Ultra Wide Band Filter Using Shorted Meandered Coupled Lines and Stepped Line Stubs

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Abstract:
A miniaturized ultra wide band (UWB) filter is proposed and implemented using short circuited meandered coupled lines. In addition, stepped impedance open circuit stubs are incorporated along with the input and output feed lines for achieving wide stop band rejection characteristics. UWB filter over 3.1GHz to 10.6GHz has been analyzed and experimentally validated. The proposed filter has been designed in microstrip medium having thickness of 0.78mm and dielectric constant of 2.17. The insertion loss is found to be less than 1.2dB and group delay variation is less than 0.04ns within the pass band of the UWB filter. Size of the miniaturized experimented filter is 17mm×17mm×0.78mm.

Key Words: coupled line; stub; UWB; stop band.

1 INTRODUCTION

Extensive research work has been proposed in the design UWB of devices and systems in the license free unlicensed UWB band (3.1GHz to 10.6GHz) for short range wireless communication applications. Band pass filter is one of the essential passive components in the UWB technology. Different types of topologies/structures have been studied and reported in various literature [1-6]. Attention is also arising to design filter with wide stop band. Modern wireless communication systems such as UWB transceivers require miniaturized low loss, wide pass band filters with extended stop band characteristics. Though several types of designs such as broadside coupled lines, ring resonators, open /short circuit stubs and multi-mode resonators have been reported in literature for the design of such filters [1-6].

Design of a compact wide band pass filters with good in band filtering performance, sharp selectivity and wide stop band still remains as key issues in many system designs. Though conventional high impedance half wavelength parallel-coupled line filter has several salient features, it suffers from constraints of photolithographic and manufacturing processes to realize closely spaced lines required for tight coupling. On the other hand, half wavelength resonator based filters suffer from immediate spurious response at 2fo which limits the performance of the system. Multiple coupled transmission lines with defected ground have been successfully employed by the authors to achieve wide band operation [7].

In this paper, an UWB filter using short circuited coupled line along with meandered line and open circuit stubs is presented along with the following advantages: i) Miniaturization using short circuited coupled lines along with meandered lines, ii) Stop band widening using open circuit stubs, iii) Cross-coupling between the input and output through short circuited coupled lines for improving the selectivity. The filter structure is shown in Fig. 1.

Section II contains the analysis procedure for the design of the proposed filter followed by experimental results and discussions in section III. Section IV concludes this paper.
Substrate thickness ‘h’ : 0.78mm
Substrate permittivity ‘$\varepsilon_r$’ : 2.17.
The basic structure of the proposed filter has input and output feed lines connected to a short circuited quarter wave coupled lines. A meandered transmission line is also connected across input and output. Open circuit stubs 1, 2, 3 and 4 are connected along the feed lines. Combination of all these ensures spurious-free filter response up to 18GHz.

**Circuit Analysis:** Analysis of the entire filter is based on splitting it into different sections namely open circuit stubs, short circuited coupled lines and meandered coupled lines and analyzing each section. Fig. 2 shows different sections of the filter for the sake of analysis. Even and odd mode propagation parameters are used for the analysis of the coupled line sections and coupled line sections are shown in Fig. 3.

![Fig. 2. Sections of UWB filter.](image)

![Fig. 3. Analysis procedure for coupled line sections.](image)

Short circuited coupled line sections can be characterized using impedance ‘Y’ parameters given by [8]

$$Y_{11} = Y_{22} = -j(Y_{oe} \cot(\theta_e) + Y_{oo} \cot(\theta_o)) \quad (1a)$$

$$Y_{12} = j(Y_{oe} \cot(\theta_e) - Y_{oo} \cot(\theta_o)) \quad (1b)$$

$$Y_{21} = -j(Y_{oe} \cot(\theta_e) - Y_{oo} \cot(\theta_o)) \quad (1c)$$

where $Y_{oe}$ and $Y_{oo}$ are even and odd mode admittances respectively. $\theta_e$ and $\theta_o$ are even and odd mode phase velocities respectively. Stepped impedance open circuit stubs (Fig. 4) are characterized using the following ABCD parameters

$$A_s = D_s = 1 \quad (2)$$

$$B_s = 0 \quad (3)$$

$$C_s = 1 / Z_s \quad (4)$$

$$Z_s = Z_H \left[ \frac{Z_{LOAD} + jZ_H \tan \theta_H}{Z_H + jZ_{LOAD} \tan \theta_H} \right] \quad (5)$$

$$Z_{LOAD} = -jZ_L \cot \theta_L \quad (6)$$

where $Z_L$ and $Z_H$ are low impedance and high impedances of the stepped impedance stub respectively.

![Fig. 4. Stepped impedance stub](image)

Design parameters of the filter are listed in Tables I and II. Circuit model of each section of the filter is combined with other sections to obtain the overall response of the filter. Analysis is based on cascading individual ABCD matrices of three filter sections. Scattering parameters of the filter are extracted from the overall transmission matrix. A comparison is made between the analytical results using the procedure explained above and fullwave simulations using IE3D simulator from Mentor graphics [9] as shown in Fig. 5 and a close agreement between them can be observed.

**Table I. Geometrical parameters of filter**

<table>
<thead>
<tr>
<th>Length of coupled lines ‘L_c’</th>
<th>7mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Width of coupled line ‘W_c’</td>
<td>1mm</td>
</tr>
<tr>
<td>Spacing ‘s’</td>
<td>0.8 mm</td>
</tr>
<tr>
<td>Stub lengths L_1, L_2, L_3 and L_4</td>
<td>2.9mm, 2.7mm, 2.5mm and 2.4mm</td>
</tr>
<tr>
<td>Feed line width ‘W_o’</td>
<td>2.4 mm</td>
</tr>
<tr>
<td>Meandered line width ‘W_m’</td>
<td>2.4mm</td>
</tr>
</tbody>
</table>
TABLE II. Electrical Parameters of Filter

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Even and odd mode impedances (Z_{oe}, Z_{oo}) of coupled line and meandered line sections</td>
<td>(63,50)Ω</td>
</tr>
<tr>
<td>Stub Impedances (Z_h, Z_L)</td>
<td>160Ω</td>
</tr>
<tr>
<td></td>
<td>100Ω</td>
</tr>
<tr>
<td>Line impedance (Z_o)</td>
<td>50Ω</td>
</tr>
<tr>
<td>Input and output Impedances</td>
<td>50Ω</td>
</tr>
</tbody>
</table>

Filter has the pass band from 3.1GHz to 10.6GHz. It can be observed from the results that open circuit stubs improve the stop band rejection characteristics of the filter better than 20dB.

Fig. 5. Simulation results of filter

III. EXPERIMENTAL RESULTS

Fig. 6 shows the experimental prototype UWB filter. The input and output feed lines are designed with line impedance of 50Ω. Dimensions of the filter are 17mm×17mm×0.78mm. The filter is tested using vector network analyzer Agilent N5230A. Fig. 7 show that measured results and fullwave simulation using IE3D are in good agreement. Measured frequency band of the filter is 3.1GHz to 10.6GHz. Insertion loss of the filter is less than 1.2dB within the desired pass band. Stop band rejection is better than 20dB up to 18GHz while the second harmonic (13.7GHz) of the filter has been suppressed to a level of 20dB. Measured Group delay over the pass band is constant to within ±0.04ns as shown in Fig. 8.

Fig. 6. Assembled UWB filter

IV. CONCLUSIONS

In this paper, a compact UWB filter is designed and realized using short circuited coupled lines and meandered coupled lines along with open circuit stubs. Open circuit stubs were embedded with input and output feed lines for achieving wide stop band characteristics. The measured insertion loss is 1.2dB and return loss is 13.5dB over the pass band of 3.1-10.6GHz. The UWB filter exhibited stop band rejection of better than 20dB up to 18GHz. Overall dimensions of the filter are 0.5λ_g×0.5λ_g×0.024λ_g

REFERENCES


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