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Wideband Notched Balun with Bandpass Filtering Characteristic Using Liquid Crystal Polymer Technology

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Abstract **-** In this paper, A wideband microstrip/slotline coupling structure for filtering balun BPF with a notch is demonstrated here in this work. The presented work utilizes the technology of liquid crystal polymer (LCP) with particular application in multilayer circuits. The presented work is simple, have a really light weight, very cheap in cost and relatively miniaturized. For validation purposes of this process, an in-house prototype was initially designed, to be later simulated and fabricated demonstrating very good agreement. The broadside coupling mechanism is implemented in this approach in which it was further validated through a parametric study on the notching methodology.

Keywords**:** filtering balun, multilayer, microstrip (MS), slotline, wideband, broadside-coupling, liquid crystal polymer (LCP), notch.

1. Introduction

In recent days, for RF front-end, baluns having bandpass filtering characteristics (BPF) have received increasing attention and significant implementation in modern wireless systems for being used as a multifunctional passive device. This multifunctional performance combines both balun and filter functionality. A result, this multifunctionality not only provide the traditional unbalanced-balanced transformation yet, can also introduce frequency selectivity simultaneously. In the following, a balun BPF with dual-mode mechanism is proposed in [1] implementing ring resonators and using the inherent property of out-of-phase. Dual mode patch resonators are used to develop balun filter in [2]. Single-/dual- band balun BPFs are shown in [3]. Despite the good performances obtained in the reported works, they all can only provide narrow band performance. In [4] and [5], BPFs with wideband behaviour and good selectivity are designed using different topologies. However, the complexity and design footprint are considerably increased.

In order for the previously discussed issues to be appropriately addressed, particularly obtaining the desired broadside-coupling strength for wideband performance, the technology of liquid crystal polymer (LCP) applied for multilayer implementations is employed in this work which can facilitate an optimum solution for the previously discussed issues. LCP multilayer technology can principally offer excellent electrical and physical characteristics such as: low loss tangent, miniature designs, outstanding packaging flexibility, reduced cost, facilitated integration solutions and a specially unique thermal conductivity.

The frequency is highly valuable and limited as a resource. Therefore, the frequency spectrum is increasingly crowded due to many purposes. This results in having the spectrum being full of undesired signals when a specific operation is required and interferences may occur. Such unwanted signals include narrow band radio signals for instance: wireless local-area networks (WLAN). This issue can be tackled by introducing a narrow rejection band (notch) inside the desired passband [6]-[10].

The motivating goal of this work is to demonstrate a wideband filtering balun with simple structure and compact size with inexpensive realization. A multilayer broadside coupled microstrip/slotline resonators for balun BPF with embedded notch is introduced herein. The Design is etched on both sides of the substrate (top and bottom) in which strong coupling can be obtained using broadside mechanism. The fabricated prototype demonstrates a good agreement with the simulated results.

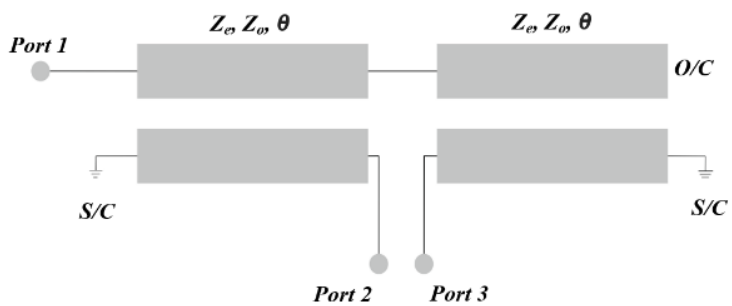
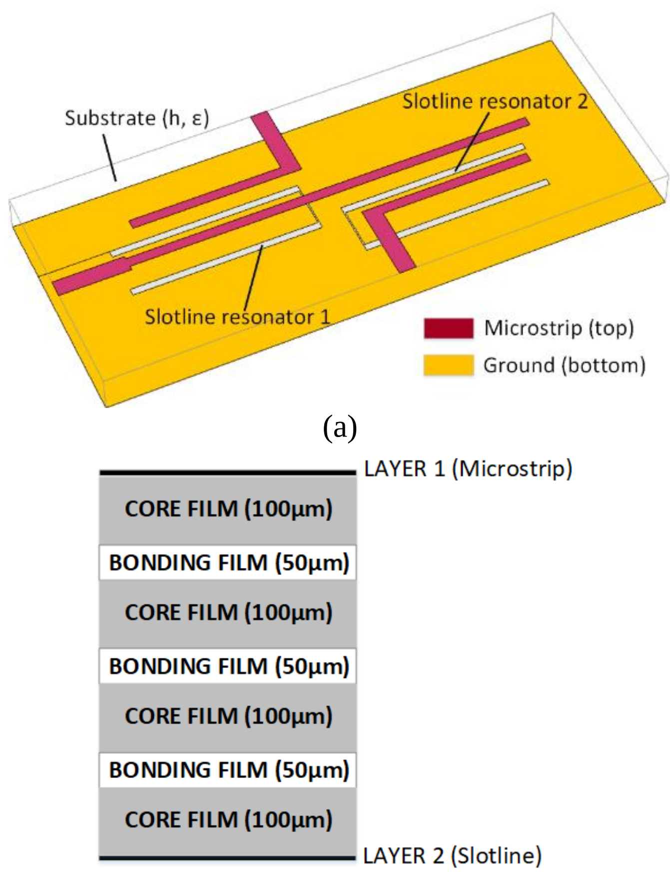


Fig. 1: Conventional Marchand balun with two sections implementing edge-coupling mechanism.

2. Design of Broadside-Coupled Balun and Analysis

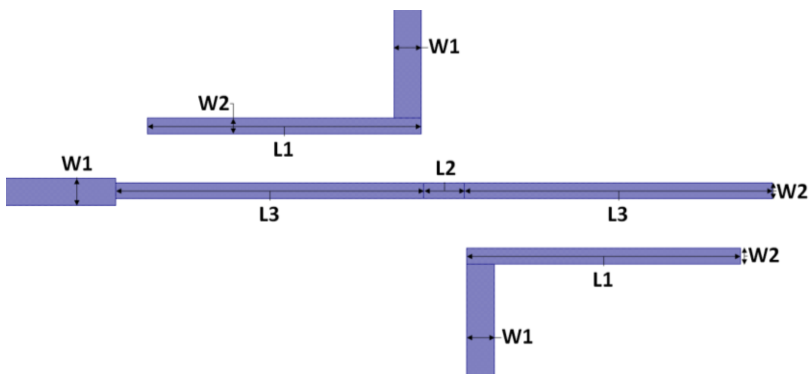
Fig. 1 depicts the famously well-known Marchand balun topology. It is formed by two edge-coupled lines using microstrips. In order to obtain wideband performance, the coupled section must have high coupling coefficient [11]. However, the conventional method of edge-coupled microstrip lines cannot obtain such strong coupling in the printed circuit board (PCB) fabrication for planar devices. Broadside coupling can provide the solution for this problem where in this paper, microstrip and slotline are broadside coupled demonstrating high coupling illustrated in a wideband operation. The 3D schematic for the broadside coupled wideband balun structure in addition to the stack of implemented layers used here in the multiple layers applied are depicted in Fig. 2.



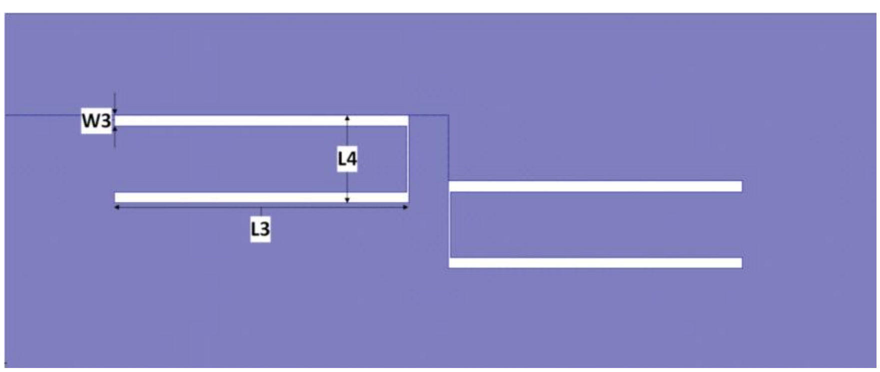
(b)

Fig. 2: (a) 3-Dimensional view of the design (without notch) and (b) cross-sectional view of the stack of layers used.

This design is fully constructed in one substrate having a thickness of *h* and a dielectric constant of ε_r. On the top side of the dielectric substrate, one microstrip line acts as single-ended feeding input line whereas the other two act as balanced feeding output lines using the broadside microstrip to slotline coupling mechanism. In principle, when port 1 (unbalanced) is excited, the signal is simultaneously coupled to the slotline resonators underneath with identical magnitude but out-of-phase. On the bottom side of the dielectric substrate acting as the ground plane, two half-wavelength short-circuited slotline resonators are realized in which they are folded in U-shape for size reduction and overall compactness. This study was performed using LCP material (dielectric constant ε_r =3, loss tangent tan δ =0.0025) with overall thickness of height (h=0.55 mm). It is crucial to mention that core films in LCP technology have a various melting temperature equal to *315°* in contrast to *280°* for bonding films of the same material for which a lamination process was created for this multilayer prototype fabrication. In Fig. 3, both layers (top and bottom) employed in this work are separately illustrated with the associated dimensions corresponding to each one as follows: W1=1.2, W2=0.7, W3=0.5, L1=12, L2=1.8, L3=13.5 and L4=4 (all measures are in millimetres).



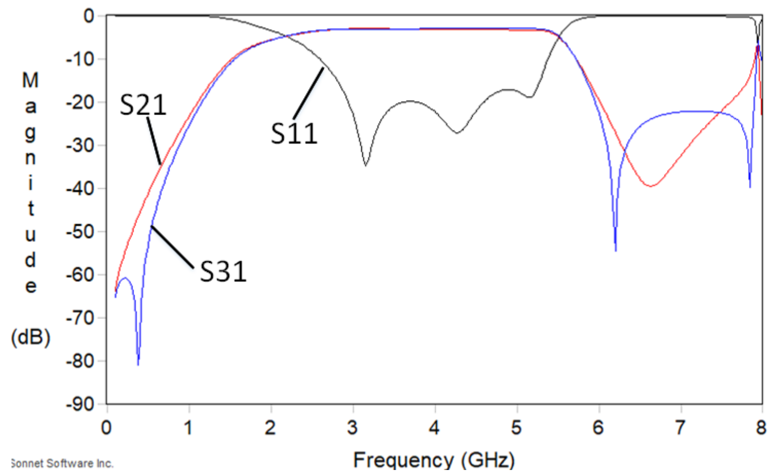
(a)



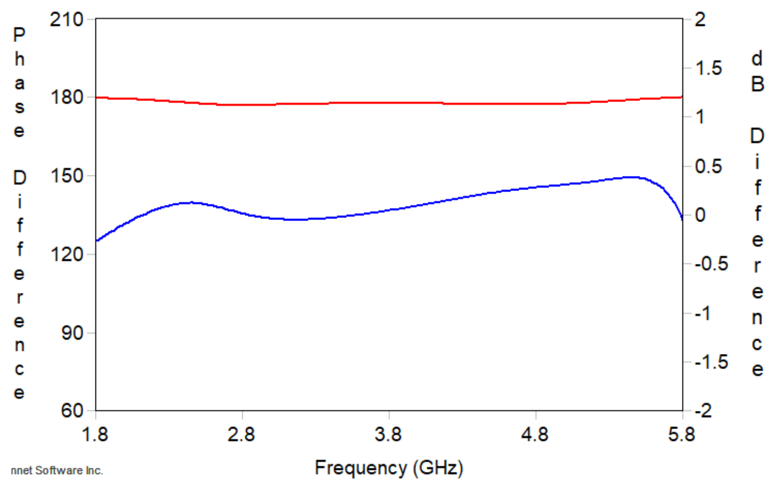
(b)

Fig. 3: Schematic dimensions (a) top side (b) bottom side.

Fig. 4 demonstrates the simulated results of the design including *S*-parameters as well as phase and magnitude balances. Three transmission poles can be observed inside the passband which is caused by the slotline resonators and I/O microstrip transmission lines, while transmission zeros outside the passband are caused by I/O microstrip lines cross-coupling. The simulated in-band return and insertion losses are better than 17 dB and 0.37 dB respectively. On the other hand, the phase difference was found to be about ± 3.0° whereas the magnitude difference is around ± 0.4 dB across the wide frequency band.



(a)



(b)

Fig. 4: Simulated response. (a) S-parameters. (b) Phase and magnitude balances.

3. Notching Structure

Due to the increasingly crowded spectrum and existing radio systems using narrow band signals within the WB passband, such as IEEE 802.11a WLAN and others, the demand for and balun filters capable of suppressing such signals is ever increasing. Fig. 5 presents the notching structure implemented in this work.

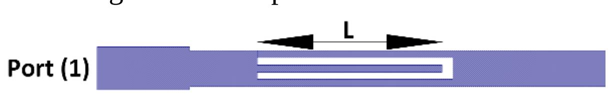


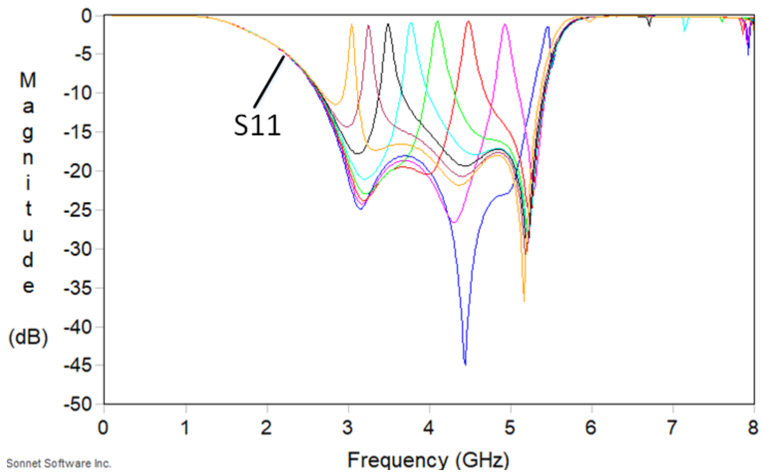
Fig. 5: Implemented notching mechanism.

The notch band can be controlled and applied at any desired frequency using various parameters. In order to study the effect of parameter (L) on the allocation of the notch within the passband, a parametric sweep was performed resulting in various resonant frequencies of the corresponding notch as shown in table 1 and demonstrated in Fig. 6.

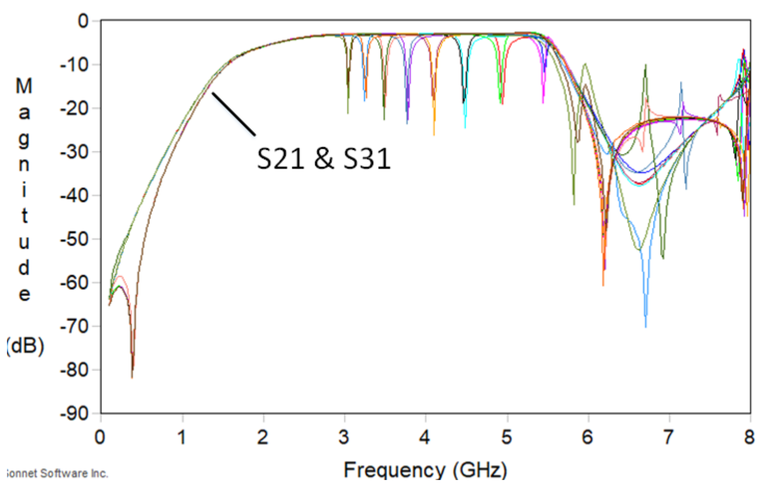
As a result of presented discussion and analysis, a wideband microstrip slotline broadside-coupled notched filtering-balun was initially designed, later simulated and eventually fabricated with centre frequency of 3.75 GHz GHz and 93% 3-dB FBW. The proposed prototype was manufactured using in-house fabrication facilities to be be later measured using a Microwave Network Analyzer (N5225A PNA).

Table 1: Parametric sweep of (L).

L (mm)	Frequency (GHz)	L (mm)	Frequency (GHz)
9	5.4	13	3.7
10	4.9	14	3.4
11	4.4	15	3.25
12	4.0	16	3.0



(a)



(b)

Fig. 6: Parameter (L) sweep. (a) return loss [S_{11}]. (b) Insertion loss [S_{21}].

Simulation and measurement responses of the fabricated prototype for *S*-parameters responses are shown in Fig. 7. It can be easily realiszed that the graphs for the simulation and measurement responses show good agreement with exceptional minimal variations may be attributed to tolerances in fabrication. The fabricated prototype's photograph is illustrated in Fig.8.

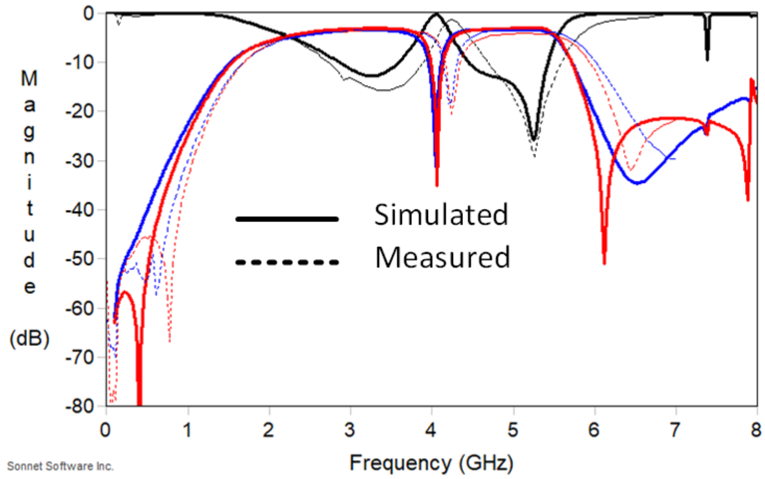


Fig. 7: Simulated and measured response of the fabricated prototype.

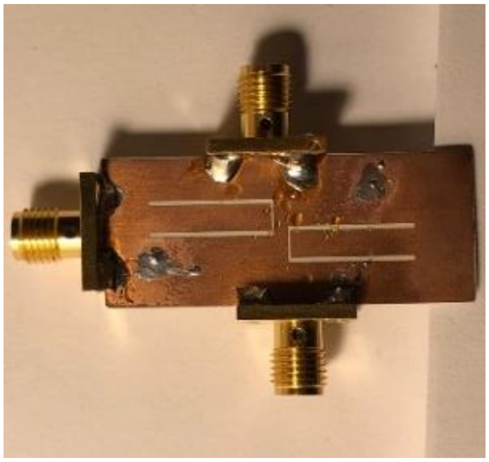


Fig. 8: Photo of the fabricated prototype.

4. Conclusion

In conclusion, this paper presents a new balun bandpass filter operating in wideband passband. This was achieved using microstrip/slotline resonators in broadside coupling mechanism. This is accomplished via the absolute flexibility introduced by multilayer LCP technology. The fabricated prototype of the notched balun filter demonstrates the validity of the design in which simulated and measured results are in good agreement.

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