Mollaei, M. S.M.; Heydarian, R.; Zanganeh, E.; Sedighy, S. H.

**Triple-Bands Ka-Band Frequency Selective Surface Filter with Different Polarized Transmitting Performance in Each Band**

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Abstract—A triple-bands frequency selective surface (FSS) filter composed of combined enhanced Jerusalem and Gangbuster unit cells over square substrate integrated waveguide (SIW) cavities is presented. The enhanced Jerusalem cells produce two pass-bands with rotated polarization outputs while the enhanced Gangbuster one produces one pass-band with same polarized outputs in comparison with the input wave polarization. The pass-bands of the proposed FSS are at 33.5 GHz, 35.1 GHz and 36.8 GHz. The simulation results verify the proposed idea ability and capability.

Index Terms—fss filter, polarization, SIW.

I. INTRODUCTION

For decades, frequency selective surfaces (FSSs) have attracted researchers due to their wide range of applications. The FSS filtering performance is used in many devices and systems such as multi-beam antennas, large aperture antennas, satellite communication and Quasi-Optical systems [1]-[4]. In these applications, employing multi-band filters with different polarized outputs in each band leads to more compact structure and cut the costs. In order to obtain pass band polarization rotator, first, a polarization rotator FSS for 90° polarization rotation has been introduced [4]; then, FSS filters with arbitrary polarization rotation has been reported [5,6]; however, an FSS filter with different polarization output can enhance the performance of aforementioned applications. In this paper, a triple-bands spatial filter FSS based upon substrate integrated waveguide (SIW) cavities is presented. In order to obtain different amount of polarization rotation at each band outputs, enhanced Jerusalem and Gangbuster unit cells are combined. Moreover, the square SIW cavities are employed to prevent overlap between current distributions of these surfaces. The enhanced Jerusalem unit cell produces two pass-bands which also rotate polarization of transmitted waves while the enhanced Gangbuster one produces one pass-band between the other two pass-bands related to the enhanced Jerusalem cell.

II. DESIGN PHILOSOPHY

Figure 1 shows the proposed triple-bands FSS structure. The structure unit cell includes four different SIW cavity sub-cells. The electromagnetic waves enter through the slots on the front surface of the SIW cavities in a specific frequency range and excite it. Then, the excited cavities transmit the wave to the other side of structure by inserting slots on the back side of the structure. The output polarization of each band is determined with respect to the angle between input and output slots. According to Fig. 1, the sub-cells which include the parallel input and output slots perform as enhanced Gangbuster surface over SIW cavities and transmit the input wave to the output with similar polarization while the sub-cells which include the orthogonal input and output slots perform as enhanced Jerusalem surface over SIW cavities and transmit the waves with rotated polarization. Beside one pass-band of enhanced Gangbuster surface, enhanced Jerusalem surface with periodic distance equal to wavelength between cells produces two pass-bands, also.

A. Design and Simulation

The slots, as input and output ports, play a key role in the structure performance. Indeed, waves enter the SIW cavities through the slots and transmitted to the other side of the structure through the back unit cell slots. With respect to this fact, slots should be designed in a way that only the waves in the desired frequency band can pass through them. As it well known, the frequency resonance of a slot is depended on its length where the following equations formulate this relationship [4]:

\[ f_{rs} = \frac{c_0}{2l}\sqrt{\varepsilon_{eff}} \]  

where \( c_0 \) is the speed of light, \( l \) is the slot length and \( \varepsilon_{eff} \) stands for the substrate effective electric permittivity.

Alongside the slots, SIW cavities require careful design as the second type of resonators. In fact, decreasing overlap between current distributions of Gangbuster and Jerusalem FSSs is the main reason of using SIW cavities. Moreover, in order to maximize the coupling between waves and cavity, the dominant mode of square SIW cavity needs to be excited. The following well known equation defines the relationship
between dimensions of square SIW cavity and its different modes resonance frequency [4]:

$$f_{re} = \left(\frac{c_0}{2\sqrt{\epsilon_r}}\right)\sqrt{\left(m/W_{eff}\right)^2 + \left(n/W_{eff}\right)^2 + \left(p/h\right)^2}$$  \hspace{1cm} (2)

\[W_{eff} = W - d^2/0.95b\]  \hspace{1cm} (3)

where the electric field of the mode is maximum, the resonance frequency can be increased [7]. Considering this theory, first a square SIW cavity with frequency resonance of dominant mode at 30 GHz is designed, and then by inserting a metallic via at the center of square SIW cavity (maximum E filed at dominant mode), the frequency resonance of dominant mode reaches to the intended frequency. Alongside the slots and square SIW cavity design, the slot positions on the square SIW cavity sides are important. The slot should be located where the distributed current arrows of dominant mode in the cavity are perpendicular to them to achieve more pure polarization. Figure 2 shows the current distribution of dominant mode in square SIW cavities.

The proposed FSS structure is designed on Rogers RT/5880 (1.57 mm thickness) substrate and simulated by CST Microwave Studio. The presence of slots on square SIW cavities and their edge effects can create slight changes on the design parameters value achieved by equations (1) and (2). The optimized values for these parameters which shown in Fig. 1 are tabulated in Table. The simulation results of the proposed FSS filter are plotted in Fig. 3. As it can be seen, the structure performs as triple-band filter which its first and third pass-bands transmit waves with 90° polarization rotation (pertinent to the enhanced Jerusalem sub-cell) and its second pass-band transmit same polarized waves as incident waves (pertinent to the enhanced Gangbuster sub-cell). To clarify more, the structure converts linear vertical polarization (because input slots are horizontal) to both vertical and horizontal, but in different frequency bands.

Table: The optimized design values of the proposed FSS filter.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>W (mm)</th>
<th>a</th>
<th>d</th>
<th>p</th>
<th>l</th>
<th>s</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value</td>
<td>4.0</td>
<td>0.2</td>
<td>0.4</td>
<td>0.15</td>
<td>3.13</td>
<td>0.2</td>
<td>0.5</td>
</tr>
</tbody>
</table>

III. CONCLUSION

A triple-bands FSS filter with different polarized outputs in each band based on frequency selective surface over substrate integrated waveguide cavities has been presented in Ka frequency band. The proposed structure is constituted of the enhanced Jerusalem and Gangbuster surfaces over enhanced SIW cavities. Low cost, compact structure and design simplicity prove the ability and capability of the proposed structure.
REFERENCES


