2013 Third International Conference on Advanced Computing & Communication Technologies

# New Dual Band Dual-Mode Microstrip Patch Bandpass Filter Designs Based on Sierpinski Fractal Geometry

Yaqeen S. Mezaal, Halil T. Eyyuboğlu
Dept. of Electronic and Communication Engineering,
Cankaya University,
Ankara, Turkey
yakeen_sbah@yahoo.com,
h.eyyuboglu@cankaya. edu.tr

Jawad K. Ali
Microwave Res. Group, Dept. of Electrical
Engineering, University of Technology,
Baghdad, Iraq
jawadkali@uotechnology.edu.iq

*Abstract*— **Dual band dual mode chebychev microstrip bandpass filter designs are introduced for first time in this paper. The proposed filter designs are based on the use of dual mode square slotted patch microstrip resonator. These filter structures are fractally generated using Sierpinski fractal curve geometry applied to the conventional square microstrip patch from 1st to 2nd iteration levels where the first band designed at fundamental frequencies (5.475 ,5.45 and 5.4) GHz for each iteration while the second band( 8.925,9.15,9.05) GHz for each iteration. These filters have been designed using a substrate with a dielectric constant of 10.8 and thickness of 1.27mm.The performance of filter structures, based on resonators has been evaluated using a full-wave based electromagnetic simulator Sonnet software package. Performance simulation results show that these filter structures are compact in addition to good frequency responses and narrow bands gained .**

***Keywords**: Dual band dual mode filter, fractal filter, microwave bandpass filter, filter miniaturization, Sierpinski carpet fractal geometry.*

## I. INTRODUCTION

Compact microstrip narrow bandpass filters are preferred increasingly in recently wireless communication systems because of their low profile and high selectivity [1,2].

Dual-mode resonators have highly desirable features for the bandpass (BPF) design, such as size miniaturization, low radiation loss and ease of design because transmission-line theory and design tools can easily be implemented.

The dual-mode microstrip filters are very important in miniaturization techniques due to their high gained performance and it can be used as a double circuit in single structure as compared to single mode bandpass filter designs when two degenerate modes are coupled to each other by suitable perturbation excitation [3, 4].

Fractal geometries unlike Euclidean geometries have two unique properties: space-filling and self-similarity. These geometries, such as Koch curve, Cantor, Hilbert curve, etc., have been widely used in wide variety of RF and microwave applications especially in designing miniaturized fractal antennas and filters [1,4]. The fractal-shaped devices have spectacular advantages including compactness, narrow band or wide band, multi-band operation and high order harmonics suppression [4,5,6,7].

In this paper, new dual band dual-mode microstrip slotted patch bandpass filter designs for modern wireless communication systems, have been presented. Filter structures are generated using Sierpinski carpet fractal geometry applied to the conventional microstrip square patch filter. The resulting filter structures offer dual narrow bands with adequate chebychev frequency responses.

## II. THE PROPOSED FRACTAL SCHEME

The starting pattern for the presented bandpass filter as a fractal is a square patch with a side length L and the inserted slotted structures are based on Sierpinski carpet. This fractal geometry, Fig.1, is a deterministic fractal which is a generalization of the Cantor set into two dimensions. The Sierpinski carpet is constructed analogously to the Sierpinski gasket, but it uses squares instead of triangles. In order to start this type of fractal curve, it begins with a square in the plane, and then divided it into nine smaller congruent squares where the open central square is dropped out. The remaining eight squares are divided into nine smaller congruent squares with, again, each central is dropped out [8,9]. The process can be

978-0-7695-4941-5/13 $26.00 © 2013 IEEE
DOI 10.1109/ACCT.2013.55

continued infinitely until obtaining a limiting configuration which can be seen as a generalization of the Cantor set.

The dimension of a fractal provides a description of how much it efficiently fills a space. It is a measure of the prominence of the irregularities when viewed at very small scales [10,11].

A dimension contains much information about the geometrical properties of a fractal. From the property of self-similarity, the fractal dimension $D$ is defined as [10]:

$$D = \frac{\log(N)}{\log(1/r)} \qquad (1)$$

where $N$ is the total number of distinct copies and $1/r$ is the scale ratio. To find the dimension of the Sierpinski fractal curve, using (1), where $N = 8$ segments and $r = 1/3$, then the fractal dimension is $D = 1.892$ .

The ideal fractal structure is obtained by iterating infinite number of times. However, it has been found, practically, that the number of generating iterations is only few before the additional complexities become unrecognized [12].

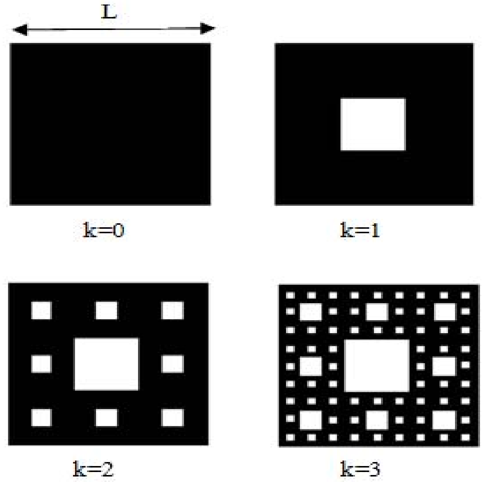

Fig. 1. The generation process of the Sierpinski fractal geometry from $0^{th}$ to $3^{rd}$ iteration levels

## III. DUAL BAND DUAL MODE FILTER DESIGN

From $0^{th}$ to $2^{nd}$ iteration dual-mode microstrip patch bandpass filter structures have been designed with dual narrow bands. It has been supposed that, these filter structures have been etched using a substrate with a dielectric constant of 10.8 , thickness of 1.27 mm and loss tangent of 0.0005 . Two 50 ohm feed lines as input and output (I/O) ports are placed in paralleled manner .The resonator is excited by using a edge spacing coupling method to I/O ports. The strip width values of I/O feeders are 0.4 mm ,0.6 mm and 0.6 mm for each iteration respectively while the edge space value is 0.4 mm for all iterations. For each iteration, the side length of the square patch resonator , L = 9 mm , has been determined as:

$$L = 0.4\lambda_g \qquad (2)$$

where

$$\lambda_g = \frac{c}{f\sqrt{\varepsilon_{eff}}} \qquad (3)$$

is the guided wavelength, , $c$ is the speed of light and $\varepsilon_{eff}$ is effective dielectric constant, $\varepsilon_{eff} = (\varepsilon_r + 1)/2$ [13,14].

The dual-mode bandpass filter response can be obtained via the excitation of the two degenerate modes by I/O feeders and setting the coupling between the two modes by suitable form of perturbation effect within the resonators[15].

The fractal shape of the proposed patch resonator acts as some perturbation effects to the symmetry of the structure, therefore the field distributions of the degenerate mode will be no longer orthogonal, and they are coupled to each other [15].On the other hand, the dimensions of the perturbations represented by existing square slots of adopted Sierpinski fractal scheme affect the strength of the coupling between the two degenerate modes of the dual-mode for designed filters .

## IV. PERFORMANCE EVALUATION

A dual-mode filter structure based on the conventional square patch resonator, and two filter structures based on resonators having the shapes of the $1^{st}$ and $2^{nd}$ iterations have been modeled and analyzed using a full-wave based electromagnetic simulator from Sonnet Software Inc. [16].This simulator performs electromagnetic analysis using a modified approach of method of moments (MoM). These filter structures are shown in Figs.(2,4,6) respectively. The corresponding simulation results of return loss and transmission responses of these filters are shown in Figs.(3,5,7) respectively. TABLE I and TABLE II show the important performance parameters of the modeled filters.It is implied from these figures and tables that the modeled bandpass filters offer two narrow band with adequate performance curves where first band have noticeable narrower bandwidth as compared with $2^{nd}$ band for all iterations. As can be seen, all of the filter responses are in chebychev case.

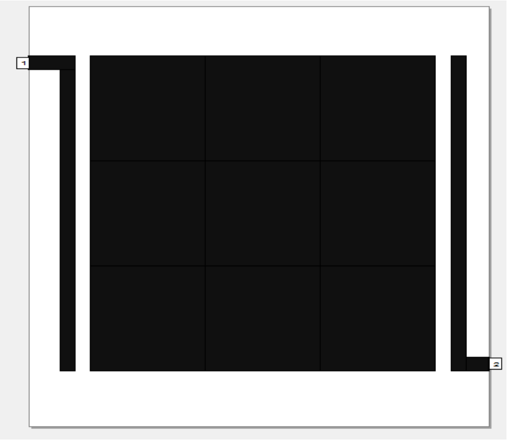

Fig. 2. The layout of the modeled conventional dual-mode square patch microstrip resonator

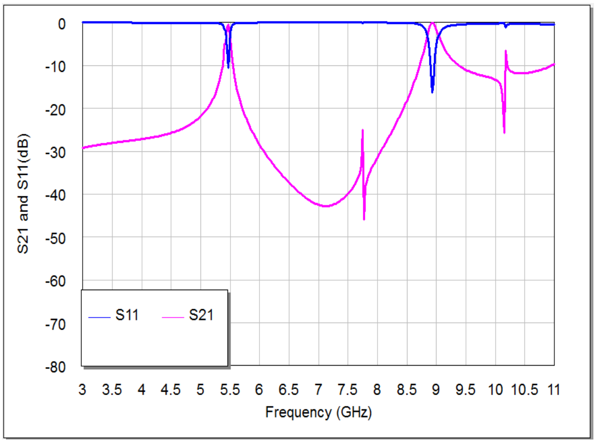

Fig. 3. Return loss, S$_{11}$, and transmission, S$_{21}$, responses for the conventional square patch microstrip bandpass filter shown in Fig. 2

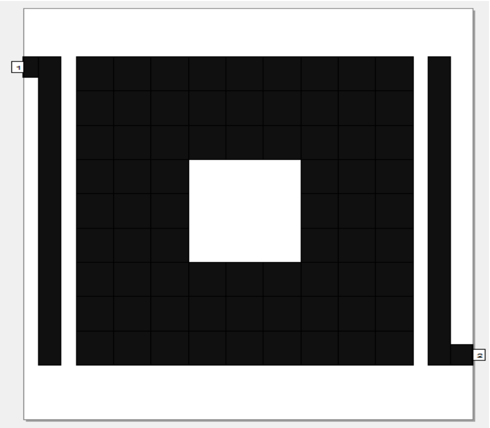

Fig. 4. The layout of the modeled 1st iteration dual-mode Sierpinski patch microstrip resonator

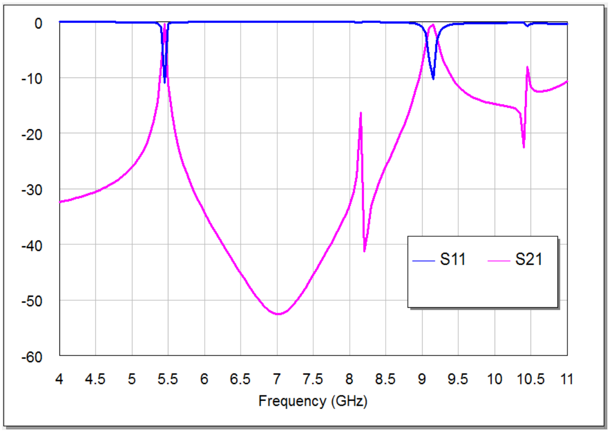

Fig. 5. Return loss, S$_{11}$, and transmission, S$_{21}$, responses for Sierpinski patch microstrip resonator filter shown in Fig. 4

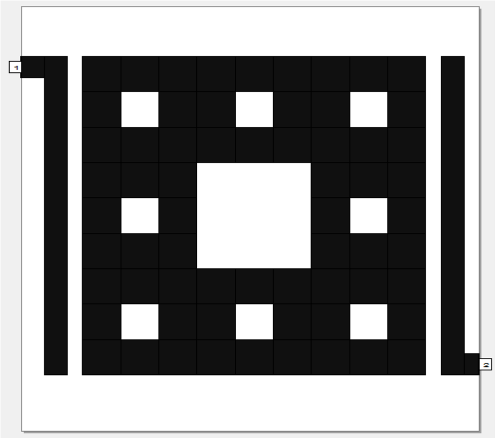

Fig. 6. The layout of the modeled 2nd iteration dual-mode Sierpinski patch microstrip resonator

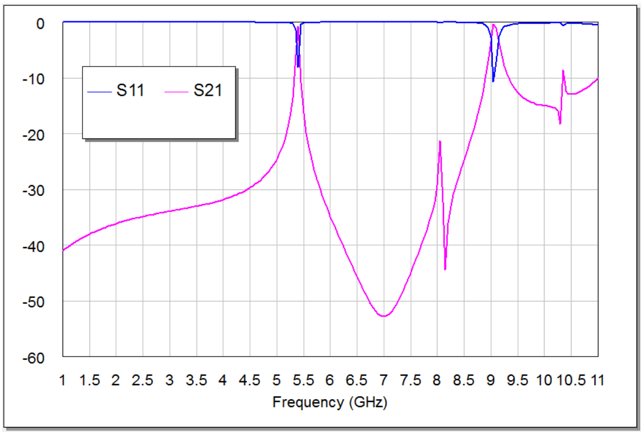

Fig. 7. Return loss, S$_{11}$, and transmission, S$_{21}$, responses for the 2nd iteration Sierpinski patch microstrip resonator filter shown in Fig. 6

TABLE I. SUMMARY OF THE SIMULATED PARAMETERS OF THE MODELED FILTERS FOR FIRST BAND

| Type<br>Parameter | K=0 | K=1 | K=2 |
|---|---|---|---|
| Return Loss (dB),S11 | -10.515 | -10.927 | -8.0026 |
| Insertion Loss (dB),S21$^0$ | -0.4039 | -0.3687 | -0.74892 |
| Center Frequency, GHz | 5.475 | 5.45 | 5.4 |
| Actual Bandwidth (-3dB) | 70 MHz | 50 MHz | 70 MHz |

TABLE II. SUMMARY OF THE SIMULATED PARAMETERS OF THE MODELED FILTERS FOR 2nd BAND

| Type / Parameter | K=0 | K=1 | K=2 |
|---|---|---|---|
| Return Loss (dB),S11 | -10.4 | -10.23 | -10.701 |
| Insertion Loss (dB),S21$^{0}$ | -0.13 | -0.43276 | -0.38627 |
| Center Frequency, GHz | 8.925 | 9.15 | 9.05 |
| Actual Bandwidth (-3dB) | 190 MHz | 140MHz | 140 MHz |

The use of square slotting principle in 1st and 2nd iteration reduces their fundamental frequency for first bands as compared to 0th iteration. This is due to the application of surface square cuts which increase the current path length, produce a decrease or shifting in the resonance frequency without changing the external dimensions.

Figs.(8-10) show some simulated samples of current density patterns using the EM simulator for the dual band dual-mode microstrip bandpass filter, based on the 2nd iteration Sierpinski fractal curve at operating frequency of 5.4 GHz , 9.05 GHz and 9.5 GHz . It is clear from these figures that only at the band frequencies (5.4 GHz and 9.05 GHz ) , the two degenerate modes are induced and coupled to each other with highest current distribution that verify dual mode property, while at 9.5 GHz , no degenerate modes are excited and lower current distribution values can been seen clearly.

The previous filter size designs can be changed to other frequencies required for other wireless communication systems by scaling estimation during modeling according to frequency requirements of the specified applications.

## V. CONCLUSION

In this paper, new dual band dual-mode microstrip Sierpinski bandpass filters with narrow band chebychev responses have been presented as a new technique for modern wireless communication systems. In this technique, filter structures have been generated from 0 to 2nd iterations of Sierpinski carpet fractal geometry and using the conventional dual-mode square patch resonator as an initiator.

The modeling and performance of proposed filters have been evaluated using a full-wave based electromagnetic sonnet simulator with a dielectric constant of 10.8 and thickness of 1.27mm.

The proposed technique can be used as a design tool for developing multiband compact microstrip bandpass filters especially for satellite communication systems.

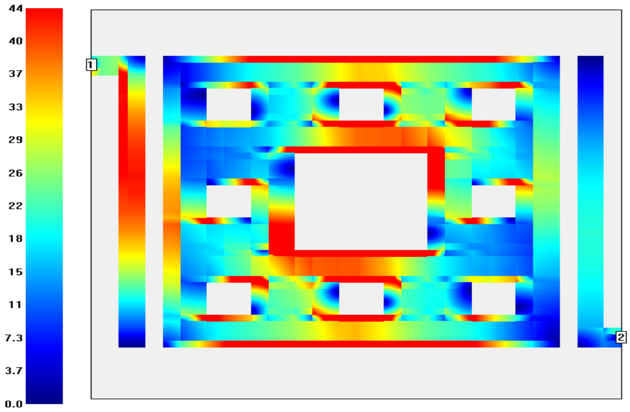

Fig. 8. Current density distribution at the conducting surface of the 2nd iteration Sierpinski BPF simulated at a resonant frequency of 5.4GHz

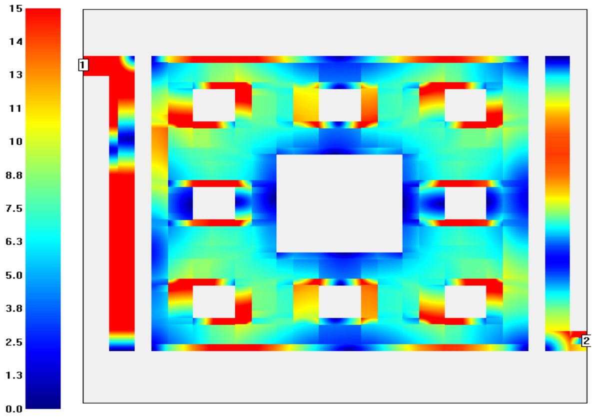

Fig. 9. Current density distribution at the conducting surface of the 2nd iteration Sierpinski BPF simulated at a resonant frequency of 9.05 GHz

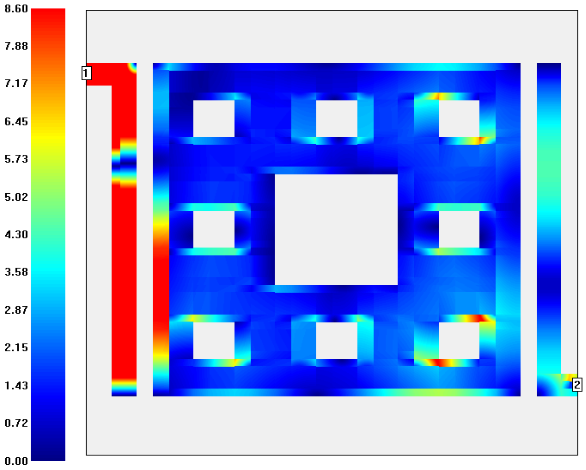

Fig. 10. Current density distribution at the conducting surface of the 2nd iteration Sierpinski BPF simulated at a resonant frequency of 9.5 GHz

ACKNOWLEDGMENT

This work is supported by the Scientific and Technological Research Council of Turkey (TUBITAK) for PhD Research Fellowship for Foreign Citizens Program under Fund Reference (B.14.2.TBT.0.06.01.03-215.01-24962) .

## REFERENCES

[1] Y.S. Mezaal, "A New Microstrip Bandpass Filter Design Based on Hilbert Fractal Geometry for Modern Wireless Communication Applications", *International Journal on advanced Computing Techniques, IJACT*, vol.1, no.2, pp.36-39, 2009.

[2] J.K. Xiao, Q.X. Chu, and H.-F. Huang, "Triangular Resonator Bandpass Filter with Tunable Operation," *Prog. in Electromag. Res., PIER,* vol. 2, pp.167–176, 2008.

[3] J.S. Hong, and M. J. Lancaster, "Recent Advances in Microstrip Filters for Communications and Other Applications," *In IEEE Colloquium on Advances in Passive Microwave Components*, London, May 1997.

[4] H. Liu, T. Fu, Y. Yang, and X. Li, "Miniaturized Dual Mode Filter Using Fractal Slot and Snaky Shape Spur Line", *J. of Electromagn. Waves and Appl., Vol. 22, 1775–1782, 2008.*

[5] I.K. Kim, et. al, "Koch Fractal Shape Microstrip Bandpass Filters on High Resistivity Silicon for the Suppression of the 2nd Harmonic," *Journal of the Korean Electromagnetic Engineering Society, JKEES*, vol. 6, no. 4, pp. 1-10, Dec. 2006.

[6] J.K. Xiao, and Q.X. Chu, "Novel Microstrip Triangular Resonator Bandpass Filter with Transmission Zeros and Wide Bands Using Fractal-Shaped Defection," *Prog. in Electromag. Res., PIER,* vol. 77, pp. 343-356, 2007.

[7] G.L. Wu, W. Mu, X. W. Dai, and Y. C. Jiao, "Design of Novel Dual-Band Bandpass Filter with Microstrip Meander-Loop Resonator and CSRR DGS," *Prog. in Electromag. Res., PIER*, vol. 78, pp. 17-24, 2008.

[8] D.H. Werner, and S. Gangul, "An Overview' of Fractal Antenna Engineering Research," *IEEE Antennas and Propagation Magazine*, vol. 45, no, 1, Feb. 2003.

[9] N.A. Saidatul, A.A.H. Azremi, R.P. Ahmad, P.J. Soh, and F. Malik, "A Development of Fractal PIFA (Planar Inverted F Antenna) with Bandwidth Enhancement for Mobile Phone Applications," 2009 Loughborough Antenna and Propagation Conference, Loughborough, UK, Nov. 16-17, 2009.

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

[11] H. Peitgen, H. Jürgens, and D. Saupe, *Chaos and Fractals*, New Frontiers of Science, 2nd Edition, Springer-Verlag , New York, 2004.

[12] J.K. Ali, and N.N. Husain, "A New Fractal Microstrip Bandpass Filter Design Based on Dual-Mode Square Ring Resonator for Wireless Communication Systems", *Iraqi Journal of Applied Physics, IJAP*, vol.5, no.1, pp.7-12, 2009.

[13] Rodney B. Waterhouse, Microstrip Patch Antennas: A Designer's Guide*,* Kluwer Academic Publishers, 2003.

[14] J.S. Hong, and M.J. Lancaster, *Microstrip Filters for RF/Microwave Application*, New York, Wiley, 2001.

[15] E.S. Ahmed, "Dual-Mode Dual-Band Microstrip Bandpass FilterBased on Fourth Iteration T-Square Fractal and Shorting Pin", radio engineering journal,vol.1 , no.2, June 2012.

[16] *Sonnet User's Guide, Release 11*, Sonnet Software Inc., North Syracuse, NY, March, 2007.