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# Novel Stepped Impedance Microstrip Bandpass Filters for Radar Applications

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**Abstract:** In this paper, the design and realization of A Novel Microstrip Stepped Impedance Resonator Bandpass Filters with two selected center frequencies (f0) 12GHz and 16GHz presented. For The design of Band pass Filters “Rogers 6035HTC" substrate material with relative dielectric constant of 3.55, Standard thickness of 0.020” (0.508mm), thickness of pec is 0.035mm and simulated on High Frequency System Simulator (HFSS). Both the designed filters performances are discussed and compared with literature. The designed Stepped Impedance microstrip BPFs have insertion loss of <1dB with the optimal average performance of 37% and 32% FBW, and return losses are 47 dB and 32dB, which is reported better when compared with the reference designs.

**Index Terms:** FBW, HFSS, Insertion loss, Microstrip, Optimal Average, Resonator, Return loss.

## I. INTRODUCTION

Filters are a significant part of the communication systems, Filters assumes critical part in numerous RF and microwave applications. The Electromagnetic spectrum range is limited and should be convey, filters are acclimated select or reject the RF and microwave signals inside distributed ghastly band range and has been generally used in military and civil fields [1].

A filter is a 2-Port network used to limit the band of frequency response at an exact point in a RF and microwave system, Micro strip Bandpass filter is a microwave instrument, which permits just chosen frequency ranges and stop the frequencies above and beneath the cutoff frequencies [2].

The necessity of elite BPFs is expanding a direct result of the new improvements in the wireless communications field. The Primary highlights for the filter’s configuration utilized in the front end of RF modules are Emerging applications like wireless communications keep on defying RF and microwave channels with always unbending necessities simple creation, better, low radiation misfortune, smallness, more modest size, lower cost and lighter weight [3].

The filter size, weight, and volumes are often reduced while keeping insertion loss low for gaining the required accomplishment. Micro strip band pass filters BPFs are widely studied and tackled in the literature, different types of planar micro strip band pass filters are made up of parallel coupled lines i.e., multi-mode resonators (MMR), stepped impedance resonators (SIR), hairpin lines are proposed in various literatures [4-8].

In these designs, stepped impedance resonators are used to get a Bandpass Response. The SIR which are having an Open Circuit on one end and the Input and output ports are kept on the other ends acts as a Bandpass Filter [9-10].

## II. STEPPED IMPEDANCE FILTER THEORY

Conventionally the proposed wideband filter design starts with standard low pass prototype shown in Fig 1 and then converted into its equivalent bandpass filter configuration Fig 2. Later using Stepped Impedance Resonator transformation filter will be converted into various structures in order to attain desired characteristics.

### *A) Stepped-Impedance, L-C Ladder Type Lowpass Filters*

Figure 1(a) shows a general design of the stepped impedance lowpass microstrip filters, which utilize a fell construction of rotating high-and low impedance transmission lines. These are a lot more limited than the related guided

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wavelength, to go about as semi lumped components. The high-impedance lines go about as arrangement inductors and the low-impedance lines go about as shunt capacitors. Accordingly, this filter structure is straightforwardly understanding the L-C ladder type of lowpass filters of Figure 1(b).

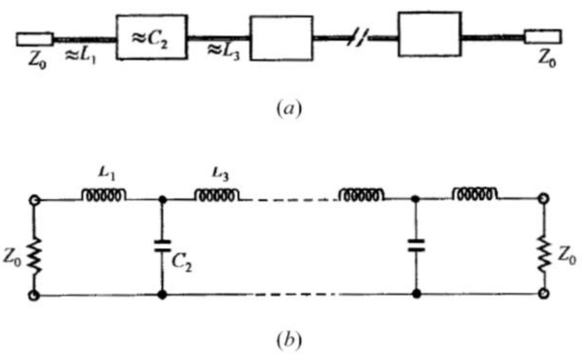


Figure 1: (a) General structure of the stepped-impedance lowpass microstrip filters. (b) L-C ladder type of lowpass filters to be approximated.

The lumped parameters of LPF can be obtained from following equations:

$$L = \frac{Z_0 g}{\omega c} \ \ and \ \ C = \frac{g}{Z_0 \omega c}$$

The calculated values of the components can be tabulated as:

Lumped wideband bandpass filter To design the wideband bandpass filter from its low pass prototype, the computed values from above table can be used in the formulas as follows:

a) Parallel connections of LC

$$L_1 = \frac{g_1 \Delta Z_0}{\omega_0} \ \ and \ \ C_1 = \frac{1}{\omega_0 g_1 \Delta Z_0} \quad ---(1)$$

b) Series connections of LC

.

Band pass Filters L-C element values calculated from (1) and (2) as indicated shown in the Table.I and Based on the values of Table.I the L-C ladder type of bandpass filter approximated as shown in the Figure.2

TABLE I: BAND PASS FILTERS L-C ELEMENT VALUES

| 10-14GHZ Band pass Filters L-C element values | | | | 14-18GHZ Band pass Filters L-C element values | | | |
|---|---|---|---|---|---|---|---|
| Para-meter | Calculated Value of the component | Parameter | Calculated Value of the component | Para-meter | Calculated Value of the component | Para-meter | Calculated Value of the component |
| $C_1$ | 261.9 fF | $C_6$ | 1.496pF | $C_1$ | 145.5 fF | $C_6$ | 1.496fF |
| $L_1$ | 690.9pH | $L_6$ | 121.0pH | $L_1$ | 690.9 pH | $L_6$ | 67.21pH |
| $C_2$ | 795.8fF | $C_7$ | 59.36fF | $C_2$ | 795.8 fF | $C_7$ | 32.98fF |
| $L_2$ | 227.4pH | $L_7$ | 3.048pH | $L_2$ | 126.3 pH | $L_7$ | 3.048pH |
| $C_3$ | 59.36fF | $C_8$ | 795.8 fF | $C_3$ | 32.98 fF | $C_8$ | 795.8fF |
| $L_3$ | 3.048nH | $L_8$ | 227.4 pH | $L_3$ | 3.048 pH | $L_8$ | 126.3pH |
| $C_4$ | 1.496pF | $C_9$ | 261.9 fF | $C_4$ | 1.496 fF | $C_9$ | 145.5fF |
| $L_4$ | 121.0pH | $L_9$ | 690.9 pH | $L_4$ | 67.21 pH | $L_9$ | 690.9pH |
| $C_5$ | 45.47 fF | | | $C_5$ | 25.26 fF | | |
| $L_5$ | 3.979 nH | | | $L_5$ | 3.979 nH | | |

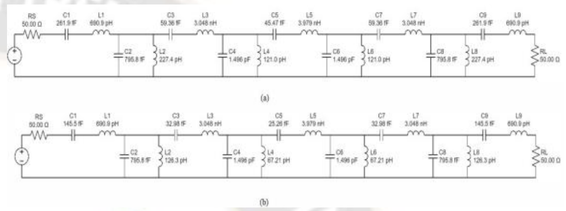

Figure 2: L-C ladder type structure of Band Pass filter prototypes (a)10-14GHz BPF (b) 14-18GHz BPF

In this paper 9th order bandpass filters at 12GHz and 16GHz resonant frequencies with matched impedance of 50 ohm and return loss (> 40 dB) with the insertion loss (<1) is Proposed in different topologies. The main focus is to achieve the bandwidth of >4GHz with the proposed filter designs. The Design Specifications of Band Pass filters are listed in Table I and the substrate specifications are listed in Table II.

TABLE II: DESIGN SPECIFICATIONS OF BPFS

| Specification | BPF1 | BPF2 |
|---|---|---|
| Order of the Filter, N | 9 | 9 |
| Center Frequency($f_0$) | 12GHz | 16GHz |
| Impedance | 50 Ohms | 50 Ohms |
| Proposed Fractional Bandwidth | 0.25 | 0.33 |
| Proposed Bandwidth | 4GHz | 4GHz |

*B) Substrate Specifications: Rogers 6035HTC*

In High power RF and microwave applications RT/duroid 6035 HTC high frequency circuit materials with ceramic filled PTFE utilized. For the plan of bandpass filters this substrate material is utilizes on account of its thermal conductivity is High and warmth dissemination additionally improved, so it empowers low working temperatures for high power RF and microwave applications. loss tangent also additionally Low and Excellent high frequency execution, lower insertion loss and thermal stability of traces.

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TABLE III: SUBSTRATE SPECIFICATIONS

| Specification | Values |
|---|---|
| Dielectric constant | 3.55 |
| Standard Thickness of Substrate, H | 0.020" (0.508mm) |
| Metal thickness | 0.035 mm |
| Loss tangent | 0.0037 |

Based on the Substrate specifications and resonant frequency Transmission line Specifications are calculated for both the BPF's and mentioned in the Table IV.

## III. DESIGN AND ANALYSIS OF STEPPED IMPEDANCE FILTERS

Based on the values mentioned in the Table IV the Conventional Band pass Filters are generated using HFSS.

The 9th order microstrip Stepped Impedance resonator bandpass filters with the center frequency of 12GHz and 16GHz cross sections are modeled in Fig.2 (a)&(b) and the simulated response of the conventional stepped impedance resonator bandpass filters shown in Fig.3(a)&(b). The Bandpass filters are fed with a 50 ohm microstrip line at input and output.

TABLE IV: TRANSMISSION LINE SPECIFICATIONS

| 10-14GHZ BPF | | | 14-18GHZ BPF | | |
|---|---|---|---|---|---|
| Component | Transmission line specifications | | Component | Transmission line specifications | |
| | W (mm) | L (mm) | | W (mm) | L (mm) |
| C1 | 3.044 | 0.3 | C1 | 3.4814 | 0.25 |
| L1 | 0.3 | 10.53305 | L1 | 0.35 | 7.6412 |
| C2 | 3.044 | 0.3 | C2 | 3.4814 | 0.25 |
| L2 | 0.3 | 9.8259 | L2 | 0.35 | 6.9053 |
| C3 | 3.044 | 0.3888 | C3 | 3.4814 | 0.418 |
| L3 | 0.3 | 9.5823 | L3 | 0.35 | 6.6481 |
| C4 | 3.044 | 0.5665 | C4 | 3.4814 | 0.5534 |
| L4 | 0.3 | 9.3214 | L4 | 0.35 | 6.4963 |
| C5 | 3.044 | 0.6279 | C5 | 3.4814 | 0.6136 |
| L5 | 0.3 | 9.2769 | L5 | 0.35 | 6.4559 |
| C6 | 3.044 | 0.5643 | C6 | 3.4814 | 0.5534 |
| L6 | 0.3 | 9.3214 | L6 | 0.35 | 6.4559 |
| C7 | 3.044 | 0.3867 | C7 | 3.4814 | 0.418 |
| L7 | 0.3 | 9.5823 | L7 | 0.35 | 6.6481 |
| C8 | 3.044 | 0.3 | C8 | 3.4814 | 0.25 |
| L8 | 0.3 | 9.8259 | L8 | 0.35 | 6.9053 |
| C9 | 3.044 | 0.3 | C9 | 3.4814 | 0.25 |
| L9 | 0.3 | 10.53305 | L9 | 0.35 | 7.6412 |

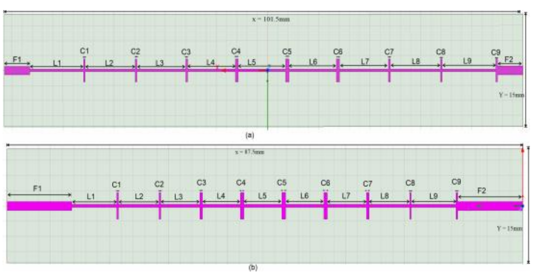

Figure 3: Conventional 9th order MSIR Bandpass Filters 2D View in HFSS (a)10-14GHz BPF (b)14-18GHz

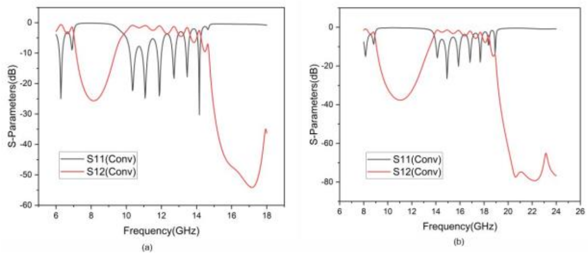


Figure 4: Conventional 9th order MSIR Bandpass Filters Simulated responses: (a)10-14GHz BPF (b)14-18GHz

After observing the Conventional Microstrip stepped impedance Resonator bandpass filter responses, the 3dB bandwidth is <2GHz, So in order to improve the 3dB bandwidth and FBW the filters are further optimized as mentioned in the Table.5.

TABLE V: OPTIMIZED TRANSMISSION LINE SPECIFICATIONS

| 10-14GHZ BPF | | | 14-18GHZ BPF | | |
|---|---|---|---|---|---|
| Component | Transmission line specifications | | Component | Transmission line specifications | |
| | W (mm) | L (mm) | | W (mm) | L (mm) |
| F1 | 1.11 | 5 | F1 | 1.12 | 11 |
| C1 | 3.044 | 0.3 | C1 | 3.4814 | 0.25 |
| L1 | 0.3 | 0.7 | L1 | 0.35 | 0.52 |
| C2 | 3.044 | 0.3 | C2 | 3.4814 | 0.25 |
| L2 | 0.3 | 9.5 | L2 | 0.35 | 6.79 |
| C3 | 3.044 | 0.3888 | C3 | 3.4814 | 0.418 |
| L3 | 0.3 | 9.82 | L3 | 0.35 | 6.90 |
| C4 | 3.044 | 0.5665 | C4 | 3.4814 | 0.5534 |
| L4 | 0.3 | 9.58 | L4 | 0.35 | 6.64 |
| C5 | 3.044 | 0.6279 | C5 | 3.4814 | 0.6136 |
| L5 | 0.3 | 9.32 | L5 | 0.35 | 6.49 |
| C6 | 3.044 | 0.6279 | C6 | 3.4814 | 0.5534 |
| L6 | 0.3 | 9.27 | L6 | 0.35 | 6.4559 |
| C7 | 3.044 | 0.56 | C7 | 3.4814 | 0.418 |
| L7 | 0.3 | 9.32 | L7 | 0.35 | 6.6481 |
| C8 | 3.044 | 0.38 | C8 | 3.4814 | 0.41 |
| L8 | 0.3 | 9.58 | L8 | 0.35 | 6.9053 |
| C9 | 3.044 | 0.3 | C9 | 3.4814 | 0.25 |
| L9 | 0.3 | 9.82 | L9 | 0.35 | 6.93 |
| C10 | 3.044 | 0.3 | C10 | 3.4814 | 0.25 |
| L10 | 0.3 | 9.50 | L10 | 0.35 | 6.77 |
| L11 | 0.3 | 0.71 | L11 | 0.35 | 0.5 |
| F2 | 1.11 | 5 | F2 | 1.12 | 11 |

The Novel MSIR Bandpass Filters with resonant frequency at 12GHz and 16GHz with improved 3dB bandwidth is Shown in the Figure 5.

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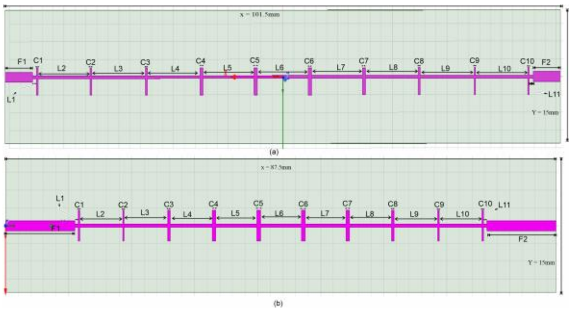


Figure 5: Novel MSIR Bandpass filters 2D View of (a).BPF1(b).BPF2

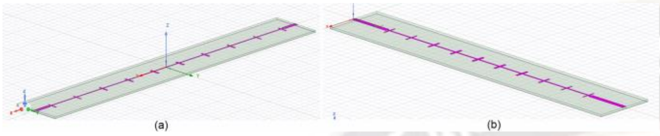



Figure 6: Novel MSIR Bandpass filters 3D view (a). BPF1 (b) BPF2

The simulated characteristics of the proposed Novel MSIR Bandpass filters are obtained by using HFSS. To showcase the performance of the novel designed bandpass filters , the responses are compared with the conventional Bandpass filters.

Fig.7 illustrates the simulated responses of the Conventional Stepped impedance Resonator vs Novel MSIR Bandpass filter designs. The Simulated responses of Novel designs shows that for the BPF1 the Insertion loss is 0.9dB and return loss is 47dB and the 3dB bandwidth is 4.45GHz and FBW is 37% and for the BPF2 the Insertion loss is 0.9dB and return loss is 32dB and the 3dB bandwidth is 5GHz and FBW is 32%.

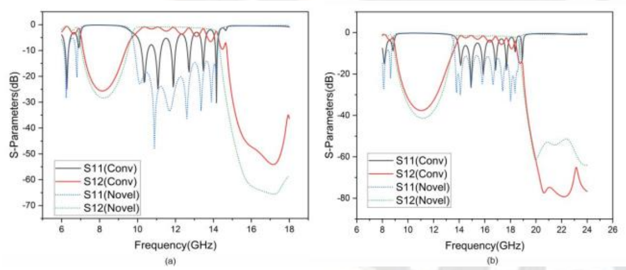
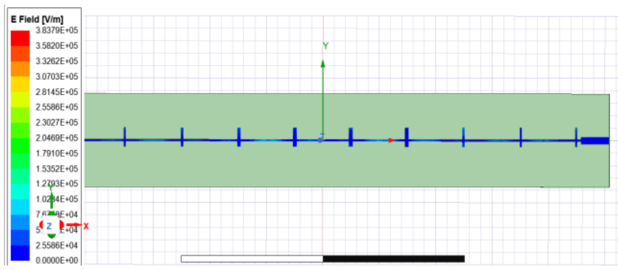
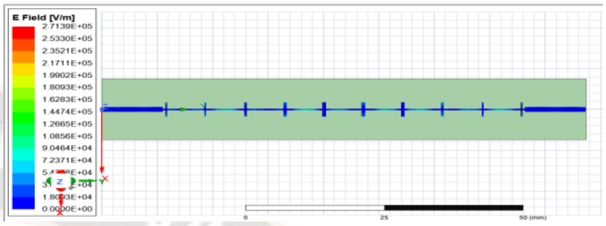



Figure 7: Simulated responses of Novel MSIR Bandpass filters (a) BPF1 response (b) BPF2 response

The current distribution of the designed Novel MSIR Bandpass filters which operates 10-14GHz and 14GHz to 18GHz frequency Shown in Figure 8.




(a)




(b)

Figure 8: Current distribution of Novel Stepped Impedance Microstrip Bandpass filters

(a) BPF1 Current distribution (b) BPF2 Current distribution

The Novel MSIR Bandpass filters are fabricated using the RT/duroid 6035 HTC Substrate material with 0.035mm thickness of PEC as shown in the Figure 7.

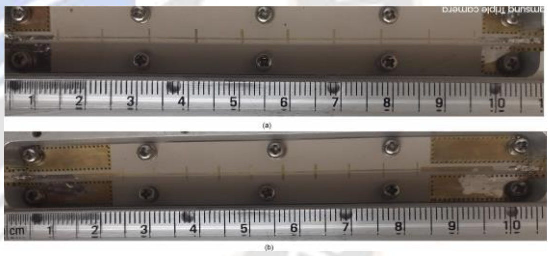


Figure 9: Fabricated Novel MSIR Bandpass filter (a) BPF1 (b) BPF2

The performances of the fabricated filters are measured by using Agilent E5071C ATO 79866 network analyzer as shown in the Figure 8.

Figure 10: Performance Mesurement of Novel MSIR Bandpass filters using Agilent E5071C ATO 79866

Figure 10 illustrates the simulated and measured S-parameters of the two Novel MSIR Bandpass filters. The measured and simulated results are found to have reasonably good agreement with each other.

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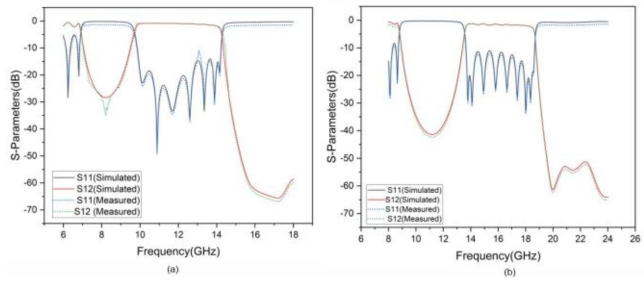


Figure 11: simulated and measured S-parameters of the two Novel MSIR Bandpass filters

## IV. CONCLUSION

In this paper the Novel Microstrip Stepped impedance resonator bandpass filters resonant at f0= 12 GHz,16GHz are designed, the design of Band pass Filters used "Rogers 6035HTC" substrate material with relative dielectric constant ($\varepsilon_r$) of 3.55, Standard thickness of 0.020" (0.508mm), thickness of pec is 0.035mm and simulated on High Frequency System Simulator (HFSS). The optimization performed with the conventional filter designs and compared. Performances of the MSIR Bandpass filters have the fractional Bandwidth of 37% and 32% with the low insertion loss i.e.,0.9 dB and the return losses are 47dB and 32dB respectively. The Novel Bandpass filters are Fabricated and Compared the performance with Simulated, found to have reasonably good agreement with each other The design results revealed that the efficiency of filter can be enhanced by incorporating SIR techniques. This not only eases the design procedure but also imparts compactness to filter size. Due to these elegant features; the proposed filters can be employed in numerous of microwave and modern wireless systems.

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