DESIGN OF 4TH ORDER MICROSTRIP HIGH PASS FILTER USING WRIST WATCH SHAPED DEFECTED GROUND STRUCTURE AT 2.5 GHZ

Abhishek Singh Bhadoriya¹, Sandeep Kumar Agrawal², Mahendra Kumar Pandey³
¹PG Scholar, Department of Electronics, Rustamji Institute of Technology, BSF Academy, Tekanpur, Gwalior, India
²Asst. Prof., Department of Electronics, Rustamji Institute of Technology, BSF Academy, Tekanpur, Gwalior, India
³Asst. Prof., Department of Electronics, Rustamji Institute of Technology, BSF Academy, Tekanpur, Gwalior, India

Abstract-The performance of a high pass filter (HPF) with and without Defected ground structure has been analyzed. The Defected Ground Structure is in “wrist watch” Shape. Parameters of the proposed configuration were calculated at the centre frequency of 2.5 GHz with dielectric constant of 4.4, loss tangent of 0.02 and substrate height of 1.6mm. Results were simulated using computer simulation technology software (CST). The undesired sidebands and fluctuations of response are concentrated by using modified ground structure. Also the cutoff point of the high pass filter is shifted to a higher frequency and an enhancement in selectivity. The filter can be useful in various RF circuits where fewer fluctuations are required in pass band.

Keywords: High pass filter (HPF), Modified Ground Structure, DGS, Short Circuited Stub

I. INTRODUCTION

A microwave filter is a two-port network used to control the frequency response at certain point in a microwave system by providing transmission at frequencies within the pass band of the filter and attenuation in the stop band of the filter. Depending on the requirements and specifications, RF/microwave filters may be designed as lumped element or distributed element circuits; they may be realized in various transmission line structures, such as waveguide, coaxial line, and micro strip. [1]

For designing high performance and compact filters, a defected ground structure has been widely used. A Defect on ground can change the propagation properties of a transmission line by changing the current distribution and applied field between the ground plane and upper surface.

PBG and EBG structure are also a type of DGS, which is created by etching different periodic shapes in the ground plane. So many etched shapes for the micro strip could be used as a unit DGS. [8]

An LC unit circuit can represent the unit DGS circuit. They provide inductive and capacitive elements connected in series, which remove undesired output response fluctuations; move the high pass filter frequency limit to a higher value and the selectivity of a particular band is also improved [2][7].

In this proposed work an arbitrary shape of DGS is used to improve the parameters of the filters like return loss, transmission coefficient etc. And also the dimension of these different shapes varies to find efficient response. A lot of different shapes of DGS were tested and the more efficient one is introduces in this work.

II. IMPLEMENTATION OF 4TH ORDER HIGH PASS FILTER

The proposed high pass filter (HPF) consists of shunt short circuited stubs of electrical length \( \Theta \) at some specified frequency \( f_c \) (usually the cut off frequency of HPF). These elements were separated by unit elements (UE) of length 2 \( \Theta \) shown in the figure 1 [6]. This type of filter has very wide band response for small \( \Theta \) but this requires a high value of impedance in the short circuited stub (SC-Stub). To design high pass filter let us consider the cut off frequency \( f_c \) in GHz and 0.1dB Ripple in pass band up to 5GHz.

As in figure: the electrical length \( \Theta \) can be determined by equation (1) [3-6]:

\[
\left( \frac{n}{\Theta_c} - 1 \right) f_c = 5 \quad (1)
\]

With the help of \( \Theta \) and order of high pass filter, element values of optimum distributed high pass filter with 0.1dB ripple was obtained. For given terminating impedance \( Z_0 \) the associated impedance values can be determined by equation (2) and (3) [12]

\[
Z_i = \frac{Z_0}{Y_i} \quad (2)
\]

\[
Z_{i,i+1} = \frac{Z_0}{Y_{i,i+1}} \quad (3)
\]

For \( i=1, 2,\ldots, 6 \)

Synthesis of W/h [12]

\[
W = \frac{8e^\lambda}{e^2A-2} \quad (4)
\]

With

\[
A = \frac{20}{60} \left[ \frac{e^{r+1}}{2} \right]^{0.5} + \frac{e^{r+1}}{e^r-1} \left( 0.23 + \frac{0.11}{e^r} \right)^{0.5} \quad (5)
\]
Zc = Impedance (in Ohm) and \( \varepsilon_r \) (dielectric constant) = 4.4, W= width, h = height of dielectric which is taken as 1.6mm. Effective dielectric constant of dielectric material given by equation (6) and (7) [9]

For \( \frac{w}{h} \leq 1 \)
\[
\varepsilon_{re} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2} \left( 1 + 12 \frac{w}{h} \right)^{-0.5}
\]

For \( \frac{W}{h} > 1 \)
\[
\varepsilon_{re} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2} \left[ \left( 1 + 12 \frac{W}{h} \right)^{-0.5} + 0.04 \left( 1 - \frac{W}{h} \right)^2 \right]
\]

Whereas guided wavelength is given by equation (8).
\[
\lambda_g = \frac{300}{f(GHz) \sqrt{\varepsilon_{re}}}
\]

\( \varepsilon_e = \) Effective dielectric constant, \( f = 1.48 \) GHz Lengths of the elements (l) were determined by equation (9) [12].

\( \Theta_c = \beta \cdot l \)

Where \( \beta \) is the phase constant.

III. FILTER DESIGN

The dimensions of length and width of the elements was calculated using the Microstrip design equations for a resonant frequency \( f_c = 2.5 \)GHz. The dimensions of the element values for the 4th order of high pass filter at a cut off frequency \( f_c 2.5 \)GHz is shown in the table 1.

<table>
<thead>
<tr>
<th>Element</th>
<th>Admittance Values (mho)</th>
<th>Impedance value(ohm)</th>
<th>Length of element (mm)</th>
<th>Width of element (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit Element</td>
<td>( Y_{12}=Y_{34} =1.46 )</td>
<td>( Z_{12}=Z_{34} =45.75 )</td>
<td>( L_{12}=L_{34} =21.71 )</td>
<td>( W_{12}=W_{34} =3.037 )</td>
</tr>
<tr>
<td></td>
<td>( Y_{23}=1.025 )</td>
<td>( Z_{23}=47.55 )</td>
<td>( L_{23}=21.71 )</td>
<td>( W_{23}=3.28 )</td>
</tr>
<tr>
<td>Short Circuit Stub</td>
<td>( Y_1=Y_4 =0.416 )</td>
<td>( Z_1=Z_4 =121.26 )</td>
<td>( L_1=L_4 =11.28 )</td>
<td>( W_1=W_4 =0.42 )</td>
</tr>
<tr>
<td></td>
<td>( Y_2=Y_3 =0.45 )</td>
<td>( Z_2=Z_3 =90.45 )</td>
<td>( L_2=L_3 =11.34 )</td>
<td>( W_2=W_3 =0.96 )</td>
</tr>
</tbody>
</table>

TABLE 1: Element values of the proposed configuration

The structure of proposed design for 4th order high pass filter is shown in figure 2. HPF is printed on the FR4 lossy substrate of dielectric constant 4.3, loss tangent 0.02 and thickness of 1.6mm. with dimension of length 80mm and width 25mm.

The DGS layout with wrist watch type shape and two circles has been considered. The other dimensions of proposed DGS are kept constant as in geometry without DGS. The DGS structure is shown in figure 4. The response of this proposed configuration after applying DGS is shown in figure 5. The radius of an etched circular ground structure is 5mm at the unit element which is placed at the exact middle portion of the proposed design and the radius of an etched circular ground structure is 2mm at the short circuit stubs which is nearer with the bigger circular structure of the ground plane.
IV. RESULT AND DISCUSSION

The proposed structure of 4th order high pass filter was simulated using the CST Microwave Software. The simulated return loss of the proposed HPF is shown in the figure 3. With the use of SMA Connector of 50Ω at both the ports of filter, the response of the filter is symmetric at both the ports $S_{11} = S_{22}, S_{12} = S_{21}$. The graph shown in figure 3 shows that the cut off frequency is at 2.5GHz, means that the signals are allowed to pass above this frequency. An attenuation of -55dB is provided below cut-off frequency. Return loss after 2.5 GHz is below -10 dB which shows perfect impedance matching for pass band. From the figure 5, it is clearly seen that the cut off frequency is same in both the designs. The return loss is about -26 dB above cut-off and attenuation below cut-off is -65 dB. A configuration of printed Microstrip high pass filter with and without using DGS shapes was proposed and analyzed at the centre frequency $f_c = 2.5$GHz with the dielectric constant of 4.3 and at the height of 1.6mm. It has been found that results of HPF using DGS are better than the results of HPF where DGS is not applied. The sidebands fluctuations are reduced in this design.

REFERENCES


