International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-8 Issue-2, July 2019

Performance Characteristics of Modified Sierpinski Fractal Asntenna for Multiband Applications

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Abstract*: *The emerging advanced wireless communication technology desires more compact, multiband, moderate gain antennas. These features can be accomplished by designing of the Fractal antennas with advanced features. This paper introduces a Modified Sierpinski Fractal antenna with compact, multiband and moderate gain specifications with an embedded Rectangular slot on the regular Sierpinski triangle . The fractalisation is extended from 0 to 4 iterations to examine the radiation characteristics. Two substrate materials ARLON, FR4-epoxy are considered individually with ε_r values 2.2, 4.4 respectively and the height of the substrate is chosen as 1.6 mm. The efficient tool ANSYS HFSS High frequency structure simulator software package is used to design and simulate the proposed antenna structure in the frequency band of 1 to 10 GHz. The simulation results are reported and studied for all the four iterations in which the 4th iteration final geometry possess better results with 4 resonant frequencies that resonates in C band and X band in case of ARLON whereas 6 resonant frequencies obtained in the same frequency bands in case of FR4 epoxy. The multiband behavior can make these structures to serve in Satellite, Military and Radar wireless communications. The resultant gain values are also maximum about 13.67dB for ARLON and 7.69 dB for FR4-epoxy materials. It is also observed that the percentage of miniaturization of about 71.53% is obtained with this modified rectangular slotted fractal geometry, suitable to multiband applications.

Index Terms*: *Fractalization, Haussdroff dimension , Initiator, magnification factor ,miniaturization.

I. INTRODUCTION

The designing of new innovative antennas by researchers leads to advancement in modern communication systems and wireless technology . Most of the design engineers are focusing on the theory of fractal geometry with antenna design [1].

The complex geometrical structures like length of coast line, density of clouds and the branching of trees, even though have non integer dimensions and self similar structure, they can be defined by the Fractal geometry. Fractals finds the application in many areas of science and engineering including antenna design too.

The modern telecommunication systems concerned with driving engineering efforts to develop multiband and compact size antennas. The conventional non fractal antennas usually designed to operate only at relatively narrow range of frequencies with a minimum size limitation, as electrically small size antennas generally are poor radiators. Fractal shaped antennas becoming a useful way to design the advanced antennas which possess multiband and miniaturization characteristics based on the principals of self similarity and constant impedance properties [1] .

A Fractal structure is a result of repetitive generation of the same structure having fractional dimension [2].The iterative structures come interlaced with one another by fractal phenomenon. Fractals are majorly categorized as Deterministic and random. Sierpinski triangle referred to deterministic category, which is composed of several scaled copies of it [3].The Fractal geometry extensively finds its application in analyzing statistics, modeling nature, computer graphics and of course designing antennas[4], [5]. The unique geometrical features of advanced antennas based on fractal geometry have been investigated [6]-[9] and the performance analyzed in terms of various properties like size, gain and the multi frequency behavior is also reported. A variety of fractal antennas are designed for communications were first published in 1995 by N. Cohen in [10]. A patch antenna array with high Directivity is inspired by the Sierpinski Fractal antenna and is simulated for two iterations [11]. A modified Sierpinski Fractal antenna is designed as a dual frequency microstrip multi tasked antenna with metalized foam [12]. A Sierpinski fractal geometry for four iterations is designed and is simulated to obtain multi resonance frequencies [13]. This paper describes the modified Sierpinski triangle with an embedded rectangular slot on the basic cell, fractalised up to four iterations for the purpose of reduction of size, which produces radiations in C band and X band. The design considers ARLON, FR4 substrate materials and the simulated results are compared for both materials in terms of the number of resonance frequencies, return loss, VSWR and Gain.

Revised Manuscript Received on 30 July 2019.

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Retrieval Number B2397078219/19©BEIESP
DOI: 10.35940/ijrte.B2397.078219
Journal Website: www.ijrte.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

Table. I Parameters Of Designed Modified Sierpinski Structure

Parameter	value
substrates	ARLON, FR4
Substrate height	1.6 mm
Dielectric constant	2.2 for ARLON
Dielectric constant	4.4 for FR4 epoxy
Patch width	102 mm
Patch length	90 mm
Substrate length	112 mm
Substrate width	108 mm

II. MODIFIED SIERPINSKI GEOMETRY

Sierpinski triangle is one of the widely studied Fractal geometry employed for EM applications. The initiator is a simple triangle with height taken as 90 mm and the base length is chosen as 102 mm in order to observe two inclined angles on the base equal. as shown in the Table I, for 0-iteration and subtraction of a triangle whose dimensions are scaled by half of the initiator gives the structure of 1st-iteration. The same procedure is being followed and 40 triangular subsets are subtracted from the basic cell to obtain 4th-iteration geometry. This standard Sierpinski geometry produces 68.36% miniaturization.

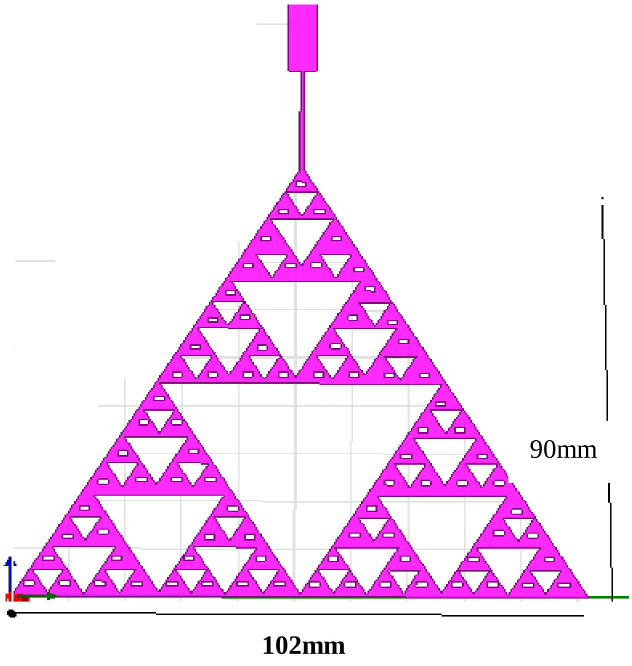


Fig.1 .Modified Sierpinski 4- Iteration Fractal Geometry

The scaling factor is ½ [10] and the area being zero [11]. Which means each iteration is half that of its previous iterations and similarly height of the triangle is also chosen to follow the same. The concept of Haussdroff dimension of the Sierpinski triangle is given by $D = \log_{10} N / \log_{10} M$. Where N is the number of similar copies physically left after each iteration and M is the magnification factor. Doubling the side of the Sierpinski triangle creates three copies of itself so the Haussdroff dimension is 1.585 [10], and the area remaining after each iteration is clearly 3/4 of the area from the previous iteration and an infinite no of iterations makes the area to be zero. The decrease in the area not only favors the miniaturization characteristics but also concentrates the current. This means, the density of the current increases at clusters of the area in geometry. The proposed modified SPK geometry subtracts a rectangular slot of dimensions 28mm X 16 mm from the initiator for the purpose of miniaturization and compact size. The dimensions of the rectangle are scaled accordingly for the respective iterations. The repeated removal of 40 triangular subsets with its 81 rectangular slots from the patch creates 4th- iteration structure as shown in Fig 1. The radiations are observed in C,X frequency bands in case of ARLON material as well as FR4 material.

III. DESIGN PROCEDURE

The dimension details of the proposed modified Sierrpinski gasket Fractal antenna are demonstrated in Table I. The length and width of the substrate are 108mm, 112mm respectively. The embedded rectangular geometry is optimized at 28mm length , 16mm width .Feed line length is optimized at 25mm. The structure has been designed for four iterations considering ARLON, FR4 substrates individually for comparing performance characteristics and simulated using effective CAD Tool in the HFSS and the same has been represented in the Fig 2 (a),(b),(c),(d),(e) respectively. The geometry starts from the designing of a rectangular patch and is cut into triangular form. A small rectangular slot has been removed from the triangular structure to create an initiator as 0th-iteration .The 1st-iteration of the modified geometry designed by transforming the embedded basic cell into three triangles with three rectangular slots. These 3 rectangular slotted triangles transformed into a total of 9 to create 2nd-iteration. This procedure repeated for 4 times through which the 4th- iteration final geometry is generated with maintaining the same ratios for both the triangles and rectangles

The excitation is provided to the modified geometry using a lumped port technique with 50Ω microstrip line as a feed line. This feed line impedance is different from the patch impedance, which causes mismatch characteristics. For this reason, a transformer is placed between the patch and the feed line, which is nothing but a microstrip line whose impedance considered equal to that of the patch impedance. The length and width of the microstrip line are chosen using an online microstrip line calculator. The proposed antenna geometry is designed for wireless communication applications. The effects of different substrate materials on the frequency response and characteristics are depicted using HFSS Tool as shown in the Fig.3

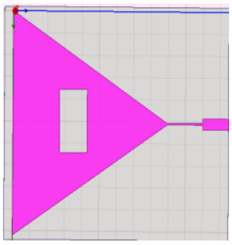


Fig.(a). Iteration-0

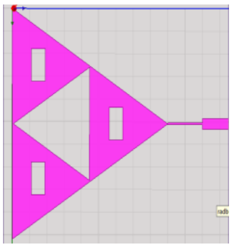


Fig.(b).Iteration-1

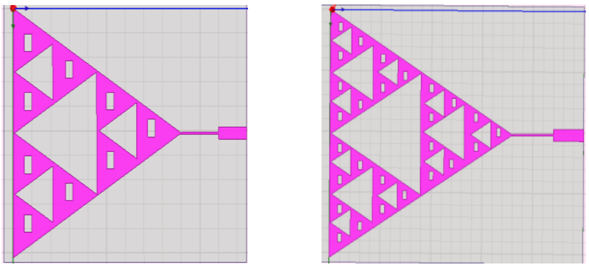


Fig.(c). Iteration-2 **Fig.(d).Iteration-3**

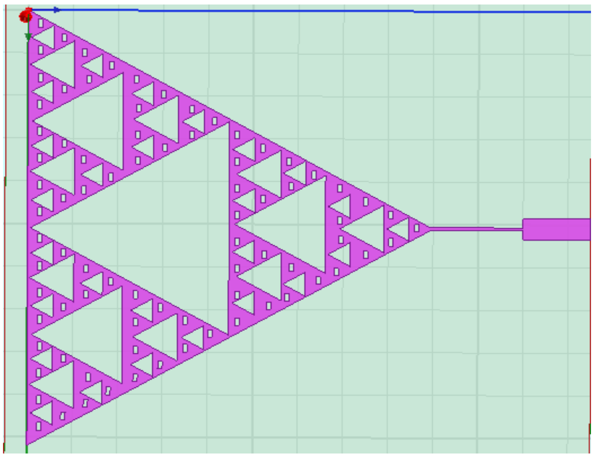
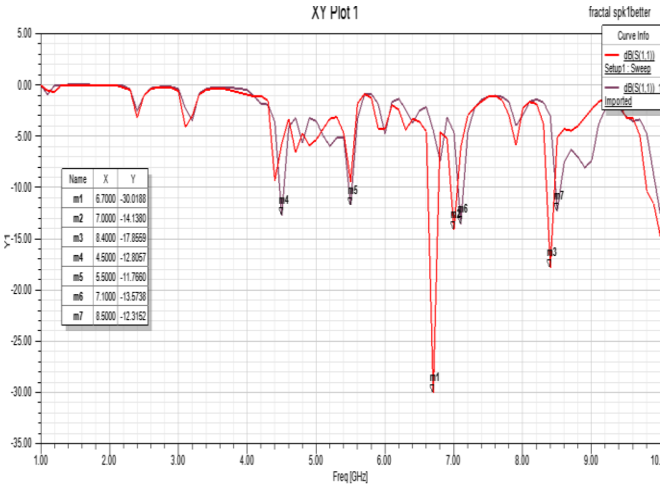


Fig.(e).Iteration-4

Fig 2. **(a), (b), (c), (d), (e) Modified Sierpinski Fractal Geometries**

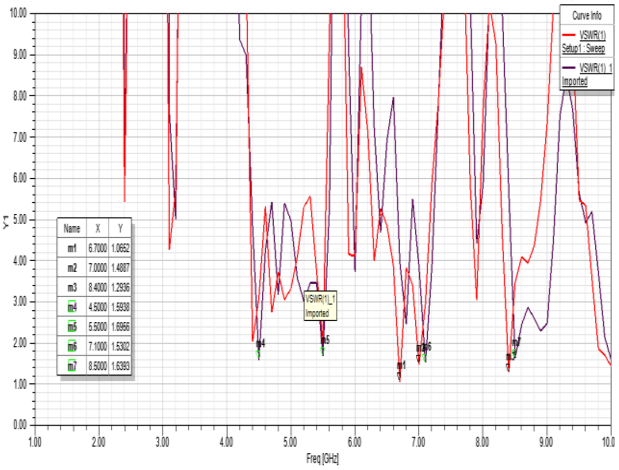
IV. SIMULATION RESULTS

The overall performance of the proposed antenna involves simulation results for all the four iterative structures including initiator with mentioned dimensions. The parameters like resonance frequencies, Return loss, VSWR, and Gain are plotted as shown in the Fig.3 and are reported in the Table II. The basic cell of iteration-0 resonates at 6.7 GHz, 7.0 GHz, 8.4 GHz with respective return losses -30.01 dB,-14.13 dB,-17.8 dB in case of ARLON whereas it resonates at 4.5 GHz, 5.5 GHz, 7.1 GHz, 8.5 GHz with return losses -12.8 dB, -11.7 dB ,-13.57 dB, -12.3 dB respectively in case of FR4 material..The iteration-2 and iteration-3 also resonating at various frequencies as shown in the table with lesser gain values as compared to iteration-4. The iteration-4 of ARLON resonates at 4 different frequencies 4.9 GHz , 5.9 GHz, 8.4 GHz, 9.7 GHz with a considerable S(1,1) parameter magnitude of less than -10 dB and is minimum whose value is -15.87 dB at 9.7 G Hz whereas the iteration 4 of FR4-epoxy resonates at 6 different frequencies 3.5 GHz, 3.8 GHz, 4.0 GHz, 6.3 GHz, 7.2 GHz, 8.9 GHz and the minimum value of S(1,1) parameter is -22.27dB occurs at 8.9 GHz. The VSWR values at these resonance frequencies are good in analogous to reflection coefficient curves. The gains are also defined by the 3D polar plots as in FIg.4. The iteration 4 of ARLON obtains maximum gain about 13.67 dB where as 7.69 dB is obtained for FR4. The radiation characteristics are compared for ARLON substrate with FR4-epoxy substrate and the performance is reported by various parameters listed in the Table II. The percentage of miniaturization obtained after 4 iterations is about 71.53% which is preferable for compact antenna designs



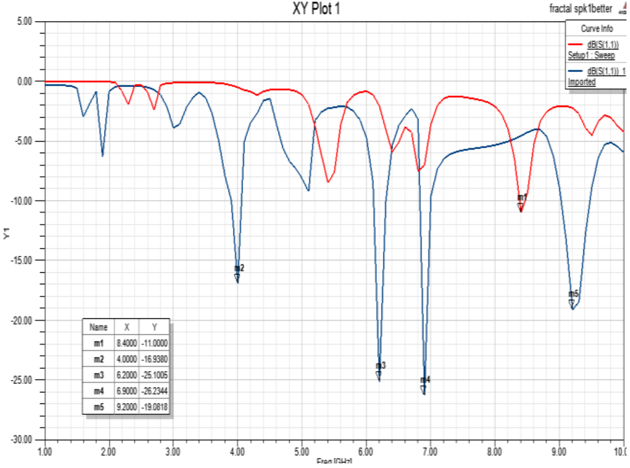
Name	X	Y
m1	6.7000	-30.0188
m2	7.0000	-14.1380
m3	8.4000	-17.8559
m4	4.5000	-12.8057
m5	5.5000	-11.7660
m6	7.1000	-13.5738
m7	8.5000	-12.3152

Fig(A).Iteration-0 Return Loss



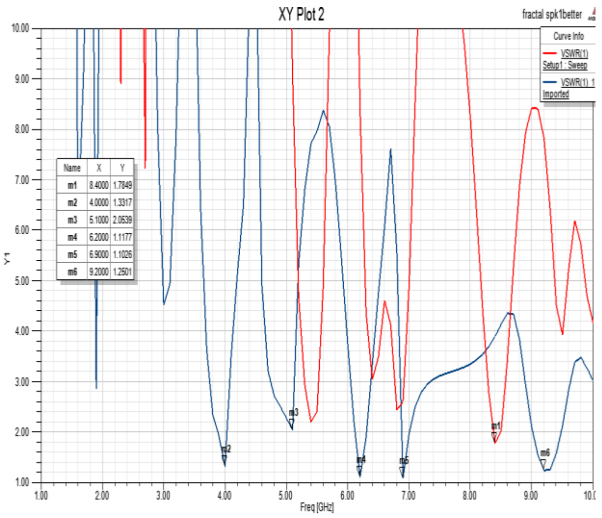
Name	X	Y
m1	6.7000	1.0652
m2	7.0000	1.4887
m3	8.4000	1.2936
m4	4.5000	1.5938
m5	5.5000	1.6966
m6	7.1000	1.5302
m7	8.5000	1.6393

Fig(B). Iteration-0 VSWR



Name	X	Y
m1	8.4000	-11.0000
m2	4.0000	-16.9380
m3	6.2000	-25.1005
m4	6.9000	-26.2344
m5	9.2000	-19.0818

Fig(c). Iteration-1 Return Loss



Fig(D) .Iteration-1 VSWR

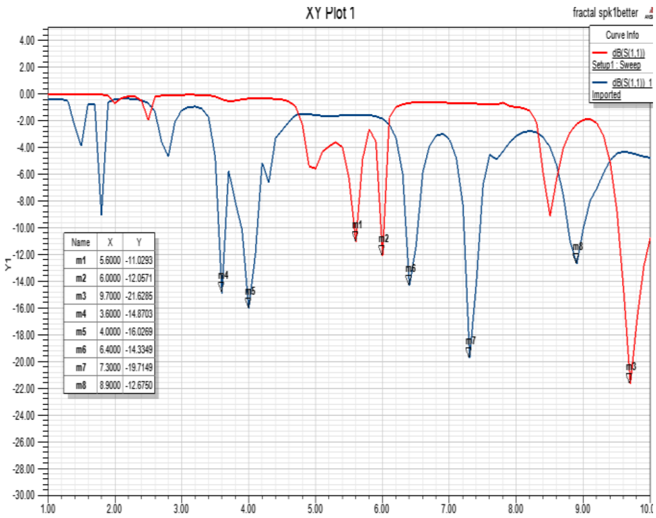


Fig.(G). Iteration-3 Return Loss

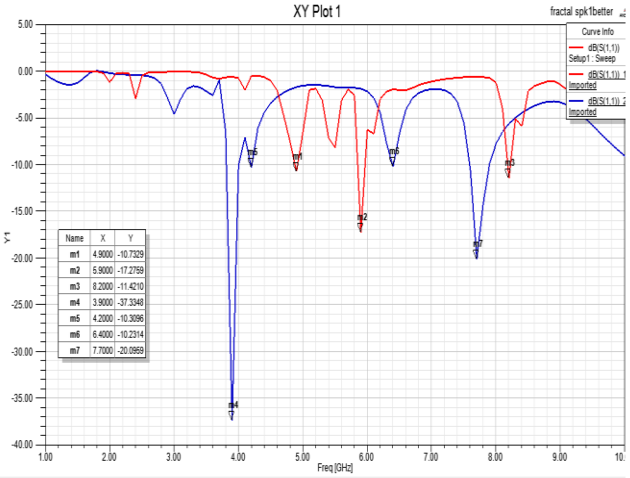


Fig.(e). Iteration-2 Return Loss

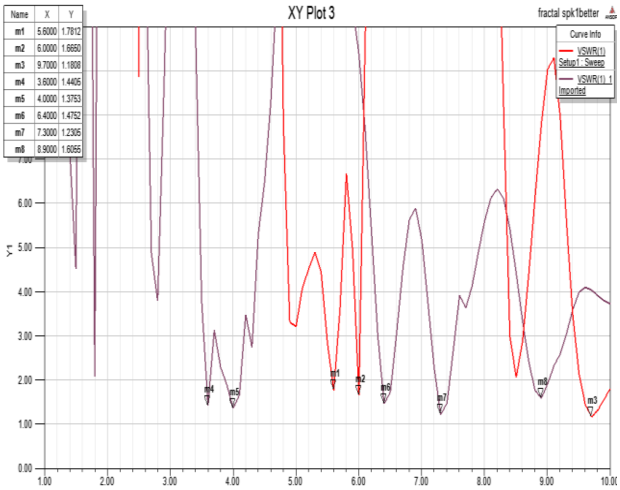
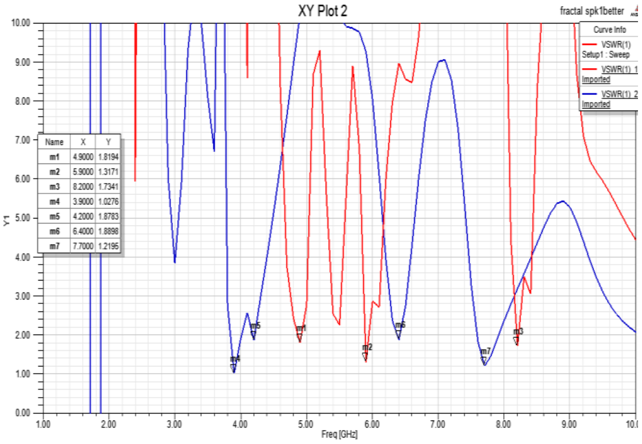


Fig.(h). Iteration-3 VSWR



Fig(f). Iteration-2 VSWR

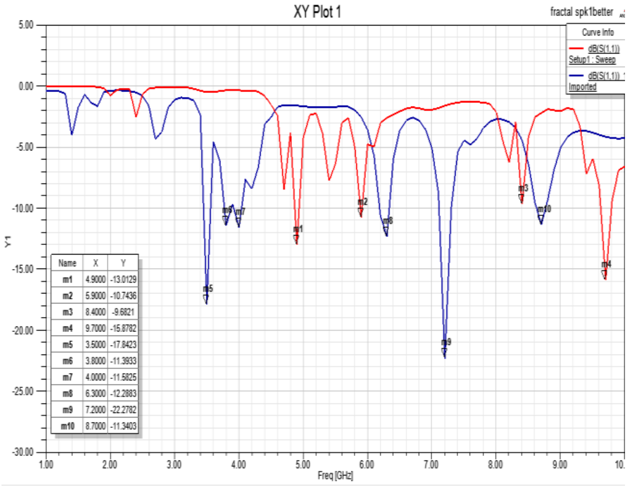


Fig.(i). Iteration-4 Return Loss

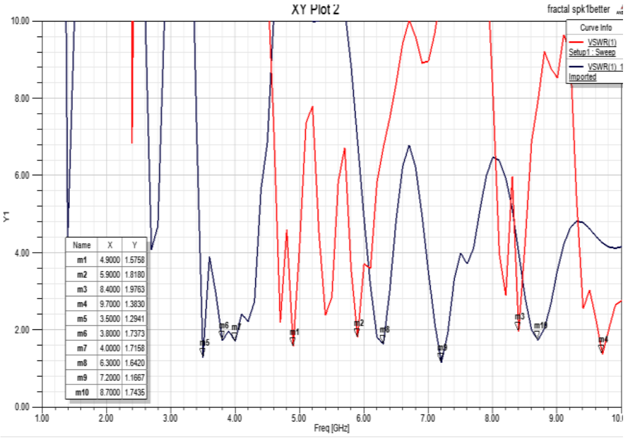
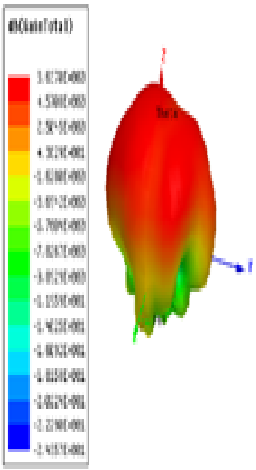


Fig.(j). Iteration-4 VSWR

Fig.3. (a) ,(b), (c), (d), (e) Return loss and VSWR plots for ARLON and (f) ,(g), (h), (i), (j) Return loss and VSWR plots for FR4



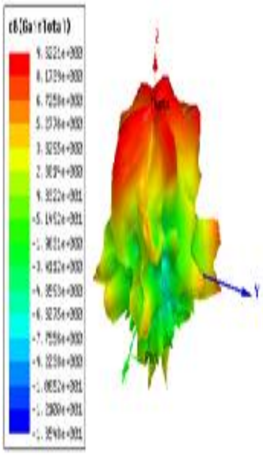
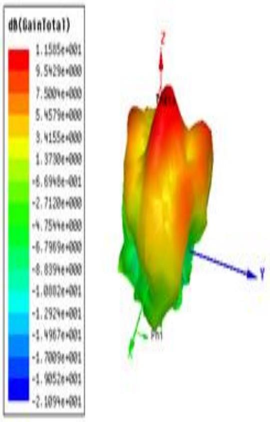
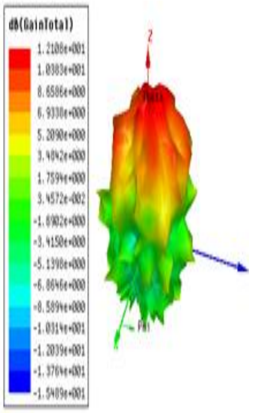
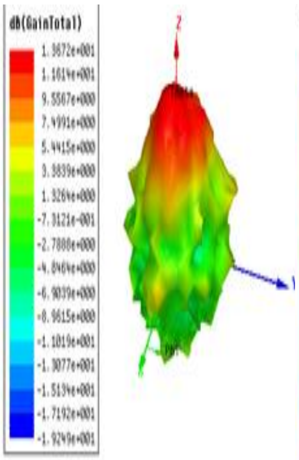


Fig.(a).Iteration-0 **Fig.(b). Iteration-1**





Fig(c) . Iteration-2 **Fig.(d) . Iteration-3**



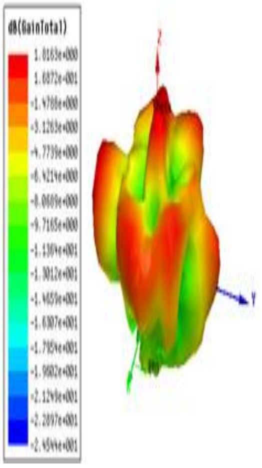
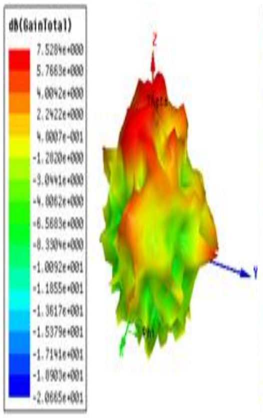
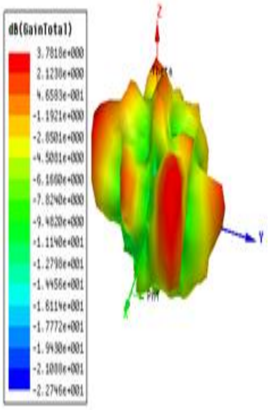
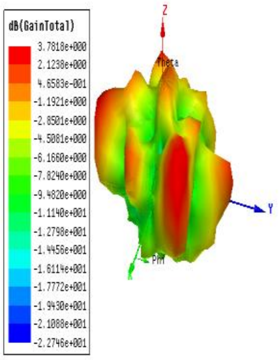


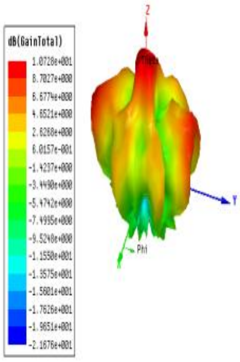
Fig.(e).Iteration-4 **Fig.(f). Iteration-0**





Fig(g). Iteration-1 **Fig.(h). Iteration-2**





Fig(i) . Iteration-3 **Fig(j) . Iteration-4**

Fig.4 (a) ,(b), (c), (d), (e) . 3D Polar plots for ARLON and (f) ,(g), (h), (i), (j) 3D Polar plots for FR4

Table. II.Simulation Results of Proposed Modified SierpinskiFractalAntenna

S.NO	f_r(GHz)		VSWR		S11(dB)		GAIN(dB)		Miniaturization
Iteration	**ARLON**	**FR4**	**ARLON**	**FR4**	**ARLON**	**FR4**	**ARLON**	**FR4**	
Iteration 0	6.7 7.0 8.4	4.5 5.5 7.1 8.5	1.06 1.48 1.29	1.593 1.69 1.53	-30.01 -14.13 -17.8	-12.8 -11.7 -13.57 -12.3	6.727	1.07	10%
Iteration 1	8.4	4.0 6.2 6.9 9.2	1.78	1.331 1.117 1.10 1.36	-11.0	-16.9 -26.1 -26.2 -19.0	9.62	1.81	32.5 %
Iteration 2	4.9 6.6 8.2	3.9 4.2 6.4 7.7	1.21 1.31 1.73	1.02 1.37 1.19 1.21	-10.7 -17.2 -11.4	-32.3 -10.3 -10.2 -20.0	11.58	3.78	49.37 %
Iteration 3	5.6 6.0 9.7	3.6 4.0 6.4 7.3 8.9	1.78 1.68 1.18	1.47 1.375 1.475 1.23 1.60	-11.0 -12.0 -21.62	-14.87 -16.02 -14.33 -19.71 -12.67	12.10	7.52	62.46 %
Iteration 4	4.9 5.9 8.4 9.7	3.5 3.8 4.0 6.3 7.2 8.7	1.57 1.81 1.97 1.38	1.29 1.73 1.71 1.64 1.16 1.74	-13.01 -10.74 -9.68 -15.87	17.84 -11.39 -11.58 -12.28 -22.27 -11.34	13.67	7.69	71.53 %

V. CONCLUSION

In this paper the performance of proposed modified rectangular slotted Sierpinski Fractal antenna is reported not only by changing the number of iterations from 0 to 4 but also considering two different substrate materials known as ARLON and FR4 epoxy. As the number of iterations are increased from 0 to 4, the resonant frequencies obtained are increasing which radiates in C, X frequency bands. The fourth iteration has 4 resonant frequencies and has a maximum Gain of 13.67 dB with a minimum S(1,1) parameter as -15.9 dB in case of ARLON whereas 5 resonant frequencies obtained with a Gain of 7.69 dB and S(1,1) parameter as -22.27 dB for the FR4 epoxy. By choosing different substrates, radiation characteristics and resonance frequencies can also be controlled for multiband applications. The miniaturization value of the general Sierpinski geometry model is about 68.36%, where further miniaturization about 71.53% gained in the modified structure by the removal of 81 rectangular slots and 40 triangular slots from the patch surface. One may find a constraint with the phenomenon of meshing in HFSS Tool while simulating the triangular geometries. The rectangular gridding cannot incorporate the entire triangular geometries properly, which causes the simulated results slightly deviate from that of the practical but with an acceptable little deviation. Keeping in view of this problem a modified form of geometry can be employed with its fabrication.

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