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Design of Combinational Fractal Microstrip Patch Antenna using Two Feeding Techniques

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Abstract **– The great advances in communication system led to the demand of a multi-band, larger gain, compact, low-profile fractal antennas to hold up multiple wireless applications. The self-similarity property of Fractal antenna is advantageous in generating multiple frequencies or enhancing bandwidth. This paper describes the design and simulation of combination of sierpinski and crown shaped fractal antenna up to third iteration on IE3D software The propounded antenna is designed on 1.6mm thick FR4 substrate with dielectric constant, E_r of 4.4 and is fed with 50 ohms for two types of feeding and is mounted above the ground plane at a height of 6 mm.**

Details of the measured and simulated results of the individual iterations is presented and discussed.

Keywords **– Feed, Fractal, Microstrip Antenna, Sierpenski Fasket.**

I. Introduction

In communication system, variety of microstrip antennas are being utilized, the most usual of which is microstrip patch antenna [12]. A patch antenna is a narrow band, wide-beam, low-profile, light-weight, conformal-shaped antenna fabricated by etching the antenna element pattern in metal trace joined to an insulating dielectric substrate. It is incorporated with a flat rectangular sheet or "patch" of metal, mounted over a larger sheet of metal called a ground plane. A patch antenna is mainly constructed on a dielectric substrate employing the same materials & lithography techniques in order to make printed circuit boards. Microstrip or patch antennas [6] are becoming more and more useful because they can be printed directly onto a circuit board. Furthermore, they are becoming ubiquitous within the mobile phone market [1]. These are somewhat inexpensive to manufacture and design because of the simple 2-dimensional physical geometry. These are also proficient of dual & triple frequency operations. These are highly efficient, easily integrated to circuits, compatible to the planer & non-planer surfaces and MMIC design. All these features make microstrip antennas widely implemented in many applications, such as high performance aircrafts, wireless communication satellite and missile applications. Fractal antennas [11] can be put to use in a variety of applications, especially where space is minimal. An exemplar illustrating the advantages of fractal in antenna system is the phased arrays, where fractals can diminish mutual coupling. Additionally, microstrip patch antennas are also subjected to some drawbacks, Narrow bandwidth being a serious curb. Different techniques [2] are proposed to improve it, and one of the methods proposed by various researchers is by cutting slots on it.

In this paper we have presented a design of microstrip Patch antenna using Crown & Sierpienksi fractal slots [13], with an aim to achieve a smaller size antenna [4]. Target of this work is to design a microstrip patch antenna and carrying out results using commercial simulation software like IE3D. IE3D, from zeland software, Inc.[7], is an electromagnetic simulation and optimization software useful for circuit and antenna design. IE3D has a menu driven graphic interface for model generation with automatic meshing, and uses a field solver based on full wave , method-of-moments to solve current distribution on 3D and multilayer structures of general shape. IE3D usually focuses on general planar and 3D metallic structures in layered dielectric environments.

II. Design of Fractal Antenna

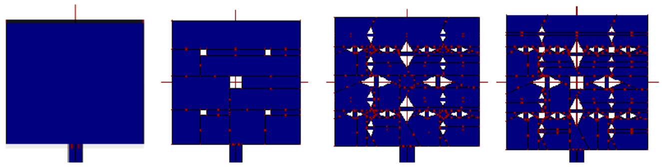

Fig.1. Sierpenski & crown combinational with Reference, 1st iteration, 2nd iteration, 3rd iteration

Design Parameters

The transmission line model is used to design rectangular microstrip fractal antenna.

Patch Width and Length

The first step is to design the patch is choosing a suitable di-electric substrate of suitable thickness. For rectangular microstrip antenna, the width W and the length L depends on the resonant frequency f_r and the parameters of the substrate employed [9]

To design the rectangular patch width of the antenna is given by-

Width of the Patch

$$W = \frac{c}{fr}\sqrt{\frac{2}{Er+1}} \qquad (1)$$

Where, c is the speed of light,

f_r is the resonant frequency.

Effective Dielectric Constant

$$\epsilon_{reff} = (\epsilon_r + 1)/2 + (\epsilon_r - 1)/ 2\sqrt{1 + 12\, h/w} \qquad (2)$$

Where, ϵ_{reff} is the effective dielectric constant,

ϵ_r is the dielectric constant,

h is the height of the substrate,

W is the width of the patch.

Taking into Account the Fringing Effect

The fringing fields along the width of the structure are taken as radiating slots and the patch antenna is electrically seen to be a bit larger than its physical size.

$$\Delta L = 0.412h\,\frac{(\epsilon reff+0.3)\left(\frac{W}{h}+0.264\right)}{(\epsilon reff+0.258)\left(\frac{W}{h}+0.8\right)} \qquad (3)$$

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Calculating the effective length of the patch

$$Leff = \frac{c}{2fr\sqrt{\epsilon r}} \quad (4)$$

Calculating the actual length of the patch

$$L = Leff - 2\Delta \quad (5)$$

There are various ways to feed a microstrip fractal antenna and we have used the coaxial feed & microstrip line feed technique[15].

II. MICROSTRIPLINE

First Iteration

First a microstrip patch at the required operating frequency is designed. One crown square fractal slot is cut from the centre and 4 crown square fractal slots are cut on each corner of the central slot. The dimension of the central crown square fractal slot is 4-4(length-width) and the dimensions of each of the four corner fractal slots are 2-2(length-width).The length of the microstrip patch is L= 20 mm and W=20 mm. Figure 2 shows the location of the feed. The feed location is adjusted so as to connect to the metallic portion of the patch.

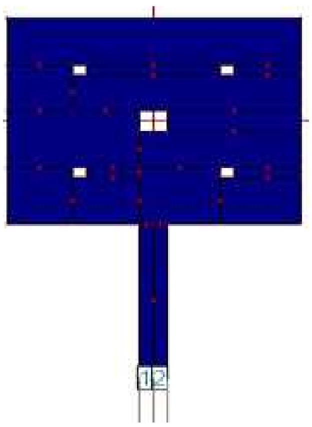

Fig. 2. The model for 1st iteration

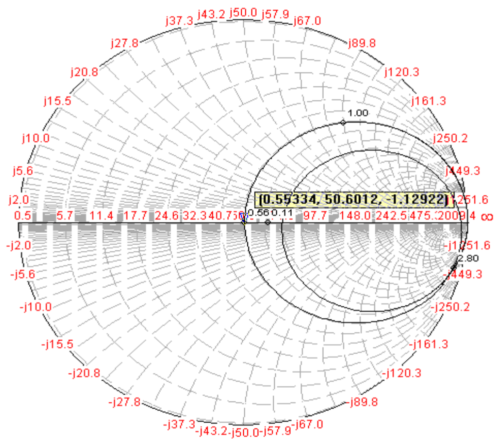

Fig. 3. Input impedance loci using smith chart of first iteration

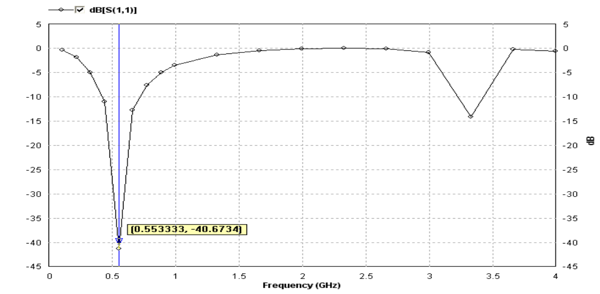

Fig.4. S11 parameter

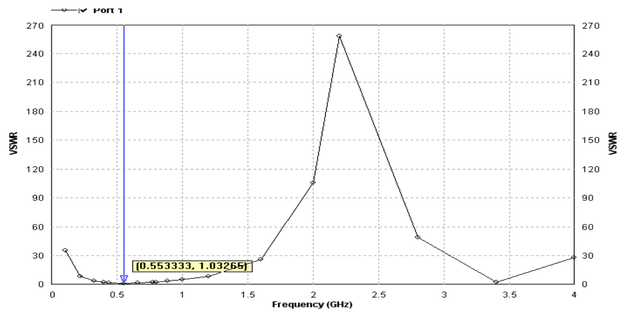

Fig. 5. VSWR

Figure 2 shows the model of I[st] iteration antenna. Figure 3, 4, 5 shows the results from IE3D simulations, as may be noted that the antenna has a good return loss of magnitude -40.6734 at the frequency 0.553333.

Second Iteration

The geometry of iteration II of proposed microstrip patch antenna using Crown & Sierpienksi fractal slots is presented. This design comprised of four Sierpienksi fractal slots which are cut facing each side of the rectangular microstrip antenna, again four Sierpinski fractal slots are cut facing the centre of the patch. The dimensions of these eight Sierpienksi fractal slots are 4-4(base-height) Then between each of these Sierpienksi fractal slots and the corners of the rectangular microstrip antenna eight Sierpienksi fractal slots, with dimensions of 2-2(base-height) each, in the same design are cut.

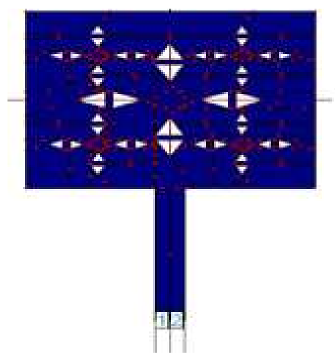

Fig. 6. The model for 2[nd] iteration

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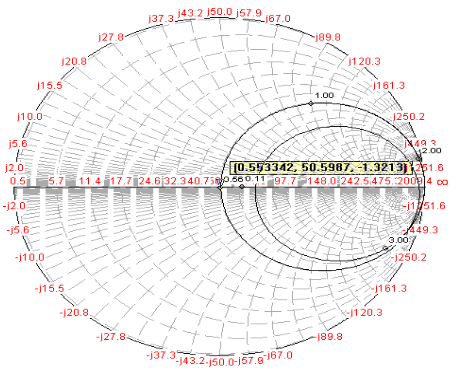

Fig. 7. Input impedance loci using smith chart of second iteration

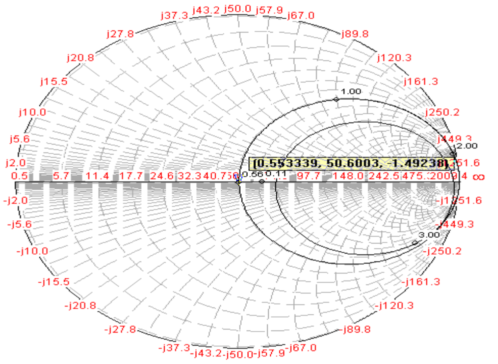

Fig. 11. Input impedance loci using smith chart of third iteration

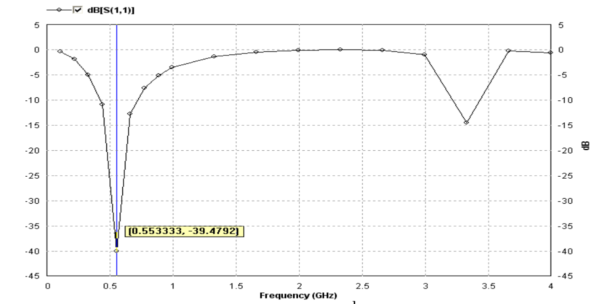

Fig. 8. S11 parameter for 2nd iteration antenna

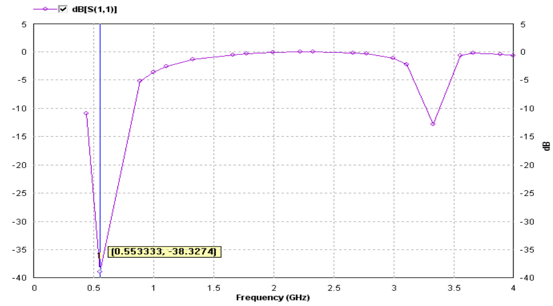

Fig.12. S11 parameter

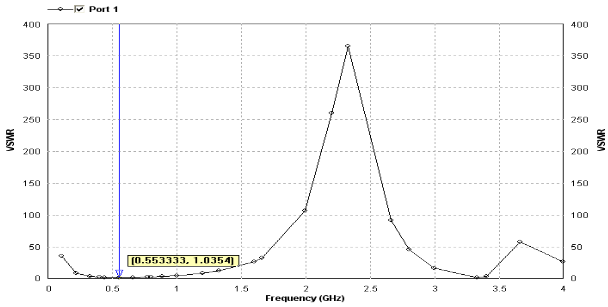

Fig. 9. VSWR

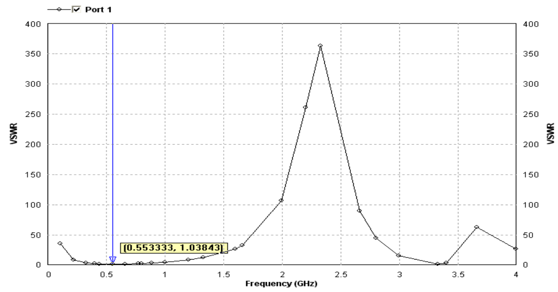

Fig. 13. VSWR

The figure 6 shows the model of 2nd iteration antenna. Figure 7, 8, 9 shows the results from IE3D simulations, as may be noted that the antenna has a good return loss of magnitude -39.4792 at the frequency 0.553333.

Third Iteration

The geometry of 3rd iteration of proposed microstrip patch antenna using Crown & Sierpienksi fractal slots presented. Third iteration is obtained by combining the geometry of both iterations 1 & 2.

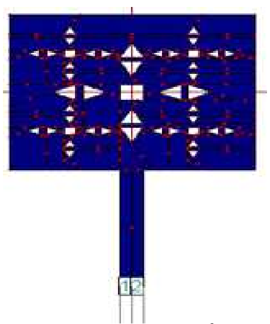

Fig. 10. The model for 3rd iteration

The figure 10 shows the model of 3rd iteration antenna. Figure 11, 12, 13 shows the results from IE3D simulations, as may be noted that the antenna has a good return loss of magnitude -38.3214 at the frequency 0.553333.

III. Probe Feed

Iteration 1

The figure 14 shows the model of Iteration 1 for probe feed antenna & the input impedence loci using smith chart. The points for the probe feed are (x, y) = 3, 9).

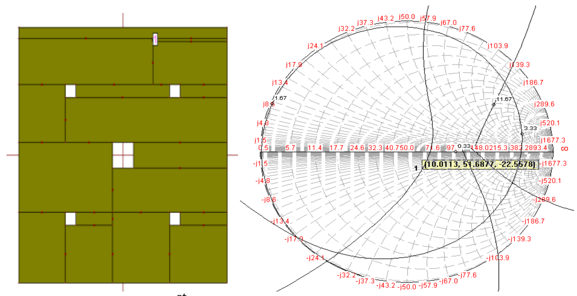

Fig. 14. Model for 1st iteration, I/P impedance loci using smith chart

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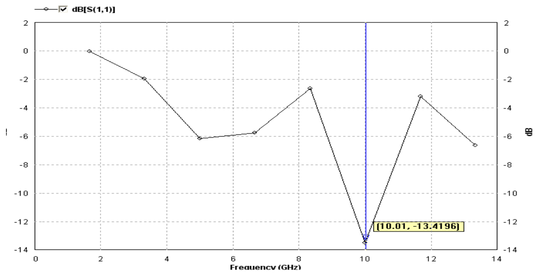

Fig. 15. S11 Parameter

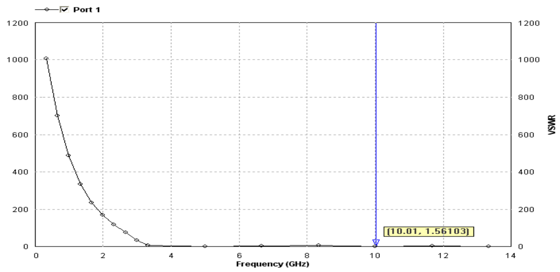

Fig.16. VSWR

Iteration 2

Fig. 17 shows the location of the probe feed. The probe feed location is adjusted so as to connect to the metallic portion of the patch & where a max. return loss is observed. Fig. 18, 19 presents the results from IE3D simulations.

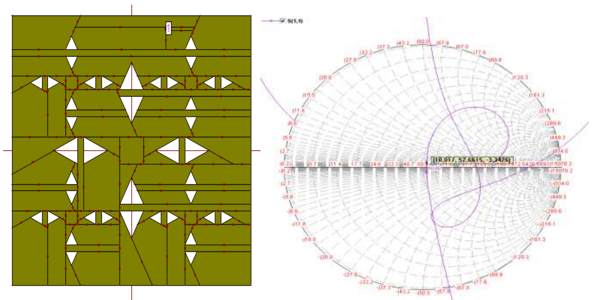

Fig. 17. Model for 2nd iteration, smith chart

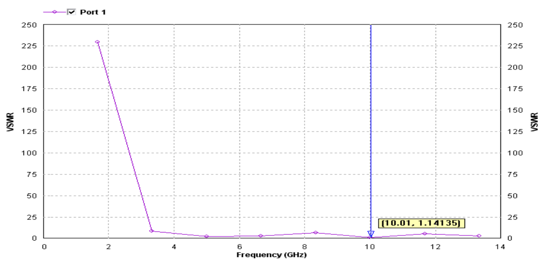

Fig.18. VSWR

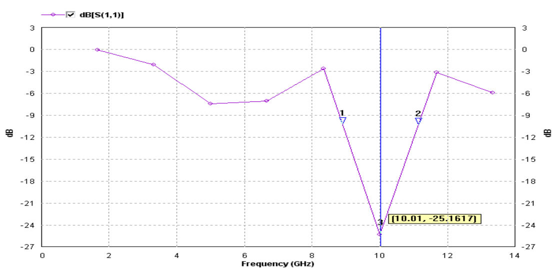

Fig.19. S11 Parameter

Iteration 3

Fig. 20 shows Iteration 3 for probe feed & the location of feed. The probe feed location is adjusted so as to connect to the metallic portion of the patch and where a maximum return loss is observed. Fig. 21 and 22 shows the results from IE3D simulations.

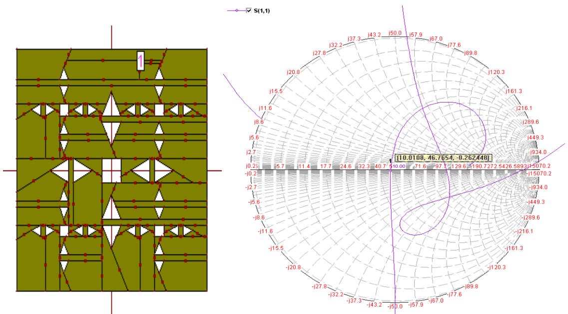

Fig. 20. Model for 3rd iteration, smith chart

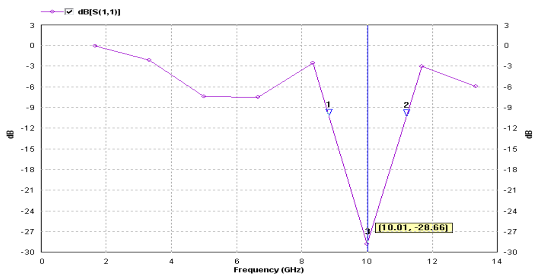

Fig. 21. S11 Parameter

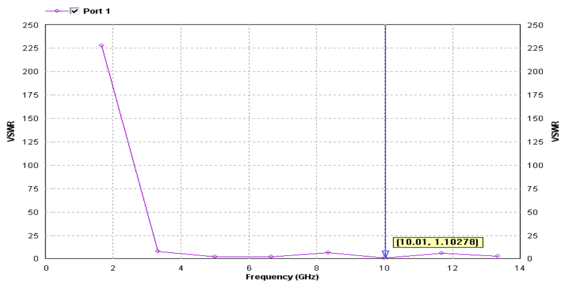

Fig. 22. VSWR

Table 1. Comparison of different results of Iteration 1, 2&3

TRANSMISSION –LINE FEED

Types	Iteration 1	Iteration 2	Iteration 3
Resonant frequency	0.553333	0.553333	0.553333
Bandwidth	53.01%	53.02%	53.04%
VSWR	1.03265	1.0354	1.03843
Return Loss	-40.6734	-39.4792	-38.3214

PROBE FEED

Types	Iteration 1	Iteration 2	Iteration 3
Resonant frequency	10.01	10.01	10.01
Bandwidth	10.7%	22.37%	23.78%
VSWR	1.56103	1.14135	1.10278
Return Loss	-13.4196	-25.1617	-28.66

IV. Conclusion

Design is simulated and result of the designed antenna is obtained using two different feeding techniques [14]. Traditionally, the wideband antennas (spiral and log-periodic) and arrays [10] designed using Euclidean geometry [8]. The results demonstrated a maximum patch size reduction by the propounded fractal antennas, without deteriorating antenna's performance, such as the return loss and radiation pattern, vswr. This size reduction technique is loading the inductive elements along the patch edges, and loading self-similar slots inside the patch, to increase the length of the current path. The basis of the maintenance of the antenna radiation patterns is the self-similarities and centro symmetry of the fractal shapes [9].

The main advantages of the propounded method are: (i) size reduction (ii) maintained radiation patterns, (iii) wider operating frequency bandwidth (iv) simple and easy design. Thence, this is the most effective technique propounded for the size reduction of microstrip patch antennas so far. The small-sized patches obtained from this technique can be used in integrated low-profile wireless communication systems positively. In future fractal microstrip antenna reduced patch size and improved bandwidth can be achieved definitely.

The simulated results indicate that the antenna is suitable for wireless LAN [14] & networkable PDA, satellite communication (Direct broadcast TV), vehicle speed detection.

V. Results and Discussion

The propounded antenna has been simulated by using IE3D by Zealand Software Inc.[7] . It is considered as a standard for electromagnetic simulation packages. The prime formulation of the IE3D is an integral equation that is obtained through the use of Green's functions. This paper presented a square microstrip patch antenna combining [13] Crown and Sierpienksi fractal slots is fabricated on a FR4 substrate of relative permittivity of 4.4 & thickness 1.6 mm. It is mounted above the ground plane at height of 6 mm. [5]

Table 1 shows the variation of return loss with frequency, VSWR and Bandwidth for iteration I, II and III for transmission line feed & coaxial feed. [3]

Plot result shows resonant frequency 0.553333 GHz for transmission line feed & 10.01 GHz for coaxial feed. Return loss for the iteration I, II & III is -40.67, -39.47 & -38.32 respectively for transmission line feed. Return loss for the iteration I, II & III is -13.41, -25.16 & -28.66 respectively for coaxial feed.

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