# Novel Bandpass Filters Based on Grounded Hilbert Fractal Resonators

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**Abstract**

In this paper, novel bandpass filter based on directly tapped grounded Hilbert fractal resonators is presented. By changing the via size and position, as well as by using multiple Hilbert fractal curves, the central frequency tuning range equal to 70%.is obtained.

## 1. Introduction

Metamaterials, artificial structures that exhibit electromagnetic properties generally not found in nature, have recently attracted considerable attention. They are used in a variety of optical and microwave applications, and, among other benefits, offer potential for miniaturization of passive microwave devices.

On the other hand, due to their space-filling property, fractal curves allow the design of infinite-length lines on a finite substrate area, and are also of great interest for miniaturization of passive microwave devices. Hilbert fractal is an open curve that has ends on the opposite sides, and thus it is convenient for usage in structures such as the end-coupled microstrip resonator. With this idea, compact microstrip resonators and cross-coupled filter using Hilbert fractal curves have been proposed, [1]-[3].

Recently, a novel CRLH dual-band resonator has been proposed, based on the grounded Hilbert fractal resonator, [4]. In this paper, a novel bandpass filter design is presented, which uses grounded Hilbert resonators directly tapped to the feed lines. The influence of the via position and dimensions on the performances of the proposed filter are analyzed in detail, as well as the influence of using multiple fractal curves.

## 2. Filter configuration and results

Grounded Hilbert resonator is shown in Fig. 1. It consists of a two-dimensional Hilbert fractal of the second-order, grounded by a via in its middle and capacitively coupled to 50-Ohm feeding lines, [4]. The bandpass filter presented in this paper consists of two grounded Hilbert resonators which are directly tapped to the 50-Ω feed lines and capacitively coupled by $s$=1mm gap, Fig. 2. The fractal line width and spacing are $w$=$g$=700 µm, while the vias, positioned in the middle of the resonators, are modeled with a square cross-section with $d$=100µm. The whole structure is realized on 1.27mm thick Taconic substrate with $\varepsilon_r$=9.8 and dielectric loss tangent equal to 0.0025. Conductor losses are modeled by using bulk conductivity for copper. The overall dimensions of the filter are 4.9x10.8mm, i.e $\lambda_g$/8x $\lambda_g$/4 on a given substrate. All simulations have been performed using EMSight, EM simulator in Microwave Office.

The simulated response of the proposed filter is shown in Fig. 3. The ripple-free passband is centered at 3.16 GHz and characterized by small insertion loss equal to -0.95dB, and the fractional bandwidth equal to 7.5%. Two deep poles exist at 1.75 and 3.95GHz, while the second harmonic is positioned at approximately 2.5$f_{c1}$.

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Fig. 1: Grounded Hilbert fractal resonator.

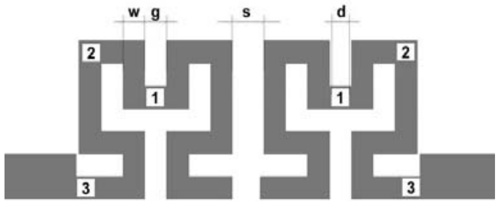


Fig. 2: Configuration of the proposed filter with three different via positions denoted by numbers.

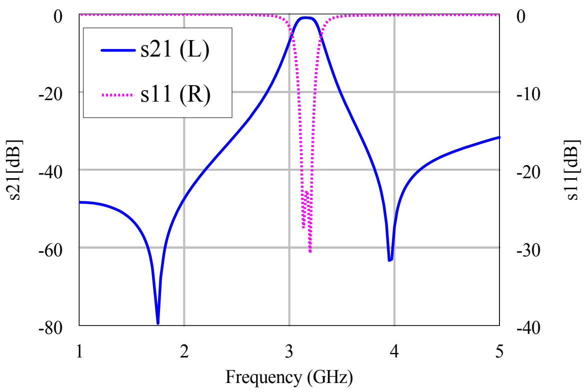


Fig. 3: Simulated response of the proposed filter.

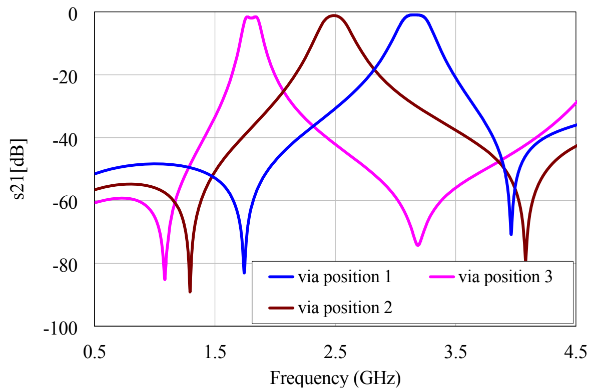


Fig. 4: Influence of the via position on the filter performances.

In order to investigate the influence of the via positions, three different configurations have been analyzed, shown in Fig. 2, and their responses are compared in Fig. 4. It can be concluded that the part of Hilbert curve between the feed line and the via does not affect the filter response. Therefore, placing the via closer to the feed line causes increase of the inductance of the structure, which in turn results in a significant shift of the passband towards lower frequencies and increase of the insertion loss and the ripple. By changing via position, central frequency tuning range greater than 40% is obtained. The ripple, caused mainly by the changed coupling between the resonators, can be reduced by a proper choice of the gap *s*.

Changing the via size also affects the filter performances. Simulation results for four different via dimensions *d*=100, 200, 300 and 400μm, placed in the position 1, are compared in Fig. 5. Due to reduced via inductance, the central frequency is shifted towards higher values as the size of the via is increased, while the insertion loss and the ripple are increased.

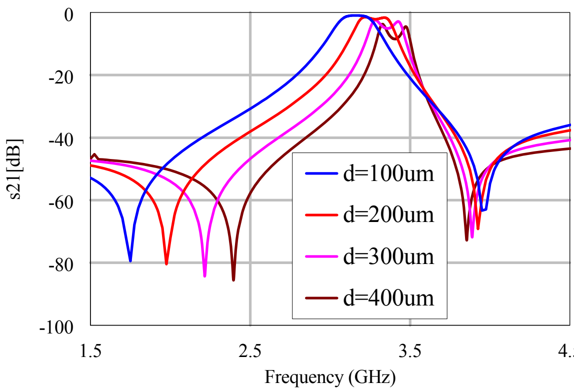


Fig. 5: Influence of the via dimensions on the filter performances.

Further decrease of the filter's central frequency can be achieved by using resonators that consist of two serially connected Hilbert curves, Fig. 6. Owing to their increased length, such structures have greater inductance and thus exhibit lower resonant frequency. Due to the fact that the part of Hilbert curve between the feed line and the via does not affect the performances, only one via is used in each resonator. The different via positions are denoted by numbers in Fig. 6.

Fig. 7 shows simulated responses of the second-order bandpass filters with multiple Hilbert resonators, for different via positions. It can be seen that the passband can be shifted down to 1GHz and the tuning range of approximately 70% can be obtained. However, decrease of the central frequency is accompanied by increased insertion losses and passband ripple.


Fig. 6: Configuration of the filter with multiple Hilbert resonators.

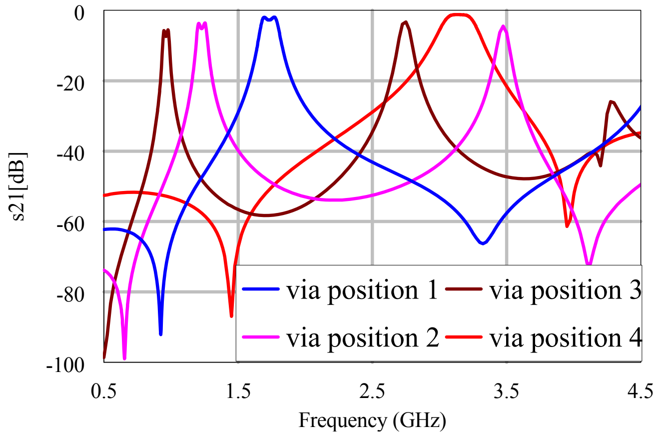


Fig. 7: Simulated response of the filter with multiple Hilbert curves for different via positions.

## 3. Conclusion

Novel second-order bandpass filter based on the grounded Hilbert resonators is presented, with the overall dimensions equal to $\lambda_g/8$x $\lambda_g/4$ on a given substrate. The influence of the via dimensions and its position to the filter performances has been analyzed in detail. By changing the via position, central frequency tuning range greater than 40% is obtained. To further decrease filter's central frequency, resonators that consist of two serially connected Hilbert curves are used and the tuning range of more than 70% is obtained.

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