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Research Article

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Design of Compact Monopole Antenna for Wireless Applications

Srivatsun G *, Sapna BA and Anushya

Abstract

There is a need for compact electronic equipment's for which the size of antenna needs to be miniaturized. For obtaining miniaturization and wide bandwidth characteristics multi fractal contours are proposed. Fractal structure has two different properties such as space filling and self-similarity. By using iteration procedure fractal structures are designed. The proposed antenna is centered at 2.4 GHz desirable for many wireless applications.

Keywords: Dual mode; Fractal; Monopole antenna; Parallel stubs; Octagonal patch resonator; Wireless applications

Introduction

The tremendous increase in portable wireless communication device requirements are increasing day by day for which the size of the antenna need to be miniaturized. For that, small size antenna is required. Antenna miniaturization is a difficult task because size of the antenna depends on bandwidth and gain. In an octagonal patch resonator, different fractal structures are introduced to achieve wideband and compact size. Miniaturization is achieved in the design by using two open ended parallel stubs [1].

Fractal structures are more in nature. Best example is branches in trees. The fractal structures namely Sierpinski carpet, Giuseppe Peano, Minkowski, Koch are deployed in the octagonal patch for the design of fractal antennas [2]. Fractals have many applications in engineering field. Branches such as forest sciences, geology, physiology and wireless communication. Due to the properties of fractal geometries, the design has several applications. It is mainly used to reduce the memory space and speed for finite element analysis of vibration problems. It improves input matching ability and multiband/wideband characteristics. In addition to this, metamaterial transmission lines are also used for many practical applications. By using metamaterial transmission line, the size of the antenna is further reduced [3].

The proposed work is the design of compact monopole antenna with the attractive octagonal patch resonator with square perturbation in the diagonal. Using square perturbation, dual mode response is achieved. The simulation results are taken in this paper are carried out using Advanced Design System (ADS) 2015.01 with the resonant frequency of 2.4 GHz and by using different fractal structures wideband characteristics is also achieved [4].

Problem Statement

The tremendous growth in the wireless communication systems and services has imposed additional requirements on the related antennas to be miniaturized and multiband. In conventional antenna, increasing the order of the filter leads to improvement in selectivity and reduction in insertion loss but it increases the size of the antenna by increasing the number of resonators. In the proposed design, by using metamaterial transmission line and fractal structures miniaturization of the antenna is achieved. Since it provides multiband, it is used for many wireless applications [5].

Antenna design

The compact monopole antenna was designed using Advanced Design System (ADS) tool with resonant frequency of 2.4 GHz. The below Table 1 shows the specification for the design [6].

Table 1: Design specifications of monopole antenna.

Requirements	Value
Substrate	RT/Duroid 6010
Dielectric constant	10.2
Thickness of substrate	1.27 mm
Loss tangent	0.0023
Resonant frequency	2.4 GHz
Simulation tool	ADS 2015.01

The antenna design is done by using iteration procedure. First, the octagonal patch resonator is designed and obtained the results. After that, different fractal structures are introduced in the patch. Therefore, the geometry of the octagonal patch resonator with two parallel stubs is shown in Figure 1. In order to achieve dual mode response, square perturbation is used in the diagonal of the patch with the dimension 2.1 × 2.1 mm. The side length (a) of the patch is considered to be 6.88 mm. The gap between the different iterations is 0.2 mm. In this paper, two fractal structures are designed namely Sierpinski carpet and

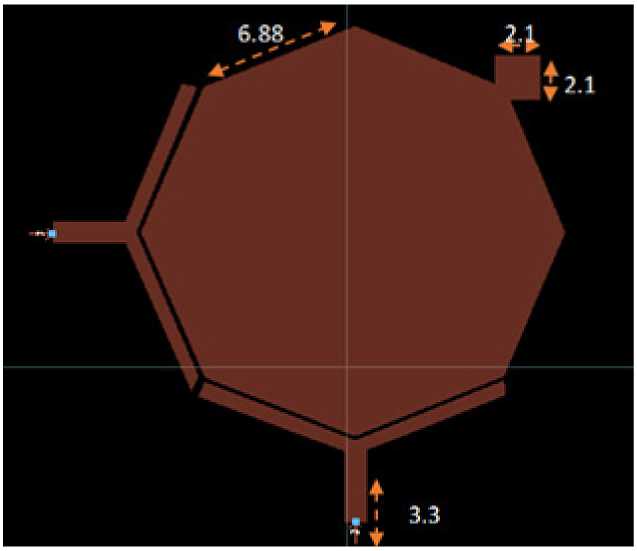

Figure 1: Dual mode configuration of octagonal patch resonator.

***Corresponding author:** Srivatsun G, Associate Professor, Department of Electronics and Communications Engineering, PSG College of Technology, Coimbatore, India, E-mail id: gsn.ece@psgtech.ac.in

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Giuseppe Piano. The simulated response gives the better return loss and wide bandwidth [7].

The wavelength of the octagonal patch resonator is found to by using equation (1).

$$\lambda_g = \frac{300mm}{f_0(GHz)\sqrt{\varepsilon_{eff}}}$$

Where Ɛeff is the effective permittivity and λg is the guided wavelength. For the patch, wavelength is found to be 52.8 mm at the resonant frequency of 2.4 GHz. The area of the octagonal patch if found by using the following equation (2).

$$A_n = \left(\frac{0.56}{2}\right)^n \times 2a^2(1+\sqrt{2}), n \geq 0$$

Where A is the side length, n is the number of iterations, *An* is the area of the octagonal patch. The length and width of the slot in each iteration is obtained by using equation 3 and equation 4

$$l_n = \frac{0.56}{(4)^{n-1}} \times L, n \geq 1$$

$$W_n = \frac{0.22}{(4)^{n-1}} \times L, n \geq 1$$

The gap between the patch and stub is found to be 0.2 mm and distance between the two stubs is 0.284 mm.

Figure 2 represents the simulation results of dual mode response with the resonant frequency of 2.4 GHz. Here the return loss is found to be -17.267 dB and bandwidth of 110 MHz observed at -10 dB on both sides. Here, -10 dB represents 90% of the power is obtained in the output only 10% will be loss [8].

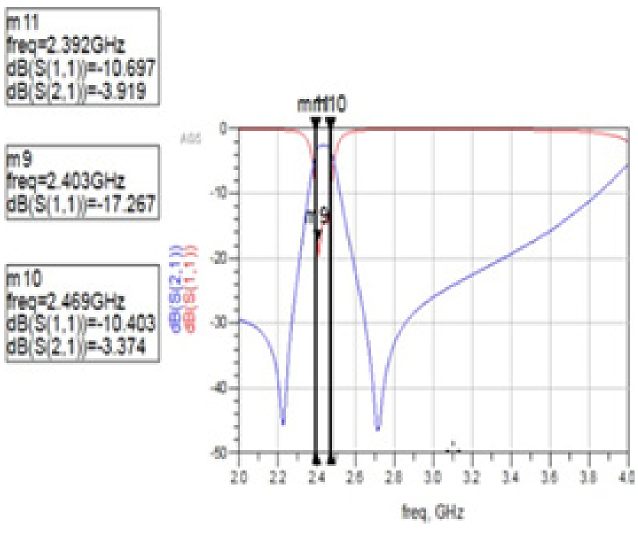

Figure 2: Simulation results of dual mode response.

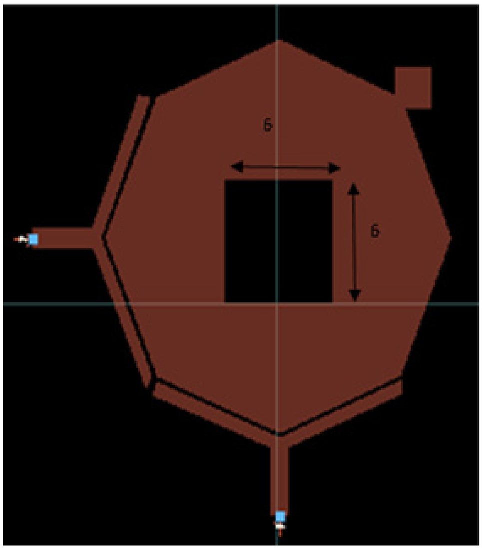

Figure 3: Initial structure of Sierpinski carpet.

Sierpinski Carpet Structure

The Sierpinski carpet is constructed from Sierpinski sieve. Two iterations are done in this paper. Figure 3 represents the initial structure of Sierpinski carpet. Here the square dimension is 6 × 6 mm and Figure 4. represents the first iterated structure of Sierpinski carpet with dimension of 3 × 3 mm. Here, substrate used design is RT/duroid with relative permittivity of 10.2, thickness of 1.27 mm and loss tangent of 0.0023. The design gives better return loss, insertion loss and bandwidth [9].

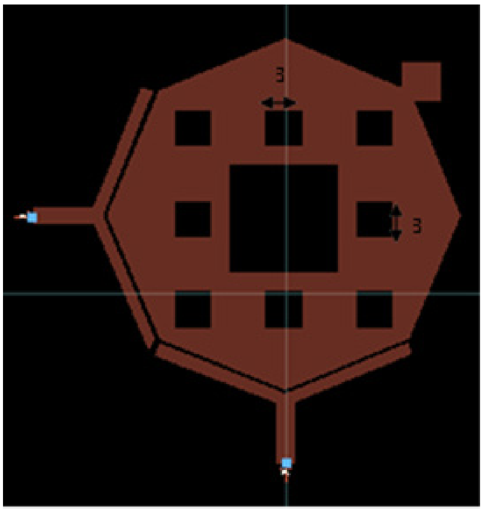

Figure 4: First iterated structure of Sierpinski carpet.

Figure 5 represents the comparison results of initial and first iteration. It gives better return loss, insertion loss and bandwidth. Further iteration is not possible because of the area constraints of the octagonal patch. So, Giuseppe Peano fractal structure is designed. In that three iterations are done. In each iteration, there is an improvement of return loss and reduced insertion loss is achieved. In addition to that wideband is also is achieved [10].

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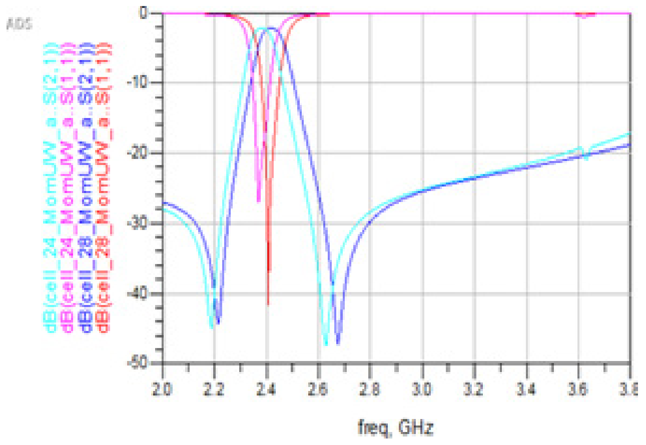

Figure 5: Comparison graph of initial and first iteration.

Table 2 represents the comparison results of Sierpinski carpet. Here, the first column represents number of iterations, second column represents the return loss obtained in two iterations, third column represents the insertion loss and last column represents the bandwidth obtained in the design. Here, there is better return loss, reduced insertion loss but there is no improvement in the bandwidth [11].

Table 2: Comparison result of Sierpinski carpet.

Iteration (n)	Return loss (dB)	Insertion loss (dB)	Bandwidth (MHz)
K0	-15.119	-2.437	650
K1	-39.544	-2.282	650

Giuseppe Peano Structure

Giuseppe Peano fractal structure is more popular fractal since it has many applications in wireless communication. In this paper initial iteration and furthermore two iterations are done to achieve more miniaturization and wideband characteristics.

Figure 6 represents the initial iteration of Giuseppe Peano with dimension of the slot is 4 × 4 mm. The initial structure itself gives better return loss and bandwidth. The following table represents the simulated results of initial iterated structure of Giuseppe Peano. The octagonal patch dimensions are same as that of dual mode configuration. Further two iterations also give better simulated results compared to Sierpinski carpet [12].

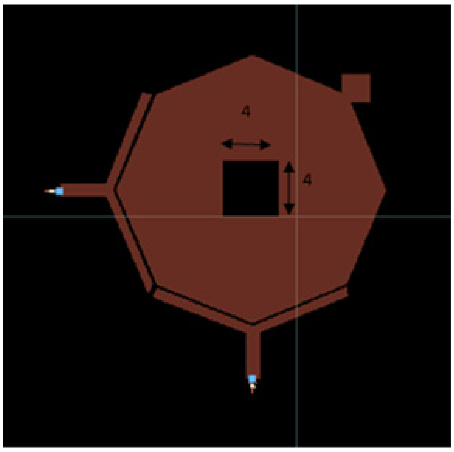

Figure 6: Initial structure of Giuseppe Peano.

Figure 7 represents the first iterated structure of Giuseppe Peano whose dimensions are mentioned in the Figure 6. It gives better results compared to initial structure. Figure 8 represents the second iterated structure of Giuseppe Peano structure. Further iterations are also possible in an octagonal patch. This iteration has better bandwidth compared to two iterations. The following graph represents the comparison results of initial structure, first iteration and second iteration [13].

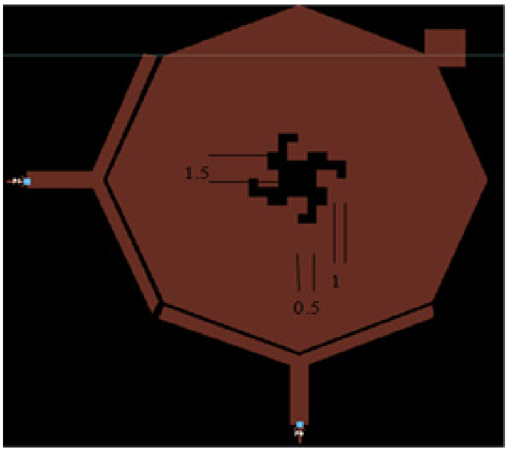

Figure 7: Design of first iterated Giuseppe Peano structure.

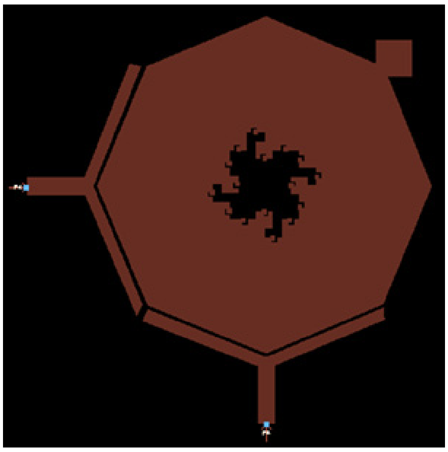

Figure 8: Design of second iterated Giuseppe Peano structure.

Figure 9 represents the comparison graph of initial, first and second iterations of Giuseppe Peano structure. Comparison results are tabled below.

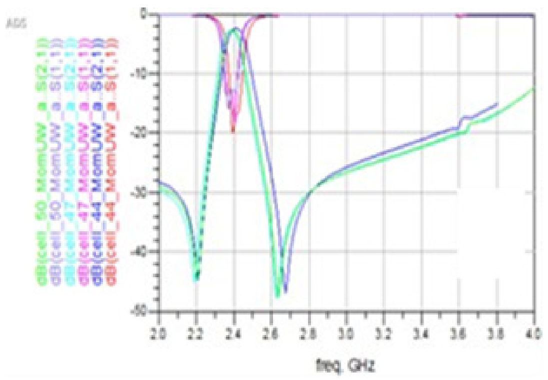

Figure 9: Comparison graph of three iterations.

Table 3 represents the comparison result of Giuseppe Peano structure. Here returns loss is better compared to Sierpinski carpet but in Sierpinski carpet there is no improvement in the bandwidth but in Giuseppe Peano, both bandwidth and return loss are improved. Therefore, simulated results are more efficient in Giuseppe Peano structure than Sierpinski carpet [14].

Table 3: Comparison result of Giuseppe Peano.

Iteration (n)	Return loss (dB)	Bandwidh (MHz)
K0	-18.556	710
K1	-12.908	660
K2	-17.619	730

Results and Discussion

Table 4 represents the comparison results between Sierpinski carpet and Giuseppe Peano structure. Compared to Sierpinski carpet, bandwidth of Giuseppe Peano is better. Return loss is optimum in both the structures [15].

Table 4: Comparison between Sierpinski carpet and Giuseppe Peano structure.

Name of the Pattern	Iteration (n)	Return loss (dB)	Bandwidh (MHz)
Sierpinski carpet	K0	-15.119	650
	K1	-39.544	650
Giuseppe Peano	K0	-18.556	710
	K1	-12.908	660
	K2	-17.619	730

Conclusion

A compact monopole antenna using different fractal slots on an octagonal patch centered at 2.4 GHz is designed and realized. The dual mode response is obtained by varying the size of the square perturbation at the diagonal corner of the patch. Sierpinski carpet, Giuseppe Peano slots are realized. The measured antenna parameters such as return loss, insertion loss and bandwidth. The parameters of different slots are realized using iteration procedure. The maximum number of iterations is 3. The simulation and measurement results demonstrate that the dual mode fractal filter offers good performance in terms of low insertion loss, better return loss, high selectivity and ease of design. The compactness in circuit size makes the proposed design suitable for wireless applications in wireless LAN systems covering the 2.4 GHz range for the channels of IEEE 802.11 b/g/n.

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Author Affiliations

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Department of Electronics and Communications Engineering, PSG College of Technology, Coimbatore, India