Polarization-Insensitive Ku-band Frequency Selective Surface (FSS)

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***Abstract*—A wideband, low profile frequency selective surface (FSS) is presented for Ku-band (12.4 – 18 GHz). The proposed design is fabricated on two substrates with a total thickness of <λ/10. The complimentary unit cell shape results in a miniaturized FSS design as well as wideband performance. The designed FSS is polarization-independent due to the unit cell symmetry. The simulated results of the proposed unit cell show the flexibility for selecting the desired bandwidth by changing the relevant parameters easily.**

Keywords—Frequency selective surface, wideband, miniaturized element, band-pass, polarization insensitive

I. Introduction

A Frequency Selective Surface (FSS) is a periodic structure arranged in a two-dimensional array of metallic patches or apertures. For traditional FSSs, periodic arrays of resonant elements are often used to achieve band-pass or band-stop behavior (depending on the use of patch or slot periodic arrays). Because of its frequency selective performance, FSSs have been the focus of intensive investigation for various applications including satellite, aircraft, and radome design [1]-[4]. For radar and satellite communication systems, the demand for designing radomes that can provide proper spatial filtering performance to remove unwanted signals is rising. Since FSSs can provide such a response, integrating an FSS into a radome is of interest. In addition, the ability to design low-profile FSSs is also a benefit as it relates to radome integration. Also, for some radome applications, polarization and incident angle of the incident electric field are unknown. As such, the design of an FSS, independent of these parameters for both incident transverse electric (TE) and transverse magnetic (TM) waves, is desired [5], [6]. In this work, a honey-comb shaped wideband FSS at Ku-band frequencies (12.4-18 GHz) is presented. Using Ansys HFSS (full-wave modeling software), the transmittance response of the proposed FSS unit cell and the effect of relevant parameters determined.

II. FSS Design

The proposed FSS is fabricated on two Rogers 5880 boards (with permittivity of 2.2 and loss tangent of 10^{-3}). The thickness of each substrate is 0.78 mm (< λ/25). The low-profile FSS is composed of three metallic layers and two substrate layers, as shown in Fig. 1a. The proposed FSS features a hexagonal (honey-comb) shape that facilitates miniaturization of the FSS, which is important for compact and low-profile unit cell design. In Fig. 1b and 1c, the unit cells employed in this design are illustrated.

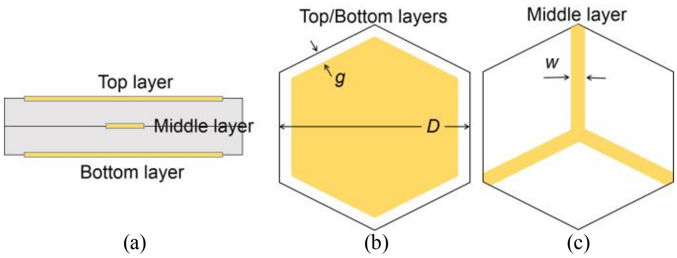
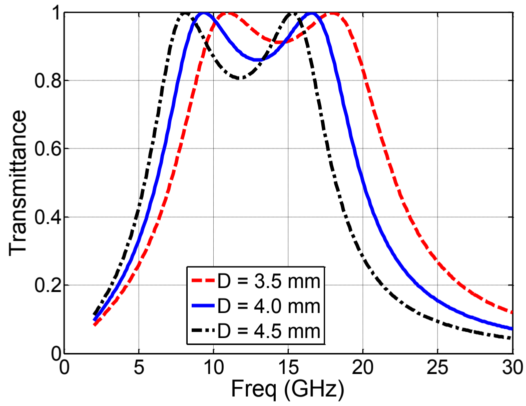
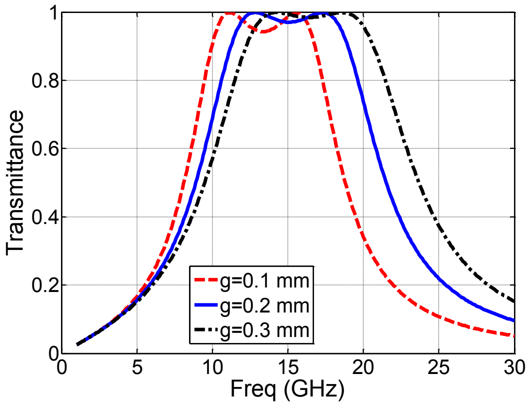


Fig. 1. Proposed FSS unit cell, (a) top and bottom layers, and (b) middle layer.

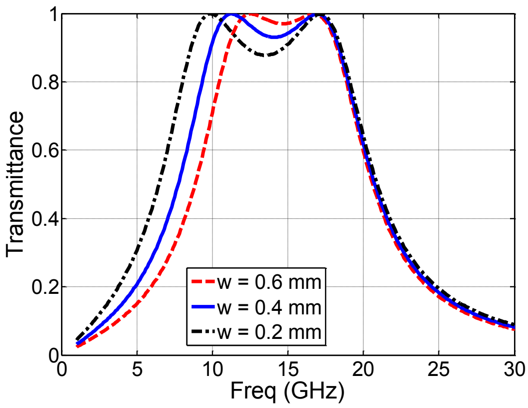
From the proposed design, an equivalent circuit model can be determined for each layer, which are in turn connected through a transmission line. The top and bottom layers behave as large capacitors with small inductance, while the middle layer (consisting of a wire grids) can be modeled as inductor with a small capacitance. Thus, the two resonances of this equivalent circuit can be tuned to achieve wideband performance. In addition to wideband band-pass filtering performance, miniaturized unit cell size as well as a polarization-insensitive FSS response (due to the symmetry of the unit cell) are obtained. For the proposed design, the transmittance response of the unit cell is considered to be tuned to the desired frequency band (Ku-band). In Fig. 2, a parametric study of the hexagonal patch and slot dimensions on the transmittance response of the FSS is presented. As seen in Fig. 2a, by increasing the size of the unit cell for a given g and w, the overall operating frequency will decrease. From Fig. 2b, by increasing the spacing between the patch and the unit cell boundary (g), the lower and upper cut-off frequencies increase. While both unit cell size or patch size have the same effect on frequency response behavior, the sensitivity of the transmittance response to the patch size (i.e., effect of g) is greater. This is due to the decrease in capacitive loading between adjacent patches on both the top and bottom layers when *g* is changed. At the same time, by increasing the spacing between the hexagonal slot and the unit cell boundary (*w*), shown in Fig. 2c, wider inductive lines are achieved which results in increasing the lower cut-off frequency, while the upper cut-off frequency remains fixed.



(a)



(b)



(c)

Fig. 2. Parametric study results of transmittance response, (a) unit cell size with a fixed *g* and *w* values, (b) inductive loading width with fixed unit cell and capacitive patch size, and (c) capacitive patch loading with fixed unit cell and inductive loading width.

In Fig. 3, the effect of incident angle and polarization on the FSS transmittance response is shown. As seen, by changing the polarization angle, the transmission response of the FSS does not change due to the symmetry of the unit cell, resulting in a polarization-insensitive FSS design. Also, changing the incident angle (of the incident electric field) from 0 to $\pi/12$ rad has effect (shift from 12.4-18 GHz to 13.2-20 GHz) on the transmittance results.

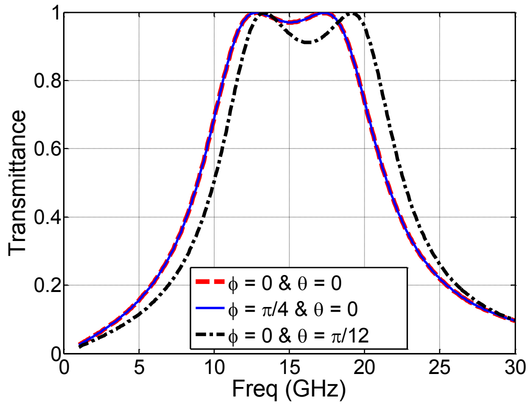


Fig. 3. Effect of incident angle and polarization on FSS response.

III. Conclusion

A wideband, low profile frequency selective surface (FSS) for Ku-band (12.4-18 GHz) radome applications is presented. The proposed FSS has a thickness of $<\lambda/10$ at the center of the operating band. The design is also polarization-insensitive. The complimentary unit call shape results in a miniaturized FSS design with wideband performance. As shown, the FSS response can be adjusted to the desired frequency bands by tuning the unit cell size and the patch and slot dimensions.

IV. References

[1] W. Wang, P. Zhang, S. Gong, B. Lu, J. Ling, and T. Wan, "Compact angularly stable frequency selective surface using hexagonal fractal configurations," *Microwave and Optical Technology Letters,* vol. 51, no. 11, pp. 2541-2544, 2009.

[2] S. Zabri, R. Cahill, and A. Schuchinsky, "Compact FSS absorber design using resistively loaded quadruple hexagonal loops for bandwidth enhancement," *Electronics Letters*, vol. 51, no. 2, pp. 162-164, 2015.

[3] M. De Cos, Y. Alvarez, and F. Las-Heras, "Novel broadband artificial magnetic conductor with hexagonal unit cell," *IEEE Antennas and Wireless Propagation Letters*, vol. 10, pp. 615-618, 2011.

[4] M. Gustafsson, A. Karlsson, A. Rebelo, and B. Widenberg, "Design of frequency selective windows for improved indoor outdoor communication," *IEEE transactions on antennas and propagation*, vol. 54, no. 6, pp. 1897-1900, 2006.

[5] S. Ditti, and S. Das, "On a polarization-independent frequency-selective surface (FSS)," *Microwave and optical technology letters*, vol. 44, no. 3, pp. 249-251, 2005.

[6] C. Sabah, F. Dincer, M. Karaaslan, E. Unal, and O. Akgol, "Polarization-insensitive FSS-based perfect metamaterial absorbers for GHz and THz frequencies," *Radio Science*, vol. 49, no. 4, pp. 306-314, 2014.