A Compact Wideband Bandpass Filter Based On Folded High – Low Impedance Resonator

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***Abstract* — A novel wideband bandpass filter with sharp roll-off using folded high – low impedance resonator with aperture based edge coupled technique is presented. The proposed bandpass filter has a 3 dB fractional bandwidth of 101.8% and the structure is compact. The centre frequency of the filter is 5.5 GHz. The prototype filter is designed using a low cost FR4 glass epoxy substrate with a dielectric constant 4.4 and a thickness of 0.8mm. IE3D software is used for the simulation and optimization of the filter structure. Sharp roll-off of the filter structure is achieved by the two transmission zeros generated by the centrally loaded folded high - low impedance resonator. Stopband performance with 17.23 dB suppression level is obtained upto 13.6 GHz.**

Keywords— Bandpass filters, folded, aperture, high- low impedance

I. INTRODUCTION

The ever growing demand of modern wireless communication implies the vital requirement of wideband bandpass filters for the implementation of current and future communication systems. Good wideband bandpass filters should be characterized by sharp selectivity, good in and out of band performances, low cost and simple design procedures. The wideband filter blocks are employed to remove the unwanted signals and noise from the communication systems. Traditional filter design approaches like end coupled, parallel coupled and the hairpin line method fails to meet the specifications due to the requirements of tight coupling and uncontrolled nonlinear frequency dispersion over the entire wide bandwidth of interest [1]. In order to increase the passband bandwidth, there must be more number of poles in the passband. The main design considerations for developing an ideal bandpass filter are very low insertion loss in the passband, infinite return loss in the passband and good selectivity of the passband with required fractional bandwidth. Recently, wide array of techniques was proposed to design wideband bandpass filter configurations. These techniques can be categorized as hybrid microstrip/coplanar waveguide (CPW) techniques [2], electronic band gap structure (EBG) loaded techniques [3] multi-layer broadside techniques with liquid crystal polymers [4] and low temperature co-fired ceramics (LTCC) as packaging materials, cascaded high/low pass filter techniques [5], optimum short circuited techniques and the multiple mode resonator techniques. In [6], pseudo-inter digital stepped impedance resonators were proposed to develop a wideband filter. Keeping the aforementioned requirements, our aim is to develop a simple, highly selective, low cost filter implemented using an easily available material with a wide pass band.

In this paper, a novel folded high – low impedance resonator with aperture based edge coupled wideband bandpass filter which is having low cost and easily implementable structure with sharp roll-off and two transmission zeros at both lower and upper passband edges is proposed. The filtering performance is achieved by the combined action of the aperture based inter-digital coupled lines and the folded high – low impedance resonator. The folded high – low impedance resonator provides wide pass band response but fails to meet the out of band characteristics. Aperture based three line parallel coupling is applied to the central resonator for enhancing the out of band characteristics. The proposed wideband bandpass filter is designed using a low cost material, FR4 epoxy substrate. The filter provides very good in and out-off band performance. The relative dielectric constant of the material is 4.4, with thickness 0.8 mm and a dielectric loss tangent of 0.02. The simulation of the proposed filter structure is carried out using EM simulation software IE3D and the measurements are taken using R&S ZVL 13 Vector network analyzer.

II. WIDEBAND BANDPASS FILTER DESIGN

The proposed filter having the required wideband characteristics has the final structure as shown in Fig. 1. The black region represents input and output feed lines and the centrally loaded folded resonator. The pink region is the aperture cut placed in the ground plane exactly behind the three line parallel coupled lines. Aperture coupling is employed here in order to ensure tight coupling between the three line parallel coupled structures. The thickness of the resonators and feed lines is 0.035 µm. This compact structure has dimensions 19.7 x 8.8 mm, which results in a total physical area of 173.36 sq.mm. The port lengths are selected such that, the connection of SMA connectors cause minimum interference with the input and output signals. The width of ports are 1.5 mm for proper impedance matching, since the substrate used is FR4 with 0.8 mm thickness.

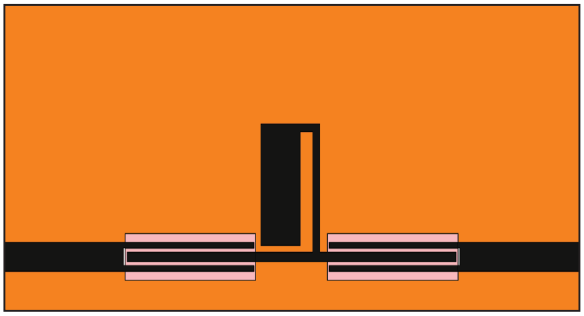

Fig. 1. Layout of the proposed filter structure

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A. Centrally Loaded Folded Resonator

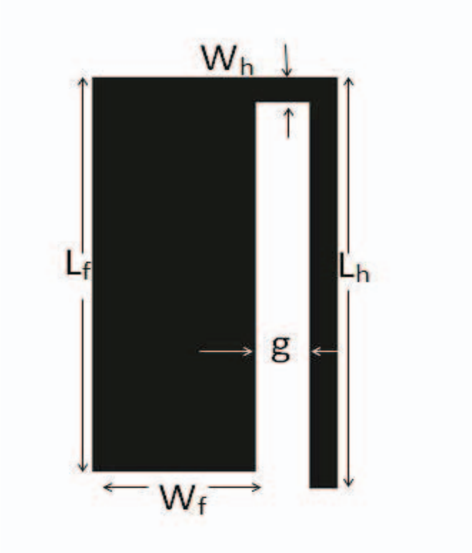

Fig. 2. Layout of the folded high - low impedance resonator

The layout of the centrally loaded folded high – low impedance based resonator filter structure is shown in Fig. 2. The effective dielectric constant, Ɛrh and the impedance of the high impedance section, Z_h having width 0.4 mm is 3.057 and 95.41 Ω respectively. The dimensions of the resonator are given as follows: $W_h = 0.4$, $L_h = 6.6$, $g = 0.75$, $L_f = 6.2$ and $W_f = 2.25$ (all dimensions are in mm). The effective dielectric constant, Ɛrf and the impedance of the low impedance section, Z_f having width 2.25 mm is 3.44 and 39.30 Ω respectively. Folded configuration ensures compactness of the filter structure. Folded high – low impedance resonator produces transmission zeros both at lower and upper passband edges having frequencies 2.3 GHz and 9.5 GHz respectively. The transmission characteristics of the resonator are given in Fig. 3.

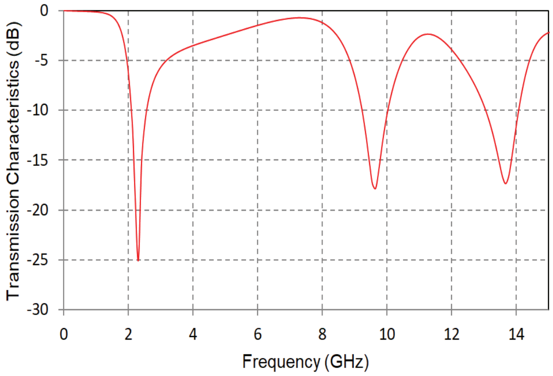

Fig. 3. Simulated response of the folded resonator

B. Aperture based three line coupled resonator

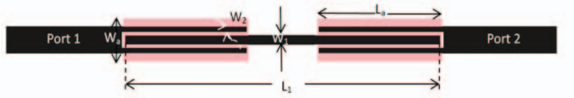

Fig. 4. Layout of the aperture based parallel coupling structure

The folded resonator achieves two transmission zeros at both passband edges but fails to meet the stopband requirements. For ensuring better stopband characteristics, aperture based three line parallel coupling is applied to the basic folded resonator. The configuration of the filter structure is as shown in Fig. 4 with the following dimensions: $L_1 = 19.3$, $W_1 = 0.5$, $W_2 = 0.2$, $W_a = 2.4$ and $L_a = 7.7$ (all dimensions are in mm). The benefit of applying three line parallel coupled lines is to band limit the out of band performance of the folded resonator by the two transmission zeros generated by the aperture-based coupled structure. The frequency response of the filter is given in Fig. 5 which is having two transmission zeros at 0.01 GHz and 11.6 GHz.

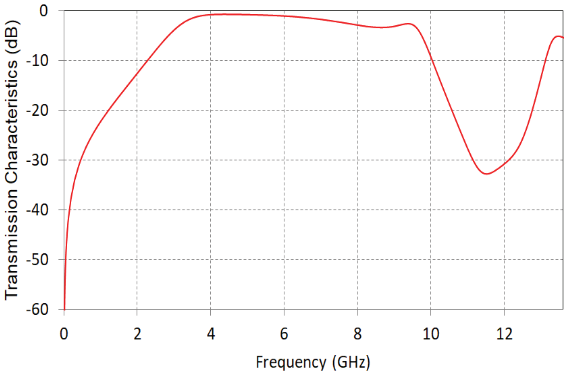

Fig. 5. Simulated response of the aperture coupled filter

III. FIELD INTENSITY CHARACTERISTICS

For verifying the relationship between the obtained results and the field behavior of the proposed filter, a study of field intensities is carried out using simulation software IE3D and is given in Fig. 6 (a) – (c).

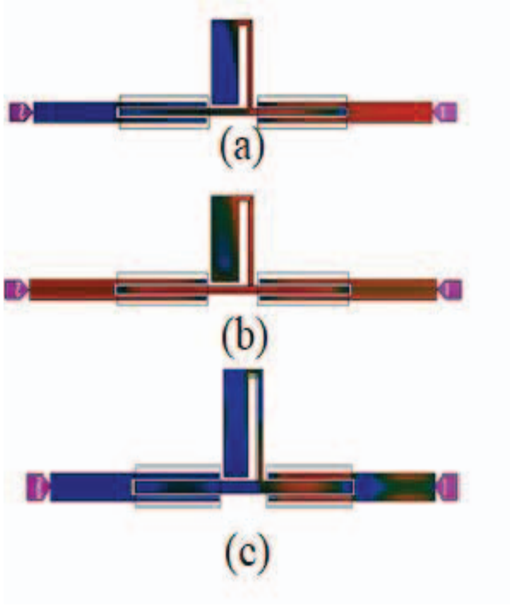

Fig. 6. Electric field intensities at: (a) lower stopband @ 1 GHz (b) passband @ 5GHz (c) upper stopband @ 15 GHz

The frequencies upto the lower cut-off frequency are the lower stopband and the range of frequencies above the upper cut-off frequency are termed as upper stopband. The electric field intensity at 1 GHz and 15 GHz are taken here for visualizing the field intensities at lower and upper stopband and at passband centre frequency 5 GHz respectively is as shown in Fig.6 (a) to (c). At stopband, the field distribution shows that almost all energy is locked near the input port and it is not coupled to the output.

IV. RESULTS & DISCUSSIONS

To demonstrate the proposed concept, the designed wideband filter is fabricated on a low cost FR-4 substrate having dielectric constant 4.4 and thickness of 0.8 mm. IE3D is used for the optimization of the proposed filter. For ensuring impedance matching the input and output ports are properly matched. Since we are using the FR4 substrate with thickness 0.8mm, the width of both ports must be 1.5mm. The optimized design parameters of the proposed filter are as follows: $L_1 = 19.3$, $W_1 = 0.5$, $W_2 = 0.2$, $W_a = 2.4$, $L_a = 7.7$, $W_h = 0.4$, $L_h = 6.6$, $g = 0.75$, $L_f = 6.2$ and $W_f = 2.25$ (all in millimeters). The 3 dB pass band covers the range of 2.7–8.3 GHz and it has a fractional bandwidth of 101.8 %. The measured return loss is better than 10 dB within the pass band, and sharp selectivity is observed because of the two transmission zeros in the lower and upper cut-off frequencies. In addition, the group delay variation within the pass band is only 0.2 ns, showing a good linearity. The frequency responses of the basic filter are shown in Fig.7, where SL represents solid line and DL represents dotted line. The group delay characteristics is given in Fig. (8).

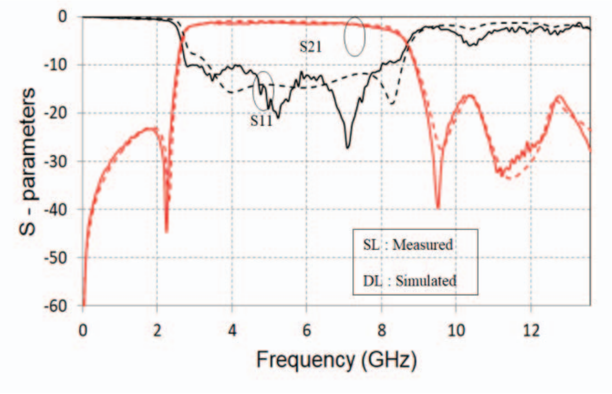

Fig. 7 Frequency response of the filter for the range (0-13.6 GHz)

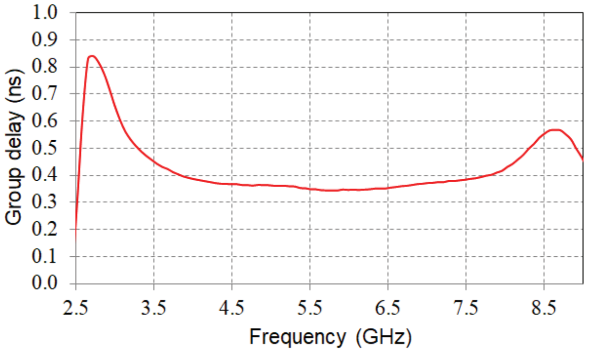

Fig. 8 Measured group delay response of the filter for the range (2.5-9 GHz)

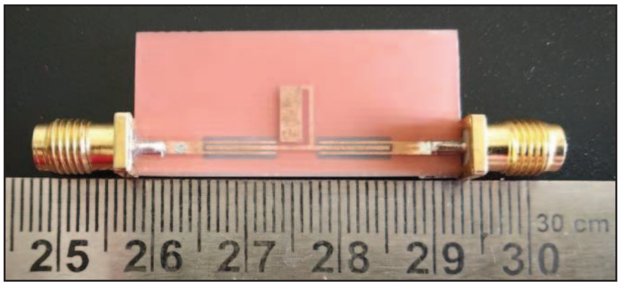

Fig. 9 Top view of the fabricated filter

Fig. 10 Bottom view of the fabricated filter

The photograph of top and bottom view of the fabricated filter is shown in Fig. 9 and Fig. 10 respectively. The table given below shows the comparison of the proposed structure with the existing structures.

TABLE I. COMPARISON OF THE PROPOSED FILTER WITH EXISTING FILTERS

Ref.	**Center frequency (GHz)**	**3- dB FBW (%)**	**Loss tangent, tan δ**	**Upper stopband fc (GHz)**
[7]	4.0	67	0.0009	8.5
[8]	4.175	28.02	0.004	7
[9]	3.0	80	0.0005	7.5
[10]	5.3	-	0.0009	10
[11]	3.52	62.75	0.02	9.72
[12]	4.5	69.1	0.0029	12.5
Proposed	5.5	101.8 %	0.02	13.6

As illustrated in TABLE I, the obtained parameters of the fabricated filter are wide fractional bandwidth and a suppression level greater than 17.23 dB up to 13.6 GHz.

V. CONCLUSION

A novel low cost wideband bandpass filter with wide pass band, sharp skirt rejection characteristics and good return loss characteristics is designed and simulated. The filter prototype is based on a novel folded high - low impedance resonator with parallel coupled aperture based backside. The fabricated filter exhibits better skirt selectivity characteristics by the introduction of transmission zeros generated by the high – low impedance based central resonator. A very good return loss (better than 10 dB), an insertion loss of 1.2 dB and an impedance band width of 5.5 GHz are obtained from the simulations. The out of band performance of the filter is very good with a suppression level of 17.23 dB up to 13.6 GHz. The proposed filter demonstrates the implementation of a cost effective bandpass filter which fulfills the performance requirements of the wideband communication systems.

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