

## HARMONIC REDUCED HIGH SELECTIVE BANDPASS FILTER USING OPEN ENDED COUPLED RESONATORS AND DEFECTED GROUND STRUCTURE

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### ABSTRACT

Recent developments in wireless communication systems demand good Band pass filter (BPF) with high quality factor and good selectivity to select the required signal from the adjacent signals. In this paper one coupled Band pass filter with centre frequency 2GHz and 30% Fractional Bandwidth (FBW) has been designed with rectangular split ring coupled resonators forming with conventional Microstrip transmission line. This designed BPF has been simulated with the help of MoM based IE3D electromagnetic EM simulation software. Here it is found that the proposed BPF provides second harmonic nearer to the twice of its passband centre frequency and some other few harmonics. Therefore, in this paper attention also has been given towards the suppression of harmonics with the help of Defected Ground Structures (DGS) in addition with the proposed coupled microstrip BPF.

**Keywords:** Microstrip, split ring resonator, defected ground structure, elliptical, bandpass filter

## 1. INTRODUCTION

It is well known that when two transmission lines are placed in close proximity to each other and one line is excited with a known signal, then there will be an interaction of electromagnetic fields. This interaction effect known as *desirable coupling* is used to design different microwave circuits, such as directional couplers, filters etc. The closer the lines interaction or coupling will be stronger. The interaction effect will be more due to the increasing of the coupling area also.

A defected structure etched in the metallic ground plane of a microstrip line is attractive solution for achieving finite pass band, rejection band and slow-wave characteristics. The defected structure effectively disturbs the shield current distribution in the ground plane and thus, introduces high line inductance and capacitance of the microstrip line. Thus, it obtains wide stop band and compact size, which meet emerging application challenges.

Dumb-bell shaped DGS is explored first time by D. Ahn and applied to design a lowpass filter [1,2]. Unit cell has been described as a one-pole Butterworth filter, where the capacitance comes only from the transverse slot width and the inductance comes only from the loop. The study of dumbbell DGS with various head shape have appeared in the literature recently and they are used to design filters, couplers, dividers and amplifiers [3-5], [7-10] etc. It is well known that a filter with attenuation poles and attenuation zeros at finite frequencies shows higher selectivity compared to all pole filter. A DGS with quasi-elliptical response was proposed by Chen J.-X recently [6].

In this paper, BPF has been designed with the help of microstrip coupled rectangular split ring resonators. The proposed structure response has been simulated which shows that the BPF filter provide good selectivity, good skirt rate and high quality factor with some unwanted harmonics or spurious.

Therefore, attention has been given towards the suppression of those harmonics with the help of DGS structures.

## 2. FREQUENCY CHARACTERISTICS

Bandpass filter based on microstrip coupled split ring resonators has been investigated. To improve the coupling two split ring resonators connected back to back has been used as a single unit and two such units are placed to closed approximation with small separation. The inter resonator couplings are realized through fringe fields of the microstrip open-loop resonators.

The filter is fabricated on the Arlong based PTFE substrate with dielectric constant 3.2, 0.79 mm thickness and 0.0025 loss tangent. The layout of the filter is shown in Fig. 1(a). By taking the center frequency at 2 GHz, the perimeters of the resonators are optimized for quarter wavelength. The outer length  $a = 16$  mm is taken for designing of the resonator. The separation between two rings is  $S = 0.2$  mm considered for obtaining good amount of coupling. Split gap of the resonator,  $g = 0.2$  mm. Input /output lines have width  $W = 1.92$  mm identical to 50 ohm microstrip transmission line. The structure is simulated with MoM based IE3D software and the S-parameters are plotted in Fig. 1(b). The passband center frequency at 1.93 GHz, 20dB bandwidth 0.556 GHz ( $f_1 = 1.67$  GHz and  $f_2 = 2.226$  GHz) and the passband insertion loss of 1.57 dB and FBW = 28.8%

( $FBW = \frac{(f_2 - f_1)}{f_0} \times 100\%$ ) are observed. The harmonics are centered at

4.5 GHz, 5.8 GHz, 7.4 GHz and 9.2 GHz.

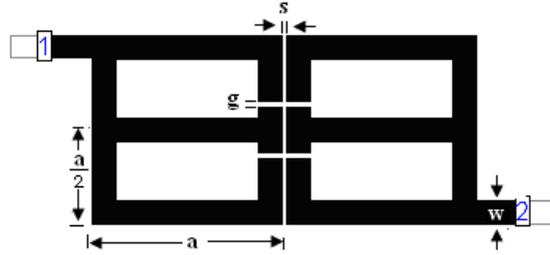


Fig. 1(a) the schematic diagram

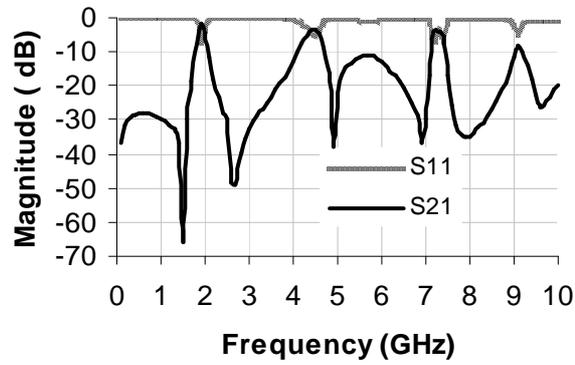
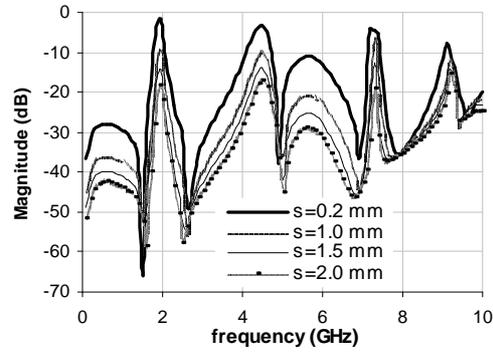


Fig. 1(b) simulated S-parameters

### 3. PARAMETRIC STUDY OF THE PROPOSED STRUCTURE

Parametric study of the proposed structure has been done with the variation of the separation ( $s$ ) between two resonator units keeping all other dimensions constants. The response of the resonators for different cases has been shown in the Fig. 2(a)

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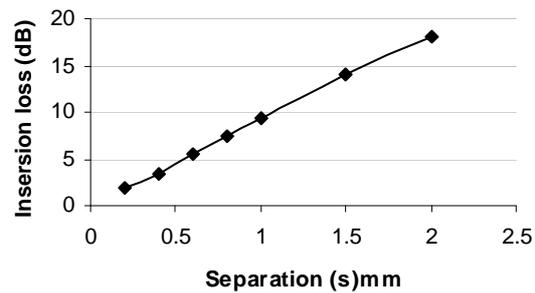


**Fig. 2(a) S-parameters with different separations**

From the above figure it has been observed that with the increment of the separation between two units the interaction effect or desirable coupling will be reduced and which is responsible for introducing more insertion loss in the passband. The obtain results of insertion losses for different 's' is shown in the following Table. 1 and has been plotted graphically in Fig. 3.

**Table 1. insertion losses for different 's'**

Separation (s) mm	0.2	0.4	0.6	1.0	1.5	2.0
Insertion loss (dB)	1.9	3.49	5.52	9.4	14.1	18.2



**Fig. 3 Insertion losses for different 's'**

#### 4. BANDWIDTH ENHANCEMENT AND REDUCTION OF INSERTION LOSS

To enhance the bandwidth performance and reduces the insertion loss one dumbbell shape DGS unit has been introduced in the coupling region under the coupled lines [7]. The slow-wave factor of the microstrip line increases with the inclusion of the DGS, which enhances the coupling between the lines and better passband performance is achieved. The DGS cell consists of two square slots of length,  $p=4$  mm and connected symmetrically by a thin transverse slot of width,  $q =0.5$ mm and length 2 mm. The prototype of the filter is fabricated with Arlon make substrate as illustrated in Fig. 4(a) and the scattering parameters are shown in Fig. 4(b).

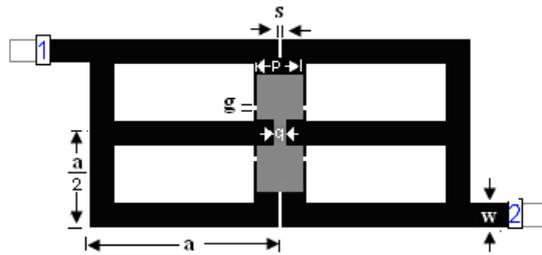


Fig. 4(a) proposed structure with DGS

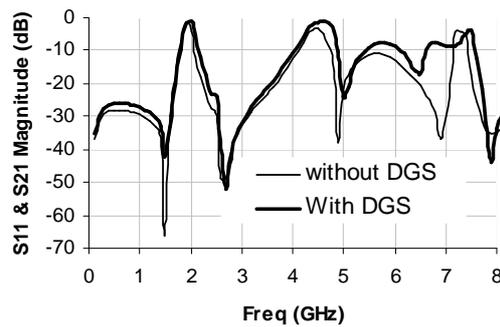


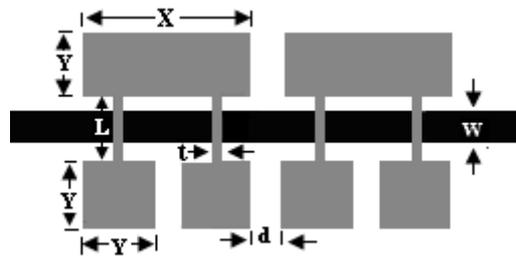
Fig. 4(a) S-Parameters

The above response shows that inclusion of DGS provides less passband insertion loss with enhanced bandwidth keeping the passband centre frequency almost same due to the strong coupling by DGS cell. It is obtained from the above structure, the centre frequency at 1.991GHz, passband insertion loss is 1.26 dB, 20dB bandwidth 0.668 GHz ( $f_1=1.685$  GHz and  $f_2 = 2.353$  GHz), FBW is 33.55% with harmonics at 4.7GHz, 6.1 GHz and 7.6 GHz respectively.

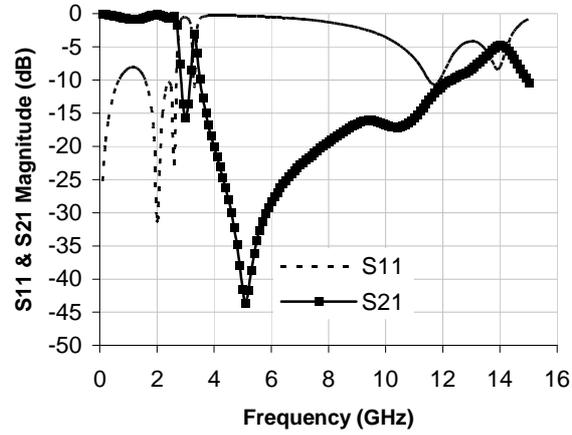
### 5. SPURIOUS REMOVAL

The spurious frequencies are removed by putting additional pairs of DGS cells under input and output feed lines. Here each DGS cell consists of a rectangular slot of length,  $X=10$  mm and breadth  $Y=4$  mm connected with two square slots of  $4\text{mm}\times 4\text{mm}$  by thin transverse slot of width,  $t= 0.5\text{mm}$  and length,  $L=4$  mm. Two square slots in a single DGS unit are separated by  $2\text{mm}$  and DGS cells are separated by a distance of  $2$  mm.

The schematic diagram of the array of DGS cells are shown in the Fig. 5(a) and the characteristic response of it is shown in the Fig. 5(b)



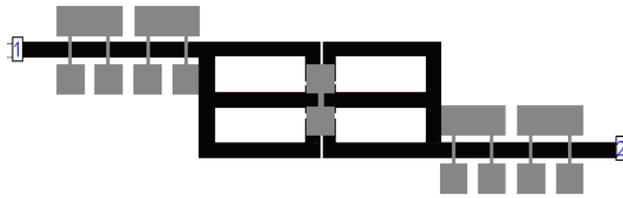
**Fig. 5(a) schematic diagram of the DGS unit**



**Fig. 5(a) characteristic response of the DGS unit**

The characteristic response shows that the DGS unit provide wide stop band. The attenuation bandwidth is almost 8GHz at -15dB and it is from 3.7 GHz to 11.5 GHz within which all of the considerable spurious are existing.

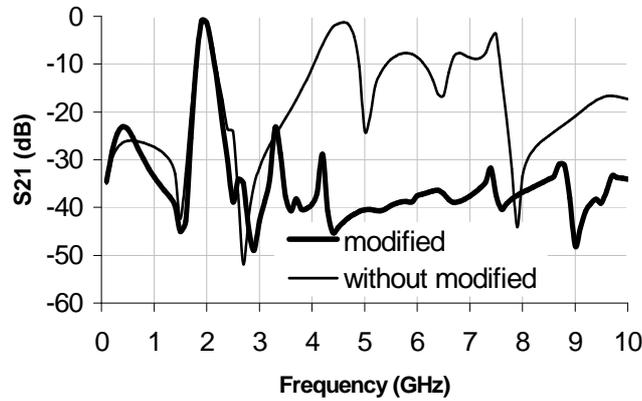
Thus the harmonics are removed by putting additional pairs of investigated DGS cells under input and output feed lines of the microstrip coupled BPF as shown in Fig. 6.



**Fig. 6(a) Schematic diagram of the coupled BPF with DGS unit**

The characteristic response of the Fig.6(a) is shown in the Fig. 6(b)

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**Fig. 6(b) Scattering parameters (S21)**

It is obtained from the above figure that the investigated bandpass filter provides passband centre frequency at 2GHz with good selectivity and quality factor without any insertion loss. The BPF is also with good skirt rate. The -20dB fractional bandwidth (FBW) is 30% ( $f_1 = 1.7$  GHz and  $f_2 = 2.3$  GHz) and the sharpness factor is almost 96.7 dB/GHz.

## 6. CONCLUSIONS

A novel spurious suppressed bandpass filter based on the direct-coupled rectangular split ring resonators is presented. The strong coupling is achieved by introducing dumbbell shaped DGS in the ground plane of the microstrip in the coupling region. An array of two new modified Pi shaped DGS structure is proposed. It exhibits the elliptic- function response and create tunable transmission zeros which are applied to suppress multi spurious responses and achieve sharp skirt selectivity.

Finally, a considerable improvement in steepness of the attenuation slope, wide attenuation frequency bandwidth and high quality BPF has been achieved

which is suitable for modern RF and Microwave satellite and mobile communication systems.

## REFERENCES

1. C.S.Kim, J.S.Park, D.Ahn and J.B. Lim, "A novel one dimensional periodic defected ground structure for planar circuits," *IEEE Microwave and Guided wave Letters*, vol. 10, No. 4, pp.131-133, 2000
2. D. Ahn, J.S.Park, C.S.Kim, J.Kim, Y Qian and T. Itoh, "A design of the lowpass filter using the novel microstrip defected ground structure," *IEEE Trans. on Microwave Theory and Techniques*, vol. 49, no. 1, pp. 86-93, 2001
3. Lim J., Kim C., Lee Y., Ahn D., and Nam S., "Design of lowpass filters using defected ground structure and compensated microstrip line," *Electronics Letter*, vol. 38, no. 25, pp. 1357-1358, 2002
4. A. Abdel-Rahman, A.K. Verma, A. Boutejdar, and A.S. Omar, "Control of bandstop response of Hi-Lo microstrip lowpass filter using slot in ground plane," *IEEE Trans. On Microwave Theory Tech.*, vol .52, no. 3, pp. 1008-1013, March 2004
5. M.K.Mandal and S.Sanyal, "A novel defected ground structure for planar circuits," *IEEE Microwave and Wireless Comp. Lett.*, vol. 16, no. 2, pp.93-95, Feb. 2004
6. Chen J.-X., Li J.-L., Wan K.-C. and Xue Q., "Compact quasi-elliptic function filter based on defected ground structure," *IEE Proc.-Microwave Antennas propagation*, vol . 153, no. 4, pp. 320-324, Aug. 2006
7. Susanta Kumar Parui, Santanu Das "Performance enhancement of microstrip open-loop resonator bandpass filter by defected ground structures," Proc. of International Workshop on Antenna Technology, Cambridge, U.K. (iWAT-07), pp.483-486, March, 2007

8. Susanta Kumar Parui, Santanu Das 'An asymmetric defected ground structure with elliptical response and its application as a lowpass filter' Int. J. Electron. Commun. (AEÜ) vol. 63 ,pp.483 – 490, 2009
9. Parui, Susanta Kumar, Moyra, Tamasi and Das, Santanu "Quasi-elliptic filter characteristics of an asymmetric defective ground structure," International Journal of Electronics, Vol.-96, No.-9, PP-915-924. September 2009.
10. Tamasi Moyra, Susanta Kumar Parui and Santanu Das "Application of a Defected Ground Structure and Alternative Transmission Line for Designing a Quasi-elliptic Lowpass Filter and Reduction of Insertion Loss" *International Journal of RF and Microwave Computer-Aided Engineering* , Vol.-20, No.-6, PP-882-888 November 2010.