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Multiband E-Shaped Fractal Microstrip Patch Antenna with DGS for Wireless Applications

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***Abstract*—In this paper multiband E-Shaped fractal patch antenna with DGS (Defected Ground Structure) has been proposed. By applying the concept of fractal geometry on rectangular patch, self-similar E-Shaped structure has been obtained. Also, by using FR-4 epoxy (Fire Retardant-4) as substrate antenna resonates at 3.7 GHz, 6.7 GHz, 7.9 GHz and 8.7 GHz respectively with bandwidth 120 MHz, 495 MHz, 225 MHz and 315 MHz at corresponding frequencies. By inserting DGS in the proposed antenna the various parameters have been improved such as return loss, bandwidth and gain. Designing and simulation of this antenna has been done by the help of IE3D Software. The application of this antenna is to make it compatible with Satellite, Wi-Fi (Wireless Fidelity), Bluetooth, Cellular Phones and Radar etc.**

Keywords: Fractal; E-Shape; DGS

I. INTRODUCTION

An antenna is an electric device which converts electric power in to radio waves, and vice versa. It is usually used with a radio transmitter or radio receiver. Antenna miniaturization is an important task in achieving an optimal design for wireless communication. Fractal geometry is used to reduce the size of patch antenna. Fractal geometries are different from Euclidean geometries which have two common properties: space-filling and self-similarity. It has been shown that the self-similarity properties of the fractal shapes can be successfully applied to the design of multiband fractal microstrip patch antennas. There are a number of fractal shapes like Sipernski Gasket, Minkowski, Hilbert Curve and Koch Curve, Fractal Arrays. Further it is analyzed that after a few iteration gain, bandwidth and other factors begin to decrease. A microstrip antenna consists of a metallic pattern on one side of a dielectric substrate and ground plane on the other side of the substrate. Microstrip antenna has disadvantages like low return loss, less bandwidth and low gain. So as to improve characteristics, fractal geometry has been applied. There are different feeding methods like microstrip line feed, probe feed to patch, inset feed and CPW (Coplanar Waveguide). In this paper coaxial feed has been given. Another method to improve antenna performance is by using defected ground structure. Defected ground structure is realized by etching a simple shape or defect from the ground plane. Depending on the shape and dimensions of the defect, the shielded current distribution in ground plane is distributed, resulting in a controlled excitation and propagation of the electromagnetic waves through the substrate layer. The shape of the defect may be changed from a simple shape to a complicated one for a better performance. In this paper by using fractal geometry algorithm E-Shaped microstrip patch antenna has been proposed. Results have been obtained by applying two iterations one by one in IE3D software. Also by introducing DGS in the same patch geometry much better results are obtained.

II. LITERATURE SURVEY

The design of E-Shape microstrip patch antenna for wireless communication has been represented and also been observed that position of feed point had a serious effect on the performance [1]. The proposed antenna had circular polarization at one of its resonance frequencies, which was realized by producing a perturbation on its initial structure. Further miniaturization of antenna might be obtained by cutting slots on its structure given in [2]. A novel type of miniature frequency selective surface (FSS) with good frequency selectivity based on fractal antenna-filter-antenna (AFA) array was presented. The AFA-based FSSs exhibited superior frequency selectivity and had lower profile than conventional FSSs as in [3]. The impedance matrix for the multiport network model of this antenna was simplified exploiting self-similarity of the geometry with greater accuracy and reduced analysis time. Dual frequency operation was achieved by suitably choosing the indentation of this fractal geometry [4]. A novel fractal patterned iris loaded cross dipole slot antenna along the broad wall of a rectangular waveguide at X-band was proposed with wideband operation. Symmetry in both the azimuth and the elevation pattern had been achieved with combined fractal slot and iris [5]. A novel compact multiband fractal printed antenna had been proposed with simulated and experimental results. Various iterations of this fractal antenna were compared, and an optimized design was presented [6]. A novel study on the modified broadband stacked patch antenna with different DGS structure had been carried out in detail. The soft nature of the DGS facilitated improvement in the performance of microstrip antenna [7]. A wide band and Wang-shaped patch antenna with low cross polarization was presented in this letter [8]. The antenna could serve simultaneously most of the modern wireless communication standards. This wideband antenna was a good candidate for multi standard wireless communication [8]. A low profile and compact wideband E-Shaped patch antenna was

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proposed. By introducing a distributed LC circuit on the backside of the conventional E-Shaped patch antenna, a new resonant frequency close to that of a conventional E-Shaped patch was obtained to produce a wideband frequency response [9, 10]. By etching the wide slot as fractal shapes, it was experimentally found that the operating bandwidth could be significantly enhanced, and the iteration order and iteration factor of the fractal shapes were experimentally studied [11]. A novel technique to reduce the size of microstrip patch antenna was proposed. It was experimentally found that the resonant frequency of the patch could be greatly lowered, and the higher the iteration order of the fractal shapes, the lower the resonant frequency become. And this property could be utilized to reduce the size of microstrip patch antennas [12]. Several properties of the antenna such as impedance, bandwidth and frequency notched characteristics, radiation patterns, gain had been investigated numerically and experimentally in detail [13].

III. ANTENNA DESIGN

Size reduction is one of the vital advantages of fractal antenna. Minkowski fractal geometry algorithm [4] is used as shown in figure 1.

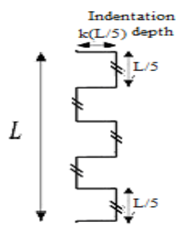

Figure 1. Minkowski Fractal Geometry [4]

Minkowski algorithm has been applied to the rectangle as shown in figure 2. By dividing length into 5 parts and removing two squares from right side of the patch, this E-Shape patch is formed. By applying further iterations self-similar structures can be made. Initially rectangle patch is taken having dimensions of 20mm by 25mm using FR-4 as substrate of thickness 2.0 mm as shown in table 1. By applying different iterations of fractal geometry self-similar structures as shown in figure 2, 3, 4 and 5 are obtained.

TABLE I. ANTENNA DIMENSIONS

Parameter	Value
Length of patch	20 mm
Width of patch	25 mm
Thickness of Substrate	2 mm
Dielectric constant of substrate	4.4
Loss tangent of substrate	0.02
Feed to Patch	Coaxial Feed

The rectangular patch having dimension 20 mm by 25 mm is taken as shown in figure 2 and coaxial feed has been given. Feed point has been chosen in such a way that impedance matching take place at that point.

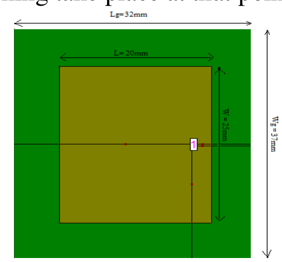

Figure 2. Basic Rectangle Geometry

Now E-Shape patch as shown in figure 3 can be obtained by using concept of fractal geometry. Vertical length of 25 mm is divided into 5 parts, each of length 5 mm. Square cuts of 5 mm length to right sides of the rectangle shown in figure 1 are made to make E-Shape.

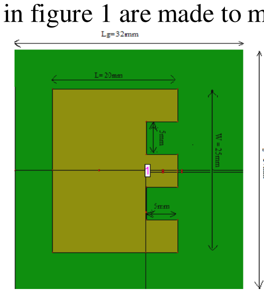

Figure 3. First Iteration on Rectangle Geometry

Now in the same way, same fractal algorithm is applied to opposite side of first iteration to obtain double E-Shape fractal antenna which is shown in figure 4.

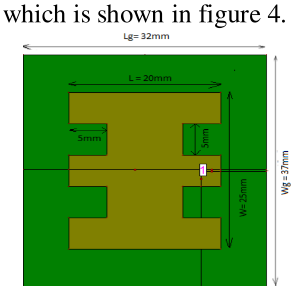

Figure 4. Second Iteration on Rectangle Geometry

Similarly, same algorithm is applied to obtain the next iteration. Two squares of 1 mm on the remaining three parts of the both side patch are removed. Feed point is being taken as x= -8, y= 0 and z=0. The result so obtained is self-similar shape as shown in figure 3. From figure 5, it is obvious that the shape repeats itself.

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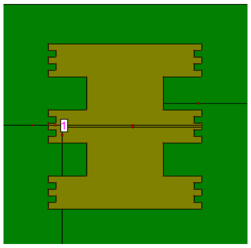

Figure 5. Third Iteration on Rectangle Geometry

By applying fractal algorithm on basic rectangular patch, a fractal structure of E-Shaped microstrip patch antenna has been obtained as shown in figure 5. Fractal geometry provides multiband characteristics and after applying defected ground structure, multiband characteristics together with good bandwidth will be achieved. In this paper T-shaped DGS has been used. This DGS has been applied on ground of the proposed antenna structure shown in figure 5.

IV. Results And Discussions

A. *Results by using FR-4 as Substrate*

Fractal geometry consists of self-similar structures. Generally the utilization of fractal geometries in antenna tends to miniaturize their physical sizes and produce multiband response in their resonating characteristics. FR-4 has been used as substrate with a thickness 2 mm. By taking rectangle patch dimension of 20 mm by 25 mm antenna resonates at 3.4 GHz, 5.5 GHz, 6.8 GHz and 9 GHz with return loss of -13.74 dB,-15.15 dB, -12.63 dB and -11.46 dB gain of 3.82 dBi, 2.91 dBi, -0.74 dBi and -3.55 dBi, directivity of 6.82 dBi, 7.44 dBi, 6.24 dBi and 6.04 dBi and at last bandwidth of 135 MHz, 180 MHz, 240 MHz and 75 MHz respectively. Different iterations of fractal geometries have been applied one by one on rectangle patch and results are analyzed as shown in table 2. Figure 6 shows return loss Vs frequency graph for different fractal iterations.

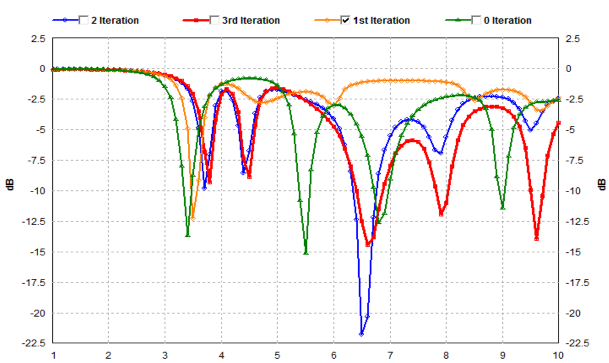

Figure 6. Return Loss Vs Frequency for different Fractal Iterations

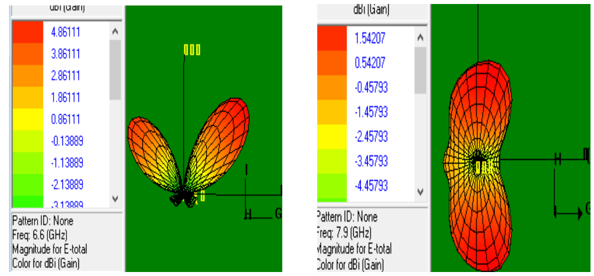

Figure 7. (a) Radiation pattern at 6.6 GHz (b) Radiation pattern at 7.9 GHz

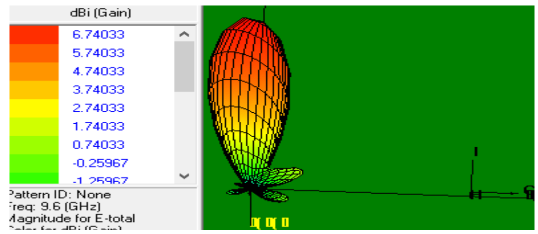

Figure 8. Radiation pattern at 9.6 GHz

In first iteration, two squares of length 5 mm have been cut to form E-Shape patch as shown in figure 2. This cause antenna to resonates at 3.5 GHz with -12.28 dB return loss, 3.82 dBi gain, 6.9 dBi directivity and 90 MHz bandwidth. In the 2nd iteration of E-Shape patch, two squares of length 5 mm have been cut out from the left side to the E-Shape patch as shown in figure 4. Antenna resonates at 6.5 GHz with -21.76 dB return loss, 4.90 dBi gain, 8.34 dBi directivity and 420 MHz bandwidth. In the 3rd iteration of E-Shape patch, squares of 1mm are cut out from the remaining three one fifth length as shown in figure 5. Antenna thus formed will resonate at 6.6 GHz, 7.9 GHz and 9.6 GHz with return loss of -14.49 dB, -11.97 dB and -13.97 dB, gain of 4.86 dBi, 1.54 dBi and 6.74 dBi, bandwidth of 465 MHz,195 MHz and 195 MHz and directivity of 8.42 dBi, 6.46 dBi and 10.87 dBi respectively. Radiation pattern of antenna resonant frequency 6.6 GHz, 7.9 GHz and 9.6 GHz are shown in figure 7 and 8.

TABLE II. Comparison Table of Different Iterations

Iteration number	Resonant Frequency (GHz)	Return Loss (dB)	Gain (dBi)	Directivity (dbi)	Band width (MHz)
0th Iteration	3.4	-13.74	3.82	6.88	135
	5.5	-15.15	2.91	7.44	180
	6.8	-12.63	-0.74	6.24	240
	9	-11.46	-3.55	6.09	75
1st Iteration	3.5	-12.28	3.82	6.90	90
2nd Iteration	6.5	-21.76	4.90	8.34	420
3rd Iteration	6.6	-14.49	4.86	8.42	465
	7.9	-11.97	1.54	6.46	195
	9.6	-13.97	6.74	10.87	195

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B. Effect of Defected Ground Structure on Fractal Patch Antenna

Fractal geometry applied on the patch provides multiband characteristics whereas DGS will provide wideband characteristics to the antenna. They are realized by etching off a simple shape defect from the ground plane of the microstrip antenna. The shape may vary from a simple geometry to a complicated one. Due to its resonant behavior, the DGS may be compared to the LC parallel resonator. When applying the DGS to antenna, equivalent inductive part increases hence improved characteristics can be obtained. By taking rectangle patch and applying fractal geometry, the results thus obtained are analyzed in table II. Effect of changing substrate shows shift in resonance frequency as shown in table III. T-shape DGS has been applied to the ground of E-Shaped structure shown in figure 9. By applying this DGS antenna shows improvement in bandwidth, gain, return loss and Directivity.

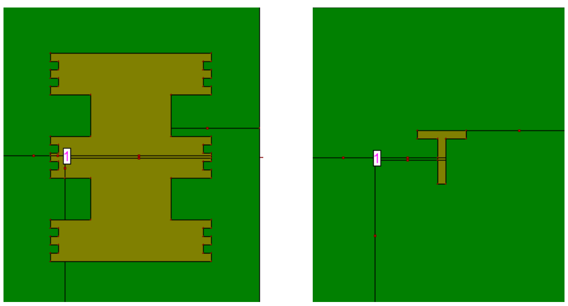

Figure 9. (a) Top View of antenna with DGS (b) Bottom view of antenna with DGS

Rectangle patch of dimension 20 mm by 25 mm is taken. FR-4 substrate having thickness 2 mm has been used as substrate. Three iterations of fractal geometry have been applied and the result geometry shown in figure 5 is obtained. By applying T-shape DGS shown in figure 9(b) it was observed that characteristics improved further. Feed point is being taken as x= -8 and y= 0. Effect of using above DGS has been shown in table III. This antenna resonates at multiband 3.7 GHz, 6.7 GHz, 7.9 GHz and 8.7 GHz with return loss of -15.61 dB, -16.99 dB, -12.18 dB and -20.70 dB. Antenna is having gain of 3.83 dBi, 4.90 dBi, 1.55 dBi and 4.26 dBi with bandwidth of 120 MHz, 495 MHz, 225 MHz and 315 MHz respectively.

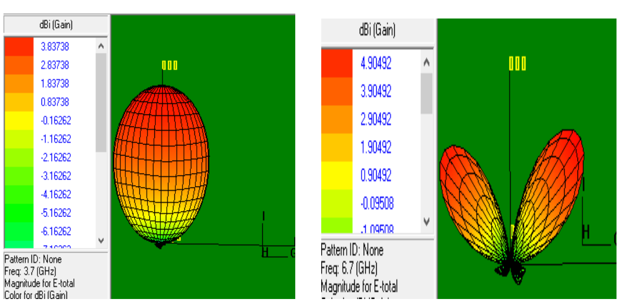

Figure 10. (a) Radiation pattern at 3.7 GHz (b) Radiation pattern at 6.7 GHz

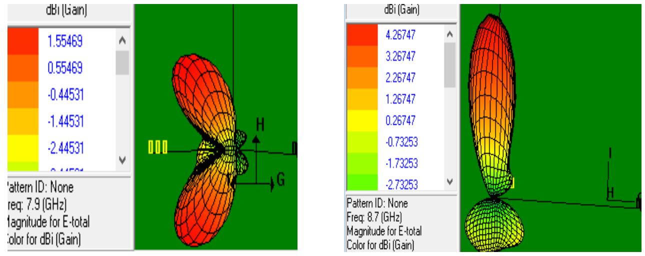

Figure 11. (a) Radiation pattern at 7.9 GHz (b) Radiation pattern at 8.7 GHz

In this study bandwidth values are obtained between the points where -10 dB return loss line cut the curve between return loss and frequency. Radiation patterns at 3.6 GHz, 6.4 GHz, 7.9 GHz and 8.7 GHz have been shown in figure 10(a), 10(b) and 11(a), 11(b). Figure 12 shows return loss Vs frequency graph for different DGS which apply on fractal 3rd iteration.

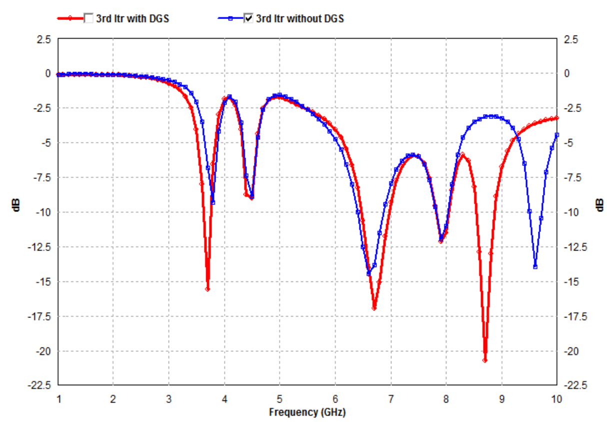

Figure 12. Return Loss Vs Frequency with DGS and Without DGS

TABLE III. COMPARISON TABLE OF 3RD ITERATION

Iteration number	Resonant Frequency (GHz)	Return Loss (dB)	Gain (dBi)	Directivity (dBi)	Band width (MHz)
3rd Iteration Without DGS	6.6	-14.49	4.86	8.42	465
	7.9	-11.97	1.54	6.46	195
	9.6	-13.97	6.74	10.87	195
3rd Iteration With DGS	3.7	-15.61	3.83	7.02	120
	6.7	-16.99	4.90	8.40	495
	7.9	-12.18	1.55	6.37	225
	8.7	-20.70	4.26	7.95	315

By applying fractal geometry number of bands increase one to three and by applying DGS to fractal patch antenna not only number of bands increases but also bandwidth, gain, directivity and return loss increases in negative

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direction. So by combination of these two techniques DGS and fractal geometry better results are obtained.

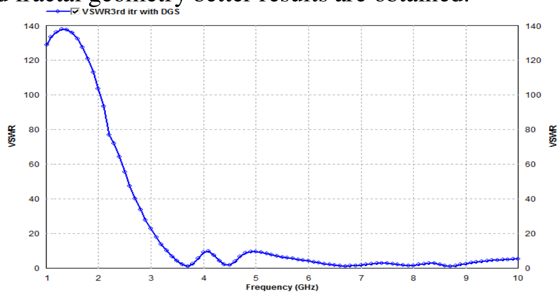

Figure 13. VSWR Vs Frequency for Final Fractal Iteration

Figure 13 shows the variation of VSWR (Voltage Standing Wave Ratio) Vs frequency for proposed fractal E-Shaped antenna with DGS. This antenna has VSWR of 1.397 at 3.7 GHz, 1.329 at 6.7 GHz, 1.652 at 7.9 GHz and 1.203 at 8.7 GHz. VSWR describes how well antenna output impedance matched to transmission line input impedance to which antenna is connected. At resonance frequency VSWR is less than 2. Smith chart is best method of representing complex frequencies with respect to represent complex impedances with respect to reflection coefficient. Figure 14 shows smith chart of proposed antenna.

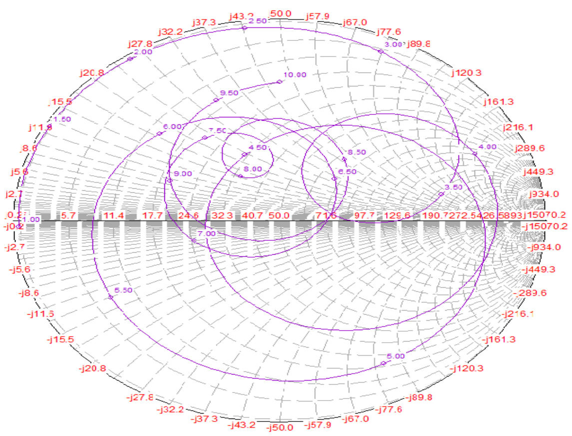

Figure 14. Smith chart of Proposed Antenna

Conclusion And Future Scope

After applying fractal geometry on microstrip patch antenna, area of patch decreases and multiband characteristics are obtained with better return loss, bandwidth, and directivity. Initially by taking rectangle patch antenna having less bandwidth and gain and then by applying fractal geometry bandwidth and return loss show much better results. By applying 3rd iteration of fractal geometry, antenna resonates at three bands. At last by applying T-shape DGS on 3rd iteration (proposed E-Shaped antenna) and antenna resonates at four bands and also bandwidth, gain and return loss shows improvement in all bands. Antenna resonates at multiband 3.7 GHz, 6.7 GHz, 7.9 GHz and 8.7 GHz. The E-Shape has return loss -15.61 dB, -16.99 dB, -12.18dB and -20.70 dB Antenna is having gain of 3.83 dBi, 4.90 dBi, 1.55 dBi and 4.26 dBi with bandwidth of 120 MHz, 495 MHz, 225 MHz and 315 MHz respectively. Designing and simulation of this antenna has been done by the help of IE3D Software. The proposed antenna is applicable for Satellite, Wi-Fi, Bluetooth, Cellular Phones and Radar etc.

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