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Design of a Sierpinski Gasket Fractal Bowtie Antenna for Multiband Applications

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Abstract

This paper investigates the design and performance of Sierpinski Fractal Bowtie antenna. The concept and geometry of fractal antennas such as Sierpinski has been used in the conventional bowtie antenna to obtain multiband behaviour which is considered as very important criteria in current antenna design trends. The evaluation of Sierpinski fractal antenna is made up to two iterations. The overall dimension of Sierpinski fractal antenna is 110x70 mm^2 .The final design is able to operate at frequencies such as 1.4 GHz, 3.5 GHz, 4.6 GHz and 7.4 GHz with a gain of 6.4 dB, 9.2 dB, 6.7 dB and 9.1 dB respectively. The measured gain of the antenna is greater than other fractal antennas. The fractal antenna is successfully simulated and evaluated using ANSYS HFSS.

Keywords: Sierpinski, Bowtie, Multiband, HFSS

INTRODUCTION

Recent telecommunication systems are in need of broader bandwidth and smaller dimensions than conventional antennas. In order to fulfil these requirements the researchers are in search of advanced novel antenna designs. The advanced and novel antenna structures are designed using fractal geometries which show properties like self similarities, space filling and complexity in their structure. The word fractal is derived from the Latin word fractus which means “broken or irregular segments”. They are often constructed via some sort of iterative mathematical rule that generates a fractal from a conventional object step by step. Applying Fractals to antennas allows for miniaturisation of antennas with both multiband and broadband characteristics. There are many research outcomes available in literature for multiband antenna design.

Liu et.al designed a H fractal antenna that is used for multiband applications]. The H-fractal planar antenna has been fabricated on an FR4 substrate with a 1.6-mm thickness. The proposed antenna can excite multiple resonances with reasonable antenna directivity. Reflection coefficients and radiation properties show that the proposed H-fractal antenna is a good candidate for a variety of antenna applications. [1]. Gemma *et.al* designed a Sierpinski bowtie microstrip antenna and its multifracton properties are analyzed [2]. It is inferred that due to the presence of fractal shaped perimeter, it can support multiband behaviour. However more fractalized antenna decreases the directivity of the antenna. Reddy and Sarma designed a novel single-layer single-probe-feed asymmetrical fractal boundary microstrip antenna for triband circular polarization (CP) operation. Four different structures without slot (Ant1), rectangular (Ant2), fractal (Ant3), optimized-fractal-slot (Ant4) are studied for multiband CP radiation. Perturbation in the structure for triband CP radiation is introduced by employing optimized asymmetrical Koch fractal curves as boundaries of a square patch and embedded rectangular slot [3].Costa and Dmitriev constructed Koch monopoles by changing the angle α of the generator. It was analyzed that the dimensions of the antenna can be reduced by choosing the angle $\alpha > 60^o$ However reducing the dimensions of the Koch antenna reduces the impedance bandwidth, lower radiation resistance and lower efficiency [4]. Patnam designed a broadband Koch fractal loop antenna with a coplanar waveguide feed .The broadband is achieved by a radial stub loaded with coplanar waveguide feed which acts as a lumped matching circuit. However adding stubs to the feed makes the designing and fabrication process complex[5].Chen et.al proposed a novel technique to reduce the size of the microstrip patch antenna. The edges of the patch are etched as Koch curves and the inner patch as Sierpinski Carpet the resonant frequency of the patch can be lowered greatly. The size reduction achieved is 77.1 % [6]. Hwang designed a broadband planar sierpinski fractal antenna for multiband application. The perturbed sierpinski fractal patch and slotted ground plane are employed to achieve broadband characteristics [7]. Moghadasi et.al (2013) designed a compact coplanar waveguide (CPW) monopole antenna is presented, comprising a fractal radiating patch in which a folded T-shaped element (FTSE) is embedded. The impedance match of the antenna is determined by the number of fractal unit cells, and the FTSE provides the necessary band-notch functionality. The filtering property can be tuned finely by controlling the length of FTSE. [8]. Liu et.al (2013) designed a dual-band microstrip radio frequency identification (RFID) reader antenna with tree-like fractal resonator. The measured results show that dual bandwidths of the antenna with -10dB return loss are 4.4% and 3.1%, respectively[9] .Ming-Tien Wu and Ming-Lin Chuang designed a CPW fed multiband bowtie antenna .Each frequency band can be easily satisfied for the broadband characteristics because the bowtie patch can be treated as broadband impedance matching [10]. S.W.Qu and C.L Ruan investigated three types of bowtie antenna with round corners including quadrate, round edge and triangular shape and found that adding round corners at the sharp vertex of the radiation edges will improve the performance of not only bowtie antenna but also others[11].

From the above literature it is inferred that adding fractals to the conventional antennas help in miniaturization and to operate at multiple frequency. Adding round corners to the sharp vertex of the radiation patch will improve the performance of the antenna. Hence in this paper a bowtie antenna is taken as the base patch and then the fractal structures are employed and analyzed. As Sierpinski Fractals are better than Koch Fractals in Multiband Applications, it is decided to use Sierpinski fractal structure on the conventional Bow-Tie Structure. The Sierpinski Fractal bowtie antenna is designed and its radiation parameters are obtained. This paper is organized as follows: The design and simulation results of Sierpinski fractal bowtie antenna are discussed in Section II and Section III respectively while Section IV gives the conclusion.

DESIGN OF SIERPINSKI FRACTAL BOWTIE ANTENNA

The Sierpinski fractal bowtie antenna is designed by considering a rounded bowtie antenna as the base patch and the recursive iterations are designed by employing Sierpinski fractal structure in it. The base patch is designed by using the dimensions mentioned in Table 1 except that one arm of the bowtie is curved. The Sierpinski fractal bowtie antenna is derived by designing two iteration structures .The Sierpinski fractal structure is shown in the Fig 1. This structure is incorporated into the bowtie antenna to and the results are analyzed.

Figure 1. Stepwise design of Sierpinski Gasket.

Table 1. Dimensions of the Bowtie Antenna

Design Parameters	
Length of the Substrate (L)	70 mm
Width of the Substrate(W)	110 mm
Length of the feed (Lf)	30 mm
Width of the feed (Wf)	1.8 mm
Arm length	44 mm
Thickness of the Substrate (h)	1.2 mm
Dielectric Constant (ε_r)	3.5
Resonant frequency	4.5 GHz

a) Dimensions of Sierpinski Gasket

The Sierpinski gasket fractal antenna is obtained as follows. First the midpoint of three sides of the triangle is taken to form an inverted triangle which is then subtracted from the main triangle. After slotting the central part, three triangles remain on the structure, which is half of the main triangle. This slotting process can be obtained for any number of iterations. In this paper two iterations are formed. With reference to the above structure the proposed Sierpinski fractal antenna is obtained by the following iteration as shown in Fig 2. Fig 3 shows the structure of the proposed Multiband Sierpinski Structure.

(a) (b) (c)

Figure 2. Iterations of the Sierpinski Fractal Design.
(a) Basic structure (I0) (b) iteration 1(I1), (c) iteration 2 (I2).

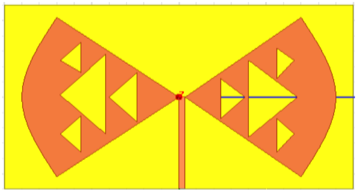
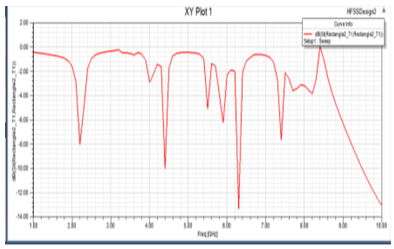


Figure 3. Structure of the proposed Sierpinski Fractal Bowtie antenna

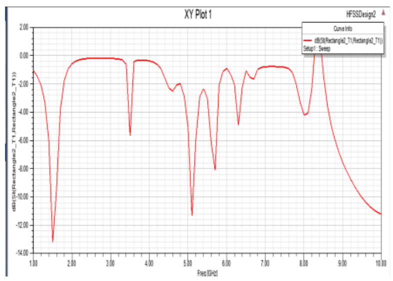
SIMULATION RESULTS OF SIERPINSKI FRACTAL BOWTIE ANTENNA

a*) Return loss*

Fig 4 gives the return loss plot obtained for iteration 0, iteration 1 and iteration 2 respectively. When compared to first iteration more no of frequencies are showing good return loss in the second iteration. Thus making second iteration promises the antenna suitable for multiband applications. The bandwidth obtained for 1.4 GHz,3.5 GHz,4.6 GHz and 7.4 GHz are 11%,6%,7% and 3% respectively. The return loss obtained is satisfactory; however the return loss can be further reduced below by choosing appropriate points. The bandwidth obtained for first and second iterations of the Sierpinski fractal antenna is greater than other conventional antennas found in literature.



(a)



(b)

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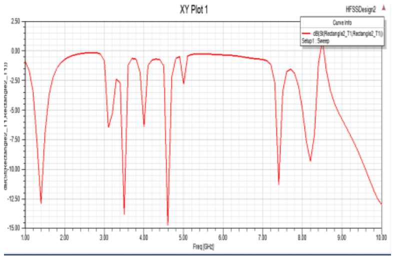
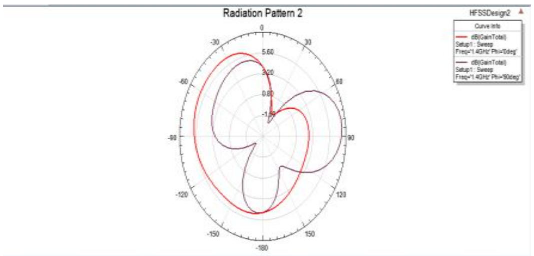


(c)

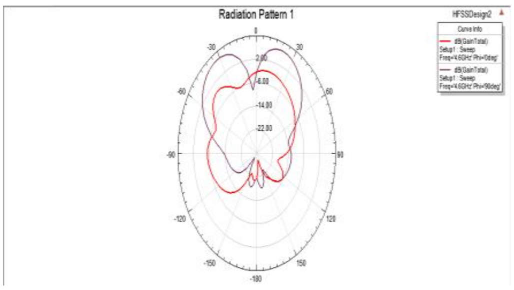
Figure 4. Return loss for the obtained frequency range a) iteration 0 b)iteration1 c)Iteration 2 .

b) Radiation pattern

Fig 5 shows the radiation pattern for the obtained frequencies in third iteration. The obtained gain for the frequencies 1.4 GHz, 3.5 GHz, 4.6GHz,7.4 GHz are 6.3849, 8.224, 5.7078 ,9.1595 respectively The radiation pattern is observed for phi=0˚ and 90˚ with theta constant .In I.4 GHz it is observed that at phi=0˚ a omni-directional radiation pattern is obtained and in phi = 90˚ it is unidirectional along 60 with presence of back lobes. In 3.5 GHz it is observed that for both phi=0˚ and 90˚ the radiation is omni directional with slight side lobes. Here the cross polarization is less when compared to 1.4 GHz. For 4.6 GHz it is observed that it is unidirectional along 60 with slight side lobes. The radiation pattern of 7.4 GHz is similar to that of 3.% GHz. It is observed that for both phi=0˚ and 90˚ the radiations are omni-directional with presence of slight side lobes It is inferred that for 3.5 GHz and 7.4 GHz the radiation pattern are omni-directional with more co-polarization whereas for 1.4 GHz and 4.6 GHz the radiation pattern are unidirectional with slight cross polarization.



(a)



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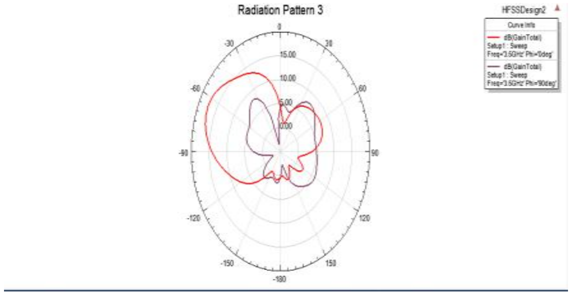

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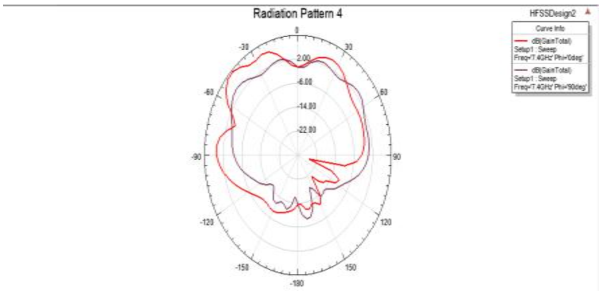

(d)

Figure 5. Radiation pattern for the frequency range a) 1.4GHz b) 3.5 GHz c) 4.6 GHz d) 7.4 GHz

(c) Current Distribution

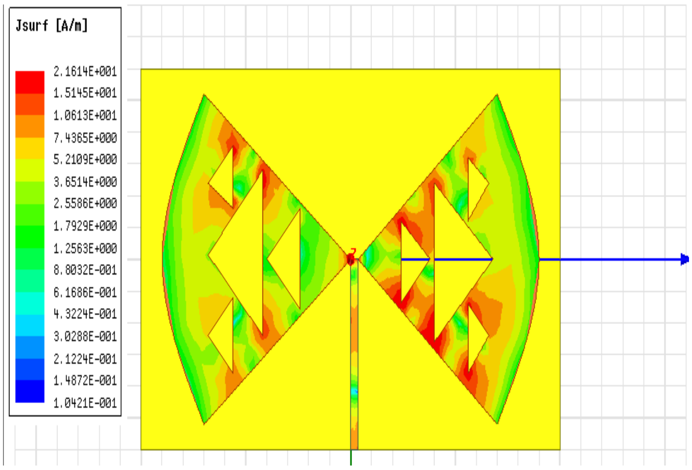

Figure 6. Current distribution of the proposed Sierpinski Gasket Bowtie antenna

It is seen that the strong current is distributed along the edge of the triangles incorporated inside the slot. When compared to conventional antenna the fractal antennas increases the electrical length by passing most of the current to flow through the patch. The minimum value of current is 0.10421 mA which is indicated by blue colour and the maximum value of current is 21.61 mA.

Table 2: Analysis of Return Loss of Sierpinski Fractal Antenna

Frequency (GHz)	Return Loss in dB		
	Iteration-2	Iteration-1	Basic Structure
1.4	-13	-10.2	-0.62
1.5	-7.0	-13	-0.67
2.4	-0.2	-0.2	-1.7
3.5	-14	-5.67	-0.5
4.1	-1.2	-0.46	-2.22
4.4	-0.7	-1.5	-10
4.5	-10.3	-16	-1.7
5.1	-0.4	-11	-0.4
5.6	-0.26	-6.24	-1.3
5.7	-0.28	-8.09	-1.5
5.8	-0.3	-2.10	-3.8
6.3	-0.4	-2.30	-13
6.6	-0.5	-1.5	-0.8
7.4	-11	-0.80	-7.6

Table 3: Analysis of Gain of Sierpinski Fractal Antenna

Frequency (GHz)	Gain in dB		
	Iteration-2	Iteration-1	Basic Structure
1.4	6.3632	2.0647	2.6667
1.5	6.814	6.384	2.6667
2.4	12.384	2.4377	3.4853
3.5	9.224	5.6318	2.3861
4.1	2.4047	0.9696	2.9949
4.4	2.6085	2.3438	4.7845
5.1	3.0078	8.7044	2.0248
4.5	6.7078	3.6175	3.7902
5.6	0.8002	3.6272	4.6432
5.7	0.7051	11.924	5.1277
5.8	0.6995	8.3865	5.3048
6.3	1.6582	4.6437	4.2031
6.6	2.8111	5.9353	6.9863
7.4	9.1595	4.2001	5.8307

CONCLUSION

Thus a bowtie antenna is designed by employing Sierpinski Gasket Fractal Structure and the results are analysed. The above design are done only for two iterations .The proposed antenna can be designed for further iterations and further more multi bands can be obtained .However when the number of iterations increases the deign becomes complicated and fabrication of such design becomes a tedious one. The increase in gain of the Sierpinski fractal bowtie antenna is evident from the current distribution. Sierpinski fractal antenna produces the maximum current at each edge of the triangular slots etched and thereby increasing the gain of the antenna. The designed antenna can be used for many wireless applications. However the overall size of the antenna is large which makes it less suitable for inbuilt applications. Further size reduction can be done by using asymmetric fractal structures which might be the future work.

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