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Research article

Computational Approach for Performance Analysis of Photonic Band Gap Structure on Defected Ground Surface with Microwave and Band Stop Filter

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Abstract

The photonic band-gap (PBG) structures are indispensable and effective measures in microwave applications that provide an effective control of electromagnetic waves ((EMW) along specific direction and performance. In this paper, a numerical simulation technique as a computational model for the performance of Photonic band gap structure (PBG) on the ground surface with band-stop and microwave characteristics has been proposed. An impact of band stop filter (BSF) has been examined with and without using photonic band gap structure (PBG). In addition to this, undesired side bands have been reduced and considerable improvement in bandwidth has been successfully achieved. Significant results of our present study are simulated using computer simulation technology software (CSTS) and fabricated structure tested on spectrum analyzer. Finally, valuable conclusive observations along with discussions on simulated results have been proposed for its future scope and further analysis.

Keywords: Photonic band gap (PBG), electromagnetic waves ((EMW), band stop filter (BSF), submarine version-A (SMA) connector, printed circuit board (PCB), defected ground structure (DGS), spectrum analyzer., wavelength division multiplexing (WDM), high impedance electromagnetic surfaces (HIES), computer simulation technology software (CSTS).

1. Introduction

Several noteworthy researchers [2,...6, 8,...14, 18] confined their attention to study and analyse problems dealing with effective control of electromagnetic waves ((EMW) using numerous techniques in the literature. Here, it is noticeable that photonic band gap structures for microstrip line have occupied a prominant place for researchers in recent years. The term photonic band-gap (PBG) is introduced as a structure which has its special characteristics for major changes in the electromagnetic properties of materials. The periodic structure created in materials such as substrate or metals; for more details, we refer Yablonovitch [18]. Simulation technique is one of the most powerful numerical techniques and pay a key role in performance analysis of various systems. In this direction, it is needless to mention that the computer simulation technology software (CSTS) is utmost useful tool [13]; which has been used here for performance analysis of photonic band gap structure on defected ground surface with microwave and band stop filter. Literature shows that several noteworthy previous researchers contributed in connection with effective control of electromagnetic waves ((EMW) using numerous techniques in defferent frameworks. For example, Hong and Lancaste [7] and Qian et al [15] confined their attention in this direction and succeeded to explore that the photonic band-gap (PBG) structures are effective in microwave applications that provide an effective control of electromagnetic (EM) waves along specific direction and performance. It is also relevant to note here that numerous techniques were studied and applied to alleviate mutual coupling in an array that includes cavity backing, partial substrate removal, corrugations, split ring resonators (SRR), defected ground structures (DGS), periodic structures like high impedance electromagnetic surfaces (HIES) or electromagnetic bandgap structures (EBG). Integration HIES/EBG structures in a microstrip antenna array are quite attractive for their ability to suppress surface waves and reduce the mutual coupling effects. These high impedance surfaces are realized with the periodic arrangement of dielectric or metallic elements; see Islam and Alam [8]. Moreover, the photonic band gap structure provides a certain frequency bands which cannot propagate. PBG structures are the most widely used in various applications like microwave filters, antenna and other electronic devices. However, Srivastava et al [16] examined that some other different structures LPF, BSF, power divider and power amplifier may be implemented. In addition to defected ground surface (DGS) and electromagnetic band gap (EBG) structures, photonic band gap (PBG) structure has been created by etching different shapes in ground surface which has capability to increase both the inductance and capacitance values of microstrip line. This technique was used by [2, 6] to reduce undesired output response and sharp stop band for LPF.

Here we remark that Dr. D’Orazio (1998) has been fabricated the PBG filter for wave length division multiplexing (WDM). For more details, we refer the research work carried out by Qian et al [15] who succeeded to analyze the PBG structure with a liquid crystal defect for the purpose of fiber optic filters. The basic phenomena behind the proposed photonic band gap (PBG) filter are forbidden gap in materials by electrons movement; for more details in this connection, we refer [14]. Very recently Qian et al [15] and Weng et al [17] used a photonic band gap structure consisting of small metal pads with grounding via in order to improve the performance of a patch antenna. Filtering phenomena of frequency bands and harmonics of the filter in microwave circuits is the key function of PBG structures.

In this paper, a numerical simulation technique as a computational approach for the performance of photonic band gap structure (PBG) on the ground surface with band-stop and microwave characteristics has been proposed. Here, significant effect of band stop filter (BSF) has been examined with and without using photonic band gap structure (PBG) and it is keenly observed that undesired side bands have been reduced and considerable improvement in bandwidth has

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been successfully achieved. Numerical results of our present study are simulated using computer simulation technology software (CSTS) and fabricated structure tested on spectrum analyzer. Finally, some conclusive observations based on simulated results have been drwan for its future scope and further analysis in an extended version.

2. Structural Design of Band Stop Filters

The proposed structures have been designed for resonating frequency of 0-1.5GHz and 3rd order maximally flat response. Using following formulas in view of Hong and Lancaste [7] –

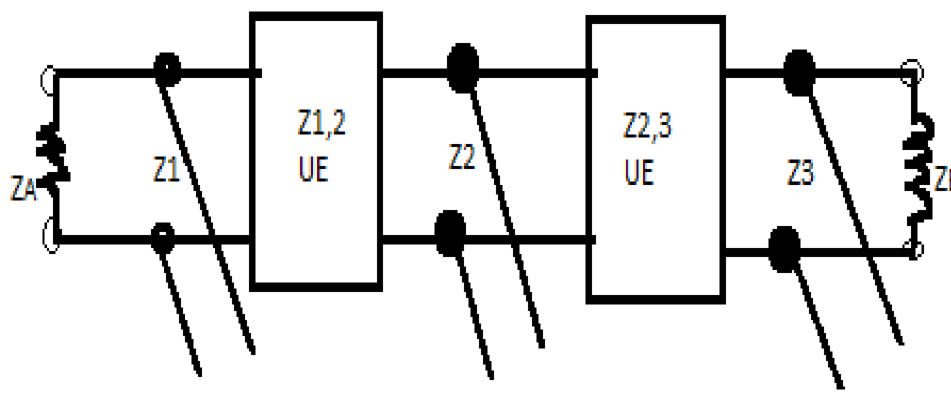

Figure 2(a): Band stop filter with open-circuited stub (UE-Unit Element)

$$Z1 = Z0\ (1 + 1/\alpha g0g1) \tag{2.1}$$

$$Z12 = Z0\ (1 + \ \alpha g0g1) \tag{2.2}$$

$$Z2 = Z0g0/\ (\alpha g2) \tag{2.3}$$

$$Z3 = Z0g0/g4\ (1 + 4/(\alpha g3g4)) \tag{2.4}$$

$$Z23 = Z0g0/g4(1 + \alpha g3g4), \tag{2.5}$$

$$Z_0 = Z_4 = Z0g0/g4 \tag{2.6}$$

The central frequency is given by following equation;

$$f_0 = \ (f_1 + f_2)/2 \tag{2.7}$$

Fractional bandwidth is given by by following equation;

$$FBW = (f_2 - f_1)/f_0 \tag{2.8}$$

where α is an arbitrary constant and determined by following equation;

$$\alpha = \ cot|\pi/2\ (1 - FBW/2)| \tag{2.9}$$

And length L is given as following;

$$L = \ (guided\ wavelength)/4 \tag{2.10}$$

Table 2.1: For impedances length and width

Impedance (Ω)	Length (mm)	Width (mm)
$Z0 = Z4 = 50$	22.01	3.049
$Z1 = Z3 = 52.70$	27.49	2.796
$Z2 = 43.650$	27.15	3.80
$Z01 = Z34 = 70$	28.0425	1.647
$Z12 = 114.976$	29.061	0.472
$Z23 = 114.976$	29.0616	0.472

For W/h ≤ 1;

$$\varepsilon re = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2}\left(1+12\frac{h}{w}\right)^{-0.5} \quad (2.11)$$

For W/h>1;

$$\varepsilon re = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2}\left(1+12\frac{h}{w}\right)^{-0.5} + 0.4\left(1+\frac{w}{h}\right)^{2} \quad (2.12)$$

Guided wavelength

$$\lambda g = \frac{300}{f(ghz)\sqrt{\varepsilon re}} \quad (2.13)$$

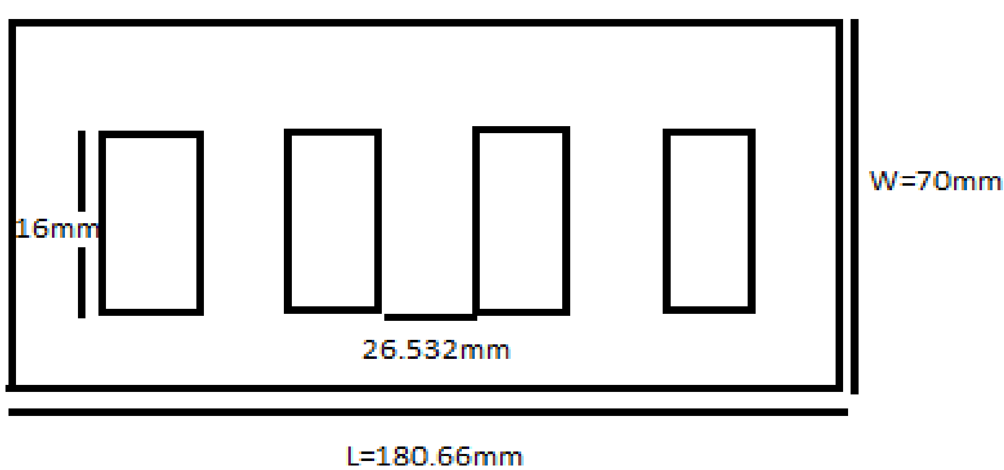

Figure 2(b): Photonic band gap structure

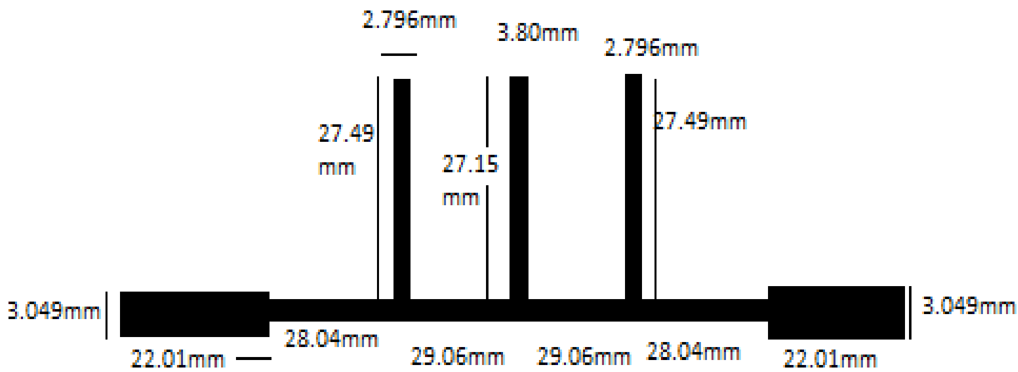

Figure 2(c): 3rd order band stop filter

The proposed photonic band gap structure and band stop filter have been fabricated on PCB using PEC material of .038mm height. The substrate of material FR-4(lossy) has been used. The height of substrate is 1.6mm, permittivity-4.3, permeability-1; thermal conductivity is 0.3w/k/m and E1-tand-0.025(const-fit).

Figure 2(d): Top view of 3rd order band stop filter

Figure 2(e): Bottom view with etched square on ground surface

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3. Simulated Results and Graphs

The same configuration has been designed with PBG (etched rectangle in ground plane) and without PBG shown in below figures 3(a)-3 (d). The graph is obtained using computer simulation technology (CSTS) and spectrum analyzer. It shows the increased bandwidth, sharp cutoff at both ends and reduction in the unwanted variation of the output.

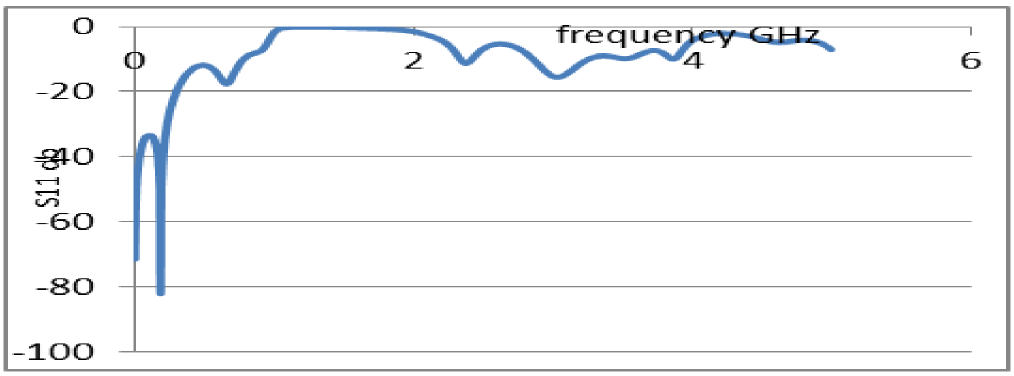

Figure 3(a): Return loss S11 (dB) versus frequency (GHz)- graph of band stop filter without PBG

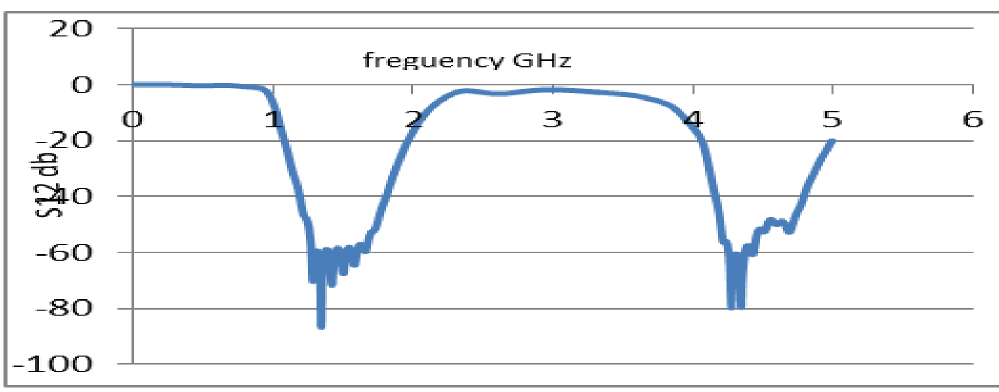

Figure 3(b): Graph of the band stop filter without PBG

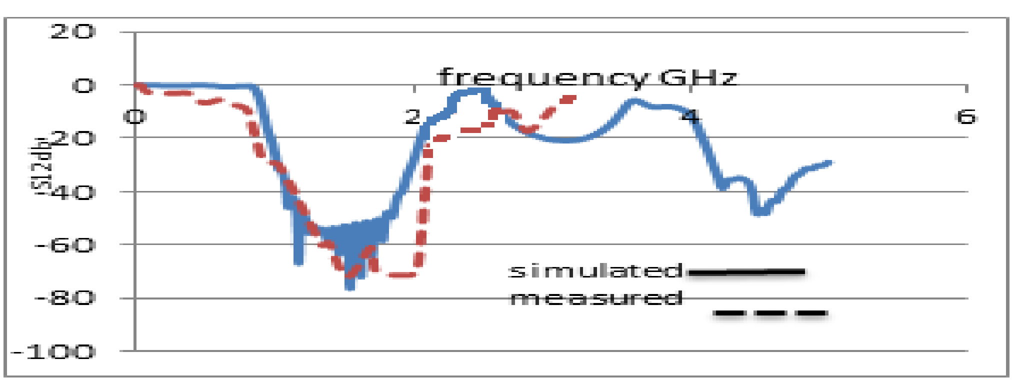

Figure 3(c): Graph S12 (dB) versus frequency (GHz) of band stop filter with PBG

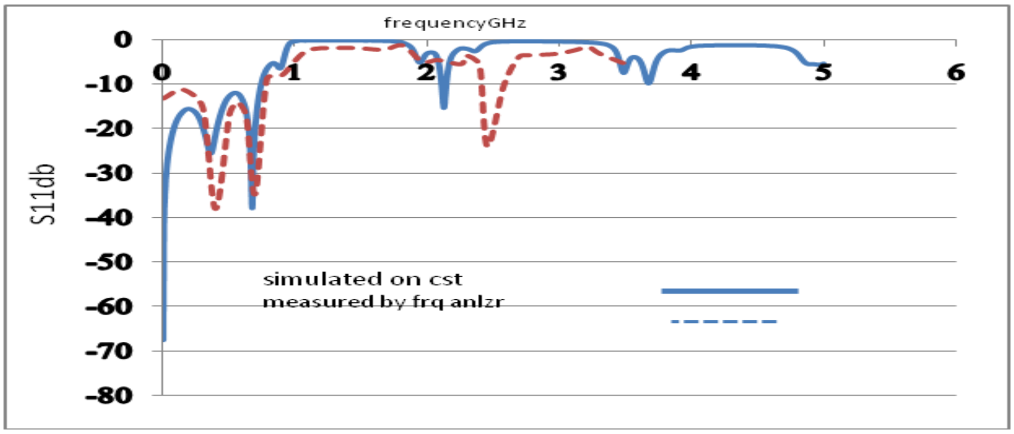

Figure 3(d): Graph for return loss (S11) dB versus frequency (GHz) of band stop filter with PBG

Figure 3 (c) shows the band stop characteristic on resonating frequency f0=1.5 GHz, and f1=1 GHz and f2=2GHz. From the proposed graph the frequency band from 0.95 GHzto 2.21 GHz is unaltered and the bandwidth of band stop filter with photonic band gap structure increased up to 25%. Hence the band width improvement has been concluded.

The structure of the photonic band gap- band stop filter described in this paper is very simple andcompact, but it provides good performance. Both measured insertion and return loss show excellent agreement and slight discrepancy between the simulated and measured results is mainly attributed to the substrate, radiation, dielectric loss and two BNC connectors.

4. Discussions and Conclusive Observations

Here, an optimal structure of the PBG-BSF has been determined for performance analysis. The structure with stop-band characteristic for broad band harmonic rejection tuning has been experimentally examined. In addition to these, we draw following significant conclusions;

- Computer simulation technology software (CSTS) as a computational model for the performance of photonic band gap structure (PBG) on the ground surface with band-stop and microwave characteristics has been used.
- Simulated results of full wave electromagnetic analyses have been found in good agreement with those experimental data.
- The BSF with increased bandwidth 20% to 25% as compare to filter implemented without using PBG has also been achieved. It has been observed that the undesired sidebands have been reduced and improvement in bandwidth also achieved.
- For the various applications where very sharp rate cutoff and reduced label of fluctuation of response is needed than use PBG for designing filter should be proposed.

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