# Quarter-Wavelength Side-Coupled Ring Filter with Open Stubs for Narrow Dual-Band

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*Abstract* – **In this paper, a combination of a side-coupled ring resonator with two open stubs is proposed to exhibit a dual band filter response. The dual band filter is fabricated on FR4 microstrip substrate and the measurement results are found to be coherent to the simulation.**

***Index terms*** **– Microstrip ring, dual-band, open stubs**

## I. INTRODUCTION

Modern wireless communication nowadays such as GSM and WLAN, require devices with multiband characteristic such as dual band RF antenna and passive filters. Regarding to the increasing demand of compact and economical filters, several topologies of dual-band bandpass filters were designed and extensively studied [1-4].

Due to compactness, good performance in microwave frequencies, dual resonance capability and transmission zeros in the rejection band, microstrip ring resonator was chosen as a popular topology for bandpass filters application with the ability to generate narrow resonances at specific frequency [5]. Each topologies were invented depending on the required bandwidth such as coupled line filters for narrow bandwidth, dual behaviour resonator filters for very narrow bandwidth and more [6, 7].

The previous microstrip ring resonator design in [3, 8, 9], required the adjustment of the perturbation along the ring and/or the adjustment of the coupling gaps. But there are tiresome calculations engaged at the early design state of this type of resonator. Then, a complete synthesis was presented in recent development, which simplified the design step of the dual mode resonator [6, 10]. An example of ring resonator topology and its response is given in Figure 1. The electrical characteristics (bandwidth, matching level in the passband and transmission zeros frequencies) of the resonator can be controlled by varying the lines impedance of the ring and the even- and odd- mode coupled line impedances.

In this paper, a dual band filter was proposed by combining a side-coupled ring resonator with two open stubs. The topology was based on the quarter-wavelength side-coupled ring resonator that was presented in [10] and [6].

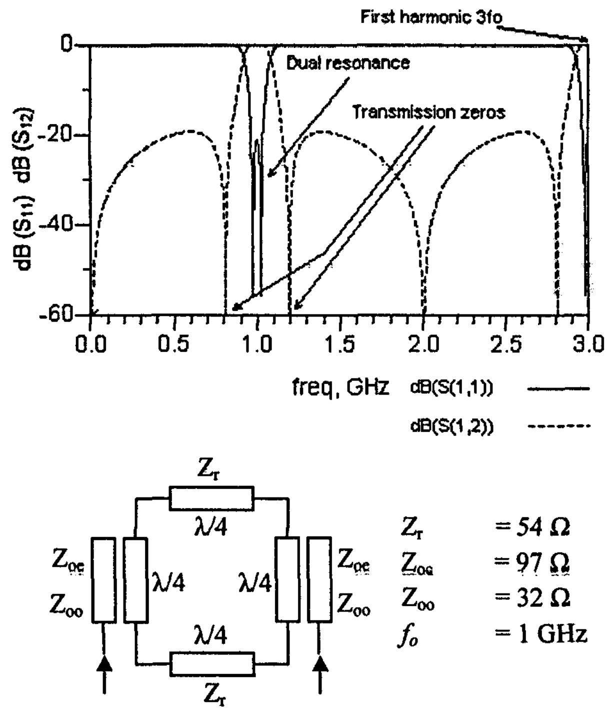



*Figure 1: The ring topology with an example of frequency response.*

The complete filter topology was further described in the next section. It was then followed by a section describing its realization using microstrip technology. Simulation results were compared to the experimental ones at the end of this paper.

## II. THE QUARTER-WAVE SIDE-COUPLED RING FILTER WITH OPEN STUBS TOPOLOGY

The topology for quarter-wavelength side-coupled ring filter with two open stubs for narrow dual-band was shown in Figure 2. The total perimeter length of the ring was equal to one wavelength at the resonant frequency, $f_o$ and in/out feeding were performed using open-ended quarter-wavelength lines. The open stubs were added to give out the dual-band response whereas; the characteristics that existed based on side-coupled ring resonator were still maintained.

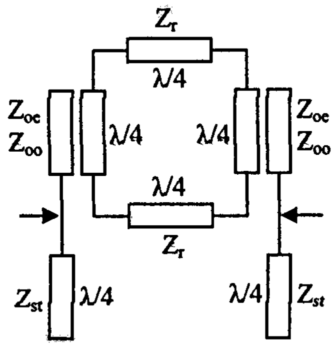



Figure 2: The dual band ring filter topology.

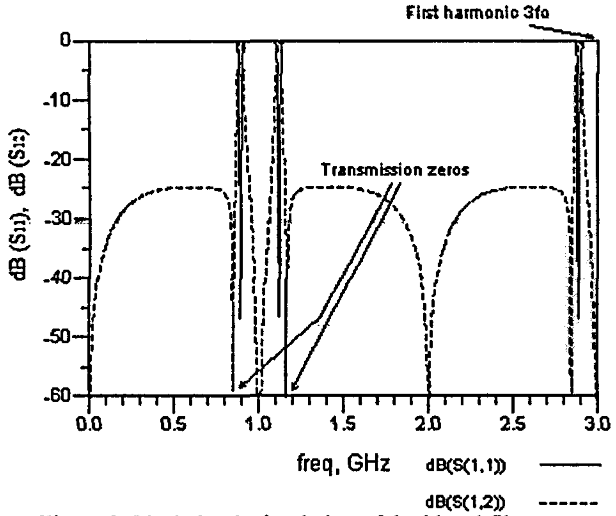



Figure 3: Ideal circuit simulation of dual band filter.

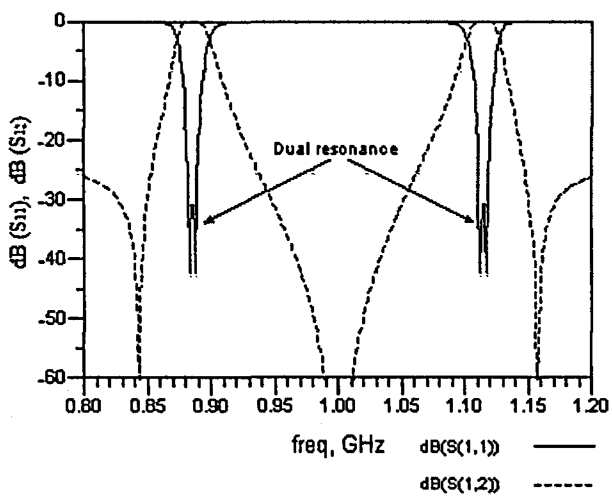



Figure 4: Frequency response of the dual band filter with dual resonance behaviour.

The response of the filter can be controlled via characteristics impedance of the ring ($Z_r$), characteristic impedance of the stub ($Z_{st}$), even-mode characteristic impedances ($Z_{oe1}$ and $Z_{oe2}$), and odd-mode characteristic impedances ($Z_{oo1}$ and $Z_{oo2}$) of the coupled lines. These parameters were involved during the design process of this filter.

Based on quarter wavelength side-coupled ring topology presented in [6, 10], the bandwidth variation can be controlled by fixing $Z_{oe}$ and choosing the desired ripple level and the transmission zero frequency. This method then was utilized to do the adjustment of this dual-band topology in order to attain the narrow dual-band response, where minimum coupling of the coupled lines was required and forcing the coupling gap to be wide.

The ideal frequency response of the filter was given in Figure 3 for a chosen set of values for the line impedance of the ring and open stubs elements: $Z_r = 59\Omega$, $Z_{oe} = 100\ \Omega$, $Z_{oo} = 33\ \Omega$, $Z_{st} = 76.26\ \Omega$. Centred at 1GHz, it can be observed that the filter had a dual band response with first harmonic existed at $3f_0$. As shown in Figure 4, dual resonance with transmission zeros can be seen clearly at the dual band response with operating frequency at 0.89 GHz and 1.11 GHz respectively. The dual band response was very narrow with 0 dB insertion loss and -30 dB of return loss due to the ideal condition of this circuit. The dual-band was produced because of open stubs behaviour and enhanced by capacitance effect of coupling at side-coupled ring.

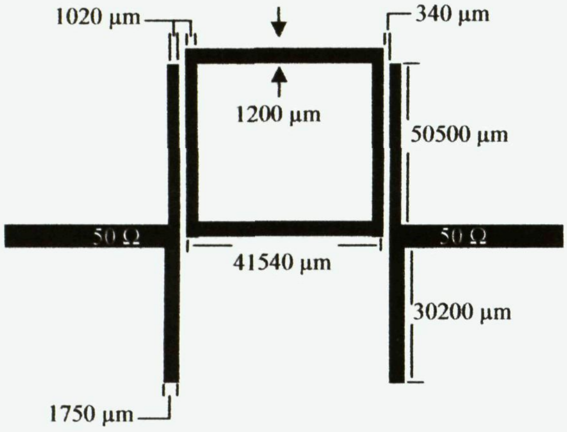
The values of impedance obtained in ideal simulation then were used to determine the dimensions in microstrip design. The width and length of parameters were calculated via CAD software and followed with a little adjustment to acquire the good response with centre frequency at 1GHz. The design was then fabricated on FR4 substrate with a relative dielectric constant of 5.4, thickness of 1.6mm with loss tangent 0.02.

## III. THE DUAL BAND MICROSTRIP FILTER REALIZATION

The simulation of the real design was executed via CAD software where the dimensions of the microstrip were determined based on the impedances obtained previously. A little adjustment of elements in term of width and length were performed. The complete layout with the lines' dimensions of the microstrip filter was shown in Figure 5 while the photograph of this filter was shown in Figure 6.

The microstrip design was then realized by using the technique of printing on a printed circuit board. Low cost was the main factor contributed to this fabrication's method. But there were disadvantages in this technique where the dimension of elements were not exactly accurate as in the schematic layout and the gap of side-coupled ring was limited to about 300 μm in order to prevent any unwanted of tiny connections happen within the gaps.

The simulated and measured data of the filter were shown in Table 1. Vector Network Analyzer (VNA) was used for the measurement part. Due to the high frequency operation, calibration was performed first before doing a measurement in order to obtain a good result.




120 mm x 100 mm

Figure 5: Layout of the dual band filter.

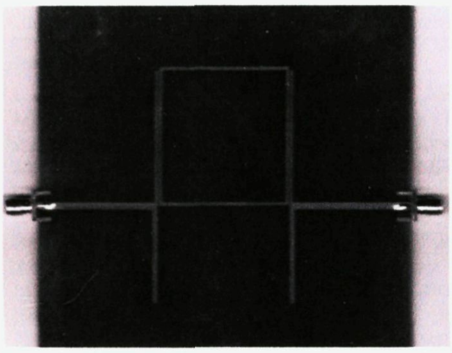


Figure 6: Photograph of the dual band microstrip ring filter with open stubs.

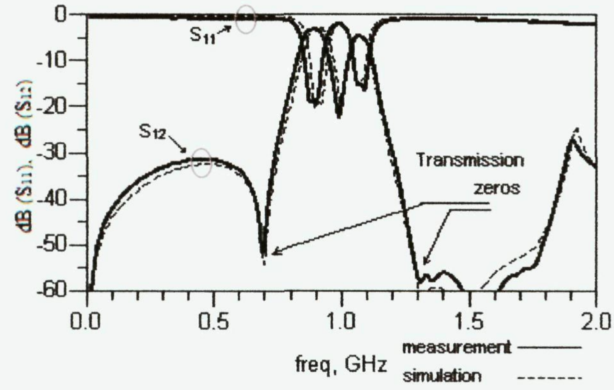



Figure 8: Simulated and measured response of the dual band filter.

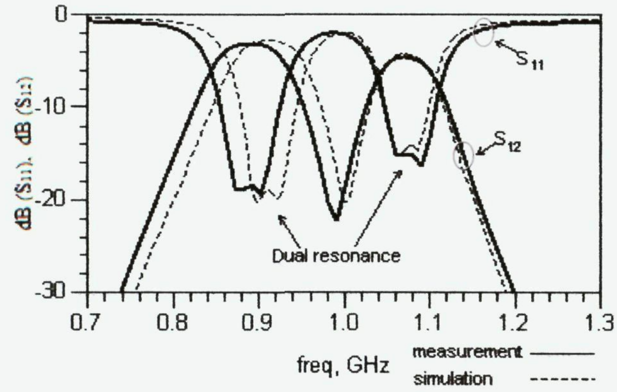



Figure 9: Simulated and measured response of the dual band filter showing the dual resonance behaviour.

TABLE I. DATA OF COMPARISON BETWEEN SIMULATION AND EXPERIMENTAL RESULT

| Parameter | Simulation | Experiment |
|---|---|---|
| Operating Frequency (GHz) | 0.91, 1.07 | 0.89, 1.07 |
| Center frequency (GHz) | 1.00 | 0.99 |
| Return Loss, S11 (dB) | -19.0, -14.4 | -18.4, -15.0 |
| Insertion Loss, S12 (dB) | -2.8, -4.3 | -3.0, -4.4 |

The simulation and measurement results of this filter were compared and shown in Figure 8. It can be observed that the centre frequency was slightly shifted to the left from 1 GHz to 0.99 GHz. Since the design was involving with dual resonance dual-band characteristics, any shift in centre frequency either to the right or left will cause the response to be ruined especially to the dual-band itself. This caused the overall results between the simulated and measured data to be different.

From Figure 9, the return loss at 1.07 GHz from simulation increased from -14.4 dB to -15.0 dB, however at 0.91 GHz, decreased from -19.0 dB to -18.4 dB respectively. Moreover, the insertion loss also increased from -2.8 dB and -4.3 dB to -3.0 dB and -4.4 dB respectively. Regarding to the high insertion loss, it indicated that the filter was not functioning properly at the design frequency.

The insertion loss of -4.4 dB can be considered as high and this was caused by the dielectric loss of the substrate that was used and the difficulty in modelling the circuit. Moreover, beside the dielectric loss, the thickness also needed to be considered as a factor contributed to the different results in simulation and measurement. In addition, poor fabrication process was also one of the reasons for the shift in frequency since in microstrip circuitries, high level of accuracy was very important. The error in the dielectric constant published by the manufacturer too resulted in the reduction of the performance of the designed filter. The iron from the soldering process also added more capacitance to the circuit and caused the measured response to shift to the left.

## IV. CONCLUSION

A new topology of dual mode dual-band bandpass filter based on microstrip ring resonator was invented and implanted with stubs to perform narrow dual-band response. A comparison of simulated and measured results was presented along with the analysis of the results. Since this filter was designed to operate in a narrow band and even dual-band designed, the radiation loss also increased. Besides, poor quality of substrate (tan $\delta = 0.02$), resulting in high insertion loss in the passband. A better quality dielectric should be used to improve the filter performance whereas good technology of fabrication was required to make the dimensions of filter at high level of accuracy.

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