Study of Various EBG Based Micro strip Filter Structures

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Abstract: In this paper, a planar EBG based microstrip filter structure is formed by etching circles in the ground plane and using a modulated microstrip line. These planar EBG microstrip structure provides a wide stopband with high attenuation with high ripples in the passband due periodicity of EBG structure. Windows are used to eliminate the ripples in the passband caused by the periodicity. The coefficients of window distribution function are used for determining the radius of the circles etched in the ground plane. In this paper, a comparison of planar EBG microstrip filter structure using fixed window distribution is done. A comparison of effect of different window distribution on passband and stopband performance is presented. It is found that the Riesz distribution gives the largest bandwidth of 7.18GHz with maximum stopband attenuation of 50dB but with large ripples in the passband while the Poisson distribution gives small ripples in both the lower and upper passband but with smallest bandwidth of 4.77GHz and stopband attenuation of 27.68dB.

Keywords- Electromagnetic Bandgap Structure, CST Microwave Studio, Modulated Microstrip Line, Photonic Bandgap Structure, Tapering Function

I. INTRODUCTION

Filtering of undesired frequencies can be done by using shunt stubs and stepped impedance lines. This technique is typically narrow band and requires large circuit area [1]. One possible way to reject a band of frequencies is to use Electromagnetic Bandgap Structure [2].

Electromagnetic Bandgap Structure is a term that is widely used now-a-days for artificial periodic structures that prohibit the propagation of electromagnetic waves at microwave and millimeter wave frequency. The 3-D periodic structures at Optical frequency are known as photonic bandgap structures [3].

EBG structures can be applied as a substrate of patch antennas to suppress the surface wave excitation [4] or as planar EBG structure by etching periodic patterns in the ground plane [5]. The planar EBG structures have the advantage of ease of fabrication and are capable of controlling the propagation of wave. These structures are compatible with microstrip structure thus making them attractive as microstrip filters.

The main aim of this work is to design a filter with wide stopband and 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. Study of various Window distributions is presented for use on EBG structures. Window distributions are applied to improve the passband and stopband performance and a comparison of effect of different fixed window distribution on the structure is presented.

II. EBG BASED MICROSTRIP FILTER STRUCTURE

A simple Dual-Plane Electromagnetic Bandgap Structure (DP-EBG) filter 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) 2.45 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 square patches of length l_a and width w_a of 5mm in the microstrip line of width (w) 2.29mm.

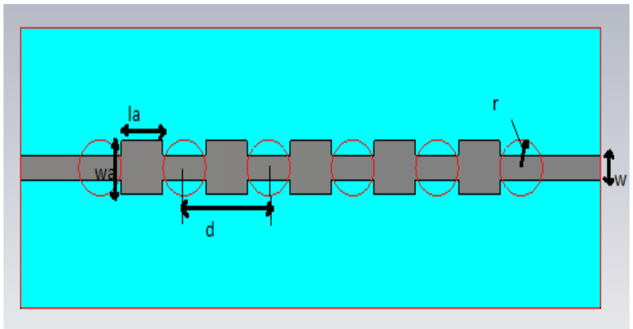

Fig.1(a) Schematic of EBG based Microstrip Filter Structure (Top View)

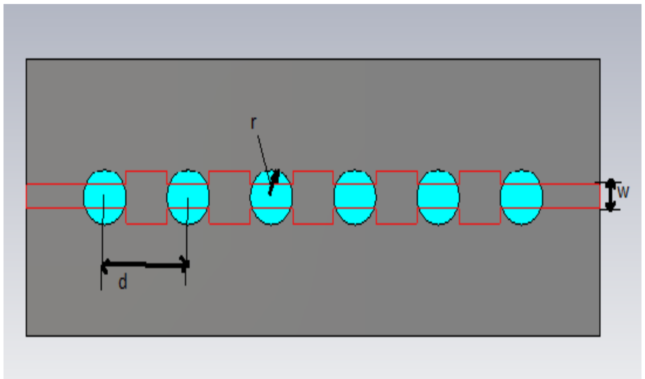

Fig. 1(b) Schematic of EBG based Microstrip Filter Structure (Bottom View)

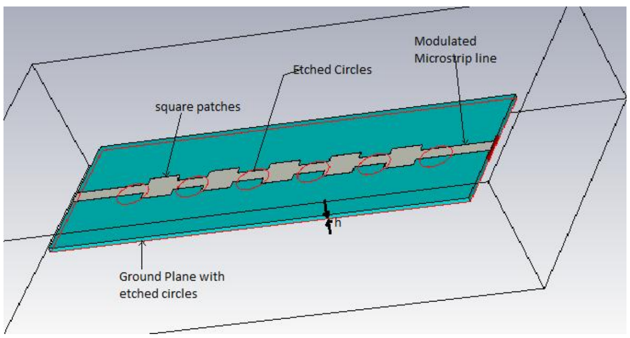

Fig. 1(c) Schematic of EBG base Microstrip Filter Structure (Side View)

The period of the structure d is defined by the distance between the centers of two adjacent circles. According to Bragg reflection condition [6], the period is given by:

$$\beta.d = \pi , \quad (1)$$

where β is the guided wavenumber.

The guided wavenumber λ_g is:

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

where f_0 is the center frequency of the stopband, c is the speed of light in free space and ϵ_{eff} is the effective permittivity of the substrate material [7].

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

The period equals half the guided wave length:

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

A single column of n circles are etched in the ground plane, however, in this paper we have designed the structure with n = 6. The radius (r) of the circle is uniform. The ratio of r and d is called filling factor which 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. The optimum value of r/d is found to be 0.25 [8]. Using the 0.25 filling factor the radius of the circles in the ground is found to be 2.59mm.

The large Bandwidth of 7.86GHz is obtained from the S_{11} parameter as shown in Fig2 (a) and the large stopband attenuation of 78dB is obtained from the S_{21} shows in Fig. 2(b) for the EBG based microstrip filter structure. The proposed structure provides the ripple level of 4.18dB in the lower passband and 7.86dB in the upper passband which is quite high.

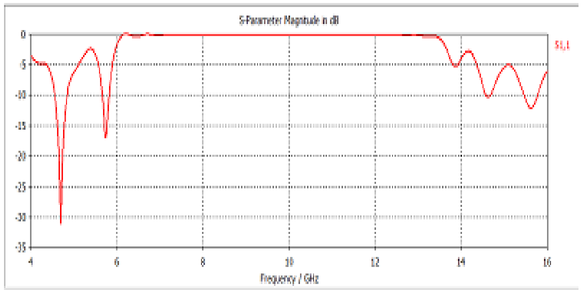

Fig. 2(a) Simulated S_{11} parameter of EBG based Microstrip Filter Structure

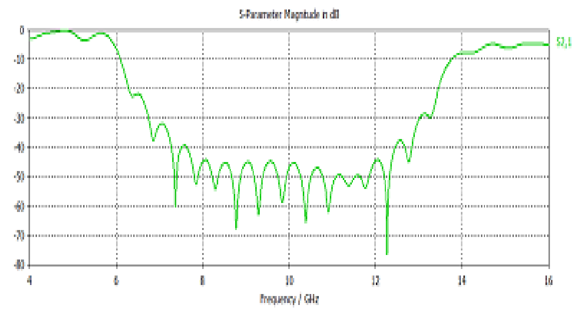

Fig. 2(b) Simulated S_{21} parameter of EBG based Microstrip Filter Structure

The ripples in the passband are caused by the periodicity of the EBG structure. Various techniques are used to reduce the ripples such as Chebyshev array, binomial array [9] and Taylor array. In this paper, we have used different Window distribution functions to taper the dimensions of the etched circles. There by for changing the radius of the circles following relationship is used:

$$r_i = r_c.T(x_i)\,, \qquad (5)$$

where i is an integer ranging from 1 to n/2 when n is even and from 1 to (n+1)/2 when n is odd number. r_i is the radius of the i^th circle and r_c is the radius of the center circle. T(x) is the tapering function and x is given as:

$$x_i = \frac{2a_i}{L}\,, \qquad (6)$$

where a_i is the distance between the center of the i^th circle and the center of microstrip line and L is the total length of the structure.

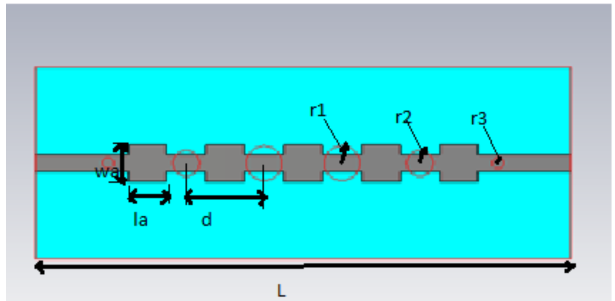

Fig. 3 Schematic of EBG based Microstrip Filter with Tapered Circles

Table1 shows different window distributions adopted to taper the radius of etched circles. It results in corresponding radius r1, r2 and r3.

TABLEI
PARAMETER OF PROPOSED FILTER

Window Distrib-ution	T(x)	r1	r2	r3
Triangular	$1-\frac{x}{a}$	2.34	1.75	0.78
Hanning	$0.5+\ 0.5Cos(\frac{x\pi}{a})$	2.48	1.69	0.36
Hamming	$0.54 + 0.46\ Cos(\frac{x\pi}{a})$	2.49	1.79	0.82
Blackmann	$0.42+0.5Cos\left(\frac{x\pi}{a}\right) + 0.08Cos(\frac{2x\pi}{a})$	2.42	1.35	0.25
Poisson	$exp\left(-\frac{x}{a}\right)$	1.8	0.87	0.42
Riesz	$1-\lvert x/a\rvert^2$	2.54	2.17	1.07
Bohmann	$\left[1-\frac{x}{a}\right]Cos\left[\frac{x\pi}{a}\right] + \frac{1}{\pi}Sin\left[\frac{x\pi}{a}\right]$	2.39	1.45	0.128

III. SIMULATED RESULTS

The return loss and insertion loss S_{11} (solid line) and S_{21} (dotted line) parameters were calculated and the simulated results are shown in Fig 4(a)-4(h).

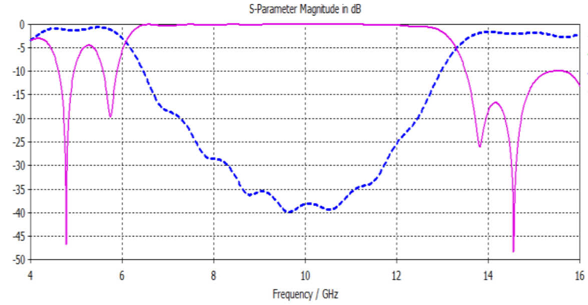

Fig. 4(a) Simulated S_{11} (solid line) and S_{21} (dotted line) for Triangular Window

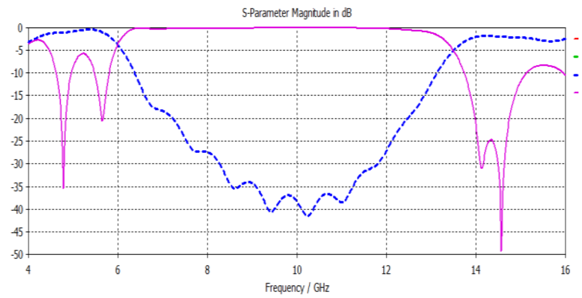

Fig. 4(b). Simulated S_{11}(solid line) and S_{21}(dotted line) for Hanning window

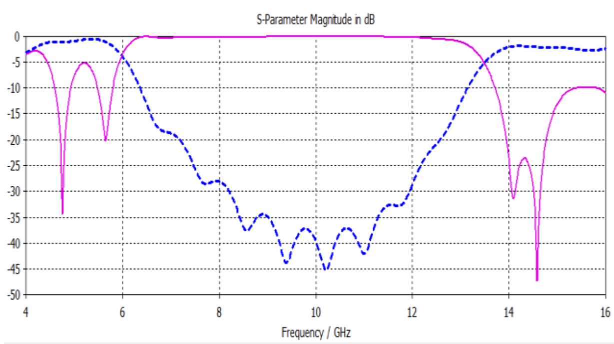

Fig. 4(c) Simulated S_{11} (solid line) and S_{21} (dotted line) for Hamming window

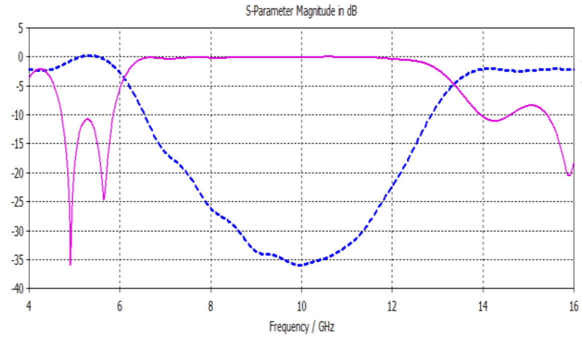

Fig. 4(d) Simulated S_{11} (solid line) and S_{21} (dotted line) for Blackmann window

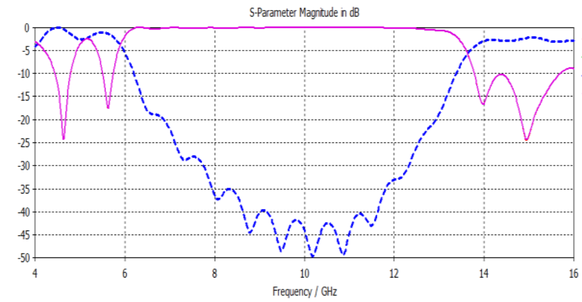

Fig. 4(e) Simulated S_{11} (solid line) and S_{21} (dotted line) for Riesz window

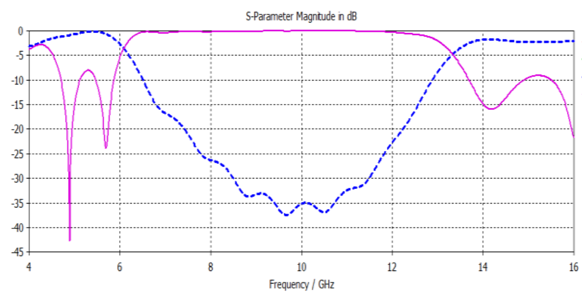

Fig. 4(f) Simulated S_{11} (solid line) and S_{21} (dotted line) for Bohman window

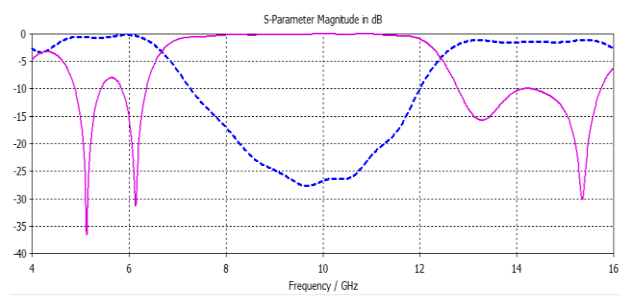

Fig. 4(g) Simulated S_{11} (solid line) and S_{21} (dotted line) for poisson window

TABLEII
COMPARISON OF EFFECT OF WINDOW DISTRIBUTIONS

Window Distrib-ution	Band-width (GHz)	Stopband Attenu-ation(dB)	Ripple Level	
			Lower	Upper
Triangular	6.5	40	1.81	2.23
Hanning	6.7	41.47	1.24	3.15
Hamming	6.8	45.2	1.1	2.9
Blackmann	6.35	35.9	2.4	2.7
Riesz	7.18	50	2.7	3.15
Bohmann	6.41	37.45	1.24	2.37
Poisson	4.77	27.68	0.9	1.7

In Table 2, the comparison of tapering functions is done which shows that the ripple in the passband of Poisson Window function is much reduced while the bandwidth is less. The Riesz tapering function has the highest bandwidth and attenuation, but with large ripple level in the passband.

IV. CONCLUSION

In this paper, the design of EBG based microstrip filter structure is presented. This structure provides a large bandwidth of 7.68dB and high attenuation but ripple level is 4.18dB in lower and 7.8dB in upper passband. The ripple level in the passband is tailored by adopting the window distributions. It is found that the Riesz distribution gives the largest stopband of 7.18dB and attenuation of 50dB and Poisson distribution gives the smallest ripples in both the lower and upper passband. The tapered EBG structure exhibit an excellent transmission in the passband. The proposed structure can be employed with other circuits to meet the requirements of passband and stopband performance.

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