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A Flower Shaped Frequency Selective Surface for WLAN Screening Applications

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Abstract: ***This communication presents a single flower shaped resonator frequency selective surface (FSS) unit cell with stable oblique angles of incidence for both horizontal and vertical polarizations. The proposed FSS structure which can impede the frequencies from 3GHz to 6GHz at 3dB insertion loss is presented. The proposed FSS comprise an improved decagon to form a flower-shaped structure that exhibits single narrow stop band characteristics. The flower shaped FSS acts like a band-stop filter with center frequency of 4.8 GHz and notch band frequency ranging from 4.2GHz to 5.3GHz at 10dB insertion loss and 320MHz bandwidth at 20dB insertion loss. The designed FSS can use for shielding of public safety WLAN frequency. We present the equivalent circuit model and the surface current distribution to illustrate the resonance characteristics of the miniaturized FSS. To validate the design and simulation results, the proposed FSS is fabricated and tested in a semi-anechoic chamber***

Keywords: ***Frequency selective surfaces, band stop, WLAN frequency.***

I. INTRODUCTION

Frequency selective surfaces consider in extensive applications because of their frequency selectivity, polarization independency and angular stability properties [1, 2]. We have used them as a band pass or band-stop filters depending on their patch or aperture type unit cells [3, 4]. We have used them in renowned applications such as antenna reflectors, absorber's, and superstrate to the antennas and for mobile communication, indoor communication, and wireless security applications and so on. FSS's has designed as two-dimensional periodic structures [2-4] or as three dimensional periodic structures [5]. Depending on the application these structures may be a single layer, multi-layer or cascaded layers. A latest systematic structure investigated that adding printed resonating lines in perpendicular to the polarization of the incidence achieve a multi narrow band response [6].

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Recently most of the literatures have concentrated on several bands [7]. Most recent work by [8] and [9] added several resonators in a symmetric manner to get the required number of bands with miniaturized output are presented.

We present an summary of literature that relates to work presented here the miniaturized band stop FSS got by using conventional cross changed into Bionic structure [10], crossed dipole into swastika shaped [11], cross dipole and circular apertures [12] for WLAN and GSM shielding applications, Minkowski island fractal [13], integrated square ring cross dipole patch with band pass and band reject characteristics with symmetric and asymmetric structures proposed where, for TM polarization structure acts like a band-reject filter [14], and convoluted interwoven structures [15] to get the desired stop band frequency response characteristics. However, as discussed in the literature, the convoluted interwoven structure is complicated to design, and it is time taking process but the reduction frequency is off around 1.9GHz.

The miniaturized single narrow band frequency selective surfaces required for reduction of harmonics without disturbing the other stop bands. These are the stable characteristics an ideal narrow band filter **design** should fulfill. This proposed structure has simple to design, which acquired from the conventional decagon resonating at 6.7GHz reduced to 4.8GHz.

This paper covers a flower-shaped resonator structure resonating at 4.8GHz with narrow bandwidth ranges from 4.2GHz to 5.3GHz which can be useful for the shielding of public safety WLAN 4.9GHz (802.11y) frequency . Using a single flower resonator unit cell with miniaturized dimensions, which is stable for all oblique angles of incidence for both TE and TM polarizations presented. An advantage of this structure is that the unit cell size is miniaturized which is less than $\lambda/6$ (0.1632λ) where λ is the free-space wavelength corresponding to the center frequency. This structure is too efficient for narrow band single frequency applications with miniaturized design. We can use this proposed design as a reflector sheet to improve the antenna bandwidth and as a superstrate to enhance the gain of the antenna.

II. UNIT CELL STRUCTURE AND ITS EQUIVALENT CIRCUIT MODEL

The flower shaped periodic metallic pattern frequency selective surface printed on one side of dielectric substrate. The proposed design also satisfies the condition of

$P < \frac{\lambda}{1+\sin\theta}$ Where λ is the wavelength of the proposed design, 'p' is the periodic unit cell dimension of the proposed FSS [1].

The flower-shaped pattern got by changing decagon (stages from 1 to 6) and subtracting 2.239 mm radius of a circle from stage 7 from the decagon to achieve single resonant path with highly stable characteristics.

Fig (1) and Fig (2) shows the unit cell development procedure stages and the geometry of the structure. For the unit cell frequency selective structure configuration commercially available dielectric substrate FR4 of thickness 1.6mm with the dielectric constant of 4.4 and the loss tangent value of 0.025 is used. The optimized dimensions of the FSS structure are P=10.2mm, g=0.2mm and w=0.2mm. The decagon used for outer side radius is of 1mm and inner side radius is 0.8mm which forms the width of each segment to be 0.2mm.The proposed structure has also been verified with equivalent circuit model as shown in Fig3.

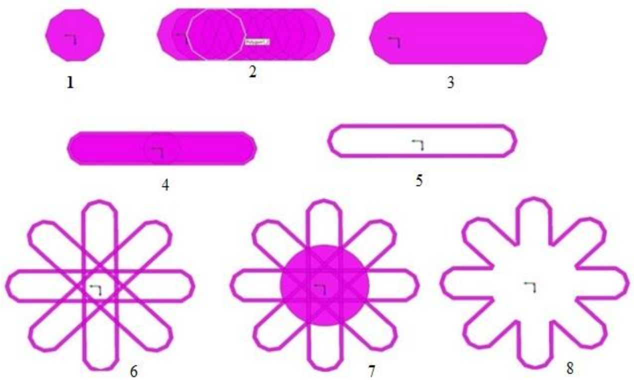


Fig 1:.Development stages of the proposed FSS structure.

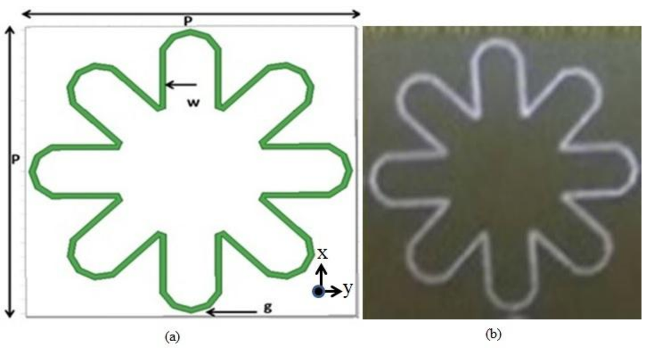


Fig 2: Unit cell of the proposed FSS structure (a) Geometry and (b) Prototype

The inductance and capacitance values obtained from [16]. The series combination of inductance L and capacitance C represents the metallic layer equivalent inductance and capacitance values. The equivalent values of inductance and capacitances are obtained as L=7nH and C=0.155pF.Fig 4 compares the full wave and equivalent circuit model output using HFSS and ADS software results.

The dielectric substrate of the proposed design is represented by an equivalent transmission line having a length of h=1.6mm with a characteristics impedance $Z_l=\frac{Z_0}{\sqrt{\varepsilon_r}}$ where Z_0 is the free space impedance. The proposed equivalent circuit is also satisfying the condition of $\frac{p(1+\sin\theta)}{\lambda} < 1$ for angle of incidence and wave length [16].

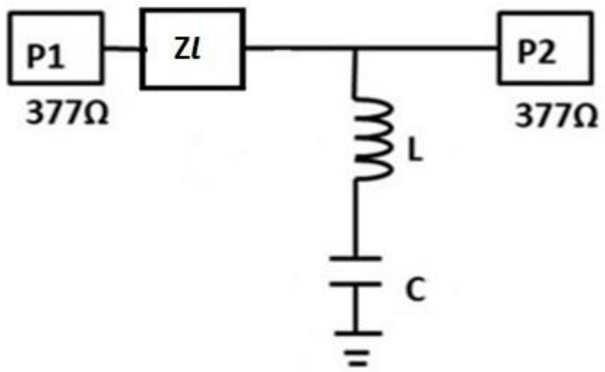


Fig 3: Equivalent circuit model of the proposed FSS.

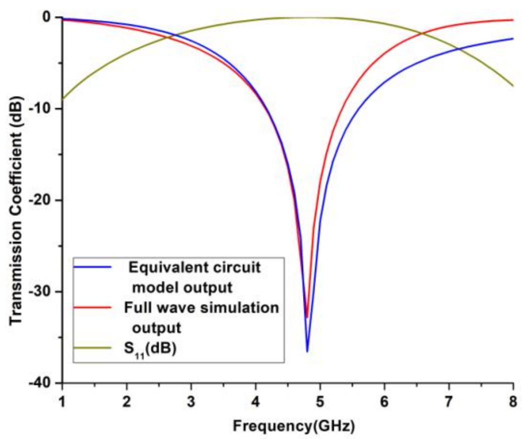
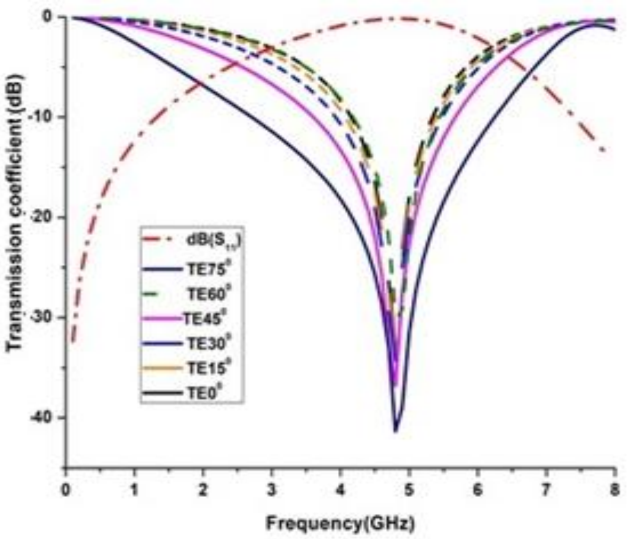


Fig 4: Comparison between ADS and HFSS results..

III. SIMULATION RESULTS DISCUSSION

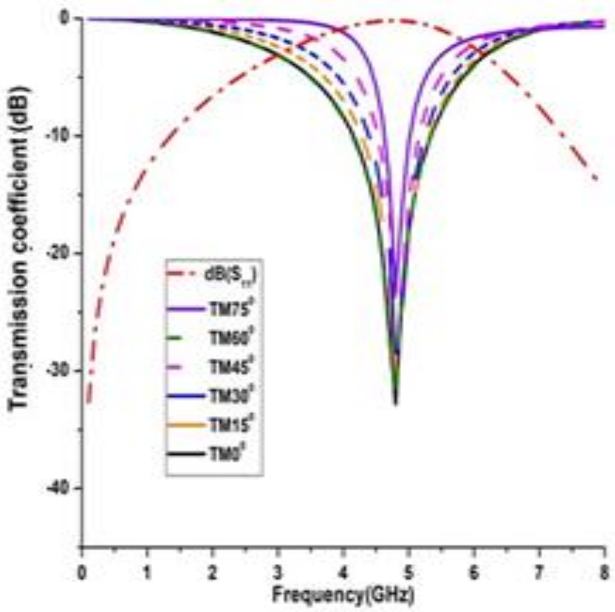
The S parameters got by using Ansoft HFSS simulator with periodic boundary conditions of master and slave with Floquet port excitation technique. When the incident wave is impinging on the metallic pattern, the proposed frequency selective structure exhibits single stop band characteristics at 4.8GHz with transmission coefficient of -32.86dB. The proposed design is symmetric for both vertical (TE) and horizontal (TM) polarizations for various angles of incidence. Fig 5(a) and (b) shows the angular stability performance of the proposed design for TE and TM polarization of incidence angles up to 75˚. The interesting point to observe is that, when an angle of incidence is increasing the transmission coefficient value is also increasing in vertical polarization whereas in horizontal polarization the transmission coefficient value reduces when the angle of incidence is increasing. We have also done the parametric analysis has also for different widths by changing the radius of decagon and circle. To make symmetry in the design, it is important to change the circle radius appropriately to get a stable performance. It is also important in this design that only outer radius of decagon has to vary to attain angular and polarization stability. The width of proposed design has an extensive effect on resonant frequency, angular and polarization stability.

The resonant frequency increases with the increase in the width and similarly it decreases with reducing the width of the layer. The structure also studied without circle subtraction (before stage 8) which is providing the two stop bands at 10.9GHz and 15.1GHz in TE mode and 8.9GHz and 14.5GHz TM mode which shows it is not frequency stable and angularly stable.



(a)

Fig 5(a): Angular stability performance of the proposed FSS structure (TE polarization).



(b)

Fig 5(b): Angular stability performance of the proposed FSS structure (TM polarization).

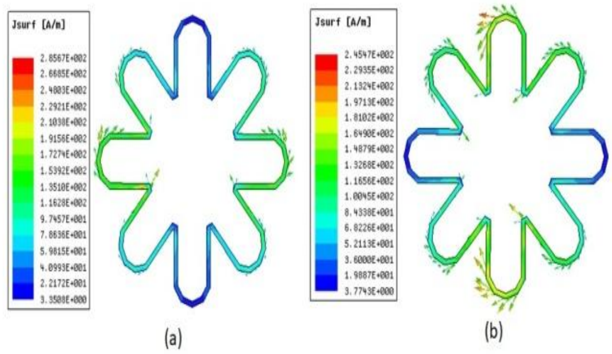


Fig 6: Surface current distribution at 4.8GHz (a) TE polarization and (b) TM polarization

To prove the resonance mechanism of the structure the surface current distribution of the proposed FSS structure at center frequency 4.8GHz illustrated in Fig. 6(a) and (b). The flower-shaped structure has 8 petals each with a width of 0.2mm. It observed from the surface current distribution that the 6 petals are contributing much in each polarization. We observe high surface current distribution in top and bottom petals for horizontal polarization and in side petals for vertical polarization. From the Figs 6(a) and (b) it observed that surface current distributed uniformly between petals and in each polarization it also changes the direction of current distribution. Also from the Fig we observe it that the width of outer radius has intense effect, and it shifts from lower to higher frequency when it increases.

IV. MEASUREMENT RESULTS

To validate the proposed FSS structure, a pro-type of the FSS fabricated and the proposed FSS contains an array of 24x24 elements with 250x250mm2 dimensions. Fig 7 shows the prototype of the proposed FSS structure. The measurement has carried out in a semi anechoic chamber using two horn antennas in two steps; one without FSS sheet the calibration has carried out, later the FSS placed in between the two horn antennas which are connected to network analyzer. We have shown the measurement fixture in Fig 8.

Fig 7:Fabricated FSS structure (24x24 unit cells).

Fig 8: Measurement set up of the proposed FSS structure.

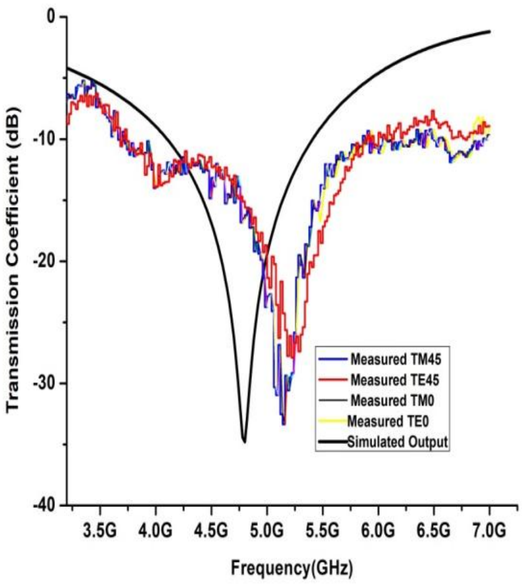


Fig 9: Measured results of the proposed FSS structure.

The measured results obtained using network analyzer in a semi-anechoic chamber shown in Fig.9. The proposed frequency selective structure exhibits single stop band characteristics at 5.12GHz with high transmission coefficient value. We observe a slight variation in resonant frequency while measuring which is due to the lossy nature of FR4 and fabrication tolerances. But we can observe that the bandwidth is in the permissible range with the simulated ones.

As, a final point, the comparison between the previous single band structures has shown in Table I, to validate the proposed FSS structure.

Table- I: Comparision with earlier single band FSS's

Ref no	FSS structure/ Resonating frequency(GHz)	Angular stability	Unit cell size/Bandwidth
10	Bionic/3.9	Up to 60˚˚	11x11mm^2/NA
11	Swastika/5	up to 60˚	7x7mm^2/400MHz (-20dB)
12	Crossed dipole with circular aperture/1.820	up to 45˚	63x63mm^2/ 1330MHz (-20dB)
13	Minkowski Island Fractal/9	NA	15.2x15.2mm^2/ 670MHz (- 10dB)
14	Integrated square ring and cross dipole patch/10.5	NA	15x15mm^{2}NA
15	Interwoven convoluted element/1.11	up to 60˚	7x7mm^2/NA
Proposed	Flower shaped/4.8	up to 75˚	10.2x10.2mm^2/ 320MHz (- 20dB)

V. CONCLUSION

We study a single narrow stop band FSS based on flower shaped design for 4.2GHz to 5.3GHz band. The proposed structure is greatly stable for all angles of incidence at the single narrow band frequency for both TE and TM polarizations. The structure has simple to design. The measured result value shows that this design can useful for WLAN frequency screening. Further miniaturization acquired by incorporating the surface integrated waveguide technology and bandwidth can enhance by using double sided and multi-layer structures. This can be considered to be a significant structure for miniaturized single narrow band frequency applications for WLAN frequency screening.

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Vahida Shaik, was born in Guntur, Andhra Pradesh state, India. She received her MTech degree from Jawaharlal Technological University, Kakinada in 2013. From 2013 to 2016, she worked as an Assistant professor in engineering colleges in Hyderabad. Since 2016, she is pursuing a Ph.D. from the School of Electronics Engineering of the Vellore Institute of Technology, Vellore, and Tamil Nadu, India. Her research interests include the design of frequency selective surfaces for shielding applications and antenna systems. She has publications in international journal and conference proceedings.

Shambavi Krishnan, received her B.E degree in Electronics and Communication Engineering from Madras University in the year 1992 and M.E. degree from College of Engineering, Anna University in the year 1994. She started her teaching profession from 1994 onwards. In 2012, she received her PhD in development of UWB antennas from Vellore Institute of Technology. Her research interest includes antennas, RF and Microwave circuits, sensing system and mm-wave communication. She has published more than 75 papers in referred journals and international conference proceedings.