Design of High Quality Factor and Harmonic Reduced Bandpass Filter Using Coupled Resonators and Defected Ground Structures

Tamasi Moyra, Susanta Kumar Parui, Santanu Das

Abstract— ***Design of good quality factor and high selective Band pass filter (BPF) is an emerging challenge of microwave engineers in modern RF, microwave and millimeter wave communication systems. Front end of the receiver in a communication system demands high performance BPF to select the required signal from the unwanted adjacent signals with improved selectivity. In this paper one end coupled Band pass filter with centre frequency 2GHz and 30% Fractional Bandwidth (FBW) at -20 dB has been designed with $\lambda/4$ rectangular split ring coupled resonators forming with 50Ω conventional Microstrip transmission line. This designed BPF has been simulated with the help of MoM besed IE3D electromagnetic simulation software. The proposed BPF provides first unwanted harmonic or spurious nearer to the twice of its passband centre frequency and some other higher harmonics at different higher frequencies. 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. Finally, one novel BPF has been designed for Satellite, GPS and Bluetooth applications of modern wireless communication systems.***

Keywords— ***microstrip, coupled resonator, defected ground structure, elliptical, bandpass filter, Q-factor, selectivity.***

I. INTRODUCTION

It is well known that when two transmission lines are placed in close proximity to each other and one line is exited 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.

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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.

II. 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 = 0.2mm. Input /output lines have width W=1.92mm 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=1.67GHz and f_2= 2.226GHz) and the passband insertion loss of 1.57dB and FBW= 28.8% ($FBW = \frac{(f_2 - f_1)}{f_0} \times 100\%$) are observed. The harmonics are centered at 4.5GHz, 5.8 GHz, 7.4 GHz and 9.2 GHz.

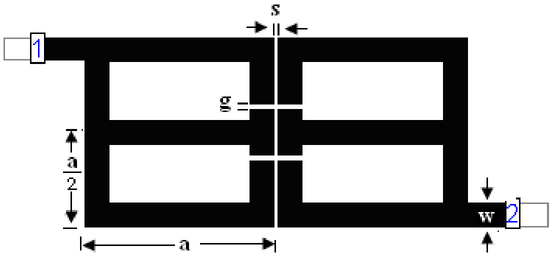

Fig. 1(a) the schematic diagram

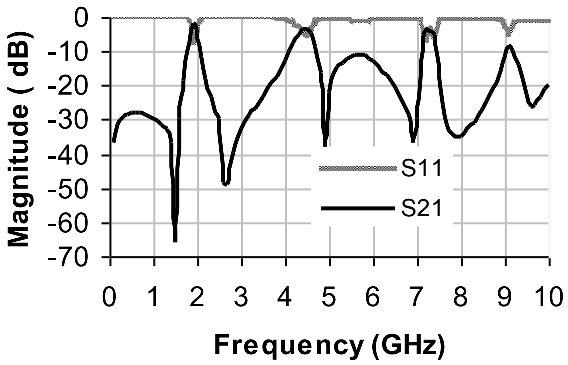

Fig. 1(b) simulated S-parameters

III. 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.

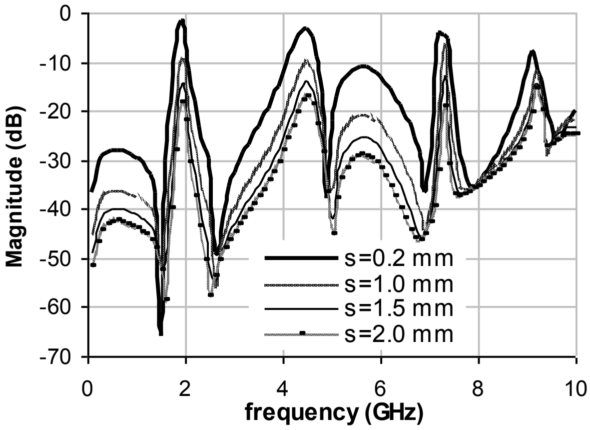

Fig. 2 S-parameters with different separations

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

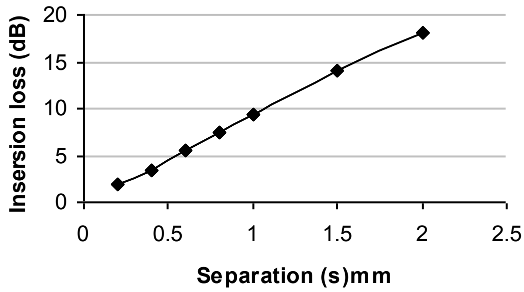

Fig. 3 insertion losses for different 's'

IV. 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 =0.5mm 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).

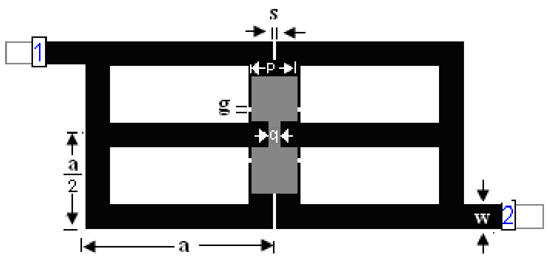

Fig. 4(a) proposed structure with DGS

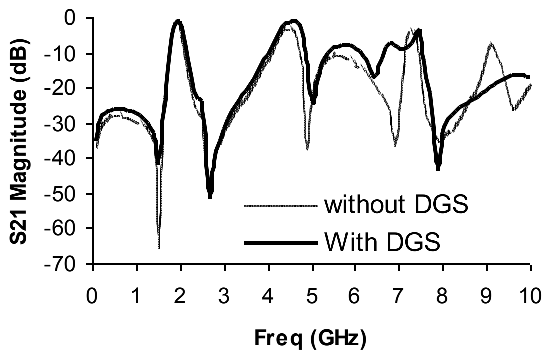

Fig. 4(b) S21-Parameters

The above response shows that inclusion of DGS provides less passband insertion loss with enhanced bandwith keeping the passbamd 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.

V. HARMONICS 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 4mm×4mm by thin transverse slot of width, t= 0.5mm and length, L=4 mm. Two square slots in a single DGS unit are separated by 2mm and DGS cells are separated by a distance of 2mm.

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)

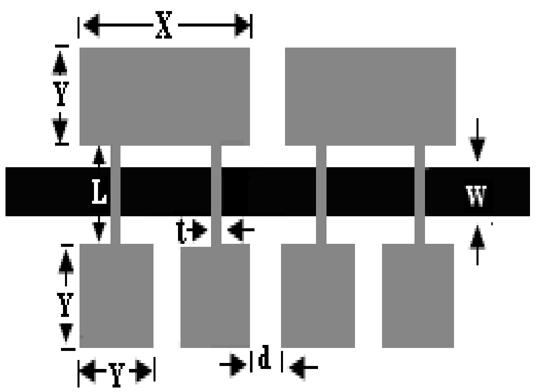

Fig. 5(a) schematic diagram of the DGS unit

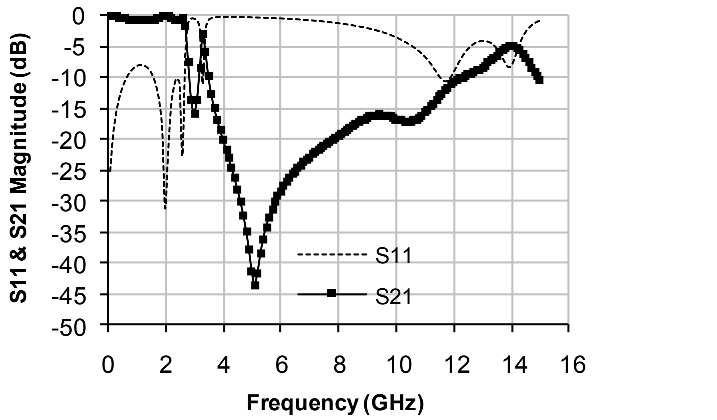

Fig. 5(b) characteristic response of the DGS unit

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.

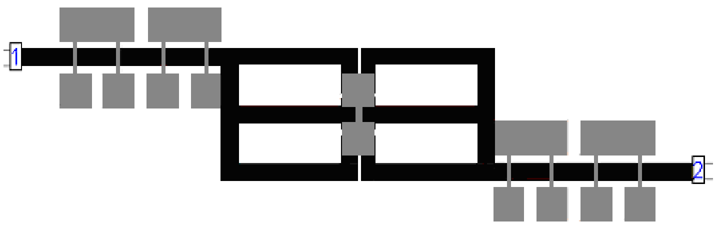

Fig. 6(a) schematic diagram of the coupled BPF with DGS units

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

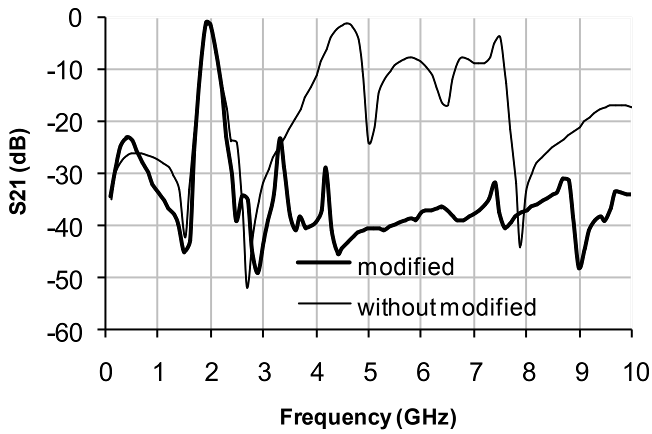

Fig. 6(b) Scattering parameters (S21)

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.

VI. CONCLUSION

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.

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