Abstract – This work demonstrates a microwave dual band bandpass filter using two L-shaped stepped impedance resonators (SIRs) and a coupled feed structure. The coupled feed structure can be a single sided or a double sided structure. Two sets of physical parameters are used to control the coupling coefficient and external quality factor. Thus, the specification, such as the central frequencies and the bandwidths of both the bands, can be achieved simultaneously. Two 2.4 GHz/5.2 GHz dual band bandpass filters for wireless local area network are fabricated. Both the experimental and simulation results are provided, with good agreement.

Index Terms – Bandpass filter, dual-band, stepped impedance resonator.

I. INTRODUCTION

Recent developments in wireless communication systems demand radio frequency (RF) devices operating in multiple, separated frequency bands. Dual-band filters become key components in the front end of wireless systems and have been studied in many literatures. For example, IEEE 802.11a/b/g wireless local area network (WLAN) products operate in the 2.4/5.2 GHz dual-band. Dual band operation can be implemented by switching between two independent single-band circuits, or developing a single circuit with dual-band function. The first approach requires a switching circuit, which increases the power consumption and insertion loss, whereas the later approach need dual band components such as dual-band filters.

The Microstrip filter is very popular in dual band filter design because of its planar structure and easier connection with other devices. Dual-band Microstrip filters can be classified into three main types.

The first type uses combination of two single band filters via a common input/output port. This type of dual-band filter is very easy to realize, because signals of the two bands pass through different resonators, allowing the two individual filters to be designed independently.

The second type involves adding notches to a wideband bandpass filter. Thus a wide pass band is separated into two narrower passbands. The advantage of this approach is that stopband response is properly considered. The drawbacks of this approach are requirement of large number of resonators and application is restricted to two relatively close passbands.

The third approach, which is often favoured for its compactness, is to employ modified resonators including stepped impedance resonators (SIRs), stub-loaded open-loop resonators or split-ring resonators. Among these, SIR is the most popular approach. The electrical length and impedance ratio of the resonators are used to control the fundamental and the spurious resonance frequencies to meet the central frequencies of the two bands. In addition to the central frequency, important specifications of a filter include the type of frequency response, bandwidth and passband ripple. These characteristics are determined by the external quality factors and the coupling coefficients using traditional coupled filter theory.

Dual band SIR filter design techniques are discussed a lot in recent literatures. The main drawback of these techniques is that the coupling coefficient and the external quality factor are controlled by a single physical parameter. Therefore, average values of these two parameters are used, which leads to a distortion of the frequency response.

In this paper, the coupling coefficient and the external quality factor are controlled by two sets of parameters using two L-shaped SIRs and one of the two coupled feed structure, the single sided and double sided. Two filters with two different coupled feed structures and two L-shaped resonators are fabricated and tested.

II. FILTER STRUCTURE & DESIGN

The geometry of an L-shaped stepped impedance resonator is shown in Fig. 1. $\theta_1$ and $\theta_2$ denote electrical lengths of high and low impedance sections, respectively. These values can be chosen arbitrarily, but for simplicity, they can be kept equal.

$$R_Z = \frac{Z_2}{Z_1} = \tan^2\left(\frac{\pi f_0}{2 f_{s1}}\right)$$

where $f_0$ and $f_{s1}$ are the fundamental and first spurious resonant frequencies. These are the two central frequencies of the dual band bandpass filter.
The layout of two filters using the L-shaped SIRs and two different coupled fed structures are shown in Fig. 2 and Fig. 3. Traditional single-band coupled resonator theory determines the frequency response based on the coupling coefficient and the external quality factor \((Q_e)\). The parameters \(D_r\), \(g_r\) controls the coupling coefficient and the parameters \(L_f\), \(g_f\) controls the external quality factor. Thus the variation in central frequencies and bandwidths can be achieved by setting these two sets of parameters properly.

The double-sided coupled fed structure is preferred over the single-sided structure as the coupling gap \((g_f)\) is typically larger in the former case, hereby relieving the requirement for precision manufacturing.

The values of \(D_r\), \(g_r\), \(L_f\), \(g_f\) can be found from construction curves obtained from EM simulation of synchronously tuned coupled resonator circuits taking care of selected substrate and central frequencies. Fig. 4 and Fig. 5 shows construction curves for coupling coefficient and external quality factor variation with respect to the four physical parameters. These graphs are taken from [1] as reference. For the filters designed and fabricated in this work, the above curves are used as base line and then optimized to achieve the desired frequency response. From Fig. 4, it can be observed that the coupling coefficient of both lower and higher band vary differently. For a selected coupling coefficient, the place where the two curves intersect, gives the values of \(D_r\) and \(g_r\).

### III. SIMULATED AND MEASURED RESULTS

Two dual band filters with two different coupled feed structures, operating at 2.4/5.2 GHz are designed and manufactured to verify the concept. The substrate used is 0.762 mm thick AD350 substrate with \(\varepsilon_r = 3.5\) and a loss tangent 0.002. The bandwidths in the lower and higher passbands are 0.5 and 0.65 GHz respectively. The photographs of the two filters are shown in Fig. 6 and Fig. 7.
The two filter configurations are simulated in ADS momentum and the physical parameters are derived after tuning as described in the previous section. Fig. 8 shows the comparison between the simulation and measured results for filter 1 i.e. the filter with single-sided coupled feed structure.

![Fig. 8. Comparison of S parameters between simulated and measured response of Filter1](image)

Fig. 8. Comparison of S parameters between simulated and measured response of Filter1

Fig. 9 shows the comparison between simulation and measured results for filter 2 i.e. the filter with double-sided coupled feed structure.

![Fig. 9. Comparison of S parameters between simulated and measured response of Filter2](image)

Fig. 9. Comparison of S parameters between simulated and measured response of Filter2

The dimensions used for fabrication for filter 1 and filter 2 (with double-sided coupled feed structure) are shown in Table 1. The comparison between simulated and measured insertion losses, bandwidths in lower and higher band for both the filters are shown in Table 2 and Table 3. A minor shift in the central frequencies is observed in both the passbands. The shift in passband is 0.08 GHz for both filter 1 and filter 2. For the second passbands these are 0.2 and 0.16 GHz respectively.

![Table 1](image)

<table>
<thead>
<tr>
<th>Filter</th>
<th>( l_1 ) (( \text{mm} ))</th>
<th>( l_2 ) (( \text{mm} ))</th>
<th>( d ) (( \text{mm} ))</th>
<th>( g_1 ) (( \text{mm} ))</th>
<th>( L ) (( \text{mm} ))</th>
<th>( g_2 ) (( \text{mm} ))</th>
<th>Overall Dimension (( \text{mm} \times \text{mm} ))</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>9.1</td>
<td>9.0</td>
<td>6</td>
<td>0.3</td>
<td>11</td>
<td>0.1</td>
<td>60 ( \times ) 74</td>
</tr>
<tr>
<td>#2</td>
<td>9.1</td>
<td>9.0</td>
<td>5</td>
<td>0.3</td>
<td>11</td>
<td>0.2</td>
<td>45 ( \times ) 77</td>
</tr>
</tbody>
</table>
IV. CONCLUSIONS

Two dual band filters using L-shaped resonators and two different coupled fed structures are fabricated and tested for the 2.4/5.2 GHz bands. The central frequencies and band widths of the two passbands are controlled by two sets of parameter. The main advantage of these type filters are that its specs can be met simultaneously.

REFERENCES


