Analysis of Coupled Microstrip Lines with DGS UWB Printed Filter

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Abstract—This paper will present a microstrip bandpass filter design with controllable cutoff frequencies. The proposed design of filter is simulated, fabricated, measured and analyzed for UWB system application. The expected of filtering range is about 3.1 GHz to 10.6 GHz. This filter also expected to produce low insertion loss. A bandpass filter, based on microstrip structure provides the advantage of easy design, lower fabrication cost and compact size and has been widely used. This filter is simulated by HFSS and result show reasonable performances over entire UWB and the averaged insertion loss for UWB of this filter is about 0.2 dB with constant group delay.

Index Terms—Bandpass, filter design, DGS, UWB,

I. INTRODUCTION

Recent research in microwave filters shows that many efforts have been focused on designing ultra wide band (UWB) band pass filter (BPFs) due to its increasing demand for ultra wide band applications because ultra wide band technology provides high data rates which results low interference, low cost, resistance to jamming and providing high data rates in multipath channel, compared with narrow wide band which provides low channel capacity, providing more interference signal in radio systems. The ultra wide band (UWB) radio system has been receiving great attention among both academic and industrial aspects, because of its attractive features in high speed wireless applications; the ultra wide band (UWB) communication has been authorized by the Federal Communication Commission (FCC) in USA released the unlicensed frequency limits from 3.1GHz to 10.6GHz for the indoor and hand held UWB systems in February 2002 [1], extensive instant bandwidth of 3.1-10.6GHz with constant group delay is required to operate in UWB filter.

A key passive component in UWB system is the front-end filter required to meet some stringent specifications including compactness, low insertion loss, flat group delay, in-band frequency rejection notch, high selectivity, and wideband rejection. These all are requirements for UWB filters and by considering these, an increasing interest has been aroused among both academic and industrial aspects on exploring various UWB components and systems [2].

Researchers have developed many UWB filters using different techniques and designs. In the recent studies there was a technique developed for designing a composite microstrip bandpass filter suitable for ultra wide band (UWB) wireless communications with the 3-dB fractional band width of more than 100%. The design is made of a highpass and a lowpass filter embedding individually into each other. The impedance of lowpass filter attenuate the upper stop band and quarter wave short circuited stubs are used to realize the lower stop band [3], the main challenge about the bandpass filter is to maintain wide stop-band and sharp passband. An UWB filter was designed in [3] that absorb high frequency signals by using a lossy composite substrate, the insertion loss of this filter was 6dB and at high frequency the impedance matching was poor and also lacking the sharpness at the lower frequency. Lumped element filter design is very difficult to design in microwave frequencies; due to limitations of lumped-element values these designs are generally unpopular. The design of filters on microstrip lines being a popular choice [4]. Another technique for the design of ultra wide band filter is the highpass filter (HPF) model in which short circuited stubs are cascaded [5]. Another simplest structure of filter consists of cascaded short circuited stubs which are separated by identical connecting lines. At the lower cut off frequencies the electrical length of these connecting lines is two times of the electrical length of the two UWB filters [6]. In [7] the UWB filter was developed by cascading of many different ring filters. In this technique there are some disadvantages i.e these types of UWB filters have sharp band rejection and their response would degrade out-of-band response and number of sections are increased producing large insertion loss and the group delay was very poor.

Because of low loss, small size and compactness, light weight and high selectivity the microstrip open loop filters have been extensively used for wireless communications systems. Many authors have suggested the microstrip square open loop resonators but the arrangement of elements will occupy a large circuit area which is not appropriate for
wireless communication system where the miniaturization is an important factor. Therefore it is necessary to upgrade new types of square open-loop micro-strip resonators which are not only an alternative designs but they also have the miniaturization factor [8]. Therefore a good filter which is suitable for wide-band band-parallel coupled band must have effective out-of-band spurious rejection and which is very good in band performance.

Dielectric resonators are also used to design the ultra wide band band-pass filter. Dielectric resonators (DR) have a lot of advantages in increasing the performance of radio frequency (RF) and microwave devices such as filters and oscillators and it is also widely used in the wireless applications, because it contains low design profile having wide band width [9]. But the performance of most the distributed resonators are limited because of the use of effective constant dielectric and there is some discontinuity in transmission lines. Strip line structures are widely used now days due to the advantages such as easy implementation of both series and shunt stubs and there is no need of holes [10]. The more famous structures of filters are more widely used because the fabrication of these filters can be done by using the printed circuit technology which is suitable for commercial applications because of their small size and lower fabrication cost. Therefore the design of a filter at low cost with high performance is of great concern. Many authors have proposed different shapes of bandpass filters such as fractal shaped microstrip coupled line, dumbbell shaped, T shaped, C shaped, E shaped etc.

Defected ground shaped (DGS) is another technique for the designing of ultra wide band bandpass filter. Basically DGS is the technique where the ground plane is transform intentionally to improve the performance of the filter. With the help of DGS technique, improvement of the steepness of the roll off, gain is observed with ease of impedance matching. Improvement in the selectivity of the filter by using DGS technique is also observed. DGS is the systematic procedure to improve the performance of the filter and it exhibits that the DGS can enhance the battenation of stop band and completely removes the parasitical passband in stopband. DGS technique can be understood clearly by etching a defected pattern in the ground plane. The limitation on gap size may be relaxed for a particular coupling, so that the space of the entire circuit area can be greatly saved [11]. Another new compact structure for the ultra-wide band (UWB) bandpass filter is the steeped impedance resonator (SIR) and rectangle slot-defected ground structure DGS which has the advantages of small size and it produces good filtering characteristics [12]. The utilization of high dielectric constant substrate, stepped-impedance resonator (SIR) structure and the slow wave effect are highly successful techniques to achieve compact size. In [13] a compact coupled micro-strip line filter design with enhanced performance qualifications by making use of symmetrical filter configuration printed on DGS was discussed. An unsophisticated design method for the coupled microstrip line bandpass filter can be found in [14]. The design methodology used in [14] is further improved to realize the compact symmetrical parallel coupled bandpass configuration by using the impression of lower portion diagonal section of the coupled lines in the upper right section to constitute a symmetrical compact band pass filters.

Ultimately the characteristics of the compact structure are more improved by realizing the I/O portions of the microstrip feed lines in DGS. In [16] another Z transformation technique is used to combine UWB filter in which the open circuited stubs are engaged to produce transmission zeroes in the upper and lower stop band to receive the sharp attenuations. Newly ultra wide band filters consists of coupling from microstrip line to coplanar wave guide which can be implemented on the basis of simple broad side coupling structure [17]. The proposed filters in [17] matched nearly all the demands of FCC’s spectrum mask. Another structure for the implementation of ultra wide band (UWB) band pass filter is suggested by using the coupled microstrip line and U-shaped ground defected ground (DGS). These filters can be combined with any UWB antenna to have better performance of overall system [18, 19]. The main advantage of UWB filter is that it can minimize the signal processing cost when combined with UWB filters in order to mitigate out-band interference.

II. THE PROPOSED FILTER CONFIGURATION

The proposed filter configuration is shown in Figure 1, where Figure 1(a) and Figure 1(b) are top and bottom views of the designed structure. The filter has been designed using duroid6010 and FR4 materials with dielectric constants of 10.8 and 4.4 respectively both having thickness of 0.508mm. The design of proposed filter is by using coupled microstrip lines and a defected ground plane separated by the substrate. The mutual inductance and capacitance can explain the coupling between each microstrip line conductor and the ground plane. In most general structures the input and output lines are connected to the ends of opposite sides of the coupled lines but here these are connected to the ends in the same sides. Without DGS this structure naturally shows a band stop property so DGS is important to consider.

Figure 1: Geometry of the filter with proposed parameters

TABLE I. Parameters of Proposed Filter Design

<table>
<thead>
<tr>
<th>Variable</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>L</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duroid (mm)</td>
<td>1</td>
<td>2.5</td>
<td>1.5</td>
<td>0.5</td>
<td>1.4</td>
<td>0.5</td>
<td>1.4</td>
<td>4.1</td>
<td>4</td>
<td>0.2</td>
</tr>
<tr>
<td>FR4 (mm)</td>
<td>1</td>
<td>2.5</td>
<td>1.5</td>
<td>0.5</td>
<td>1.4</td>
<td>0.5</td>
<td>1.4</td>
<td>5.6</td>
<td>6</td>
<td>0.2</td>
</tr>
</tbody>
</table>
Parametric analysis has been carried out to demonstrate the effect of varying lengths (L) of the coupled lines. Results of insertion loss have been shown in Fig. 1. These results show that by varying the length there is great effect on the operating bandwidth of the filter, by increasing the length, the band become congested and by decreasing length, it expands. At L=4 it almost fulfils the requirement of bandwidth passed by FCC for UWB.

![Image of cascading of bandpass filter](image1)

Figure 2: Complete geometry of the filter

III. CASCADING OF BANDPASS FILTER

Tentative improvement in the results of the above structure can be assumed by mirroring the filter. The scheme of the mirrored structure is shown in fig. 2, where Fig. 2(a) and Fig. 2(b) are top and bottom views of the mirrored structure. It is observed that mirroring deteriorates the flat behaviour of transmission coefficient however with some slight improvements in cut-off slopes. The insertion loss is increasing with the increase in frequency due to bad matching conditions at higher frequencies. Figure 7 shows the graph of insertion loss after mirroring the original structure.

![Image of complete geometry of the filter](image2)

(a) Top view

![Image of bottom view](image3)

(b) Bottom view

Figure 3: Geometry of higher order band pass filter

IV. SIMULATED RESULTS

Following are results of insertion loss of proposed filter after simulation.

![Image of effect of length at controllable higher cutoff](image4)

Figure 4: Effect of length at controllable higher cutoff

![Image of improving isolation of UWB](image5)

Figure 5: Improving the isolation of UWB from adjacent bands by varying ‘S’

Graphs shows that by varying ‘S’ the gain of the filter can be controlled.

![Image of phase response of the filter](image6)

Figure 6: Phase response of the filter for transmission and reflection coefficient.

A good filter’s response doesn’t vary rather it remains constant throughout the band. Above graph of phase shows a good linear property throughout the band.

![Image of group delay](image7)

Figure 7: Group delay

Figure 7, as shown above, signifies that the group delay is almost constant.

![Image of comparison of transmission coefficient](image8)

Figure 8: Comparison of transmission coefficient for mirrored structure with un-mirrored.

Figure 8 shows the comparison of the mirrored structure with un-mirrored structure. Graph shows that cascading of the band pass filter doesn’t lead to better performance. This is due to the matching of input to filter, because the input feed of the filter is divided, due to which there is matching disturbance and interference is also produced due to cascading. From the graph...
it is clear that the mirrored graph is more attenuated as compared to the un-mirrored graph.

Figure 9: Graph of $S_21$ using FR4 and Duroid6010

Fig. 9 shows the insertion loss of filter using both substrates. The comparison is explained in following table. TABLE II shows the result comparison of Duroid6010 and FR4. Both gives approximate bandwidth of UWB but by using FR4 with maximum attenuation becomes 8 to 9 times greater than from duroid6010 in passband. It is because FR4 have lower dielectric constant. FR4 is more cost-effective but duroid6010 have better results and brings compactness in design.

<table>
<thead>
<tr>
<th>parameters</th>
<th>Duroid6010</th>
<th>FR4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cut-off frequency</td>
<td>2.88 and 10.62 GHz</td>
<td>3.4 and 10.6 GHz</td>
</tr>
<tr>
<td>Bandwidth Cover</td>
<td>2.88-10.62 GHz</td>
<td>3.4-10.6</td>
</tr>
<tr>
<td>Pass-band Ripple</td>
<td>0.2dB</td>
<td>0.2dB</td>
</tr>
<tr>
<td>Max Attenuation</td>
<td>0.6dB</td>
<td>1.7dB</td>
</tr>
</tbody>
</table>

TABLE II. Results comparison of substrates

V. RESULTS AND DISCUSSION

A band pass filter is designed to have UWB characteristics with reasonable averaged insertion loss. Cascading of the structure is studied for improving the slope of cutoff frequency. It is observed that slope is not improved, rather cascading devastate flat behavior in the mid band range of UWB. Upper and lower cutoff frequencies are controllable in wide range through different parameters. However, cutoff frequencies are mutually inclusive. Presented filter has linear phase and hence constant group delay for transmission coefficient. The filter is good candidate for any UWB antenna to filter out undesired frequency interference and it can minimize signal processing computation.

REFERENCES