Design and Analysis of Microstrip Photonic Band Gap Filter for Suppression of Periodicity

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Abstract *–* A design for a microstrip band reject filter is presented in this paper. The proposed filter is compact in structure and provides an accurate band gap. Optimized length is applied to photonic band gap (PBG) structures etched in the ground plane for suppressing periodicity in the frequency response. Detailed analysis of the frequency response of the conventional microstrip filter along with the PBG filter has been carried out in this paper.

Keywords – Microstrip, Band Reject Filter (BRF), Photonic Band Gap (PBG).

I. INTRODUCTION

In recent times, the design of filters has become an active research area as filtering is important when used in close proximity to other circuit components, like power amplifiers in the transmitter part and low noise amplifiers in receiver part, for various RF applications. Filters can be implemented with shunt stubs [1] or stepped impedance lines in microstrip circuit [2], but these techniques require a large circuit and provide a narrow band, along with a spurious pass-band in stopband. PBG structures provide an alternative solution for these problems in microwave applications.

Microstrip lines incorporating photonic band gap structures exhibit slow wave characteristics which can be exploited to control the size of circuit layouts and periodicity. PBG structures are periodic where the propagation of waves is not allowed for some frequency bands or directions, according to the Bragg condition [3]. This is quite similar to the energy band gap concept in solid-state materials, photonic crystals, etc., which provides a means to control propagation of the electromagnetic wave.

The present work is based on the design of a conventional band reject filter with optimum design parameters [3]. The frequency response possesses periodicity, but with the help of a periodic array of structures etched on the ground plane, the spurious band gap is controlled. We show that a discrete periodic pattern is able to suppress the periodicity in the frequency response by adjusting etched size in the ground plane. For synthesis of the circuit, rigorous analysis is required, particularly for the etched section, which is very difficult to calculate. Here, we have used method of moments based IE3D simulation software [4], for the complete analysis; subsequently the result obtained is discussed.

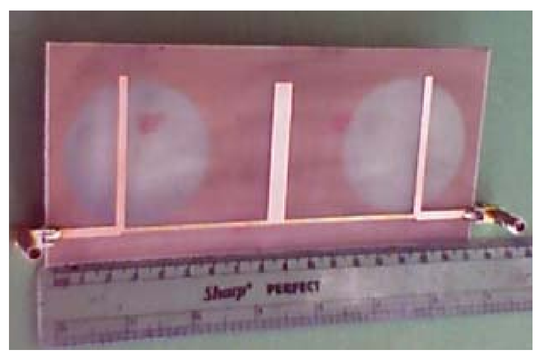

Fig. 1. Photographed layout of PBG filter.

II. FILTER DESIGN AND ANALYSIS

As shown in Fig. 1, the proposed filter is a transmission line network of a bandstop filter with open-circuited stubs, where the shunt, quarter wave-length open-circuited stubs are separated by unit elements, also called connecting lines, that are one quarter wavelength long at the mid stop band frequency. Theoretically, these filters can be designed to have any stopband width. But these filters are more suitable for the realization of wide-band band stop filters. The band reject filter is designed using the following equations for Ω_c = 1rad/sec and prototype elements, $g_0 = g_4 = 1$; g_1 =

g_3 = 0.94806; g_2 = 1.67311; $J_{1,2} = J_{2,3}$ = 0.56648; [2]

$$Z_A = Z_B = Z_0/g_o \quad (1)$$
$$Z_i = Z_0/g_i \quad (2)$$
$$Z_{i,\,i+1} = Z_0/J_{j,j+1} \quad (3)$$

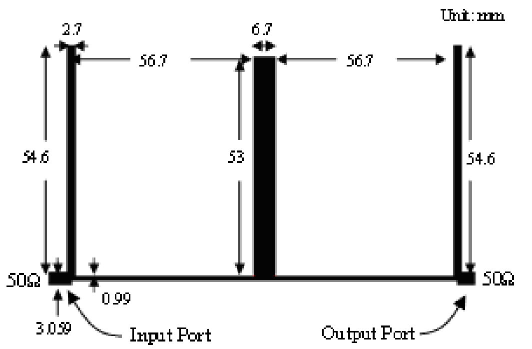

Fig. 2. Layout of microstrip band reject filter.

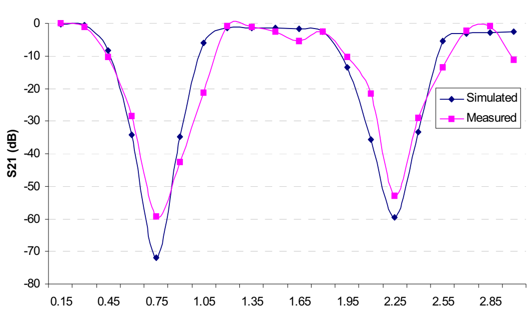

Fig. 3. Insertion loss plot of microstrip BRF.

The following are the design parameters for the proposed band stop filter:

Mid-band frequency, f_0 = 0.75GHz,
Dielectric constant, ε_r = 4.4,
Substrate thickness, h = 1.6 mm,
Loss tangent, tanδ = 0.02,
Pass band ripple = 0.1 dB,

The electrical parameters for the filter network are calculated as, $Z_0 = Z_A = Z_B = 50\Omega$, $Z_1 = Z_3$ = 52.74, $Z_2 = 29.88\Omega$, $Z_{1,2} = Z_{2,3} = 88.26\Omega$. The layout of the band stop filter is shown in Fig. 1. The microstrip filters is subsequently simulated through IE3D commercial tool [4]. The comparison plot of simulated and measured results is shown in Figs. 3 and 4. It is observed that the filter responses have spurious stop bands periodically centered at frequencies that are odd multiples of f_0. And for the microstrip band reject filter, the spurious band is found at 2.25 GHz which is '$3f_0$'.

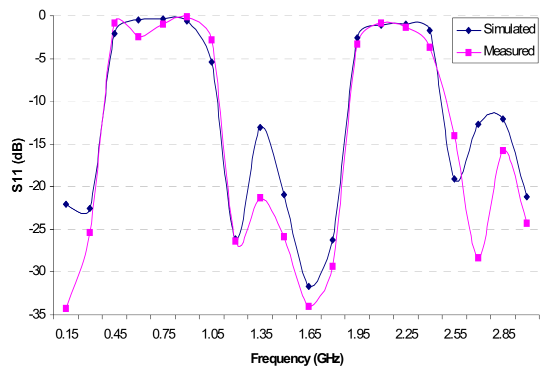

Fig. 4. Return loss plot of microstrip BRF.

III. PBG IMPLEMENTATION AND ANALYSIS

Initially, photonic band gap devices were proposed in optical applications, which have a property of preventing light from propagating in certain frequency bands [5]. In this work, we show that PBG structures with discrete periodic pattern are able to suppress the periodicity in the frequency response, with respect to 'n' – order of approximation or the number of PBG structures etched in the ground plane.

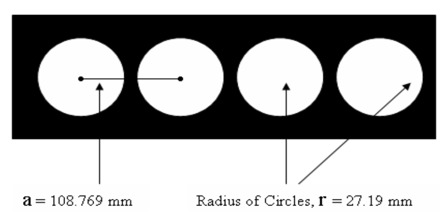

Fig. 5. Ground plane of the PBG filter.

According to the Bragg condition, the PBG structure satisfies the condition $a = \lambda_g/2$; where 'a' is the pattern period and λ_g is the guided mode wavelength [6]. And for PBG microstrip structures with circular etched holes, the optimal etched hole size is a ratio of r/a = 0.25, r – being the circle radius [7]. And it is stated in [8] they have stopband regions at different harmonics.

Fig. 5 shows the etched ground for the PBG band stop filter. The period between circles 'a' is calculated to be 108.77 mm, for λ_g = 217.54 mm and radius of the circles, r = 27.19 mm. The analytical and measured plots for insertion loss and return loss, for the PBG filter are shown in

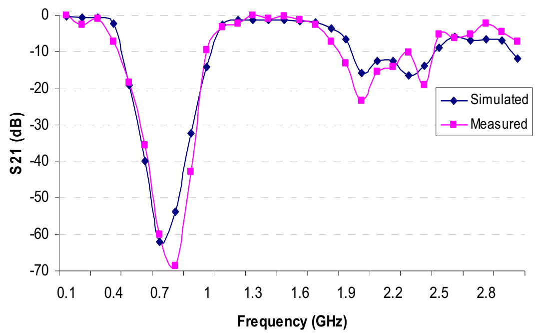

Fig. 6. Insertion loss plot for PBG filter.

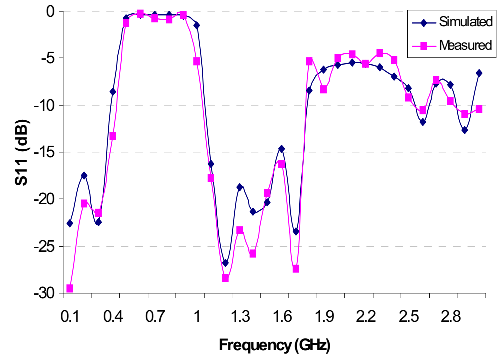

Fig. 7. Return loss plot for PBG filter.

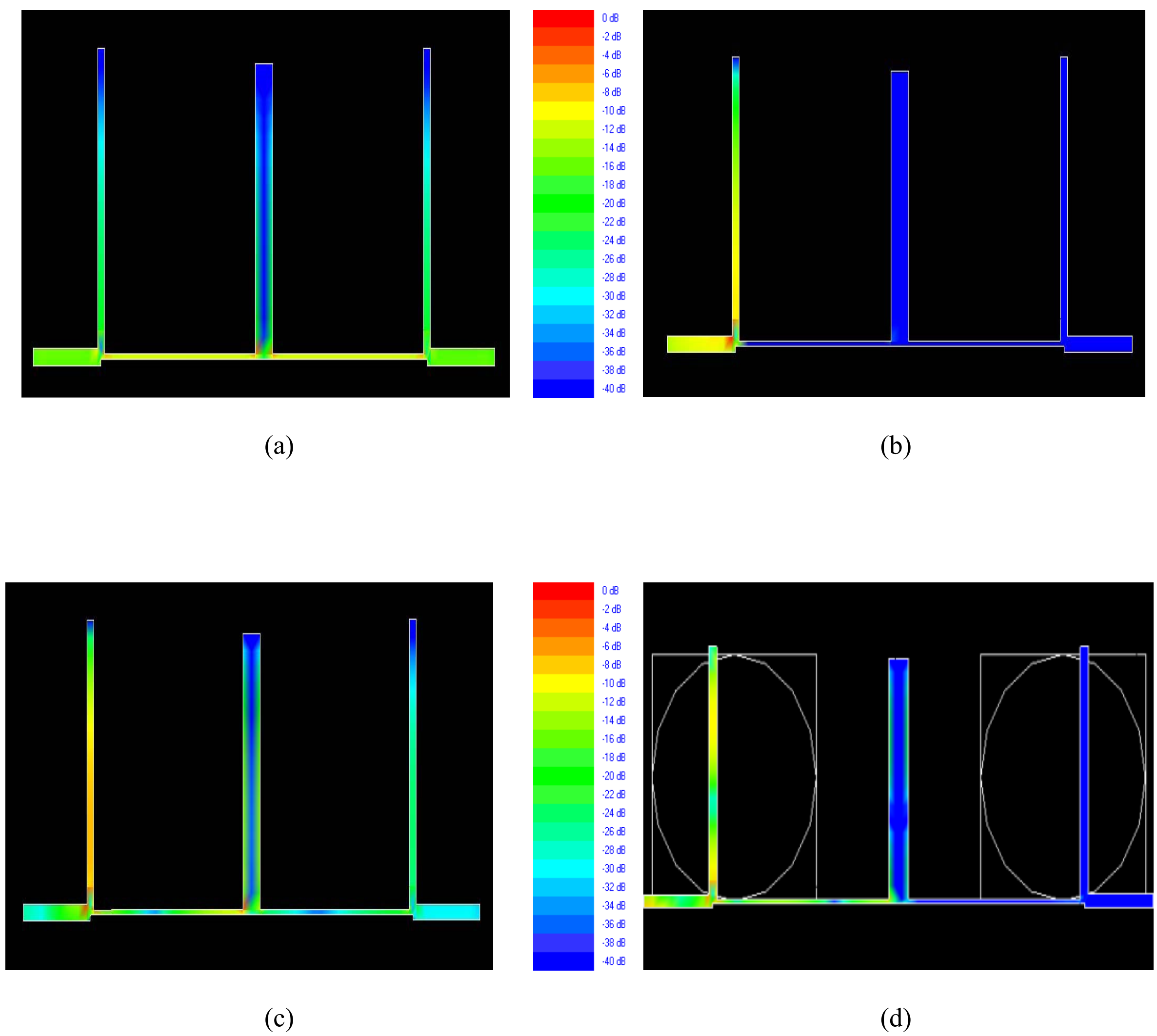

Fig. 8. Distribution of the magnitude of the current density on (a) $f_c = 0.4$GHz, (b) $f_c = 0.75$GHz, (c) $f_c = 0.9$GHz, and (d) $f_c = 2.25$GHz.

Figs. 6 and 7, respectively.

The results show good agreement with the numerical analysis, as there is suppression of the stop band at frequency, f = 2.25 GHz which has an insertion loss of nearly 22 dB, in contrast to -60dB for the conventional band reject filter. All the filters physically implemented on FR-4 'Glass/Epoxy', using conventional fabrication process. Since the Zeland IE3D software is based on the moments method, and the current distribution on filter elements is one of the primary quantities concerned, we use this program to analyze current distributions.

The current distribution function of proposed filter is shown in Figs. 8 (a-d). From the current distribution plots it is observed that the current concentration is nearly uniform for the low frequencies, and shows high attenuation at the center frequency 0.75GHz, whereas at a high frequency the distribution is completely non-uniform with more current concentration at the input port.

IV. CONCLUSION

It is observed from the simulation results that with the implementation of photonic band gap property in conventional microstrip filters, there is significant improvement in the frequency response. Spurious bands are undesirable for RF applications, and with the use of photonic band stop characteristics to forbid specific frequency bands, the proposed design may be very useful for wireless and mobile applications.

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REFERENCES

[1] K. L. Finch and N. G. Alexopoulos, "Shunt posts in microstrip transmission lines", *IEEE Trans. Microwave Theory Tech.*, vol. MMT.-38, pp. 1585-1594, 1990.

[2] J.-S. G. Hong and M.J. Lancaster, *Microstrip Filters for RF/Microwave Applications*, John Wiley & Sons Inc, 2001.

[3] D. M. Pozar, *Microwave Engineering*, John Wiley, 2000.

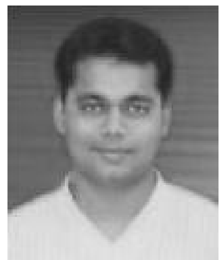
[4] IE3D Software Release – 8, Developed by M/s Zeland Software Inc.

[5] J. D. Joannopoulos et al., *Photonic Crystals: Molding the flow of light*, Princeton University Press, 2000.

[6] A. D'Ozario, et al., "Tapered Photonic Band Gap Microstrip Low Pass Filter: Design and Realisation", *IEEE Proc. Microwave Antenna Propag.*, vol. 150, no. 6, pp. 459-462, 2003.

[7] V. Radisic, et al., "Novel 2-D Photonic Band Gap structure for microstrip lines", *IEEE Microwave guided wave Letter*, vol. 8, no. 2, pp. 69-71, 1998.

[8] T. Lopetegi et al., "Novel band gap microstrip structures using network topology", *Microwave Opt. Letter*, vol. 25, no. 1, pp.411-412, 1999.



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