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Miniaturized Koch Pre-Fractal Bandpass Filter

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Abstract: Fractal geometry technique is a successful way for RF component miniaturization and this is the requirement of modern communication circuits. This study is intends to propose a dual mode BPFs based on fractal geometry to get miniaturized BPFs for ISM band applications at 2.4 Ghz. Koch fractal geometry has been used with corner cut perturbation and cross slotted perturbation techniques. Results show that the resulting BPFs possess quasi elliptic and chebyshev performance curves. A noticeable size reduction has been observed as the iteration order increases, size reduction of 74.01% has been obtained from the 3rd iterations modified Koch with cross slotted perturbation as compared with size of the conventional microstrip square patch resonator designed to operate at the same frequency and using the same substrate material.

Key words: Miniaturized BPF, pre-fractal, RF filters, fractal geometry, frequency, Iraq

INTRODUCTION

Filter networks are essential building elements in many areas of RF/microwave engineering. Such networks are used to select/reject or separate/combine signals at different frequencies in a host of RF/microwave systems and equipment (Hong and Lancaster, 2001). Microstrip filters are small in size compared with other filters such as waveguide filters, nevertheless for some applications where the size reduction is of primary importance, smaller microstrip filters are desirable, even though reducing the size of a filter generally leads to a dissipation losses in a given material and hence reduced performance. Miniaturization of microstrip filters may be achieved by using fractal geometry. Fractals generated via the infinite recursion of finite sets of contractions called Iterated Functions Systems (IFSs).

A pre-fractal is obtained by stopping this infinite iteration process to a finite step as opposed to the limit set which has (often but not always) non-integer fractal dimensions (Arrighetti and Gerosa, 2005). Fractal filters are concerned with reducing large size into small geometric regions using fractal geometry (Husain, 2008). Among the earliest predictions of the use of fractals in the design and fabrication of filters is that of Yordanov *et al.* (1991). His predictions are based on the investigation of Cantor fractal geometry. Fractal geometries used in this study were originally introduced by the Swedish mathematician Helge von Koch in 1904 (Vinoy *et al.*, 2003). The method of construction of the Koch curve is shown in Fig. 1 in which the Koch curve is simply constructed using an iterative procedure beginning with the initiator of the set as the unit line segment (step n = 0 in Fig. 1). For the conventional Koch curve, the angle (which is called the indentation angle) in Fig. 1 is 60° and the parameters s_i are equal, i.e., $s_1 = s_2 = s_3 = s_4$ (Da Costa and Dmitriev, 2006).

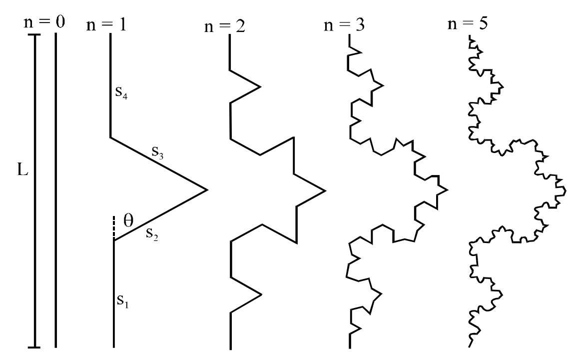

Fig. 1: The first five stages in the construction of the Koch curve (Da Costa and Dmitriev, 2006)

A design of BPF using conventional Koch curve has been reported by Ali. In this study, researcher investigate another variant of the Koch curves with dimensions smaller than the conventional Koch curves, $s_1 = s_4$ equal to one third of the total height L and the indentation angle has been changed. The simulation tool used in this study is Microwave Office v9 EM simulator from AWR.

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MATERIALS AND METHODS

Design and simulation of the proposed fractal BPFs: Up to the 3rd iteration BPFs have been designed using Koch fractal geometry with two perturbation techniques corner cut perturbation and cross slotted perturbation. The design will be accomplished in three steps:

Conventional square patch BPF: To show the effect of fractal geometry on the filter size, conventional square patch filter has been designed and simulated as a reference. The external side length of the square patch resonator, L_0 has to be calculated as (Hong and Lancaster, 2001):

$$L_0 = \lambda_g/2 \quad (1)$$

The conventional dual-mode microstrip square patch resonator with total length is shown in Fig. 2. The result shows that the reflection coefficient is still high because there is no coupling between the two modes as shown in Fig. 3, a perturbation applied to the dual-mode patch resonator for exciting and coupling a pair of degenerate modes at location that is at offset from its two orthogonal modes in the form of corner cut. The degree of coupling between the two modes depends on the size d (perturbation dimension) which in return controls the mode splitting. Tapped line feeding is used for large bandwidth BPF. While capacitively coupled feed line used for narrow bandwidth BPF, therefore capacitively coupled feed line has been used in this study. Figure 4 shows the layout of square patch resonator with corner cut perturbation d = 1 mm and Fig. 5

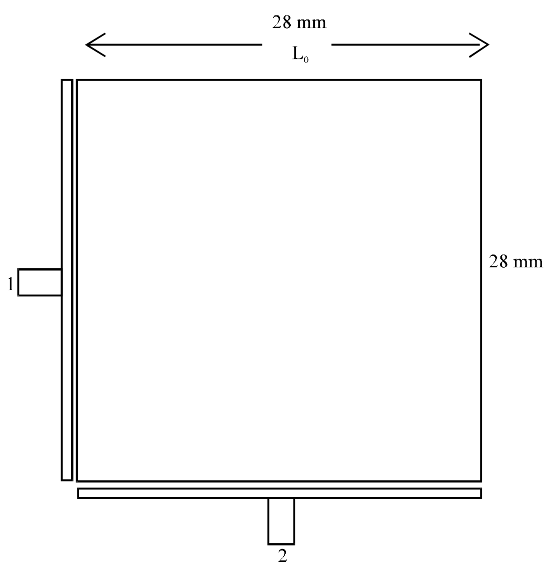

Fig. 2: Conventional dual mode square patch BPF

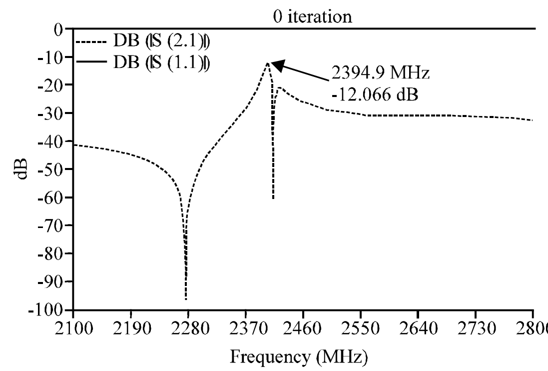

Fig. 3: Return loss (S_{11}) and tranmission (S_{21}) responses of conventional square patch

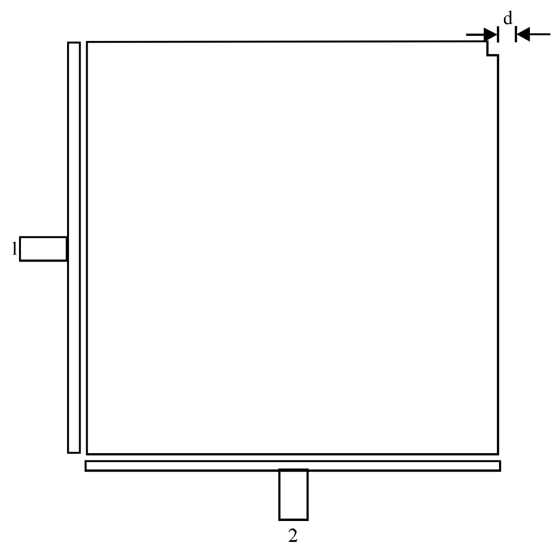

Fig. 4: Conventional dual mode square patch BPF

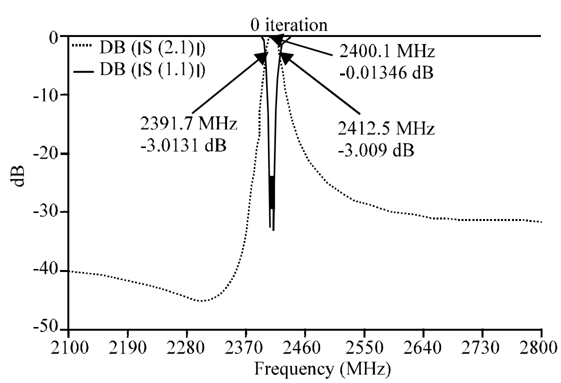

Fig. 5: Return loss (S_{11}) and transmission (S_{21}) responses of conventional square patch

Table 1: Dimensions of the conventional dual mode square patch BPF

Parameters	Values
L_0	19.996 mm
w	0.403 mm
g	0.402 mm
w_f	1.267 mm
L_f	2.41 mm
d	1 mm
A	$28\times28\,(mm)^2$

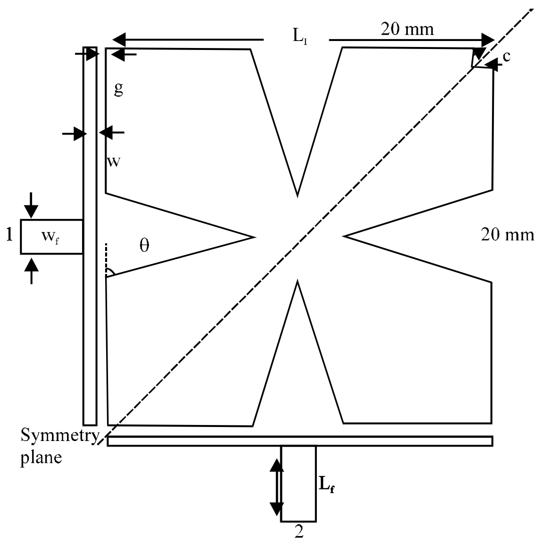

Fig. 6: The modeled layout of the 1st iteration modified koch like prefractal corner cut BPF

shows the return loss and transmission responses. Table 1 shows the dimension of the dual mode square patch BPF.

Modified Koch pre-fractal bandpass filter with corner cut perturbation: Up to the 3rd iteration fractal microstrip dual-mode bandpass filters structures have been designed for the ISM band applications at frequency of 2.4 Ghz.

These filter structures have been etched using a RT/duroid 6010LM substrate with a dielectric constant of 10.8 and thickness of 1.27 mm. The external side length L_n for square patch modified Koch at nth iteration can be calculated using the following equation (Da Costa and Dmitriev, 2006):

$$L_1 = 2^n\left[\frac{1}{3}+\frac{1}{6\cos\theta}\right]^n L_0 \tag{2}$$

Figure 6 shows the 1st iteration geometry of a miniaturized fractal filter with symmetric in structure to investigate dual-mode behavior. This filter has been modeled and simulated using the same substrate properties. For 2.4 Ghz, the fundamental frequency for (n = 1) by Eq. 2 then:

Table 2: Dimensions of the1st iteration modified Koch like pre fractal corner cut BPF

Parameters	Values
L_1	14.78 mm
w	0.402 mm
g	0.402 mm
w_f	1.262 mm
L_f	2.41 mm
d	0.702 mm
θ	73°
A	$20\times20\,(mm)^2$

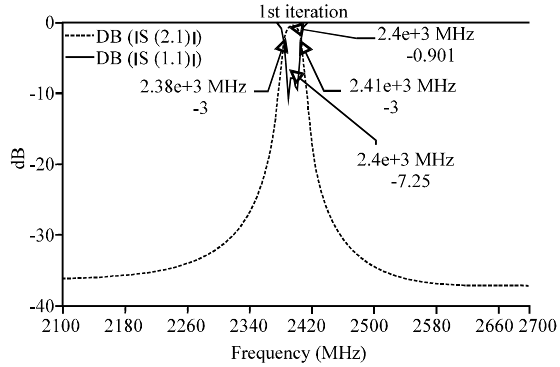

Fig. 7: Return loss (S11) and transmission (S21) responses of conventional square patch

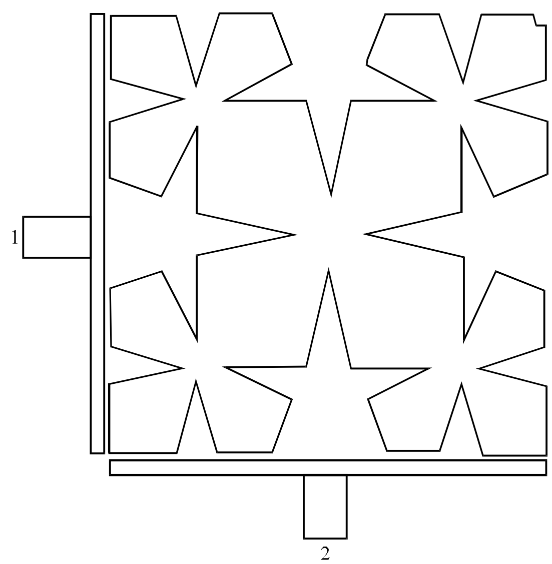

Fig. 8: The modeled layout of the 2nd iteration modified Koch like prefractal corner cut BPF

$$L_1 = 2\left[\frac{1}{3}+\frac{1}{6\cos\theta}\right]L_0$$

Figure 7 shows the return loss and transmission responses of the designed filter. Table 2 shows a summary of the modeled 1st iteration filter dimensions. The 2nd iteration fractal dual mode filter was designed and simulated. Figure 8 and Table 3 shows the layout and

Table 3: Dimensions of the 2nd iteration modified Koch like pre fractal corner cut BPF

Parameters	Values
L_2	14.02 mm
w	0.4 mm
g	0.22 mm
w_f	1.25 mm
L_f	2.16 mm
d	0.3 mm
θ	73°
A	18.5×18.5(mm)^2

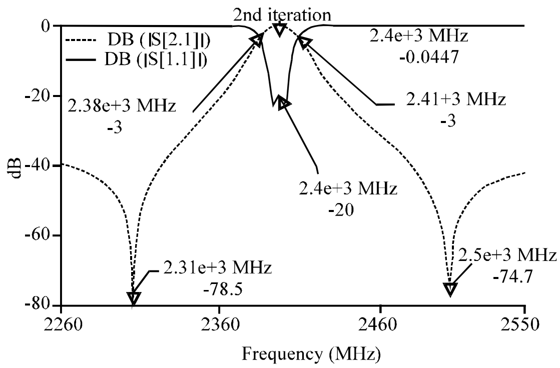

Fig. 9: Return loss (S_{11}) and transmission (S_{21}) responses of 2nd iteration modified Koch like prefractal corner cut BPF

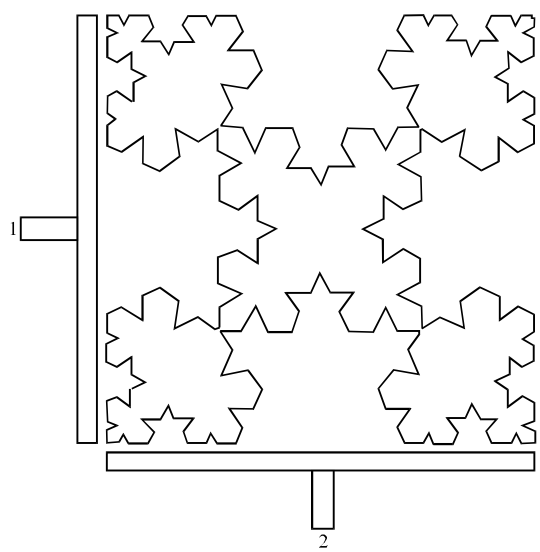

Fig. 10: The modeled layout of the 3rd iteration modified Koch like prefractal corner cut BPF

dimensions of this BPF. Simulation results show that there is a reduction in the dimension of this structure compared with the conventional and 1st iteration (Fig. 9). For further miniaturization, the 3rd iteration was designed and simulated as shown in Fig. 10 results given in Fig. 11. Table 4 shows that there is a good reduction ratio can be achieved with this design.

Table 4: Dimensions of the 3rd iteration modified Koch like pre fractal corner cut BPF

Parameters	Values
L_3	12.5998 mm
w	0.5055 mm
g	0.2981 mm
w_f	0.7 mm
L_f	1.701 mm
d	0.0639 mm
θ	63°
A	16×16 (mm)^2

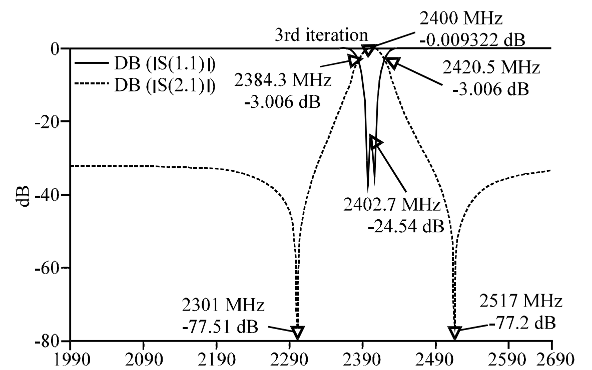

Fig. 11: Return loss (S11) and transmission (S21) response of 3rd iteration modified Koch like prefractal corner cut BPF

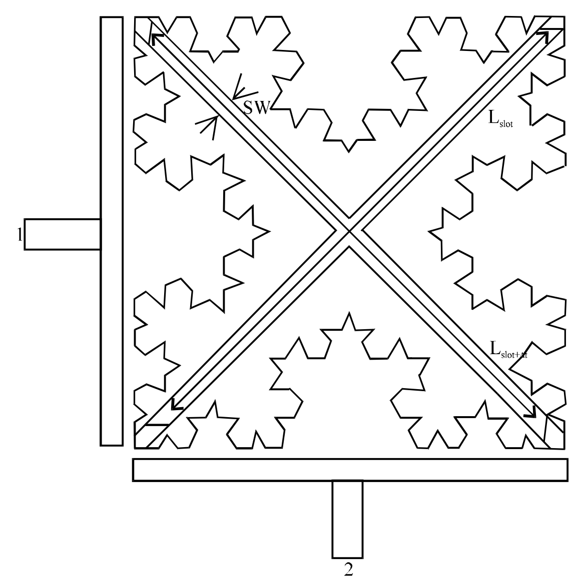

Fig. 12: The modeled layout of the 3rd iteration modified Koch like pre-fractal cross lotted BPF

Modified Koch pre-fractal bandpass filter with cross slotted perturbation: Cross slotted perturbation is another perturbation technique which has pair of cross slots cuts on the patch surface. That can reduce the circuit size and radiation loss. The same procedure in section b was applied to the cross slotted perturbation model. Figure 12

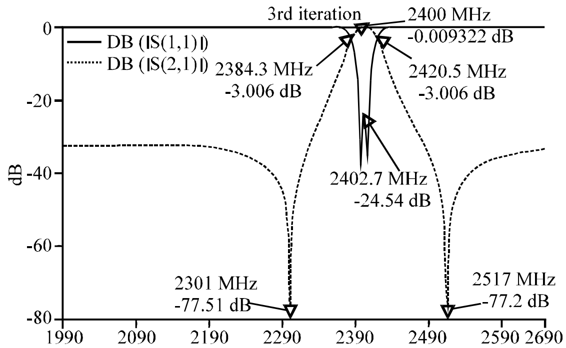

Fig. 13: Return loss (S_{11}) and transmission (S_{21}) response of 3rd iteration modified Koch like pre-fractal cross slotted BPF

Table 5: Dimensions of the modeled 3rd iteration of modified Koch pre-fractal cross slotted BPF

Parameters	Values
L_3	10.196 mm
L_{slot}	12.8636 mm
$L_{slot+\Delta l}$	12.8637 mm
Sw	0.4214 mm
g	0.2975 mm
w	0.5 mm
w_f	0.7 mm
L_f	1.8 mm
θ	63°
A	13.6×13.6 (mm)^2

shows the 3rd iteration modified Koch with cross slotted perturbation. Figure 13 shows return loss and transmission (responses) results in Table 5 that shows the reduction in size of about 74.01% can be achieved with this type of filter as compared with the conventional square patch BPF.

RESULTS AND DISCUSSION

Table 6 summarize the simulation results for the two cases corner cut and cross slotted perturbations.

Results show that the cross slotted perturbation (3rd iteration) gives better size reduction which reaches to 74.01%.The resulting dimension for BPF with cross slotted is 13.6×13.6 (mm)^2 which is suitable for many applications.

Table 6: Comparison between square patch and fractal BPFs

Filter type	Overall dimension (mm)^2	FBW (%)	Q_{ext}	Size reduction (%)
Square patch	28×28	0.833	120	...
Corner cut				
1st iteration	20×20	0.879	113.744	49
2nd iteration	18.5×18.5	1.0875	91.95	56.345
3rd iteration	16×16	1.12	89.22	67.347
Cross slotted				
3rd iteration	13.6×13.6	1.504	66.482	74.01

CONCLUSION

This study introduces the design and simulation of dual mode BPF, based on fractal geometry with two perturbation techniques (corner cut and cross slotted). Simulation results show a size reduction of 74.01% can be achieved using modified Koch curve with cross slotted perturbation technique as compared with the conventional dual mode square patch BPF.

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