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Novel Microstrip bandpass Filter with different Substrates of Koch Fractal Curve with Harmonic Suppression

K.Vijayalakshmi[1]
[1]PG Scholar, Department of ECE,
[1]SSN College of Engineering,
Kalavakkam – 603 110, Tamil Nadu, India
[1]vijisathyasri@gmail.com

S. Karthie[2]
[2]Assistant Professor, Department of ECE
[2]SSN College of Engineering,
Kalavakkam – 603 110, Tamil Nadu, India
[2]karthies@ssn.edu.in

ABSTRACT: **In this paper, the Koch shaped fractal filter curve is designed which is used in the modern wireless applications. Where this filter provides high selectivity and gives better performance. This Koch shape curve is designed upto 2nd iteration using 2.45GHz as centre frequency. In ideal case, return loss will be above 10db and insertion loss will be 0db. The comparison of two substrates is done with (RT/Duroid 6010,RT/Duroid 5880 and FR4) and the performance of the filter structure is evaluated. The filter frequency is decreased with increasing iteration which reduces the size of patch. The main objective of the Koch fractal is to reduce the size of the filter and reduce the fabrication cost.**

Keywords—Koch fractal geometry, ,Microstrip bandpass filter

I. INTRODUCTION

Modern wireless communication systems require high performance narrow band RF/microwave bandpass filters(BPFs) having high selectivity and low insertion loss. It is also important to reduce their size and weight in order to integrate them with other components as a single chip system[1]. A planar microstrip BPF is a good for this purpose. There are various topologies to implement microstrip bandpass filters. They are end-coupled, parallel coupled, hairpin, inter digital and combline filters. Microstrip coupled line filters have been used to achieve narrow fractional bandwidth bandpass filters(BPFs) due to their relatively weak coupling.[2]

Fractal geometries have two common properties; space-filling and self-similarity, making them different from Euclidean geometries. Fractal curves are well known for their unique space-filling properties. It has been shown that the self-similarity and space-filling properties of fractal shapes, such as Minkowski and Koch fractal curves. The filters designed with fractal geometry are having reduced return loss and good passband performance. [3]

The fractal filter provides better performance when compared to the non-fractalized filters. The filter is designed for the center frequency of 2.4GHz.The perturbation element is formed at the inner corner in order to excite the passband with two transmission zero. The resonant frequency will be move towards the lowest frequency when the number of iteration increased.

In this paper, the dual mode bandpass structure is designed using the microstrip patch resonator. The pertubation element is added to the microstrip patch resonator at the corner. In order to achieve the frequency response and the size reduction technique is based on applying Koch curve for the first and second iterations. The same design has been carried out for different substrate and finally, the performance of the filter is compared by measuring the insertion loss and return loss.

II. THE FILTER STRUCTURE GENERATION PROCESS

The Koch fractal geometry has been designed for three different substrate (RT/Duroid 6010,RT/Duroid 5880 and FR4). The frequency is shifted from 2.75 to 2.4GHz by increasing the iteration (the design continues upto 2^{nd} iteration). The schematic illustration of Koch fractal geometry for different iterations is shown in Fig. 1.

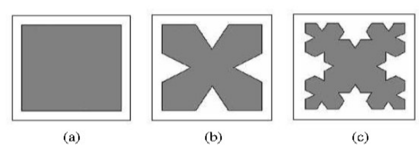

Fig.1 Design of Koch fractal (a)0^{th} iteration (b)1^{st} iteration (c) 2^{nd} iteration

To construct a Koch curve, begin with a straight line and divide it into three equally sized parts. The middle section is replaced with an equilateral triangle and its base is removed. After one iteration, the length is thus increased by a factor of 4/3. As this process is repeated, the total length of the figure tends to infinity as the length of the side of each new triangle goes to zero. The curve is determined by the iteration factor (1/3) and iteration order. Koch curve of different iteration orders is shown in Fig.2.[4]

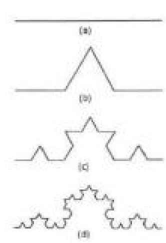

Fig. 2. Koch curve (a) level 0 (b) level 1 (c) level 2 (d) level 3

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A) Design using RT/Duroid 6010

Filters in both sets have been designed for the ISM band applications at 2.4 GHz. The design of Koch fractal based pattern using RT/Duroid 6010 substrate is shown in Fig.3. It has been supposed that these filter structures have been etched using a substrate with a relative dielectric constant of 10.2,a loss tangent of 0.0023(tan δ) and thickness of 1.27 mm. The dual-mode coupling of the two degenerate modes of all filters is achieved via capacitive coupling with input/output 50 ohms microstrip transmission lines is shown in Fig.4 and 2nd iteration of Koch curve is shown in Fig.5. The size of the patch is common for all iterations 17x17 mm^2.

At first, the side length of the square microstrip patch resonator, L_0, has to be calculated

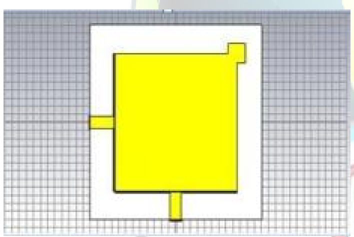
$$L_0 = 0.4\,\lambda_g, \quad (1)$$

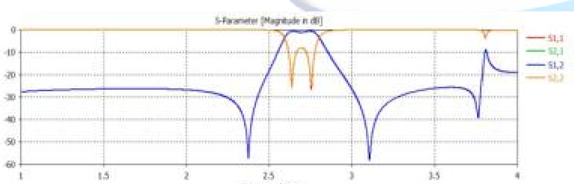
$$\lambda_g = \frac{c}{f\sqrt{\varepsilon_{reff}}}, \quad \text{where C= } 3\times10^8 \text{ m/s} \quad (2)$$

where λg is the guided wavelength,

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2}, \quad (3)$$

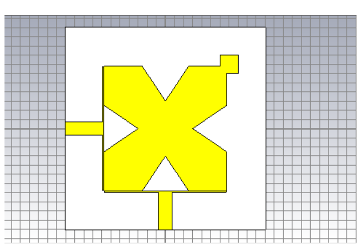
ε_{reff} is the effective dielectric constant [5].


(a) Layout



(b) Simulation

Fig. 3 Zeroth iteration of RT/Duroid 6010 substrate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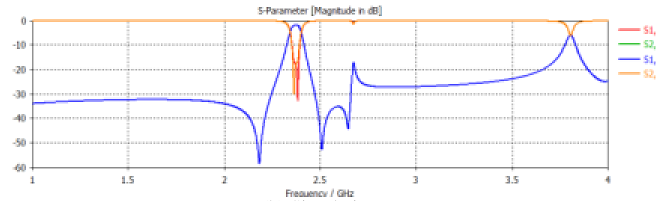
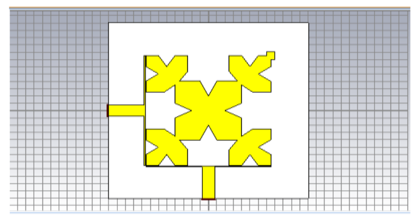


(b) Simulation

Fig. 4 First iteration of RT/Duroid 6010 substrate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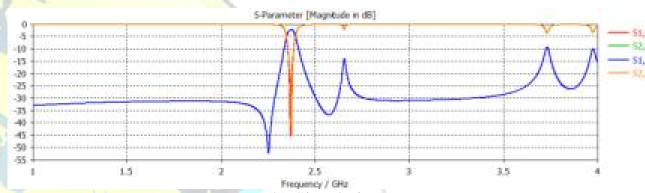


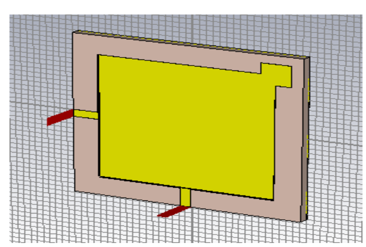
(b) Simulation

Fig. 5 Second iteration of RT/Duroid 6010 substrate

Filter structure is modeled and analyzed at an operating frequency in the ISM band of 2.4GHz. The size of the filter is reduced, the proposed resonator offers acceptable return loss and transmission loss performance with symmetrical responses about the design frequency[6].

B) Design using FR-4

The design is carried out using FR-4 substrate with the thickness of 1.6mm. The relative permittivity of the substrate is 4.4 with the loss tangent of 0.025(tan δ). The size of the patch is 26x26mm^2 is shown in Fig.6. The perturbation element is added at the corner with the size of 3.6mm. The de koch fractal is designed using FR-4 substrate for 1st iteration is shown in Fig.7. Then, the design is simulated for 2nd iteration to obtain the insertion loss and return loss is shown in Fig.8.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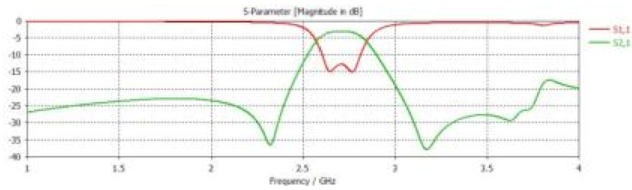
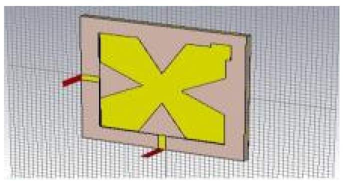


(b) Simulation

Fig. 6 Zeroth iteration of FR4 Substrate



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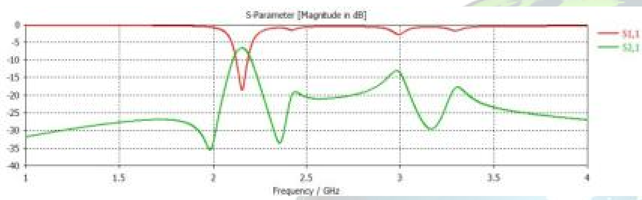
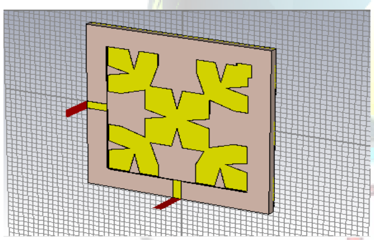


(b) Simulation

Fig. 7 First iteration of of FR4 substrate



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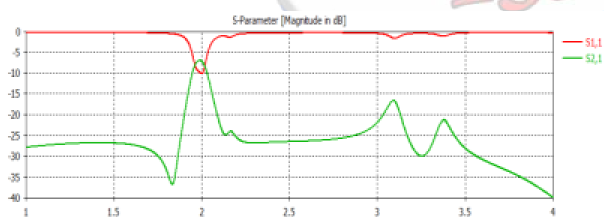
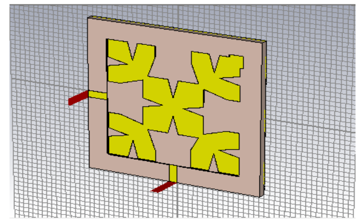


(b) Simulation

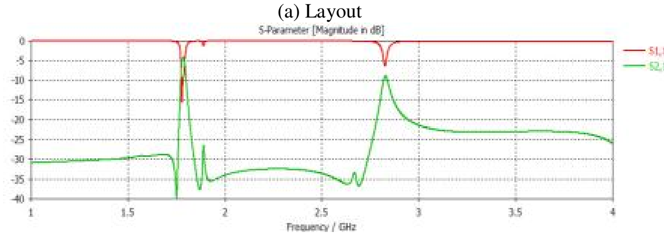
Fig. 8 Second iteration of FR4 substrate

C) Design using RT/Duroid 5880

A dual-mode microstrip patch bandpass filter with the patch has the slot structure corresponding to the 2nd iteration Koch pre-fractal geometry, has been designed for the ISM band applications at 2.4 GHz. The design of Koch fractal based pattern using RT/Duroid 5880 substrate is shown in Fig.9. The thickness of the substrate is 0.5808mm, with the relative permittivity of 10.2 and a loss tangent of 0.0023 (tan δ). The size of the patch is common for all iterations 17.2x17.2 mm^2.



(a) Layout



(b) Simulation

Fig.9 Second iteration of RT/Duroid 5880 substrate

The design is simulated using CST software tool and it is compared with measured frequency response of Koch fractal between three substrates RT/Duroid 6010, RT/Duroid 5880 and FR4

III. Filter Performance and Evaluation

A bandpass filter structure based on square patch resonator has been designed and analyzed using CST microwave tool. The coupling effect largely depends on the perturbation side length. Here, a small perturbation square patch is placed at the right top corner of patch resonator to improve the coupling of degeneration mode .

The Koch fractal which is designed using different substrates are compared with simulated and frequency response from 0th iteration to 2nd iteration and it is shown in Table 1,Table 2 and Table 3. The performance of the filter is better in the result of Koch fractal designed using RT/Duroid 6010 substrate compared with RT/Duroid 5880 and FR-4. Due to the high dielectric constant and the thickness of the substrate, the insertion loss and return loss may vary. Simulations show that the application of fractal geometries significantly lowers the size of the structure.

Table 1. Filter performance of RT/Duroid 6010

RT/Duroid 6010					
Iteration	Center freq (GHz)	S_{11} (dB)	S_{21} (dB)	Bandwidth (MHz)	Fractional BW (%)
0th iteration	2.74	-25.7	-0.59	170	6.18
1st iteration	2.64	-30.0	-0.90	100	3.78
2nd iteration	2.35	-40.1	-1.00	120	5.10

Table 2 Filter performance of FR-4

FR-4					
Iteration	Center freq (GHz)	S_{11} (dB)	S_{21} (dB)	Bandwidth (MHz)	Fractional BW (%)
0th iteration	2.70	-12.5	-3.15	280	10.3
1st iteration	2.15	-18.4	-6.67	100	4.65
2nd iteration	2.00	-20.2	-6.65	170	8.50

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Table 3. Filter performance of RT/Duroid 5880

RT/Duroid 5880					
Iteration	Center freq (GHz)	S_{11} (dB)	S_{21} (dB)	Bandwidth (MHz)	Fractional BW(%)
0^{th} iteration	2.95	-14.5	-1.21	80	2.00
1^{st} iteration	2.13	-10.8	-4.14	50	2.00
2^{nd} iteration	1.78	-13.0	-4.02	40	2.00

Table 4 Comparision of filter performance at second iteration

Substrate	Center freq (GHz)	S_{11} (dB)	S_{21} (dB)	Bandwidth (MHz)	Fractional BW (%)
RT/Duroid6010	2.35	-40.1	-1.00	120	5.10
FR4	2.00	-20.2	-6.65	170	8.50
RT/Duroid5880	1.78	-13.0	-4.02	40	2.00

A) Current density distribution

Current density distribution at the surface of the zero, first and second iteration microstrip bandpass filter with slots simulated at frequency of 2.4 GHz. The current density patterns using the CST simulator for the dual-mode microstrip bandpass filter, based on the second iteration Koch fractal curve microstrip patch resonator is shown in Fig.10. In this figure, the same color code is used as an indication for the surface current densities. It is clear that maximum current densities occur at the resonant frequency. It is worth to note the higher values of the surface current densities around the slot structure, considerably contribute to resonator size reduction.

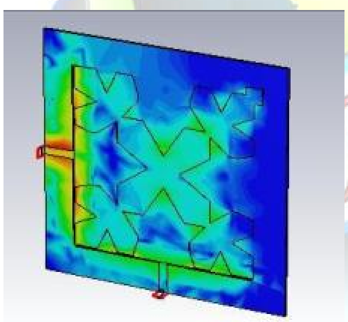
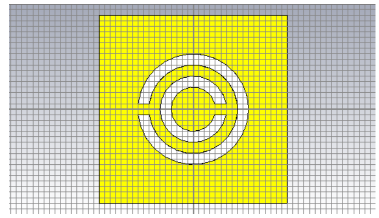


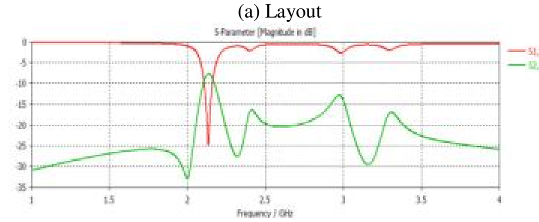
Fig. 10 Current density distribution of RT/Duroid 5880 on second iteration

B) CSRR ground structure

Complementary split ring resonator CSRR are used in Defected ground structure DSG to improve the selectivity of the proposed bandpass filter and isolation between the two passbands. CSRR are designed by etching two concentric split ring resonator in the ground plan, it has different split size and inverse direction of the rings. The yellow layer denoted the ground structure while the white surface denotes the etched part of the ring is shown in Fig.11. They are realized,on the ground plane to improve the selectivity and stopband suppression of the proposed dual-band bandpass filter is shown in Fig.12.

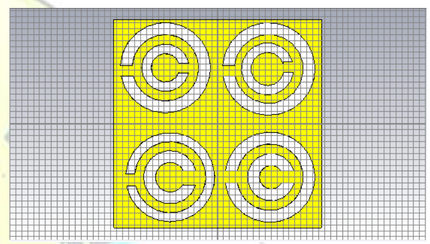


(a) Layout

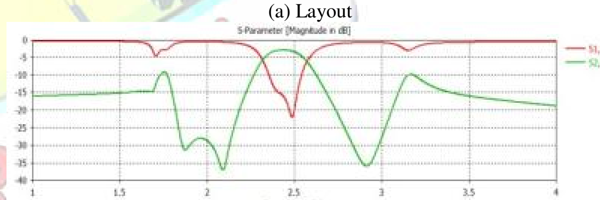


(b) Simulation

Fig. 11 CSRR for first iteration using FR4 substrate with single SRR



(a) Layout



(b) Simulation

Fig. 12 CSRR for first iteration using FR4 substrate with multiple SRR

IV. CONCLUSION

The Koch fractal BPF has been designed with the center frequency of 2.4GHz using three different substrate namely, RT/Duroid 6010, RT/Duroid 5880 and FR-4 for S-band in wireless applications. The design is continued upto 2^{nd} iteration to achieve the center frequency and the perturbation element is added at the corner to obtain the dual mode frequency response. The main advantage of the fractal is compact size, high selectivity, better insertion loss and return loss compared to non-fractalized filters. Finally, the simulated frequency response has been compared for different substrate.

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