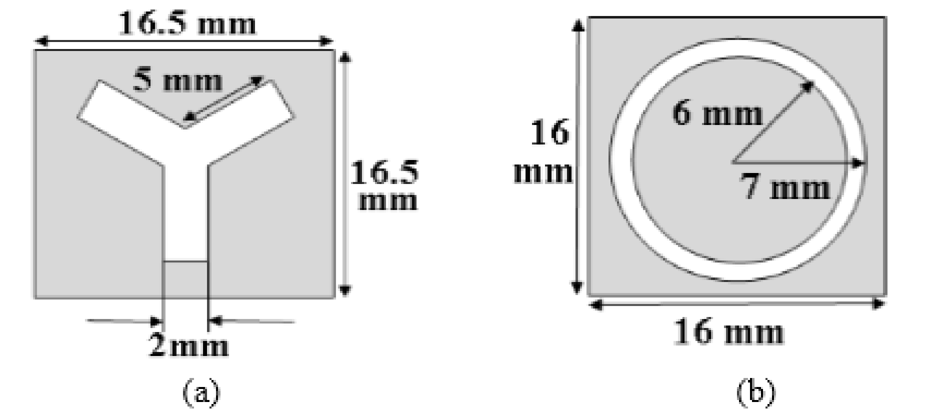


**Figure 1: (a)** Unit cell of Primary Tripole FSS and (b) Unit cell of Primary Annular ring FSS

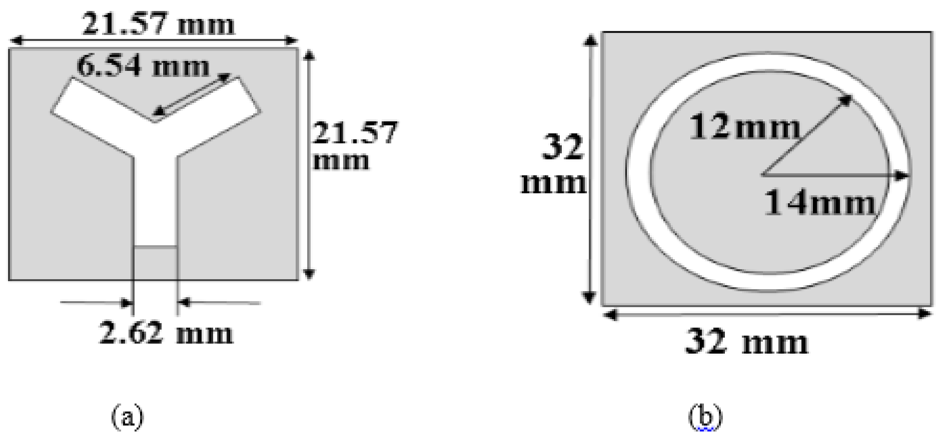


**Figure 2: (a)** Unit cell of Scaled Tripole FSS and (b) Unit cell of Scaled Annular ring FSS

**RESULT**

For the single layer FSS with tripole slots, simulated resonant frequency is 10.46 GHz. To make it resonate at 8 GHz the FSS elements are scaled. Previous dimensions and the scaled dimensions are noted in Table I. Transmitted electric field vs. frequency plot for both primary and scaled FSS is shown in Fig. 3. Scaled FSS is simulated and practically measured and also plotted in Fig. 3.

Again transmitted electric field vs. frequency plot for annular ring type FSS is shown in Fig. 4. Resonant frequency in this case is 6 GHz. To make it resonate at 3 GHz the FSS elements are scaled. Changed radius, periodicity are shown in Table I. Final scaled design is measured by standard microwave test bench after fabrication. Simulated and measured transmitted electric field vs. frequency plots are shown in Fig. 4.

Double layer annular ring FSS is simulated and measured in $0^0$ and $90^0$ polarization angle and shown in Fig 5. This structure shows moderate roll off and almost flat frequency response for 1 GHz. The comparative roll off factors for single layer FSS, single layer scaled FSS and double layer scaled FSSs with annular ring slot are shown in Table II. It is clear from the table that double layer FSS shows better roll off than single layer FSS. The final double layer design is even tested for different incident angles also. Transmitted electric field vs. frequency plot for different incident angles from $0^0$ to $40^0$ are shown in Fig. 6. A measurement setup is shown in Fig 7.

**Table I:** Comparison between dimensions of primary and scaled FSS

| Name | Parameters | Primary FSS (mm) | Resonant Frequency (before scaling) | Scale Factor | Scaled FSS (mm) | Resonant frequency (after scaling) |
|---|---|---|---|---|---|---|
| Tripole FSS | Arm Length (mm) | 5 | 10.46 GHz | 10.46/8 = 1.3075 | 6.54 | 8 GHz |
| | Arm Width (mm) | 2 | | | 2.62 | |
| | Periodicities in x and y directions (mm) | 16.5 | | | 21.57 | |
| Annular Ring FSS | Outer radius (mm) | 7 | 6 GHz | 6/3 = 2 | 14 | 3 GHz |
| | Inner radius (mm) | 6 | | | 12 | |
| | Periodicities in x and y directions (mm) | 16 | | | 32 | |

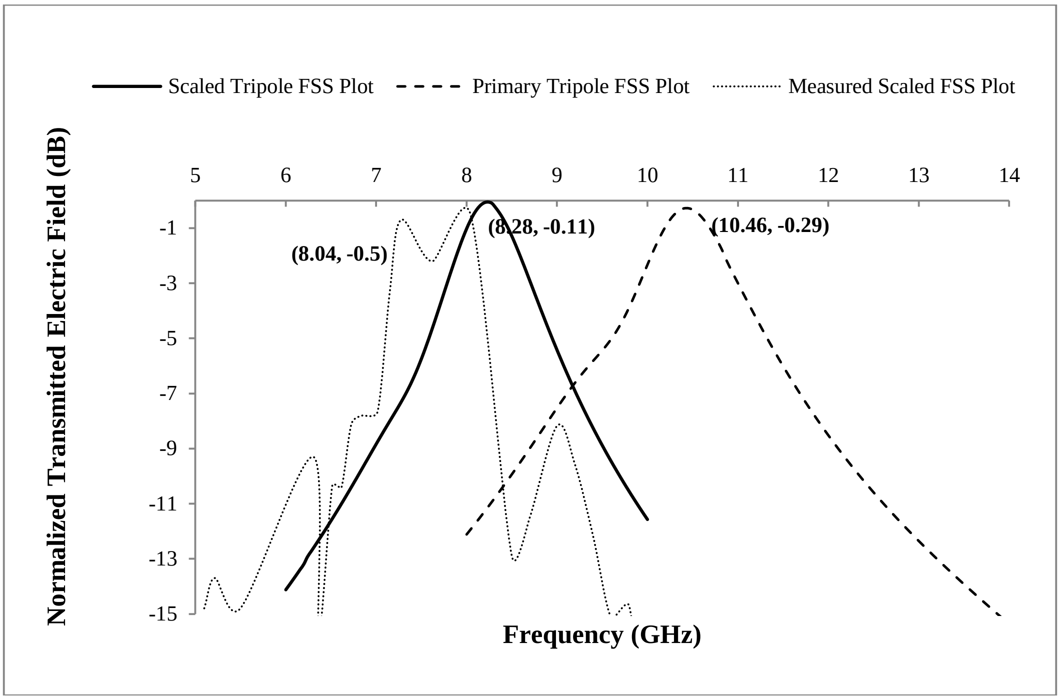


**Figure 3:** Transmitted electric field vs. frequency plot for primary and scaled tripole FSS

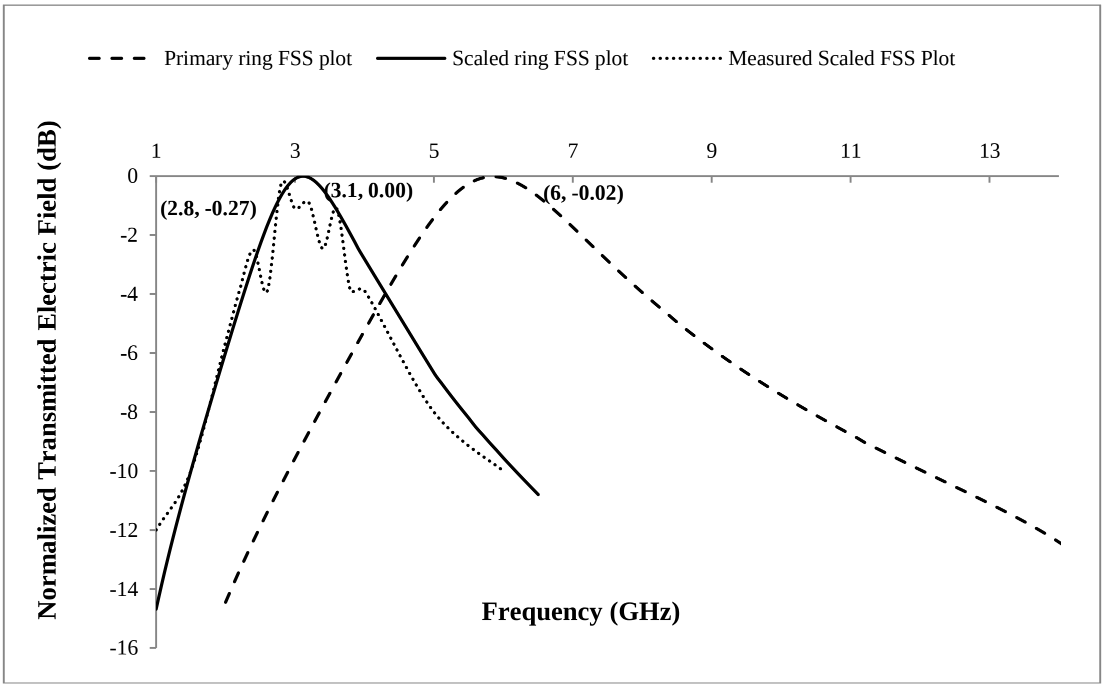


**Figure 4:** Transmitted electric field vs. frequency plot for primary and scaled ring FSS

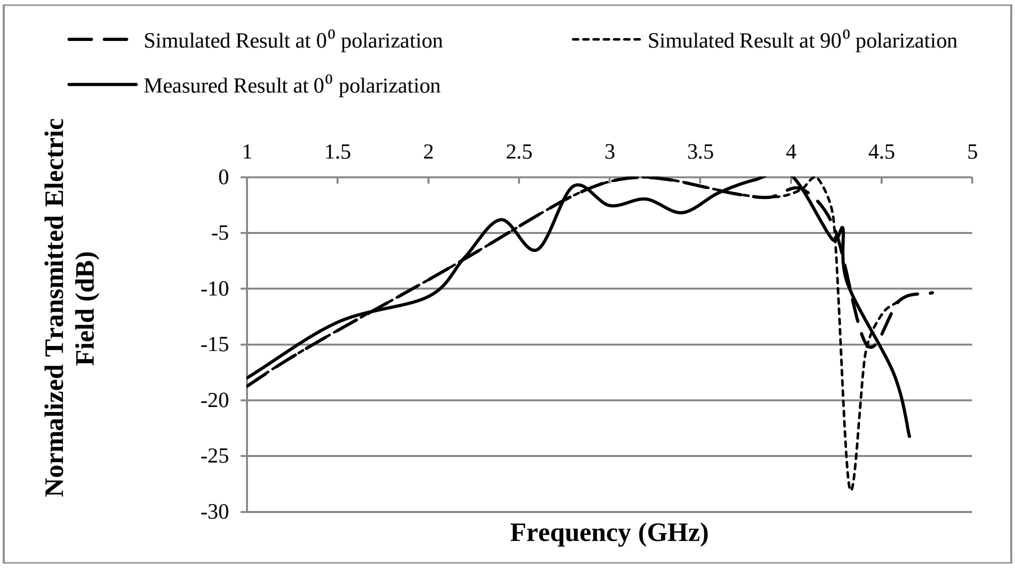


**Figure 5:** Transmitted electric field vs. frequency plot for double layered scaled ring FSS for different polarizations

**Table II:** Comparison of roll off for different annular ring slotted FSSs

| Type of annular ring FSS | Upward Roll Off | Downward Roll Off |
|---|---|---|
| Single layer primary FSS | 3.344 dB/GHz | 1.64 dB/GHz |
| Single layer scaled FSS | 5.85 dB/GHz | 3.33 dB/GHz |
| Double layer scaled FSS | 8.06 dB/GHz | 27.77 dB/GHz |

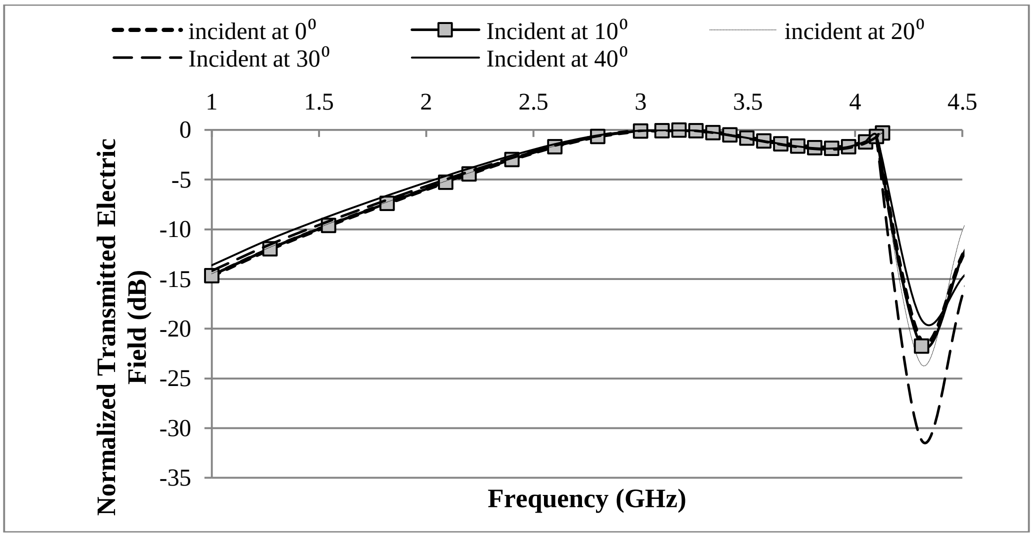


**Figure 6:** Transmitted electric field vs. frequency plot for double layered scaled ring FSS for different incident angles

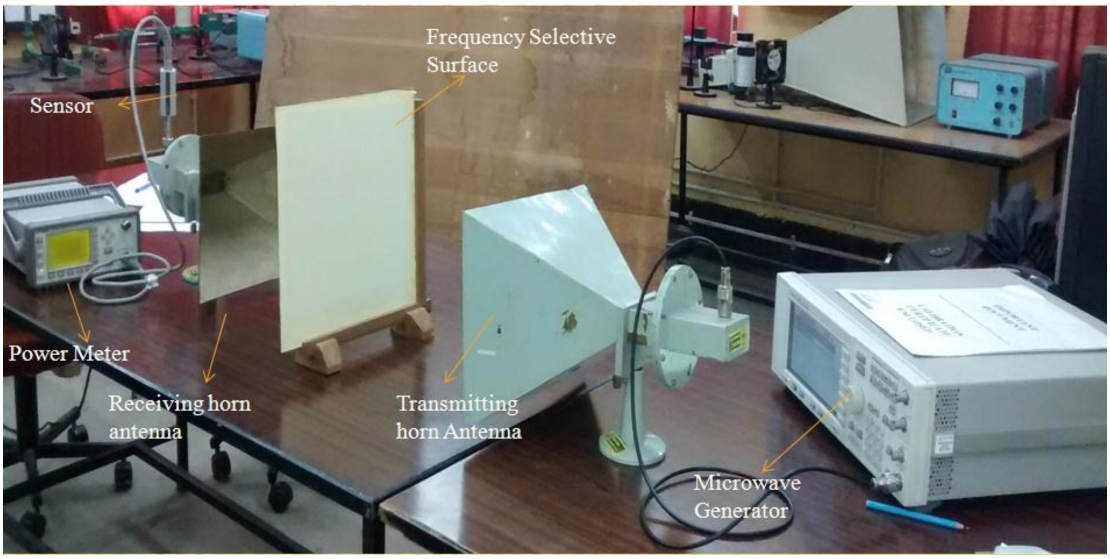


**Figure 7:** Measurement setup

## CONCLUSION

The main goal of the research work is to design a frequency selective surface with nearly flat pass band and sharp roll off response. Aperture type FSS with annular ring slots meets the requirements. Frequency response at different polarizations and incident angles are almost same. Moreover these characteristics are observed during measurement also. This method may be applied by the researchers to design FSS which can resonate at predetermined resonant frequency.

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