DESIGN OF FRACTAL-BASED TRI-BAND MICROSTRIP BANDPASS FILTER FOR ISM,WLAN AND WIMAX APPLICATIONS

Nagham Radhi and Mohammed Fadhil

Department of Communication Engineering, University of Technology- Iraq

ABSTRACT

The Peano fractal geometries exhibit a notable ability to space filling due to their distinctive characteristics. In this study, we introduce a Peano-based first-generation flat microstrip multi-band bandpass filter. The filter is presented as a possible solution for ISM, WLAN, and WiMAX applications thanks to its design with symmetric three coupled lines and asymmetric two coupled lines. The first version of the Peano fractal curve was used to design a bandpass filter with a satisfactory response at 2.44, 3.79, and 5.75 GHz. A substrate with a relative dielectric constant of 3.48 and a thickness of 0.762 mm was used to create the filter. The filter architectures' simulated performances were assessed using the CST STUDIO SUITE-based method of moments (MoM). The results show that the proposed filter architecture has good return loss and transmission properties, in addition to its reduced size and inexpensive cost.

KEYWORDS

Microstrip Band Pass Filters (BPFs), SIR resonator,WLAN ,ISM and WiMAX applications, tri-band filter, CST Microwave Studio., Compact ASLR fractal BPF filter.

1. INTRODUCTION

Fractals have been utilized in numerous scientific and engineering domains, following the pioneering contributions of Mandelbrot [1]. Fractal electrodynamics is an area of study that combines fractal geometry with electromagnetic theory to explore a novel category of radiation, propagation, and scattering issues. This field is exemplified by reference [2]. The latest advancements in wireless communication systems have introduced fresh obstacles in the creation and manufacturing of top-notch compact components. The aforementioned challenges prompt designers of microwave circuits and antennas to explore diverse fractal geometries in search of viable solutions.

The predictions made by the individuals are founded upon their analysis of Cantor fractal geometry. The creation of a microstrip lowpass filter made use of the Peano fractal curve as a defective ground structure. The results of this study suggest that, when compared to traditional dumbbell-shaped DGS low-pass filters, fractal DGS low-pass filters have a better roll-off rate or sharpness factor [3]. The utilization of the Hilbert fractal curve in the design of microstrip bandpass filters has been observed through the application of the SIR principle on individual strips of the Hilbert fractal geometry, as documented in reference [4]. The utilization of Koch fractal geometry has been implemented in the design of a band pass filter (BPF) for a double folded substrate integrated waveguide (FSIW) operating at the X band microwave frequency, as reported in reference [5]. The utilization of Minkowski-type fractal geometry has been observed in the implementation of defected ground structures for the purpose of designing miniaturized microstrip bandpass filters, as reported in reference [6]. The utilization of Minkowski fractal geometries for the purpose of modeling compact microstrip bandpass filters has been documented in literature sources [7–12]. The utilization of Peano fractal geometry has proven to be effective in the development of compact microstrip filters with single-band and dual- or multi-band capabilities for a range of communication applications, as evidenced by sources [13–18].

The microstrip filter design presented in the current study, which was inspired by [19], is meant to be used in modern communication systems. A triple-resonance band filter has been constructed at resonance frequencies of 2.44 GHz, 3.79 GHz, and 5.75 GHz, based on the iteration of the 1st Peano fractal curve. The compactness of the resulting filter is attributed to its exceptional space filling property, which is accompanied by favorable transmission and return loss responses.

2. Peano Fractal Curve

The Peano curve, which was introduced by Peano in 1890, is significant as it represents the initial instance of a space-filling curve [20]. The Peano-curve algorithm exhibits a notable characteristic in its comparatively superior compression rate when compared to the Hilbert-curve algorithm in the context of filling a two-dimensional region. This finding raises the possibility that the Peano resonator has a lower resonance frequency than a Hilbert resonator with an equivalent n iteration. Figure 1 shows the Peano fractal curve, which has a square section of S as its outer boundary. Continuation from reference [21], the total length of the line segments L(n) in a resonator composed of a slender conducting strip arranged in the shape of the Peano curve, with a side dimension S and of order n, can be expressed as follows:

$$L(n) = (3^n + 1)S \qquad (1)$$

In a microstrip resonator, the strip width (w) and the distance between the strips (g) are the variables that determine the side dimension of Peano fractal geometry. According to reference [9], the variables w and g are connected to the exterior side S and iteration order n.

$$S = 3^n(w + g) - g \qquad (2)$$

The concept of fractal dimension pertains to the degree of space-filling capacity exhibited by a pattern at the packaging level or in terms of quantity. It characterizes the distinct scaling behavior of a fractal relative to the space in which it is situated and is inherently non-integer in nature [23].

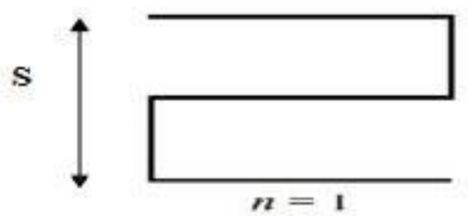


Fig.1. The first iteration level of the Peano fractal curve generation process

3. PROPOSED BAND PASS FILTER BASED ON PEANO FRACTAL

Based on the first iteration of Peano fractal geometry, the suggested design is a multi-band bandpass filter that uses a flat microstrip arrangement. The filter has been devised to incorporate both symmetric three coupled lines and asymmetric two coupled lines. As shown in Figure 2, the filter has been considered to function at the 2.44 GHz, 3.79 GHz, and 5.75 GHz resonant band frequencies. The filter structures under consideration were purportedly fabricated via etching on a substrate possessing a relative dielectric constant of 3.48 and a thickness of 0.762 mm. The dimensions of the resonator that were obtained are 26.98 mm × 18.88 mm, which correspond to approximately 0.25 λg by 0.36 λg. The TB-BPF's structural parameters have been designed and optimized in the following manner: The values provided by the user are as follows: Wf = 1.68, W1 = 0.7, W2 = 0.158, W3 = 2.37, W4 = 4.75, L_f = 2.1, L_1 = 13.82, L_2 = 8.1, L3 = 2.1, L4 = 12, t_1 = 0.54, t_2 = 0.3. These values are expressed in millimeters. At the central frequency of the first passband (2.44 GHz), the guided wavelength (λg) of the 50-Ω microstrip line over the substrate is being referred to. [24,25]:

$$\lambda_g = \frac{\lambda_o}{\sqrt{\varepsilon_{reff}}} \quad (3)$$

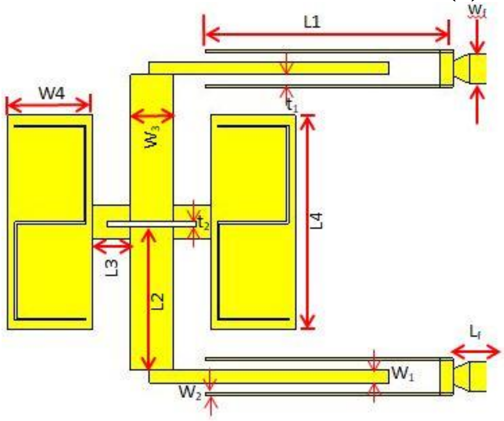


Fig.2. Depicts a microstrip bandpass filter that has been modeled with two resonators utilizing the first iteration Peano curve geometry.

4. RESULTS

Figure 3 displays the frequency responses that correspond to S_{11} and S_{21}.The findings depicted in Figure 3 indicate that the bandpass filters derived from the initial Peano fractal geometry iterations exhibit tri-band characteristics, with transmission zeros situated at the first two bands, specifically at 2.44 GHz and 3.79 GHz, respectively. Simultaneously, there exists effective isolation among the three passbands. The presence of three attenuation poles within the stopband can be discerned at frequencies of 0.011 GHz, 2.83 GHz, and 5.04 GHz.

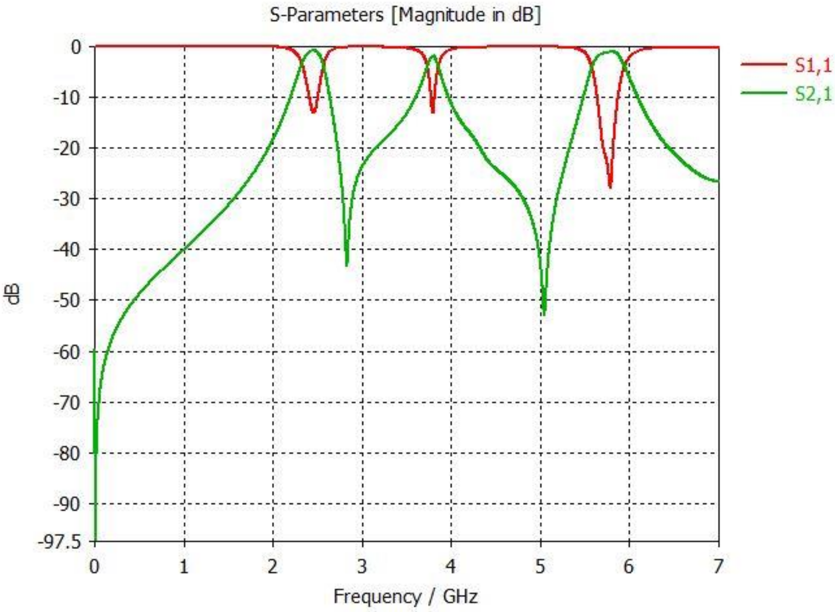
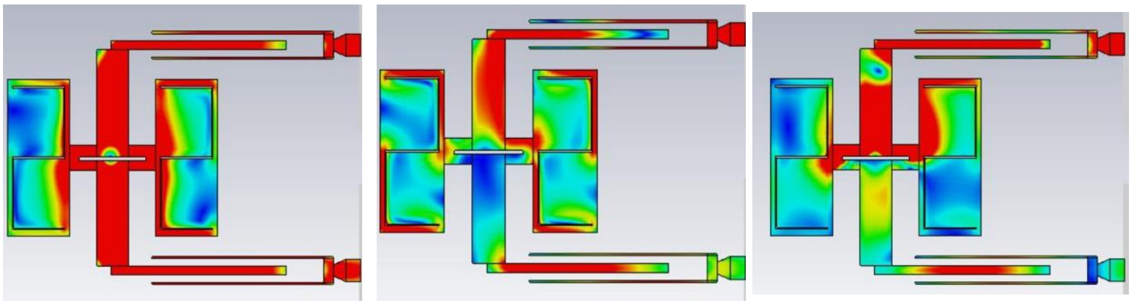


Figure 3: displays the return loss and transmission responses of the 1st iteration fractal two-resonator microstrip bandpass filter.

Figures 4 depict the surface current distributions. The responses were analyzed utilizing a sonnet simulator, with the color red representing the highest degree of coupling effect and blue representing the lowest.



2.44 GHz 3.79 GHz 5.755 GHz

Figure 4 illustrates the distribution of current density at the conducting surface of the Peano bandpass filter during the first iteration. The simulation was conducted at a the three resonant frequency.

5. CONCLUSIONS

Based on the first iteration of the Peano fractal curve, this study offers a simulation of a rectangular microstrip multi-band bandpass filter that employs symmetric three coupled lines and asymmetric two coupled lines. The proposed fractal structure exhibits a space-filling property, leading to a significant level of miniaturization. The area occupied by the fractal-based resonator has been determined to be approximately (0.25λg × 0.36λg) times the wavelength of the guided mode. The outcomes of the simulation indicate the presence of three passbands, each with a distinct central frequency of 2.44 GHz, 3.79 GHz, and 5.75 GHz, respectively. Thus, the suggested Bandpass Filter (BPF) exhibits potential for implementation in (ISM), (WLAN), and (WiMAX) applications, based on its capabilities.

REFERENCES

[1] B. B. Mandelbrot, The Fractal Geometry of Nature. New York: W. H. Freeman and Company, 1983.

[2] D. L. Jaggard, “On Fractal Electrodynamics” in H.N. Kritikos and D.L. Jaggard (eds.), Recent Advances in Electromagnetic Theory, New York: Springer-Verlag, 1990.

[3] A. Kumar, P. R. Prajapati, A. Arya and M. V. Kartikeyan, "Design studies on microstrip filter with peano fractal defected ground structure," 2016 11th International Conference on Industrial and Information Systems (ICIIS), Roorkee, India, 2016, pp. 576-581.

[4] Y. S. Mezaal, H. T. Eyyuboğlu, and J. K. Ali, “New Microstrip Bandpass Filter Designs Based on Stepped Impedance Hilbert Fractal Resonators,” IETE Journal of Research, vol. 60, no. 3, pp. 257–264,May2014,doi:10.1080/03772063.2014.922018.

[5] N. Muchhal and S. Srivastava, “Design of miniaturized high selectivity folded substrate integrated waveguide band pass filter with Koch fractal,” Electromagnetics, vol. 39, no. 8, pp. 571–581,Oct.2019,doi:10.1080/02726343.2019.1675440.

[6] J. K. Ali and H. T. Ziboon, “Design of Compact Bandpass Filters based on Fractal Defected Ground Structure (DGS) Resonators,” Indian Journal of Science and Technology, vol. 9, no. 39, Oct. 2016, doi: 10.17485/ijst/2016/v9i39/91350.

[7] J.-C. Liu, H.-H. Liu, K.-D. Yeh, C.-Y. Liu, B.-H. Zeng, and C.-C. Chen, “MINIATURIZED DUAL-MODE RESONATORS WITH MINKOWSKI-ISLAND-BASED FRACTAL PATCH FOR WLAN DUAL-BAND SYSTEMS,” Progress In Electromagnetics Research C, vol. 26, pp. 229–243, 2012, doi: 10.2528/pierc11111502.

[8] M. Alqaisy, C. Chakrabraty, J. Ali, and A. R. H. Alhawari, “A miniature fractal-based dual-mode dual-band microstrip bandpass filter design,” International Journal of Microwave and Wireless Technologies, vol. 7, no. 2, pp. 127–133, Apr. 2014, doi: 10.1017/s1759078714000622

[9] H. T. Ziboon and J. K. Ali, “Compact dual-band bandpass filter based on fractal stub-loaded resonator,” 2017 Progress In Electromagnetics Research Symposium - Spring (PIERS), May 2017, doi: 10.1109/piers.2017.8262046.

[10] H. Ahmed, H. Hammas, and M. Hussan, “Design of Compact Multiband Microstrip BPF Based on Fractal Open-Ring Configuration,” Engineering and Technology Journal, vol. 36, no. 8A, pp. 887–890, Aug. 2018, doi: 10.30684/etj.36.8a.7.

[11] M. Sujatha, N. K. Darimireddy, R. Ramana Reddy, and B. Sridhar, “Minkowski Inter-Digital Dual-Band Pass Fractal Filter for GSM Applications,” 2019 IEEE Indian Conference on Antennas and Propogation (InCAP), Dec. 2019, doi: 10.1109/incap47789.2019.9134607.

[12] Mishra, Anjay & Singh, Er.Manoj & Gautam, Dipak & Bhagat, Chandan. (2022). Assessment of Compact Minkowski Fractal Microstrip Filter for Band Applications. 10.5281/zenodo.6538787.

[13] J. K. Ali and Y. S. Miz'el, "A new miniature Peano fractal-based bandpass filter design with 2nd harmonic suppression," 2009 3rd IEEE International Symposium on Microwave, Antenna, Propagation and EMC Technologies for Wireless Communications, Beijing, China, 2009, pp. 1019-1022, doi: 10.1109/MAPE.2009.5355854.

[14] Ali, Jawad K., et al. "A Peano fractal-based dual-mode microstrip bandpass filters for wireless communication systems." Proceedings of Progress in Electromagnetics Research Symposium, PIERS. 2012.

[15] Y. S. Mezaal, H. T. Eyyuboglu, and J. K. Ali, “A new design of dual band microstrip bandpass filter based on Peano fractal geometry: Design and simulation results,” 2013 13th Mediterranean Microwave Symposium (MMS), Sep. 2013, doi: 10.1109/mms.2013.6663140.

[16] Abirami, G., Karthie, S. (2019). Design of Fractal-Based Dual-Mode Microstrip Bandpass Filter for Wireless Communication Systems. In: Smys, S., Bestak, R., Chen, JZ., Kotuliak, I. (eds) International Conference on Computer Networks and Communication Technologies. Lecture Notes on Data Engineering and Communications Technologies, vol 15. Springer, Singapore. https://doi.org/10.1007/978-981-10-8681-6_48.

[17] Jehad, Wasan A., and Yaqeen S. Mezaal. "MINIATURIZED BANDPASS FILTER BASED ON PEANO FRACTAL GEOMETRY WITH HIGHER HARMONIC SUPPRESSION." Al-Qadisiyah Journal for Engineering Sciences 4.2 (2011).

[18] J. K. Ali and Y. S. Mezaal, A New Miniature Narrowband Microstrip Bandpass Filter Design Based on Peano Fractal Geometry, Iraqi Journal of Applied Physics, IJAP 01/2009; 5:3-9.pp.3-9

[19] R. Salmani, A. Bijari, S.H. Zahiri, "Design of a microstrip dual-band bandpass filter using novel loaded asymmetric two coupled lines for WLAN applications," Journal of Electrical and Computer Engineering Innovations, 8(2): 255-262, 2020.

[20] H. Sagan, "Hilbert's Space-Filling Curve," Space-Filling Curves, pp. 9–30, 1994, doi: 10.1007/978-1-4612-0871-6_2.

[21] Jinhui Zhu, Hoorfar, and Engheta, "Peano antennas," IEEE Antennas and Wireless Propagation Letters, vol. 3, pp. 71–74, 2004, doi: 10.1109/lawp.2004.827899..

[22] Falconer, K., Fractal Geometry; Mathematical Foundations and Applications, 2nd Edition, John Wiley and Sons Ltd., Chichester, 2003.

[24] Hong, J.S., and M.J. Lancaster, (2001). "Microstrip Filters for RF/Microwave Applications", John Wiley and Sons Inc., New York.

[25] D. Swanson, "Narrow-band microwave filter design," IEEE Microwave Magazine, vol. 8, no. 5, pp. 105–114, Oct. 2007, doi: 10.1109/mmm.2007.904