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Design and Analysis of New Sierpinski Carpet Fractal antenna

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ABSTRACT

Design and analysis of new geometry for microstrip patch Sierpinski carpet fractal antenna is discussed. This Fractal structure is implemented on square and several iterations are applied on initial shape. This antenna has low profile with dimensions of 80X80X1.6 mm, low weight and easy to fabricate with coaxial feeding. The simulation results show that the proposed antenna has very good performance in return loss, impedance bandwidth and radiation characteristics. Finite element method has been employed for studying various other antenna parameters like gain and field distributions. Effect of antenna iterations stresses upon reducing metal usage thereby saving cost and also achieved good reflection coefficient.

Keywords: Sierpinski Carpet, Fractal Antenna, Impedance bandwidth, Field distributions.

1. INTRODUCTION

Fractal antenna has been proved to be an effective technique to design small and multiband antennas. Fractal antenna geometry represents self similarity and repeats itself in different dimensions filling the space effectively [1-2]. The advantages with the fractals are of multiple electric dimensions, self loaded to 50 ohm, auxiliary reactance and capacitance not needed, mutual coupling between array elements can be reduced substantially and many more. Several geometries are available like Helix, Koch curve, Hilbert curve and Sierpinski carpet etc. the reason why there are no more novel fractal antennas emerged in recent years is mostly that fractal geometry is complicate and difficult to be constructed through its configuration rule is only virtually simple iteration[3-5].

There is an important relation between the antenna dimensions and the wavelength. The relation states that if antenna size is less than λ/4 then antenna is not efficient because radiation resistance, gain and bandwidth are reduced and therefore antenna size is increased. Fractal geometry is very good solution for this problem. These structures are recognized by their self similarity property and fractional dimension [6-8]. In the recent years, the geometrical properties of self similar and space filling nature has motivated antenna design engineers to adopt this geometry a viable alternative to meet the target of multiband operation. Fractal dimensions, self similar and scaling properties, characterize these structures. The structures that are studied as antenna are not the once that we obtained after infinite iteration but those after finite iterations as desired by the designer. The space filling property lead to curves those are electrically very long but fit into a compact physical space. This property can lead to the miniaturization of antennas [9-10].

2. ANTENNA GEOMETRY

The proposed antenna consists of a Sierpinski carpet radiator on the top side of substrate material. A substrate material of RT-duroid with dielectric constant 2.2 and loss tangent 0.009 is taken in the design. The Sierpinski carpet antenna is in essence a square metallic patch divided into different congruent sub squares as shown in the figure. Unlike to the original Sierpinski antenna constructions reported in the literature in which smaller slot elements are added to the basic structure [11-12], in the new design, for higher iterations, the smaller slot elements are subtracted. In the first iteration, equal spaced double square slots are placed on the two sides of the patch as shown in figure 1. In the second iteration, single column square slots are placed on either side to the patch as shown in figure 2. From third iteration onwards we increased the number of slots and placed them in a systematic way. The feeding location is left uncovered with slots to eliminate feeding problems. The total dimension of the antenna is around 80X80X1.6 mm.

The calculation for resonant frequency corresponding to the operating band is

$$f_r = 0.26\frac{c}{h}\partial^n$$

For conventional sierpinski gasket geometry, the scale factor is taken to be two. Song et al proposed the following expression for the resonant frequency in a given band, which is valid even in cases where the geometry is perturbed to get different scale factors:

$$f_r \approx (0.15345 + 0.34\rho\kappa)\frac{c}{h}(\xi^{-1})^{\kappa}$$

Where $\xi = \frac{h_k}{h_{k+1}}$ is the ratio of the height of the gasket in the kth iteration to that in the (k+1)th iteration and, $\partial = \frac{1}{\xi}$ is the scale factor, as mentioned. If $\partial = 2$ then ξ is 0.5, $\rho = \xi - 0.230735$ and,

$$x = \begin{cases} 0\,, & k = 0 \\ 1\,, & k > 1 \end{cases}$$

The simplification of the equation provided by the Puente et al .is illustrated as

$$f_r \approx [0.15345 + 0.34(0.5 - 0.230735)]\frac{c}{h}\partial^{\kappa} = 0.245\frac{c}{h}\partial^{\kappa}$$

In light of the above notes,the equation with the effective height h_c, consideration of the largest sierpinksi gasket can be given as:

$$h_e = \frac{\sqrt{3}}{2}s_e$$

"s_e" is given as $s_e = s + t(\varepsilon_r)^{-0.5}$

With't' being the effective thickness of the substrate, the inclusion of the effective height can be given as

$$f_r \approx \begin{cases} (0.15345 + 0.34\,\rho x)\frac{c}{h_e}(\xi^{-1})^n & for\ \ n = 0 \\ 0.26\,\frac{c}{h_e}\,\delta^n & for\ \ n \rangle 0 \end{cases}$$

We can use the following expression for the prediction of the resonant frequency:

$$f_r \approx \begin{cases} (0.15345 + 0.34\,\rho x)\frac{c}{h}(\xi^{-1})^n & for\ \ n = 0 \\ 0.26\,\frac{c}{h}\,\delta^n & for\ \ n \rangle 0 \end{cases}$$

In the above equation $\rho = \xi - 0.230735$.

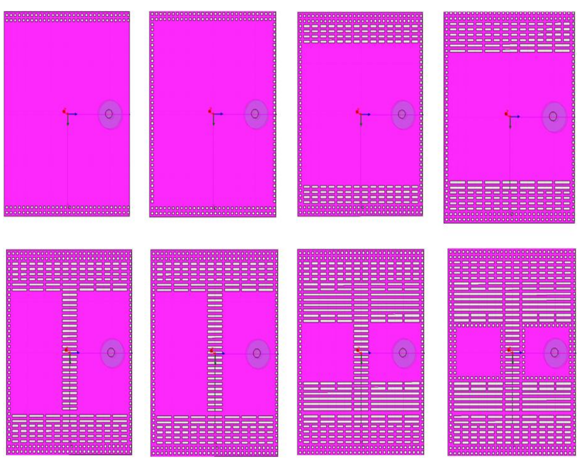

Figure 1: Sierpinski Carpet Fractal Antenna Iterations

3. RESULTS AND DISCUSSION

In order to assess the effectiveness and reliability of the design, analysis is carried out and some representative results are reported in the following to give an overview of the performance. All the simulated data have been obtained by means of an electromagnetic simulator on the Finite Element Method (FEM). By considering the electrical performance of the antenna, simulation results of return loss parameter |S11| are shown in figure 2, which consisting of return loss curve for all the iterations with respect to the frequency. The impedance matching requirements at these frequencies are fully satisfied as indicated by the simulated values of |S11|, the return loss and the resonating frequencies are tabulated for all eight iterations are presented in the table 1. The bandwidth of the antenna is calculated at -6dB return loss by taking its limits at the upper frequency and lower frequency.

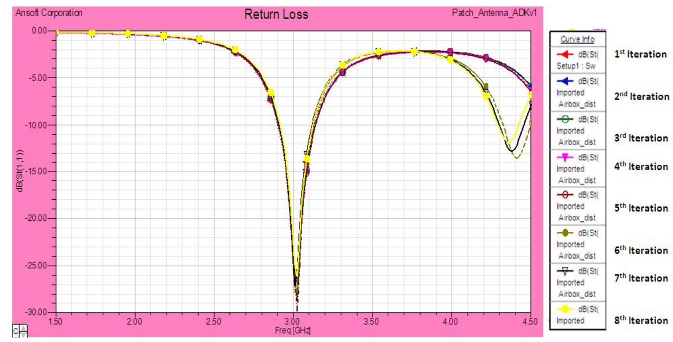

Figure 2 : Return loss Vs Frequency for all the Iterations

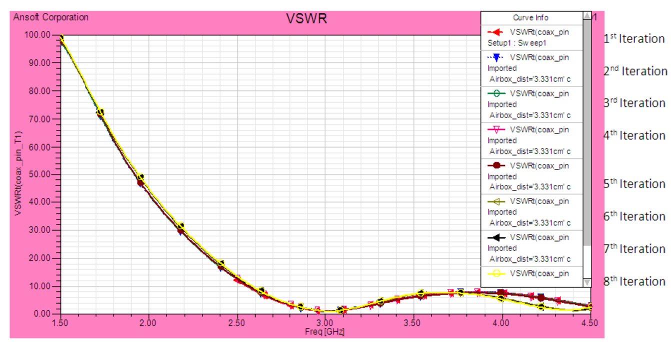

Figure 3: VSWR Vs Frequency for all the Iterations

For first five iterations the fractal antenna is resonating at single band, but from iteration six to eight, it is resonating at dual band. Surprisingly for all the eight iteration models there is no such change in the resonant frequency, except the dual band from iteration six. The peak gain and radiation efficiency is also showing stable results for all the iterations.

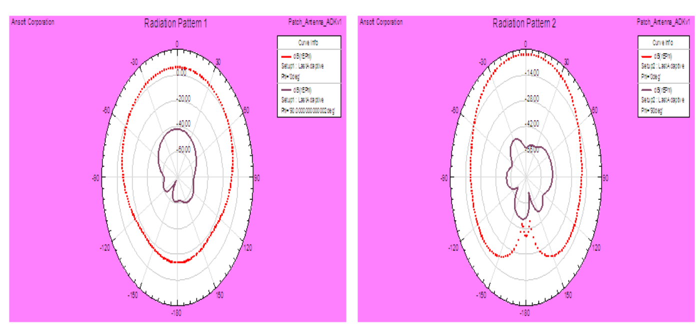

Figure 4 : Radiation Pattern at phi=0^0 and 90^0 at 3GHz and 4.3 GHz of Iteration 8

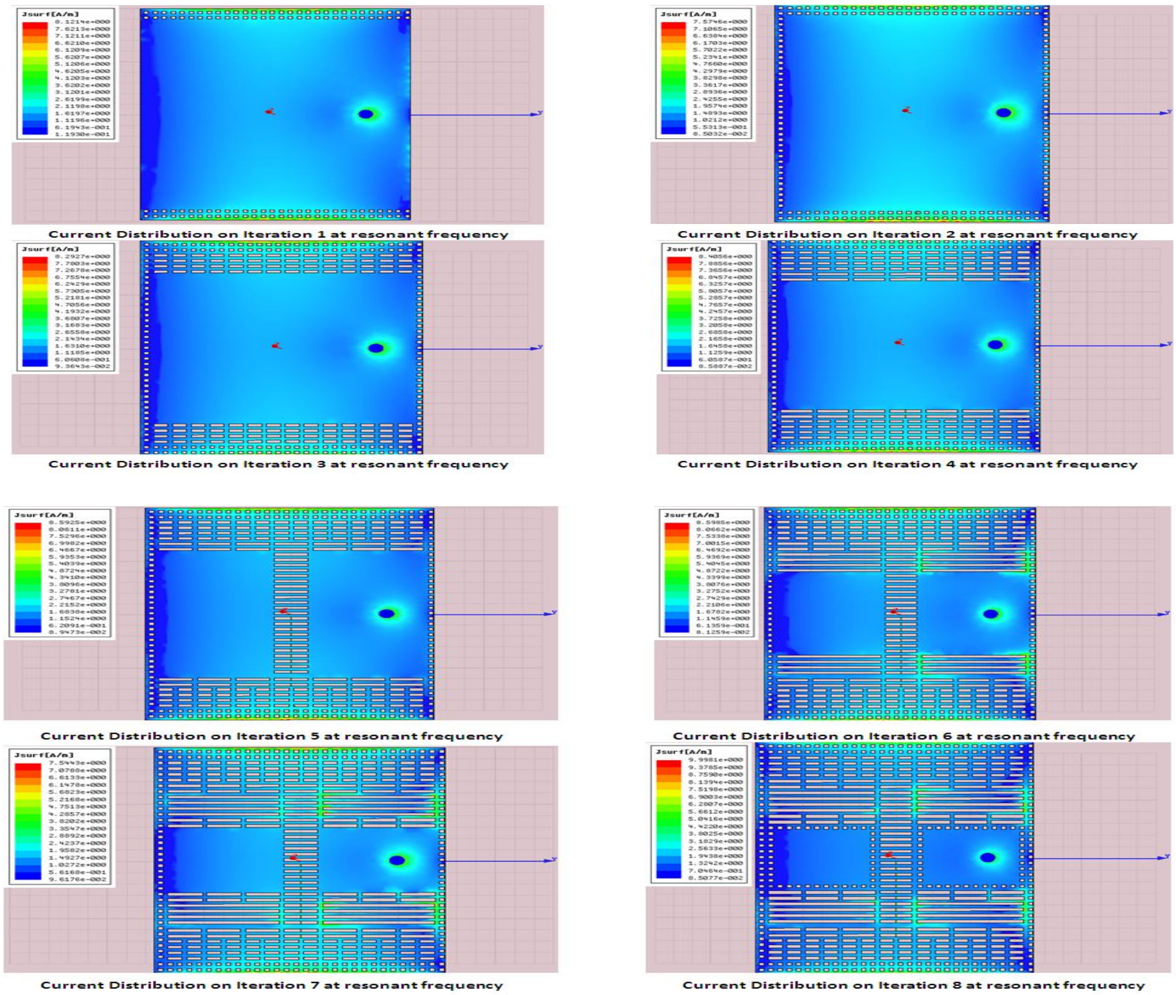

Figure 5 : Current distribution plots for 8 Iterations

Table 1 : Antenna Results

S.No	Iteration	Resonant frequency(GHz)	Return loss(dB)	VSWR	Gain(dB)	% Bandwidth
1	Iteration 1	3.0075	-27.78	1.08	8.28	0.2%
2	Iteration 2	3.0226	-28.26	1.08	8.29	0.3%
3	Iteration 3	3.0226	-28.51	1.07	8.29	0.3%
4	Iteration 4	3.0226	-29.33	1.07	8.28	0.3%
5	Iteration 5	3.0226	-29.82	1.06	8.28	0.4%
6	Iteration 6	3.0226 & 4.4095	-27.87 & -13.59	1.08 & 1.53	8.29	0.6%
7	Iteration 7	3.0075 & 4.3794	-27.12 & -12.82	1.09 & 1.61	8.28	0.6%
8	Iteration 8	3.0226 & 4.3643	-26.12 & -11.89	1.11 & 1.71	8.28	0.5%

Table 2: Antenna Output Parameters

S.No	Antenna Parameters	Iteration 1	Iteration 2	Iteration 3	Iteration 4	Iteration 5	Iteration 6	Iteration 7	Iteration 8
1	Max U	0.006134	0.006121	0.006103	0.00605	0.00604	0.00533	0.00527	0.0052
2	Peak Directivity	6.9898	6.9842	6.9698	6.9506	6.9541	6.9178	6.919	6.8984
3	Peak gain	6.9656	6.9565	6.9308	6.9093	6.9116	6.8742	6.8838	6.859
4	Peak realized gain	6.932	6.9217	6.8936	6.8722	6.8727	6.8465	6.862	6.8232
5	Radiated power	0.011082	0.011015	0.011005	0.01094	0.01092	0.00969	0.00957	0.009542
6	Accepted power	0.011075	0.011059	0.011067	0.011009	0.010987	0.009760	0.009621	0.009596
7	Incident power	0.011119	0.011114	0.011126	0.011069	0.011049	0.009799	0,009651	0.009647
8	Radiation efficiency	0.99658	0.99604	0.9944	0.99406	0.99389	0.9937	0.9949	0.99429
9	Front to back ratio	122.84	121.51	113.71	113.33	115.34	115.69	119.62	116.12

For essential revilement of fractal behavior of the proposed geometry, we illustrated surface current distribution of resonant frequencies of all the models, as shown in the figure 5. The fractal antennas are fed with coaxial probe with perfect matching by placing at proper feed location. EM wave propagates along the fractal lateral sides to the base side attenuating on and on. Low frequency has long wavelength and can travel to the furthermost while high frequency has a shorter wavelength and can only travel to the proximal ends away from the base side vertices. Figure 4 shows the antenna radiation pattern at phi=$0^0$and 90^0 for iteration 8, which is resonating at dual band.

4. CONCLUSION

Novel Fractal microstrip antennas with different iterations are successfully demonstrated. The antenna is compact, simple to design and easy to fabricate. A significant stable gain is achieved. The proposed antenna has circular polarization at one of its resonance frequencies, which is realized by producing a perturbation on its initial structure. Further miniaturization of antenna is obtained by cutting slots on its structure. The return loss and the gain are almost stable at the resonating frequencies for all the iterations.

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