Review of Antennas Deploying Fractal Slot Geometries

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ABSTRACT : *In modern era, the different variety of antennas are available that can used in the field of communication but some systems require ultra wideband and multiband antennas like commercial and military telecommunication system. Microstrip antennas have limitation of narrow bandwidth. Fractal geometries have marvellous kind of distinct properties from other antennas. For achieving the desired miniaturization and multiband properties, different shapes of fractals are used. Fractal slots can be made in microstrip patch so that its limitations can be evicted. In this paper, we studied about the different fractal slot geometries that enhance its use for different kinds of applications.*

Keywords - *Fractal, Hibert, Iteration, Koch, Sierpinski.*

I. INTRODUCTION

The broad bandwidth, low profile and multiband antennas are the inevitable requirement of any wireless communication system and have huge commercial and military applications. But simple microstrip patch antennas's advantages are limited by its narrow bandwidth. So, with the tremendous change in the technology, the demand of fractal antenna is increases because of its multiband operation. Thus, the performance of microstrip patch antennas is enhanced by using fractal geometries. The word fractal was first introduced in 1975 by Benoit Mandelbrot. Clouds, mountains, plant leaves and coastlines are the inspiration for fractal geometries [1]-[4]. Slot antennas are the antennas in which slot or hole is cut in the metallic patch wherever want according to the requirement. When the properties of slot antenna are combined with fractal antenna, then it exhibits wider bandwidth that can have various telecommunication and military applications. The slots of fractal geometry are made in patch antennas and hence it employed a good candidate for different fields. Koch Snowflake, Sierpinski gasket, Sierpinski carpet, Hilbert and Minkoski Island are the basic geometric pattern of fractal antennas [5]-[12]. To provide feed to the antenna or to excite the antenna, various types of feeding methods are available such as microstrip line, coaxial probe feed, aperture coupled feed, coplanar waveguide (CPW) feed and proximity coupled feed [13]. The first section of this paper illustrates discussion about the need of fractal slot antennas. The different configurations of fractal slot antenna are discussed in second section and subsequently followed by conclusion.

II. DIFFERENT CONFIGURATIONS OF FRACTAL SLOT ANTENNA

The narrow bandwidth of patch antennas can be made broader by inserting slots of fractal geometry in the patch. Koch Snowflake fractal slots are used to achieve bandwidth enhancement [8]. In the paper [14], a Koch fractal folded-slot antenna has been reported up to the iteration factor two. Antennas of both the three iterations are simulated and fabricated on RT/Duroid 6002 with the substrate thickness 30 mil and Koch iteration technique is adopted to obtain the final iteration geometry. The size of ground plane is 50 mm x 50 mm. For the excitation of the antenna, coplanar waveguide (CPW) feed line is used. For the inception geometry, the antenna excited at 10.45 GHz for return loss -40 dB and the obtained bandwidth is 1.211 GHz. Similarly, for the first order and second order geometry, the operating frequency is 8.05 GHz and 7.9 GHz with return loss -34 dB and -42 dB respectively as shown in Fig. 4. Also, the bandwidth is found to be 0.4 GHz and 0.34 GHz for first and second iteration respectively.

The paper [15], presented a novel design of modified Sierpinski Gasket fractal antenna (MSGFA). Mainly, Sierpinski Gasket consists of Sierpinski triangle having triangular slots in it using mid-point geometry of triangle. By the use of fractals, miniaturization of MSGFA is taking place. Here, circular shape is used to modify Sierpinski Gasket geometry which is fabricated on FR-4 epoxy substrate with relative permittivity of 4.4. The patch has 17.89 x 21.45 x 1.6 mm^3 has its dimensions. High Frequency Structure Simulator HFSS V13 Software is used for the simulation purpose. Probe feed is used to excite the proposed antenna. The proposed antenna has S-parameter (S_{11}) value is -15.77 dB at 5.51GHz and gain is 9.68dB at 9.65GHz, hence, utilities for C band (4-8GHz) and X-Band (8-12 GHz) applications. As iterations are increased from 0^{th} to 2^{nd} order, resonant frequency of proposed antenna is decreased from 5.72 GHz to 5.51 GHz.

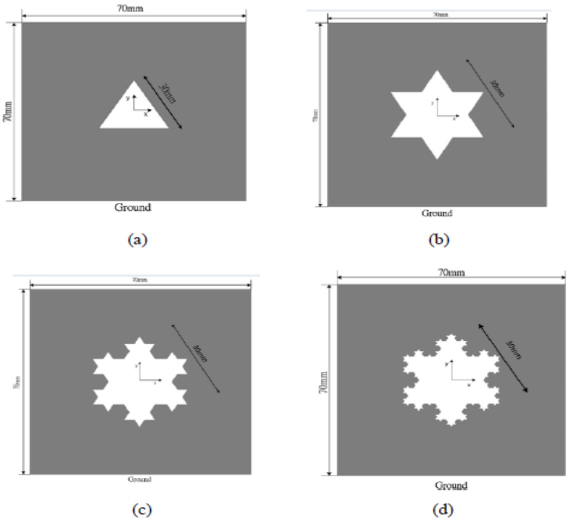


Fig. 1. Koch Snowflake Slot For Iteration Order 0-3 [8].

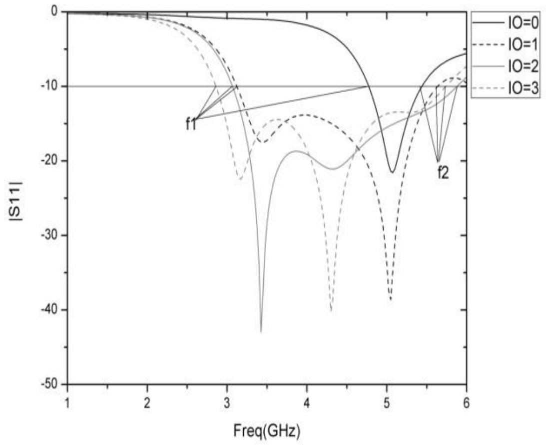
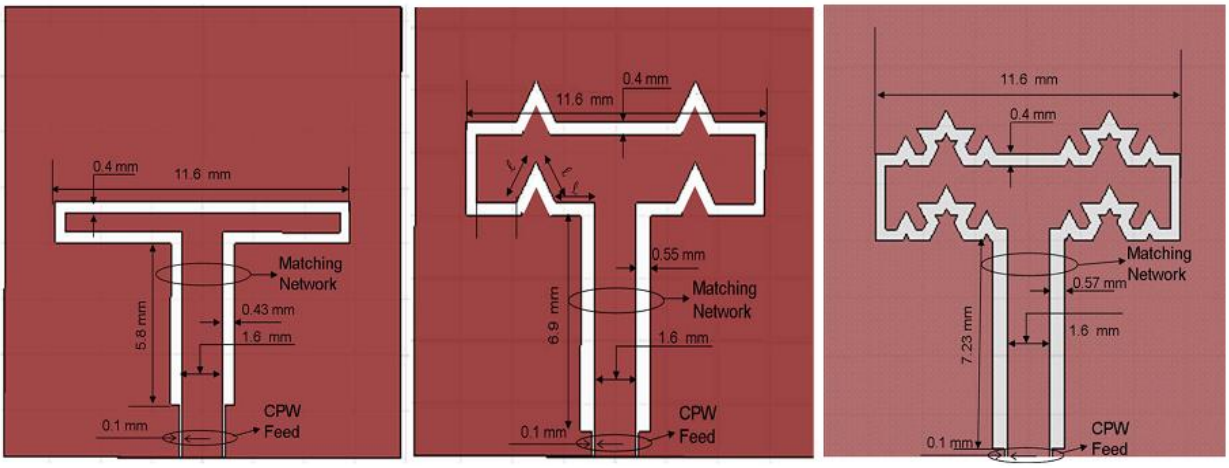


Fig. 2. $|S_{11}|$ For Iteration Order 0-3 [8].



(a) **(b)** **(c)**

Fig. 3. Schematic Layout of the (A) Zeroth Iteration, (B) First Iteration and (C) Second Iteration Koch Fractal Folded-Slot Antenna [14].

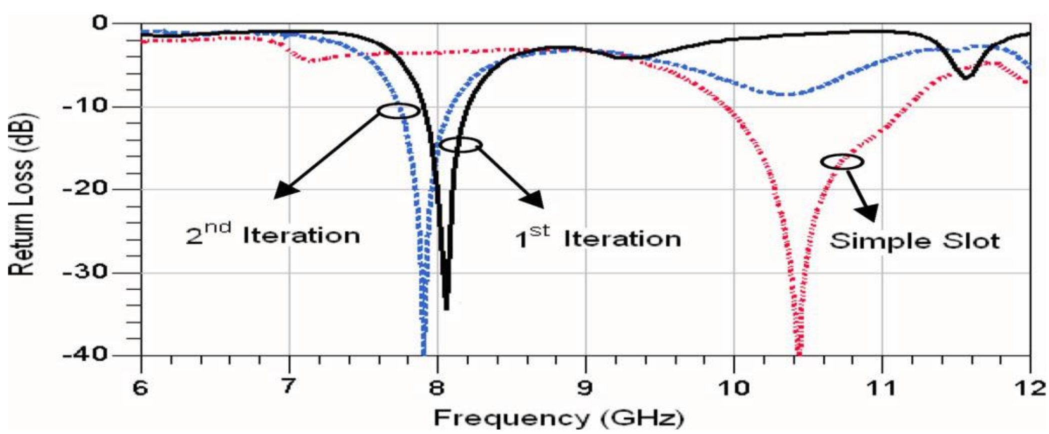
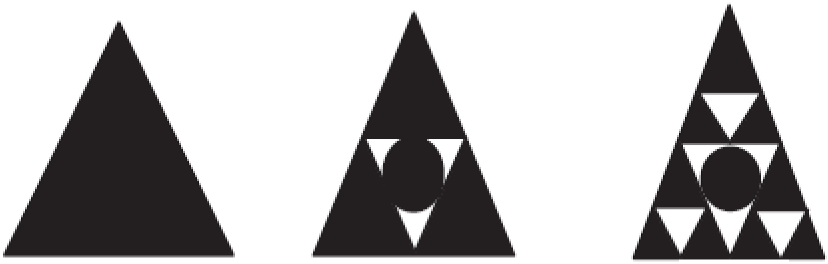


Fig. 4. Measured Return Loss for Koch Fractal Folded-Slot Antenna [14].



(a) (b) (c)

Fig. 5. Different Stages Of Iteration Process (A) Initiator (B) 1st Iteration (C) 2nd Iteration [15].

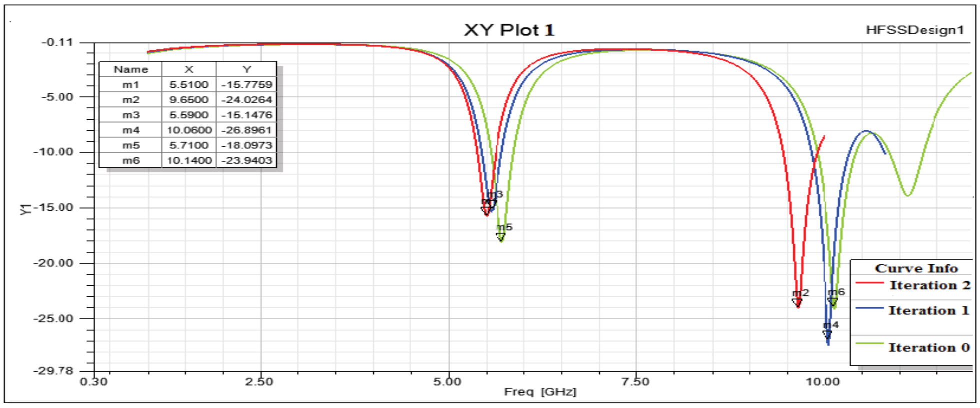


Fig. 6. Return Loss VS Frequency Plot For Different Iteration Stages [15].

In the paper [16], a wide band Sierpinski fractal based slot antenna is demonstrated. The low-profile, low-cost, compact design and miniaturization of antenna exploit its applications for various wireless communication services. The proposed antenna is fabricated on substrate thickness of 1.6 mm for FR4 with 4.4 as its relative permittivity and 0.02 as its loss tangent. With the insertion of Sierpinski fractal into a square wide slot, there is incredible change in bandwidth and hence results in broadband. The micro strip line is the feeding technique used to excite the proposed antenna and feed line is connected to SMA connector. The bandwidth of the slot antenna is enhanced to 63.4% and band covering from 1.96 GHz to 3.78 GHz. As the number of iteration increases, the number of resonance frequency is also increases.

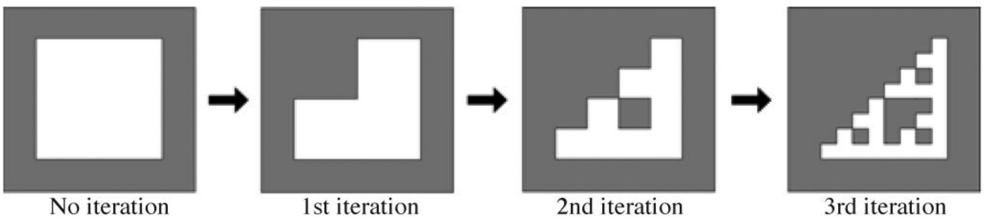


Fig. 7. Different Iteration Stages of Sierpinski Based Fractal Slot Geometry [16].

A novel design of Sierpinski carpet fractal antenna with Hilbert slot in the ground layer is presented in paper [17] and operates in 1.92 GHz to 2.17 GHz which is UMTS band (universal mobile telecommunication system). The dimension of proposed antenna is equal to 70 mm × 31 mm × 0.075 mm and occupies 30% smaller surface than the patch. The antenna is simulated and fabricated using Kapton substrate with thickness 0.075 mm, relative permittivity 3.2 and dissipation factor 0.0019 using CST Microwave Studio software. Microstrip line feed of 2.6 mm wide and 10 mm long is used to provide feed to the antenna. By folding of the patch antenna, the average frequency shift is 4.09 % which is only 2.04 % for the proposed fractal antenna.

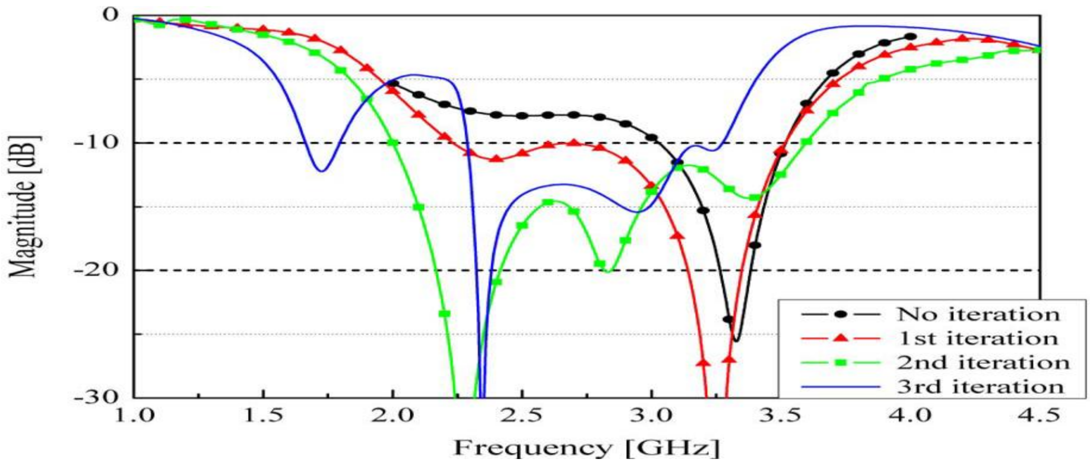


Fig. 8. Simulated Return Loss for Different Iterations of Sierpinski Based Fractal Slot Antenna [16].

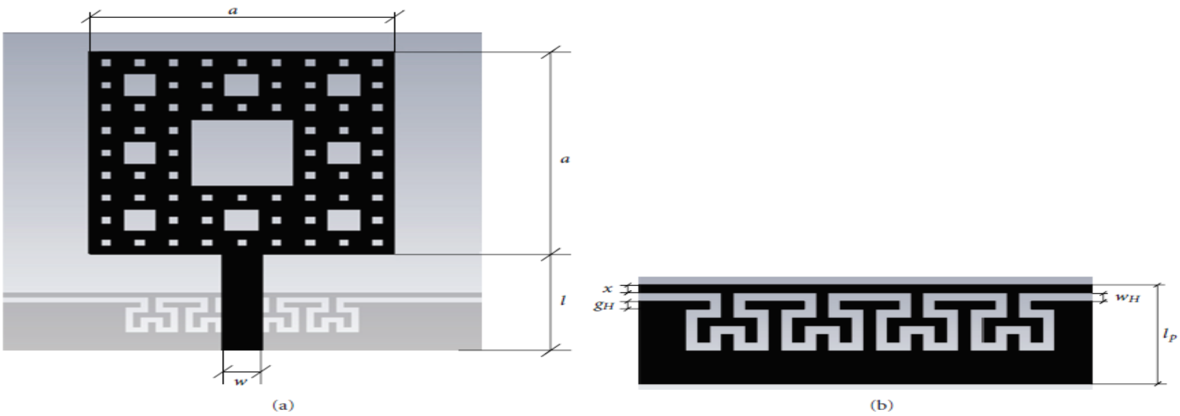


Fig. 9. Sierpinski Fractal Antenna on a Hilbert Slot Patterned Ground [17].

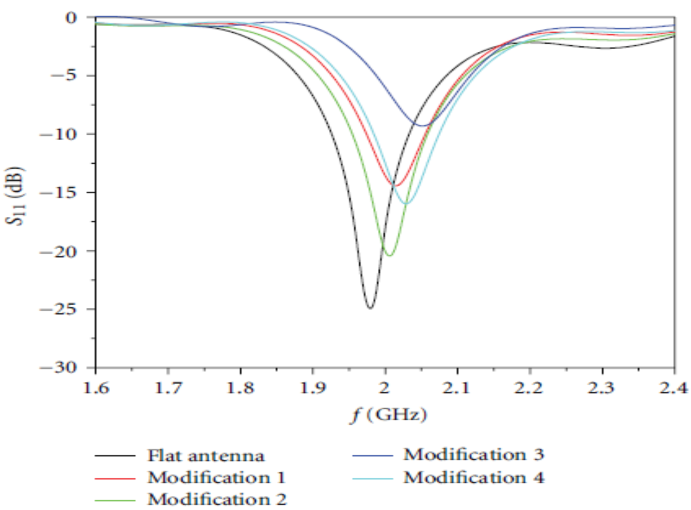


Fig. 10. Simulated S-Parameter (S_{11}) For The Sierpinski Fractal Antenna On A Hilbert Slot Patterned Ground [17].

In paper [18], for dual-band applications, the CPW-fed circular fractal slot antenna is proposed up to three iterations and enhanced its utilities for GSM applications. The proposed antenna is designed by using FR4 with substrate thickness 1.6 mm and relative permittivity, ε_r is 4.4. For half-wavelength design, the measured results obtained at frequency 0.98 GHz and 1.84 GHz with gain 3.58 dBi and 7.28 dBi and their respective bandwidth is 47.4 % and 13.5 %. Similarly for the quarter-wavelength design, the measured results obtained at frequency 2.38 GHz and 5.35 GHz with gain 3.16 dBi and 6.62 dBi and their respective bandwidth is 75.9 % and 16.1 %. The directivity is 3.58 dBi and 7.28 dBi and the axial ratio is 0.16 dB and 0.24 dB for the half-wavelength design. Similarly, the directivity for quarter-wavelength is 3.16 dBi and 6.62 dBi and the axial ratio is 0.34 dB and 0.27 dB.

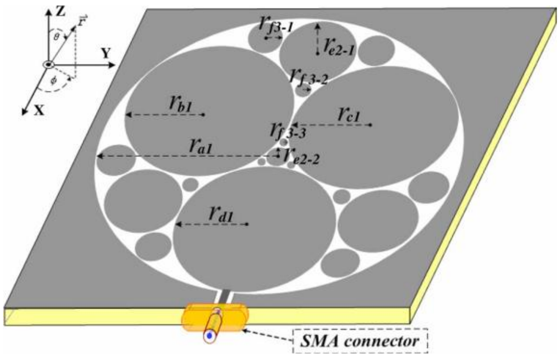
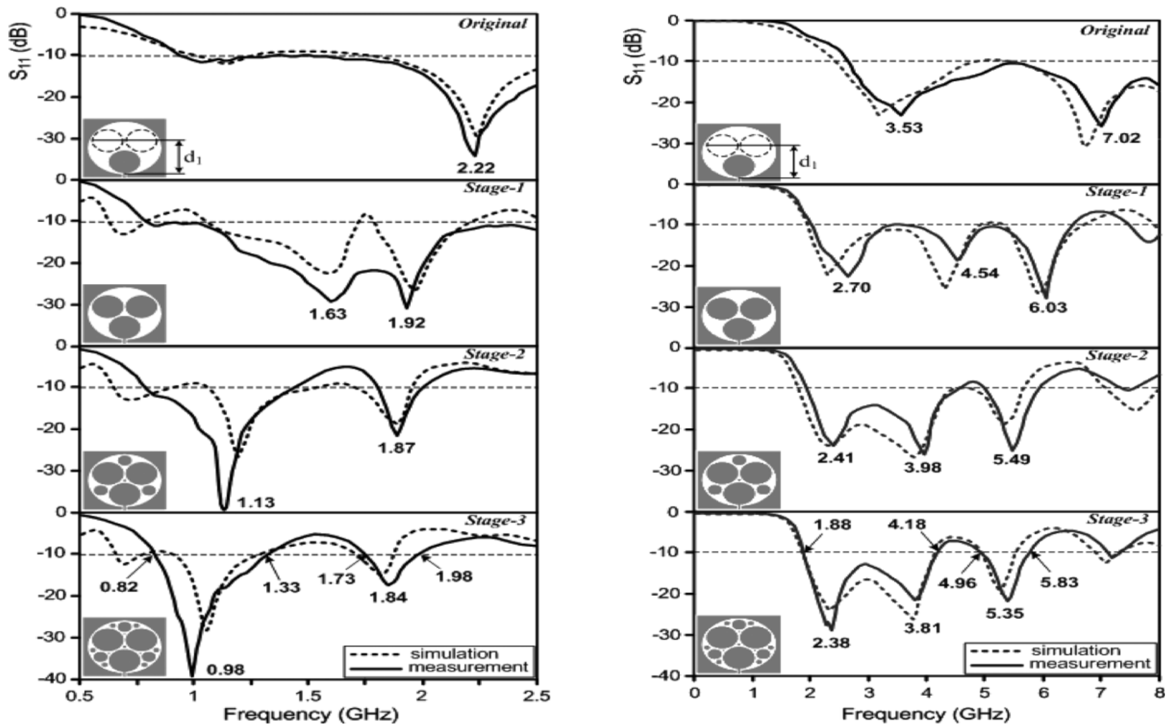


Fig. 11. Geometry of CPW-Fed Circular Fractal Slot Antenna [18].



(a) (b)

Fig. 12. Iterative S-Parameter (S_{11}) For (A) Λ/2 Design and (B) Λ/4 Design [18].

III. CONCLUSION

In this paper, study of unique and different fractal slot antenna has been done which is used for various ultra wide-band and multi-band operations. Koch, Hilbert, circular and Sierpinski are popular fractal slot geometries and easy to design. Fractal slot geometries enhanced the bandwidth of the antennas in a great extant. Fractal antennas have distinct properties which results in small size, high gain, and high efficiency antenna. With increasing the number of iterations of fractal geometry, resonant frequency increases that realized in lower return losses. Thus, the eviction of problem of narrow bandwidth can be done by the use of fractal slot geometries. These antennas have applications like in GSM, Wimax, WLAN, Bluetooth, Radar, medical imaging, satellite communication, telecommunication and in mobile system for UMTS LTE or 3G applications etc. In future, different kinds of feeding techniques can be applied and the number of iterations also can be increased.

IV. ACKNOWLEDGEMENT

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