Dual-Band Bandpass Filter with Rectangular Dumbbell Shaped Defected Ground Structure

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Abstract — In this paper, a design of rectangular dumbbell shaped defected ground structure (DGS) is presented to enhance the response of an existing design of a dual-band bandpass filter topology. The filter design is based on parallel-coupled lines connected to transmission lines forming a single ring that exhibits a dual-band response with high selectivity. The filter comprises of characteristics impedances of the transmission line represented by Zr, even-mode, Zre and odd-mode, Zro. The variety of DGS size and positions measurements are acknowledged and the impacts on the response of the filter are analysed [3]. An execution of a rectangular dumbbell shaped DGS in this topology enhances the response for both groups with centre frequency given at 2 GHz using TRF-45 material. The dimension and position of the dumbbell shape is improved individually, situated of the ground plane. The simulated and measured aftereffects of the DGS insertion are analysed and to validate the concept.

Keywords — dual-band, bandpass filters, coupled-line, Dumbbell-Shaped DGS.

I. INTRODUCTION

Recently, development of dual-band radio frequency circuit increased in various wireless communication applications. Various techniques have been applied by researchers in designing RF front ends components such as filter in order to improve the performance and minimizing the sizes. One of the techniques is to use a Defective Ground Structure (DGS). There are various DGS shapes that have been employed in the filter designs such as square, rectangular, circular, rings, spiral and many more as shown in Figure 1. Every shape of the DGS has its own attributes to enhance the response of a filter. The dimension of the DGS plays an important role for effective. A limited rejection band and passband can be accomplished alongside slow-wave characteristics by designing and etching a DGS on the ground plane.

There are likewise diverse systems other than DGS, for example, Photonic Band Gap (PBG). The PBG structures are periodic structures which have defects in the ground plane. PBG's at first were inquired about for the most part in the optical frequencies. It can be connected to extensive variety of frequencies and utilized as a part of numerous applications like lasers, antennas and different gadgets. PBG's can furnish band gap characteristics with periodic defects in the ground plane [9]-[13]. However it is difficult to design modelling for microwave or millimetre wave parts. This is for the most part because of troubles in displaying and the radiation from the periodic defects was another concern.

This paper presents a rectangular dumbbell shaped DGS implemented on an existing dual-band bandpass filter topology hence improving the bandwidth and frequency. As far as anyone is concerned, no examination has been done to add the DGS structure to this topology. The proposed topology is at first outlined in CST Studio Suite 2015 utilizing comparative parameter particulars as the current topology. When the improved DGS structure is resolved, the best simulated result is created on a TRF-45 substrate and microwave estimations are performed to approve the reproduction results.

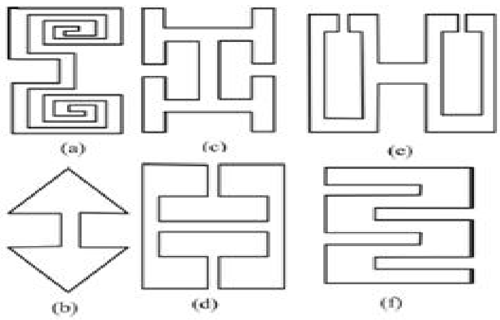

Figure 1: Various DGS shapes: (a) Spiral head (b) Arrow head (c) H shaped (d) A square open loop with slots in the middle (e) Open loop dumbbell (f) Interdigital DGS [7]

II. DUAL-BAND BANDPASS FILTER

The existing topology of the dual-band bandpass filter as shown in Figure 2. While an ideal frequency response of a filter shown in Figure 3. Frequency which is situated in between two passband is a centre frequency, f_o also known as the reference frequency. The design was done by optimising the 2 GHz as reference frequency. Frequency f_1 and f_2 are the centre frequencies of the first and second passband as shown in Figure 3 to ensure a decent selectivity from transmission zero.

The dual-band bandpass filter layout is shown in Figure 4 with dimension of the filter topology.

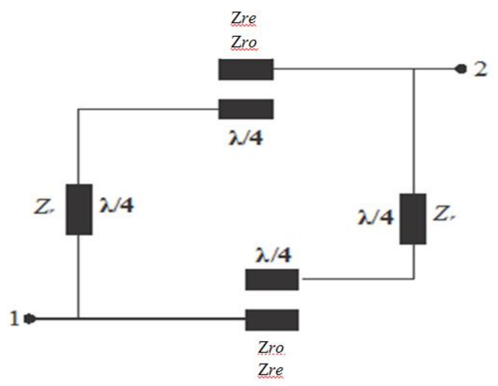

Figure 2: Topology of the dual-band bandpass filter [3]

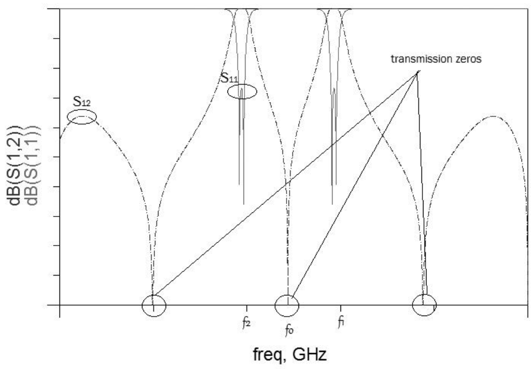

Figure 3: Ideal frequency response of the dual-band bandpass filter [3]

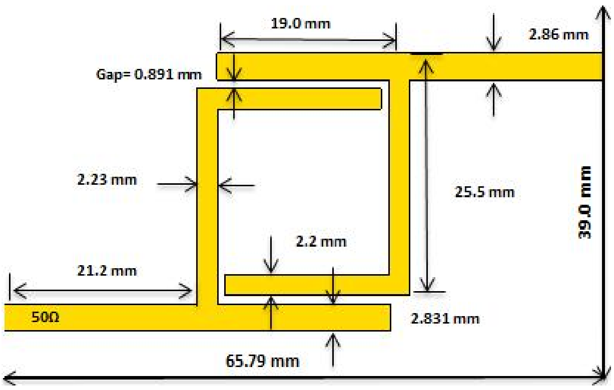

Figure 4: Circuit layout of the dual-band bandpass filter

Streamlining on the transmission lines and parallel-coupled structures are performed to get measurements as appeared in Figure 4. The substrate TRF-45 with a dielectric constant of 4.5, thickness of 1.6 mm and loss tangent of 0.0035 is simulated in CST Studio Suite 2015 as shown in Figure 5. Optimise line width at two ports (P1 & P2) of the structure in order to obtain perfect matching characteristic impedance of 50Ω.

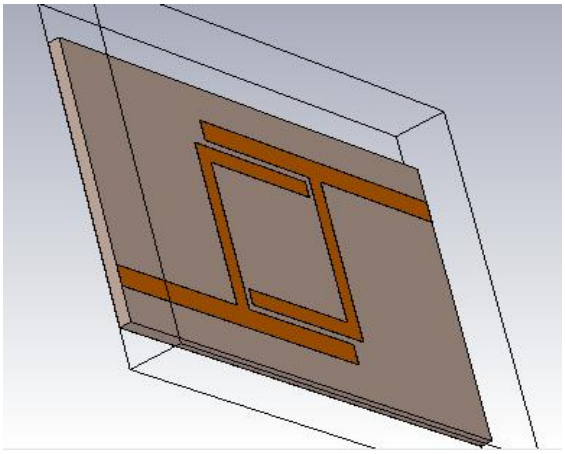

Figure 5: 3D view of the dual-band bandpass filter

From Figure 6, the simulated result produces two passbands centred at *f1*= 1.31823GHz and *f2*= 2.8341 GHz, insertion loss S_{21} = 0.33 dB and return losses S_{11} = 40.42 dB

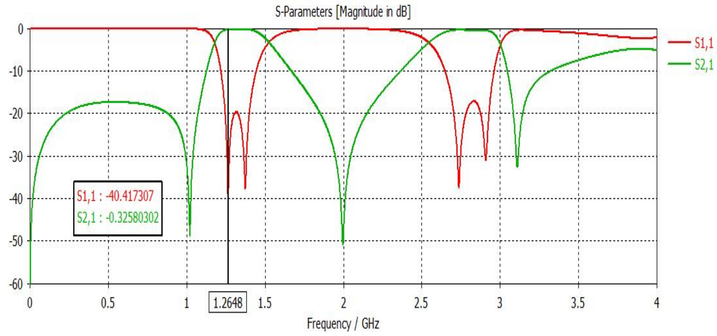

Figure 6: Simulated result

III. Dual-Band Bandpass Filter with Rectangular DUMBBELL Shaped DGS

A rectangular dumbbell shape DGS is implemented in the dual-band bandpass filter. DGS is a scratched periodic or non-periodic cascaded configuration defect in ground of a planar transmission line which bothers the shield current circulation in the ground plane cause the imperfection in the ground. This unsettling influence will change qualities of a transmission line, for example, line capacitance and inductance. In a word, any imperfection scratched in the ground plane of the microstrip can give rise to expanding effective capacitance and inductance [27]. The various dimensions of dumbbell are chosen as a= 3 mm, b= 5mm, *l*= 6.5mm and g= 1 mm.

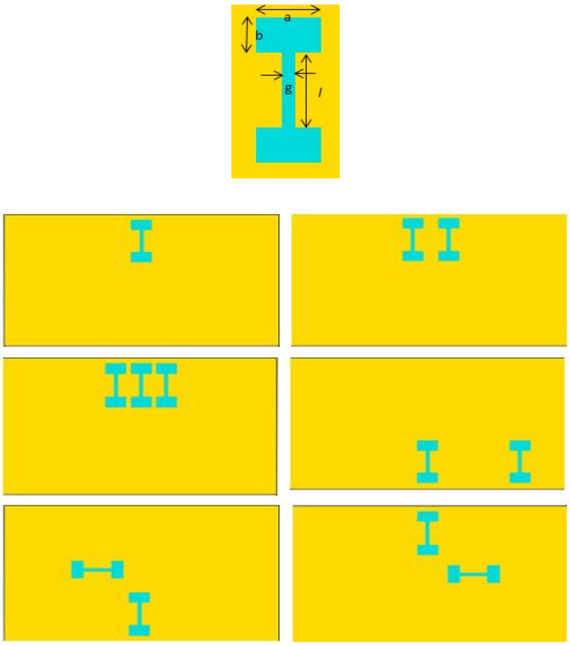

Figure 7: Size and position of the Rectangular Dumbbell DGS

The location of dumbbell DGS were move to various positions in order to obtained optimum frequency response result

IV. Result and Discussion

The proposed topology is tested through the dual-band bandpass filter on TRF-45. The measured result shows f_1 = 1.3 GHz and f_2 = 2.8 GHz, insertion loss S_{21} = 0.5 dB and return losses S_{11} = 43 dB. From simulated and measured results, frequency response at first and second rejection band almost the same. However, return losses from measured resulted higher than simulated value at second passband. Centre frequency for both condition static at 2 GHz.

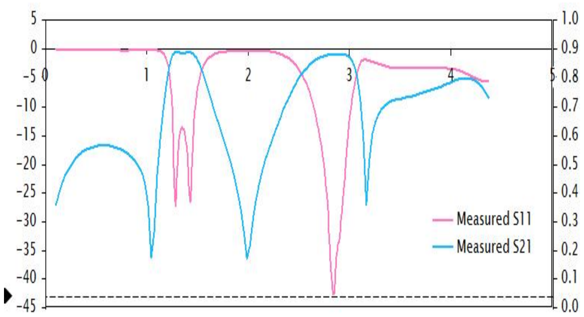

Figure 8: Simulated result

Starting with one dumbbell DGS, align position with high response as shown in Figure 9 (a) and (b). It can be clearly seen position of dumbbell shaped DGS also give an impact on the response. However the effect will only capture along transmission line and coupling lines. The 3dB cut-off frequency underneath at (a) 335 MHz (b) 341 MHz. The best dimension with high return losses S_{11} = 49.80 dB and insertion loss S_{21} = 0.337dB shown in figure 9 (b) which l=6.5 mm, g=1 mm, a=3.5 mm, and b=4 mm.

l (mm)	*g* (mm)	a (mm)	b (mm)	S_{11} (dB) *Reference*	S_{11}(dB) *Simulate*	Differences (dB)
5	0.6	2	3	50.54	51	0.46
6.5	1	3	5	50.54	51.08	0.54
8	2.5	7	4	50.54	50.54	0

Table I: Optimization of DGS size

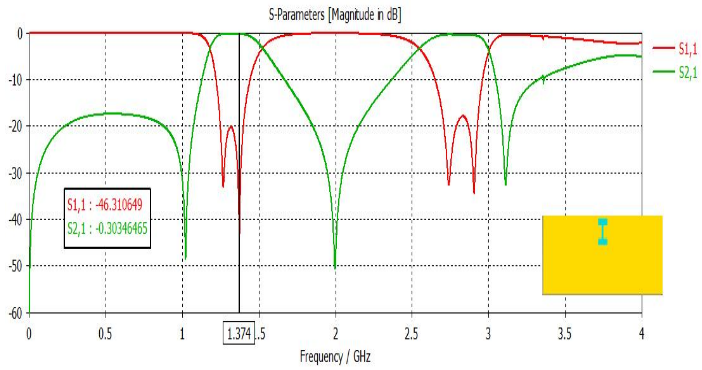

Figure 9(a): The S-parameter response of S21 & S11

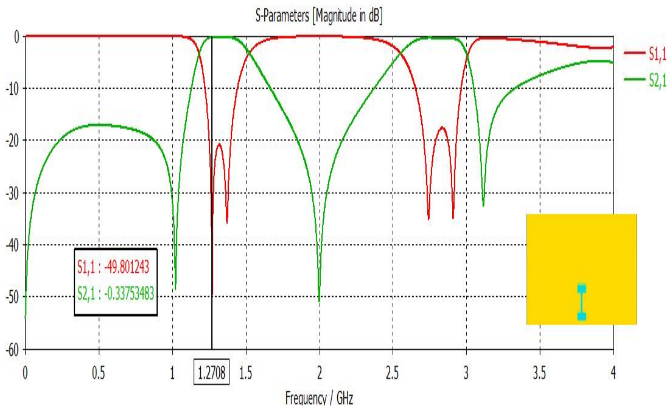

Figure 9(b): The S-parameter response of S21 & S11

The measured result shows different frequency response. This is because at the time to fabricate, machine unable to read convert file. The dumbbell shape DGS should be in vacuum while around will be annealed copper. But fabricate design vice versa as figure 10 below.

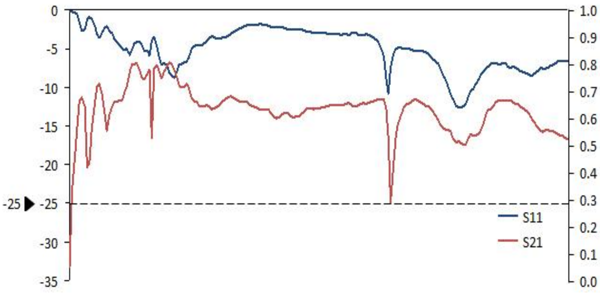

Figure 10: The measured result of S21 & S11

Two units of the dumbbell shaped DGS with separation of 1.5mm are considered. From simulated, 3dB cut-off frequency resulted at 337 MHz. Centre frequency of the stopband at 3 GHz and rejection bandwidth of 3.87 GHz. Thus show design with wide stopband and almost the same insertion loss from one dumbbell attached to dual-band bandpass filter.

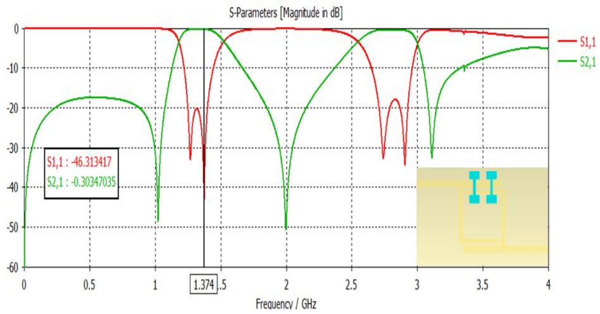

Figure 10: Simulated S-parameter of two DGS response (S21 & S11

A coupling of 3-dB is accomplished by separation of partition between the two parallel lines, which gives more adaptability in the manufacture process. Such a coupler can be composed at the craved frequency by picking the proper stopband of DGS. Insertion loss S21 = 0.303 dB and return losses S11 = 46.31 dB. By increase the gap between dumbbell shape DGS, it is found that return losses = 38.97 dB and insertion losses = 0.336 dB while centre frequency static at 2 GHz. It can be concluded that increasing gap between dumbbells shaped DGS will decrease return losses of the circuit and low cutoff frequency.

Three rectangular dumbbell Shape DGS was varied in a layout of the dual-band bandpass filter as illustrated below:

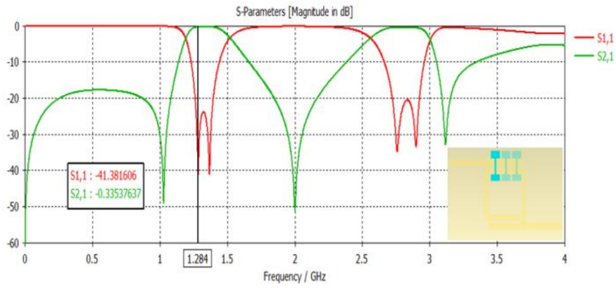

Figure 12: Layout and S-parameter response of S21 & S11 of triple dumbbell DGS

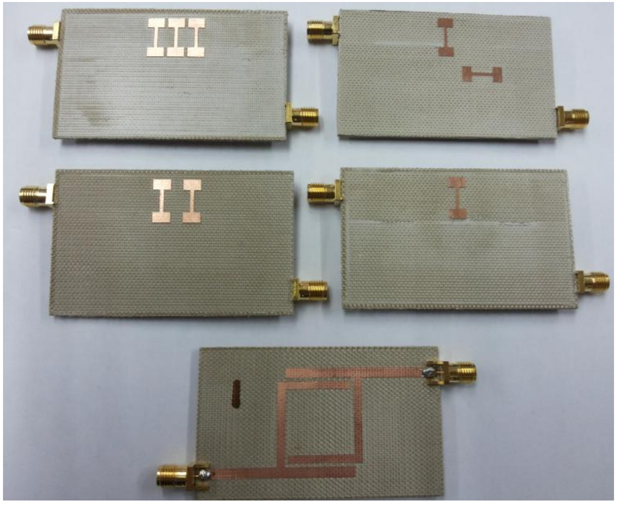

Figure 11: Layout of fabricate design

The dimensioned of the dumbbell is maintained. The spacing between DGS needs to decrease to 1 mm due to limited space of the dual band bandpass filter layout. Based on theoretical, the bandwidth and sharpness factor will increase by increasing the number of DGS. The simulated result of passband and stopband is observed. The 3dB cutoff frequency at 325 MHz, insertion loss S_{21} = 0.335 dB and return losses S_{11} = 41.38 dB. High performance of the design can be accomplished with an enhanced passband and in addition stopband by increased DGSs under coupled lines at the same time. The purpose of used more DGS are to improve the layout performance and reduce the complexity in operation.

V. Conclusion

The design of dual-band bandpass filter using a rectangular dumbbell defected ground structure was investigated. The proposed dumbbell shaped DGS has been simulated, measured and the results are analyzed. Using substrate TRF-45, the design has been simulated and compared. It shows that the isolation band of the design is more than 35 dB. However rejection band for all design are the same. Three parameters of DGS: length, width and gap influence line impedance of the filter and the changing of parameter in configuration will give extensive variety of tuning.

The substrate material has imperative influence as a part of getting acceptable measured results. A substrate selected with lowest loss tangent will give a good result for rejection band and return loss. Not only the return loss, it also improves rejection band. The steps of fabrication also influence the response of the circuit. Referring to CST Studio Suite 2015, any design create need to convert to other format before fabricate because there is no compatible software for CST Studio Suite yet. This problem affected the design which is convert inaccurate dimensions.

VI. FUTURE DEVELOPMENT

Some of future works that are interesting and recommended to improve can be done on dual-band bandpass filter. Identify parts which impact the rejection band without disrupts passband of the design. Roughly, optimization has been done as figure 12 below by reduced dimension of dual-band bandpass filter to 30%. Rejection band has been reduced but couple line and feed line need an improvement.

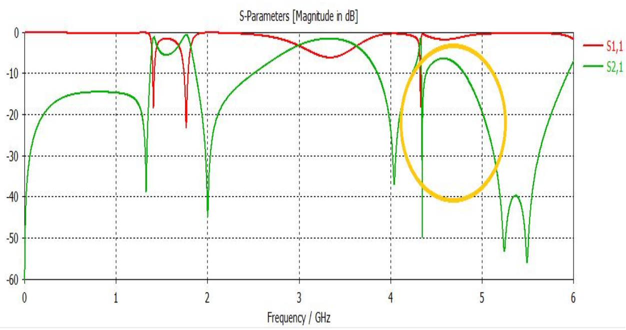

Figure 12: Reduction of dual-band bandpass filter to 30%

In term of CST Studio Suite software, need to explore the compatible fabrication software in order to improve the design. Concurrent, researcher need to convert the design two times into other format before fabricate. The dimension of fabricate not same as simulate in CST Studio Suite after measured.

REFERENCES

[1] S. Pragya and T. Raghuvir, "The Use of Defected Ground Structures in Designing Microstrip Filters with Enhanced Performance Characteristics," *Procedia Technology,* vol. 17, pp. 58-64, 2014.

[2] M. T. Khan, M. A. Zakariya, M. N. M. Saad, Z. Baharudin and M. Z. U. Rehman, "Parametric Effect of Defected Ground Structure (DGS) on the Frequency of a Bandpass Filter," in IEEE International RF and Microwave Conference, Penang, 2013.

[3] Mohd Rizsham bin Mohd Ruslan, "Dual-Band Bandpass Filter with Rectangular Shaped Defective Ground Structure', Faculty of Electrical Engineering, Universiti Teknologi MARA

[4] L. H. Weng, Y. C. Guo, X. W. Shi and X. Q. Chen, "An Overview On Defected Ground Structure," Progress In Electromagnetics Research B, vol. 7, pp. 173-189, 2008.

[5] M. K. Mandal and S. Sanyal, "An Improved Low Pass Filter using Microstrip Defected Ground," Department of Electronics & Electrical Communication Engineering, India.

[6] N. A. Wahab, Z. I. Khan, M. K. M. Salleh, M. N. Bakhtiar, N. E. A. Rashid and K. A. Othman, "Multilayer Dual-Mode Dual-Band Bandpass Filter," in Loughborough Antennas and Propagation Conference, Loughborough, 2014.

[7] K. Vikash and G. Sanjay, "A Tutorial Overview On the DGS to Design Microwave Device," in National Conference on Trends in Signal Processing & Communication, Uttar Pradesh, 2013.

[8] Ö. Kiliç, Defected Ground Structure And Its Applications To Microwave Devices And Antenna Feed Networks, Middle East Technical University, 2010.

[9] Radisic V., Qian Y., Cocciolo R., and Itoh T., "Novel 2-D Photonic Bandgap Structure For Microstrip Lines." IEEE Microwave Guide Wave Lett. vol. 8, pp. 69-71, Feb. 1998. 79

[10] Yablonovitch. E, " Photonic Band-Gap Structure," J. Opt. Soc. Amer. B. Opt. Phys., vol. 10, pp. 283-295, Feb. 1993.

[11] Qain Y., Yang F.R., and Itoh T., "Characteristics of Microstrip Lines on a Uniplanar Compact PBG Ground Plane," in Asia-Pacific Microwave Conf. Dig., pp.589-592, Dec. 1998.

[12] Qain Y. and Itoh T., "Planar Periodic Structures for Microwave and Millimeter Wave Circuit Applications," in IEEE MTT-S Int. Microwave Symp. Dig., pp. 1533-1536, June 1999.

[13] Radisic V., Qian Y. and Itoh T., "Simulation and Experiment of Photonic Bandgap Structures for Microstrip Circuits," in Proc. APMC, pp. 585-588, 1997.

[14] David M. Pozar, "Microwave Engineering,"Fourth Edition, Wiley, N.J., 2012

[15] Z. Awang, "Microwave Filter Design," in Microwave Systems Designs, Springer, 2014, pp. 285-291.

[16] C. Garg And M. Kaur, "A Review Of Defected Ground Structure (Dgs)," International Journal Of Innovative Research In Electrical, Electronics, Instrumentation And Control Engineering, Vol. 2, No. 3, Pp. 1285-1290, 2014.

[17] T. Moyra, S. K. Parui and S. Das, "Modeling and Validation of High Selective Harmonic Reduced Bandpass Filter using Coupled Resonators and Defected Ground Structure," Journal of Computational Electronics, vol. 11, pp. 330-335, 2012.