Novel Ring Resonator Bandpass Filter Design

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Abstract. In recent years, the rapid development of wireless communication technology brings the people much convenience in life and helps the easy contact between people. The filter is an important component in wireless communication system. In this paper, the ring resonators with broadside coupled mechanism are used to design a bandpass filter. The insertion loss of the filter is -4 dB and the return loss is -30 dB. The designed differential mode circuit has good frequency response with better common mode noise suppression ability. The symmetric structure can be analyzed based on the composite right/left-handed transmission-line theory. The filter is simulated by using ADS (Advanced Design System) Momentum software. The center frequency of 4GHz is designed with a bandwidth of 0.3 GHz for the designed 4-port bandpass filter. The realized filter consists of three dielectric layers and approximately 6mm by 6mm in size.

Keywords: bandpass filter, right/left-hand, common mode noise

1. Introduction

In recent years, there are a growing number of wireless communication products. The WCDMA, Bluetooth and UWB wireless communications technology are widely used in life. The components of a wireless communication include filter, balanced mixers, frequency multipliers and push-pull amplifiers. The filter is often used for signal selection.

Thus, an integration of filter is necessary to reduce the cost and size of the circuitry used in the systems. Recently, significant amount of research has been conducted to realize the integration of a differential filter and this has yielded many outcomes on the development of filters. One way to integrate a differential filter is simply through an intermatching circuit to combine the two circuit [1].This method is the simplest, but its circuit construction is very complicated. Another way would be building a bandpass filter with functionality [2]

The circuit structure is relatively simple compared to other circuits. Therefore, it requires some special filter structure. There is also another way to build a differential filter using a symmetrical 4-port network [3] [4]. By using this method, filters can be realized through odd and even mode analysis.

2. Analysis of Proposed Filter

The composite right/left-handed transmission lines (CRLH-TL) which are composed of a series capacitance and a shunt inductance have negative, zero and positive propagation constant according to characteristic of effective permittivity and permeability [5]. The equivalent circuit of the proposed 3-D structures is shown in Fig. 2(a). The filter consists of a series capacitance and a shunt inductance (LH components), as well as a series inductance and a shunt capacitance (RH components), which is referred to as the CRLH-TL. The series capacitance and shunt inductance provide the LH nature at lower frequencies and the series inductance and shunt capacitance also provide the RH nature at higher frequencies. But these resonators have much smaller size compared to the conventional Right-Handed (RH) resonators. Thus, these

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resonators have significant advantages in building filters with small size [6] [7], and has been used in a large extent for CRLH circuits [5] [8].

In this paper use the ring resonator bandpass filter in design, the filter circuit function is when the filter in the high frequency, the designed differential mode circuit has good frequency response with better common mode noise suppression ability. We will ring resonator bandpass filter circuit designed to have the same odd-mode, but not even-mode with the resonant frequency. In this way, in the differential-mode operation, ring resonator bandpass filter have same resonance frequency filter to obtain the response of the bandpass filter; In the Common-mode operation, separated to the two resonant frequencies, will effectively suppress the common mode signal, improvement for filter and the second harmonic response suppression.

Fig.1 The structure of proposed filter
(a) 3-D view of the proposed ring resonator bandpass filter circuit.
(b) Top view of the corresponding 4-ports structure.
(c) Bottom view of the proposed structure.
On the second harmonic suppression, because ring resonator bandpass filter circuit construction by used to broadside couple mechanism design; the filter can effectively suppress the second harmonic response, pushed to the center of the second harmonic frequency of 8 GHz.

2.1 Odd Mode Analysis

In odd mode excitation, a virtual ground is formed along the symmetric plane. In this case, the equivalent circuit for ring resonator can be given as shown in Fig. 2(a), which is nearly the same as the conventional discussed in [5][8]. The odd mode excitation is typical circuit architecture. It is can found equivalent circuit ring coupled line, the broadside-coupled mechanism through capacitance ($C_L$) is attributed to the edge coupling while the inductance ($L_L$) is due to the shorting via and coplanar line in the ground. The ring resonator effects are due to the capacitive coupling ($C_R$) between the patch and ground plane inductance and the current flow along the patch inductance ($L_R$).

![Fig. 2(a)](image1)

![Fig. 2(b)](image2)

Fig. 2(a) The equivalent circuit of the ring resonator bandpass filter circuit in odd mode excitation.
Fig. 2(b) Equivalent circuit of two cascaded ring resonator bandpass filter Circuit.

![Fig. 3](image3)

Fig. 3 Simulation result of the proposed structure in odd-mode excitation.

2.2 Even Mode Analysis

In the even mode excitation, a virtual open is formed along the symmetric plane. The coplanar line is connected to the vias will be considered to be open circuited. Thus, the ring resonator bandpass filter circuits is not connected to the ground and behave as pure resonators. Therefore, the resonant frequency will be determined by the size of the top metal, the circuit resonant frequency is much larger than the even-mode operation of the resonant frequency. As a result, there will be a stop band in the even mode excitation at the frequencies. The responses of the proposed structure even mode excitation in shown in Fig. 3. It can be seen that there is stop band around the frequency of 7.9 GHz. Therefore, there is a band pass around frequency of
8 GHz. This bandpass filter is the resonant modes of the ring resonator bandpass filter with open circuited vias, and will cause a spurious bandpass in final filter performance.

3. Simulation Results

As described above, the odd mode can be proposed to form ring resonator pass band while it forms a stop-band in same frequency range under even-mode excitation. The filter is designed to operate at the center frequency of 4 GHz.

This filter is fabricated on a Duroid with relative \( \varepsilon_r \) of 10.14, dielectric loss tangent of 0.02 and the layer thickness of 1mm, obtained by ADS (Advanced Design System) Momentum simulation software. It can be seen in 4 GHz with -4dB insertion loss, return loss of -30dB, Fig.3 show the wideband simulation results, and it can be seen that there is spurious bandpass around 8 GHz. Corresponding to excitation in even mode excitation. This spurious pass-band is due to the resonant modes of the broadside-coupled mechanism through, as was described in even mode excitation. The total size is 6mm x 6mm. In comparing with the related works, the used PCB area is smaller, as shown in Table 1. The ring resonator bandpass filter has the reduced size by 50% over that of conventional right-handed (RH) filter and the reduced size by 0.8% over that of Composite right/left-handed transmission lines Filter, according as its resonators have very compact size. In general, this filter can serve as a good candidate for use in RF front-end modules.

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<thead>
<tr>
<th>Table I. Dimension comparison of related filters.</th>
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<tr>
<td>Dimension of the filter (Width x Length)</td>
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<tr>
<td>Conventional RH Filter [10]</td>
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<tr>
<td>4.6mm x 15.3mm (70.38 mm(^2))</td>
</tr>
<tr>
<td>CRLH TLs Filter [10]</td>
</tr>
<tr>
<td>7.6mm x 5.4mm (41.28 mm(^2))</td>
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<tr>
<td>This work</td>
</tr>
<tr>
<td>6 mm x 6mm (36 mm(^2))</td>
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</table>

4. Conclusions

In this paper, a novel bandpass filter based on ring resonator is proposed. The ring resonators that are connected together by coplanar line in bottom ground are used to build the filter. The center frequency of 4GHz is designed with a bandwidth of 0.3 GHz for the designed 4-port bandpass filter. The insertion loss of the filter is -4 dB and the return loss is -30 dB. The ring resonator filter circuit has the features of compact size and improved return loss. The simulation results of ADS Momentum software demonstrate the performance of the proposed bandpass filter.

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6. References


