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Tapered Dual Plane Non-Uniform Electromagnetic Bandgap Filter Structures with Improved Pass-Band Performances

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Abstract: In this paper, two new methods for the designing of Electromagnetic band gap low pass filter and Electromagnetic band gap (EBG) band stop filter have been proposed. In this paper a low profile 2-D EBG low-pass filter with a U-shaped transmission line is designed. By adopting the U-shaped geometry of the microstrip line the low pass design achieves a large stop band with small in-band insertion loss and optimum large out-of-band attenuation loss with the improved pass band performances within a miniature circuit area and for the band stop filter it is observed that the filling factor plays a significant role in shaping the stop band bandwidth and lessening in pass band ripples. In this paper a comparative simulation between traditional uniform patterned EBGs designs and tapered EBGs structure has been discussed on the basis of chiefly Kaiser Distribution in association with filling factor control parameter. In order to reduce the ripple level in the pass band, EBG structure is accompanied with Kaiser Window tapering technique. The discussed structures offer new techniques to design an improved low profile micro strip low pass and band stop filter for various GHz circuits.

Keywords: Band stop filters, Electromagnetic Band gap (EBG), Filling Factor, Kaiser Window Distributions, Low Pass Filter, Ripples and Tapering Technique

I. INTRODUCTION

Periodic design that allows the flow of electromagnetic waves in a definite frequency band for certain polarisation trends and angles of incidence are known as electromagnetic band-gap (EBG) structures as in [1]. With the advancements in the field of artificial ground structures various terms have been adopted to categorize meta materials depending on their applications. EBG is an essential category of meta materials consists of ground planes that shows evidence of peculiar reflection features over the traditional Perfect Electric Conductor (PEC) as described in [1]. EBG structures have an extensive utilization as the substrate of high frequency GHz circuits as in [2] like wide-band planar antenna, band stop filter, amplifiers, reflectors, resonators patch antennas and power amplifiers to lessen the harmonics in order to improve their passband performances as described in [3], [4]. 2-D Electromagnetic Band gap design exhibits better compatibility with micro strip circuits which formulate them to work well as low pass filters and band stop filters as in [5],[6]. In this paper, an improved performance, low profile 2-D EBG design with a U-shaped microstrip line structure is proposed to work efficiently as low pass filter as obtained in [6]. In order to design EBG structure to work as a band stop filter the periodic basics like holes are impressed in the lower ground along with non uniform modulated patch line at a upper face of dielectric material. The design output of EBG resources can be enhanced with the right choice of tapering window such as Kaiser Window coefficient in association with filling factor control. In this paper, EBG structures in the form of non uniform Kaiser tapered patterns are designed in order to observe any improvement over the conventional uniform circular-patterned EBGs. The main aim of this work is to design filters with a large stop band with small in-band insertion loss and optimum large out-of-band attenuation loss with the improved pass band performances within a miniature circuit area. Kaiser window coefficients-as applied to antenna assembly are adopted to taper the radius of the etched hole patterned EBG units on the ground surface. While the traditional uniform design of the circular-patterned EBG suffers high pass band ripples in close proximity to the cut off frequency, the dual tapered non uniform EBGs structures in association with filling factor control is adopted in the forms of 2-D Kaiser tapered designs which leads to better performances by lessening pass band ripples and producing separate broad stop band in low pass filter and band stop filter respectively. In this paper it is also observed that EBG microstrip low-pass filters, structure achieves a significant reduction in physical size in comparison to EBG band stop filter physical size.

II. THEORY OF 2-D ELECTROMAGNETIC BANDGAP MICROSTRIPLINE FILTER STRUCTURES

A. Designing of Uniform Dual Plane U-Shaped Microstrip Line Low Pass Filter Structure

A uniform dual lane EBG low pass filter structure is formed by etching holes in the ground plane and a U-shaped microstrip line structure, this U shaped microstrip line is in an additional plane separated by a dielectric material of dielectric constant (ϵ_r) 2.45 and height (h) 0.8 mm as shown in Fig. 1. The ground plane is created by etching holes with radius 'R' altering correspondingly

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with the filling factor 'R/d' where'd' is the period of occurrence of etched circle in the ground plane . The period'd' of the structure is defined by the distance between the centres of two neighbouring etched holes in the ground plane. The proposed 2-D U shaped microstrip line low pass EBG filter structure in Fig.1. follows the following Bragg reflection condition as in [7], given by the following equation

$$\beta \cdot d = \pi \quad (1)$$

where β is the guided wave number.

λ_g guided wavelength given by

$$\lambda_g = \frac{c}{f_o\sqrt{\epsilon_{eff}}} \quad (2)$$

where f_0 is the center frequency of the bandgap, c is the velocity of light in vaccum and ϵ_{eff} is the effective permittivity of the dielectric substance [8].

$$\epsilon_{eff} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2\sqrt{1+\frac{12h}{w}}} \quad (3)$$

The period equals half the guided wave length:

$$d = \frac{\lambda_g}{2} \quad (4)$$

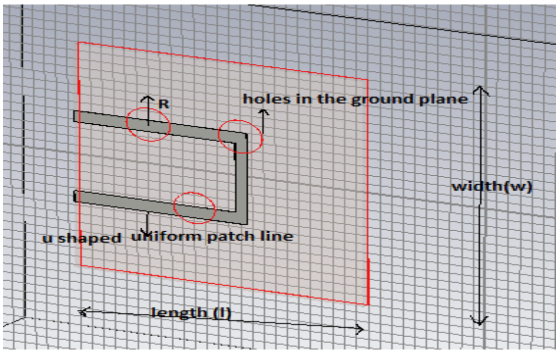

Fig. 1. Uniform dual plane EBG Low Pass Filter Structure

TABLE – I. SPECIFICATION OF UNIFORM DUAL PLANE EBG LOW PASS FILTER STRUCTURE

Filling factor(F)	Radius (R) of etched holes in the ground(mm)	Circuit size (l*w)(mm)
.20	1.96	30*26

B. Designing of Uniform Dual Plane EBG Band Stop Filter Structure

A microstrip line with an arrangement of patches etched in the ground plane shows a major stop band the conduction along the transmission line [9], Several techniques have been adopted to enhance the stop band performance. In order to make EBG to work as a band stop filter, different designs have been proposed like single plane EBG structure which consists of either of etched circles in the ground plane or patch line at the upper face of the substrate this single plane EBG band stop filter structure shows better results than conventional band stop filter but at a cost of large circuit size and cost hence in order to overcome the drawback of single plane EBG structure we combine the two single plane to design dual plane EBG band stop filter as shown in fig 2.

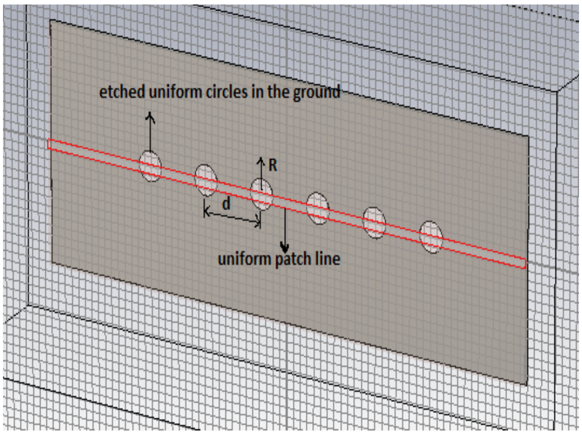

Fig. 2 Uniform dual plane EBG Band stop Filter Structure

For the uniform dual plane EBG band stop filter structure, the etched holes in the ground plane are of equal radius 'R' with a period of occurrence'd'. In uniform dual plane EBG band stop filter structure the ground plane is created by etching single line of circles with radius altering as per equation (5)

$$R = d.F$$

where'd' is the period of occurrence of the etched holes in the ground plane and 'F' is the filling factor given by

$$F = R/d$$

TABLE II. SPECIFICATION OF UNIFORM DUAL PLANE EBG BAND STOP FILTER STRUCTURE

Filling Factor (f)	Radius (R) of etched holes in the ground plane (mm)	Circuit size (l*w)(mm)
0.20	1.96	70*26

While simulation it has been observed that filling factor plays an important role in determining the stop bandwidth and stop band attenuation as in above filter structure the filling factor is 0.20 but as we keep on decreasing the filling factor we can come up with a new filter which works as an All Pass Filter for C and X band applications.

C. Designing Parameters of Dual Plane Non Uniform Kaiser Tapered Low Pass Filter Structure

Uniform 2-D low pass EBG filter structure as shown in Fig. 1 preludes a boost in the bandwidth with an elevated attenuation in the stop band at the expense of a high ripple level in the pass band therefore Kaiser window tapering approach in correspondence with their peculiar quality of filling factor control as shown in Fig 3. are to be applied to lessen the ripple level intensity in the pass band. In dual plane non uniform.

Kaiser tapered low pass structure the ground plane is created by etching holes with radius altering as in (7) and the modulated U shaped microstrip patch line is created by inserting square and rectangular patches of changing length and width.

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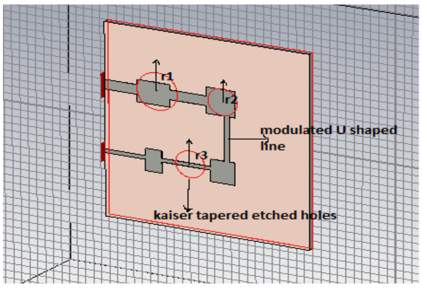

Fig. 3. Non Uniform dual plane Kaiser Tapered EBG Low Pass Filter Structure

$r_j = d.F.C(y_j)$

where $C(y_i)$ is the Kaiser Window Tapering Coefficient given as per Table III as provided in [5]:

TABLE III. TYPES OF TAPERING WINDOWS AND THEIR CORRESPONDING NORMALIZED COEFFICIENTS

Type of Tapering Window	Normalized Tapering coefficients		
	C(y1)	C(y2)	C(y3)
Kaiser	0.94	0.58	0.16
Barlett	0.82	0.46	0.09
Hanning	0.92	0.43	0.02
Cosine	0.96	0.66	0.14

TABLE IV. SPECIFICATIONS OF NON UNIFORM DUAL PLANE KAISER TAPERED EBG LOW PASS FILTER AND BAND STOP FILTER STRUCTURE

Filling factor (F)	Altering radius of etched holes in the ground		
	$r_{1(mm)}$	$r_{2(mm)}$	$r_{3(mm)}$
0.20	1.82	1.12	0.31

D. Designing Parameters of Dual Plane Non Uniform Kaiser Tapered Band stop Filter Structure

The design specification of band stop filter is similar to low pass filter structure, except of the arrangement of column of circles in the ground plane, moreover in band stop filter structure the U shaped microstrip line has been shaped differently as shown in Fig. 4.

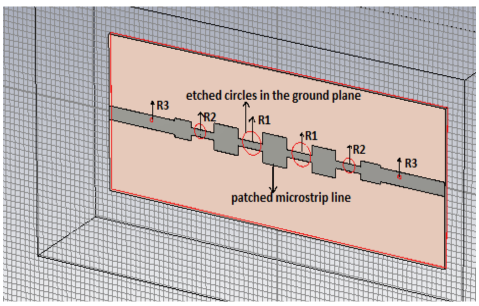

Fig .4. Non Uniform Dual Plane Kaiser Tapered EBG Band stop Filter Structure

This dual plane design shows an exceptional increase in the stop band width along with smooth pass band response. The ripple level in the passband decreases upto very few dBs by employing Kaiser window tapering technique. In dual plane non uniform Kaiser tapered band stop filter structure the ground plane is created by etching holes with radius altering as per (7) and the modulated microstrip patch line is created by inserting square and rectangular patches of changing length and width.

III. SIMULATED NUMERICAL RESULTS ANALYSIS

In order to confirm the above investigations and models as shown in Fig. 1 to Fig. 4. Some designs have been simulated on Computer simulation technology (CST) Microwave Studio (2010)Software. A straight forward dual plane Electromagnetic bandgap low pass and band stop filter arrangement is created by using ground plane and microstrip line in another plane separated by a dielectric material of dielectric constant (ϵ_r).

Optimized simulated numerical results analysis have been shown from Fig.5 to Fig.9 with EBG Filter features Tabulated as in Table V and Table VI, for dual plane Uniform and Kaiser tapered Non-Uniform dual plane EBG Microstrip Structures respectively

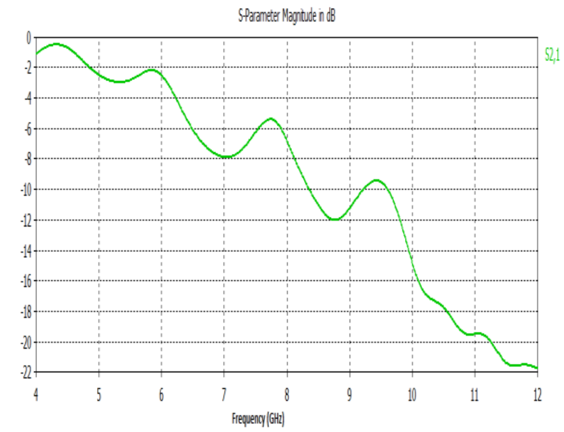

Fig.5. Simulated S21 parameter for Uniform dual plane EBG low pass filter structure

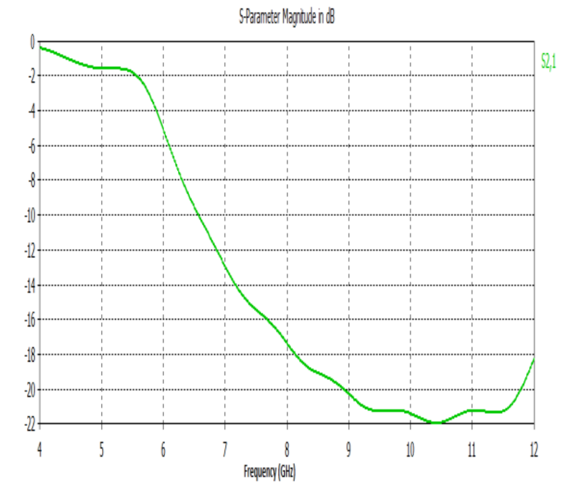

Fig.6. Simulated S21 parameter for non Uniform Kaiser tapered dual plane EBG low pass filter structure

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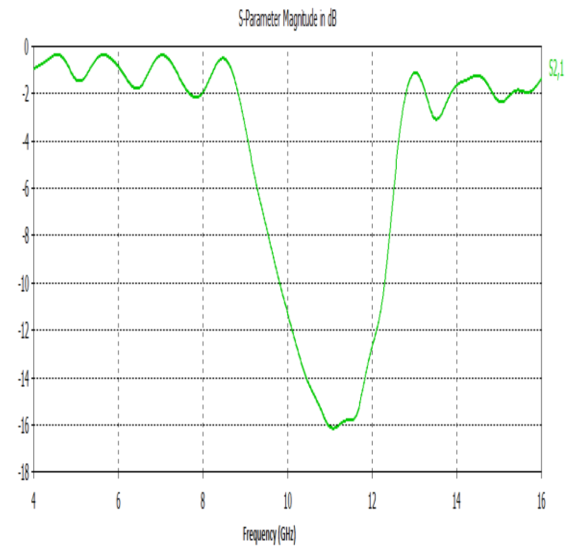

Fig.7. Simulated S21 parameter for Uniform dual plane EBG band stop filter structure

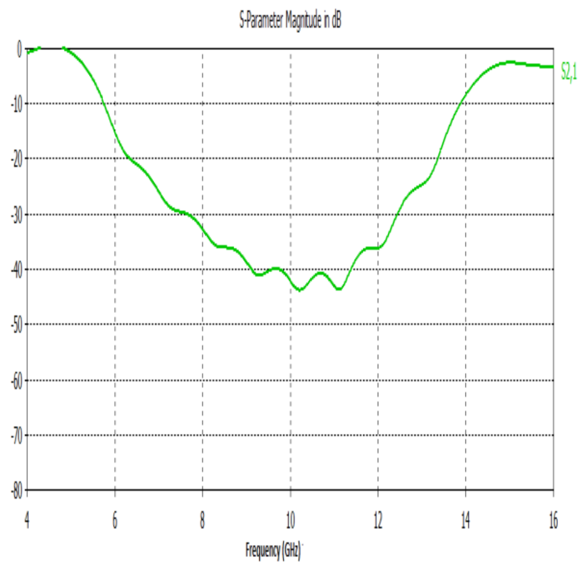

Fig.8. Simulated S21 parameter for non Uniform Kaiser tapered dual plane EBG band stop filter structure

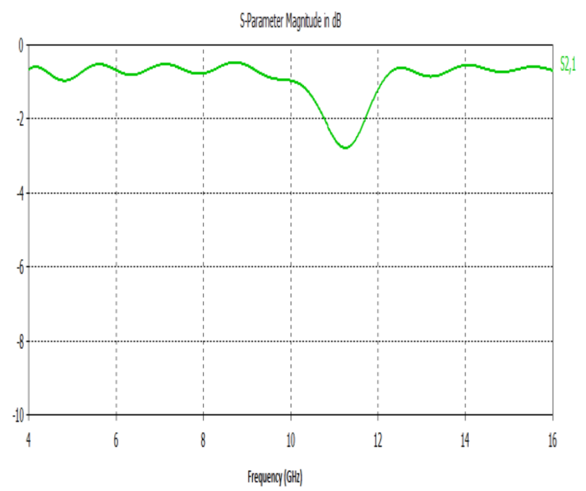

Fig.9. Simulated S21 parameter for Uniform dual plane EBG all pass filter structure with filling factor 0.12

TABLE I. NUMERICAL RESULTS OF UNIFORM DUAL PLANE EBG FILTER STRUCTURE

Filter type	Filling factor(F)	Passband Ripple Level (dB)	Stop band Attenuation (dB)	Bandwidth (GHz)
Lowpass	0.20	7.8~9.8	18	6~8
Band stop	0.20	1.4~3	11.8	3.2
All Pass	0.12	0.98~1	0.0	12

TABLE II. NUMERICAL RESULTS OF NON UNIFORM KAISER TAPERED DUAL PLANE EBG FILTER STRUCTURE

Filter type	Filling factor (F)	Passband Ripple Level (dB)	Stop band Attenuation (dB)	Band width (GHz)
Lowpass	.20	0.65~1.17	22	6~7
Band stop	.20	0.92~1	36	8

TABLE III. COMPARITIVE NUMERICAL ANALYSIS TO PREVIOUS WORK USING TAPERED DUAL PLANE EBG LOW PASS FILTER STRUCTURE

Low Pass Filter Parameters	Reference	
	[6]	Proposed Low Pass Filter Specification
Bandwidth (GHz)	3	6~7
Filling factor (R/d)	.25	.20
Cicuit size (mm*mm)	33*30	30*26
Ripple level in passband(dB)	0.20~.25	.54~.65
Tapering window	Chebyshev	Kaiser
Stop band attenuation (dB)	35	22

TABLE IV. COMPARATIVE NUMERICAL ANALYSIS TO PREVIOUS WORK USING TAPERED DUAL PLANE BAND STOP FILTER STRUCTURE

Band stop Filter parameters	Reference	
	[5]	Proposed Band stop Filter Specification
Stop Bandwidth (GHz)	4.87	8
Filling factor(R/d)	.25	.20
Cicuit size (mm*mm)	70*26	70*26
Ripple level in lower passband (dB)	.51	0.42~.52
Tapering window	Chebyshev	Kaiser
Ripple level in upper passband (dB)	5.47	3~4
Stop band attenuation (dB)	52	45~46

IV. CONCLUSION

In this paper, the design and implementation of two EBG filters has been proposed with an improved performance low profile structure . A low pass filter has been designed with a U-shaped microstrip line. Due to the dual planar and U-shaped design of the modulated microstrip line, this projected EBG low pass filter structure exhibits prominent passband performances than single plane EBG structure Similarly the design and simulation of dual plane EBG microstrip band stop filter structures has been presented. The proposed band stop filter structure gives wide bandwidth of 8 GHz in association with filling factor of 0.20 and gives very large stop band attenuation of about 46dB in the stop band ,in both the filter designs the Kaiser window tapering technique has been adopted in order to improve the pass band performances like ripples level, bandwidth etc. For future aspects These simulated dual tapered EBG filter designs will be fabricated using PCB technology and for more specific practical analysis this fabricated design will be tested on Vector Network Analyser (VNA). These filter has its application in monolithic-microwave integrated circuit (MMIC) technology like in amplifiers, reflectors and in many more microwave frequency circuits applications.

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