3. Calculated Parameters for Design

Following are the parameters which have been already calculated for the designing of end coupled filter in which fractal technique is to be implemented [8]:

1. Frequency bandwidth 0.028 or 2.8%
2. Number of poles, N=3
3. Mid band frequency f0= 6GHz.
4. Pass band ripple 0.01dB
5. Element values are g0 = g4 = 1.0, g1 = g3 = 1.0316, and g2 = 1.1474
6. Dielectric constant ε_r =10.8
7. Thickness of substrate h=1.27mm.
8. The line width for microstrip W=1.1mm.
9. Characteristic impedance Z_o = 50 ohm.

The layout of the filter in which fractal technique is to be implemented is shown below in the figure:

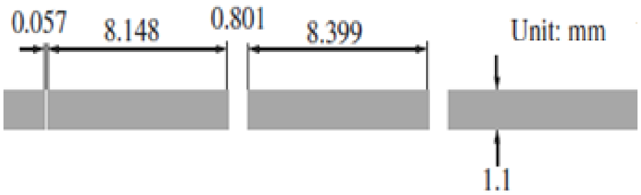

Figure 2: Dimension geometry of band pass filter

4. Designing of End Coupled Microstrip-Line Band Pass Filter Using Fractal Technique

In this section the designing of end coupled band pass microstrip line filter by using fractal techniques has been described. The microstrip line filter in previous section is modified here by using fractal rectangular curves (FRC) to get the better frequency response.

Here we will modify the geometry of the end coupled band pass filter shown in fig. 2 with the help of Fractal Rectangular Curves (FRCs). For this purpose FRC equations (1 and 2) are used in order to calculate the values of length, width area and perimeter of the proposed filter. Here the iteration is done only once (i.e. FRC-1).

The filter shown in fig. 2 is called the zero iteration geometry of the proposed filter design. The zero iteration design is made up of three rectangular sections having lengths l_1 = 8.148 mm, l_2 = 8.399 mm, l_3 = 8.148 mm and equal width of 1.1 mm. For the calculation of the parameters of the proposed filter FRC-1 is used on each rectangular section. Let us start with middle (second) rectangular section of the zero iteration filter having length 8.148 mm and width 1.1 mm as shown in Fig. 3.10. And the parameters for the FRC-1 can be calculated with the help of the equations 1 and 2 as:

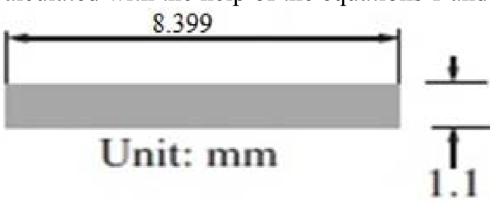

Figure 3: Middle section of the end coupled filter with zero iteration

Area of the zero iteration section will be given by:

$$A_2^0 = l_2 W = 8.399 \text{ x } 1.1 = 9.2389 \text{ mm}^2 \quad (3)$$

Where, two in the suffix of A represents the no. of the filter section and zero on the power represents order of the iteration. And l_2 is the length of the section and W is the width.

And the semi-diagonal length is given by:

$$D_1^0 = \frac{1}{2}\sqrt{8.148^2 + 1.1^2} = 4.11095 \text{ mm} \quad (4)$$

The perimeter is given by:

$$\Pi_2^0 = 2\,(8.399 + 1.1) = 18.998 \text{ mm} \quad (5)$$

Now the area of the first iteration (FRC-1) of this section by using the equation 2 will be:

$$A_1^1 = A_1^0 \left(\frac{2^2-1}{2}\right)^2 = \frac{9}{4} A_1^0 = 22.416525 \text{ mm}^2 \quad (6)$$

The semi-diagonal length for the first iteration by using equation 1 is given by:

$$D_2^1 = 2\, D_2^0\, (1/4) = 2.117681 \text{ mm} \quad (7)$$

The perimeter for the first iteration with the help of equation 2 is given by:

$$\Pi_2^1 = 2\, \Pi_2^0 = 2 \text{ x } 18.998 = 37.996 \text{ mm} \quad (8)$$

These values of parameters represent the design of the first iteration of the filter section. This design will have larger area and perimeter as compared to its zero iteration. There will four more rectangles (red coloured) each of area one ninth (1/9) of the zero iteration added on each corner of the zero iteration geometry as shown in Fig. 4. Here these four rectangles which are lying at corners will have one third (1/3) length and width of the zero iteration. In order to satisfy all equations and parameter values for FRC-1 design the one forth (1/4) area of these small rectangles at corner will lie inside the area of the zero iteration section.

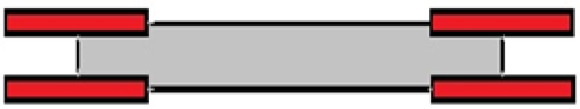

Figure 4: First iteration (FRC-1) of the middle section of filter

For first and third section of the zero iteration filter fractal technique is implemented only at air gap side because at the other sides of these sections we have to connect the input and output ports. Keeping in mind that these two sections are similar in dimensions therefore, the first iteration geometry of these sections will be the mirror image of each other. So we have to calculate the value of the parameter only once which will be application for both. The zero iteration of the first and third section is shown in Fig. 2 whose length l_1=l_3 is 8.148 mm and width is 1.1 mm.

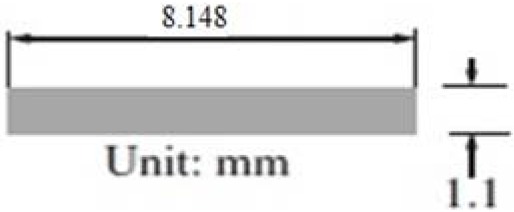

Figure 5: First/Third section of the end coupled filter with zero iteration

Area of the zero iteration section will be given by:

$$A_1^0 = l_1 W = 8.148 \text{ x } 1.1 = 9.9629 \text{ mm}^2 \qquad (9)$$

Where, two in the suffix of A represents the no. of the filter section and zero on the power represents order of the iteration. And l_2 is the length of the section and W is the width.

And the semi-diagonal length is given by:

$$D_1^0 = \frac{1}{2}\sqrt{8.148^2 + 1.1^2} = 4.11095 \text{ mm} \qquad (10)$$

The perimeter is given by:

$$\Pi_1^0 = 2\,(8.148 + 1.1) = 18.496 \text{ mm} \qquad (11)$$

Now the area of the first iteration (FRC-1) of this section by using the equation 2 will be:

$$A_1^1 = A_1^0 \left(\frac{2^2-1}{2}\right)^2 = \frac{9}{4} A_1^0 = 22.416525 \text{ mm}^2 \qquad (12)$$

Since there will be input connector present at the LHS of the geometry so fractal techniques will not be implemented at LHS, in the case to calculate the actual area of the geometry we have to exclude the area of small rectangles (red) lying outside the geometry.

In this case actual area will be:

$$A_1^1 \text{ (actual)} = A_1^1 - \text{(Area lying outside)}$$

$$A_1^1 \text{ (actual)} = 22.416525 - 1.4938 = 20.922725 \text{ mm}^2 \qquad (13)$$

The semi-diagonal length for the first iteration by using equation 1 is given by:

$$D_1^1 = 2\,D_1^0\,(1/4) = 2.055475 \text{ mm} \qquad (14)$$

The perimeter for the first iteration with the help of equation 2 is given by:

$$\Pi_1^1 = 2\,\Pi_1^0 = 2 \text{ x } 18.496 = 36.992 \text{ mm} \qquad (15)$$

Since there will be input connector present at the LHS of the geometry so fractal techniques will not be implemented at LHS, in the case to calculate the actual perimeter of the geometry we have to exclude the length of small rectangles (red) lying outside the geometry.

$$\Pi_1^1 \text{ (actual)} = \Pi_1^1 - \text{(Length lying outside)}$$

$$\Pi_1^1 \text{ (actual)} = 36.992 - 9.2480 = 27.7440 \text{ mm} \qquad (16)$$

These values of parameters represent the design of the first iteration of the filter section. This design will have larger area and perimeter as compared to its zero iteration. There will two more rectangles (red coloured) at RHS each of area one ninth (1/9) of the zero iteration added on each corner of the zero iteration geometry as shown in Fig. 7. Here these two rectangles which are lying at corners will have one third (1/3) length and width of the zero iteration. In order to satisfy all equations and parameter values for FRC-1 design the one forth (1/4) area of these small rectangles at corner will lie inside the area of the zero iteration section.

Figure 6: First iteration (FRC-1) of the first section of filter

Similarly the last (third) section of the filter will be the mirror image of the geometry shown in Fig. 6 which is shown below in Fig. 7.

Figure 7: First iteration (FRC-1) of the third section of filter

Now all the desired parameters of FRC-1 of the all sections of the filter have been calculated from above mentioned equations, which are mentioned in table 1 below. And the geometry of the filter can be drawn with the help of these parameters as shown in Fig. 8.

Table 1: Proposed Filter parameters with FRC-0 and FRC-1

Parameters FRC	First Section of the Filter		
	A_1 (mm^2)	D_1 (mm)	Π_1(mm)
FRC-0	9.9629	4.1109	18.496
FRC-1	20.9227	2.0554	27.7440
Parameters FRC	**Middle Section of the Filter**		
	A_2 (mm^2)	D_2 (mm)	Π_2
FRC-0	9.2389	4.2353	18.998
FRC-1	20.7875	2.1176	37.996
Parameters FRC	**Third Section of the Filter**		
	A_3 (mm^2)	D_3 (mm)	Π_3
FRC-0	9.9629	4.1109	18.496
FRC-1	20.9227	2.0554	27.7440

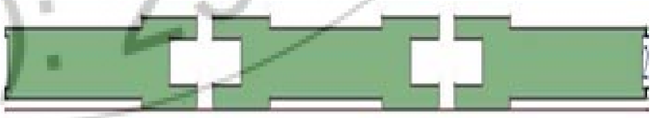

Figure 8: Proposed geometry of the End Coupled Filter using FRC-1on IE3D Simulator

5. Simulation Result

The result of the simulation on IE3D Simulator of the proposed filter is shown in figure 9. The simulation result shows the characteristics of a band pass filter which operates at 6 GHz. And both the curves namely insertion loss curve and return loss curve are quite smooth.

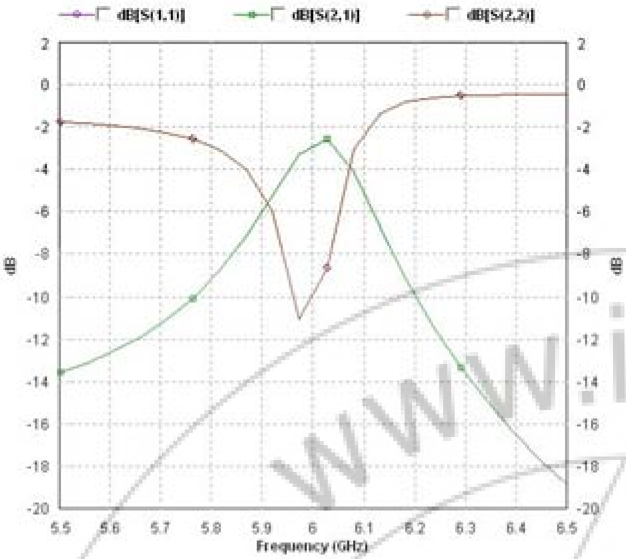

Figure 9: Simulation result of the proposed filter (using FRC-1) on IE3D simulator

6. Conclusion

The simulation result clearly shows good insertion loss and return loss curves which define the characteristics of a band pass filter which operates at 6 GHz. The pass-band of the filter is fine and free from unwanted disturbances such as higher order harmonics, ripples etc. The proposed filter can be easily fabricated and is very compact. The proposed filter is an efficient, high-performance and flexible filter.

7. Future Scope

So it can be concluded that the fractal technique improved the performance of the microstrip filter by reducing the harmonics and provide easier designing capabilities because of their self-similarity and space filling properties. But there is still lot of scope and work which can be done like:

1. Modification can be done in the filter design by changing the width and spacing between coupled lines to operate if at different cutoff frequencies.
2. The higher order iteration fractal curves such as FRC-2, FRC-3 can also be used for better results.
3. The response of these simulators can also be compared with the response of actually fabricated filter.
4. Other mode advanced simulation software such as AWR, HFSS etc. can also be used for efficient and better simulation purpose.

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Author Profile

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