Multilayer Dual-band Bandpass Filter

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Abstract **– This paper concentrates on designing a dual band bandpass filter suitable for wireless application. The filter is using multilayer technique by connecting two-quarter wavelength parallel coupled-lines to two half-wavelength lines through vias mode. The impact of the topology proposed, showing influence of the different impedance such as line impedance; Zr, even mode impedance; Zoe and odd-mode impedance; Zoo. Those parameters were analysed thoroughly. The filter was designed using TRF45 (Taconic) with reference frequency of 2 GHz by using multilayer technique. Observations on the controlling parameters are conducted to investigate the effect of the transmission zeros.**

Keywords: Dual band, bandpass filter

I. INTRODUCTION

The enhancement of wireless systems nowadays is equally proportionate to the demand for dual band bandpass filter. Since it was a multifunctional system, it required multiband operations. Previous case study of single layer shows delimits the control of the pass-bands [1]-[2]. By proposing the dual band bandpass filter, it may reduce the size and cost of the system itself. Instead of going for single layer, which can limits the performance and in term of controlling the pass-band, thus, this paper proposing this filter is to overcome the problems [3].

There are many different ways to design the dual-band bandpass filter. As in [4], two tunable passbands were generated with the impedance ratio of the stepped-impedance resonator at desired frequencies. By using that particular design, it proved that good dual-band performance and its ability to control the center of frequency but at the same time, the size remained. As proven by [5] individual passbands can be obtained with different coupling coefficients between adjacent resonators. However, each resonator must be connected to two open-circuited stub-loaded resonators to control the transmission zeros individually at each passband edge. Compared with the conventional direct-couple filters [6], extra transmission zeros near the passband edges can be achieved while generating cross coupling effects and not compromising the size of the circuit.

For this paper, the limitations only covers multilayer dual band bandpass filter as depicts in Figure 1 where two half-wavelength connected to two quarter-wavelength coupled lines creating dual path structure.

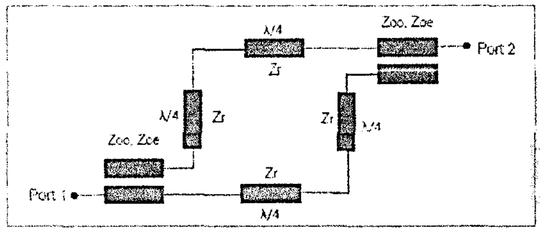

Fig 1: Topology of the ideal dual band bandpass filter

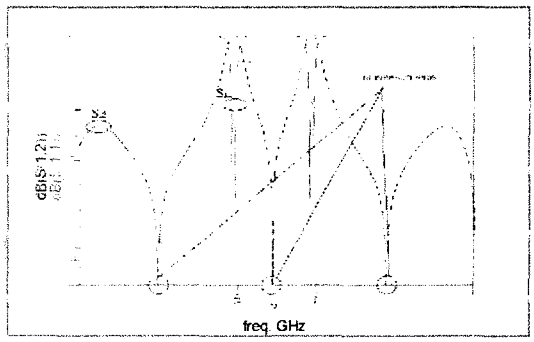

Fig 2: Frequency response of the ideal dual band bandpass filter

II. MULTILAYER DUAL BAND BANDPASS FILTER

Figure 1 shows the topology of the proposed dual-band bandpass filter whereas the figure 2 depicts the response of the filter itself. Basically, a filter can be constructed with combination of the 2 different filters which is low pass and high pass filter. Meaning that, the response of a bandpass filter is actually combination of those filters. It can be seen that the response is symmetrical to each other. By using concept of symmetry, reference frequency f_o can be of any value. Nonetheless, only certain ranges of the bandwidth/frequency are allowed at pass-band stage.

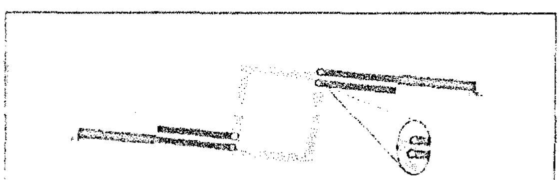

Fig 3: Dual band bandpass filter in a 3D view

Figure 3 depicts the 3D view of the multilayer dual band bandpass filter. This filter comprises 3 layers. First and second layer are substrate and the third layer is the ground. The connection between those lines are, both feed-lines are connects to theparallel coupled-lines. First layer is feed-lines whereas the second layer is the parallel coupled-lines. Those lines are connecting to each other through vias. There are many different techniques can be applied in order to connect the feed-lines and the coupled-lines for example blind, micro or hidden type. For this case study, through-hole is applied.

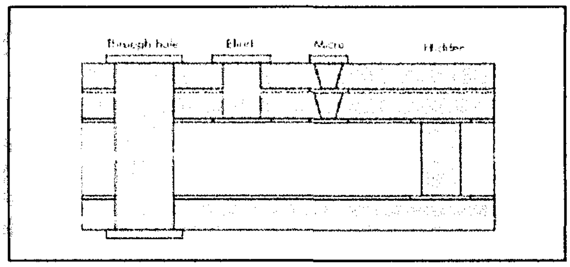

Fig 4: Various types of vias.

During the configuration to determine the frequency response, all the parameters are tuning until the results similar to the benchmark; ideal response. The said parameters are the width and length of the optimization impedance, W_{io} and L_{io} respectively, width and length of the quarter-wavelength, W_r and L_r respectively, and width and length of the coupled-lines, W_c and L_c respectively. The value of G denotes as the gap between the parallel lines. The diameter of the via, D_p, and lastly the diameter of the via hole, D_v. All parameters mentioned above were obtained from the working impedances Z_r, Z_{oo} and Z_{oe}. Figure 5 below shows the result of working impedances.

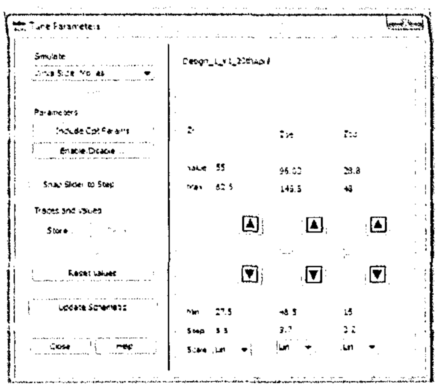

Fig. 5: Results of working impedances of Z_r, Z_{oo} and Z_{oe}

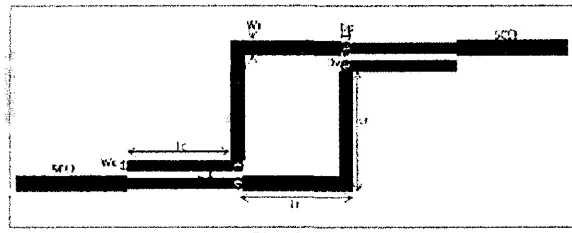

Fig. 6: Dual band bandpass filter in a circuit layout; Wr = 6.064mm, Lr = 12.380mm, Wc = 2.295mm, Lc = 18.087mm, G = 1.064mm, Dp = 2mm and Dv = 1mm.

III. OPTIMIZATION

All the optimization impedances (W_r, L_r, W_c, L_c and G) are varies to each other to obtain the best characteristic of the filter response such as amount of the frequency separation between the passbands, the bandwidth and the in-band ripple level of the passbands.

Certain optimization impedances such as L_r and L_c (as depict at Fig 7 and Fig 8) cause more shifts in the response whereas the gap, G affects the presence of the dual-mode in S_{11}. In Figure 7, as the length of the parallel coupled-lines decreases, the passband shifts to the right. In Figure 8, the whole response shifts to the right when the length of the quarter wavelength decreases. It can be deducted that the length of the optimization parameters affect the shifts of the response more than any other aspect of the response.

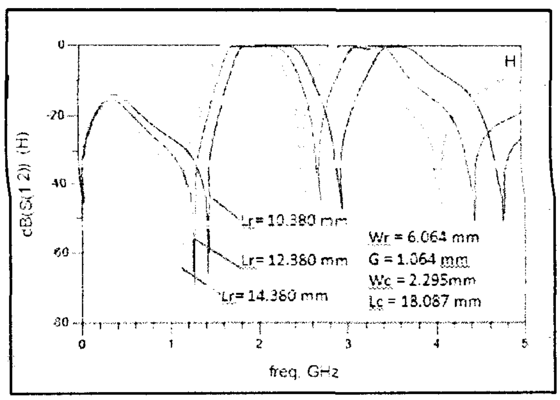

Fig. 7: Frequency response of the topology with variations of the optimization impedance L_r

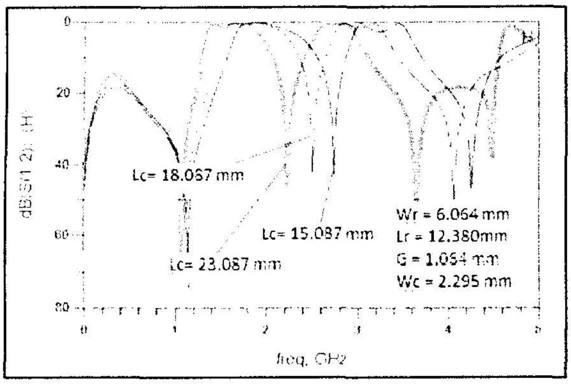

Fig. 8: Frequency response of the topology with variations of the optimization impedance L_c

Figure 9 and Figure 10 exhibits dual band bandpass responses of S_{12} where the reference frequency of the transmission line length is f_0. As seen in the figures below, when the width of the quarter-wavelength, W_r and parallel coupled-line, W_c are increased, the separation between the bandwidth improves as well as the rejection band.

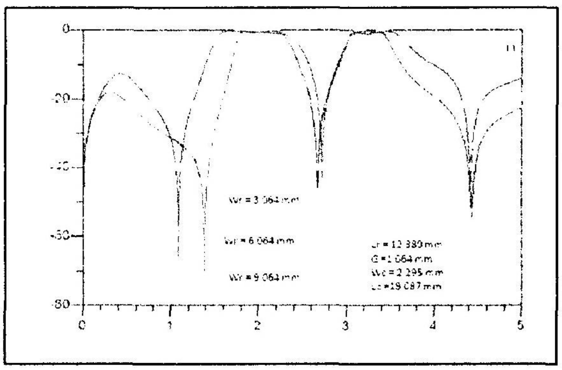

Fig. 9: Frequency response of the topology with variations of the optimization impedance W_r

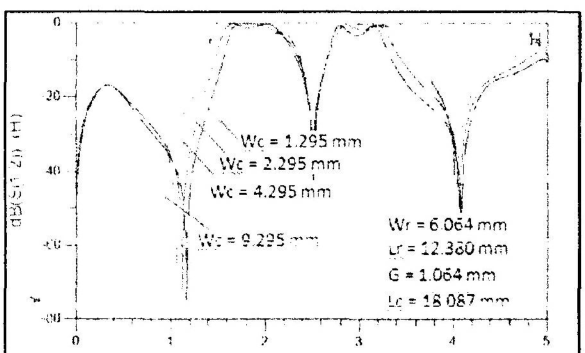

Fig. 10: Frequency response of the topology with variations of the optimization impedance W_c

IV. RESULTS AND SIMULATION

For the response for the ideal topology, it can be seen at Figure 11. The dual pole of the band and the S_{11} and S_{12} clearly plotted. The frequency f_0 acts as the reference frequency of the design and is at the center of the two pass-bands. Frequencies f_1 and f_2 are the center frequencies of the first and second pass-band which makes the design have three transmissions zeros to ensure good selectivity.

As for this case study, Taconic (TRF45) will be acts as a substrate. The characteristic of TRF45 are; substrates thickness, h =1.6mm, dielectric constant, ε_r = 4.5, copper thickness, t = 0.035mm and loss tangent, $\tan\delta$ =0.0035. Topology will be design based on the characteristic of the substrate along with the parameters obtained. The dimensioned of the layout is illustrated at Figure 12 whereas the result is depicts at Figure 14.

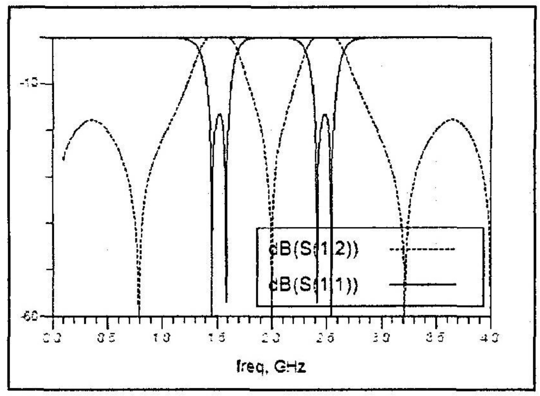

Fig. 11: Frequency response of the ideal topology.

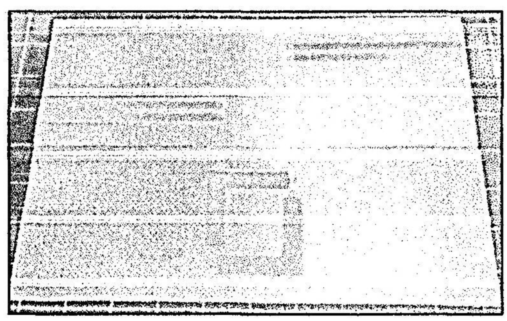

Fig 12: Fabricated dual band bandpass filter on TRF45 board

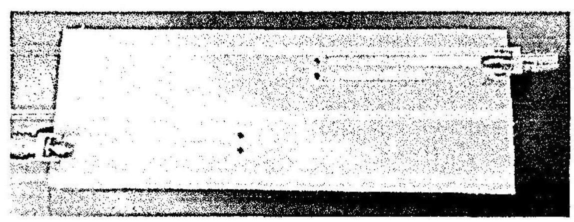

Fig 13: Multilayer dual-band bandpass filter

After applying the multilayer technique, it can be observed from the simulation results that the multilayer circuit design has a better control of the passbands as well as having a high rejection.

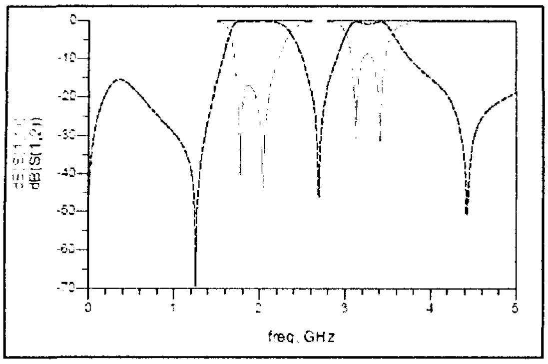

Fig 14: Simulated result of dual band bandpass filter

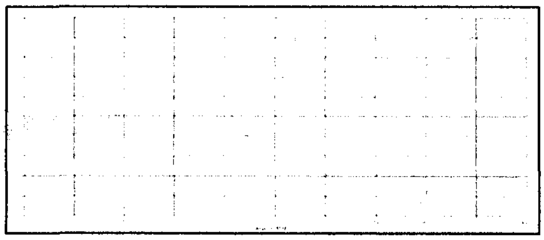

Fig 15: Measured result of dual band bandpass filter

Both result of simulation and measured are compared. Both results are depicts at Figure 14 and Figure 15 respectively. In overall, the both result is not similar to each other. In simulated result, the pass-bands are centered at 2.01 GHz with relative bandwidths of 31%. The measured result is having hanging ground. Due to using Taconic substrate, the insertion loss and return loss is low.

V. CONCLUSION

The objective of this project to design, simulate and measured a dual band bandpass filter are successfully achieved. This filter is using multilayer technique by connecting two-quarter wavelength parallel coupled-lines to two half-wavelength lines. This design is found to be adaptable to medium-band application. In future, it is also highly recommended to improvise the topology circuit at the feed-lines to minimize the radiation.

VI. ACKNOWLEDGEMENT

First and foremost, I would like to thank my supervisor, Dr Zuhani Ismail Khan for her endless support throughout completing this project. Not forgetting, my family who always be my side through thick and thin. Financial support from Ministry of Higher Education and Universiti Teknologi Mara for this project is gratefully acknowledged.

VII. REFERENCES

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