Design of New Compact Photonic Band Gap Filter and Their Advantages

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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 f₁=4.5GHz and f₂=5.5GHz. Choosing Z₀=50ohm, g₀=1.1468, g₁=1.3712, g₂=1.9750, g₃=1.3712, g₄=1.1468, and g₅=1. Length of L-resonators l₁=8.9mm and l₂=8.9mm half guided wavelength Spacing of main line and resonators s₁=s₅=0.292mm, s₂=0.292mm, s₃=0.292mm and s₄=0.292mm.

![Figure 1(a). L-resonator narrowband Band stop filter](image_url)

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

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

![Figure 1(b). Response of L-resonator band stop filter](image_url)

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

Chebyshev functions of first kinds order \( n \)

\[
T_n(x) = \cos(n \cos^{-1} x)
\]

Chebyshev functions of second kinds order \( n \)

\[
U_n(x) = \sin(n \cos^{-1} x)
\]

And calculation of parameters made by given equations

\[
Z_a = Z_b = Z_0\]

\[
Z_l = Z_0 \frac{g_1}{g_0}
\]

\[
Z_{lt+1} = Z_0 \frac{J_{lt+1}}{J_l}
\]

\[
t = j \tan\left(\frac{n f}{f_0}\right)
\]

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

<table>
<thead>
<tr>
<th>Impedance (ohm)</th>
<th>Width (mm)</th>
<th>Length (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( Z_a = Z_b = 50 )</td>
<td>1.85</td>
<td>5.475</td>
</tr>
<tr>
<td>( Z_a = Z_b = 52.74 )</td>
<td>1.7</td>
<td>14.32</td>
</tr>
<tr>
<td>( Z_a = Z_b = 29.88 )</td>
<td>4.25</td>
<td>13.73</td>
</tr>
<tr>
<td>( Z_a = Z_b = 93.97 )</td>
<td>0.528</td>
<td>14.89</td>
</tr>
</tbody>
</table>

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 \( f_1 = 1.25 \text{GHz} \) and \( f_2 = 3.75 \text{GHz} \) and \( Z_0 = 50 \text{ohm} \).

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:

\[
f_0 = \frac{f_1 + f_2}{2}
\]

Calculation for Fractional Band Width

\[
FBW = \left(\frac{f_2 - f_1}{f_0}\right)
\]

\( g \)-values of the prototype filter

\( g_0 = g_4 = 1 \), \( g_1 = g_3 = 0.8794 \)

\( g_2 = 1.1132 \), \( z_a = z_b = 50 \Omega \)

Calculation for impedences

\[
Z_1 = Z_a \left(1 + \frac{1}{g_0 g_1}\right)
\]

\[
Z_2 = \frac{Z_a g_0}{g_2}
\]

\[
Z_3 = \frac{Z_a g_0}{g_4} \left(1 + \frac{1}{g_3 g_4}\right)
\]

\[
Z_{12} = Z_a \left(1 + \frac{1}{g_0 g_3} g_4\right)
\]

\[
Z_{23} = \frac{Z_a g_0}{g_4} \left(1 + \frac{1}{g_3 g_4}\right)
\]

\[
x = \cot\left(\frac{\pi}{2} \left(1 - \frac{FBW}{2}\right)\right)
\]

<table>
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<tr>
<th>Impedance (ohm)</th>
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<th>Length (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( Z_a = Z_b = 50 )</td>
<td>1.85</td>
<td>5.475</td>
</tr>
<tr>
<td>( Z_a = Z_b = 106.85 )</td>
<td>0.3</td>
<td>15.15</td>
</tr>
<tr>
<td>( Z_a = 44.92 )</td>
<td>2.3</td>
<td>14.85</td>
</tr>
<tr>
<td>( Z_a = Z_b = 93.97 )</td>
<td>0.45</td>
<td>14.05</td>
</tr>
</tbody>
</table>

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.
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 $\varepsilon_r$ is 4.4 and $\mu_r$ -1.

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.

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.
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


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