*URSI GASS 2023, Sapporo, Japan, 19 – 26 August 2023*

# Frequency Selective Surface Design For X-Band Radome Applications

Recep Baş* [(1)(2)], İlhami Ünal[(2)], Aysun Sayıntı[(2)], Sergey B. Panin[(2)], Aziz Taner Astarlıoğlu[(3)] , Nursev Erdoğan [(3)], Ahmet Kizilay[(1)]

(1) Department of Electronics and Communication Engineering, Yildiz Technical University, Istanbul, Turkey; e-mail: recepbas.iu@gmail.com; akizilay@yildiz.edu.tr

(2) Millimeter Wave and Terahertz Technologies Research Laboratories (MILTAL), Marmara Research Center (MRC), TUBITAK, Gebze-Kocaeli, Turkey; e-mail: ilhami.unal@tubitak.gov.tr; aysun.sayinti@tubitak.gov.tr; sergiy.panin@tubitak.gov.tr

(3) Turkish Aerospace, Advanced Material, Process and Energy Technology Center, Ankara, Turkey; e-mail: aziztaner.astarlioglu@tai.com.tr; nursev.erdogan@tai.com.tr

## Abstract

This work presents a comparison of two different frequency selective surface (FSS) structures with band pass characteristics at X-Band (8.2-12.4 GHz) frequencies. Square slot FSS and circular slot FSS structures are designed and printed on FR4 substrate. Measurement results and simulation results of both FSS structures are in good agreement. Measurement results show that a passband ($|S_{21}|$>-0.5dB) is achieved between 8.2-8.68 and 9.08-11.87 GHz for circular slot FSS and 8.2-11.65 GHz for square slot FSS with wider passband characteristic.

## 1 Introduction

Frequency selective surfaces (FSS) are periodic structures that consists of conductive elements or patches that act as spatial filters of electromagnetic energy. They can act as band-stop or band-pass filters. Generally FSS structures are utilized in different applications such as filters, reflectors, absorbers, radome [1] and recently they are used in sensors applications [2-3].

Increasing popularity of studies on antenna technologies have provided radomes as an important study topic since radomes protect antenna physically and reduce the observability of the antenna.

In this study square slot and circular slot FSS structures are designed and fabricated (Fig. 1). Additionally analytical results of square slot FSS structure based on equivalent circuit model are used for comparison.

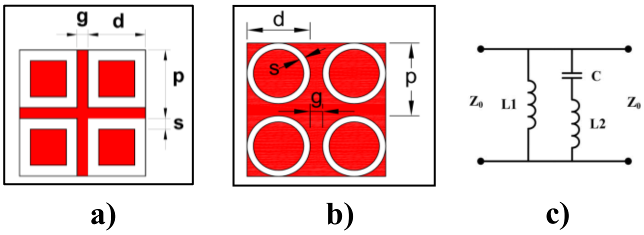


**Figure 1.** a) Square slot FSS, b) Circular slot FSS c) Equivalent circuit model of Square Slot FSS

## 2 Design and Simulation of FSS Structures

In literature there are many different FSS structures. This study focus on square slot FSS and circular slot FSS structures since they behave as a band pass filter due to their equivalent circuit model. Equivalent circuit model (ECM) of square slot FSS contains an LC circuit as shown in the Fig. 1. In order to get analytical results for square slot FSS structure, ECM formulas [4-5] are utilized to obtain transmission response ($S_{21}$) values. To improve ECM results, effective dielectric constant formula with 'N' parameter which is presented in [5] is used. In order to obtain a good passband response at X-Band frequencies both structures are simulated on CST Studio software based on changing dimensions. An FR4 substrate material with 4.29 dielectric constant and 0.019 loss tangent and 1 mm height is used for those simulations.

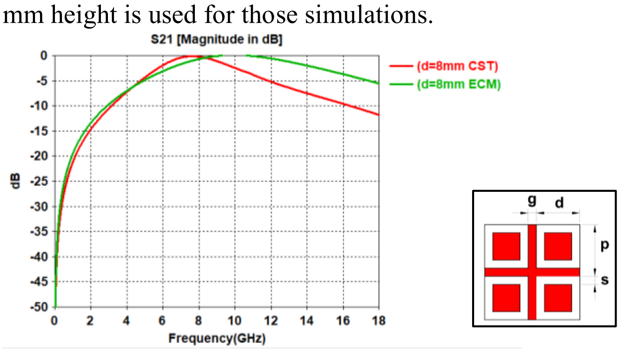


**Figure 2.** Frequency Response of $S_{21}$ for Square Slot FSS with d=8 mm, g=1 mm, s=1 mm

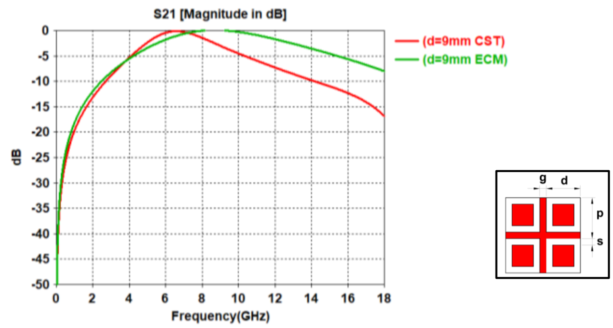


**Figure 3.** Frequency Response of $S_{21}$ for Square Slot FSS with d=9 mm, g=1 mm, s=1 mm

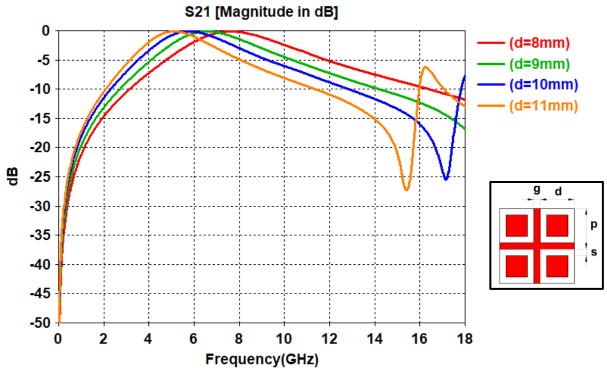


**Figure 4.** Frequency Response of $S_{21}$ for Square Slot FSS with s=1 mm, g=1 mm for different d

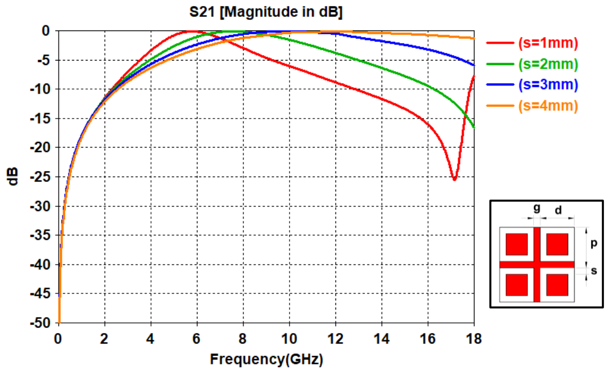


**Figure 5.** Frequency Response of $S_{21}$ for Square Slot FSS with d=10 mm, g=1 mm for different s

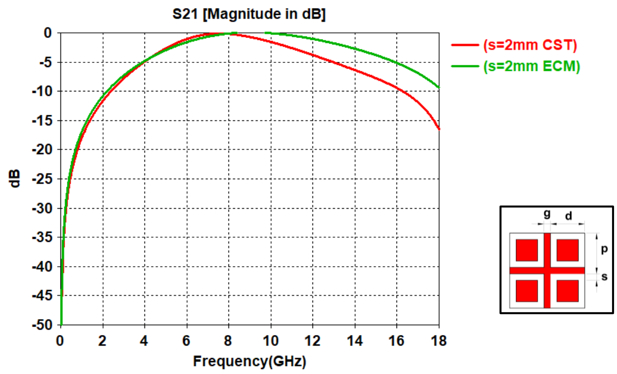


**Figure 6.** Frequency Response of $S_{21}$ for Square Slot FSS with d=10 mm, g=1 mm

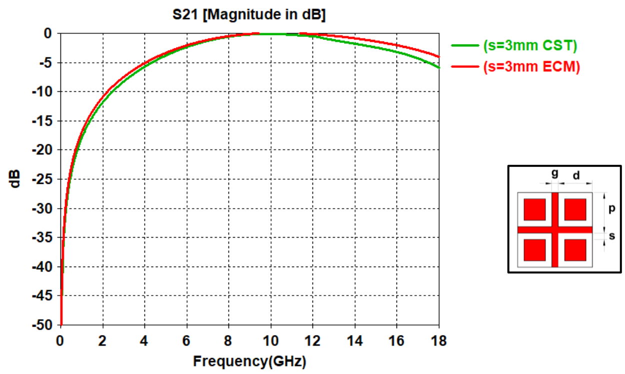


**Figure 7.** Frequency Response of $S_{21}$ for Square Slot FSS with d=10 mm, g=1 mm

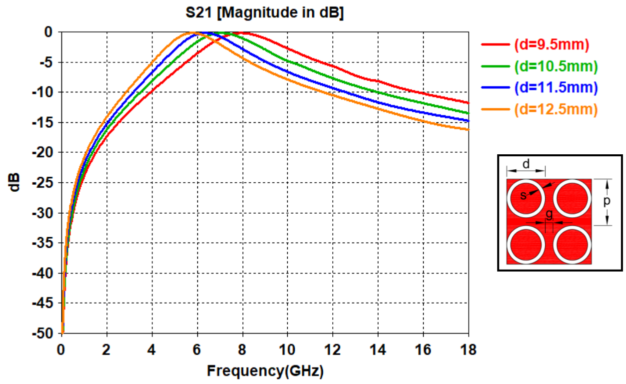


**Figure 8.** Frequency Response of $S_{21}$ for Circular Slot FSS with s=1 mm, g=1 mm for different d.

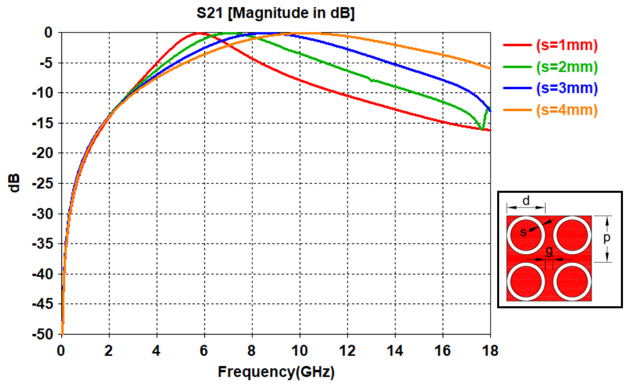


**Figure 9.** Frequency Response of $S_{21}$ for Circular Slot FSS with d=12.5 mm, g=1 mm for different s.

When Fig. 2 to Fig. 9 are examined, final dimensions of square slot FSS are selected as d=10 mm, g=1 mm, s=3 mm and p=11 mm. Also final dimensions of circular slot FSS are d=12.5 mm, g=1 mm, s=4 mm and p=13.5 mm.

## 3 Fabrication and Measurement

In order to validate the simulation results, both FSS structures are printed on an FR4 substrate with 4.29 dielectric constant and 0.019 loss tangent and 1 mm height. Fabricated products are shown in Fig. 10 and Fig. 11.

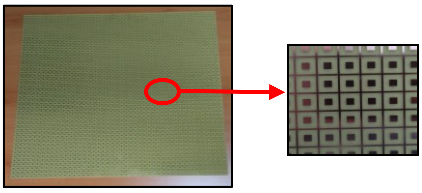

**Figure 10.** View of Fabricated Square Slot FSS

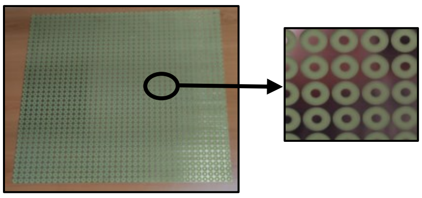

**Figure 11.** View of Fabricated Circular Slot FSS

The transmission measurements were performed at X-Band (8.2-12.4 GHz) and Ku Band (12.4-18 GHz) with N5230A Agilent Vector Network Analyzer inside the anechoic chamber. Standard horn antennas with 15dBi gain are used for free space transmission measurements, as they are aligned with the case of normal wave incidence onto the FSS structures. After calibration, the samples with the size of 506.9 mm x 506.9 mm (square slot FSS) and 514.3 mm x 514.3 mm (circular slot FSS) were placed in the middle position between the antennas. The distance between antennas was around 1.5 m (Fig. 12).

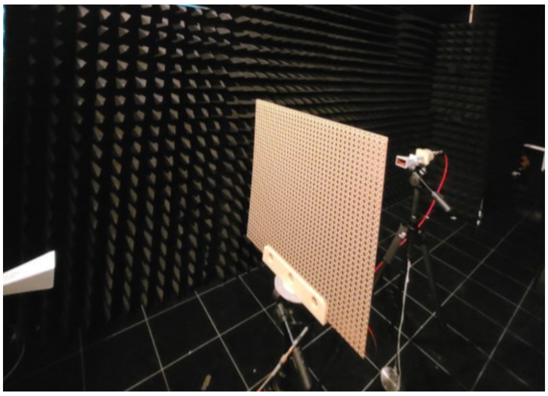

**Figure 12.** Setup for Free Space Transmission Measurements

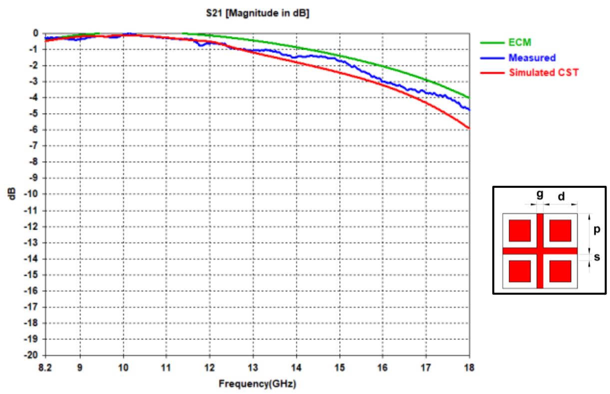


**Figure 13.** Comparison of Simulation and Measurement Results of Square Slot FSS Structure

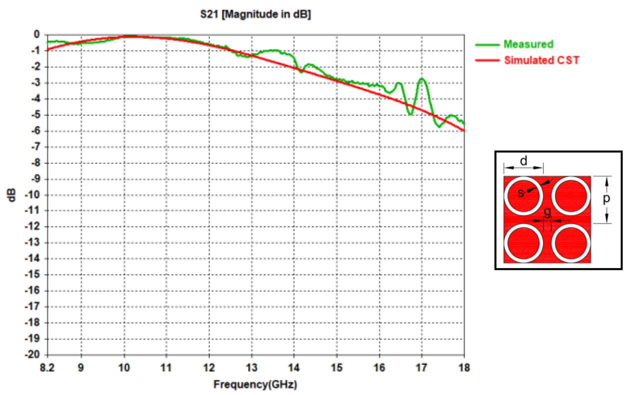


**Figure 14.** Comparison of Simulation and Measurement Results of Circular Slot FSS Structure

## 5 Conclusion

In this study, a square and a circular slot FSS are designed, fabricated and compared to each other. The measurement results illustrates that square slot FSS structure have wider passband characteristics below -0.5 dB. Even though the circular FSS structure have also a good passband characteristics, square slot FSS structures have less area and easy shape to fabricate. The measurement results are in good agreement with simulations. In the future, these designs can be implemented as one of the layers of multiple layered FSS structures in order to achieve better band pass characteristics such as flatter passband and sharper fall-of curve. Since ECM calculations and simulation results of square slot FSS have a good similarity except for high frequencies in some cases; additionally, ECM computations for circular slot FSS would be also utilized in comparison, in the future.

## Acknowledgements

This work was supported by Turkish Aerospace Inc..

## References

[1] B. A. Munk, “Frequency Selective Surfaces Theory and Design,” New York: Wiley, 2000.

[2] S. D. Jang, B.W. Kang, and J. Kim, “Frequency selective surface based passive wireless sensor for structural health monitoring,” *Smart Materials and Structures*, **22**, 2, p025002, December 2012.

[3] M. Mahmoodi and K. M. Donnell, “Novel FSS-based sensor for concurrent temperature and strain sensing,” *2017 IEEE International Symposium on Antennas and Propagation & USNC/URSI National Radio Science Meeting*, 2017, pp. 679–680.

[4] D. Ferreira, R. F. S. Caldeirinha, I. Cuiñas and T. R. Fernandes, “Square Loop and Slot Frequency Selective Surfaces Study for Equivalent Circuit Model Optimization,” *IEEE Transactions On Antennas and Propagation*, **63**, 2, pp. 3947-3955, 2015.

[5] G. L. R. Araujo, A. L. Campos, A. M. Martins; “Improvement of the Equivalent Circuit Method for Analysis of Frequency Selective Surfaces Using Genetic Algorithms and Rational Algebraic Models,” *Progress in Electromagnetics Research Letters*, **55**, 2015, pp. 67-74.