TUNABLE FREQUENCY SURFACE DESIGN BETWEEN 2.43GHZ AND 6GHZ

Bora Döken[1] and Mesut Kartal[2]

[1]Department of Electronics and Communications Engineering, Istanbul Technical University, Istanbul, Turkey
[2]Department of Electronics and Communications Engineering, Istanbul Technical University, Istanbul, Turkey

ABSTRACT

Reconfigurable frequency selective surfaces (FSSs) which have more than one frequency response are demanded by recent communication systems. Tuneable FSS design is presented as a solution proposal to these demands in this work. Four-legged loaded element geometry is modified in order to achieve wide tuning range by inclusion of varactor diodes. Frequency tuning range is increased %11 by comparing with the "Four Legged Loaded" element geometry. Achieved results show that proposed structure allows tuning between 2.42GHz-5.94GHz frequency bands. Analyses are executed with Ansoft HFSS v.15 software.

KEYWORDS

Frequency selective surface, FSS, periodic structures, active FSS, reconfigurable FSS, varactor diodes

1. INTRODUCTION

Periodic conducting structures exhibit different filter characteristics when interacting with incoming electromagnetic waves[1, 2]. These periodic structures are called as frequency selective surfaces (FSSs). They can be divided into two main categories: reconfigurable FSSs or non-reconfigurable FSSs. Non-configurable FSSs generally have one frequency response[1-6]. Reconfigurable FSSs which have more than one frequency response are intensively researched nowadays[7-18]. Reconfigurable FSSs are demanded due to the intensive usage of radio propagation in indoor environment. Mutual interference between adjacent wireless networks in indoor environment is becoming an important issue due to reducing the communication speed significantly[19-25]. Isolating the wireless networks by using frequency selective surfaces (FSSs) can be an efficient solution for such interference problems. Non-configurable FSSs cannot be an effective solution due to the changing environment conditions. Frequency spectrum is needed to be utilized effectively especially in indoor environments. Indoor environment radio communication protocols are defined between 300MHz and 6GHz frequencies[17]. Therefore, a new band stop FSS geometry which can be tuned in wireless frequencies of indoor environment (between 2.42GHz and 3.94GHz) is proposed in this work.

Reconfigurable frequency selective feature is mostly acquired by the inclusion of lumped elements, such as varicaps, PIN diodes and etc. in specific locations within each unit cell[17, 26, 27]. Inclusion of lumped elements allows control on the frequency response by changing the applied bias voltage. Reconfigurable FSSs can be divided into two main categories: switchable[15, 27] and tunable[8, 9, 12, 17, 18, 28, 29]. Tuning feature allows adjusting the resonant frequency response to the desired frequency bands. Besides, fabrication and installation

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errors can also be compensated. This feature is mostly acquired by inclusion of varactor diodes into specific locations in unit cell. Number and locations of the varactor diodes in unit cell, their electrical properties and FSS geometry mainly affect the tuning performance. Varactor diodes represent different equivalent capacitance values depending on the applied reverse biased voltage. Therefore, resonant frequencies of FSSs can be shifted by adjusting the applied voltages to active components.

In this work, “Four Legged Loaded”[1]is chosen as initial unit cell geometry (FSS). Unit cell geometries are connected to each other by inclusion of varactor diodes at the end of the legs where induced charges condense. Therefore, unit cell geometries itself are used to bias varactor diodes as a biasing grid. Wide tuning performance is achieved by placing varactor diodes where induced charges condenses. Subsequently, in order to achieve wider tuning range, four legged loaded geometry is modified by widening the end of the legs. Analyzes and optimization of the proposed surface were executed with Ansoft HFSS v.15 software which uses numerical techniques. Besides, equivalent circuit model were used to define the unit cell behavior of FSS at the design and optimization stages. Achieved results show that wide tuning range between 2.42GHz and 5.94GHz frequencies is achieved by using a simple structure on one layer.

In this paper, design process, simulation and measurement results are presented in Section II and the results are discussed in Section III.

2. DESIGN & MEASUREMENT

In this design, “Four Legged Loaded” is chosen as initial unit cell (FSS) geometry due to having stable frequency response and simple in structure. “Four Legged Loaded” FSS and its equivalent circuitare shown in Figure 1.Equivalent circuit model (EC) is used to define the behavior of FSS at the design and optimization stages. According to EC model, the equivalent capacitance value ($C \propto \frac{s}{g}$) is mainly determined by the gap distance (g) and the width of the gap (s) between periodic element geometries. Equivalent inductance value ($L \propto \frac{d}{w}$) is mainly determined by the length (d) and the width (w) of the current path on the periodic element geometries. The equivalent impedance and the resonant frequency equations (Eq. 1) of the FSS are derived from the given equivalent circuit model.

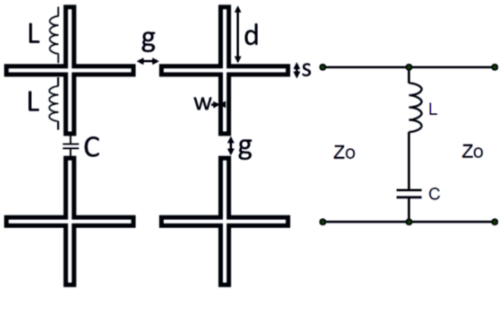


Figure 1. “Four Legged Loaded” FSS and its equivalent circuit

$$Z = \frac{1 - w^2 LC}{\mathrm{jwC}} f_{\mathrm{r}} = \frac{1}{2\pi\sqrt{LC}} \tag{1}$$

It is obvious from Eq. 1 that the resonant frequency of FSS can be tuned by changing the equivalent capacitance value (C). Varactor diodes behave as a variable capacitor (C_p) depending on the applied bias voltage. Therefore, in this work, varactor diodes are placed between unit cell geometries in order to adjust equivalent capacitance value (C, C= $C_g + C_p$). "C_g" and "C_p" denotes the equivalent capacitance between geometries and equivalent capacitance of varactor diodes respectively. The SMV2201-040LF varactor diode is chosen in the design. Its equivalent capacitance values are between 0.23pF-2.1pF depending on the applied reverse bias voltage. Resistances (2kΩ) are placed parallel to the varactor diodes in order to reverse bias them. 2kΩ resistance value is chosen considering the minimum impedance value of the varactor diodes and to limit the flowing current value. Analyzes of the proposed periodic structure are executed with Ansoft HFSS v.15 software which is based on finite element method. Proposed FSS (Figure 1) is optimized according to relationships explained above. Figure 2-3 show obtained simulation results for different capacitance values of varactor diodes for 30 degrees of incidence angles (θ). According to the achieved results, minimum 30dB attenuation is obtained in the desired frequency band between 5.78GHz and 2.62GHz frequencies at TE polarization. However, lower quality factor (Q) of the LC circuit widens "-20dB" bandwidth for large values of varactor capacitance. Besides, resistors of the biasing circuit and the dielectric material employed increase the transmission losses outside the resonant frequency bands.

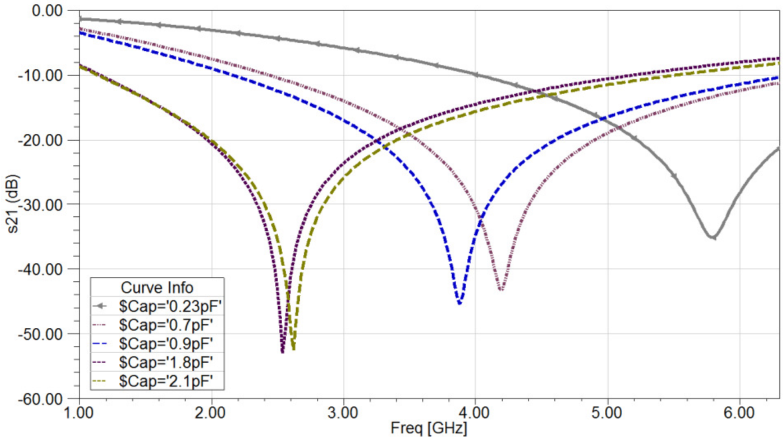


Figure 2. S_{21} curves for different equivalent capacitance values (TE polarization, $\theta=30^0$)

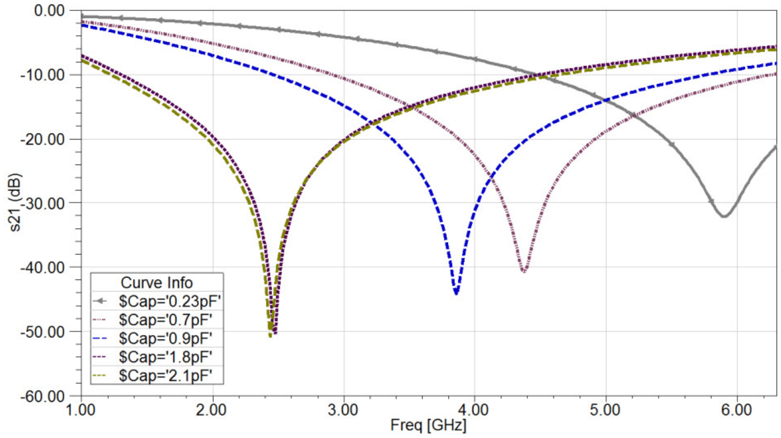
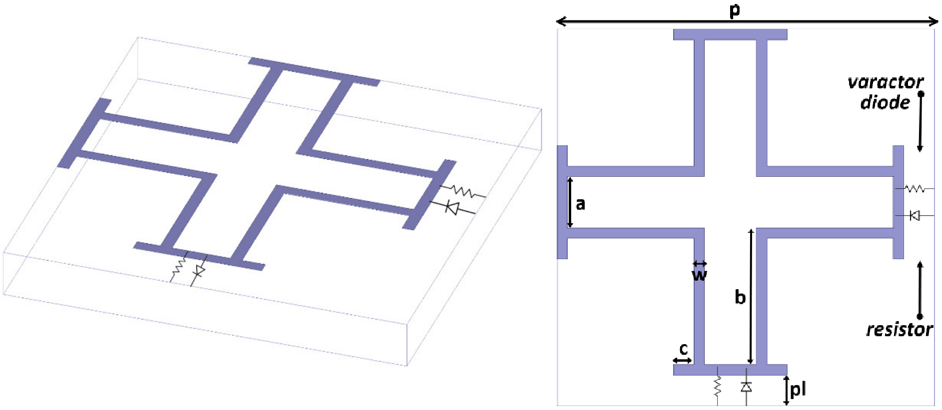


Figure 3. S_{21} curves for different equivalent capacitance values (TM polarization, $\theta=30^0$)

Subsequently, in order to achieve wider tuning range, four legged loaded geometry is modified by increasing (parameter c) the end widths of the legs as shown in Figure 4. All the other parameters (except c) are kept same. Analyzes of the proposed periodic structure are executed with Ansoft

HFSS v.15. Proposed FSS (Figure 3) is optimized according to relationships explained above. The following dimensions are obtained at the end of the optimization process: h=0.8mm (thickness of the FR4 substrate) and the other values in (mm) are p= 6.4, a= 1, b=2.35, c=0.4, w=0.2, pl=0.3.



(a) (b)

Figure 3. FSS geometry (a) Trimetric view (b) Top view

Figure 4-5 show obtained simulation results for different capacitance values of varactor diodes when the angle of incidence (θ) is 30 degrees. According to the achieved results, minimum 30dB attenuation is obtained in the desired frequency band between 5.94GHz and 2.42GHz frequencies at TE polarization. Tuning range is increased %11 comparing with the "Four Legged Loaded" element geometry. However, resonant bandwidths increases due to the increased equivalent capacitance (C_g) values between unit cell geometries.

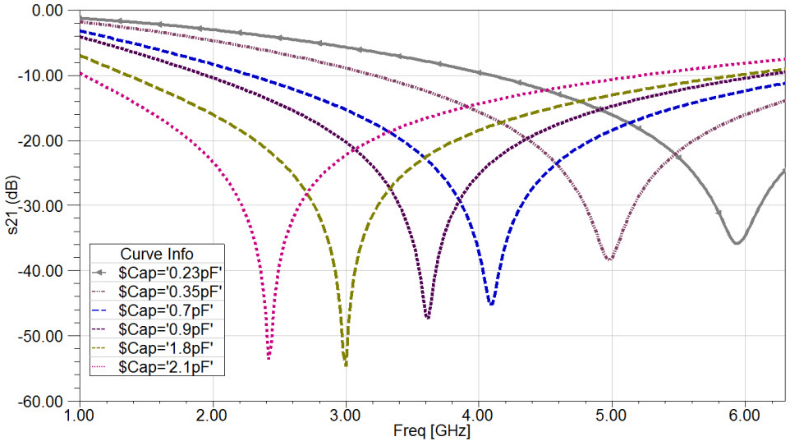


Figure 4. S_{21} curves for different equivalent capacitance values (TE polarization, $\theta=30^0$)

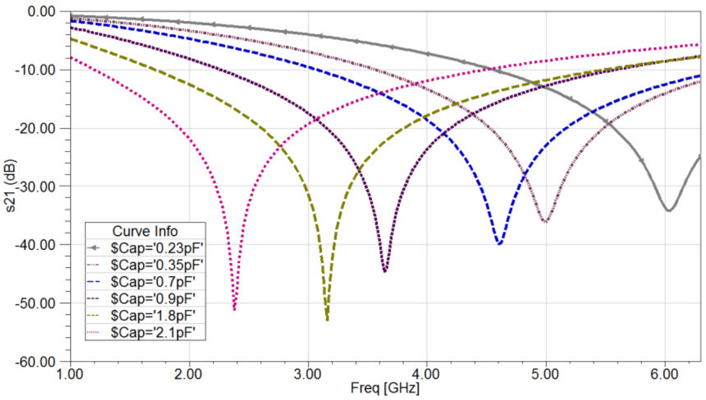


Figure 5. S_{21} curves for different equivalent capacitance values (TM polarization, $\theta=30^0$)

Figure 6-7 show the simulation results for limit equivalent capacitance values (0.35pF, 1.8pF) at 0^0, 15^0 and 30^0 of incidence angles for both TE and TM polarizations respectively. Achieved results show that minimum 30dBattenuation is obtained in the desired frequency band for the oblique incidence angle ranging from normal to 30^0. However, observed frequency shift relative to normal incidence is about 10% at TE30 and 4% at TM30.Measurement results show that the incorporation of the varactor diodes degrade the angular stability, as expected [16].

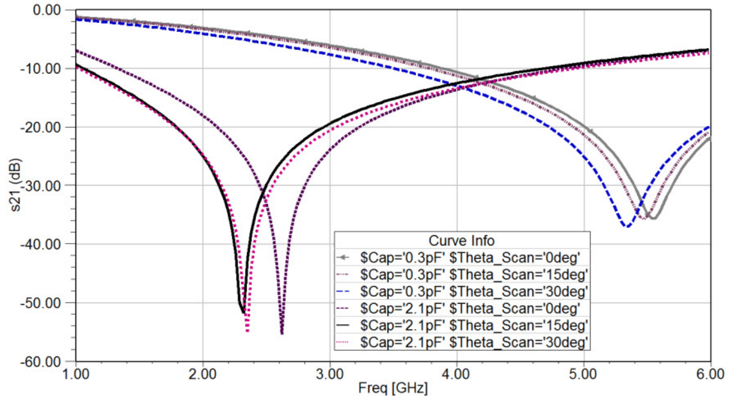


Figure 6. S_{21} curves for different incidence angles (TE polarization, $\theta=0^0$, $\theta=15^0$, $\theta=30^0$)

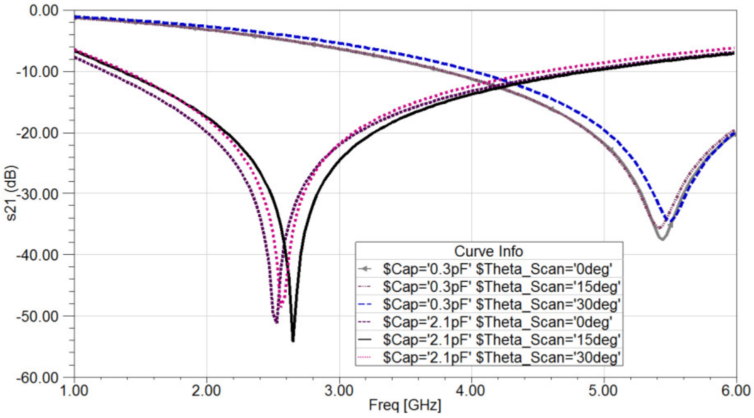


Figure 7.S_{21} curves for different incidence angles (TM polarization, $\theta=0^0$, $\theta=15^0$, $\theta=30^0$)

3. CONCLUSIONS

Band stop FSS geometry with having wide tuning feature is proposed in this work. Minimum 30dB attenuation is achieved in the desired frequency band between 2.42GHz and 5.96GHz frequencies. By adding capacitive edges to the end of legs of "Four Legged Loaded" FSS geometry frequency tuning range is almost increased %11 by comparing with the "Four Legged Loaded" element geometry. Obtained thickness of the structure is only 0.8mm which also gives the possibility of using this design as a structural surface material for blocking the ISM signals.

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AUTHORS

Bora Döken received the B.Sc. degree in electric and electronic engineering and M.Sc. degree from “Satellite Communication and Remote Sensing” department of Informatics Institute from the Istanbul Technical University, Istanbul, Turkey, in 1992 and 2010, respectively. He is currently working toward the Ph.D. degree at the Informatics Institute of Istanbul Technical University. After working in various positions in the private sector, he became an Instructor at the Istanbul Technical University from October 2007. He is currently involved in the areas of FSSs, periodic structures, antennas, and metamaterials.

Mesut Kartal (M’91) received his MS degree in 1993 and Ph.D. degree in 2000. Currently, he is an associate professor in the Istanbul Technical University, Department of Electronics and Communication Engineering. His research interests include remote sensing, inverse problems, RF and microwave design engineering, as well as modelling, design, simulations and analysis, and CAD techniques in high frequency region.

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