



# DESIGN OF COMPACT DUAL-MODE FRACTAL BASED MICROSTRIP BAND REJECT FILTER

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## ABSTRACT

In this paper, a combination of the dual-mode technique and the fractal based resonator geometry has been adopted to design a compact band reject filter. The proposed filter structure relies mainly on that of the triangular patch resonators with an embedded slit structure. The Koch fractal geometry has been applied to the uncoupled side lengths of the triangular patch resonator. The filter structure has been modeled, and its performance is evaluated using the commercially available method of moment (MoM) based simulator, Sonnet. Results imply that the resulting dual-mode response seriously affected by the uncoupled side lengths of the triangular patch resonator. The consequences of varying the Koch indentation angle and the slit length on the resulting filter performance have been explored. Simulation results have confirmed the validity of the proposed resonant structure to realize a compact dual-mode stopband microstrip filter.

**Keywords:** compact bandstop filter, fractal-based BSF, Microstrip BSF, fractal geometry.

## 1. INTRODUCTION

During the last three decades, the designers of microwave circuits have adopted the various fractal geometries to find solutions for many applications with ever increasing challenges. The resulting advantages involve, among many, broader bandwidths, more compact sizes, and improved performance [1]. However, the successful application of different fractal geometries to produce compact size and multiband antennas, [2-5], had encouraged researchers to apply these geometries to design compact planar filters for various wireless applications. A considerable amount of literature has been published on this issue. In the past two decades, a number of researchers have sought to design various types of filters using this technique.

The advantageous use of Peano fractal geometry as applied to the conventional square open-ring resonators has led to producing miniaturized bandpass filters (BPFs) and BSFs, with high performance [6-10]. Hilbert, Moore, Minkowski and other fractal geometries have also found their ways to construct compact microstrip BPFs and BSFs [11-16].

In this context, Koch fractal geometry and its variants are utilized in the design of small size planar resonators based BPFs as reported in the literature [17-19]. In [17], Koch fractal shaped resonators are used in the design of compact parallel coupled BPFs for mm-wavelength applications. The resulting filters offer passbands response with high 2nd harmonic suppression. Dual-mode microstrip BPFs design, based on the 1st and 2nd iteration Koch and modified Minkowski fractal curves, have been reported in [18, 19]. The resulting filters have shown to offer size reduction as compared with the conventional microstrip square patch BPFs with good in-band and out-of-band responses. Furthermore, Koch fractal geometry has been employed to shape the defected ground structure used in the design the dual-band microstrip BPF reported in [20]. It is worth to note that

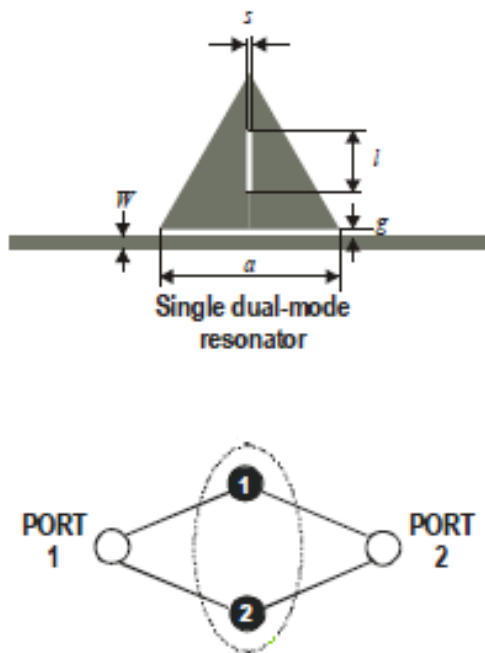
Koch fractal geometry can take many variants other than that are based on the one-third and an indentation angle of 60 degrees. The modified variants of this geometry, with different indentation angle other than 60 degrees, are selected by the antenna designers as reported in [21].

In this paper, a dual-mode microstrip BSF with modified Koch fractal based triangular resonators is presented as a candidate for use in various wireless applications. The resulting BSF offers a small size besides reasonable filter responses. The variation of the indentation angle of the fractal structure employed in the filter design provides a tuning means of the resonant band.

## 2. THE PROPOSED FILTER CONFIGURATION

The idea of the suggested BSF structure, presented in this paper, is based on the triangular patch BSF reported in [22] and shown in Figure-1. A triangular patch resonator with an embedded slot constitutes the reported filter. The analyses of this filter reveal that the uncoupled side lengths of the triangular resonator play a significant role in determining the resonant frequency of the stopband. The uncoupled side lengths of the triangular microstrip patch resonator provide necessary current density to realize the required resonance. Applying particular type of fractal geometries to the uncoupled side lengths will increase the path length that governs the resonant frequency.

For this purpose, Koch fractal geometry has been proposed. Figure-2 shows the generation process of the traditional Koch fractal curve. The angle  $\alpha$  in this configuration has the value of  $60^\circ$ . Applying the conventional Koch fractal geometry to the uncoupled side lengths of the triangular patch will cause them to intersect at the center of the patch. To avoid such an intersection, the angle  $\alpha$  has been selected with values less than  $60^\circ$ . The resulting modified Koch fractal geometry has been proposed in the antenna design to produce compact and multiband antenna performance [21].



**Figure-1.** The structure dual-mode microstrip BSF reported in [22].

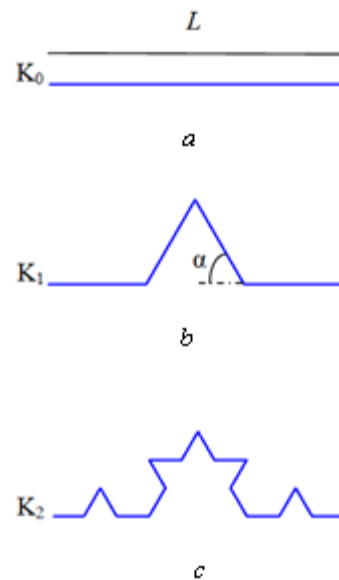
The length  $L_n$  of the modified Koch side length, for the  $n$ th iteration, can be calculated as [21]:

$$L_n = 2^n \left( \frac{1}{3} + \frac{1}{6 \cos \alpha} \right)^n L \quad (1)$$

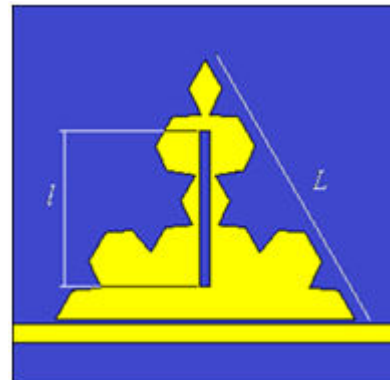
### 3. THE PROPOSED FILTER DESIGN AND PERFORMANCE EVALUATION

The modeled BSF structures are etched using a substrate with a relative dielectric constant of 10.8 and thickness of 1.27 mm. Many filters are modeled based on the filter structure shown in Figure-3 with various indentation angle and with different fractal iteration levels. The input/output ports have  $50\Omega$  characteristic impedance. This corresponds to a transmission line width of about 1.15 mm. The performance responses of the modeled filters have been evaluated using the Method of Moment (MoM) based EM simulator, Sonnet [23]. In all of the modeled filters, the resonator side lengths have been kept with a fixed side length of 15 mm.

Keeping the side length constant of the modeled resonators makes easy to compare the size reduction that takes place since the same substrate with the same dielectric constant has been utilized throughout the modelling process. Based on this, with the variation of the slit dimensions and changing the values of the indentation angles, the performance of the proposed filters has been evaluated.



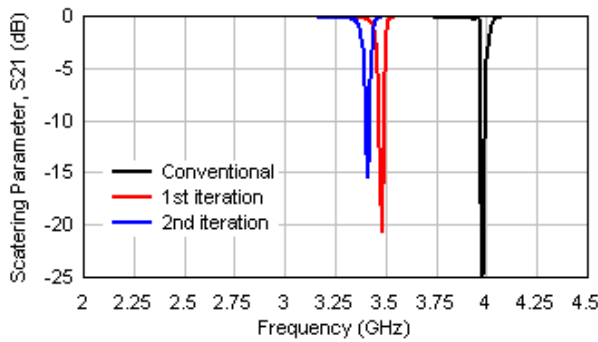
**Figure-2.** The Steps of growth of Koch fractal geometry: (a) the generator, (b) and (c) the 1st and 2nd iterations [21].



**Figure-3.** The layout of the modeled BSF.

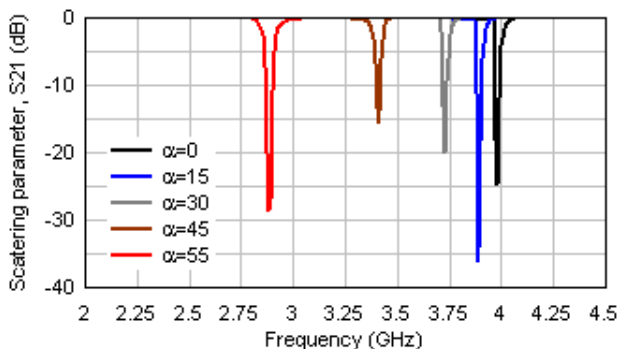
### 4. PERFORMANCE EVALUATION

The effect of the fractal iteration level has been first studied. For this, many filters with different iteration levels, up to the second iteration, have been modeled. The simulated scattering parameters,  $S_{21}$ , responses of the modeled filters are presented in Figure-4. Apparently, the applications of Koch fractal geometry to the uncoupled side lengths results in lowering the resonant frequency of stop-band; as the iteration level increases the resonant frequency becomes more lower. This means more size reduction is achieved with higher iteration levels. The resonant frequencies are 3.98, 3.48, 3.41 GHz corresponding to the zero, first and second iterations, respectively. The results also reveal that there's no considerable change in the resulting bandwidth of the modeled filters.



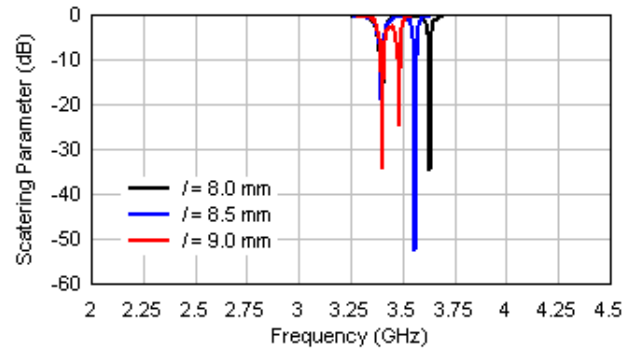
**Figure-4.** The simulated scattering parameter S21 responses of the proposed filter design with the iteration level as a parameter.

Besides, the effect of varying the indentation angle on the filter performance at the second iteration has been investigated. Figure-5 demonstrates the effect of changing the indentation angle on the resulting filter response based on 2nd iteration Koch fractal. It is clear that as the angle is increased more size reduction results in as predicted by (1). It is noted that with the angle equal to zero, the resulting response will be the same as that reported in [22] because the resulting filter structure will be no longer with a fractal shape. Figure 5 shows the S21 response of the filter 2nd iteration with angle is a parameter in the range of 0-55 degrees. It is clear that for an indentation angle equal to 55 degrees, the modeled filter offers a stopband centered at about 2.875 GHz. This represents a size reduction of about 70% as compared with the non-fractal triangular BSF.



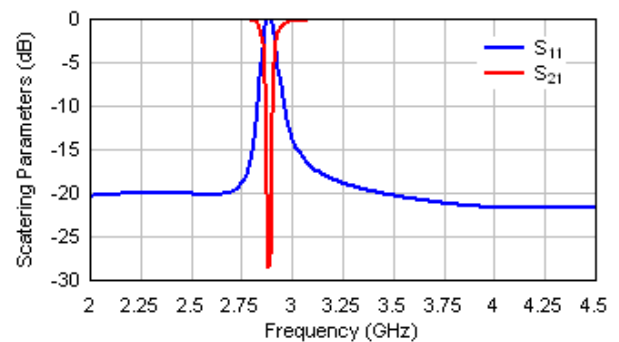
**Figure-5.** The simulated scattering parameter S21 responses of the 2<sup>nd</sup> iteration Koch fractal BSF design with the indentation angle  $\alpha$  as a parameter.

The effect of varying the slit length of the filter has been demonstrated in Figure-6. In this context, an interesting result has been observed. The effect of changing the slit length results in controlling the position of mode 2 while keeping mode 1 unchanged. The same effect has been noticed in [22].



**Figure-6.** The effect of varying the slit length on the resonant of the proposed BSF.

Figure-7 displays the response of the filter based on the 2nd iteration Koch with angle 55 degrees with percentage reduction 13.2 %. The center frequency of this filter is 2.88 GHz with insertion loss more than -25 dB. The final filter performance is demonstrated in Figure-7.



**Figure-7.** The simulated scattering parameters S21 and S11 responses of the modeled filter.

Figure-8 demonstrates the current distributions on the surface of the proposed filter with the responses depicted in Figure-7 at different frequencies in the stopband and outside it. In the stopband, at 2.88 GHz, it is evident that no signal could pass from the input port to the output port since all the current is distributed around the resonator and the slit. However, out of the stopband at frequencies 2 GHz and 3.39 GHz, almost there is no current in the resonator, and most of the signal passes through the input port to the output port.

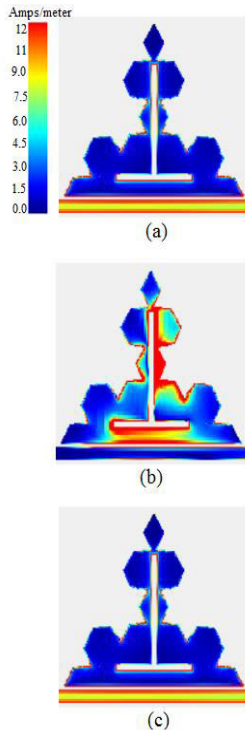
Examining Figure-5 again, the filter size can be expressed in terms of the guided wavelength. In this case, the filter side length  $L$  is found to be of about  $0.37\lambda_g$ , where:

$$\lambda_g = \frac{c}{f\sqrt{\epsilon_e}} \quad (2)$$

$$\epsilon_e \approx \frac{\epsilon_r + 1}{2} \quad (3)$$



where  $c$  and  $\epsilon_e$  represent light speed and effective dielectric constant respectively. However, most of the commercially available EM simulators provide a direct calculation of the guided wavelength at a particular frequency and given substrate parameters. For the existing design, the guided wavelength is calculated to be about 39.1 mm at the design frequency.



**Figure-8.** The current distributions on the surface of the filter at (a) 2 GHz, (b) 2.88 GHz, and (c) 3.39 GHz.

## 5. CONCLUSIONS

The design of a compact fractal-based dual-mode microstrip BSF, for use in modern communication services, has been presented in this paper. The conventional triangular resonator has been modified according to Koch fractal geometry to produce the proposed BSF structure. Simulation results confirm that the proposed technique offers more filter miniaturization, in particular with the application of higher fractal orders. Also, the results show that, with a fixed resonator side length, the variation of the fractal structure indentation angle makes the filter resonating at considerable range frequencies. Furthermore, results reveal that the proposed filter design, besides the compact size, provides more degrees of freedom; making it an attractive choice for the filter designers.

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