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Novel ultra-wide band stop filter on silicon and alumina

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Abstract- **Ultra wide band compact band stop filter topology is proposed for working from C to K band. The structure has been fabricated and tested on both alumina and silicon substrates with two different thicknesses. It is demonstrated that substrate thickness plays a major role in determining the effective bandwidth. The tested bandwidth of the proposed topology exceeds 100% on 25mil substrate which further enhances to 150% on 10mil substrate without compromising the RF performances. Measured performance shows stop band transmission loss better than 2.5 dB with return loss more than 10 dB for both the substrates.**

Index Terms- **Dual behavior resonator, band stop filter, attenuation zero, stepped impedance resonator (SIR), open stubs**

I. INTRODUCTION

Band stop filter is an important noise reduction device in communication trans-receivers and radar systems associated with filtering out unwanted signals and passing out the desired ones. Several microwave components such as diplexers, switches, local oscillators, mixers are composed of band stop filter. Present days wireless sensor networks also comprise of the band stop filter. Size reduction of the band stop filter without compromising its performance is a very important consideration for wireless communication systems. Reported planar topologies such as shunt connected L-resonator [1], microstrip inter-digital resonator [2], spur line filters [3] etc. are all suitable for the narrow stop band operations. For wider stop-band, photonic band gap as well as defected ground plane structures have been widely applied to microwave and millimeter wave systems [4, 5]. In these structures, the stop-band is dependent on the etching in the ground plane resulting in large dimensions and alignment problems between the signal strip-line and the ground plane. The structure reported by Wang & Her [6] overcome this limitation and shows compact filter structure utilizing stepped-impedance resonator approach (SIR) in spurline topology. However this structure needs extensive CAD optimization and needs tight fabrication tolerances for desired performances. The structure shown by Hsieh and Wang [7] is also band limited and maximum achievable bandwidth with it is 70%. Bandwidth more than 100% may only be achieved when either circuit crosses theoretical limits or the design gets modified accordingly [8]. In this communication we propose a new design effectively using coupling and impedance variations to achieve wider bandwidth to cross the barrier of 100% bandwidth reaching up to 150% using a single topology.

II. ANALYSIS OF THE PROPOSED TOPOLOGY

Proposed filter is designed using transmission lines and utilizing coupling effectively for the placement of attenuation zeros. Transmission lines with different impedances construed as stepped-impedance resonator is used to effectively place zeros and poles. It is found that the impedance and length ratio can be simultaneously varied to enhance bandwidth of the filter. Optimum impedance ratio and length is finalized keeping fabrication aspects into consideration. Transmission zeros are purposely located at lower frequency to achieve high skirt selectivity. On contrary, it is adequately situated at higher frequency, to increase rejection bandwidth. In brief, asymmetrical stub placement along with varying width is used for the optimization of the bandwidth. The proposed topology as shown in figure 1 consists of input and output transmission line of half-wavelength (3 mm) followed by four sections of bended open circuited lines having coupled interaction shown through 'A', 'B' and 'C' in figure 1. The λ/2 transmission lines are used to tune the frequency response by optimizing the impedance value associated with line width. Each coupled section is quarter-wavelength at the center frequency and the upper section which is combination of 'A' and 'B' have been chosen to have impedance ratio less than 1 whereas bottom section consisting of 'B' and 'C' have been chosen for impedance ratio greater than 1. Little length optimization has been carried out to compensate the losses. Coupling 'B' depends primarily on the gap which is kept around 0.14 mm. This arrangement result in ultra wide bandwidth which can be attributed to the change in modal phase velocity encountered in coupled sections [9].

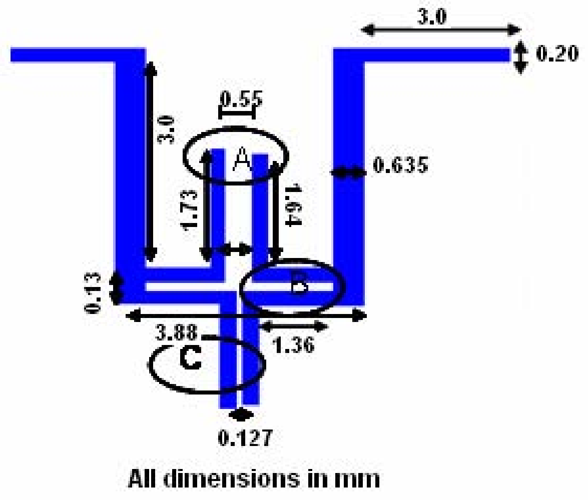

Figure 1. Proposed structure with dimensions

III. FILTER FABRICATION

The band stop filter discussed here is fabricated on the alumina (10 mils, 25 mils) and on silicon substrates (675µ) respectively. Fabrication steps on alumina are standard lithography methods but on silicon, extra steps related to metallization are added. After subjecting to standard thin film substrate cleaning cycles, high resistivity silicon substrates are sputtered with thin layer of chromium (200 – 300A°) followed by 7000A° of gold film on both sides of substrates. The sputtered metallization is electroplated with gold to achieve required thickness of 4.5 µm ± 3% and circuits are patterned using standard optical lithography and subtractive etching process.

IV. MEASURED RESULTS

Filters realized on the alumina and silicon substrates are tested using the vector network analyzer PNA (8261A). Filters are extensively simulated using electro-magnetic CAD tool [10]. Layout of the fabricated filter on 10 mils alumina and comparison of the simulated and measured results are shown in figure 2. Results demonstrate return losses of 28 dB in wider stop band with less than 2.5 dB insertion loss. With the available resources, calibration is carried out up to 26.5 GHz only. Total size comes out to be around 5.5 mm x 5.5 mm. Further the structure is patterned and tested on 25 mils (635 µm) alumina and 675 µm silicon. Comparison of simulated and measured results on silicon substrate is shown in figure 3. It is observed that there is a close agreement between simulated and measured performance which is further verified on 25 mils alumina substrate. Performance comparison of all the fabricated and tested topologies is shown in table 1.

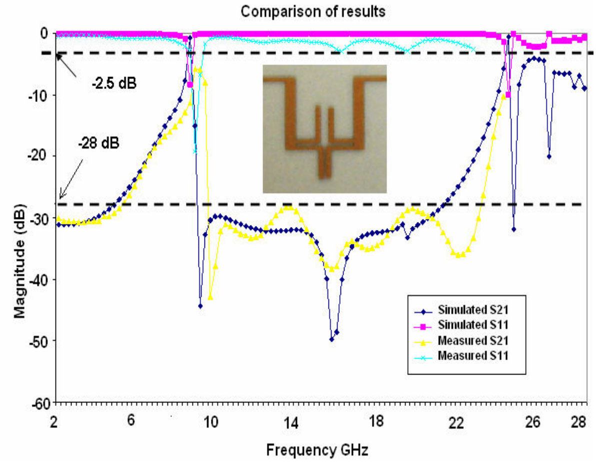

Figure 2. Ultra wide band BSF topology on alumina substrate

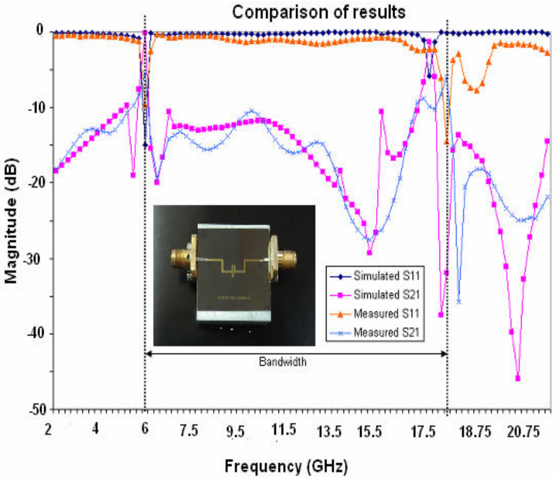

Figure 3. Layout and comparison of results on silicon substrate

Table 1: Comparison of results on different substrates

Specs	Alumina (250 μm)	Alumina (635 μm)	Silicon (675 μm)
Return Loss (dB)	> 28	> 12	> 10
Insertion Loss (dB)	<2.0	<2.0	<2.5
Freq. Range (GHz)	9-25	5.8-17.8	4-16

The band pass characteristics of the filter as evident in Fig 2 shows a very sharp and narrow band characteristics having the insertion loss of less than 2 dB with return loss of around 10 dB in 200 MHz band at the lower end i.e. 8.5 GHz-8.7GHz as well as at the upper band lying between 24.15GHz - 24.25 GHz. The same characteristics are observed on silicon substrates as shown in Fig 3 having higher losses within 200 MHz bandwidth. The results degrade with silicon due to its limited resistivity resulting in surface wave propagation in association with calibration error at the higher end of frequency band.

VI. CONCLUSIONS

Ultra wide bandwidth topology is constructed by utilizing simple concept of shorted coupled sections. This is for the first time new topologies with more than 100% bandwidth along with better electrical characteristics have been reported. The effect of different parameters on the overall performance has been studied using electro-magnetic simulation tools. Same configuration has been fabricated on alumina and its performance is compared with that on silicon. The present analysis also demonstrates that high resistivity silicon substrate can be effectively used as an RF substrate for future RF-CMOS applications. This topology can find extensive applications in instrumentation and for effective suppression of harmonics encountered frequently in active circuits both in MIC and MMIC. It will also be highly useful for narrowband band pass filter with sharp rejection characteristics.

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