MAT JOURNALS
Journal of Radio and Television Broadcast
Volume 3 Issue 2

Utilization of Electromagnetic Band Gap Cells for Performance Improvement of Co-Planar Waveguide Ultra Wide Band Filters

[1]K. Mohamed Ibrahim, **[2]H. Umma Habiba**
[1]Ph.D. Scholar, [2] Professor,
Department of Electronics and Communication Engineering, Sri Venkateswara College of Engineering, Sriperumbudr, Anna University, Chennai.
E-mail: *[1]vkmuhammad@gmail.com, [2]ummahabiba@svce.ac.in*

Abstract

This paper presents the characteristic design of compact coplanar waveguide (CPW) band pass filter cascaded with electromagnetic band gap (EBG) resonator. The electromagnetic band gap resonator used in this design reduces the size and suppresses the harmonic response of the filter. An accurate bandwidth is achieved by alteration incidences of the announcement zeros at the pass ensemble edge. The designed filter exhibits a good upper stop band with rejection greater than 25dB below 20GHz. Electromagnetic Band-Gap cells in combination with CPW structures are presented with good performance metrics.

Keywords: *electromagnetic band gap (EBG) resonator, compact coplanar waveguide (CPW), CPW-BPF*

INTRODUCTION

EBG structures can be investigated exhausting a number of procedures. These procedures collapse into three groupings: (1) Lumped element model, (2) Periodic transmission line method, and (3) Full wave numerical methods. The lumped constituent model is the unpretentious one that designates the EBG configuration as an LC resounding circuit (Shown in Figure 1). The beliefs of L and capacitance C are resolute through the geometry of EBG. And EBG's resonance behavior is used to explain the band gap feature of the EBG structure. The advantage of this model is it is simple to understand.

The disadvantage is that, the results are not very accurate because of the simplified approximation of L and C.

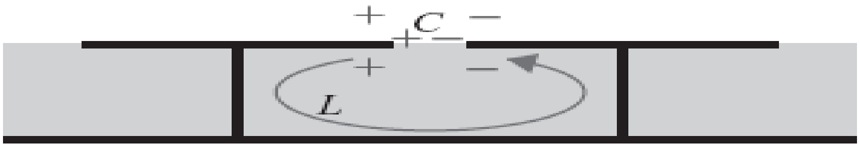

Fig 1: *Lumped LC model for EBG analysis*

In periodic transmission line method, Floquet periodic boundary condition is used. Numerical methods use both time domain and frequency domain approach for analysis of EBG structures.

RESONANCE BEHAVIOUR OF EBG

The EBG unit cells have an additional phenomenon which is self resonance[1]. At microwave frequencies, the unit cells are defined by a change of the characteristic impedance of the transmission line. Therefore the effects of self-resonances are expected to be proximal or even overlapping over the same frequency range [3].

It has been observed that the response of a unique cell of a periodic structure is wider and smoother (lower Q factor) than the frequency response of a resonator (higher Q factor).

DESIGN CONSIDERATIONS OF CPW

The three most common applications for CPW circuits are:

a) For high-frequency microwave monolithic integrated circuits (MMICs) where low inductance access to ground is critical;

b) Lower-frequency applications where backside processing may be challenging or cost prohibitive [such as fabrication of integrated circuits (ICs) on a SiC substrate],

c) And broadband applications where dispersion becomes an issue.

For high-frequency MMICs, practical substrate thickness and backside via inductance dictate whether to design in microstrip or CPW [2]. For instance, GaAs MMIC amplifiers have become commonplace and are commercially available from a variety of sources. For commercial processes at W-band, 4 Mil GaAs substrates are a common choice because they are easily handled and microstrip designs can still be successfully designed. However, limitations in device and bypass grounding begin to come into play.

A second very practical issue for microstrip designs at high frequencies is availability of low-inductance shunt capacitors for either bypassing or grounding. The impact of ground access by a substrate via is easily possible. Large amounts of current passes through the structure to the output microstrip line. A common practice to overcome this problem in millimeter-wave microstrip circuit design is to add radial stubs to the decoupling networks to bypass in-band frequencies by forming a virtual short circuit. The resonant geometry radial stubs typically use a considerably amount of chip real estate, which adds to the chip cost. Additionally, resonant geometry stubs on a moderately electrically thick substrate easily couple to adjacent structures. Therefore, accurate design requires a significant amount of EM simulations where possible coupling paths should be included in the simulation. This makes millimeter-wave microstrip time consuming and CAD intensive.

A final limitation to microstrip design at higher operating frequencies is due to limitations in backside processing. Therefore, it is expected that the highest-frequency MMIC circuits will continue to be implemented in CPW. One issue that must be carefully understood in CPW design [4] is the presence of other modes. There are a variety of modes that must be dealt with, or a design may suffer from unexpectedly high losses or visible resonances in the frequency response. These are coupled slot line mode, parallel plate CPW and ungrounded slot-line mode.

Potential excitation of the coupled slotline mode is prevalent in all CPW configurations (grounded or ungrounded) due to CPW’s three-conductor nature. Although the two outer conductors are considered to form a single conductor, in most places the two ground planes are not physically connected. This very fact means that another dominant mode called coupled slotline mode can propagate in the structure. For the CPW mode, the electric field starts on the center conductor and is symmetrically terminated on the two ground planes. For the coupled slotline mode, the three unconnected conductors are at different potentials and the fields in one of the slots of the CPW are seemingly reversed in direction. In practice, this undesired mode is easily handled by connecting the two ground planes. This places the two ground planes at the same potential and therefore shorts out the coupled slotline mode. This is done in MMIC circuits simply by using an airbridge. In practice, lower-frequency PCB and MIC circuits are connected to coaxial cables using connectors which should short the coupled slotline mode if soldered at both grounds. In practice, ground straps or airbridges are commonly attached at all discontinuities and periodically along electrically long CPW transmission lines.

ANALYSIS OF CPW STUBS

Shunt Short Stub and Folded Shunt Short Stub

A shunt short stub implemented on CPW structure consists of a CPW transmission line with short end in the adjacent ground metallic strips. For circuit symmetry, two grounds of center strip have the same circuit pattern. Air-bridges on the short-ended CPW are employed for odd mode suppression. The conventional CPW shunt short stub is shown in Figure 2.

This structure is known as a shunt resonator. Air-bridges are frequently employed at the other end to suppress the propagation of the parasitic odd mode (slot-line mode). To reduce the length of the short stub, the most straightforward way is to fold the structure.

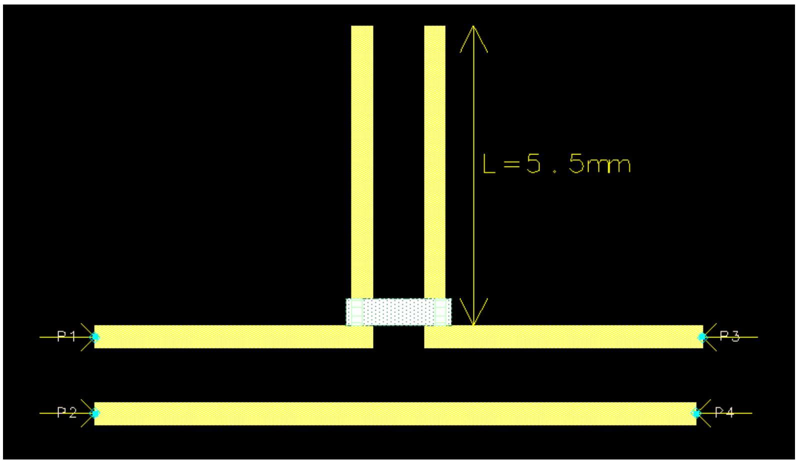

***Fig 2:** Layout of shunt short stub*

The compared S-parameters of shunt short-stub and folded shunt short stub with *Z1*=50 ohm characteristic impedance, are shown in Figure 3.

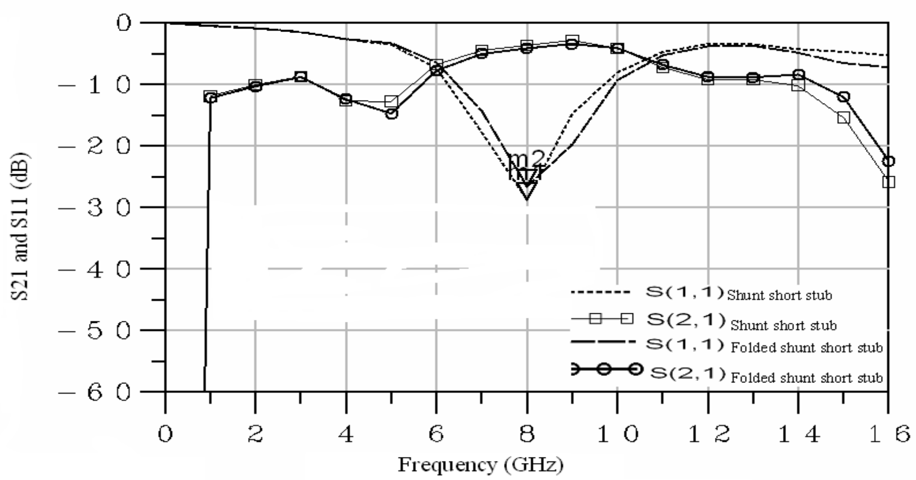

***Fig 3:** Comparison of Shunt short stub and folded shunt short stub*

From the transmission-line theory, these stubs function like a resonator and the fundamental resonant frequency is at about 8GHz and the transmission zero is at 10GHz.

Series Open stub and Series Short Stub

A series open stub (Figure 4) implemented on CPW structure, consists of a CPW transmission line with the center conductor slots on either side connected to each other. This creates an open-circuit at the end of the slots, which transfers to a short circuit at the input port at the resonant frequency and gives a bandpass response. A series short stub (Figure 5) implemented on CPW structure, consists of a CPW transmission line with short end in the center metallic strip. As current flows through this short section, current density has been changed. This short-ended section can be model as an inductor in lower frequency. The compared simulated S-parameter data of the CPW series open stub and series short stub structure is shown in Figure 6.

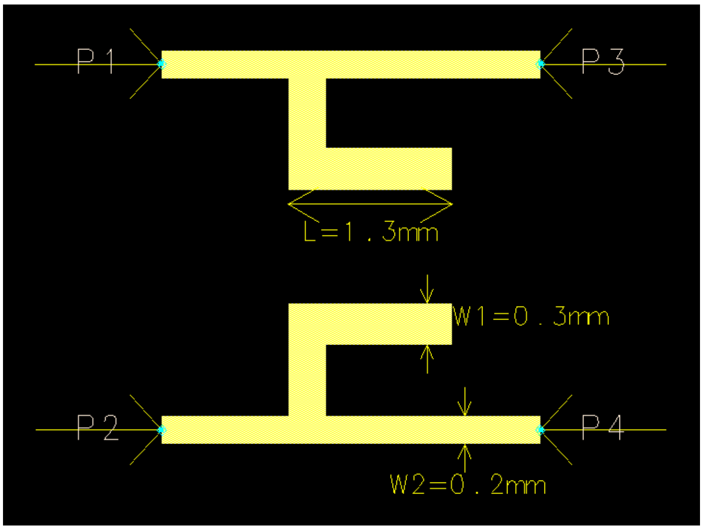

Fig 4: *Layout of Series Open stub*

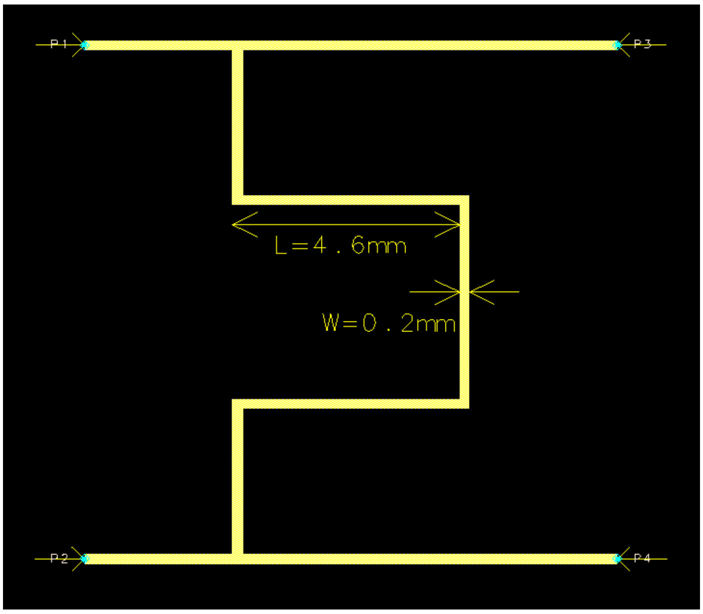

Fig 5: *Layout of Series short stub*

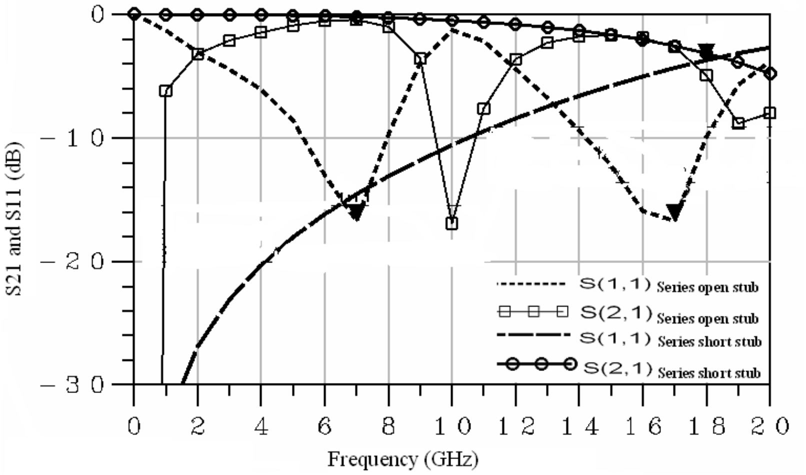

Fig 6: *Comparison of series open stub and series short stub*

DESIGN OF BPF WITH CPW RESONANT STRUCTURES

The configuration of the proposed CPW-BPF is depicted in Figure 7 and 8. The CPW-BPF is, in essence, the combination of folded shunt short stub and series open stub. The lower cut-off frequency basically dominates by folded shunt short stub, and the higher cut-off frequency dominates by series open stub. The simulated S parameters of the CPW-BPS with unfolded or folded shunt stubs are shown in Figure 9. It is shown that there is no significant difference in S-parameter data between these two cases, albeit both configurations lead to poor stopband rejection. However, the folded shunt short stub has the issue of radiation, and a series short stub can alleviate the radiation-loss. The slot-line portion of the folded short stub functions as a magnetic dipole antenna. Here, the CPW series short stub structure is added into the CPW-BPF in asymmetric configuration as shown in Figure 7 and 8. It shows that the energy transmit from different ports. When the energy is transmitted from port1, it will enter the folded shunt short stub, and radiated by the slot-line portion. On the contrary, transmitting from port 2, the energy will first encounter the series short stub structure. Then, the series short stub structure will soon take effect in the stopband, with most of the energy being reflected back. Only a minor amount of energy enters the slot-line portion, so the radiation-loss is unapparent.

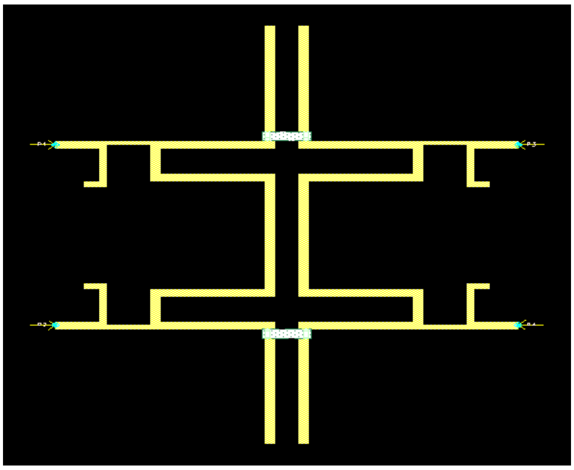

Fig 7: *Wide band CPW-BPF with shunt resonator*

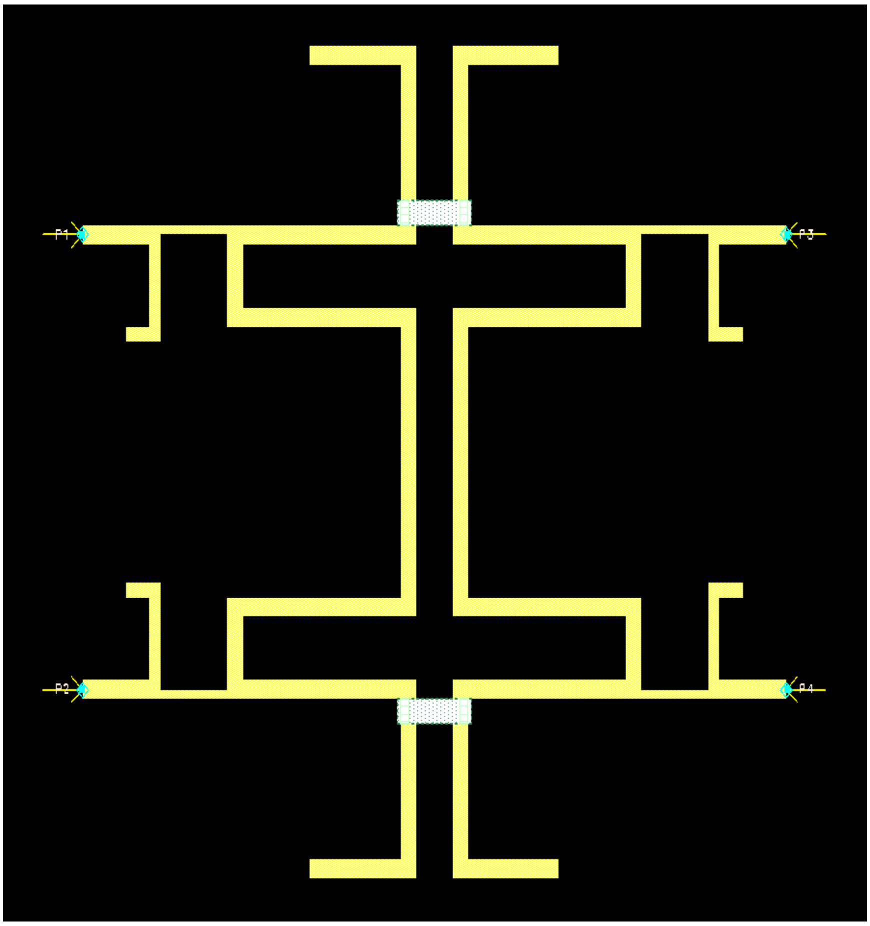

Fig 8: *Wide band CPW-BPF with folded shunt resonator*

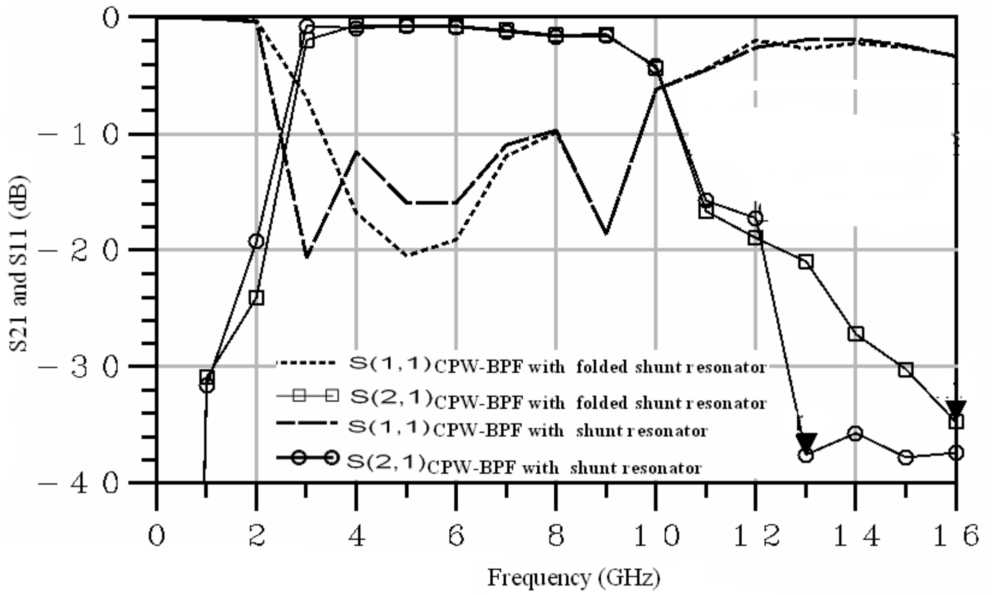

Fig 9: *Comparison of simulated responses of wide band CPW-BPF with shunt resonator and folded shunt resonator*

The simulated group delay response for Wide band CPW-BPF with shunt resonator and folded shunt resonator are shown in Figure 10 and 11.

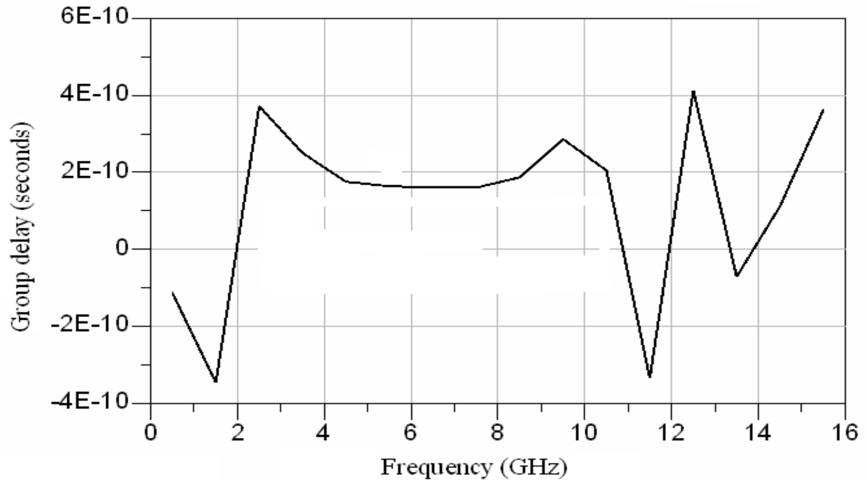

Fig 10: *Group delay response of CPW-BPF with shunt resonator*

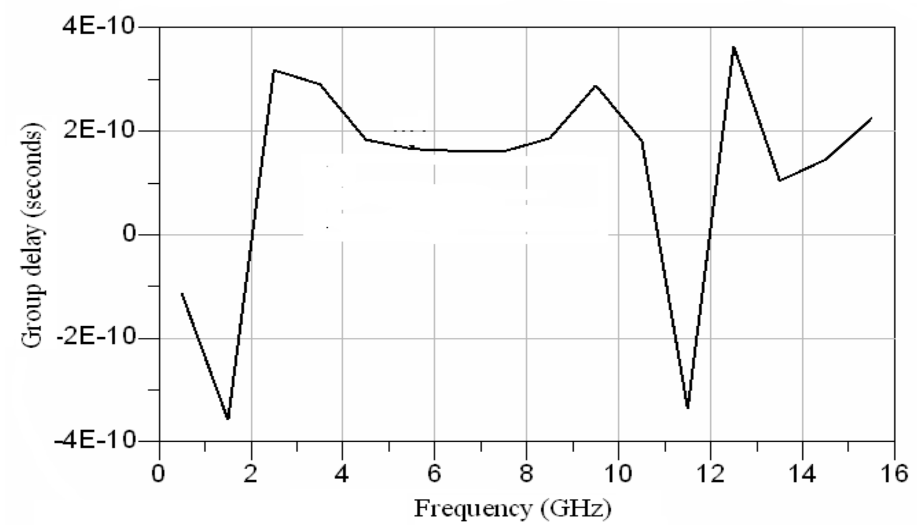

Fig 11: *Group delay response of CPW-BPF with folded shunt resonator*

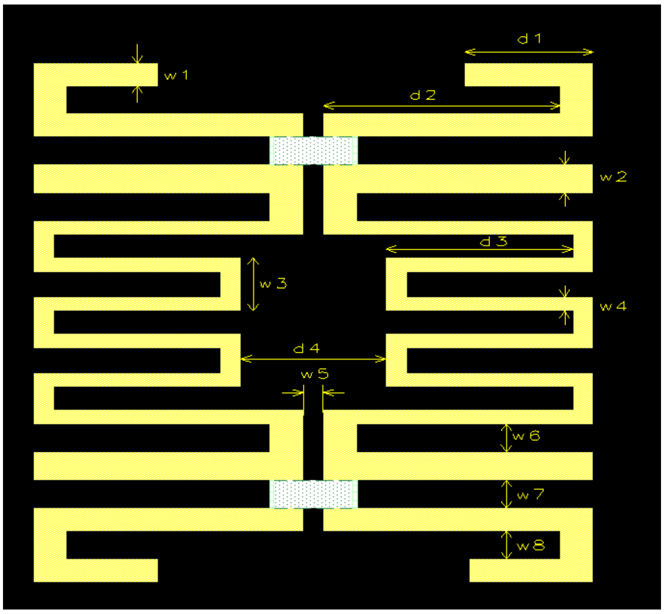

Fig 12: *Layout design of CPW-BPF*

MODIFIED BPF WITH CPW RESONANT STRUCTURE

In order to improve the performance, the CPW unit cell [6] is modified as shown in Figure 12.

Layout dimensions:
d1=3.1 mm,d2=5.7 mm,
d3=4.5 mm,d4=3.5mm,
W1=0.8 mm,W2=1 mm,
W3=1.9 mm,W4=0.5 mm,
W5=0.5, W6= 1mm,
W7 =1 mm.
W8= 1mm
unit cell

The simulated responses for insertion loss and return loss performances for various stub lengths W3 are shown in Figure 13. It can be seen that, the stub length W3 can be varied to get the desired response.

As it can be seen from the response, increasing the stub lengths from 1.8 mm to 2 mm improves the performance of insertion loss characteristics. But the return loss performance is observed to become better with decreasing stub length. Based on the specific application, the stub lengths can be chosen.

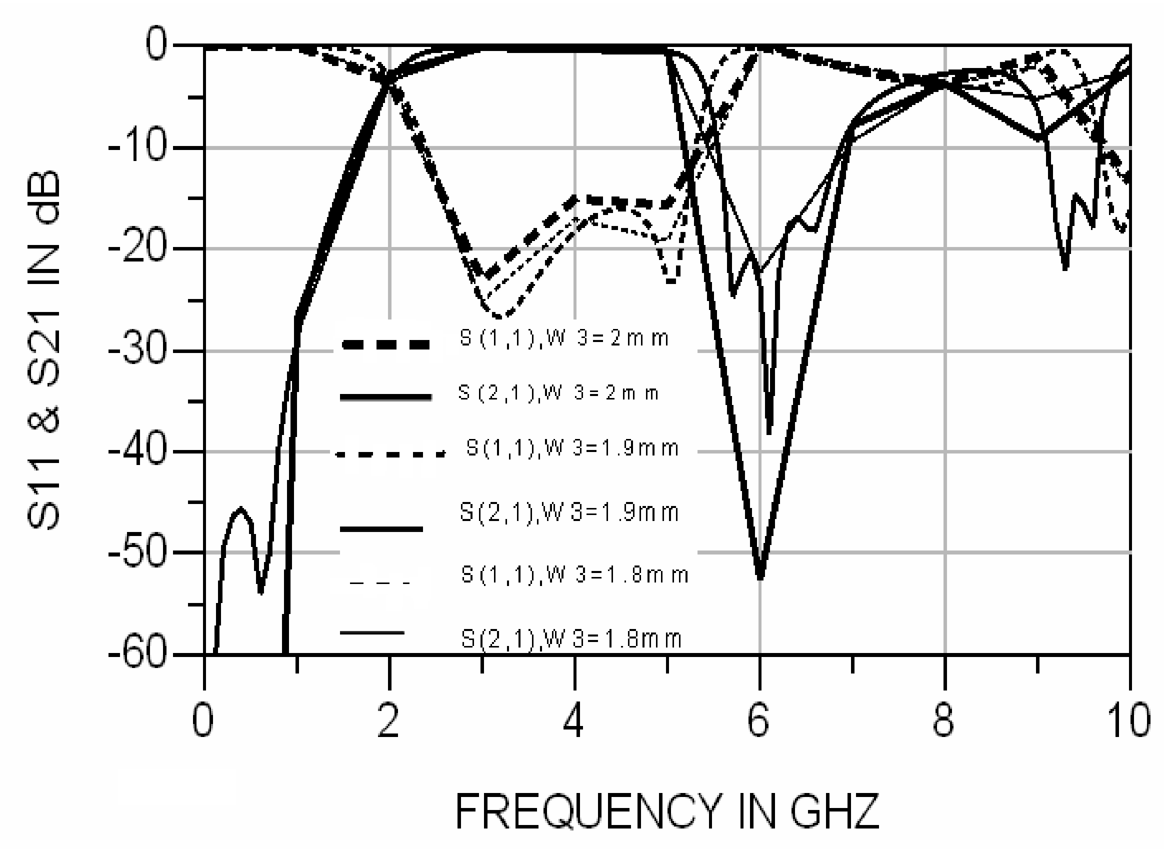

***Fig 13:** Simulated S-parameters of CPW- BPF unit-cell for different stub length of W3*

FILTER WITH CPW AND EBG UNIT CELLS

CPW – EBG Unit Cell

It is proposed to combine EBG unit cell with CPW structure to fine tune the performance further. The layout of CPW-EBG unit cell is shown in Figure 14. The simulated Insertion loss and return loss performances for various values of stub length d3 (shown in CPW-EBG unit cell structure), is shown in Figure 15.

It could be observed that varying lengths of stubs can be used to achieve the desired performance of insertion loss and return loss.

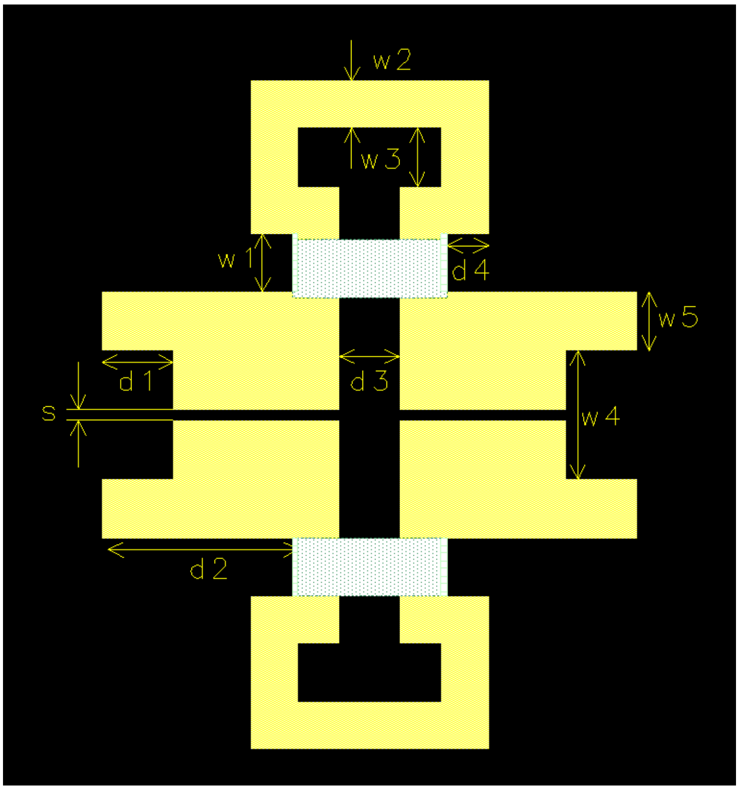

Fig 14: *Layout design of CPW-EBG unit cell*

Layout dimensions:
S=0.2mm,d1=1.2mm,
d2=3.2 mm, d3=1 mm,
d4=0.8mm,W1=1 mm,
W2=0.8 mm,W3=1 mm,
W4=2.2 mm ,W5=1 mm.

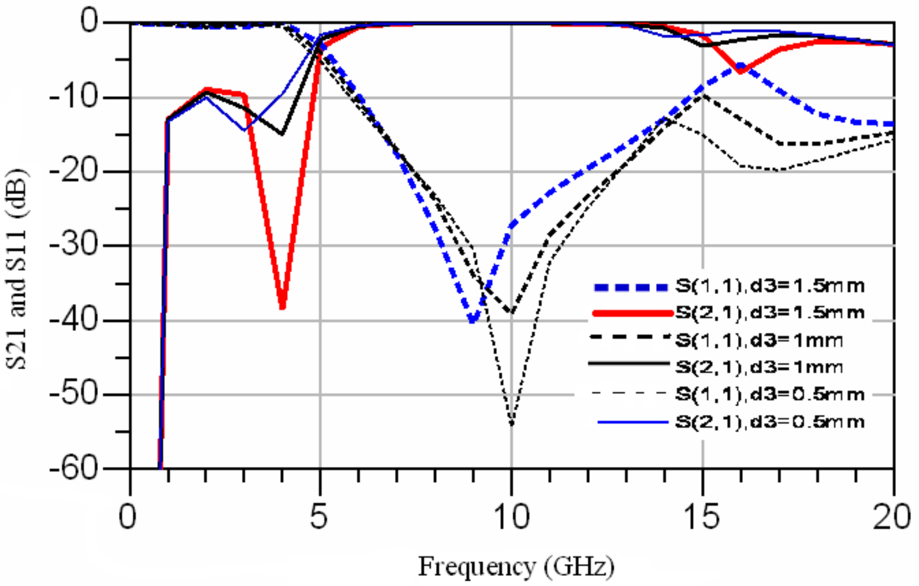

Fig 15: *Simulated S-parameters of the CPW-EBG resonator for different stub length of d3*

CPW and Slotted Line EBG Structure

The layout is composed of a low pass and high pass section [5]. By combining low pass and High pass structures, the upper and lower side band rejections can be separately designed. The 3 dB cut off frequencies of low pass and high pass sections are designed in such a way that the Band pass response of combined structure meets the proposed design requirement. Thus the desired bandwidth may be adjusted by a control of the cut-off frequencies of low pass and/or high pass sections. Compared to coupled resonator structures, realization of this filter will be easier. The low-pass and high-pass sections of the filter are accomplished by cascading low-pass unit-cell and high-pass unit cell structures periodically.

The layout structure is shown in Figure 16. Here, the slots on the signal strip and ground planes of CPW are used to realize the series inductor and shunt capacitor. The 3 dB cut-off frequencies of the low-pass and high-pass unit cell structures can be adjusted by varying their cell sizes. As seen in the simulated result (Figure 17), better stop band performance for the low pass and high pass sections have improved the upper and lower stop-band attenuation characteristics of the proposed filter. This technique of combining low-pass and high-pass periodic structures offers more design freedom for Ultra Wide band Band pass filter design.

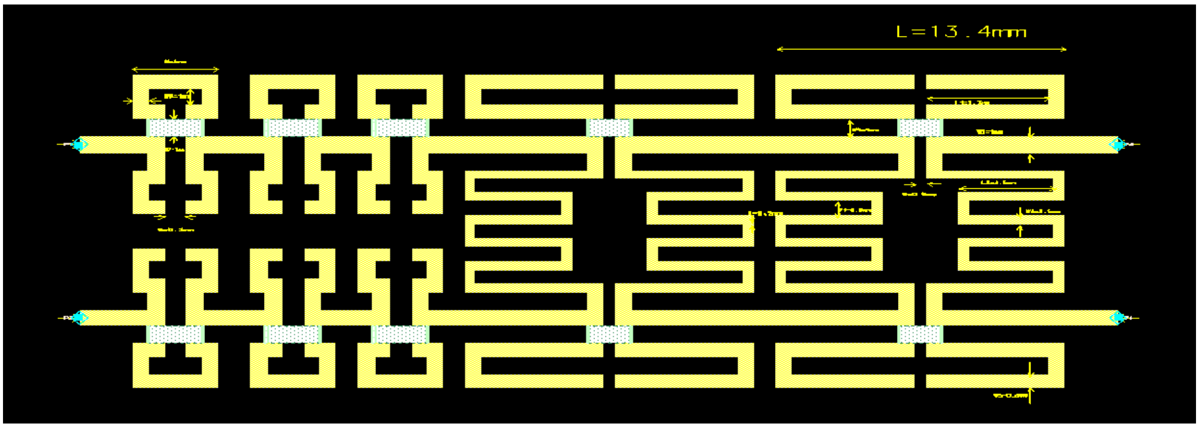

***Fig 16:** UWB filter using CPW – Slotted line EBG structure*

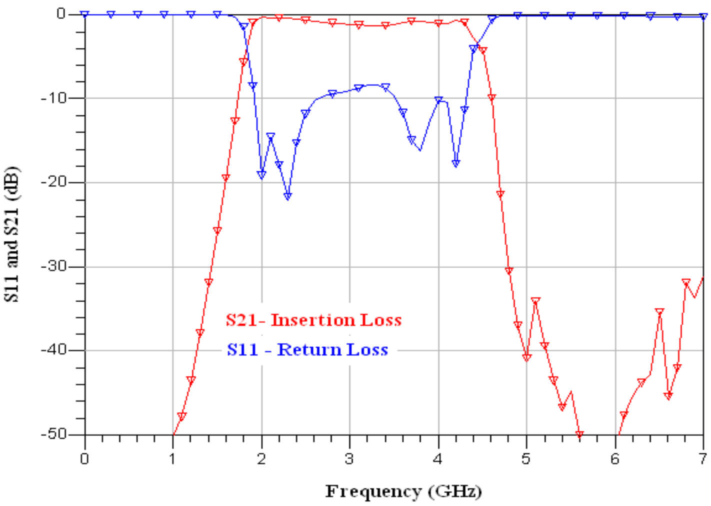

***Fig 17:** Simulated results for structure shown in Figure 3.16*

CONCLUSION

In this paper, wideband CPW band pass filters based on the cascade of low pass and high pass filters are proposed. The design of proposed band pass filter is accomplished by the separate design of low pass and high pass sections. The rejections for upper and lower stop bands for the proposed band pass filter can be improved separately simply by cascading more low pass and highpass unit-cell structures, respectively. By varying the unit cell size of the appropriate sections, the bandwidth is controlled and so comprehensively greater bandwidth is achievable. The sharper roll-off and better rejection ratios at stop-band make them suitable for Microwave Integrated circuit applications.

REFERENCES

1. Shuhong Fu, Chuangming Tong and Ximin Li, “Characteristics of A CPW Mushroom-Like Resonator and Its Application to Wideband EBG Filter”, Proceedings of International Symposium on Signals, Systems and Electronics (ISSSE2010), 978-1-4244-6355-8/10, ©2010 IEEE.
2. Al-Naib, I.A.I. and Koch, M. “Highly miniaturised single metal layer CPW bandstop filters based on spiral resonators”, Electronic Letters, Vol. 46, No. 18, 2010.
3. Arokiaswami Alphones and Jin Cheng, “Compact Interdigitated Microstrip Bandpass Filter with Meandered EBGs”, Proceedings of the 39th European Microwave Conference, Rome, Italy, pp. 439-444, 2009.
4. Atallah Balalem, Ehab K.I. Hamad, Jan Machac and Abbas S. Omar, “Bandpass Filters on a Modified Multilayer Coplanar Line”, 0-7803-9542-5/06/ pp. 531-534, ©2006 IEEE.
5. “Band pass Filter, Electronic device including band pass filter, and method of producing A band pass filter” Pub no: US 2007/0262834 AI, Pub, Date: Nov.15,2007
6. David M. Klymyshyn, Himal C. Jayatilaka, Martin Börner and Jürgen Mohr, “High Aspect-Ratio Coplanar Waveguide Wideband Bandpass Filter With Compact Unit Cells”, IEEE Transactions on Microwaves Theory and Techniques, Vol. 57, No. 11, pp. 2753-2760, 2009.