Design of New Compact Photonic Band Gap Filter and Their Advantages

Pooja Sahoo and P. K. Singhal
Department of Electronics and communication Engineering, Madhav Institute of Technology and Science, Gwalior (M.P), India
Email: sahu.pooja2009@gmail.com

***Abstract*—In this paper it has been reported that the insertion loss is improving and return loss is maximizing due to the effect of photonic band gap structure. Using photonic band gap structure on the filter surfaces have been provided information about the increasing bandwidth up to 30% of band stop filters. To use of the PBG filters, the broad stop band has been obtained, slow wave factor increased, compensate for fabrication of tolerance has been improved and the unit elements of the band stop filter with open-circuited stub has been redundant and more compact configuration obtained.**

***Index Terms*—PBG (photonic band gap), band stop filter (BSF), printed circuit board (PCB), defected ground structure (DGS), computer simulation technology software (CST), spectrum analyzer**

I. Introduction

The photonic band-gap (PBG) [1] structures are effective in microwave applications that provide an effective control of electromagnetic (EM) waves along specific direction and performance. Photonic band gap structures for microstrip line have been topic of research in recent year. The term PBG is introduced as a structure which influence or even changes the electromagnetic properties of materials. The periodic structure created in materials such as substrate or metals [2]. Recently a Photonic band gap structure consisting of small metal pads with grounding via which used to improve the performance of a patch antenna [1], [2]. The PBG structure provides a certain frequency bands which cannot propagate. PBG structures are most widely used in various applications like microwave filters, antenna and other devices. The different structures LPF, BSF, power divider, power amplifier etc. may be implemented [3]. In addition to DGS (defected ground plane) [4] and EBG (electromagnetic band gap) structure, PBG have been created by etching different shapes in ground plane, which increase the inductance and capacitance values of microstrip line. The above technique used for eliminate undesired output response and sharp stop band for LPF [5], [6].

Dr. D'Orazio [1998] has been fabricated the PBG filter for wavelength division multiplexing (WDM) and Villar [1999] has been analyzed the PBG structure with a liquid crystal defect for the purpose of fiber optic filters.

The basic phenomena behind the proposed photonic band gap filter are forbidden gap in materials by electrons movement [7]. The most important function of PBG structures is the filtering of frequency bands [8], and harmonics of the filter in microwave circuit.

II. Band Stop Filter Design

Fig. 1(a) shows the schematic of proposed narrowband Bandstop filter with L-resonators. Five order microstrip bandstop filter in Chebyshev prototype with passband ripple of 0.1 db. The desired band-edge frequencies to equal-ripple points are f_1=4.5GHz and f_2=5.5GHz. Choosing Z_0=50ohm, g_0=1.1468, g_2=1.3712, g_3=1.9750, g_4=1.3712, g_5=1.1468, and g_6=1. Length of L-resonators l_h=8.9mm and l_v=8.9mm half guided wavelength Spacing of main line and resonators s_1=s_5=0.292mm, s_2=0.292mm, s_3=0.292mm and s_4=.292mm.

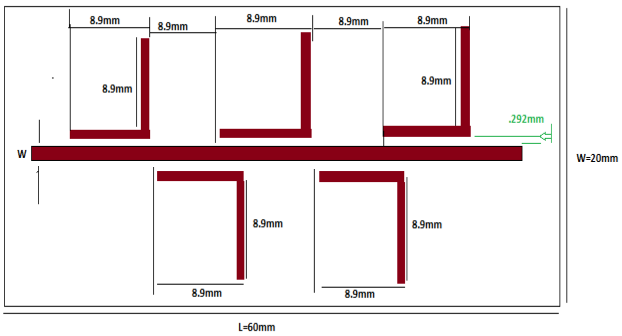

Figure 1(a). L-resonator narrowband Band stop filter

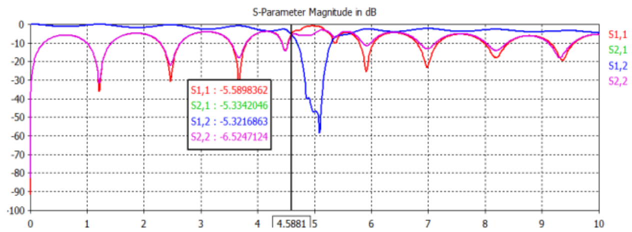

Figure 1(b). Response of L-resonator band stop filter

The response of L-resonator band stop filter shows in Fig. 1(b), provides very narrow bandwidth at 5GHz cutoff frequency.

Fig. 2(a) shows the schematic design of an optimum microstrip bandstop filter with three open-circuited stubs

Manuscript received December 23, 2013; revised May15, 2014.

doi: 10.12720/ijeee.3.2.84-88

and FBW=1.0 at a midband frequency f_0=2.5GHz. Now assuming a passband return loss of -20dB, which corresponds to a ripple constant ε=0.1005 and Choosing Z_0=50ohm. The optimum bandstop filter is synthesized using optimum transfer function.

Chebyshev functions of first kinds order n

$$Tn(x) = cos(n\,cos^{-1} x) \tag{1}$$

Chebyshev functions of second kinds order n

$$Un(x) = sin(n\,cos^{-1} x) \tag{2}$$

And calculation of parameters made by given equations

$$Z_a=Z_b=Z_0 \tag{3}$$

$$Z_i=Z_0/g_i \tag{4}$$

$$Z_{i,t+1}=Z_0/J_{i,t+1} \tag{5}$$

$$t = j\tan\left(\frac{\pi}{2}\frac{f}{f_0}\right) \tag{6}$$

Following Table I show technical parameters for designing of an optimum microstrip band stop filter.

TABLE I. PARAMETERS CALCULATION FOR FILTER DESIGN

Impedance (ohm)	Width(mm)	Length(mm)
Z_a=Z_b=50	1.85	5.475
Z_1=Z_2=52.74	1.7	14.32
Z_2=29.88	4.25	13.73
Z_{12}=Z_{23}=93.97	0.528	14.89

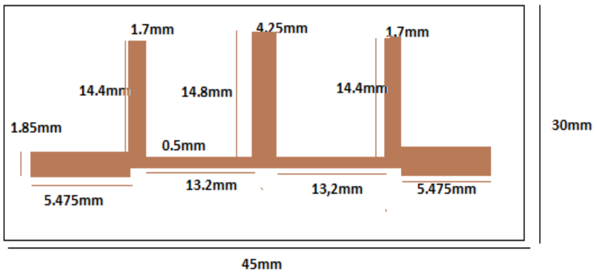

Figure 2(a). Optimum microstrip band stop filter

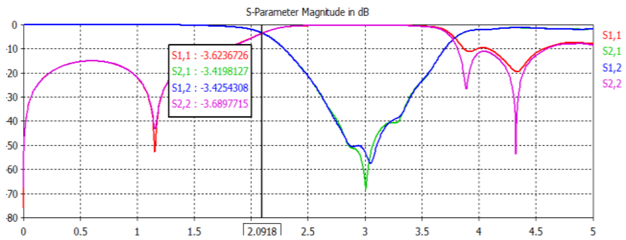

Figure 2(b). Response of optimum band stop filter

The microstrip filters have been designed on a substrate which has thickness of 1.6mm and a dielectric constant of 4.4. The open-end and T-junction effects should also be taken into account for determining the final filter dimensions. The optimum design demonstrates substantially improved performance with a steeper stopband response.

The response of optimum microstrip band stop filter shows wide bandwidth at 3GHz cutoff frequency which is greater than L-resonator BSF bandwidth.

Fig. 3(a) have been designed for improve the response of L-resonator band stop filter. It designed for a three order microstrip Band stop filter in Chebyshev prototype with Passband ripple of 0.05dB. The desired band-edge frequencies to equal ripple points are f_1=1.25GHz and f_2=3.75GHz and Z_0=50ohm.

Following Table II shows calculated value for chebyshev prototype band stop filter with open circuit stub. Equations for designing Band stop filter with open circuit stub are

Calculation for cutoff frequency:

$$f_0 = \frac{f_1 + f_2}{2} \tag{7}$$

Calculation for Fractional Band Width

$$FBW = \left(\frac{f_2 - f_1}{f_0}\right) \tag{8}$$

g-values of the prototype filter

$$g_0 = g_4 = 1.0,\ g_1 = g_3 = 0.8794$$
$$g_2 = 1.1132,\ z_a = z_b = 50\Omega$$

Calculation for impendences

$$Z_1 = Z_a\left(1 + \frac{1}{\propto g_0 g_1}\right) \tag{9}$$

$$Z_2 = \frac{Z_a g_0}{\propto g_2} \tag{10}$$

$$Z_3 = \frac{Z_a g_0}{g_4}\left(1 + \frac{1}{\propto g_3 g_4}\right) \tag{11}$$

$$Z_{12} = Z_a(1+\propto g_0 g_1) \tag{12}$$

$$Z_{23} = \frac{Z_a g_0}{g_4}(1+\propto g_3 g_4) \tag{13}$$

$$\propto = cot\left[\frac{\pi}{2}\left(1 - \frac{FBW}{2}\right)\right] \tag{14}$$

TABLE II. PARAMETERS FOR BAND STOP FILTER WITH OPEN CIRCUIT STUB

Impedance(ohm)	Width(mm)	Length(mm)
Z_a=Z_b=50	1.85	5.475
Z_2=Z_3=106.85	0.3	15.15
Z_2=44.92	2.3	14.85
Z_{12}=Z_{23}=93.97	0.45	14.05

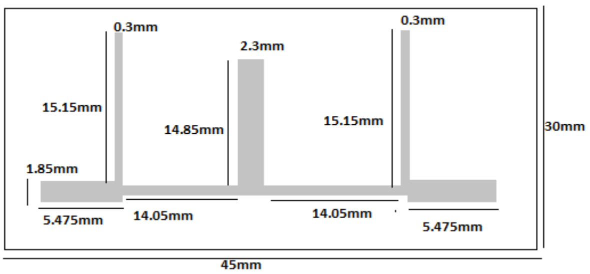

Figure 3(a). Chebyshev prototype band stop filter

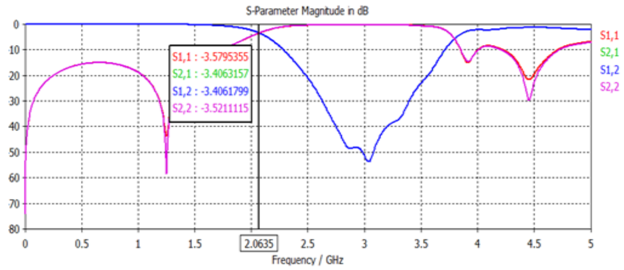

Figure 3(b). Response of Chebyshev Prototype Band Stop Filter

Fig. 3(b) shows the response of chebyshev BSF, provide wider bandwidth on 3GHz cutoff frequency, bandwidth is exactly same of the optimum BSF filter but greater than the L-resonator BSF.

III. Design of PBG Structure

PBG structures have been designed for unaltered the frequencies band for particular response of the filters. It has been designed back surface of the PCBs. Few photonic band gap (PBG) structures have been demonstrated on FR-4 substrate Pcbs with thickness of 1.6mm and ε_r is 4.4 and μ-1.

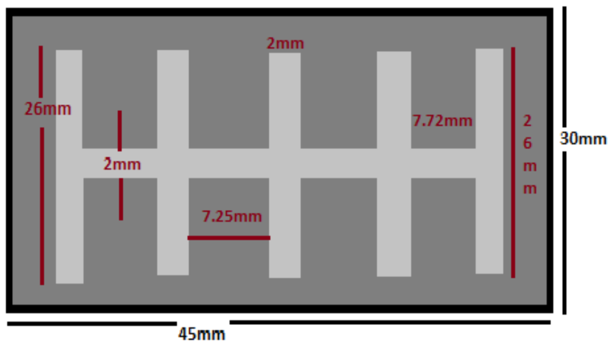

Figure 4(a). E-Shapes photonic band gap structure

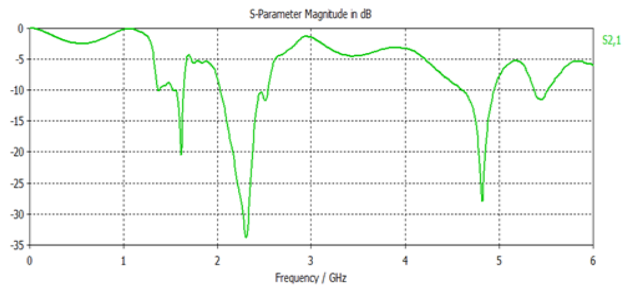

Figure 4(b). Insertion loss vs frequency for E-shapes PBG

Now we have seen that in Fig. 4(b) two stop band obtained at 2.2GHz and 4.9GHz cut off frequency. The first band obtained at S_{21} -30db and second stop band at S_{21} -27db. So E-shape PBG structure can be used where two stop band at different frequencies are required.

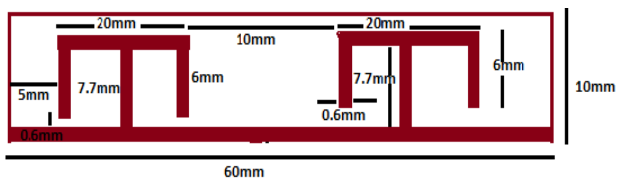

Figure 5(a). T shape photonic band gap structure

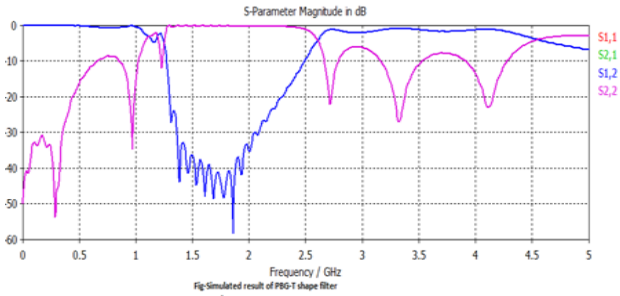

Figure 5(b). Response of T shape photonic band gap structure

Fig. 5(a) is another type of PBG filter which provide wide stop band at 1.65GHz cutoff frequency and bandwidth is 1.3GHz. The bandwidth is 78.7879% of its cutoff frequency.

IV. Result

The performance of elliptic function band stop filter (BSF) with PBG is studied and simulated without using coupled line in Fig. 2(a) and with resonator in Fig. 1(a). for example hardware simulation is shown in Fig. 6(a) and response shown in Fig. 6(b). Result simulated on CST [9] software and measured by frequency analyzer and obtained result shows S_{11} -78db and S_{21} 0db with PBG structure, which provide wider band gap than the responses of Fig. 1(b), Fig. 2(b) and Fig. 3(b). input and outport ports signals are shown in Fig. 6(c). in Fig. 6(d) dotted line shows measured result by frequency analyzer.

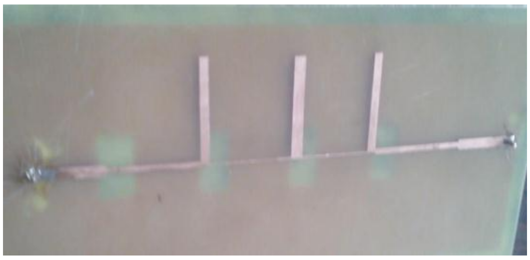

Figure 6(a). Front view of 3rd order BSF

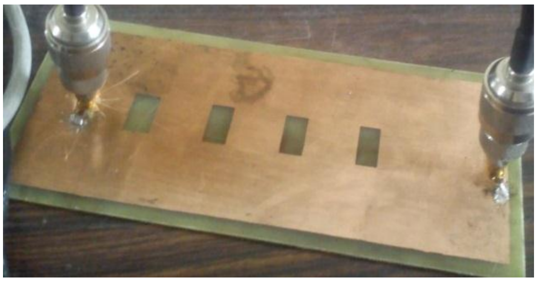

Figure 6(b). Bottom surface with PBG structure

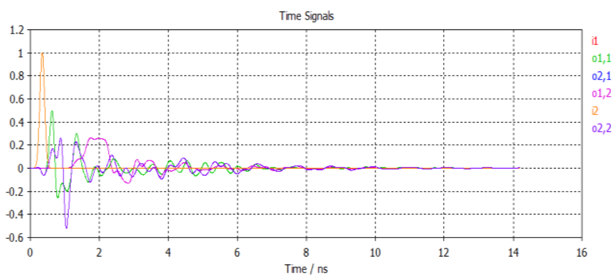

Figure 6(c). I/O ports signals

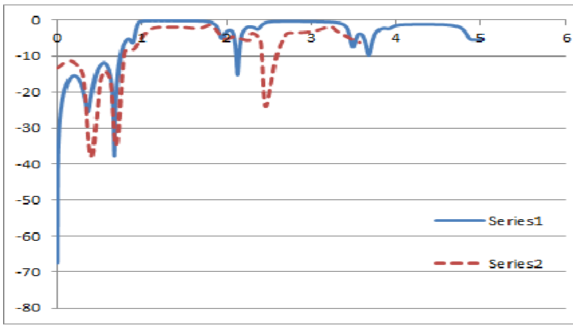

Figure 6(d). S11 vs. frequency for BSF with PBG structures

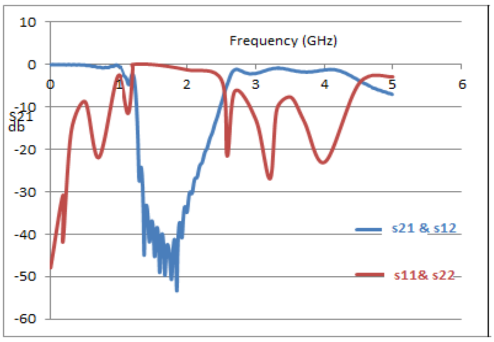

Figure 6(e). S21 vs. frequencies for BSF without PBG structure

Now smith charts for this PBG filter shown in Fig. 6(f) for return loss and insertion loss, provide the great stability for the filter reponse.

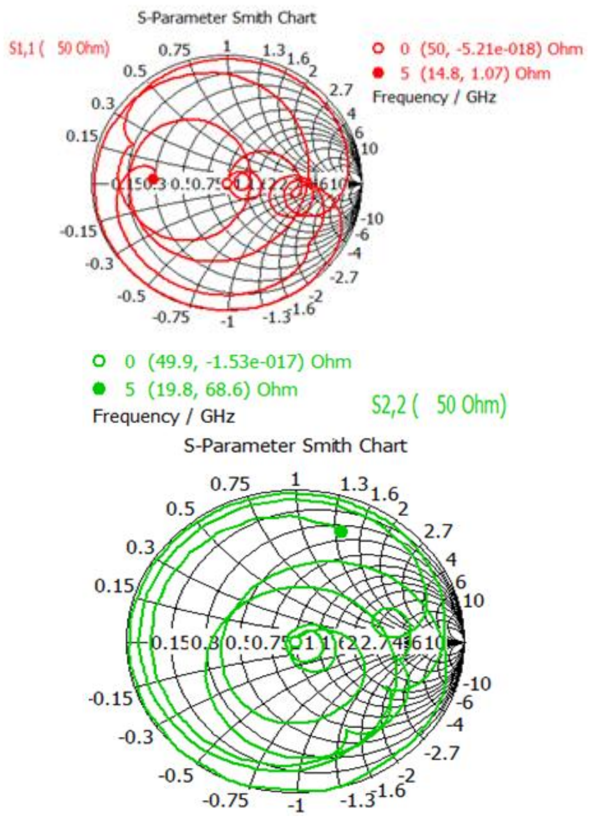

Figure 6(f). Smith chart for the proposed PBG filter

V. Conclusion

Conclusion are made by the various responses obtained in Fig. 1(b) for L-resonator, Fig. 2(b) for band stop filter and Fig. 3(b) for open circuit band stop filter and various PBG structure response shown in Fig. 4(b) and Fig. 5(b) which have been designed for different cut off frequencies. These novel PBG structures have wide stopband and compact size, which can be easily incorporated into the ground planes of PCB's or any other planer structures.

Experimental results of a Bandstop filter on a substrate with the PBG ground plane displays a broad stopband as shown in Fig. 6(c) and Fig. 6(d). In the passband the measured slow wave factor is 1.5-2.8 times greater and insertion loss is the approximately same level compared to a conventional BSF. Calculation and comparison of the response of band stop filter (BSF) with and without using photonic band gap structure (PBG) was done. The PBGs structures designing are very simpler than the design of band stop filters. Results are simulated using computer simulation technology software (CST) and fabricated structure tested on spectrum analyzer. The undesired sidebands and fluctuations of response are reduced by using PBG and improvement in bandwidth is achieved in case of band stop filter (BSF). This PBG structures should find wide applications for high-performance in microwave circuits.

References

[1] C.-H. Lin, G.-Y. Chen, J.-S. Sun, K.-K. Tiong, and Y. D. Chen, "The PBG filter design," in *Proc. PIERS*, Hangzhou, China, Mar. 24-28, 2008, pp. 29-31.

[2] F.-R. Yang, K.-P. Ma, and Yongxi Qian, "A unipolar compact photonic bandgap structure and its applications for microwave circuits," *IEEE Transactions on Microwave Theory and Techniques*, vol. 47, no. 8, Aug. 1999.

[3] H. Oraizi and M. S. Esfahlan, "Miniaturization of wilkinson power dividers by using defected ground structures," *Progress in Electromagnetics Research Letters*, vol .4, pp. 113-120, 2008.

[4] J.-K. Xiao and Y.-F. Zhu, "New u-shaped DGS bandstop filters," *Progress in Electromagnetics Research C*, vol. 25, pp. 179-191, 2012.

[5] S. Y. Huang and Y. H. Lee, "Compact u-shaped dual planar EBG microstrip low-pass filter," *IEEE Transactions on Microwave Theory and Techniques*, vol. 53, no. 12, Dec. 2005.

[6] A. Balalem, A. R. Ali, and J. Machac, "Quasi-Elliptic microstrip low-pass filters using an interdigital DGS," *IEEE Microwave and Wireless Components letters*, pp. 1531-1309, 2007.

[7] J.-S. Hong and M. J. Lancaste, *Microstrip Filters for RF/Microwave Application*, John Wiley & Sons, 2004.

[8] L. Singh and P. K. Singhal, "Design and comparision of band pass trisection microstrip filter," *International Journal of Engineering Research and Technology (IJERT)*, vol. 2, no. 2, Feb. 2013.

[9] Microwave Studio, *CST (Computer Simulation Technology)*, Horizon House, Dec. 2011.

Dr. Promod Kumar Singhal was born in Gwalior, India in 1965. He received his Ph.D. degree in Electronics Engineering from Jiwaji University Gwalior in 1987. He has published more than 125 papers in journals and international conferences contributing in the field of microwave filters, antennas and microwave photonics. He has visited more than 9 countries. He held the post of Head of Department from 2009 to 2012 in MITS. Currently, he is a professor of an autonomous college, Madhav Institute of Technology and Science, Gwalior, University RGPV. He is a member of IEEE & others. His main interest includes microwave filters designing, antenna designing & their applications.

Pooja Sahoo was born in Agra (U.P.) in 1988. She received her B. Tech. in Electronics & Telecommunication Engineering from Anand Engineering College, Agra in 2010. She worked as an Assistant Professor during 2010 to 2012 at MITS, Gwalior and is presently pursuing her M.E in (Control Communication & Networking Engineering) since 2012 in the same institute. She has one research paper in journal, one in conference proceeding.