Performance of Two Microstrip Low Pass Filters on EBG Ground Plane

Anjini Kumar Tiwary, Nisha Gupta

Abstract – **This paper compares the performance of two microstrip filters designed and fabricated on an EBG ground plane. The proposed filter designs show sharp rejection and wide stop band. The design is based on the calculation of parameters from traditional high-low impedance method. A comparison of the results show that Chebyshev low pass filter offers wider rejection band width in comparison to maximally flat low pass filter designed on EBG structure.**

Keywords – **Electromagnetic Bandgap, Microstrip Low Pass Filter, High-Low impedance.**

I. INTRODUCTION

Modern communications, portable and array applications demand high performance compact filters that exhibit excellent pass band and stop band characteristics. Microstrip filters have attracted a lot of attention due to their intrinsically high performance, compactness, light weight and compatibility with MMIC technology. Conventional microstrip low pass filters with stepped-impedance provide good filtering functionality [1]. However, their filtering functionality is limited by the fabrication and their intrinsic loss such as ohmic metallic loss due to the width of the microstrip and radiation loss due to the large discontinuity. The introduction of electromagnetic bandgap (EBG) structure to the microstrip structure provides a powerful tool for the development of compact microstrip filters with high performance.

EBG structure is a periodic structure that prohibits the propagation of electromagnetic waves in certain frequency band at microwave or millimeter wave frequencies. EBG structure can be implemented on microstrip line by incorporating periodic structure either on substrate or on ground plane e.g. by drilling periodic holes through the substrate or by etching in the ground plane. The first method involves complexity in drilling through the substrate and is also difficult to model and analyze. However, the second method is easy to implement by just etching periodic patterns on the ground plane. Such structures have advantage of low cost and easy fabrication since they are compatible with standard planar circuit technology for microwave/millimeter wave applications. In the past most of the research has been focused on realizing high performance low pass filters with passband and out-of-band coincident with the EBG passband and stopband [2], [3].

The authors are with the Department of Electronics and Communication Engineering, Birla Institute of Technology, Mesra, Ranchi, 835215 Jharkhand, INDIA, E-mail: aktiwary@bitmesra.ac.in, ngupta@bitmesra.ac.in

EBG structures are also useful for constructing filters including band-stop filters and band-pass filters and are used to improve stopband performance of conventional lowpass and bandpass filters as well [4-11].

In this paper, response of a maximally flat low pass filter is compared with Chebyshev low pass filter fabricated on EBG ground plane. A prototype model is developed using low cost FR4 dielectric sheet and the simulated results are also compared with the experimental results.

II. THEORY

The centre frequency of the stop band of EBGs that satisfies Bragg's condition is calculated approximately with the following expression [12]:

$$ßa=\Pi \quad (1)$$

where, a is the period of the EBG pattern, ß is the wave number in the dielectric slab. The term ß is defined as

$$\beta = \frac{2\pi f_0}{C}\sqrt{\varepsilon_e} \quad (2)$$

where, f_0 is the Stop band centre frequency, ε_e is the effective relative permittivity of dielectric slab and C is the speed of light in free space. Using the above expression, the period for any stop band frequency can be determined.

III. DESIGN OF HYBRID EBG STRUCTURE

The Hybrid EBG structures are etched on FR4 substrate with a dielectric constant of 4.4 and thickness of 1.56 mm and loss tangent as 0.016.

A 5^{th} order Chebyshev filter with pass band ripple 0.01 is compared with maximally flat low pass filter with cut off frequency of 1GHz in both the cases. Method of analysis begins with the calculation of inductive and capacitive stubs with the help of traditional high-low filter design method.

The proposed hybrid structure is one in which the dimension and the period of the structure on the substrate as well as on the ground plane are perturbed simultaneously. The period and the dimension between the two centered EBGs are a_0 and d_0 respectively.

Full-wave electromagnetic simulation is performed using commercial software, Zeland IE3D. When the EBG structures on the ground plane and the signal line are placed as shown in Fig. 1(b), the simulation result shows no improvement in stop band phenomena.

However, the results of the extensive simulation process indicate that there should be an offset between the two structures [13]. It is observed that as the offset distance is varied, and with an offset of (1/8) a_0 to a_0 [as shown in Fig. 1(c)], the ripple in the pass band region are improved significantly along with the improvement in the rejection band width and rejection ratio in Chebyshev low pass filter. The optimum result is obtained at one quarter of the EBG period.

IV. SIMULATION RESULT AND DISCUSSION

A conventional low-pass stepped-impedance filter is designed for the performance comparison with hybrid EBG. The simulation starts with the conventional low pass filter (LPF) etched on the FR4 substrate as shown in Figure 1 for three different configurations such as conventional, slots in the ground plane and offset slots in the ground plane. The Figure 2(a) and 2(b) show the current flow in both pass band and stop band respectively. It is seen that the current flows without any attenuation in pass band region while its gets attenuated to a great extent in the stop band region and practically no current reaches the output port in stop band region. This in turn improves the stop band characteristics. The S-parameters characteristics for maximally flat LPF are obtained for all the three cases as shown in Figure 3. The offset slots structure generates an LPF response up to the 0.68 GHz with minimum insertion loss and 20 dB wide-rejection bandwidth from 2.12 GHz to 3 GHz as shown in Figure 3(b) in maximally flat low pass filter. On the other hand, a poor stop band phenomenon is observed for the second case when the slots are placed without any offset.

Next the Chebyshev low pass filter is designed for the same cutoff frequency for all the three cases namely the conventional, with slots and with offset slots. The S-parameters characteristics for Chebyshev LPF are obtained for all the three cases as shown in Figure 4. The structure with offset slots generates an LPF response up to the 0.56 GHz with minimum insertion loss and 20 dB wide-rejection bandwidth extending from 0.86 GHz. to 1.81 GHz and 1.85 GHz. to 3 GHz. as shown in Figure 4(b) in Chebyshev low pass filter. The design parameters for the offset slot EBG structure are listed in Table 1 and Table 2.

TABLE 1
FOR MAXIMALLY FLAT LPF

Periods in mm		Dimensions in mm	
a_0	55.6 mm	d_0	8.56 mm

TABLE 2
FOR CHEBYSHEV LPF

Periods in mm		Dimensions in mm	
a_0	57.0 mm	d_0	9.9 mm

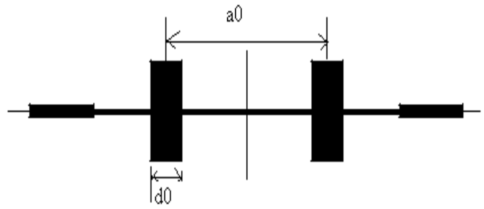

Fig.1(a).LPF Top view

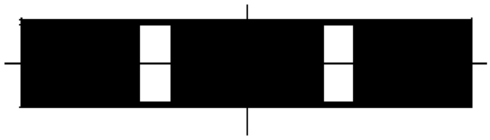

Fig.1(b).LPF Bottom view with slot

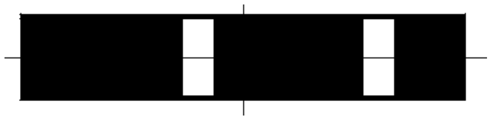

Fig.1(c).LPF Bottom view with slot and offset

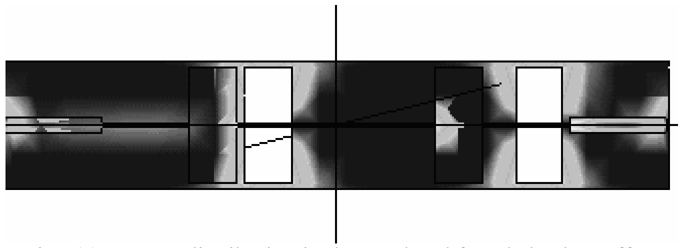

Fig.2(a).Current distribution in the passband for Chebyshev offset LPF

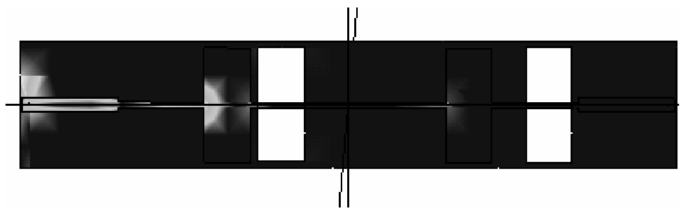

Fig.2(b).Current distribution in the stopband for Chebvshev offset LPF

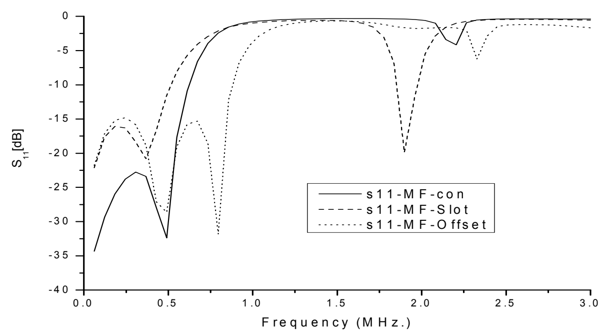

Fig.3(a). S11-parameters characteristics of a maximally flat LPF

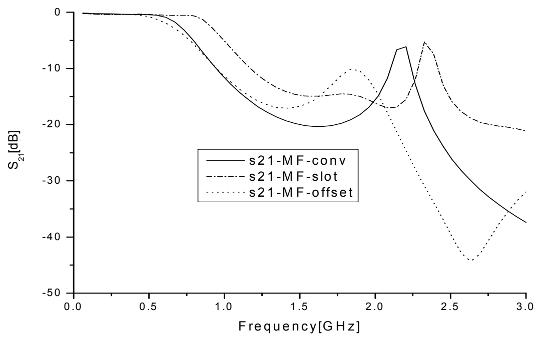

Fig.3(b). S21-parameters characteristics of a maximally flat LPF

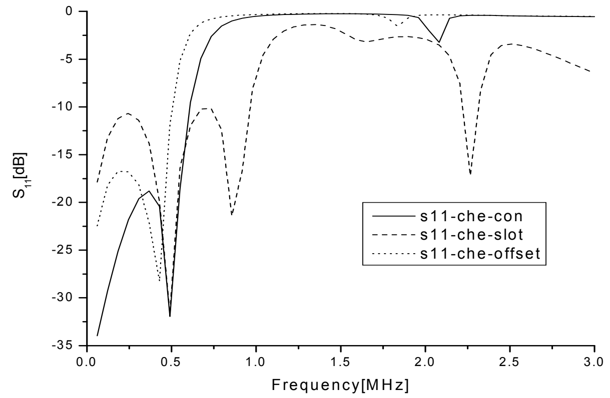

Fig.4(a). S11-parameters characteristics of a Chebyshev LPF

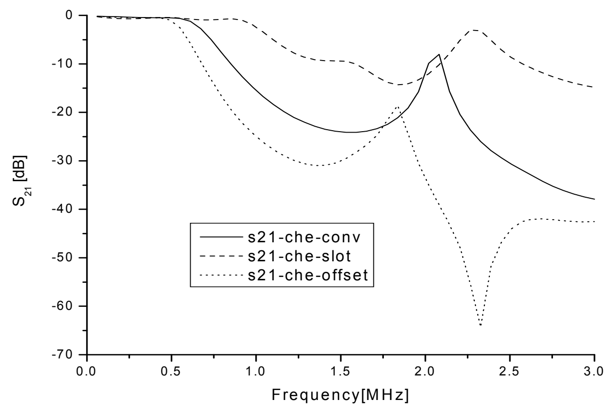

Fig.4(b). S21-parameters characteristics of a Chebyshev LPF

As seen in Figure 4(b), the maximum attenuation is around 64.03 dB at 2.33 GHz and an improved 20 dB rejection bandwidth is from 0.86 to 1.81 GHz and 1.85 to 3 GHz in Chebyshev LPF whereas in Figure 3(b) maximally flat LPF the maximum attenuation is around 44.30 dB at 2.63 GHz and an improved 20 dB rejection bandwidth is from 2.12 to 3 GHz. The 40 dB rejection bandwidth is 2.09 GHz to 3.0 GHz in Chebyshev LPF whereas in maximally flat LPF it is zero. This clearly shows that the offset slot EBG Chebyshev LPF has an enhanced performance, as compared to that of the conventional stepped-impedance filter in terms of higher rejection bandwidth. As a matter of fact, this phenomenon of improvement in stopband characteristics for the case of offset slot may be attributed to the existence of pole in this particular case which is absent for the case of conventional and with slots EBG LPF. Finally a prototype model is developed using LPKF PCB prototype machine. The performance characterizations of the fabricated filters are finally measured with PNA Series Vector Network Analyzer. The simulated results are compared with experimental result. As shown in Figure 6 and Figure 7, the characteristics of simulated result are almost similar to the result of the experimental one in both the low pass filters. The insertion loss characteristics also reveal low loss characteristics which help in minimizing the EMI.

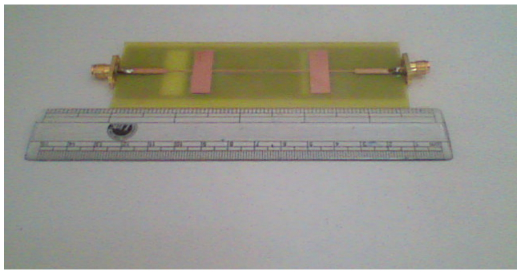

Fig.5. Prototype model of offset slot EBG LPF

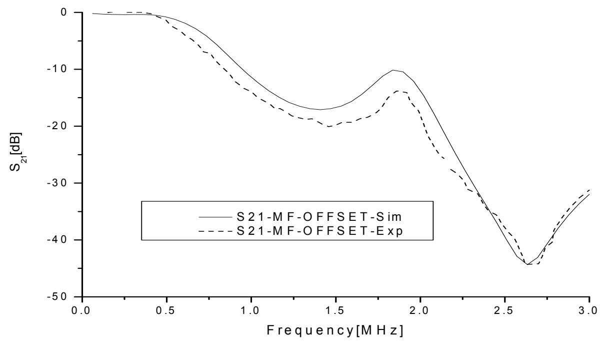

Fig.6. Comparison of simulated and experimental results for maximally flat LPF

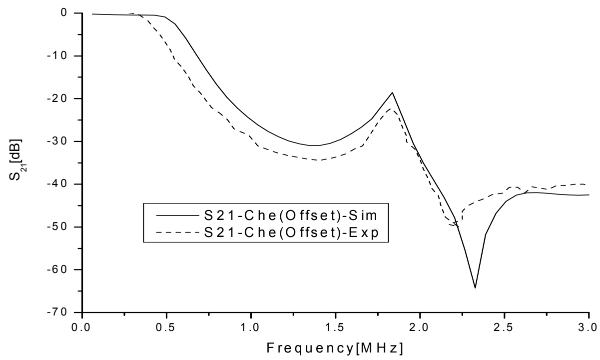

Fig.7. Comparison of simulated and experimental results for Chebyshev LPF

V. Conclusion

Chebyshev low pass filter and maximally flat low pass filter have been designed, simulated and fabricated for the conventional, with slots and with offset slots EBG patterns. The characteristics of the two show that Chebyshev low pass filter with offset slots of one quarter of EBG period has advantages of improved rejection bandwidth in comparison to maximally flat low pass filter. Further, the maximum attenuation is also higher in Chebyshev low pass filter in comparison to maximally flat low pass filter in the stop band region for offset slots EBG pattern. Therefore, the Chebyshev LPF with offset slots by one quarter of EBG period is very well suited for the EMI/EMC application.

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