A Compact Dual-band Bandstop Filter Based on Fractal Microstrip Resonators

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Abstract— Fractal geometries are found attractive to designers seeking for compact size microwave circuits and antennas. In this paper, Peano fractal based open-loop resonators are adopted to design dual-band microstrip band-stop filters (PSFs). The suggested filter structure is essentially based on that of the conventional open-loop rectangular microstrip resonators. The resonators of the proposed PSF structure are made in the form of Peano fractal geometry with different iteration levels. Many filters have been modeled, and their performances have been evaluated using a commercially available full-wave electromagnetic simulator. Each of the modeled filter structures contains two pairs of open loop fractal based resonators with different iteration levels. The lower frequency band-stop performance is attributed to the resonators with higher iteration level while the higher frequency band-stop performance is due to the resonators with lower iteration level. Simulation results for the proposed microstrip filters have confirmed the validity to realize compact dual-band narrow-stopband microstrip filters. A comparative study implies that higher size reduction of the realized filter has taken place as the iteration level of the fractal microstrip open-loop resonators becomes higher. The results presented show that the fractal-based resonators can be used to construct compact narrow-stopband filters suitable for a wide variety of the recently available communication applications.

1. INTRODUCTION

Fractal geometries are characterized by two unique properties; space-filling and self-similarity. These properties have opened new and essential approaches for antennas and electronic solutions in the course of the most recent 25 years. This preliminary stage gives a prologue to the benefits given by fractal geometry in antennas, resonators, and related structures. Such profits incorporate, among numerous, wider bandwidths, littler sizes, part-less electronic parts, and better performance. Additionally, fractals give another era of optimized design tools, initially utilized effectively in antennas but applicable in a general manner [1].

Various fractal geometries have been applied to the conventional microstrip resonators that are successfully adopted to design compact microwave microstrip filters and planar circuits. Based on the conventional square patch, Sierpinski fractal curve has been applied to design a dual-mode microstrip bandpass filter [2, 3]. Other fractal geometries, such as Hilbert, Moore, have been also adopted to design miniaturized bandpass filters [4, 5]. Minkowski fractal based microstrip resonators have more attracted microwave filter designers to be successfully applied to produce compact dual-mode microstrip bandpass filters [6–11]. However, research works dealt with the application of fractal based structures to design microstrip BSFs have been seldom reported in the literature [12], where a Peano fractal shaped open stub microstrip resonator has been proposed to reduce the second harmonics of a dual-mode bandpass filter. On the other hand, Peano fractal geometries have been successfully applied to the conventional resonators to produce high-performance miniaturized single-mode and dual-mode microstrip bandpass filters [13–16]. The high space-filling property of this fractal geometry makes it an attractive choice to design bandpass filters with high size reduction levels.

In this paper, a compact DBBSF with Peano fractal based resonators is presented. Peano fractal curve, with different iteration levels, has been applied to shape microstrip resonators. The proposed filter structure is composed of two groups of microstrip resonators with different iteration levels. This will result in more compact microstrip BSFs with dual stopband responses.

2. THE PROPOSED FILTER CONFIGURATION

The structure of the proposed BSF represents an improvement of that of the conventional BSF with open-loop square ring resonators depicted in Figure 1. In this filter, the resonant frequency of the stopband is dependent on the perimeter of the open-loop square ring resonator [17, 18].

An interesting feature the Peano fractal curve has, as shown in Figure 2, is that it has a relatively higher compression rate than the other space-filling fractal curves such as Hilbert, Moore

Figure 1: The structure of the microstrip of the open-loop resonator BSF reported in [17, 18].

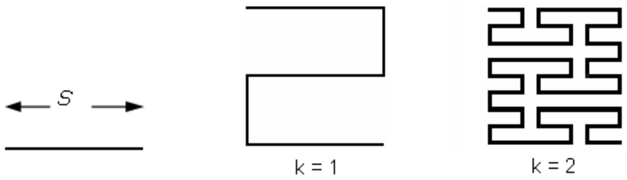

Figure 2: The steps of the growth of the Peano pre-fractal structure [12].

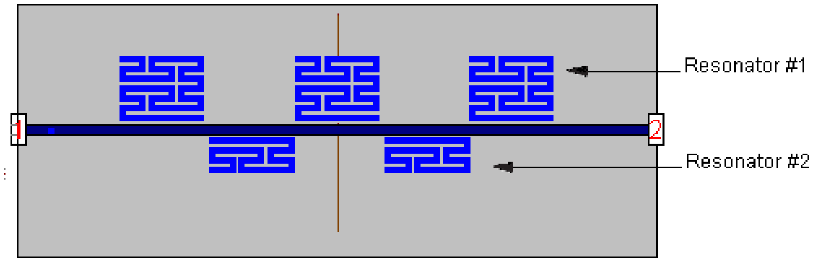

Figure 3: The proposed dual-band BSF configuration with fractal based resonators.

geometries. This suggests that the Peano resonator may resonate at a lower fundamental resonant frequency. The length included, $L(k)$, in the kth iteration pre-fractal structure in terms of the initial line segment, S, is given as [12]:

$$L(k) = \left(3^k + 1\right) S \tag{1}$$

Theoretically, as k goes to infinity, the resulting length goes to infinity. The ability of the resulting structure to increase its perimeter in the successive iterations was found very triggering for examining its size reduction capability as a BSF.

The proposed BSF configuration will constitute two groups of fractal based resonators, located at both sides of the feed line; each with different iteration level of Peano pre-fractal structures shown in Figure 3. Therefore, each group will create its own resonant band as each will have different length.

3. THE FILER DESIGN AND PERFORMANCE EVALUATION

To validate the idea of the proposed filter, three BSFs have been modeled; each with resonators based on Peano fractal geometry of the 2nd iteration level depicted in Figure 2. Two types of resonators, resonator #1 and resonator #2, are used with different length; representing fractions of the Peano fractal geometry of the 2nd iteration as demonstrated in Figure 3. The first filter uses only resonator #1, the second filter only resonator #2 while the third filter uses both resonators. These filter structures have been modeled and analyzed using the commercially available EM simulator, IE3D [19] using a substrate material with a relative dielectric constant of 10.8 and substrate thickness of 1.27 mm. This simulator performs electromagnetic analysis using the method of moments (MoM). The input/output ports have 50 Ω characteristic impedance. This corresponds to a microstrip line width of about 1.2 mm.

The side length of all the resonators of the modeled filter has been kept unchanged with S equal to 8.60 mm with trace width of about 0.6 mm. The enclosed lengths of the resonators #1 and 2 are 79.57 mm and 47.20 mm respectively. The resulting responses of the modeled filters are depicted in Figures 4–6. It is clear that the results in Figures 4 and 5 imply that the filters with single type resonator offer a single band stopband dependent on the resonator length. Consequently, the lower

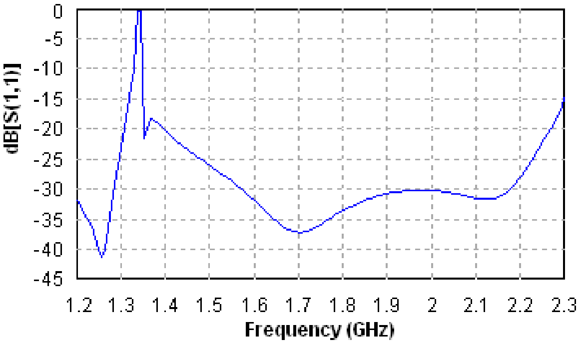

Figure 4: The simulated S_{11} response of the modeled BSF with resonators #1 alone.

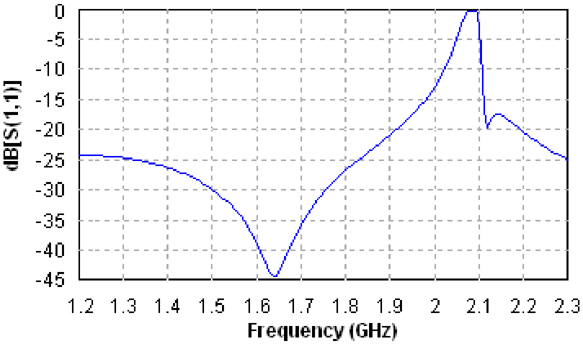

Figure 5: The simulated S_{11} response of the modeled BSF with resonators #2 alone.

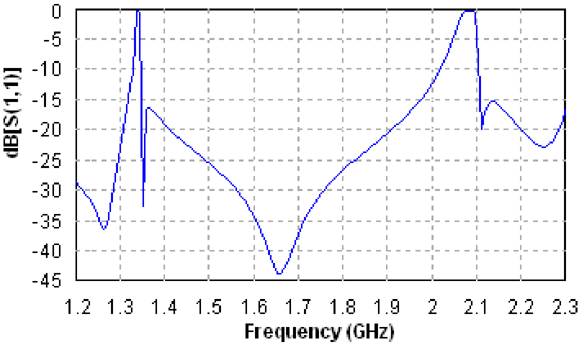

Figure 6: The simulated S_{11} response of the proposed dual-band BSF.

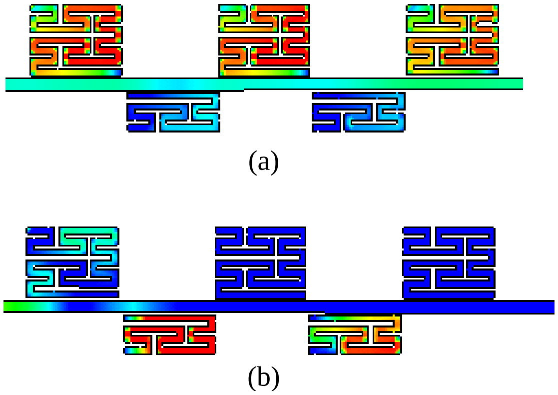

Figure 7: Current distribution on the surface of the proposed dual-band BSF at: (a) 1.34 GHz and (b) 2.08 GHz

stopband, centered at 1.34 GHz, is attributed by the resonator #1 and the higher one, centered at 2.08 GHz, is attributed by resonator #2. In terms of the corresponding guided wavelength, λ_{g1} and λ_{g2}, the side lengths of the two resonators represents about $0.10\lambda_{g1}$ and $0.16\lambda_{g2}$ respectively, where λ_g;

$$\lambda_g = \frac{\lambda_0}{\sqrt{\varepsilon_{eff}}} \tag{2}$$

where ε_{eff} is the effective dielectric constant and can be calculated by empirical expressions reported in the literature [17]. This length has been found to be more compact as compared with that reported in [17]. The BSF that uses the resonator #1 has higher selectivity response with steep roll-off rate as compared with that using resonator #1. This is because the former is a 3rd order filter while the latter is a second order one.

On the other hand, Figure 6 implies that when the two resonators are employed in the filter structure, the resulting response has two stop bands; exactly at the same frequency and shape as if each resonator works alone. This suggests that; using pairs of resonators with different lengths the positions of the stopband could be varied as required for certain applications. In addition, the frequency ratio of the two stop bands can be adjusted by choosing the appropriate resonators length ratio. To a certain extent, the proposed filter can be suggested to be a candidate for use in a wide variety of dual-band wireless applications.

Figure 7 demonstrates the surface current distribution on the proposed filter structure at 1.34 GHz and 2.08 GHz. The resulting current distribution confirms the results of Figures 4 and 5 in that each resonator works independently as if it exists alone. In Figure 7(a), the resonator #1 resonates at 1.34 GHz, while in Figure 7(a), the resonator #2 resonates at 2.08 GHz.

4. CONCLUSIONS

A compact size dual-band microstrip BSF has been presented in this paper. The application of two pairs of Peano fractal based resonators, with different length enclosed, results in compact dual-band BSF. The use of different length fractal shaped resonators could be used to vary the frequency ratio of the two stop bands which can be determined by the two resonators enclosed lengths. To a certain extent, the proposed filter can be suggested to be a candidate for use in a wide variety of dual-band wireless applications.

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