Compact Dual-Mode Microstrip Band Reject Filters Based on Koch Fractal Geometry

Hayder S. Ahmed, Department of Electrical Engineering, University of Technology, Iraq
Ali J Salim, Department of Electrical Engineering, University of Technology, Iraq
Jawad K. Ali, Department of Electrical Engineering, University of Technology, Iraq

Available at: https://works.bepress.com/hayder-sahmed/3/
Compact Dual-Mode Microstrip Band Reject Filter Based on Koch Fractal Geometry

Microwave Research Group, Department of Electrical Engineering, University of Technology, Iraq

Abstract- In this paper, a new fractal-based microstrip dual-mode band stop filter (BSF) has been presented. The proposed filter structure is mainly based 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 EM simulator, Sonnet. Results reveal that the resulting dual-mode response depends heavily on the uncoupled side lengths of the triangular patch resonator. A parametric study has been conducted to explore the effect of the Koch indentation angle and the slit length on the resulting filter performance. Simulation results have confirmed the validity of the proposed resonant structure to realize a compact dual-mode stopband microstrip filter.

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 benefits include, among many, wider bandwidths, smaller sizes, and better performance [1]. The successful application of Peano fractal geometry to the conventional square open-ring resonators has led to producing miniaturized bandpass filters (BPFs) and BSFs, with high performance [2-6]. Hilbert, Moore, Minkowski and other fractal geometries have also found their ways to design miniaturized microstrip BPFs and BSFs [7-11].

In this context, Koch fractal geometry has been adopted in the design of compact microstrip resonators based BPFs as reported in the literature [12-15]. In [12], 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 fractal curves, have been reported in [13, 14]. 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 [15]. It is worth to note that Koch fractal geometry can take many variants other than that is 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, have been adopted by the designers of antenna designers as reported in [16].

In this paper, a compact dual-mode microstrip BSF with modified Koch fractal based triangular resonators is presented. The resulting BSF offers a compact size besides reasonable filter responses.

2. THE STRUCTURE OF THE PROPOSED FILTER
The idea of the proposed BSF structure is essentially based on the triangular patch BSF reported in [17] 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 conventional Koch fractal curve. The angle $\alpha$ in this configuration has the value of 60°.

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°. The resulting modified Koch fractal geometry has been proposed in the antenna design to produce compact and multiband antenna performance [16].

The length $L_n$ of the modified Koch side length, for the nth iteration, can be calculated as [16]:

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

where \( L \) and \( \alpha \) are as shown in Figure 2. As it is implied from (1), with the angle \( \alpha \) equals to zero the resulting geometry is no longer be a fractal and the filter structure will be the same as that depicted in Figure 1. It is expected then; further miniaturization is possible when adopting structures with the angle \( \alpha \) larger than zero and with higher iteration levels.

3. THE PROPOSED FILTER DESIGN AND PERFORMANCE EVALUATION

Substrate material, with relative dielectric constant of 10.8 and thickness of 1.27 mm, is adopted in the modeling of the proposed microstrip BSFs. Many BSFs have been modeled based on the structure depicted in Figure 3 with different ideation 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 [18]. In all of the modeled filters the resonator side lengths have been kept with fixed side length of 15.0 mm.

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, S21, responses of the modeled filters are shown in Figure 4. It clear that 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.](image)

On the other hand, the effect of varying the ideation angle on the filter performance at the second iteration has been investigated. Figure 5 demonstrates the effect of varying the ideation 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 clearly shown that with the angle equal to zero, the resulting response will be the same as that reported in [17] 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 as a parameter in the range of 0–55 degrees.
Figure 5: The simulated scattering parameter S21 responses of the 2nd 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 found in [17].

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

Figure 7: The simulated scattering parameters S21 and S11 responses of the proposed filter.

Figure 7 displays the filter response of the filter base 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 presented as shown in Figure 7.
Figure 8: The current distributions on the surface of the proposed filter at (a) 2 GHz, (b) 2.88 GHz, and (c) 3.39 GHz.

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.

4. CONCLUSION

The design of a compact fractal-based dual-mode microstrip BSF, for use in wireless applications, has been presented in this report. 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, especially when applying higher fractal iteration level. Furthermore, the parametric study reveals that the proposed filter design, besides the compact size, provides more degrees of freedom; making it an attractive for the filter designers.

REFERENCES