

Parallel Coupled Wide Pass-Band Filter with Dual Square Complementary Split Ring Resonator and Defected Ground Structure

Aviral Verma, Manish Kumar

Department of Electronics and Communication, Madan Mohan Malaviya University of Technology, Gorakhpur, India
Aviralavi2015@gmail.com

Abstract— In this work, a novel design for obtaining wider pass-band was proposed using dual-square complementary split ring resonator and squared symmetrical defected ground structure. Parallel coupling was also amalgamated which helps to achieve wider band-width. Ideally, microwave filters were designed to have high return loss, diminutive insertion loss, coordinated impedance and stable frequency selectivity to avert redundant signal interference in the spectrum. The proposed structure provides excellent selectivity of -46 dB and -28 dB at the lower and upper cut-off frequencies respectively. Defected ground structure (DGS) improved the return loss of this work and insertion loss of nearly zero dB was obtained. The prototype was designed using ANSOFT HFSS 13.0 where centre frequency was maintained at 4.97 GHz. With reference to other filter techniques, better results were obtained in terms of return loss, insertion loss, selectivity, pass-band stretch, fractional band-width and Q-factor.

Index Terms— Band-Pass Filter; Coupling, Defected Ground Structure; Dual-Square Complementary Split Ring Resonator (DS-CSRR).

I. INTRODUCTION

The need for frequency selection in wireless sector has been constantly growing, demanding for filters that provide a wider pass-band spread, low insertion loss, compact planar structure, sharp rejection rate and excellent selectivity. In relation to this, Band-pass filter (BPF) allows certain signals in the ambit and attenuating frequencies outside the range, satisfying the criteria for good signal selection. The provision of broader pass-band BPFs by integrating parallel coupled micro-strip lines has led to numerous applications in microwave designs. Easy fabrication, simple design, planar frame and wider bandwidth are the essentials for such designs [1]. Broad-band spectrum using micro-strip parallel coupling, specific in S-band wireless communication was proposed in [2]. A non-uniform line resonant structure with triple parallel-coupled lines having loading stubs was intended in [3]. Single transmission element and three coupled micro-strip lines were provided for constricted rejection band [4]. The precincts of each division of micro-strip lines grounded the result in transmission zeros at the termination of pass-band. Multi-mode resonators (MMRs) along with micro-strip lines provide satisfactory for wide-band [5]. MMRs with parallel coupled lines make the filter compact and provide a wider upper stop-band. Quad-coupled filter with superiority in terms of band rejection and high insertion loss was proposed in [6]. Fractional Band-width (FBW) of nearly 60% was attained using spectral domain analysis method [7]. Increased fractional band-width

of nearly 80% was realized in [8], although stop-band rejection rate was low.

Different three coupled micro-strip line filters for broader pass-band have been proposed in [9-13]. A stepped-impedance stub-loaded resonator UWB band-pass filter with insertion losses in close proximity of 1.4 decibels was intended in [14]. Quasi-Chebyshev approach along with MMR to achieve a FBW of 50% was intended in [15]. Split ring resonators (SRR) based meta-material micro-strip lines are very essential structures, in which a high magnetic susceptibility can be obtained in meta-materials. It helps to create strong magnetic coupling to the applied electromagnetic field and obtains a high quality factor. Complementary split ring resonators (CSRR) are the negative depiction of SRR [16] and have negative value of permittivity. Usually, the transmission is barred in the neighborhood where resonance is achieved, but a higher value of quality factor is acquired via CSRRs. Resonant designs are imprinted in the ground of band-pass filter in order to increase the frequency selectivity of the filter [17]. Wide-band band-pass filter with adequate selectivity but high insertion loss was shown in [18]. Defected ground structures (DGS) have been applied to BPF to provide higher value of return loss and better performance in various applications of filtering [19]. Numerous applications in satellite communication and sensor technology creates demand for simple and efficient devices [20].

The present work therefore, focuses to develop a BPF using dual parallel coupled micro-strip lines along with DS-CSRR, with and without DGS. Additionally, in coupling based DS-CSRR, an inner core square is deployed and the design is simulated both with and without DGS. Resonators usually enhance the performance and frequency selection and edges. Diminution in resonant frequency is seen and also transmission zeros are obtained at each precincts. Characteristic impedance of 50 ohm for micro-strip line is designed for I/O feed lines. Both designs of wider pass-band band-pass filter using DS-CSRR with and without DGS are discussed and results are discussed in further level of this work.

II. DESIGN AND ANALYSIS OF DS-CSRR BPF FILTER

In this section, the proposed method for filter designing is discussed for two different configurations; implemented without using defected ground structure and then extended the work using defected ground structures.

A. Wide-band filter without DGS

The proposed design conceptualizes innovation in the existing wideband filters and its operability can be extended to attain excellent fractional bandwidth and low quality factor. A new and improved dual parallel-coupled structure with double square CSRR implemented without DGS is proposed in figure 1 [20]. The top view is shown in Figure 1 (a) and bottom view in Figure 1 (b). Further, defected resonant structure was etched in the strip lines to provide a wide pass-band BPF. FR4_EPOXY substrate was used in filter designing, which has a permittivity of 2.6 and 0.8mm thickness. The width (w) of micro-strip line was kept 2.14mm to match the characteristic impedance of 50 ohm. Two symmetrical double square complementary split ring resonators were used for the design.

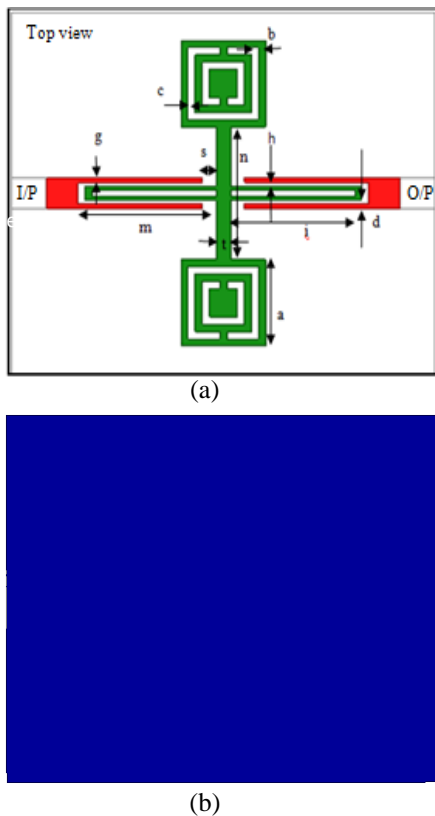


Figure 1: Configuration of wide pass-band BPF using Dual-Parallel Coupled line DS-CSRR without DGS. (a) Top view (b) Bottom view

Table 1

Dimensions of various parameters in the design of filter

Parameters	Dimensions
width of micro-strip line (w)	2.14mm
thickness of substrate	0.80mm
a	6.00mm
b=c	0.50mm
d	0.60mm
g	0.225mm
h	0.25mm
i	8.8mm
m	9.8mm
n	9.15mm
s=t	1.00mm

The dimensions for the design are listed in Table 1 and the parameters are shown in Figure 1. Double square complementary split ring resonator structure was placed along the vertical section of micro-strip line, which enhances the coupling efficiency.

Another structure for wide-band BPF is shown in Figure 2, where a smaller square of dimension ($v=0.5\text{mm} \times 0.5\text{mm}$) was cut in the innermost core. Figure 2 (a) shows the top view, while Figure 2 (b) shows the bottom view of the filter. The configuration was implemented without defected ground structure on FR4_EPOXY substrate with dielectric constant of 2.6 and 0.8mm thickness. Micro-strip line width ($w=2.14\text{mm}$) was maintained to match the characteristic impedance of 50 ohm.

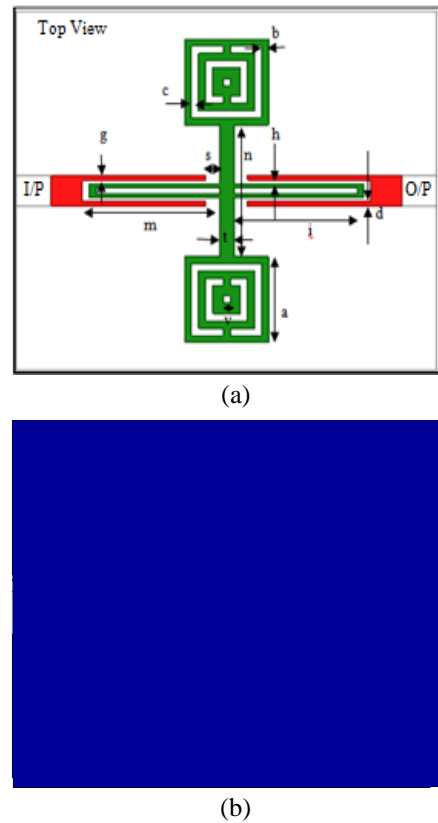


Figure 2: Configuration of wide pass-band BPF using Dual-Parallel Coupled line DS-CSRR and inner core square without DGS. (a) Top view (b) Bottom view

B. Wide-band filter with DGS

Defected ground structure schemes are usually applied to increase the return losses and provide better selectivity. Enhanced rejection rate and better frequency selection are the key parameters on which DGS plot plays its role. A scheme of filter designing using DGS was applied to the ground of DS-CSRR wide-band filter. Two Symmetrical squares were deployed in the ground of size ($l=8\text{mm} \times 8\text{mm}$), separated by length ($n=9.15\text{mm}$). Figure 3 shows the design of proposed wide-band filter using DGS. Figure 3 (a) shows the top view whereas Figure 3 (b) shows the bottom view of the filter structure. Both squares were placed symmetrical to each other with respect to the centre. Investigation of the design was carried out.

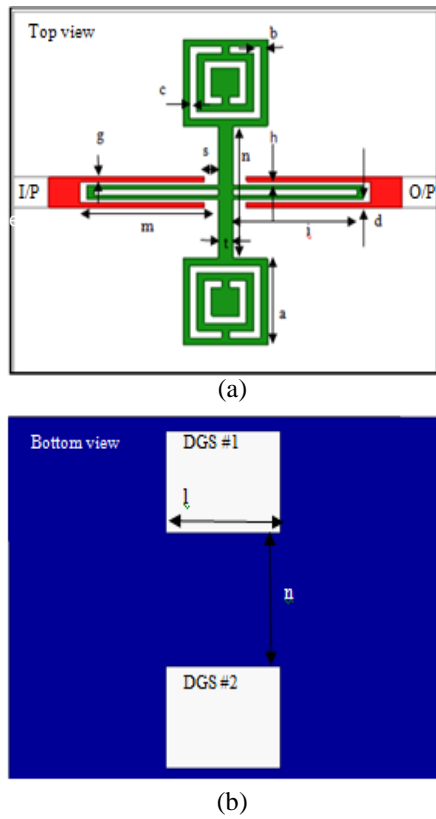


Figure 3: Configuration of proposed wide pass-band BPF using Dual-Parallel Coupled line DS-CSRR with DGS. (a) Top view (b) Bottom view

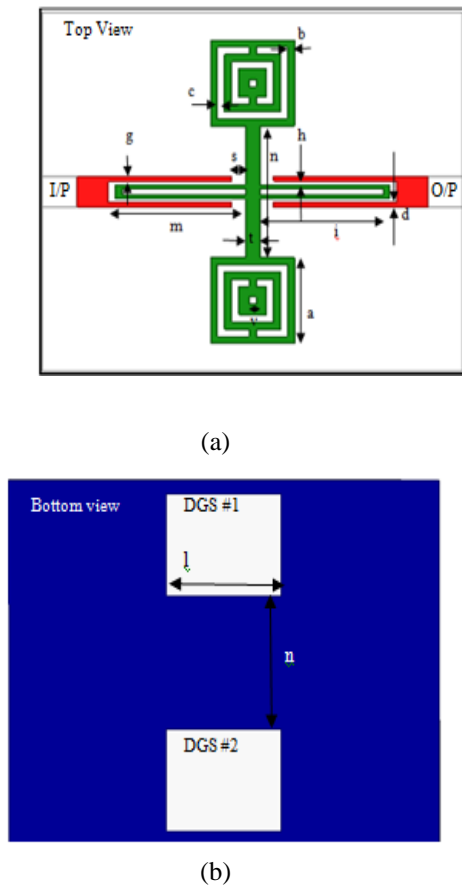


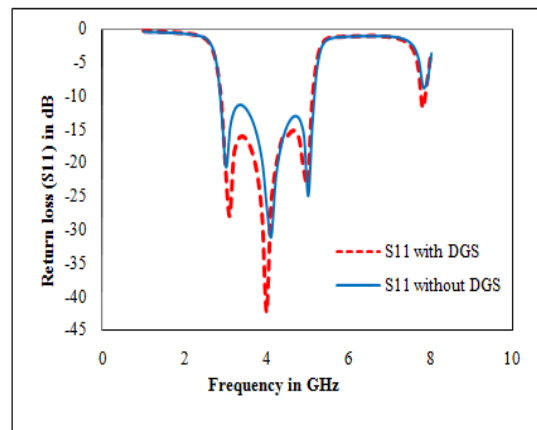
Figure 4: Configuration of proposed wide pass-band BPF using Dual-Parallel Coupled line DS-CSRR and inner core square with DGS. (a) Top view (b) Bottom view

Figure 4 shows the configuration of wide-band BPF using dual-parallel coupled line DS-CSRR with smaller core

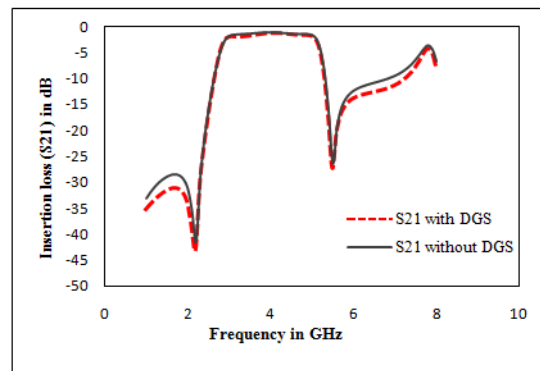
square of dimension 0.5mm x 0.5mm employed using DGS. Figure 4 (a) shows the top view while Figure 4 (b) shows the bottom view of the filter. Performance based on return loss and selectivity was analyzed using defected ground structure, framed on the bottom side of substrate.

III. CHARACTERIZATION RESULTS AND DISCUSSION

The simulated frequency spread of the proposed wide-band filter using parallel coupled lines and DS-CSRR with and without using defected ground structure is shown in Figure 5. The return loss of the wide pass-band filter without DGS was approaching 11 decibels; insertion loss was nearly 1.0 decibel in the spread. Further, the insertion loss of band-pass filter was below 31 decibels in the frequency range from 0 to 2.7 GHz and below 12.7 decibels in the range 6.7 GHz to 8 GHz. The return loss in the stop-band was close to zero decibel. The fractional bandwidth was nearly 60%, stating a low Q-factor. Transmission zeros were present on both sides of pass-band spectrum, providing a higher rejection rate and selectivity, stated as -43.4 decibels at 2.7 GHz and -28.3 decibels at 6.7 GHz respectively. Comparatively, the structure deployed with DGS gave excellent increase in the return loss of 13.3 decibels; insertion loss in the close proximity of 1.0 decibel. In the frequency range from 0 to 2.7 GHz, insertion loss was below 29 decibels and below 12.7 in range 6.97 to 8 GHz. Also, the use of defected ground structure resulted in excellent selectivity and rejection rate as high as -42 decibel at 2.7 GHz and -28 decibel at 6.97 GHz. Table 2 shows the comparison of return and insertion losses for the design.



(a)



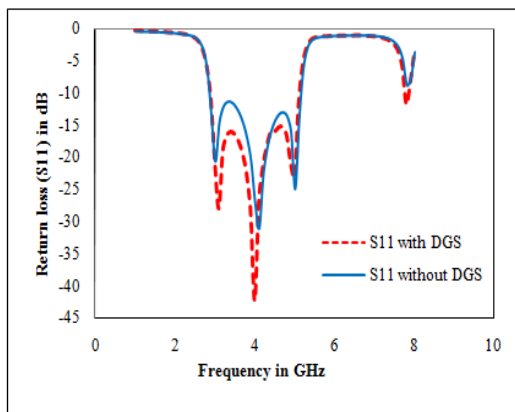
(b)

Figure 5: S-parameter result of proposed wide pass-band BPF using Dual Parallel Coupled line DS-CSRR. (a) S11 with and without DGS (b) S21 with and without DGS

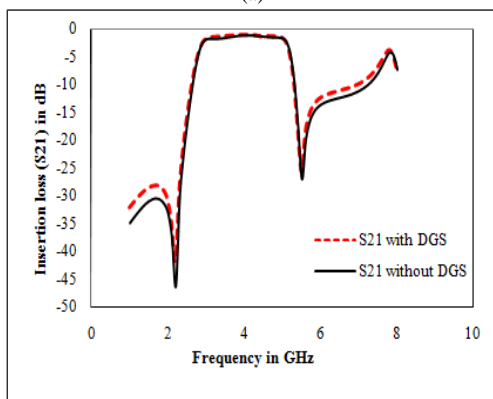
Table 2
Comparison of the proposed design with and without DGS

Design	S11 dB	S21 dB
Proposed design with DGS	13.3	1.0
Proposed design without DGS	11.2	1.0

Further, an analysis was carried for wide-band filter using parallel coupled lines DS-CSRR and inner core square with and without defected ground structure, as shown in Figure 6. The return loss of the wide pass-band filter without DGS was approaching 11.4 decibels; the insertion loss was nearly 0 decibel in the spread. Further, the insertion loss of band-pass filter was below 30 decibels in the frequency range from 0 to 2.7 GHz and below 12.7 decibels in the range 6.7 GHz to 8 GHz. The return loss in the stop-band was close to zero decibel. The fractional bandwidth was nearly 60% stating a low Q-factor. Transmission zeros were present on both sides of pass-band spectrum, providing a higher rejection rate and selectivity, stated as -46.3 decibels at 2.7 GHz and -27 decibels at 6.7 GHz respectively. Comparatively, the structure deployed with DGS gave excellent increase in the return loss of 15.2 decibels; insertion loss in close proximity of 1.0 decibel. In the frequency range from 0 to 2.7 GHz, the insertion loss was below 28 decibels and also below 11.5 in range 6.97 to 8 GHz. Further, the use of defected ground structure resulted in excellent selectivity and rejection rate as high as -42 decibel at 2.7 GHz and -28 decibel at 6.97 GHz. Table 3 shows the comparison of return and insertion losses for this design.



(a)



(b)

Figure 6: Result of proposed wide pass-band BPF using Dual Parallel Coupled line CSRR and inner core square. (a) S11 with and without DGS (b) S21 with and without DGS

Table 3
Comparison of the proposed wide pass-band BPF using dual parallel coupled line CSRR and inner core square with and without DGS

Design	S11 dB	S21 dB
Proposed design with DGS	15.3	0.9
Proposed design without DGS	11.4	1.0

Table 4 shows the comparison with various other topologies of band-pass filtering proposed in the past decades.

Table 4
Comparison with Various Other Topologies

Reference	S21 dB	S11 dB	Dielectric constant/height(mm)
[1]	1.0	12.0	2.65/0.8
[2]	1.0	11.0	10.8/1.27
[6]	1.1	10.0	10.8/0.635
[9]	1.6	15.0	10.5/0.635
[12]	2.0	7.0	2.55/0.8
[13]	2.0	12.5	10.5/0.635
[14]	1.4	11.0	2.550.8
[15]	1.5	7.0	2.55/0.8
[21]	0.5	12.0	2.6/0.8
Proposed work with DGS	1.0	15.0	4.4/0.8

IV. CONCLUSION

This paper presents two designs of band-pass filter using dual parallel coupled lines and double square CSRR. They were investigated twice: without DGS and with DGS. Dual asymmetric parallel-coupled lines provided a firm coupling over wide pass-band region. The bandwidth enhancement was also examined with DGS on the ground plane. The characteristic results showed variation in return loss and sharp selectivity for both of the designs. The average insertion loss was low in the pass-band regions. Return loss was higher than 15 decibels with DGS and greater than 11 decibels without DGS. Further, fractional bandwidth was high resulting in nominal Q-factor, indicating a wider pass-band. Compact size, planar structure along with superior frequency selectivity and sharp rejection rate of desired pass-band were achieved. The proposed DGS filter structure implied an improved and adequate performance, which is apt for various wireless applications.

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