A High Performance and Small Sized Four-Fold Microstrip Hairpin Line Bandpass Filter at 2.250 GHz for Communication Systems

Jagdish Shivhare, B. V. R. Reddy

Abstract: The contents of this technical paper is presented a new class of multi-folded hairpin line microstrip bandpass filter with improved performance, low cost and great reduction (60-65%) in size compared to a conventional hairpin line bandpass filter. The expected frequency responses have been simulated/optimized by using The Agilent-make ADS/IE3D-Zealand softwares. The measured results are very close to the simulated/optimized results.

Keywords—Substrate, folded-hairpin line resonator, miniaturized microstrip filters, narrow band, selectivity, slow wave, ADS/IE3D softwares.

I. INTRODUCTION

Planar structured multi-folded hairpin line microstrip bandpass are easy to filters are easy to fabricate by using low cost printed circuit technology. The folded-hairpin line topology has the advantage of desirable narrowband, moderate return loss, compact structure and low cost microstrip filters make the design more meaningful for further development and applications in the modern mobile radio communication systems. A multi-fold hairpin line bandpass filter has been designed on the RT-Duroid-Alumina substrate of dielectric constant 10.2 and thickness of 1.27 mm. The width of the microstrip is determined for 50 ohms and is made large, the peripheral of each resonator is made a square, length of the U-shaped coupled lines is extended to its maximum and the gap between coupled lines is made as small as possible[1]. By using the imperical equations. Graphs and simulation/optimization, we have obtained the total size of a fourth-order conventional hairpin line filter at 2.250 GHz is 35 mm x 20 mm (A=700 mm²). At the same center frequency the size of a multifold hairpin line bandpass filter will be 18 mm x 15 mm (270 mm²) i.e. 38.6 % of A or reduction in size is approx. 61% compared to the size of the conventional hairpin line bandpass filter at the center frequency 2.250 GHz.

II. THE CONCEPT OF THE FOUR-FOLDED HAIRPIN LINE RESONATOR

The length of parallel coupled filter is too long and the size increases with the order of filter. To solve this problem, hairpin line filter, using folded λ/2 resonator(U-shaped) structures were developed.

Manuscript Received on April 2015.

Jagdish Shivhare, Department of Electrical, Electronics and Communication Engineering, ITM University, Sector-23A, Gurgaon-122 017, India.

B. V. R. Reddy, University School of Engineering & Technology, Guru Govind Singh Indraprashth University, Sector -16C, Dwarka, Delhi, India.
III. DESIGN PROCEDURE OF FOUR-FOLD
HAIRPIN LINE RESONATOR FILTERS

Desired specifications of the filter:
Centre Frequency (CF) : 2.25 GHz
Insertion loss : < 4 dB
Passband (3 dB) Bandwidth : ± 0.025 GHz w.r.t. c.f.
Stopband (30 dB) Bandwidth : ± 0.075 GHz w.r.t. c.f.
Return Loss in passband : >15 dB
Input/output Impedance : 50 Ohms

The design methodology and supporting softwares are available to design, simulate/optimize the multi-folded hairpin line filters[5-6]. Design calculations of four-fold hairpin line microstrip filters can be done in the following steps[7-11].

1. Finding the element values of LPF prototype by using the approximate synthesis method. The relations between the bandpass design parameters and the lowpass elements are

\[ Q_{cd} = Q_{co} = C_j / \Delta \omega \]

\[ k_{p,n} = k_{N,n}, N = 1 \text{ to } N/2 \]

\[ k_{m,n+1} = \frac{\Delta \omega J_n}{C_m} \text{ for } m = N/2, \]

\[ k_{m,n-1+2} = \frac{\Delta \omega J_{n-1}}{C_{m-1}} \text{ for } m = N/2. \]

where
\[ \Delta \omega : \text{ fractional bandwidth of the bandpass filter,} \]
\[ C : \text{ Capacitance of the lumped capacitor} \]
\[ J : \text{ Characteristic admittance of the inverter} \]
\[ N : \text{ degree of the filter} \]

2. To calculate the resonator parameters: The length of the coupled lines can be calculated by:

\[ \cot \theta_p = \frac{R + \sqrt{R^2 + 2Z_c^2 \sin^2 \theta_p}}{2Z_c \sin \theta_p} \]

and \[ R = (Z_{pe} + Z_{po}) \cos \theta_p - (Z_{pe} - Z_{po}) \]

where \[ \theta_p : \text{ Electric length of the resonator} \]
\[ Z_c : \text{ Characteristic impedance} \]
\[ Z_{pe} : \text{ Even mode impedance} \]

3. Calculations for the coupling parameters,
4. Input/output tapped length,
5. Geometric parameters,
6. Optimization of filter parameters by varying the geometric dimensions,
7. The values of coefficient of coupling between resonators can be calculated against the distances between the resonators,
8. The design technique uses an approximation polynomial and a low filter prototype.

\[ \theta_{1/2} = \theta_1 = \arccot \left( \frac{G_s}{\sqrt{Q_c}} \right) \]

\[ G_s = \frac{f_{p1} f_{p2}}{FBW} \]

\[ M_{23} = M_{34} = \frac{f_{p2}}{\sqrt{Q_2}} \]

\[ M_{ij} = \frac{f_{p1}^2 - f_{p2}^2}{f_{p1}^2 + f_{p2}^2} \]

Where \[ f_{p1} \text{ and } f_{p2} \text{ are the lower and higher split resonant frequencies of a pair of coupled resonators. We have used EM simulator to model the coupling coefficient and external Q. The hairpin transmission lines and bends are realized by using the MBEND90X and MLIN elements. [12-13].} \]

Fig. 4 Input/output tapped electrical length.

Fig. 5 Schematic diagram
Optimized Dimensions of resonators of the filter

$L_1$: 2.86 mm, $L_2$: 3.53 mm, $L_3$: 4.87 mm, $W_1$: 0.67 mm, $W_2$: 0.70 mm, $G_1$: 0.53 mm, $G_2$: 0.33 mm, $G_3$: 0.43 mm, $G_4$: 0.82 mm, $D_{12}=D_{34}$: 1.54 mm, $D_{23}=D_{41}$: 2.73 mm

Size of the filter: 18 mm x 15 mm (270 mm$^2$), i.e. 38.6% of 700 mm$^2$ (35 mm x 20 mm of conventional hairpin line filter).
A High Performance and Small Sized Four-Fold Microstrip Hairpin Line Bandpass Filter at 2.250 GHz for Communication Systems

Fig. 11 Comparison of simulated and measured results of the filter

Fig. 12 Measured results in 0.2 GHz span

Fig. 13 Measured results in 0.1 GHz span
Fig. 14 Measured results in 0.062 GHz span

Fig. 15 Measured results in 5 GHz span
A High Performance and Small Sized Four-Fold Microstrip Hairpin Line Bandpass Filter at 2.250 GHz for Communication Systems

1.TABLE: COMPARISON OF SIMULATED AND MEASURED RESULTS OF THE FILTER

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Parameters</th>
<th>Unit</th>
<th>Design Specs.</th>
<th>Four-fold Simulated</th>
<th>Four-fold Measured</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Center frequency</td>
<td>GHz</td>
<td>2.250</td>
<td>2.256</td>
<td>2.300</td>
<td>Acceptable</td>
</tr>
<tr>
<td>2</td>
<td>Insertion loss in band</td>
<td>dB</td>
<td>&lt; 5</td>
<td>6.12</td>
<td>4.48</td>
<td>Acceptable</td>
</tr>
<tr>
<td>3</td>
<td>Passband 3dB-band width (Lower side)</td>
<td>GHz w.r.t.c.f.</td>
<td>±0.025</td>
<td>±0.025</td>
<td>±0.026</td>
<td>Acceptable</td>
</tr>
<tr>
<td>4</td>
<td>Passband 3dB-band width (Upper side)</td>
<td>GHz w.r.t.c.f.</td>
<td>±0.025</td>
<td>±0.025</td>
<td>±0.024</td>
<td>Acceptable</td>
</tr>
<tr>
<td>5</td>
<td>Stopband 30 dB-bandwidth (Lower side)</td>
<td>GHz w.r.t.c.f.</td>
<td>±0.080</td>
<td>±0.080</td>
<td>±0.088</td>
<td>Acceptable</td>
</tr>
<tr>
<td>6</td>
<td>Stopband 30 dB-bandwidth (Upper side)</td>
<td>GHz w.r.t.c.f.</td>
<td>±0.080</td>
<td>±0.080</td>
<td>±0.074</td>
<td>Acceptable</td>
</tr>
<tr>
<td>7</td>
<td>Return loss in passband</td>
<td>dB</td>
<td>&gt;15</td>
<td>&gt;10</td>
<td>&gt;10</td>
<td>Acceptable</td>
</tr>
<tr>
<td>8</td>
<td>Size of filter (Reduction in size)</td>
<td>mm² %</td>
<td>Minimum</td>
<td>18 mm x 15 mm=270 mm²</td>
<td>38.6 % of A=700 mm² Reduction (61.4 % of A)</td>
<td>Acceptable</td>
</tr>
</tbody>
</table>

Fig.16 Photographs of the developed fourth-order hairpin line filter

V. RESULTS AND DISCUSSIONS

The desired center frequency is 2.250 GHz, but the best simulated/optimized center frequency is 2.256 GHz to obtain other parameters as per given specifications. The measured center frequency 2.297 GHz i.e shifted by 0.041 GHz to the upper side of the center frequency due to inaccuracy in fabrication/input-output connections, improper grounding etc. The deviations in passband, stopband and return loss are also due to inaccuracies in fabrication but are acceptable.

VI. CONCLUSION

This paper presents a four-fold microstrip hairpin line bandpass filter design techniques. The reduction in size of the four-order filter are 61% of the optimized size (A) of the conventional hairpin line bandpass filter at 2.297 GHz centre frequency. The measured results are close to the simulated/optimized results. There are limitations of the design in terms of inaccuracy of sharp folding and coupling between the adjacent and cross-coupled folded hairpin line resonators in the filters. The developed filter can be used for RF/wireless communication systems.

REFERENCES


Published By: Blue Eyes Intelligence Engineering & Sciences Publication Pvt. Ltd.


[12] ADS Agilent-make softwares for design and simulation/optimization

[13] IE3D-Zealand software for design and simulation/optimization