

Design of Frequency Selective Surfaces Filter-A Review

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ABSTRACT: This paper presents how to design a Frequency Selective Surfaces (FSSs) filter. Filter is used to extract the electromagnetic waves in spaces. A conducting sheet perforated with apertures or an array of periodic metallic patches constitute FSSs and it is usually designed to provide four standard spectral response: low-pass, High-pass, band-pass and band-reject. A band-pass filter with frequency range from 2GHz-8GHz was designed using FSSs. Simulation results for both filters are produced using Agilent ADS software.

KEYWORDS: Periodic structure, Filter, band-pass filter, band-stop filter.

I. INTRODUCTION

Frequency Selective Surfaces is conducting sheet perforated with apertures or an array of periodic metallic patches. Its function as spatial filters forelectromagnetic(EM) waves [1]. The FSS element are much smaller than the operating wavelength, which is less than $1/13 \lambda$. For this miniaturized element, grating lobes are restrained and do not appear event to 25 GHz. Moreover, the FSS has stable performances for various incident angles. Design procedure and measurement results of the FSS are presented and discussed [2].

Design of a very thin layer modified miniaturized-element FSS producing a single-pole band-pass response in addition to a transmission zero is presented. The modified design is just a single-sided circuit board with a particular unit cell consisting of a loop centered within a wire grid [3]. Proposed design utilizes non-resonant sub-wavelength constituting unit cells with unit cell dimensions and periodicities in the order of 0.15λ . The FSSs have an overall thickness of $\lambda_0/30$, which is considerably smaller than thickness of second-order FSSs designed using traditional techniques. Two band-pass FSS prototypes operating at X-band are designed, fabricated, and tested [4].

A three layer structure composed of three metal layers, separated by two electrically thin dielectric substrates. Each layer is a two-dimensional periodic structure with sub-wavelength unit cell dimensions and periodicity. The unit cell of the proposed FSS is composed of a combination of resonant and non-resonant elements. proposed structure has an extremely low profile and an overall thickness of about $\lambda/24$ [5]. FSSs designed using this technique use a combination of resonant and non-resonant. The main advantage is the design low-profile and ultrathin FSSs that can provide sharp frequency selectivity [6].

BSF is designed with FSS unit cells modifying the cross-loop slots. The centre frequency (f_0) of the BSF is 6.6 GHz, and the 3-dB bandwidth varies by the number of cascading unit cells [7].

To produce a equivalent circuit and to estimate the resonant frequency and reflection phase of Jerusalem cross-based artificial magnetic conductor (JC-AMC) structures for waves normally incident on the structure. The JC-AMC structure is composed of an array of Jerusalem cross-shaped frequency selective surfaces (JC-FSSs) printed on a metal-backed dielectric slab without vias [8].

The elements studied are 1) Square loop, 2) Double Square loop and 3) Gridded Square loop. The circuit models are within 1.5% of average deviation against reference data [9]. The analysis and equivalent circuit modeling of square patch FSS adopting an efficient vector-fitting is proposed. The simulations of microstructure are performed with CST Microwave Studio on single-substrate for different physical parameters, angle of incidences and polarizations [10].

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A new technique for designing dual-band frequency selective surfaces with arbitrary bands of operation and second-order band-pass responses is presented and experimentally verified [11]. A dual-band frequency selective surface (FSS) in low frequencies with miniaturized element. A dual- concentric square element with two different slot sizes is constructed to realize dual-band passband responses. Each passband is realized by a square slot structure. Besides, we reduce the slot sizes to make the element miniature and compact [12].

Spatial band-pass filter resonant at 1.5 mm and based on a frequency-selective surface (FSS) was analyzed and fabricated. It consists of circular apertures arranged in a hexagonal lattice and was modeled using a hybrid finite-element/boundary-integral method, which accounted for metal thickness and conductivity [13].

II. DESIGN AND ANALYSIS

Frequency selective surfaces is also known as filters of electromagnetic waves, mainly in frequency, though they do find application in the angular spectrum. There are two frequency sensitive processes which are commonly exploited in the design of these surfaces. One is the interference of waves reflected from cascaded partially transmitting boundaries (broadly similar to the Fabry-Perot interferometers well known in optics), and the other is the resonant interaction of waves with segments of conductor - normally periodic arrays of conducting elements or slots in conducting screens.

There three principle technique used to design and analysis. They are,

- A modal analysis
- Equivalent circuit approach,
- Iterative process.

The first method is modal analysis in which the distribution of current induced in conducting elements (or fields in slots) is represented as a series of suitable basis functions (usually sinusoidal functions or waveguide modes).

The second method is an equivalent circuit approach which models the arrays as lumped impedances on a transmission line.

The third method is an Iterative process. A first estimate of the element current induced by the incident field E_{inc} is used to calculate the local electric field distribution E , which is then forced to zero at the surface of the conductors. This modified field is in turn used to recalculate the element current distribution.

For designing the Frequency Selective Surfaces, the primary parameters of FSS has to be set.

- The thickness h of the substrate according to Fabry-Perot resonance condition, the substrate thickness h is defined in (1)

$$h = k * \frac{c}{2f_{pass} \sqrt{\epsilon_r}} * \cos \left[\arcsin \left(\frac{1}{\sqrt{\epsilon_r}} \sin \theta \right) \right]$$

where $f_{pass} = 300$ GHz, $k = 2$ and c is the speed of light in vacuum. Therefore, the required thickness is $h \approx 289.7 \mu\text{m}$ for easy fabrication, the thickness of wafers can be set at $h \approx 302 \mu\text{m}$.

- The length L of the cross dipole slots For easy fabrication, the thickness of wafers can be set as W ; the length L of the slots should be half wavelength in the substrate.

$$L = \frac{\lambda}{2} = \frac{c}{2f_{pass} \sqrt{\epsilon_a}}$$

$$\epsilon_a = \frac{1 + \epsilon_r}{2}$$

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where ϵ_{eff} is the effective dielectric permittivity, approximately. For a resonance at $f_{\text{pass}} = 300$ GHz, the slots length is $L = 0.197 \mu\text{m}$. Moreover, the initial value of slot width is set to $W = 0.03 \text{mm}$. It should be mentioned that the slight difference of W can result in slight difference of resonance frequency.

➤ The size of the unit cell ($T_x = T_y$). The size of the unit cell T_x can be used to define the stopband frequency of the filter. The required size of the unit cell is given by

$$T_x = T_y = \frac{c}{f_{\text{stop}} (\sqrt{\epsilon_r} + \sin \theta \sin \phi)}$$

The periodicity is $T_x = T_y = 0.176 \text{mm}$ for the FSS with a stopband at 450 GHz. However, the slot length L is bigger than the size of the unit cell. Therefore, T_x and T_y are initially set to be 25% larger than the length of the slots ($T_x = T_y = 0.25 \text{mm}$).

Dielectric substrates are used to provide structural support and stabilization to the angular response of FSS. The dielectric substrate's permittivity has a great influence on FSS design. In a single layer of FSS, FSS is attached to one side of the dielectric substrate.

The resonant frequency (f_r) of FSS array is dependent on the thickness of the supporting dielectric substrate. If the FSS is loaded with thick dielectrics, the resonance frequency is reduced by a factor. Different FSS dielectric arrangements will influence the frequency selective response to a different extent and improve the stability of FSS performance over a range of incident angles.

When electromagnetic energy is incident on a FSS, currents are induced on the conducting elements. These induced currents then re-radiate EM waves from these conducting elements. Various methods for analysing periodic structures have been developed with computational intensive approaches such as the mutual impedance method, the method of moments (MoM), the infinite element method (FEM), the infinite-difference time-domain (FDTD) method, and Equivalent Circuit (EC) method. Out of these, EC method was chosen as it is a simple and powerful technique.

Using this technique, FSS can be modelled as energy-storing inductive or capacitive components which are determined by the shape of its elements, but the analysis is limited to linear polarizations and simple FSS element geometries. The most commonly used technique is hybrid method.

For analysis the frequency selective surfaces. There three step,

- A single metal screen can be considered
- Each unit cell of the periodic array may comprise only one aperture
- The structure is illuminated by a uniform plane wave incident from the normal direction ($\theta = 0, \phi = 0$).

A. Band-Pass filter design

Band-pass filter passes only the passband frequency signal and attenuate all frequency outside the passband. Figure1: The element consists of two dipole and two legged loaded element. The dipole is supported for only linear polarized wave. So we use crossed dipoles. FR4 material is used in substrate, whose permittivity is 4.2, loss tangent is 0.025, and thickness $h = 2.0 \text{mm}$. Agilent ADS software used to calculate the performance of the filter.

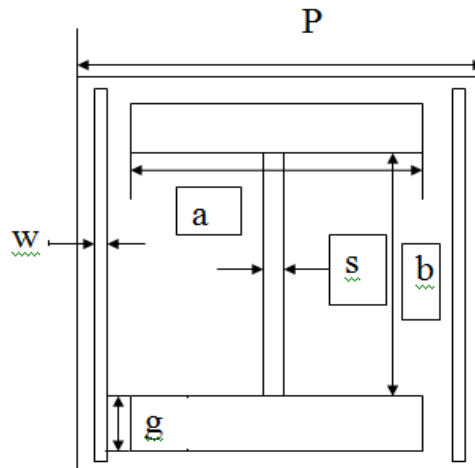


Figure 1: FSS Unit cell

Designed with geometrical values of the structure are $p = 4.5$ mm, $a = 3.8$ mm, $b = 3.3$ mm, $w = 0.15$ mm, $s = 0.2$ mm, $g = 0.5$ mm. The FSS is assumed to be infinite periodic structure.

Figure 2: Shows the forward transmission response ($S(2,1)$) The band-pass response occurs at about 6.3GHz. -3dB bandwidth of the passband is from 4.1GHz-7GHz. The type of filter is identified by the forward transmission parameter. Here the forward transmission shows band-pass filter response.

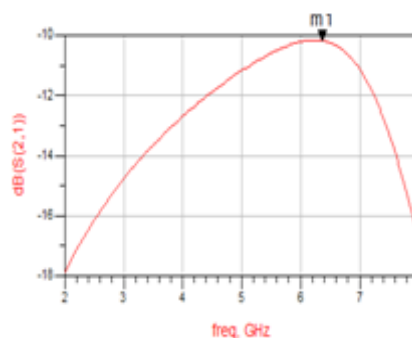


Figure 2: Simulation of S-parameter for the FSS unit cell

III. EXPERIMENT RESULTS

To measure the response of two filters. The s-parameter is calculated using Agilent ADS software tool. The parameters are

- dB(S(1,1)) - Input Reflection Coefficient,
- dB(S(1,2))- Reverse Transmission
- dB(S(2,1)) - Forward Transmission
- dB(S(2,2))- Output Reflection Coefficient

Figure 7: shows all the s-parameter simulation of band-pass filter. The band-pass response occurs at about 6.3GHz. -3dB bandwidth of the passband is from 4.1GHz-7GHz.

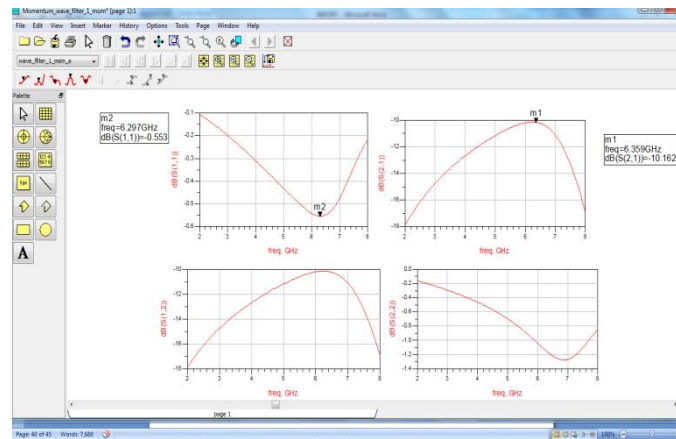


Figure 7: S-parameter for band-pass filter

Same as for band-stop filter the s-parameter is calculated by Agilent ADS software. Figure 8: shows all the s-parameter simulation of band-stop filter. The band-stop response occurs at about 8.3GHz. -3dB bandwidth of the passband is from 7GHz-10GHz.

IV. CONCLUSION

The band-pass filter the frequency range is 2GHz-8GHz was designed using Frequency Selective Surfaces. The design of band-pass filter consists of combination of dipoles and two-legged element. The design of band-stop filter consists of combination of two or more dipoles. Two filters are simulated by using Agilent ADS software tool. S-Parameters are calculated for both filters. Low-pass filter and High-pass filter will be designed using Frequency Selective Surfaces. Circuitual approach for four filters will be proposed.

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