

Design and Simulation of Miniaturized Multiband Fractal Antennas for Microwave Applications

S. Suganthi, *Member IACSIT*, D. Kumar, and S. Raghavan

Abstract—Though there exists a variety of antennas for various purposes, the thirst for excelling in this area is ever increasing. This paper proposes a new miniaturized fractal antenna as a combination of Minkowski and Koch curves. The structure of the proposed antenna is the result of the modifications made with the basic fractal square and triangular curves. The design and simulation have been performed using IE3D, a full-wave electromagnetic simulator. It offers the best accuracy for planar microstrip antenna designs. The simulation with microstrip feed and coplanar waveguide feed systems and the results reveal that both the designs are extremely good in terms of multiband operations.

Index Terms—Antenna, coplanar waveguide feed, fractal, IE3D, microstrip feed and miniaturization

I. INTRODUCTION

In view of the progress of the recent communication systems and increase in application areas with vital requirements such as small size, less weight and better performance, the miniaturized multiband antennas are in great demand. Microstrip antennas are a class of miniaturized antennas with many advantages like light weight, conformability, low cost etc. For simple radiating patch shapes, the design can be carried out easily. However, being high Q electromagnetic structure, a microstrip antenna exhibits a narrow bandwidth. Many times it is considered as one of the major limitations. On the other hand, fractal antennas have attracted the attention of the researchers because of the features like small size and multiband characteristics [1].

In 1975, the fractal geometry was first defined by B.Mandelbrot [2] to describe complex geometries and it was generated with an iterative procedure. Followed by his concept, there had been many reports proposed by researchers with different fractal structures in the recent years. Sierpinski fractal antenna is based on the triangular (gasket) filled shape, Koch snow-flake fractal antenna[3] is developed using triangular curve and the Hilbert or Minkowski fractal antenna[4] design is based on the square curve. Some of the basic fractal curves are shown in Fig.1.

Fractals have plane or space filling and the self-similarity properties [5]. The use of fractal geometries in antenna design has shown to be a good strategy in order to attain the following benefits: broadband and/or multiband frequency response, compact size compared to conventional designs while maintaining good efficiencies and gain, mechanical simplicity and robustness and flexibility of designing for particular multi-frequency characteristics. Fractal antennas are mainly categorized into four types such as fractal line antennas, fractal three-dimensional antennas, fractal planar

antennas and fractal antenna arrays. In this paper, the design of fractal planar antenna as a combination of Minkowski and Koch curves is considered.

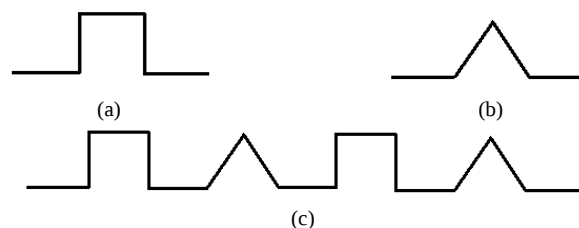


Fig. 1. Basic fractal curves (a). Minkowski curve (b). Koch curve (c). Minkowski-koch combined curve

II. ANTENNA DESIGN

The design and simulation are performed using IE3D electromagnetic simulation software. There are many ways of feeding the designed antennas. The CPW, microstrip, slot line, coaxial probe are some feed methods. In this paper both microstrip and CPW feed systems are used. The antenna is fed by a 50 ohms microstrip feed as shown in Fig.2a. The final design is a radiating fractal antenna separated from the ground plane by the substrate with a thickness of 1.6mm. The CPW (coplanar waveguide) feed system is shown in Fig.2.b. In this case, both the radiating structure and the CPW are in the same plane on the substrate. Copper is used for designing the radiating structure. The thickness of the copper layer is 0.016mm. The substrate is FR4 with relative epsilon 4.4 and board size 52mm x 20mm. This is preferred because of ease of fabrication and availability. The metallic printed portion spreads over an envelope of size 44mm x12mm on the substrate in both the cases.

A. Design of Minkowski-Koch Fractal Planar Antenna Structures

The proposed Minkowski-Koch fractal patch antenna structure is shown in Fig.3. The element length for each side of square or triangle is 4mm. The antenna is centre fed by a microstrip of size 4mm x 2mm in one case and 3.5mm x 4mm in the other. Another simulation was also performed for the same antenna with CPW feed system.

The Minkowski-Koch fractal thin microstrip antenna structure is shown in Fig.4. The width of antenna strip is 1mm in this type. The simulation for this antenna was performed with the above two different feed systems. The width of the center conductor (feed strip) can be adjusted for better results. The geometry of the proposed design was made manually. MATLAB coding can also be done for obtaining further iterations. The fundamentally important aspect of this fractal design is that the area occupied by the antenna remains the same while the perimeter gets increased

with respect to iterations.

III. ANTENNA CHARACTERISTICS

A microwave antenna can be characterized by many parameters such as radiation patterns (polar and azimuth) as a function of angle, return loss characteristics, VSWR(voltage standing wave ratio), impedance, efficiency, gain and directivity as a function of frequency etc.

The radiation pattern describes the way in which the electromagnetic energy is propagated in space as function of angle; the return loss locates the resonance frequency; the VSWR and the impedance determine the matching conditions for maximum power transfer; the gain and the directivity indicate the ability of the antenna in radiating the power. The directivity(D) is a measure of how much an antenna concentrates on the radiation at specific angles. This is shown by the following equation.

$$D = 4\pi |E(\theta, \phi)|^2 / \int |E(\theta, \phi)|^2 d\theta d\phi$$

where $|E(\theta, \phi)|$ is the relative E-field density at specific angles. The directivity of an antenna is only dependent upon the $E(\theta, \phi)$ at all the angles. Its unit is dBi meaning the dB value compared to an ideally isotropic pattern or a pattern with constant $|E(\theta, \phi)|$. The gain(dBi) is defined as the directivity (dBi) excluding the loss on the antenna (dB) as well as any mismatch loss (dB).

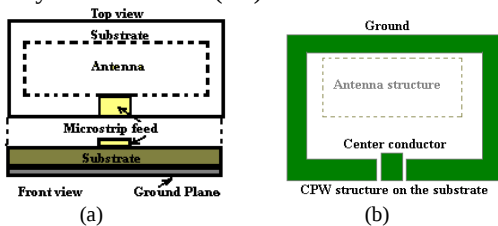


Fig. 2. Feed systems (a) Microstrip (b) CPW (top view)

IV. SIMULATION

The designed antennas were simulated using IE3D electromagnetic simulation software. IE3D is a full-wave electromagnetic solver. It solves the Maxwell Equations, governing the macro electromagnetic phenomenon. There is no much assumption involved except the numerical nature of the method. Therefore, the solution remains extremely accurate.

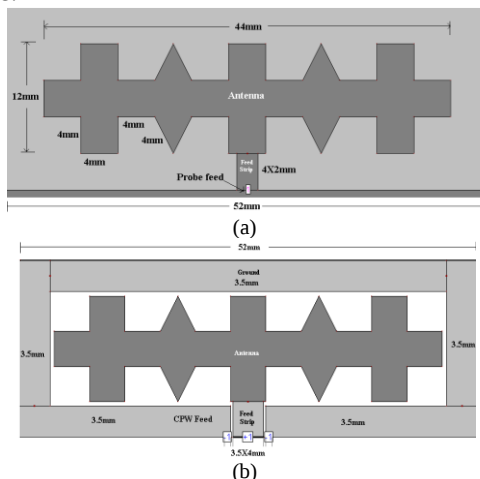


Fig. 3. Minkowski-koch fractal patch antenna (a) Microstrip fed (b) CPW fed

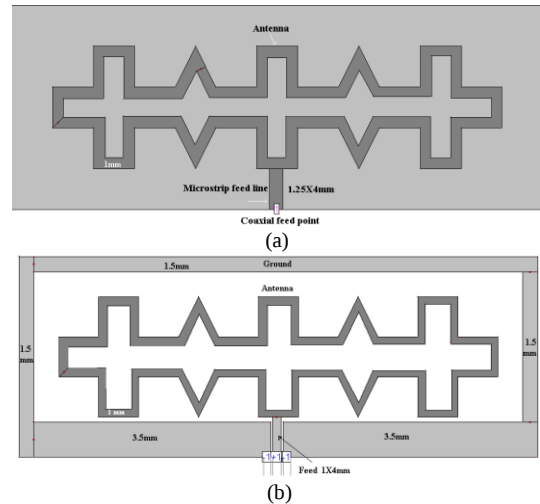
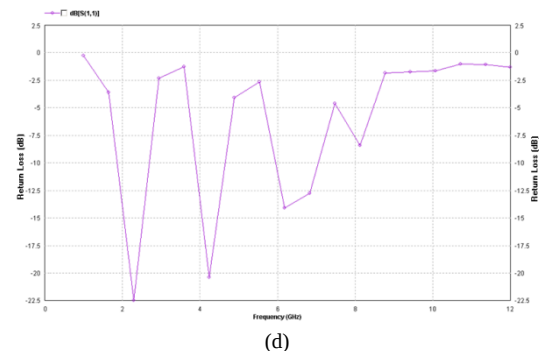
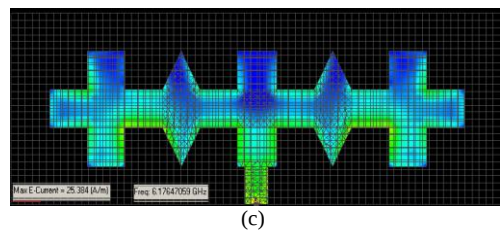
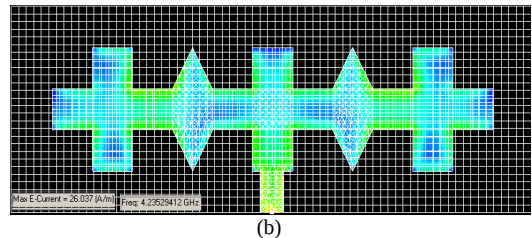
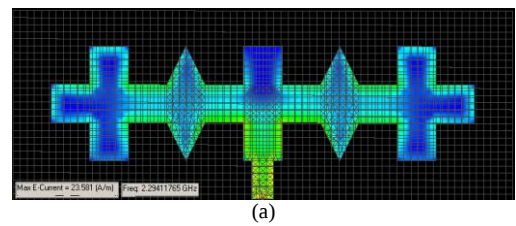
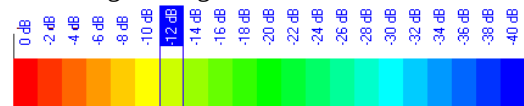
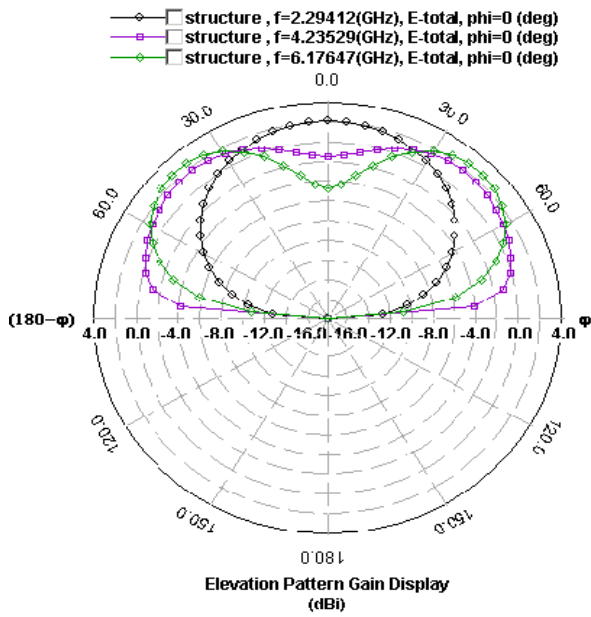


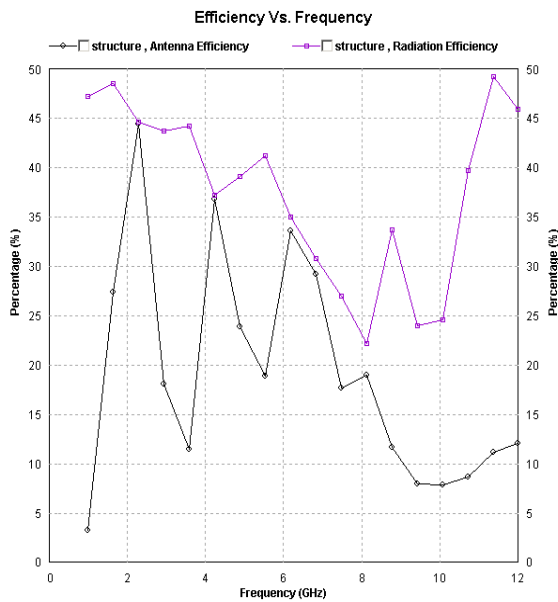
Fig. 4. Minkowski-koch fractal thin microstrip antenna (a)Microstrip fed (b) CPW fed

This paper, in addition to simulation, compares the microstrip fed and CPW fed simulation results for these two antennas. The simulation results of fractal patch and thin microstrip antennas for both the feed systems are shown in figures from Fig.5 to Fig.8.

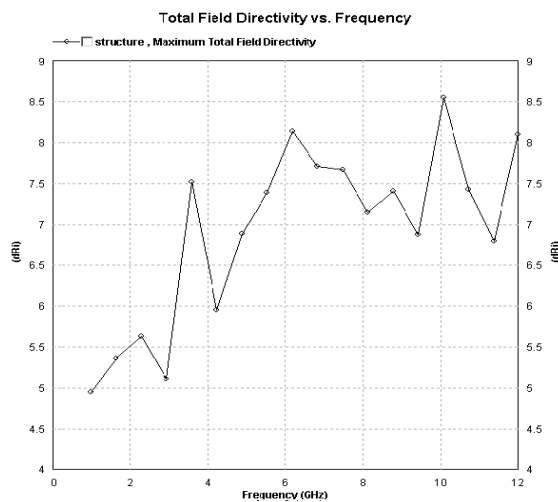




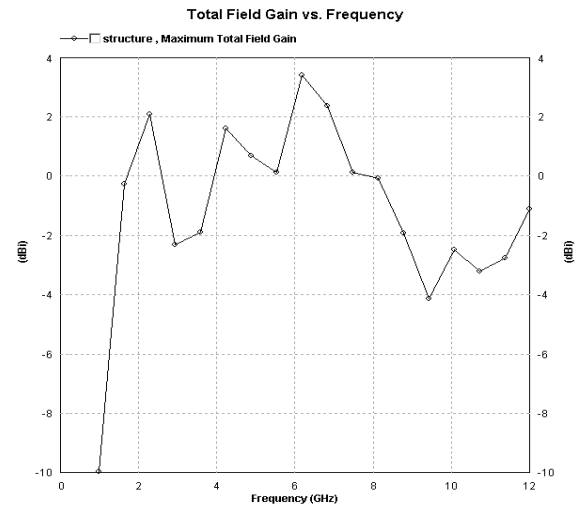
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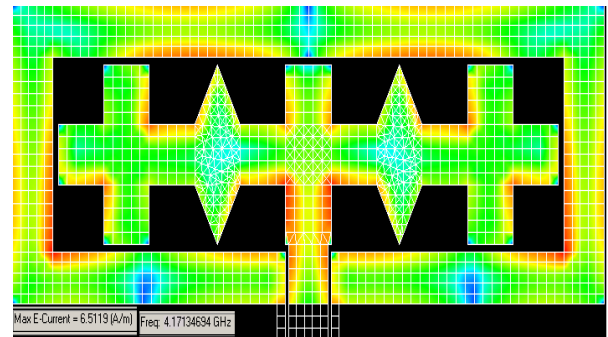


(g)

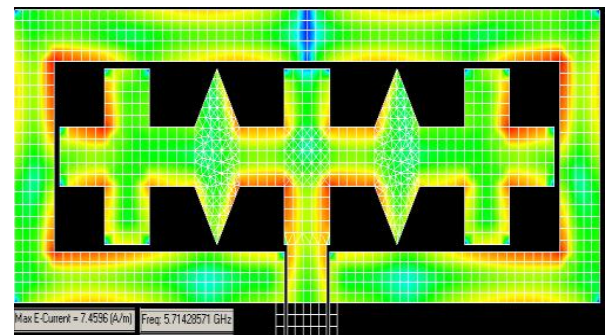


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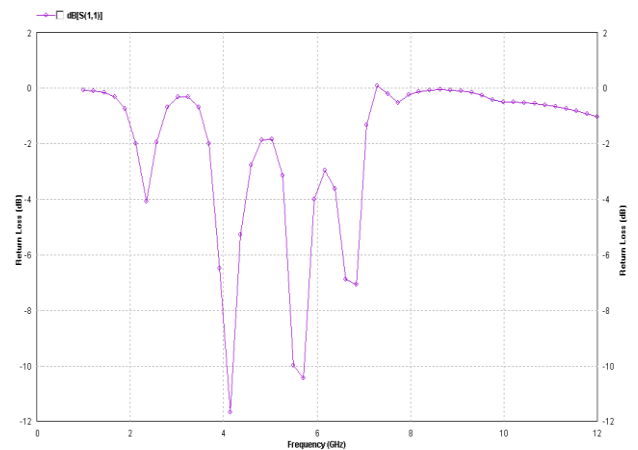
Fig. 5. Simulation results of microstrip fed patch antenna (a) Current distribution at f=2.29GHz (b) Current distribution at f=4.24GHz (c) Current distribution at f=6.18GHz (d)Return loss(S_{11}) versus frequency (e) Polar radiation pattern (f) Efficiency (g) Directivity (h) Gain



(a)



(b)



(c)

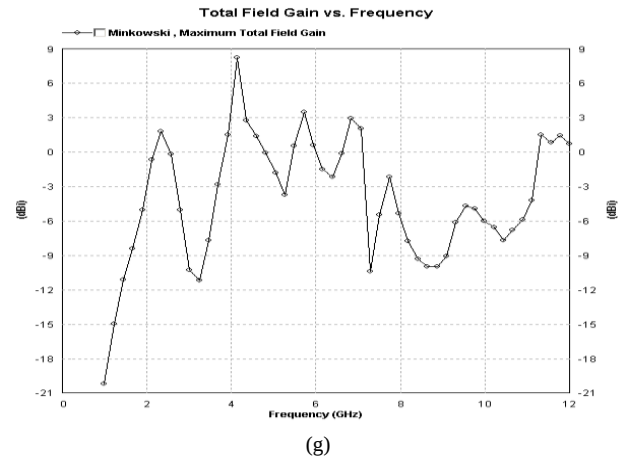
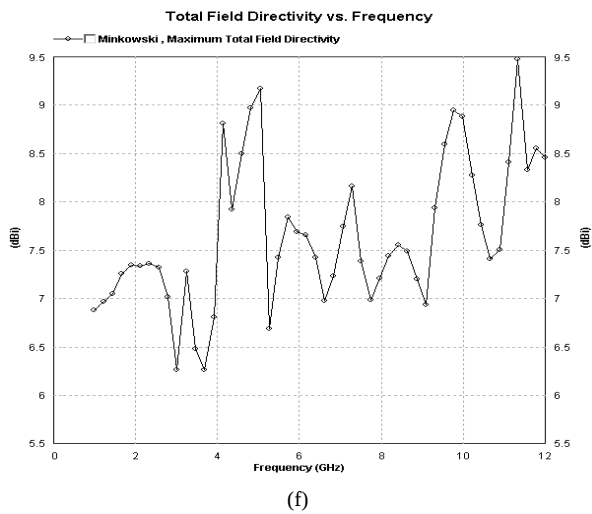
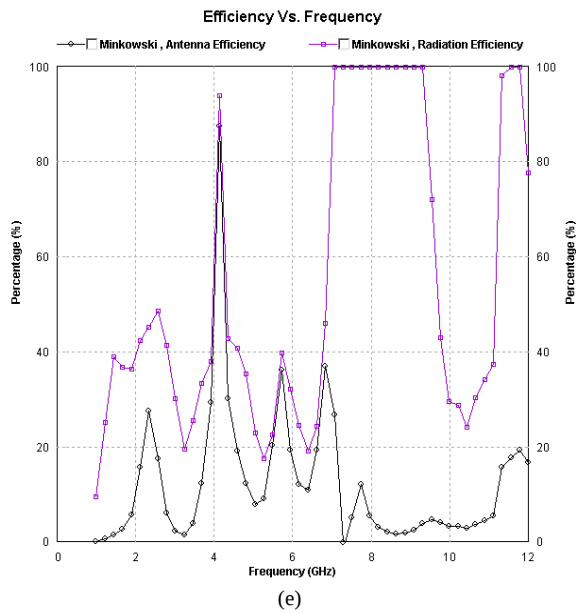
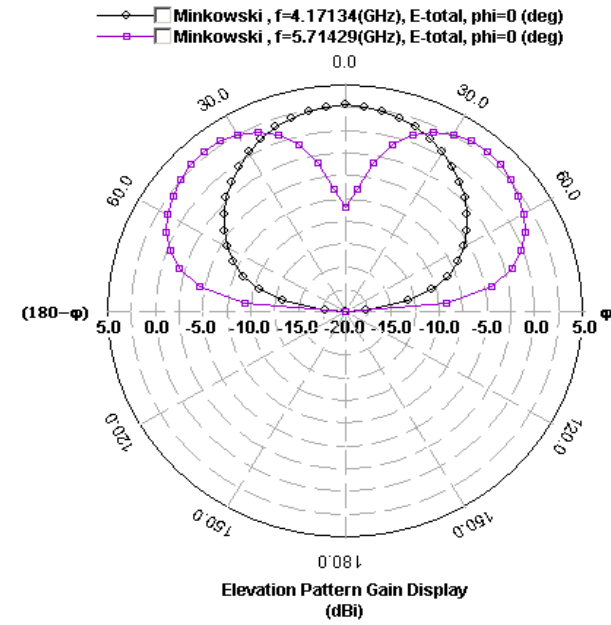
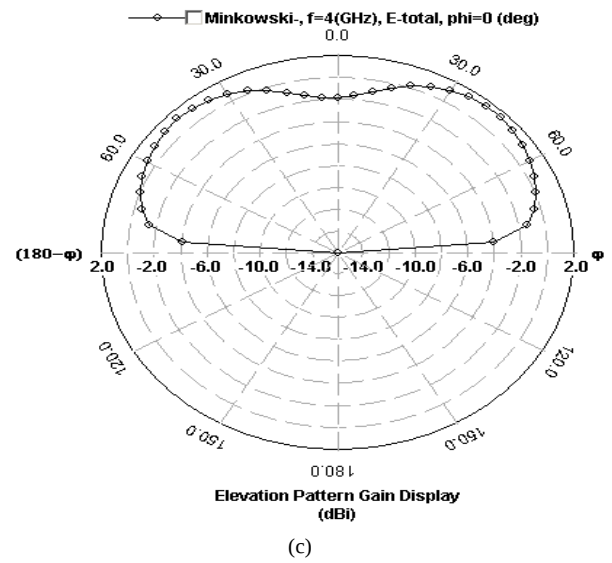
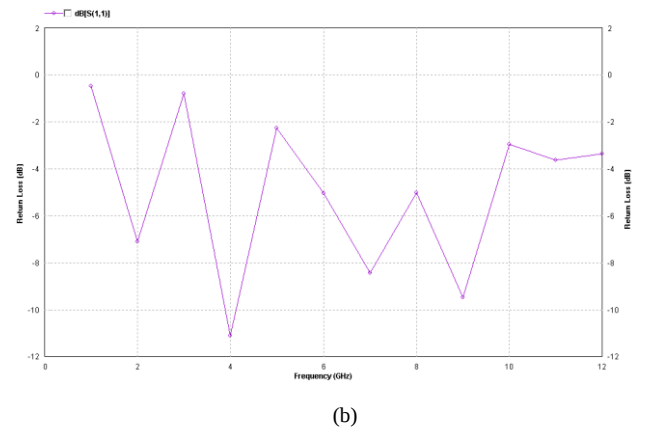
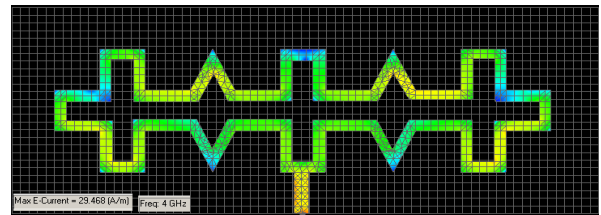
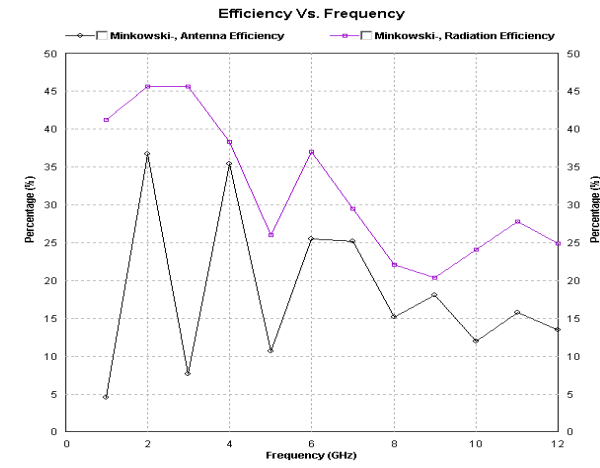
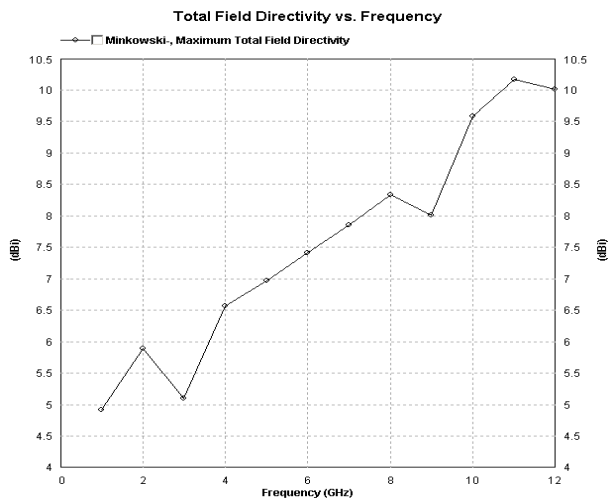


Fig. 6. Simulation results of CPW fed patch antenna (a) Current distribution at $f=4.17\text{GHz}$ (b) Current distribution at $f=5.71\text{GHz}$ (c) Return loss(S_{11}) (d).Polar radiation pattern (e) Efficiency (f) Directivity (g) Gain

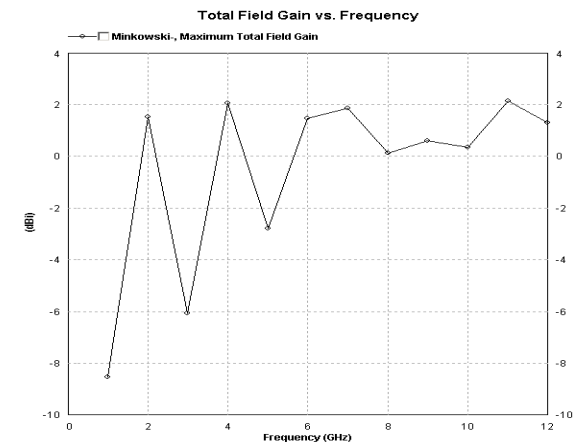




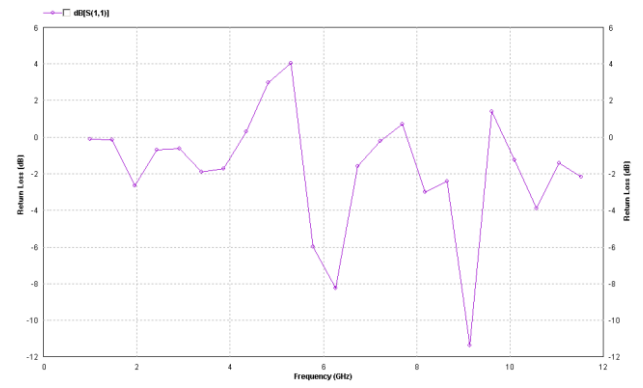
(d)



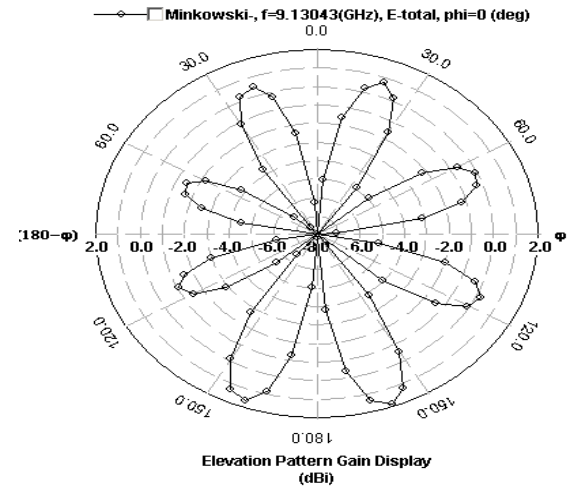
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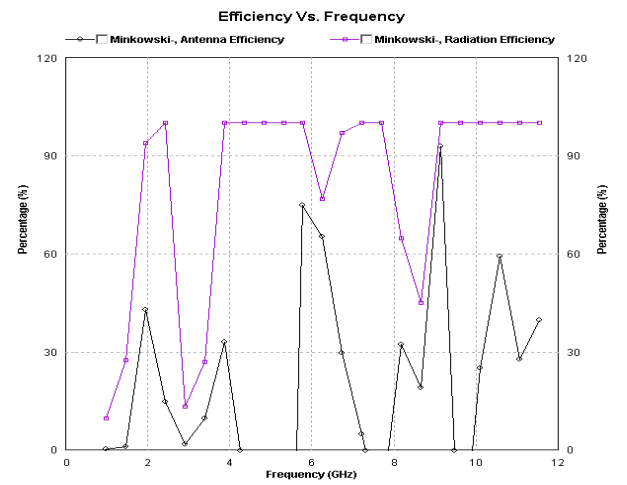
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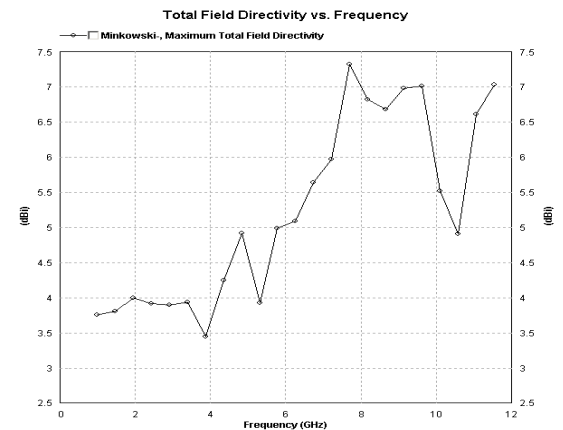
(b)



(c)

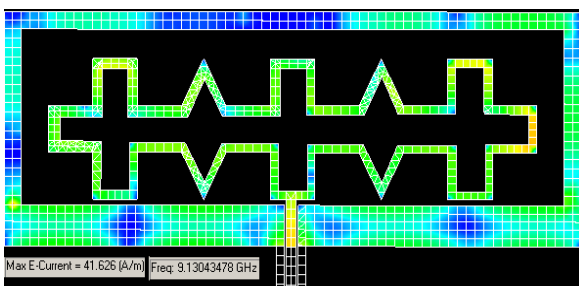


(d)



(e)

Fig. 7. Simulation results of microstrip fed thin microstrip antenna (a) Current distribution at $f=4\text{GHz}$ (b) Return loss (S_{11}) (c) Polar Radiation pattern (d) Efficiency (e) Directivity (f) Gain



(a)

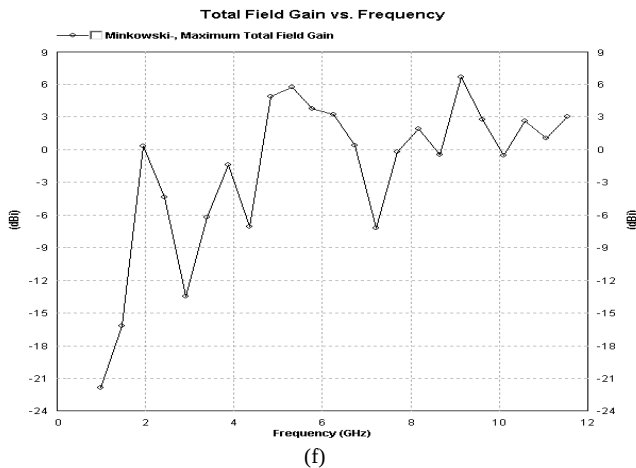


Fig. 8. Simulation results of CPW fed thin microstrip antenna (a) Current distribution at $f=9.13\text{GHz}$ (b) Return loss(S_{11}) (c).Polar radiation pattern (d) Efficiency(e) Directivity (f) Gain

TABLE I: PERFORMANCES OF PROPOSED ANTENNAS

Antenna	f_0	RL	f_u	f_l	BW	D	G	$\eta\%$	
								R	A
Patch (micro strip)	2.29	-22.5	2.6	1.8	0.8	5.7	2.2	45	45
	4.24	-20.1	4.6	3.9	0.7	5.9	1.8	36	36
	6.18	-14	7.0	5.9	1.1	8.2	3.2	35	34
Patch (CPW)	4.17	-11.5	4.2	4.1	0.0	8.7	8.5	95	90
	5.71	-11.2	5.7	5.5	0.2	7.5	3.5	40	36
Strip (micro strip)	4	-11.2	4.2	3.8	0.3	6.5	1.5	38	30
Strip (CPW)	9.13	-11.4	9.2	9	0.2	6.9	7	100	94

V. RESULTS AND DISCUSSION

For the geometries shown in Fig.3 and Fig.4, the simulations have been performed and the results are tabulated. The results of simulation show that the new Minkowski-Koch fractal antennas perform satisfactorily and yield good results. They provide good radiation pattern, appreciable gain, directivity and efficiency at resonant frequencies. Moreover, these antenna structures provide resonant frequencies at 2.29, 4, 4.17, 4.24, 5.71, 6.18, and 9.13GHz with good bandwidths. The Table I shows details of performance of all these antennas. All frequencies are in GHz with RL - the return loss(dB), f_0 - the resonant frequency, f_u - the upper cut-off frequency, f_l - the lower cut-off frequency, BW- the bandwidth(GHz), D- the directivity(dBi), G- the gain (dBi) and η - the efficiency(R for radiation and A for antenna).

However, there are some limitations in this simulation, such as setting maximum meshing frequency, meshing cell size (cells per wavelength). Usually, more cells in a simulation yield higher accuracy. However, one cannot just try to increase them as desired because computer memory will not be enough.

VI. CONCLUSION

Fractal antennas prove to be providing size reduction and multiband operations. The designed and simulated antennas are basically a combination of Minkowski and Koch curves, exhibiting resonance at various frequencies with considerable bandwidths of operation. They can be used in S band (2-4GHz), C Band (4-6GHz) and X band (8-12GHz) applications; specifically suitable for various wireless handheld devices. However, an optimum selection of position of the feed is important for better results. It is observed that the computational time for simulation for CPW fed system is 50% less than that of the microstrip feed system. The future work is to fabricate and test the performance for conformation and agreement with the simulated results.

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