A Wide band Miniaturized Square Patch Antenna with Kite-shape fractals for WLAN/Wi-Fi Applications

Prof. B. B. Tigadi
Department of Electronics & Communication
Maratha Mandal College of Engineering
Karnataka, India.

Dr.V. R. Udupi
Principal
Maratha Mandal College of Engineering
Karnataka, India.

Abstract— This paper presents line fed miniaturized square fractal antenna containing small Kite-shape fractals. The proposed patch antenna is designed with a resonating frequency of 2.4 GHz and FR4 dielectric substrate and the fractals are introduced step by step. The Fractal antenna is developed through the iterative process for bandwidth enhancement without scarifying the gain much. The antenna design is simulated and optimized using Zealand IE3D EM simulation software to regulate the geometry for better performance. The improved antenna characteristics like frequency response, return loss, radiation pattern and efficiency make it suitable for Wireless Local Area Network WLAN and Wi-Fi applications.

Keywords—Kite shape Fractal; Bandwidth; ZelandIE3D; Gain; Wireless Local Area Network (WLAN); Return loss; radiation pattern .

I. INTRODUCTION

The Microstrip patch antennas are gaining importance in wireless communication because of their inherent advantages. But these antennas suffer from demerits like narrow bandwidth, low gain and low efficiency. There are several techniques to mitigate these demerits. The main prerequisite of most of the wireless communication systems is the design of low profile, wideband or multi-band miniaturized antennas [1]. The antenna will not be competent if its size is less than quarter wavelength [2]. The suitable solution to this problem is a Fractal geometry which contains self- similar elemental structures called Fractals. The deterministic fractals are created of numerous scaled-down duplicates of themselves. The self similar structure of Fractal antennas lead to bandwidth improvement and multi-band operation capability [2-4]. The typical examples are Sierpinski gasket, Koch loop and Minkowski island etc. The initiator may be of square, triangle, circular or Polygonal structure. The random Fractal antennas consist the elements of randomness which permit the simulation of natural phenomena. The fractals are created by carrying various iterations starting from initiator.

In recent years, lot of research activities are taking place in the fractal antenna field because of its attractive merits. Super wide bandwidth is achieved by creating Triangular fractals in an octagonal patch [2,7]. In [5], a coplanar waveguide fed Koch fractal antenna is developed for WLAN/WiMAX applications. Multiband operation is demonstrated by designing Fractal microstrip antenna with Lotus pod fractals [6]. The fractal antenna geometry also contains self-similar slots which increase fringing but the presence of slots leads to decrease in overall metal area which reduces the gain.

In this paper, section I presents introduction. Section II describes the calculation of initiator size using various design equations and development of fractal antenna. Section III covers simulation process of antenna and discussion of results. Lastly, significant conclusions are made in section IV so that proposed antenna is used for some important applications.

II DESIGN OF PROPOSED ANTENNA

The geometry creating process begins with a basic calculation of dimensions of a patch, then inserting the fractals. Initially, the dimensions of rectangular microstrip patch antenna are determined using the design equations as depicted below [6]. The basic rectangular patch antenna called initiator is designed with a resonating frequency of 2.4 GHz, FR4 substrate with a dielectric constant $\varepsilon_r = 4.4$, substrate height h =1.6 mm and loss tangent δ=0.002. The dimensions of rectangular patch antenna are: patch length L_p = 28 mm, patch width W_p = 39 mm, ground plane Length L_g = 38 mm and ground plane width W_g = 49 mm. The patch is truncated to the size of 28mmX28 mm which pushes the resonance frequency to the specified value without affecting the antenna performance much.

The width of a patch is calculated using the formula

$$W_p = \frac{c}{2f}\sqrt{\frac{2}{\varepsilon_r+1}} \qquad (1)$$

Where 'ε_r' is the dielectric constant, 'c' is velocity of light and 'f' is the resonant frequency of antenna.

In the process of fringing, the field lines propagate both in air and the dielectric substrate hence effective dielectric constant is calculated using the formula,

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{\varepsilon_r} + \frac{\varepsilon_r-1}{\varepsilon_r} * \left[1+12\frac{h}{w}\right]^{-\frac{1}{2}} \qquad (2)$$

Where, 'h' is the height of the substrate and 'w' is width of the patch.
The effective patch length is

$$L_{eff} = \frac{c}{2f\sqrt{\varepsilon_{reff}}} \qquad (3)$$

The patch length extension ΔL is

$$\Delta L = h * 0.412\left[\frac{\varepsilon_{reff}+0.300}{\varepsilon_{reff}-0.258}\right] * \left[\frac{\frac{w}{h}+0.262}{\frac{w}{h}+0.813}\right] \qquad (4)$$

The actual length of a patch is

$$L_p = L_{eff} - 2\Delta L \qquad (5)$$

The ground plane dimensions are:

Length of ground plane

$$L_g - L_p + 6h \qquad (6)$$

Width of ground plane

$$W_g = W_p + 6h \qquad (7)$$

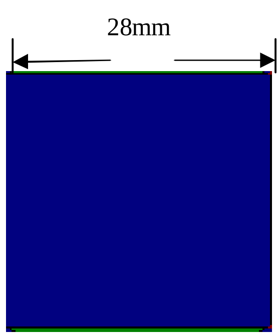

Fig.1. Square Patch Initiator

The antenna with fractal geometry is achieved through iteration process in which the fractals are gradually introduced in the initiator. In the first iteration, there are four fractals placed along the diagonals as shown in Fig.2. The number of fractals are increased iteration by iteration as shown in Figures 2, 3 and 9. The fractals are self-similar scaled down elements of a leader which resemble kite. This microstrip patch antenna exhibits diagonal symmetry and can be referred as diagonally symmetric microstrip fractal antenna (DSMFA) with Kite shape fractals. In all the iterations, the antenna structures are fed by microstrip line feed as it is simple and easy to fabricate [7].

III RESULTS AND DISCUSSION

The Fractal patch antenna structure is configured and simulated using Zealand IE3D software. In iteration I, there are four fractals arranged along the diagonals as shown in Fig.2. It exhibits minimum return loss of -11 dB at a resonating frequency 2.3 GHz but maximum gain is 3.7 dBi at 2.2 GHz. The bandwidth at -10 dB return loss is 180 MHz. However radiation efficiency has almost constant value 60% in the frequency range 1.5 GHz to 2.25 GHz where as overall antenna efficiency is 53%.

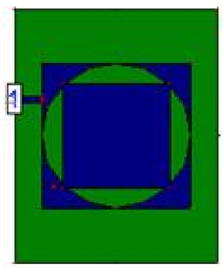

Fig.2.Iteration-I

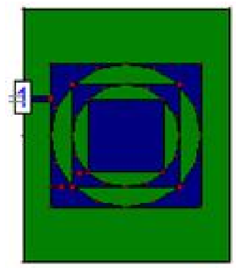

Fig.3.Iteration-II

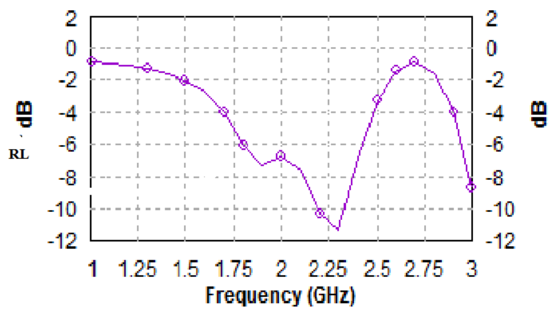

Fig.3. Return Loss(RL) for Iteration-1

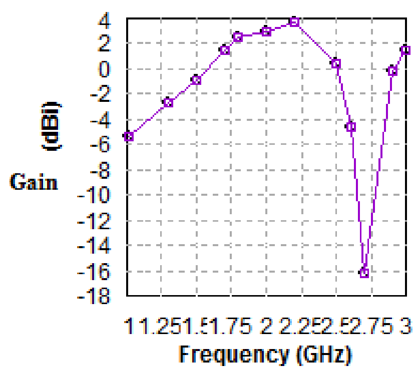

Fig.4. Frequency Response of Iteration-1

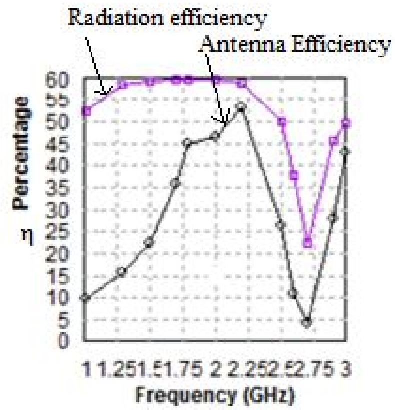

Fig.5. Efficiency(η) vs frequency for Iteration-1

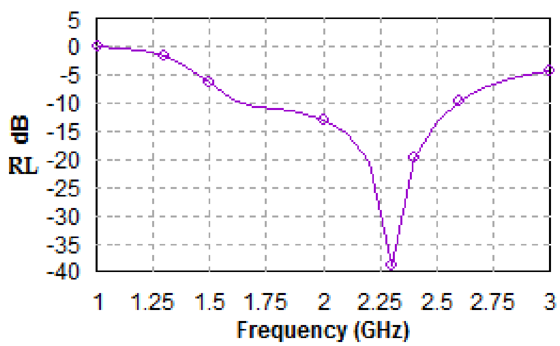

Fig.6. Return Loss (RL) of Iteration-2

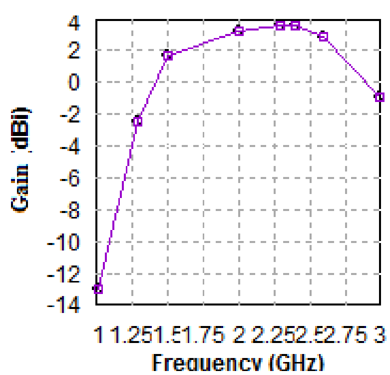

Fig.7. Frequency Response of Iteration-2

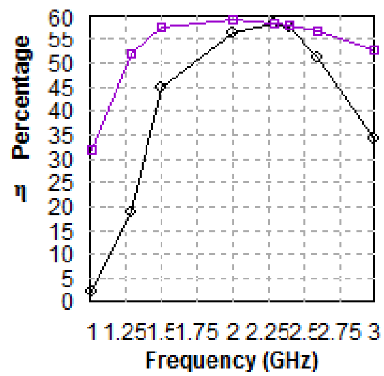

Fig.8. Efficiency(η) vs Frequency of Iteration-2.

The number of fractals is given by

$$N_f = 4n \quad (8)$$

where '*n*' is the integer denoting the number of iterations 0,1,2,3…n. The number of fractals is doubled in second iteration. The minimum return loss is -39 dB at the resonating frequency, 2.3 GHz rather than 2.4 GHz. Comparatively the bandwidth at -10 dB return loss is enhanced to 800 MHz. The maximum field gain is 3.8 dBi and the radiation efficiency and overall efficiency are of same value, 58% at the resonance frequency, 2.3 GHz.

As the iteration process progresses the number of fractals increase and also number of slots. This results in the reduction of metal area which diminishes the antenna gain slightly however it augments the bandwidth. These effects can be observed from the outcomes of last iteration. The minimum return loss -44 dB is at a resonance frequency 2.4 GHz which is the design frequency itself. It is noticed from the frequency response plot shown in Fig.11 that the gain is almost constant over the frequency range 2.0 GHz to 2.75 GHz. The maximum gain at the resonance frequency 2.4 GHz is 3.7 dBi which is not reduced much. The efficiency vs frequency plot shown in Fig.12 depicts that both radiation efficiency and overall antenna efficiency are above 55% over the frequency range 2.0-2.75 GHz.

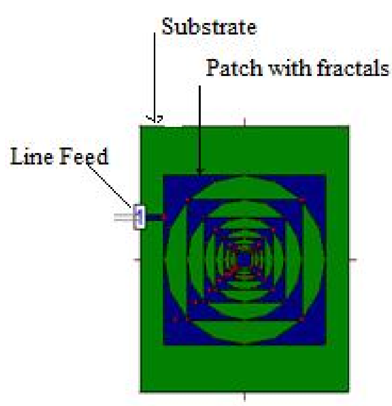

Fig.9. Fractal Patch Antenna with Kite-shape fractals

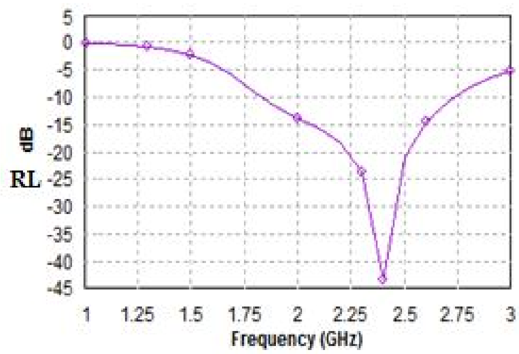

Fig.10. Return Loss(RL) of a Fractal antenna with Kite- Shape Fractals.

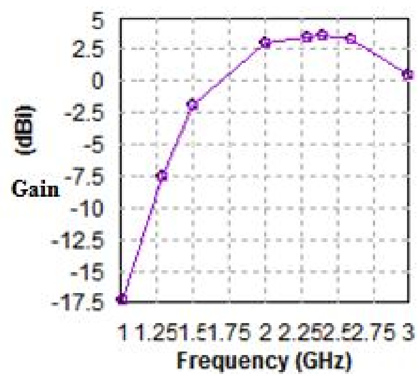

Fig.11. Frequency response of Fractal antenna with Kite- shaped fractals

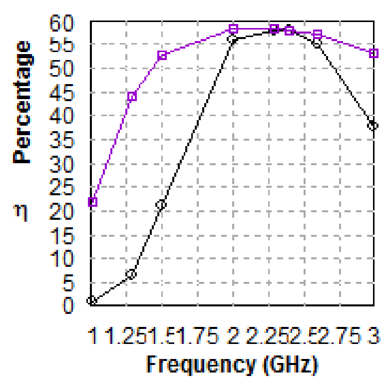

Fig.12. Efficiency vs Frequency

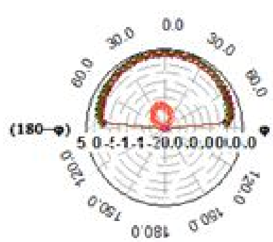

Fig.13. Gain Pattern

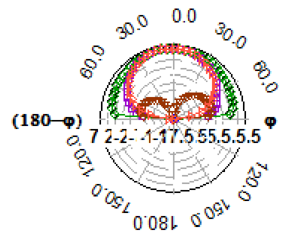

Fig.14. Directivity Pattern

IV. CONCLUSION

The Microstrip antenna with Kite shape fractals is proposed for bandwidth improvement. Various iterations are carried out and their results are compared. The final design exhibits a bandwidth of 900 MHz at -10 dB return loss without scarifying the gain much. The minimum return loss -44 dB is achieved at a specific design frequency 2.4 GHz with a maximum gain of 3.8 dBi. The hemispheric radiation pattern is obtained with increased directivity. The maximum radiation efficiency of 58% is achieved. The antenna gain is almost constant over the frequency range 2.0-2.75 GHz which makes it suitable for WLAN/Wi-Fi applications.

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