International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Impact Factor (2012): 3.358

Microwave Bandpass Filter Based on Electromagnetic Band Gap Structure

Trupti Dhole[1], Satish Narkhede[2]

[1]Pune Institute of Computer Technology, Pune University, Pune, India

[2]Pune Institute of Computer Technology, Pune University, Pune, India

Abstract: ***In this paper, a microwave bandpass filter with mushroom-like EBG and transmission line using two layer structure is proposed. The proposed structure is composed of the four units of conventional mushroom-like EBG which are cascaded to yield multi-bandpass characteristic. The characteristics of the conventional mushroom-like EBG and one, two and three slit-top mushroom-like EBG are studied and compared. Finally the simulated and measured results for transmission characteristics are investigated and are in good agreement.***

Keywords: Electromagnetic Band Gap (EBG), mushroom-like EBG,multi-bandpass filter, slit-top.

1. Introduction

Radio frequency (RF) engineers with the rapid growth of wireless markets [wireless local area network (WLAN),mobile communication, radio frequency identification (RFID),global positioning system (GPS) applications] are facing challenges of small volume, wide bandwidth, power efficient, and low cost system designs. RF and microwave filters are vital components in a various electronic systems. Recently several band pass filters are reported in the literature[1-8] exploring different approaches like coplanar waveguide (CPW), step impedance resonators (SIR) and hybrid microstrip.

Periodic structures are abundant in nature. Many studies since last 20 years have proven that the when this structures interact with electromagnetic waves, an exciting phenomenon such as band gap in the frequency spectrum appears. Meta materials including electromagnetic band gap (EBG) structures, left handed materials (LHM),frequency selective surfaces (FSS) and double negative (DNG) materials found useful applications in antennas and microwave circuits having electromagnetic properties. During earlier stage of researchers electromagnetic band gap (EBG) structures was also termed as photonic band gap (PBG) structure due to its use in optical field. EBG structures are compatible with standard planar microwave circuit technology due to its advantages like low cost, easy fabrication and miniaturized circuit.

To reduce filter size resonators are preferred most but sometimes they are unable to improve spurious response, so slow-wave EBG structures are proposed and implemented by to reduce size as well as to improve response of the filter [1]. EBG structures helps for isolating digital circuits from analog/RF circuits and avoids Simultaneous Switching Noise (SSN) [2]. Defected Ground Structures (DGS) are used to design filters by etching circular ,triangular, rectangular holes and dumbbell shape holes in the ground plane to improve the performance of the filter [3]. The design of band pass filter cascading fork resonator and EBG structure is proposed to reduce filter size with better performance [4]. Several novel EBG structures are proposed such as uni-planar compact EBG (UC-EBG) ,Multi-Slit L-Bridge EBG [5] and Fork-like EBG [6].

In this paper , the challenge is to design the multi-band pass filter with a Mushroom-like EBG structure. The slit top truncated structures are compared with conventional mushroom-like EBG. The simulation results by using Ansoft HFSS software will show the curves of transmission characterisrics,S_{21} of the filter.

2. Theory

The mushroom-like EBG structure behaves as a network of parallel resonant LC circuit, which acts as a network of a two-dimensional electric filter to block the flow of current. It consists of a lattice of metal patches, connected to a solid metal sheet by vertical conducting vias.

While interacting with electromagnetic waves, the electric charges are built up between ends of adjacent patch and the sheet between the top and bottom plate, which can be considered as a capacitance. At the same time, the current flows around the path through the vias and the bottom plate, which results in inductive effect [7]. The mushroom-like EBG and its equivalent circuit is shown in figure 1 below.

Central frequency of the band gap is given by,

$$f = \frac{1}{2\pi\sqrt{LC}} \tag{1}$$

Where,

$$L = \mu_0 h \tag{2}$$

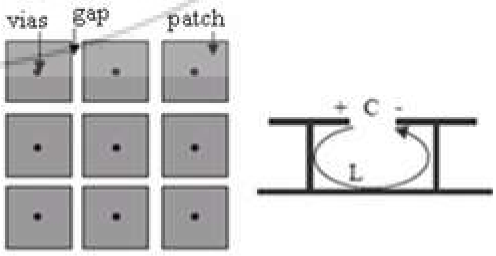


Figure 1: Two dimensional Mushroom-like EBG structure and its equivalent circuit

Licensed Under Creative Commons Attribution CC BY

$$C = W\varepsilon_0 \frac{(1+\varepsilon_r)}{\pi} \cosh^{-1}\left(\frac{W+g}{g}\right) \quad (3)$$

$$L = \mu_0 h$$

Where,
W = Patch width
g = Gap width
h = Substrate thickness
The bandwidth of the band gap is given by,

$$BW=\frac{1}{\eta}\sqrt{\frac{L}{C}} \quad (4)$$

Impedance Z becomes zero when frequency is

$$f_1 = \frac{1}{2\pi\sqrt{L_1(C_1+C_2)}} \quad (5)$$

Thus, a short circuit between the microstrip line and the ground has been created. On the other hand Z becomes infinite when frequency is

$$f_2 = \frac{1}{2\pi\sqrt{L_1 C_2}} \quad (6)$$

3. Design and simulation results of multi-band pass filter

In this section the conventional mushroom-like EBG structure and Mushroom-like EBG structure with one, two and three slit tops are designed. The normal parameters of microstrip patches for two layer compact EBG structure are given as follows: Patch width (w) = 10 mm, Gap width(g) = 1 mm, Substrate height (h_1) = (h_2) = 1.6 mm, Via radius (r) = 1 mm, Layer 1 and layer 2 subtrate with dielectric constant(ϵ_1) and (ϵ_2)=4.4 and microstrip line with width and length as 2mm and 48mm respectively.

The conventional mushroom-like EBG structure with above parameters is shown below.

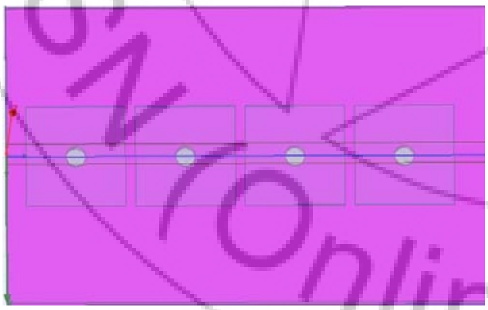


Figure 2: Conventional mushroom-like EBG structure

The transmission characteristics of above designed structure shows one bandgap between frequencies 2.8GHz to 4GHz with more than -50dB attenuation and 4 passbands.

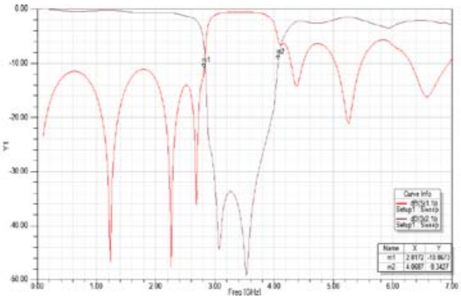


Figure 3: Transmission characteristics of conventional mushroom-like EBG structure

The effect of one slit-top on conventional mushroom-like EBG structure is studied. The following structure is designed with slit length (l_s)=6.8mm and slit width (w_s)=0.2mm.

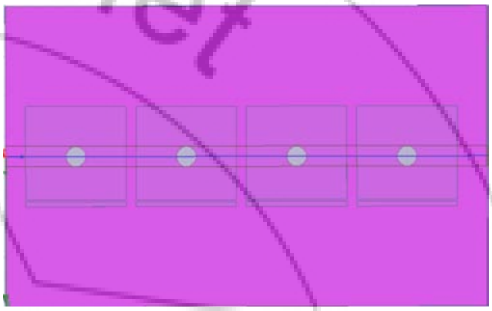


Figure 4: Mushroom-like EBG structure with one slit-top

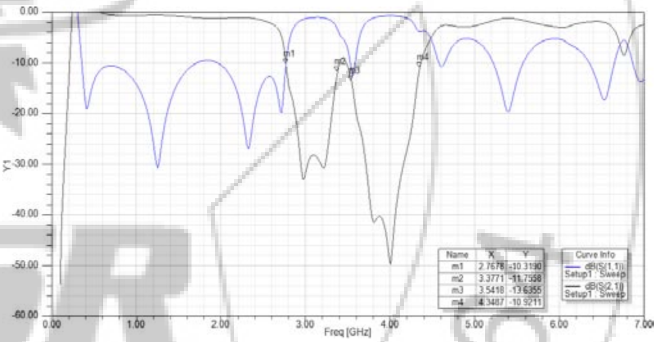


Figure 5: Transmission characteristics of mushroom-like EBG structure with one slit-top

As compare to conventional mushroom-like EBG the transmission characteristics with one slit-top shows dual band filter characteristics. Two bandgaps between frequencies 3.1GHz to 3.8 GHz and 4.1GHz to 4.5GHz with more than -30dB attenuation.

The effect of two slit-tops on conventional mushroom-like EBG structure is studied. The following structure is designed with Slit width (w_s)=0.2mm,Slit length (l_{s1})=6.8mm and Slit length (l_{s2})=7.8mm.

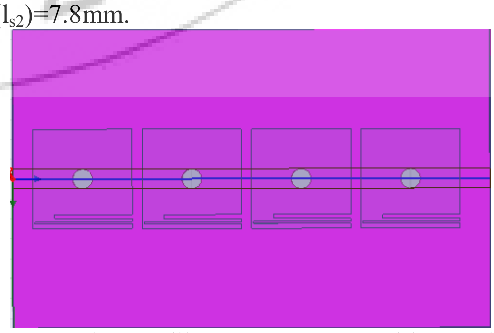


Figure 6: Mushroom-like EBG structure with two slit-tops

Licensed Under Creative Commons Attribution CC BY

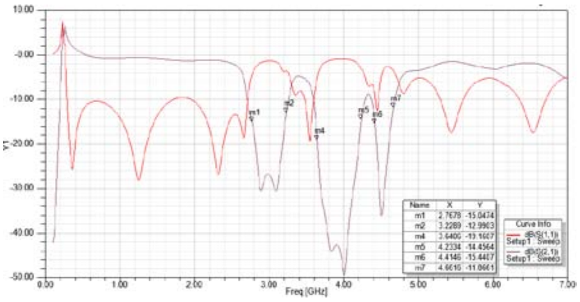


Figure 7: Transmission characteristics of mushroom-like EBG structure with two slit-tops

As compare to mushroom-like EBG with one slit-top the transmission characteristics with two slit-tops shows three bands. Three bandgaps between frequencies 2.7GHz to 3.2 GHz ,3.6GHz to 4.2GHz and 4.4GHz to 4.6GHz with more than -30dB attenuation. The effect of three slit-tops on conventional mushroom-like EBG structure is studied. The following structure is designed with Slit width (w_s)=0.2mm,Slit length(l_{s1})=6.8mm,Slit length(l_{s2})=7.8mm Slit length(l_{s3})=9.8mm.

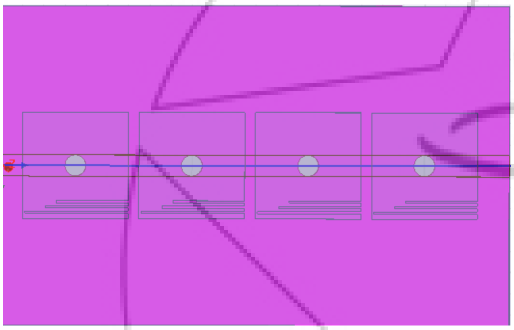


Figure 8: Mushroom-like EBG structure with three slit-tops

As compare to mushroom-like EBG with two slit-tops the transmission characteristics with three slit-tops shows more than three bands. Three bandgaps between frequencies 2.7GHz to 3.2 GHz , 3.6GHz to 4.2GHz and 4.4GHz to 4.7GHz with more than -30dB attenuation.

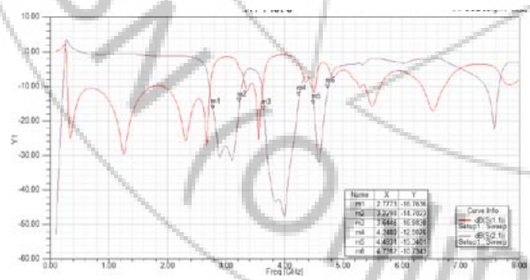


Figure 9: Transmission characteristics of mushroom-like EBG structure with three slit-tops

4. Experimental Results and Comparison

The transmission characteristics (S_{21}) of bandpass filters is tested using Vector Network Analyser (VNA). The fabricated structures are as follows. Figure 10 shows the microstrip line structure of layer one. While figure 11 and figure 12 depicts structure of layer two of mushroom-like EBG structure with one and two slit tops. And conventional mushroom-like EBG structure and mushroom-like EBG with three slit tops are also fabricated and tested. Figure 13 shows conventional mushroom-like EBG structure with SMA connectors.

Figure 10: Fabricated structure of Microstrip line

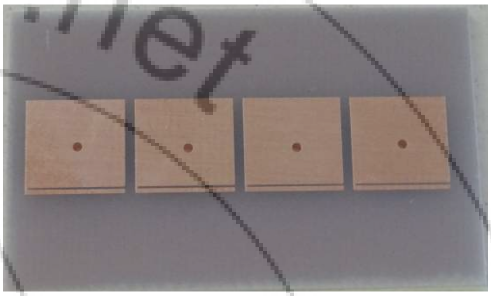


Figure 11: Fabricated structure of Mushroom-like EBG structure with one slit-top

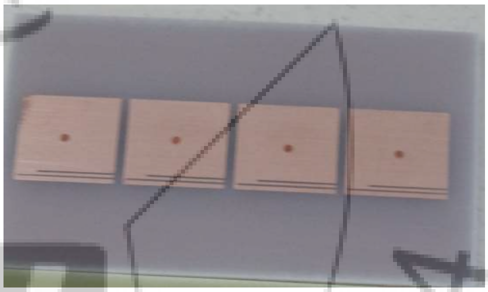


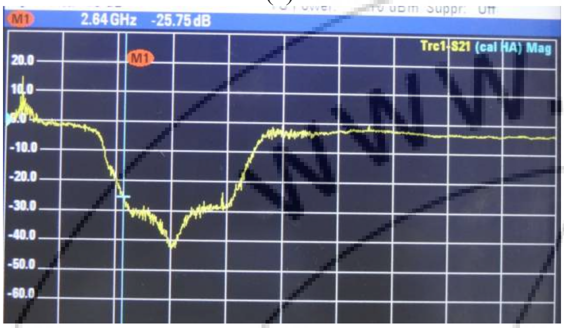
Figure 12: Fabricated structure of Mushroom-like EBG structure with two slit-tops

Figure 13: Fabricated structure of Mushroom-like EBG structure with two SMA connectors on both side

Figure 14 depicts experimental setup of conventional mushroom-like EBG structure filter and the display shows result with one stop band between 2.52 GHz to 3.42 GHz with more than 10 dB attenuation and two pass bands.

Licensed Under Creative Commons Attribution CC BY

(a)



(b)

Figure 14: (a)experimental setup of conventional mushroom-like EBG structure filter (b) S_{21} characteristics

Figure 15 depicts S_{21} characteristics for mushroom-like EBG structure with one slit top. It shows two stop bands with attenuation of 50 dB and three pass bands.

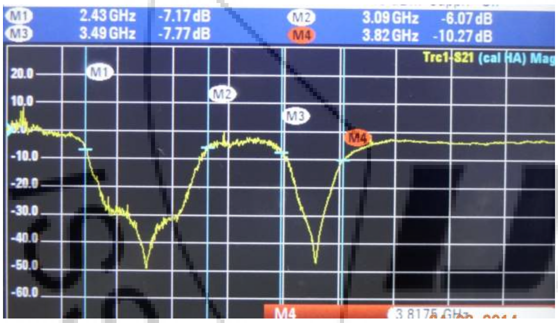


Figure 15: S_{21} characteristics of Mushroom-like EBG structure with one slit-top

Figure 16 depicts S_{21} characteristics for mushroom-like EBG structure with two and three slit tops. It shows three stop bands with attenuation more than 10 dB and four pass bands.

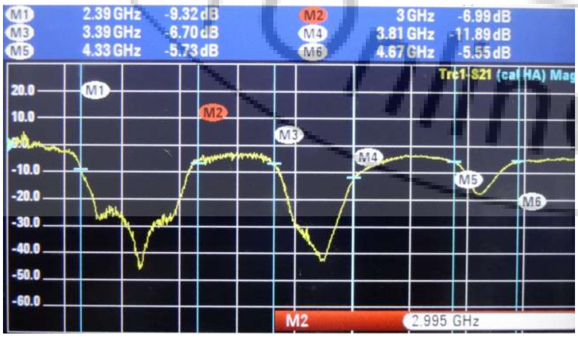


Figure 15: S_{21} characteristics of Mushroom-like EBG structure with two and three slit-tops

5. Conclusions

The proposed structures provide an idea for designing more efficient electromagnetic structure for microwave circuit applications such as filters, diplexers, demultiplexers and other passive circuits. This structure helps to produce multiple passbands within same structure. Experimental results and simulated results are in good agreement. The experimental results for mushroom-like EBG with three slit top is near about same with structure of two slit tops. The fabrication cost is more. The above structure is designed for feasibility study, and changes in the structure can be made as per the application requirement. Future work will incorporate to design structure for specific application purpose.

6. Future Scope

Future work will incorporate to design structure for specific application purpose. The fabrication is costly so design can be changed to reduce fabrication cost. The above structure is designed for feasibility study, and changes in the structure can be made as per the application requirement.

References

[1] Vitaliy Zhurbenko, Viktor Krozer and Peter Meincke,"Miniature Microwave Band pass Filter Based on EBG Structures", *Proceedings of the 36th European Microwave Conference,* Manchester UK, September 2006.

[2] Madhavan Swaminathan,"*Power Integrity Modelling And Design For Semiconductors And Systems*", Prentice Hall, November 2007.

[3] S.M.Shakil Hasan,M.N.Mollah,"Dumbell Shape EBG Structure-Worth to EBG Assisted Microwave Filter Designing",*IEEE Asia-Pacific Conference on Applied Electromagnetics*,Malaysia,2012.

[4] H.Umma Habiba,M.Deepika and D.Lavanya,"Compact Microstrip Band Pass Filter using Fork & EBG Resonator for UWB application", IJERA ISSN : 2248 - 9622 NCACCT, India, March 2013.

[5] S.Manukonda,"UWB suppression of Simultaneous Switching Noise using Multi-Slit-L-bridge EBG structure",*International Conference on Communication and Signal Processing*, India, April 2013.

[6] Li. Yang,Mingyan Fan and Fanglu Chen,"A Novel Compact Electromagnetic BandGap (EBG) Structure and its Application for Microwave Circuits", *IEEE Transaction On Microwave Theory And Techniques,* Vol. 53, No. 1, January 2005.

[7] A.Yatongchai,R.Wongsan and M.Krairksh,"Design of a Demultiplexer using Slit-top Mushroom-Like Electromagnetic Band Gap Structures",*IEEE Asia-Pacific Conference on Antennas And Propagation*,27-29,Singapore,August 2012.

[8] D.Li,C.Tong,J.Bao,"A Novel Band pass Filter Of Substrate Integrated Waveguide(SIW) Based On S-shaped EBG", *Progress In Electromagnetics Research Letters*,Vol.36,191-200,2013.

[9] Anchal Chugh, Dr. Rajesh Khanna," Study of Various EBG Based Micro strip Filter Structures*", International Journal of Engineering Trends and Technology (IJETT)*, Vol.4,May 2013.

Licensed Under Creative Commons Attribution CC BY

[10] Alka Verma," EBG Structures And Its Recent Advances In Microwave Antenna", *International Journal of Scientific Research Engineering & Technology (IJSRET),* Vol.1 ,pp 084-090 ,August 2012.

[11] B.J.Yang,Tzu An Ku,"Filter Design Using Electromagnetic Band Gap in Microstrip Reference Plane for Packaging Applications",*12th Electronics packaging Technology Conference*",2010.

[12] H.Elsaied,Maher M.Abd Elrazzak,"Novel Planar Microstrip Low Pass Filters Using Electromagnetic Band Gap(EBG) Structures",Middle East Conference on Antennas and Propagation,Egypt,2010.

Author Profile

Trupti Dhole has received the B.E. degree in Electronics from Amrut Vahini College of Engineering and M.E. degree in Microwave Engineering from Pune Institute of Computer Technology in 2010 and 2014, respectively. Worked in Metropolitan Education Trust for one year as a lecturer for Electronics I,II &III subjects and now working in Pune Vidhyarthi Griha College Of Engineering And Technology as a lecturer.

Licensed Under Creative Commons Attribution CC BY