Modeling of Dual-Band Bandpass Filter with Triangular Shaped DGS

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Abstract — **This paper proposed a dual-band bandpass filter with triangular shaped defective ground structure (DGS). The filter topology made up of a coupled-line connected directly to line impedance with a same structure connected in parallel which produce a dual-path filter design. Triangular shaped DGS is added to the design in order to observe the changes in frequency response. It is found that the implementation of triangular shaped DGS improves the first passband with centre frequency of 1.086 GHz when compared with non DGS filter. The optimised size of the DGS is 150 mm^2 located at the centre and at the quarter wavelength lines of the filter.**

Index Terms **— Microwave filters, dual-band, bandpass filters, defective ground structure (DGS)**

I. INTRODUCTION

For the wireless communication applications to perform better, various configurations have been proposed and applied to the existing microwave devices including photonic bandgap (PBG), stepped impedance resonator (SIR) and defected ground structure (DGS). Although PBG improves directivity of antennas, DGS is easier to be designed and implemented. Moreover, it has a higher precision with regular defect structure which is very practical for microwave circuit.

Various slot geometries have been reported [1-5] such as spiral head, square, dumbbell, hexagonal, arrow head and interdigital DGS. Researchers agreed that DGS implementations produced better frequency selectivity [7, 9, 12, 20 & 21, 24] and miniaturized the size of the filter [7-15, 21-23]. Since each DGS provides its own distinctive characteristics depending on its geometry, such circuit functionalities as filtering unwanted signals and tuning high-order harmonics can easily be accomplished by means of placing the required DGS patterns, which correspond to the desired circuit operations without increasing circuit complexity [6].

The miniaturized dual-band bandpass filter in [7] used stepped impedance resonator (SIR) and DGS to improve frequency selectivity. Meanwhile the design in [9] improved stopband of the filter, resulting in wide stopband and better frequency selectivity. The dumbbell shaped defected ground structure bandpass filter reduced harmonics in the passband and 60 % size reduction [10]. Besides, DGS improved the mutual coupling between the resonators [11]. DGS along with microstrip structure were also used to achieve a compact dual band filter [12] and bandstop filter response [13]. The designed filter by Khan et al. [14] changed the capacitance and inductance of transmission line where current distribution in microstrip line is disturbed. To the advantage, smaller circuitry size and better band edge skirt was offered by achieving a bandpass response with a DGS unit.

In [15] the BPF was etched with four rectangular shaped DGS on the ground plane, where the obtained insertion loss was nearly 0 dB meanwhile the return loss was less than 10 dB. In other research, the circle ring DGS were used to improve the passband performance and suppressed high modes in upper stopband [16]. A triangle-shaped coplanar waveguide DGS in [17] increased the path of current and area of capacitance, which suggest that this design has a potential to be applied RF and microwave circuits applications. The dumbbell shaped DGS implemented in [24] improves the steepness of the first and second passband of the filter. The position of the DGS is placed at the centre and the edges of the parallel-coupled lines. This filter is potentially applied in future wireless communication system.

In this paper, a triangular shaped DGS is implemented on a dual-band bandpass filter topology [26] and is designed in CST Studio Suite. The passband frequencies change when the height of substrate and the size, as well as the position of DGS is varied. The isolation band shifted to the right or left when the parameters differed. The simulation is then compared without DGS implementation and TRF-45 substrate.

II. METHOLODY

The approach of the project design is represented in the flow chart in Fig. 1.

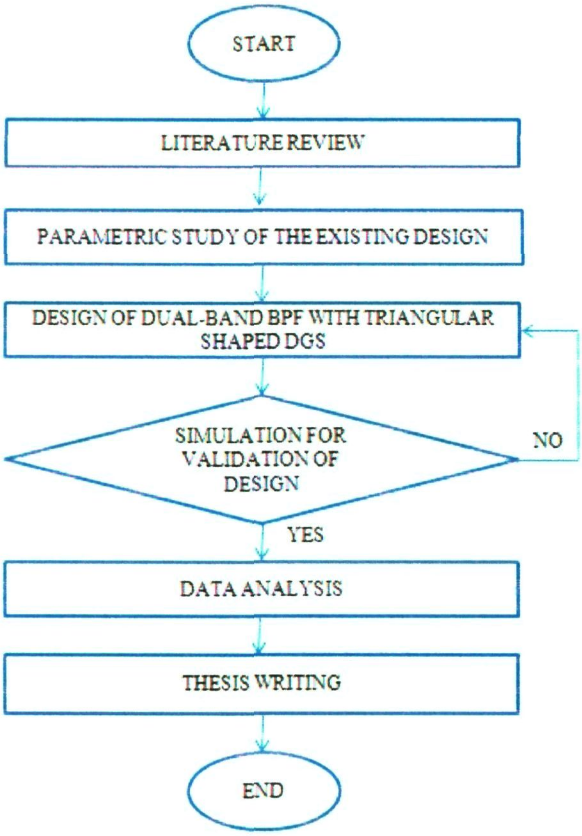

Fig. 1: Flow chart of dual-band bandpass filter design

The project focuses on how the implementation of DGS affects the frequency response by varying its position. An ideal response is attained from the dual-band bandpass filter by optimising the height of the substrate and width of the feed line. Hence, triangular-shaped DGS are added to the topology to study the behaviors of frequency response. Three sizes of triangular were implemented on the filter and compared. The optimise size of triangular DGS is then varied to four different positions to be observed.

III. DUAL-BAND BANDPASS FILTER DESIGN

The ideal filter topology in Fig. 2 consists of the quarter-wavelength coupled line directly connected to quarter-wavelength transmission line and parallel connected with another similar connection. The dual passband was obtained by varying the value of the line impedance, Z_r and even- and odd-mode impedances of the couple-lines, Z_{oe} and Z_{oo}. The ideal response of the filer topology is shown in Fig. 3. Dual-band responses are well separated by a center frequency, f_0. The first passband center frequency is indicated as f_1 and the second passband frequency as f_2. The frequency response gives three transmission zeros for better selectivity of frequency.

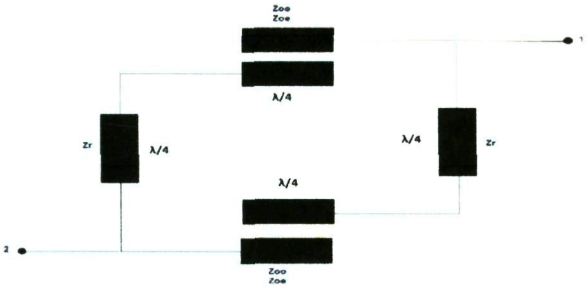

Fig. 2: Topology of the proposed dual-band bandpass filter [26]

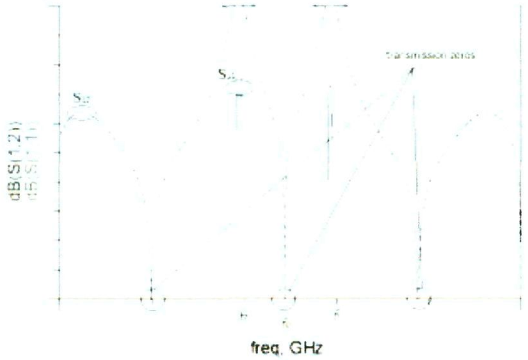

Fig. 3: Frequency response of the proposed dual-band bandpass filter [26]

Fig. 4 shows the circuit design of dual-band bandpass filter on FR-4 substrate where the relative dielectric constant, ε_r = 4.3, thickness = 1.6 mm and loss tangent, tan δ = 0.025. The height of the substrate was varied to obtain two required passbands. The feed-line was set at 50 Ω to determine the width of the microstrip.

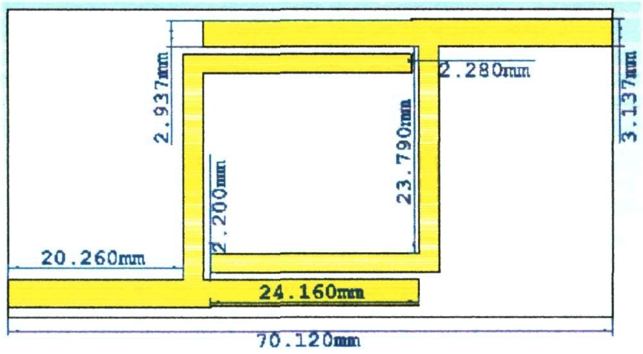

Fig. 4: Circuit layout of the microstrip dual-band bandpass filter

IV. DUAL-BAND BANDPASS FILTER WITH TRIANGULAR SHAPED DGS

The proposed dual-band bandpass filter was designed by adding triangular shaped DGS as shown in Fig. 6 to the topology. The implementation of DGS is supposed to improve the response by disturbing the current distribution on the ground plane and increasing the inductance and capacitance. The size as well as the position of DGS were varied and compared to observe the effect on frequency response. The filter was simulated using FR-4 substrate with dielectric constant, ε_r = 4.3, substrates thickness, h=1.6 mm with loss tangent, tan δ = 0.025.

A. Size Comparison

In order to obtain the best triangular shape, the DGS was designed with three different sizes and placed at five different places. As shown in Fig. 7(a), the first passband only shows a slight change compared to the second passband when the size of DGS is 100mm^2. Fig. 7(b) shows the response for 150mm^2 triangle DGS when applied to the topology. Unlike before, the changes can be seen in the first and second passband. Fig. 7(c) also shows clearer effect on both passbands when 200mm^2 DGS was implemented. However, the second passband obtained is lower than 150mmm^2 DGS.

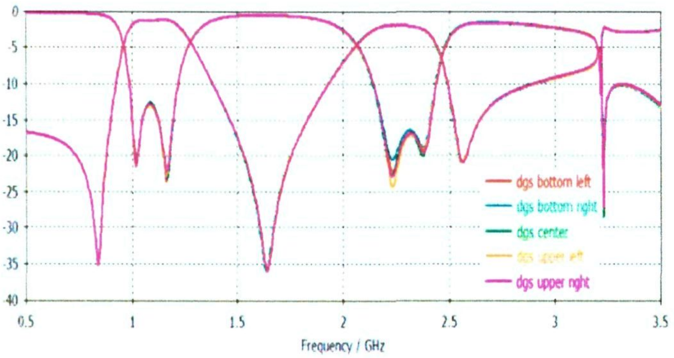

Fig. 7(a): Frequency response for 100mm^2 DGS

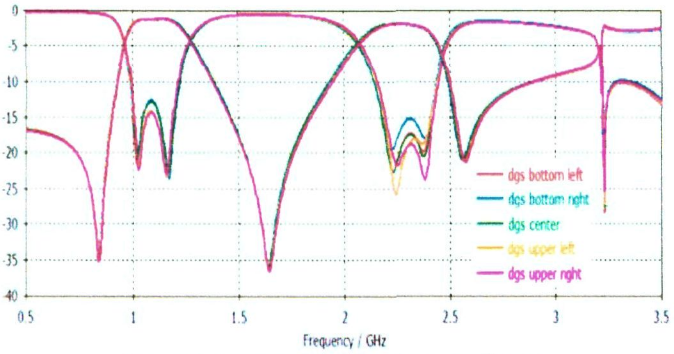

Fig. 7(b): Frequency response for 150mm^2 DGS

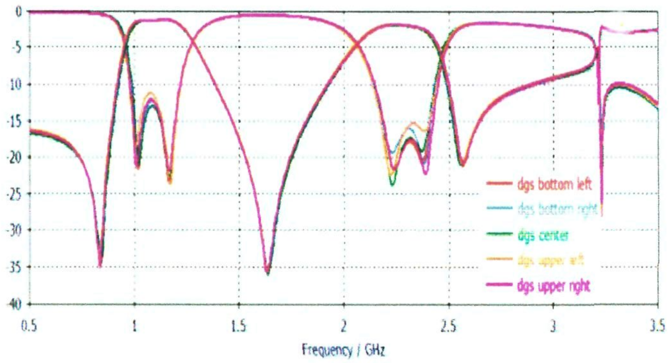

Fig. 7(c): Frequency response for 200mm^2 DGS

From the graphs comparison, the 150 mm^2 triangular shaped DGS shows higher passband frequency and steeper isolation band at 1.641 GHz.

B. Position Comparison

The DGS with size of 150mm^2 is applied as it shows significant response when compared. Fig. 8 shows four different positions of DGS placed on the ground of the filter.

They are placed at the feed lines, the wavelength line, centre and parallel-coupled lines.

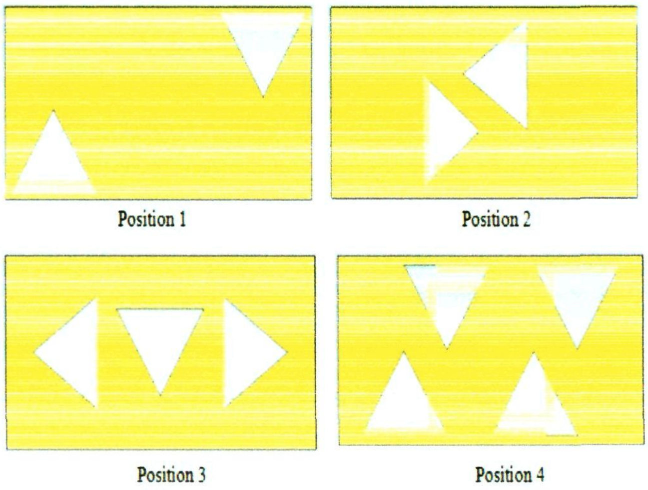
Position 1
Position 2
Position 3
Position 4

Fig. 8: Various positions of DGS

V. RESULT AND DISCUSSION

A. Dual-band bandpass filter without DGS

The simulation result produces passband centred at 1.089 GHz (f_1) and 2.315 GHz (f_2). The isolation level, f_0 at 1.641 GHz achieves more than 30 dB while the outer rejection band is 17.56 dB. The insertion loss is lower than 3 dB and the 3dBbandwidth for both passband is at 250 MHz and 260 MHz, as shown in Fig. 9.

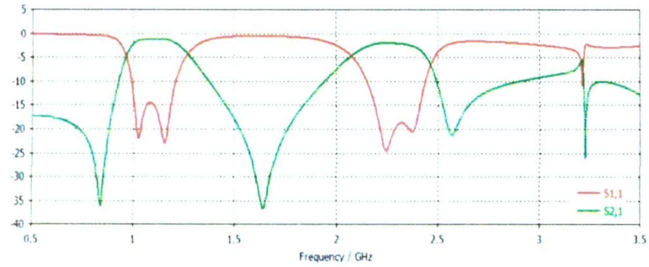

Fig. 9: Simulation of S11 and S21 for the optimized filter

B. Dual-band bandpass filter with DGS

Fig. 10(a), (b), (c) and (d) show graphs obtained from the various positions of DGS. Overall, the first passband, the second passband and the isolation level only affected a little when DGS is implemented in these positions. The response between first and second passband is not synchronous, whilst the isolation level only shows a slight change.

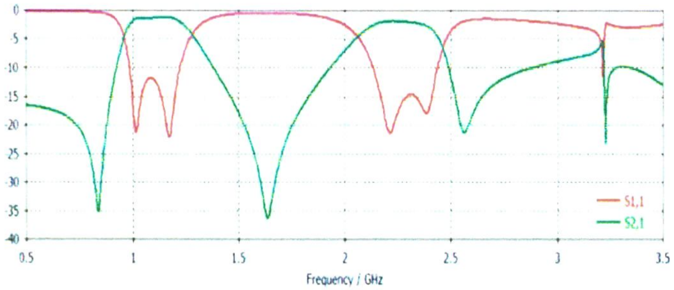

Fig. 10(a): Graph obtained from position 1

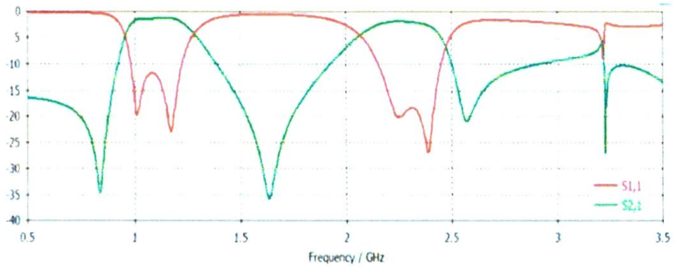

Fig. 10(b): Graph obtained from position 2

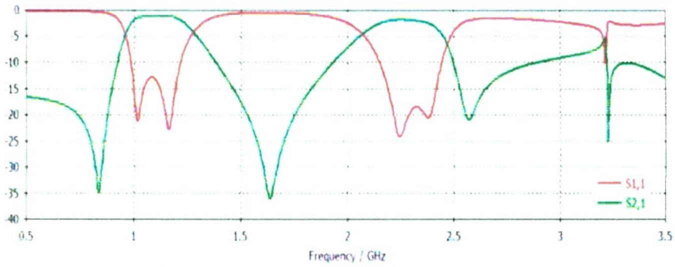

Fig. 10(c): Graph obtained from position 3

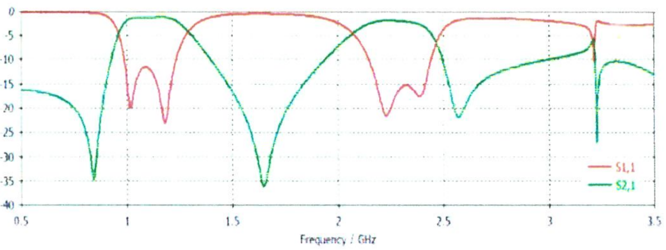

Fig. 10(d): Graph obtained from position 4

A comparison is made to see which position yields better response as shown in Fig. 11. The DGS placed in position 3 produced lowest outer rejection band and steeper isolation band. The insertion loss for both bands is less than 3 dB.

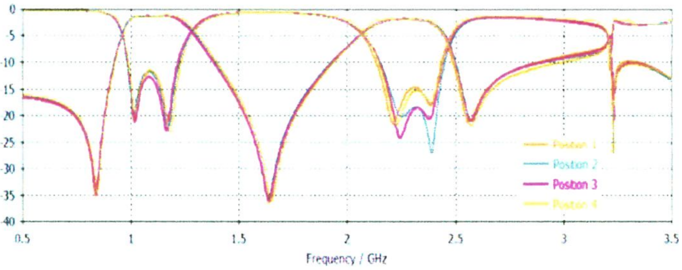

Fig. 11: Comparison between various positions of DGS

The first passband, second passband and isolation level are compared in Table II. From the table, it can be observed that the position of DGS has no big impact to the response of the filter. In this observation, position 3 shows better frequency response in term of both passband.

Table II: Different DGS positions

Position	1st passband, f_1 (dB)	2nd passband, f_2 (dB)	Isolation level, f_0 (dB)
1	11.91	14.68	36.25
2	11.78	18.41	35.79
3	12.98	18.64	36.02
4	11.59	15.43	35.91

The filter is then compared with and without DGS as obtained in Fig. 12. The change is only at first passband which differ about 2dB. The S21 does not show significant effect somehow, except at the outer rejection band.

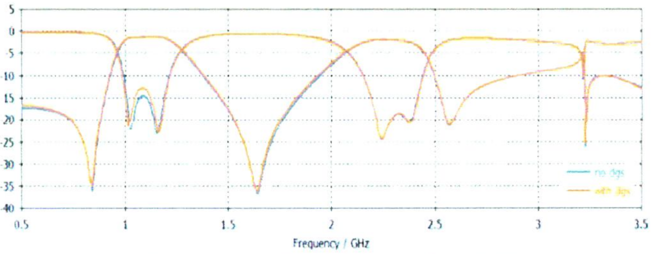

Fig. 12: Comparison with and without DGS

Fig. 13 shows the comparison between two substrates which is FR-4 and TRF-45. TRF-45 produces steeper passband and isolation band at 1.611 GHz. The insertion loss differ more than 1 dB for both bands. The frequencies for all transmission zeros shift but better than using FR-4 due to different dielectric constant, where TRF-45 is equal to 4.5.

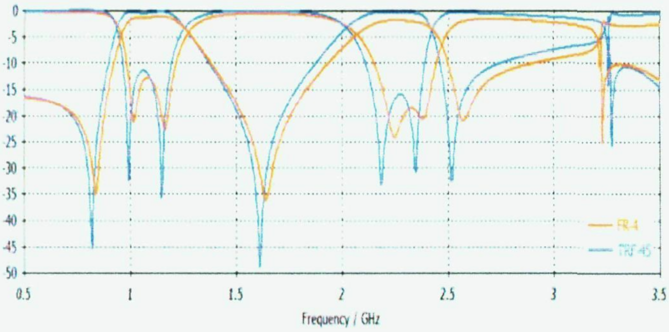

Fig. 13: Comparison between FR-4 and Taconic RF-45

VI. CONCLUSION

A dual-band bandpass filter has been designed with triangular shaped DGS towards the existing dual-band topology. The filter design was investigated with variation of DGS sizes and positions. Even so, the response obtained from the implementation does not give much impact. Overall, the first passband is obtained around 1 GHz, the second passband around 2 GHz while the isolation level at about 1.6 GHz. The harmonic distortion also cannot be eliminated. This distortion might be improved by adding stub to the filter, which is not covered in this investigation.

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