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Microstrip Electromagnetic Bandgap Filter using a Poisson Tapering Window

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ABSTRACT: In this paper, a planar Electromagnetic Bandgap (EBG) microstrip filter is formed by etching circles in the ground plane and using a modulated microstrip line. These planar EBG structure configurations provide wide stopband with high attenuation but with ripples in the passband. To eliminate the ripples caused by the periodicity of EBG structure a variable Poisson distribution is used to taper components of the proposed structure. A comparison of EBG structure with variable $\alpha = 2$, 3 and 4 of Poisson distribution is done. It is found that the structure with $\alpha = 2$ provides the largest bandwidth of 6.2 GHz and stopband attenuation of 29.27 dB with reduced ripples in the lower and upper passband.

KEYWORDS: Electromagnetic Bandgap Structure, CST Microwave Studio, Modulated Microstrip Line, Poisson Distribution, Microstrip filter, Photonic Bandgap Structure, Tapering Function

I. INTRODUCTION

Filtering of undesired frequencies can be done using shunt stubs and stepped impedance lines in a microstrip structure, but these techiqued require large circuit area and spurious passband and stopband [1]. One possible way to reject a band of frequencies is use Electromagnetic Bandgap Structures [2]-[4].
The electromagnetic bandgap (EBG) structure has been a widely accepted term for artificial periodic structure. These periodic structures exhibit the rejection of band of frequencies in millimeter and microwave range. The 3-D periodic structures at optical frequency are known as Photonic Bandgap Structures [1], [2].
They can be applied to the substrate of microwave circuits such as patch antennas to improve performance [3], [4] or as planar EBG structure [5] by etching patterns in the ground plane. Planar EBG structures are widely used because of their prominent stopband characteristics and ease of fabrication.
The main aim of this work is to design a filter with wide stopband with reduced ripples in the passband. In this paper, EBG based Microstrip Filter Structure is formed by etching circles in the ground plane and using a modulated microstrip line. Poisson Window Distribution is used to reduce the ripples caused by the periodicity of EBG structure. The proposed structure improves the stopband and passband performance. The structure is designed and simulated using CST Microwave Sudio [6].

II. EBG BASED MICROSTRIP FILTER STRUCTURE

A simple Dual-Plane Electromagnetic Bandgap Structure is formed by using defected ground plane and a modulated microstrip line in another plane separated by a substrate of dielectric constant (ϵ_r) 3.48 and height 0.762mm as shown in Fig 1. The defected ground plane is formed by etching single column of circles with uniform dimension and the modulated microstrip line is formed by inserting the square patches of length l_a and w_a of 5mm in the microstrip line of width (w) 2.29mm.

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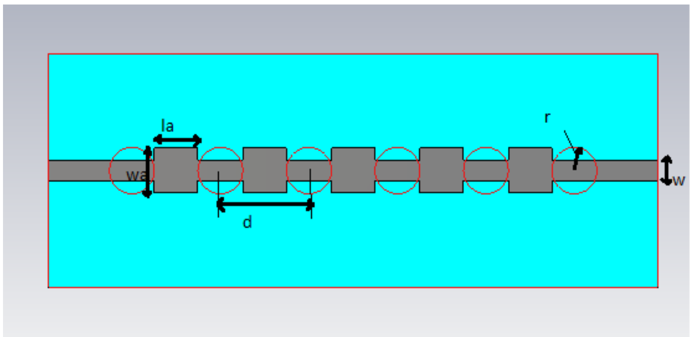

Fig.1.(a). Top view of EBG based microstrip filter structure

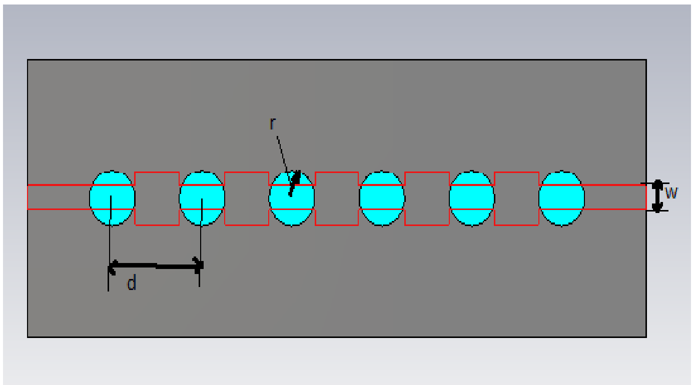

Fig.1.(b). Bottom view of EBG based microstrip structure

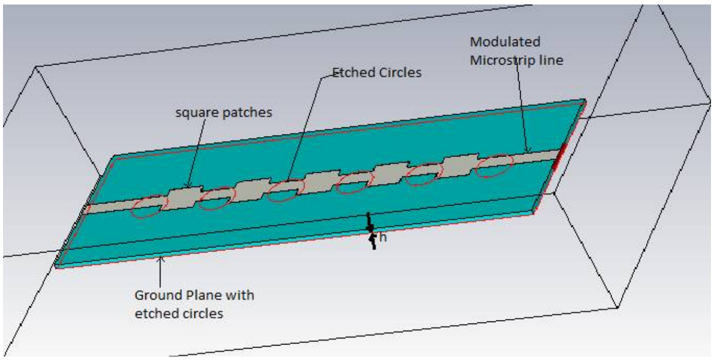

Fig.1.(c). Side view of EBG based microstrip filter syructure

The microstrip line feed used is of 50Ω. It is designed for a frequency of 10GHz and is analyzed using CST Microwave Studio Software. The period of the structure d is defined by the distance between the centers of two adjacent circles. According to Bragg reflection condition, the period [7] is given by:

$$\beta . d = \pi \qquad (1)$$

where β is the guided wave number.
The guided wave number λ_g is given by:

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$$\lambda_g = \frac{c}{f_0\sqrt{\epsilon_{eff}}} \quad (2)$$

where $f_o$is the center frequency of the stopband, c is the speed of light in free space and$\epsilon_{eff}$is the effective permittivity [8] of the substrate material.

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

The period equals half the guided wavelength:

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

A single column of n circles are etched in the ground plane, however in this paper we have designed the structure for n = 6. The radius of the circle is uniform. The ratio of r and d is called filling factor which is used to indicate the relative size of EBG cell to the period of the structure. For no overlap between any circles it ranges from 0 to 0.5. For a compromise between the stopband and pasband the optimum value is 0.25 [9]. Using the 0.25 filling factor the radius of the circles is found to be 2.24 mm.
This structure provide the wide bandwidth of 7.79 GHz as shown in Fig 2(a) and stopband attenuation of 68.34 dB as shown in Fig 2(b) but the ripple level is 3.16 dB in the lower and 8.18 dB in the upper passband which is quite high.

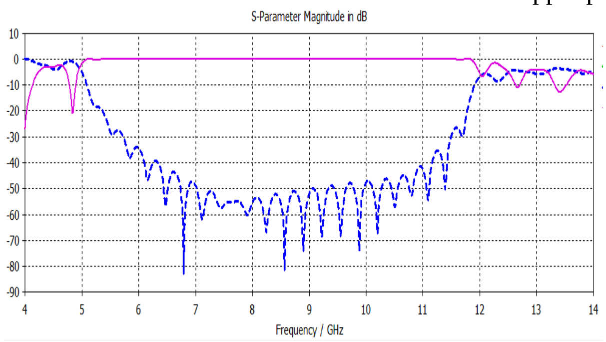

Fig.2.- S-parameter of EBG based Microstrip Filter Structure [S_{11} (solid line) and S_{21} (dotted line)]

The ripples in the passband are caused by the periodicity of the EBG structure. Various techniques were adopted to eliminate the ripples in passband such as Hamming, Hanning, Blackmann and Kaiser [10]. In this paper, we have used poisson window to taper the dimensions of etched circles[11]. It results in corresponding radius r_1, r_2 and r_3.

$$T(x) = \exp\left(-\alpha\frac{x}{a}\right) \quad (6)$$

Table1- Parameter of proposed Filter Structure

Poisson Distribution	α = 2	α = 3	α = 4
r_1	1.87	1.7	1.55
r_2	1.29	0.98	0.75
r_3	0.9	0.57	0.36

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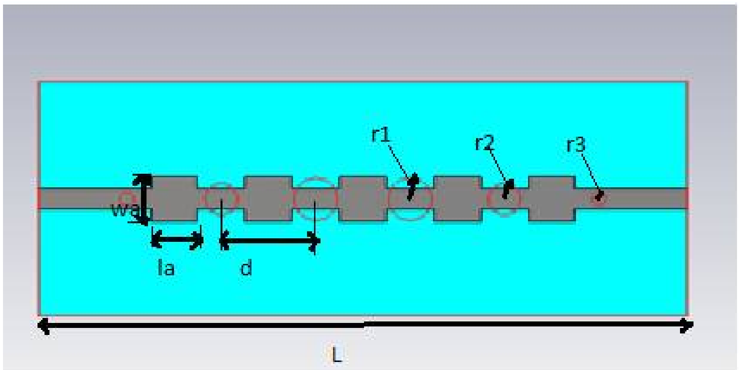

Fig.3.- Schematic of Tapered EBG based Microstrip Filter Structure

III. SIMULATED RESULT

The return loss S_{11} and insertion loss S_{21} parameters for the designed structure were calculated and the simulated results are shown in Fig.4. The bandwidth is 6.2 GHz for α = 2 with the corresponding value of stopband attenuation of 29.27 dB. This structure shows the highest bandwidth and attenuation with lower ripples in the passband. The bandwidth and attenuation for α = 3 are 5.8 GHz and 23.85 dB and for α = 4 are 5.53 GHz and 21.93 dB.

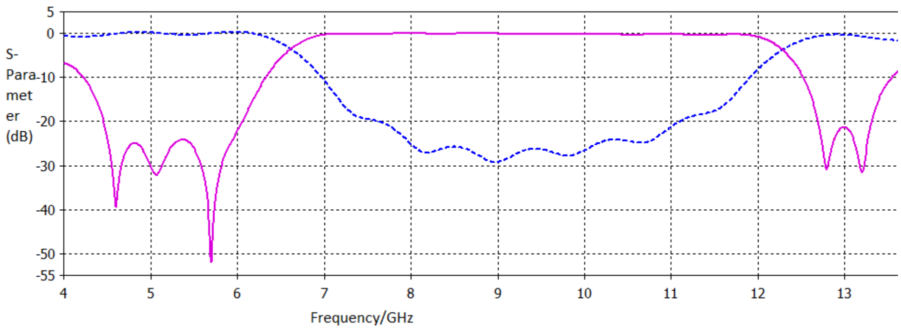

Fig.4.(a) S-parameter for α = 2 [S_{11} (solid line) and S_{21} (dotted line)]

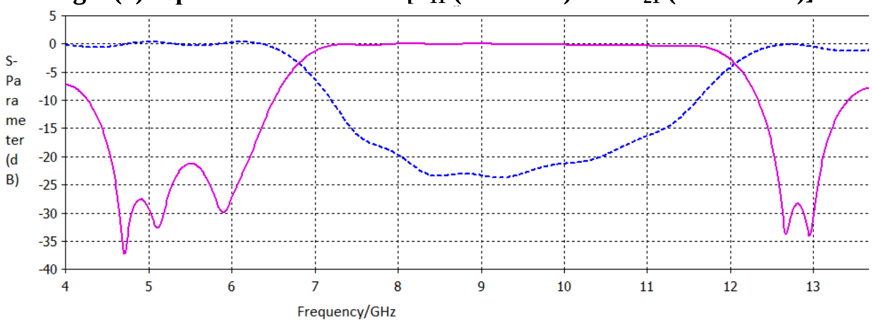

Fig.4.(b)- S-parameter for α = 3[S_{11} (solid line) and S_{21} (dotted line)]

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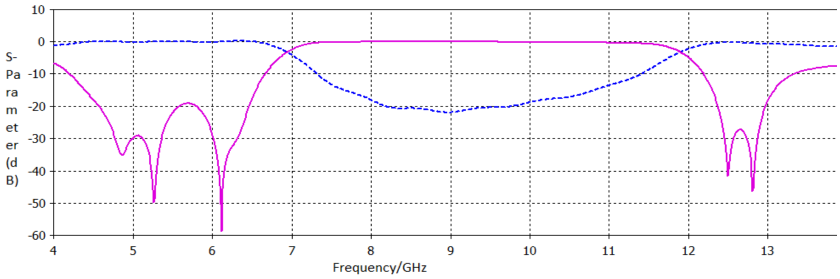

Fig.4.(c)- S-parameter for α =4[S_{11} (solid line) and S_{21} (dotted line)]

Table 2- Comparison of EBG Microstrip Filter with Poisson Distribution

Poisson Distribution	Bandwidth(GHz)	Stopband Attenuation(dB)	SLL	
			Lower Ripples(dB)	Upper Ripples(dB)
α = 2	6.2	29.27	0.34	1.5
α = 3	5.8	23.85	0.39	1.34
α = 4	5.5	21.93	0.39	1.66

IV. CONCLUSION

In this paper, the design of an EBG based microstrip filter structure has been presented. Due to the modulated microstrip line and the dual-plane arrangement of EBG structures, the proposed structure obtains excellent stopband performance but the ripple level is large.

The proposed structure shows the application of Poisson tapering window to the periodic pattern etched in the ground plane of the structure provides appreciable performance improvement reducing the ripples in the passband. The comparison shows the structure with α = 2 show the largest bandwidth and attenuation with lower ripples in the passband. The proposed filter structure is easy to fabricate and is able to achieve superior passband and stopband characteristics.

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