SPLIT RECTANGULAR STRUCTURED DIFFERENTIAL BAND PASS FILTER WITH GOOD COMMON MODE SUPPRESSION

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ABSTRACT
A Differential Band Pass Filter (DBPF) with improved common mode suppression is focused in this paper. A Cross shaped resonator (CSR) with loaded coupled structure and capacitive termination is designed along with the split rectangular structure (SRS). This loaded lump capacitor offers an improved bandwidth. The SRR offers better Common Mode (CM) suppression. The length and Width of the Micro strip lines are adjusted to produce a widened Stop band under the CM operation. This DBPF centered at 3.5GHz and the suppression is better than -20 dB. The CSR is attributed by differential mode (DM) transmission zeros (TZ) and DM transmission zeros (TZ). The loaded structure has DM and CM TZs, with these CM TZs the suppression is better. The main purpose of this design is to improve the bandwidth. The Fractional Bandwidth (FBW) of about 3 dB is achieved for the range of about 2 to 5 GHz. The proposed design results are similar to theoretical and simulated results.

Index Terms— Differential Band pass Filter (DBPF), Cross shaped resonator (CSR), Fractional Bandwidth (FBW), Differential mode (DM) and common mode (CM), Split rectangular structure (SRS).

I. INTRODUCTION
Balanced circuit plays a major role in modern communication systems when compared to single ended signaling. Much effort has done for developing various balanced filters to meet the requirement of CM suppression in modern communication systems. In wireless and satellite communication the need for higher bandwidth BPF is required. The filter needs to have high immunity to EMI and environmental noise. Many DBPF has recently designed with the above specifications. But the filters are not up to the higher bandwidth range. In this paper an improved band of DBPF is achieved. Loaded coupled structure and cross shaped resonators are used in [1] to obtain 2 GHz bandwidth. The Coupled cross shaped resonator (CCSR) in [2] is designed to act as a DBPF with 1 GHz bandwidth with the range of 4-5 GHz. In reconfigurable DBPF with coupled cross shaped resonator in [2] is loaded with capacitive termination to increase the bandwidth to the range of 2.5GHz [3]. A Differential Band Pass Filter has two modes of operation i.e., Common mode and differential mode [4]. During DM the filter acts as pass band and in CM the filter behaves as stop band [5]. Cross shaped resonators are cascaded for UWB applications [6]. Better filter selectivity is done in [7] by adding two additional TZs. By adding capacitive termination in [9] insertion loss is reduced, rejection skirts outside the pass band is sharpened. In this design a cross shaped resonator, loaded coupled structure, and capacitive termination with split rectangular structure is used to achieve bandwidth of 3.5GHz. This DBPF is widely used in a RF/microwave and millimeter wave systems to transmit energy in pass band and to attenuate energy in one or more stop bands. This design is mainly focused on balanced circuit in order to improve the CM suppression compared to other designs.

II. CROSS SHAPED RESONATOR
The cross shaped resonator as in Fig. 2 has a central resonator with shunt short stub (0s1) and open stub (0s2) are added to it. Let Y be the characteristic admittance of the central resonator and the stubs, then the input admittance of the crossed resonator is

\[ Y_{in} = \frac{Y_{01} + Y_{02} + Y_{0s2} - cot\theta_1}{1 - cot\theta_1(tan\theta_2 + tan\theta_2 - cot\theta_1)} \]  

Fig.1 Differential Band pass filter with Split rectangular structure.
For simplicity, $\theta_1 = \theta_2 = 0$ is assumed. Therefore,

$$Y = f\frac{2\tan\theta + \tan\theta_2 - \cot\theta_1}{1 - \tan\theta_1(\tan\theta + \tan\theta_2 - \cot\theta_1)}$$  \hspace{1cm} (2)

Firstly, a special resonance condition will be considered. When $\theta = 90^\circ$

$$Y_{in} = \lim_{\theta \to 90^\circ} \frac{f}{\sum_{n=1}^{n-1} \frac{\tan\theta - \cot\theta_n}{\tan\theta + \cot\theta_n}} = 0$$  \hspace{1cm} (3)

In CSR the micro strip lines with electrical length $\theta_1$ & $\theta_2$ act as a virtual line in differential band pass filter. This virtual line will be an electrical wall for differential mode and magnetic wall for common mode.

III. SPLIT RECTANGULAR STRUCTURE

The split rectangular structure is proposed in this filter design to widen the bandwidth. The SRS is designed by using two micro strip lines placed parallel to each other to suppress the common mode signals effectively. The micro strip lines are joined to form a rectangular structure by adding micro strip bends at the corner.

IV. LOADED COUPLED STRUCTURE

Loaded coupled circuit (Fig. 4), where $C$ and $L$ are the self capacitance and self inductance and $C_m$ represents mutual capacitance.

From the Fig.4 the reference plane $T_a-T_a'$ and $T_2-T_2'$ is seen as two-port network that may be described by the following set of equations:

$$I_L = j\omega CV_2 - j\omega C_mV_2$$  \hspace{1cm} (4)

$$I_2 = j\omega CV_2 - j\omega C_mV_2$$  \hspace{1cm} (5)

Let $C$ be the self capacitance seen in one resonant loop of Fig.4 the capacitance present in the adjacent loop is shorted. The second term on the R.H.S of Eq. (4) & Eq. (5) are the induced currents are resulted from the increasing voltages present in resonant loop 2 and loop 1 respectively. Thus from Eq. (4) & Eq. (5) four $Y$ parameters are:

$$Y_{21} = Y_{22} = -jC$$  \hspace{1cm} (6)

$$Y_{12} = Y_{11} = -jC_m$$  \hspace{1cm} (7)

V. INTENDED TECHNIQUES OF FILTER

The objective of this proposed design is to sustain a balanced circuit. Two Split Rectangular structures are implemented in this design (Fig.1). This SRS is constructed with two micro strip lines connected by micro strip bends. Let $\theta_3$ & $\theta_4$ be the electrical length of micro strip lines used in upper SSR and $\theta_5$ & $\theta_6$ for the lower SSR in this differential band pass filter as shown in Fig.1. The four loaded coupled structures are added at the input & output ports of this filter design. The loaded coupled structure and split rectangular structure is connected by micro strip line of electrical length $\theta_7$ & $\theta_8$ in the upper and lower half of this filter to maintain a balanced circuit. Micro strip T junction and micro strip cross junction are used at all junction points to reduce coupling loss in this filter. A cross shaped resonator at the center of this filter design is used as the connector between upper and lower SRS. The capacitive terminators of electrical length $\theta_9$ & $\theta_{10}$ are used at the ends of the CSR.
VI. DISCUSSION OF RESULT

For the experimental validation this filter is fabricated on RO4003 with dielectric constant of 3.38, TanD of 0.0027 and H of 0.508mm.

Figure 5 show the layout of split rectangular structured DBPF. The fabricated structure has L_1=12.4mm, L_2=13.4mm, L_3=12.4, L_4=14.88mm, L_5=0.2mm, L_6=0.2mm, W_1=0.2mm, W_2=0.4mm, W_22=0.2mm, W_22'=0.2mm, W_3=0.4mm, W_3'=0.2mm, W_4=0.2mm, W_5=0.4mm, S=0.15mm. The layout of loaded coupled structure and split rectangular structure (SRS) are shown in the Fig. 5 (b) & 5 (c).

VII. ANALYSIS OF DIFFERENTIAL BAND PASS FILTER

As illustrated in the table below, the cross shaped resonator in the ref.1 has achieved a BW of 2GHz. In the ref.2 by adding the capacitive termination in the cross shaped resonator increased the bandwidth to 2.5GHz. Instead of cross shaped resonator by using coupled cross shaped resonator in the ref.2 the bandwidth is 1GHz. In this proposed design by adding split rectangular structure the bandwidth is increased to 3GHz which is high compared to other differential band pass filters.

<table>
<thead>
<tr>
<th>Works</th>
<th>f_0 (GHz)</th>
<th>FBW (%)</th>
<th>BW (GHz)</th>
<th>S_{11} (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ref. 1</td>
<td>3.5</td>
<td>40</td>
<td>2</td>
<td>&lt;15</td>
</tr>
<tr>
<td>Ref. 2</td>
<td>4.5</td>
<td>22</td>
<td>1</td>
<td>&lt;30</td>
</tr>
<tr>
<td>Ref. 3</td>
<td>4.5</td>
<td>82</td>
<td>2.5</td>
<td>&lt;30</td>
</tr>
<tr>
<td>Ref. 5</td>
<td>4</td>
<td>65</td>
<td>2.6</td>
<td>&lt;20</td>
</tr>
<tr>
<td>SRS DBPF</td>
<td>3.5</td>
<td>50</td>
<td>3</td>
<td>&lt;25</td>
</tr>
</tbody>
</table>

F_0=Center frequency, FBW= Fractional Bandwidth, BW= Bandwidth, S_{11}= Insertion Loss, SRS DBPF= Split rectangular structured differential band pass filter.

VIII. CONCLUSION AND FUTURE ENHANCEMENT

Split rectangular structured Differential band pass filter with loaded coupled structure and capacitive termination is proposed in this paper. This proposed filter has good agreement between stimulated and measured results. The increased bandwidth, sharp skirts, wide stop band is achieved. The Fractional Bandwidth (FBW) of about 3 dB and center frequency of 3.5GHz is achieved for the range of about 2 to 5 GHz. The insertion loss is less than -25dB is obtained. The coupled cross shaped resonator is used instead of cross shaped resonator to increase the bandwidth about 3.5 GHz. Any other structures and resonators can be added to decrease the insertion loss to a greater extent of <40 dB.
REFERENCES


