3d Reconfigurable Frequency Selective Surface
Singaram¹, Vaishnavi², Pavithra³

Electronics and Communication Engineering, KPR Institute of Engineering and Technology, Arasur, Coimbatore. singaram1189@gmail.com
Electronics and Communication Engineering, KPR Institute of Engineering and Technology, Arasur, Coimbatore. vaishu071998@gmail.com
Electronics and Communication Engineering, KPR Institute of Engineering and Technology, Arasur, Coimbatore. gpavithraganesan98@gmail.com

Abstract

The concept of a novel reconfigurable 3-D frequency selective surface (FSS) showing band stop response using concentric cylinder is proposed. The polarization and angular-independent operation are provided by proposed 3-D RFSS. It offers band stop response in the L-band and S-band of microwave frequency. Using sliding technique, the proposed novel reconfigurable 3-D FSS have reconfigurability and achieves frequency tuning from 1 GHz to 4 GHz by sliding the outer cylinder over the inner cylinder.

Keywords— Sliding technique; frequency response; three-dimensional reconfigurable frequency selective surface (3-D RFSS).

1. Introduction

Over the years, the research on frequency selective surfaces (FSSs) gained more attention among researchers. The importance of it being is attributed to its wide range of applications. FSSs are periodic structures used widely in hybrid radomes, bandstop filters, dichroic reflectors, shielding. The sharper filtering response with good angular performance and better design flexibility can be realized by unit cell of frequency selective surface [1]. The broadband band stop filtering response of 3-D FSS is suggested in [10] under liner polarized condition. The effective shielding provided by frequency selective surface is high [2]. But bandwidth is one of the problems in designing FSS. To overcome this Multilayer or complicated structures are used [3]. Square cylinder unit cell element is suggested in [4]. 3-D FSS offers multiple transmission zeros with rectangle shape metallic plates and T type are introduced into the air region [5]. The 3-D FSS with more than 57% bandwidth is proposed in broad selectivity of waves with stable behavior under oblique incident angle from 0 to 80 degrees in TM waves [4]. The polarization independency is provided in modified double square loop element based FSS [6]. The FSS consist of loop wire [7] provides transmission poles separated by transmission zeros. Frequency Selective surface have applications of satellite communications and microwave systems. The reconfiguration of transmission and reflection coefficient 3D FSS has high frequency PIN diodes with 1.45GHz and 2.45GHz [8]. In [9] suggested using holes in multilayer printed circuit board, the polarization of both TE and TM wave and frequency stability is offered. The angular stability is provided by single layer annular ring FSS [11] is used. The quasi elliptic filtering response is obtained by using dielectric layer as non-resonating node [12]. Using jetting multiple ink layers at edges and entire element is [13] improved. The polarization and angular independent operation are achieved [14] as a stable response of TE and TM modes. For ultra-wide band applications [15] offers stable polarization. In this paper polarization and angular independent operation are obtained by using two concentric cylinders placed over one another with band stop response in L and S microwave frequency band.
2. Unit Cell Design And Analysis

The unit cell is shown in Fig. 1. The reconfigurable 3-D FSS unit cell is designed using two cylinders C1 and C2. The inner cylinder C1 has a diameter of D1 with height h1 and outer cylinder C2 has a diameter of D2 with height h2, respectively. The cylinder C1 and C2 has thickness t1 = 2 mm. The unit cell is made of steel with conductivity= 7.69×10^6 S/m. The unit cell is placed on Teflon substrate with relative permittivity εr =2.1 and thickness t = 10 mm. The inner cylinder is inserted into the outer cylinder and the cylinders are attached to each other firmly. The resonant frequency of the proposed 3-D Reconfigurable FSS is given by

\[
F \propto \left( \frac{P^2}{8P + 11Q + h_{\text{eff}}} \right)^{\frac{1}{2}}
\]

\[
P = \frac{(D1 + D2)}{4}
\]

\[
Q = \frac{(D1 − D2)}{2}
\]

where \(h_{\text{eff}}\) is the effective height of the unit cell, \(F\) is the resonant frequency of the Reconfigurable FSS and D1 and D2 are the diameters of the cylinders C1 and C2 respectively. It is viewed that any change in the \(h_{\text{eff}}\) alters the resonant frequency. Hence, frequency reconfiguration is achieved by varying the effective height \(h_{\text{eff}}\) of the 3-D Reconfigurable FSS.

3. Simulation results and discussion

The simulation of the proposed 3-D Reconfigurable FSS is done using CST MWS. The unit cell is designed with Teflon substrate of effective height 15 mm. The software utilities floquet ports to analyze the operation of the Frequency Selective Surface. The polarization for the proposed 3-D RFSS for TE and TM modes simulated transmission characteristics of are shown in Fig 2. The proposed 3-D reconfigurable FSS act as a band stop filter at 3.2 GHz is known. The 90% attenuation of incident wave of FSS demands polarization-independent operation. The bandwidth offered reconfigurable FSS is 700 MHz at 50-dB reference level of transmission loss. From Fig. 2, it is observed that the proposed 3-D FSS with its symmetrical unit cells offers identical response for TE and TM modes of incident wave. Thus, it supports polarization independent operation. The deployment capability of the FSS for various angular incidents of the electromagnetic wave is identified using Angular insensitive property of the Reconfigurable FSS.
For both TE and TM modes of operation, it is observed from the simulated $|S_{21}|$ that the FSS offers stable operation for various values. It is seen that the use of Teflon as substrate with its $\varepsilon_r$ higher than air provides higher value of $|S_{21}|$ at its operating frequency compared to FR4 and Foam. The choice of Teflon substrate is advised in proposed 3-D FSS for free-standing electromagnetic shielding applications.

4. Reconfigurable operation of the proposed FSS

The various frequency response is achieved by varying effective height $h_{\text{eff}}$ of the cylinders. The various values of $h_{\text{eff}}$ that is 20mm, 25mm, 30mm and the h1 and h2 has same height of 15mm. Fig.5 shows the simulated characteristics. The band stop response of proposed FSS, is tuned at 3.2 GHz with 700 MHz of bandwidth for 50db level. When the height of the outer cylinder is varied then the central frequency of the band stop response is also varied to 2.2Ghz, 3Ghz, 3.2Ghz. As shown in the figure 2, resonant frequency of the proposed 3D FSS is directly proportional to the height of the cylinder which we slide over another. So, the band stop response of FSS can be varied by changing the effective height by moving the cylinder up or down. For achieving the band stop response in the higher frequency another cylinder is added over the outer cylinder in each unit cell. This increases the effective height of the cylinder. It offers the polarization independent operation, when the symmetric unit cell is used.

Fig. 3: Unit cell profile of the existing 3-D FSS for $h_{\text{eff}}$ =25mm.

Fig. 4: Simulated Transmission characteristics ($S_{21}$) of the existing 3-D FSS for various angles of incidences $0^\circ,15^\circ,30^\circ$. 
Fig. 5: Unit cell profile of the existing 3-D FSS for $h_{eff}=28$mm.

Fig. 6: Simulated Transmission characteristics ($S_{21}$) of the existing 3-D FSS for various angles of incidences $0^\circ, 15^\circ, 30^\circ$.

Fig. 7: Unit cell profile of the proposed 3-D FSS for $h_{eff}=30$mm.
Fig. 8: $S_{21}$ curves obtained for design steps of the proposed FSS unit cell at normal incidence angles $0^\circ, 15^\circ, 30^\circ$.

5. Conclusion

A 3D reconfigurable FSS with bandstop frequency response is presented in this paper. The unit cell which we constructed consists of two CTCs. The proposed 3-D FSS provides bandstop response and offers frequency tuning from 1.86 to 3.30 GHz by sliding technique. In addition, the proposed 3-D FSS delivers polarization independency and is insensitive to incident angles up to $45^\circ$. The proposed 3-D RFSS is the potential candidate in offering bandstop response for the L- and S-band microwave frequencies. Further tuning to subsequent bands is also possible with usage of additional cylindrical unit cells in the proposed 3-D FSS. The proposed 3-D FSS offers the advantage of tunable operation in simple configuration without the use of active components.

References


