# Design and Simulation of Compact Dual-Band Microstrip Antennas for Wireless Applications.

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**Abstract – This paper describes the design and simulation of compact dual band microstrip patch antennas: (1) Single-slotted rectangular microstrip antenna (RMSA) with ground slot. (2) Minkowski fractal microstrip patch antenna, using IE3D electromagnetic simulation software. The rectangular microstrip patch antenna is realised by single slotted single band rectangular microstrip antennas having slot in the ground plane. The open ended slot in the antenna generate wide impedance band which is shifted to lower frequencies by the effect of slot in the ground plane. The length and position of each slot is altered to operate the antenna in IEEE 802.11a WLAN frequency (5.15-5.35 and 5.725-5.825GHZ). Minkowski fractal microstrip patch antenna based on minkowski curve is advantageous due to their multiple resonating capabilities or enhancing the bandwidth. The performance characteristic of the fractal antenna is studied at four different stages to meet the frequency requirement for GSM and GPRS systems, C-band and wide band applications.**

***Keywords—Open ended slot, IEEE802.11a WLAN band, fractal, IE3D electromagnetic solver.***

## I. INTRODUCTION

With the huge advancement in wireless communication systems and increasing its applications, multiband antenna with various shapes and design have become a great demand and desirable for various wireless applications, which gives raise to different shapes and types of antenna for the variations in antenna characteristic. The frequency band ranging from 5.15-5.35 and 5.725-5.825GHz used in IEEE 802.11a WLAN application is realised here by the method of slot loaded patches. The slot could be of different shapes such as toothbrush, double bend, cross, rectangular shape etc..,. In this proposed rectangular microstrip patch antenna, rectangular slot is used both on the antenna patch and the ground plane, and perhaps the most popular among the antennas as they produce wide impedance bandwidth. Rectangular slots have been proved to be versatile radiating elements; they can be designed not only for dual band applications but also for triple, wide band as well as circular polarization operation. Since the slot designs have no vias, no added material and less intense manufacturing tolerances, they are quite promising or the mutual coupling problems. The proposed antenna is realised by open ended slot in the single slotted antenna which is responsible to generate a wide impedance band [1]. By the effect of slot in the ground plane the generated band is shifted to lower frequencies. The ground plane acts as a signal return path and the slot on this plane introduces discontinuities with in the path and produces slow wave effect which is responsible to shift the resonant frequency to lower values. In this paper the design of dual band rectangular microstrip antenna for WLAN applications is realized by aggregating single slotted compact antennas with rectangular ground slot. And one more proposed antenna in this paper is minkowski fractal antenna, it’s a dual band patch antenna based on minkowski curve [5][7] which is iterated at four different stages for gsm and gprs systems, c-band and wide band applications. There are different shapes and types of antennas designed for the variations in antenna characteristics. There are various shapes such as sierpinski, gasket, minskowsi, Hilbert curve; Koch curve, tree structure, etc are considered for the design of antennas. Here in this paper the fractal antenna with a minskowsi curve is considered. Fractal technique has got numerous applications in the field of science which includes fractal electro dynamics where the fractal concepts are combined with electromagnetic theory. Fractal antenna engineering focuses on two areas one is the design and analysis of fractal elements and other concerns to the application of the fractal theory to the design of antenna arrays. Both the antenna types are highly desired in various commercial and military sectors. Most of the fractal antenna elements posses’ compact size, low profile and cost, multi-band operations, easy feeding and their shape can be modified for better optimization. The fractal geometries features two properties self similarity and space filling properties. Both these properties become a reason attractive to consider fractal geometry. Self similarity of antenna holds the duplication of itself at several scales and can operate at several wavelengths in similar fashion, which reduces the antenna size and occupies lesser space. The space filling property fill the area occupied by the fractal antenna as the number of iteration is increased. Higher the order of fractal antenna, lesser the antenna size .This reason makes the fractal antennas compact, multiband and use full for cellular applications and microwave applications.

## II. PATCH ANTENNA DESIGN EQUATIONS.

The length and width of the patch antenna are calculated by the following equations [4]. Where c is the velocity of light and Ɛr dielectric constant of the substrate.

1. Calculation of width: The width of the microstrip patch antenna is given by the equation as,

$$w = \frac{c}{2f\,[\frac{\varepsilon r+1}{2}]^{.2}}$$

2. Calculation of effective dielectric constant:

$$\varepsilon_{reff} = \left(\frac{\varepsilon r+1}{2}\right) + \left(\frac{\varepsilon r-1}{2}\right)[1+{}^{10h}/_{w}]^{1/2}$$

3. Calculation of effective length:

$$L_{eff} = \frac{c}{2f_0\,(\varepsilon_{reff})^{1/2}}$$

4. Calculation of length extension:

$$\frac{\Delta l}{h} = 0.412\,\frac{(\varepsilon_{reff}+0.300)({}^{W}/_{h}+0.262)}{(\varepsilon_{reff-0.258})({}^{W}/_{h}+0.813)}$$

5. Calculation of actual length of the patch:

$$L = L_{eff} - 2\Delta L.$$

6. Calculation of ground plane dimensions (Lg and Wg): Ideally the ground plane is assumed to be infinite size in length and width but practically it is impossible to make such infinite size ground plane. So to calculate the length and width dimensions of the ground plane following equations are used.

$$L_g = L + 6h, \quad W_g = W + 6h.$$

## III. SINGLE SLOTTED RECTANGULAR MICROSTRIP ANTENNA (RMSA) WITH GROUND SLOT.

The geometry of each slotted antenna is formed by modifications at three stages. In the first stage, a rectangular microstrip patch antenna having length Lp=12mm, and width Wp=8mm is designed as reference antenna which is Antenna1 as shown in Fig.1 (a) The substrate used is FR4 epoxy with relative permittivity of 4.4, loss tangent of 0.02 and substrate thickness is 1.5875mm. In the second stage, two rectangular slots(open ended) are inserted separately at different positions inside the RMSA which are Antenna2 and Antenna3 respectively as shown in Fig.1(b) and (c) which results in the enhancement of the impedance bandwidths[1] of both the antennas with respect to Antenna1. In the third stage, modification is done by inserting two rectangular slots L1 and L2 of nearly quarter wave in length, inside the ground plane of Antennas 2 and 3 giving rise to Antennas 4 and 5 as shown in Fig.1 (d). The size of the ground plane is taken twice the patch area size to realize the effect of infinite ground plane and to maintain the compactness of the design. Simulated reflection coefficient versus frequency plots of Antennas 1-5 are shown in fig.10. Resonant frequencies of Antennas 2 and 3 have lowered by the insertion of slot in the ground plane as shown in Table.1. Variations in length and position of the ground slot and open ended slots L1 and L2 leads to the shift in resonant frequency to lower values. Antennas 4 and 5 resonate at 5.15-5.35 and 5.725-5.825GHz for WLAN applications respectively. Geometries of Antennas 4 and 5 are combined to realize double slotted RMSA with slotted ground plane, i.e.Antenna6 as shown in Fig.2. The ground slot length and position is same as shown in Fig.1 (d). A simulated result of Antenna6 shows the dual bands plane, i.e.Antenna6 as shown in Fig.2. The ground slot length and position is same as shown in Fig 1 (d). A simulated result of Antenna 6 shows the dual bands operating at 5.125 and 5.75 GHz. Coupling between the two slots in Antenna 6 is minimum. The optimized dimension of the ground slot is taken as 13.4 x 0.8 $mm^2$ [2][6]. The simulated characteristic of the double slotted RMSA nearly matches with the combined simulated characteristics of the single slotted RMSAs as shown in Fig 10.

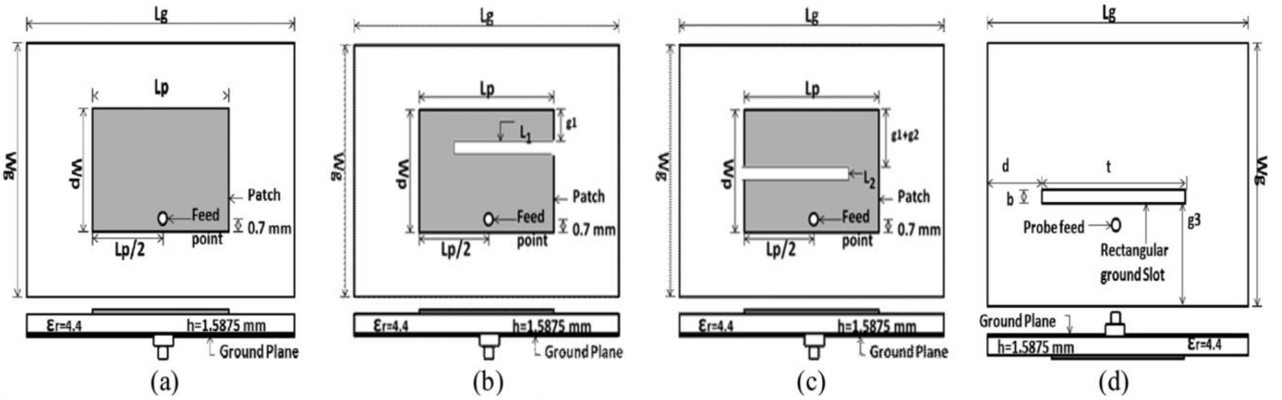


Fig 1. Reference RMSA and single-slotted RMSAs. (a) Antenna 1 or reference RMSA. (b) Antenna 2 or L1 slotted RMSA. (c) Antenna 3 or L2 slotted RMSA. (d) Back view of Antenna 4 when front view is same as shown in Fig. 1(b), and back view of Antenna 5 when front view is same as shown in Fig. 1(c). Antenna dimension are: Lp=12mm, Wp=8mm, Lg=24mm, Wg=16mm, and h=1.5875mm. Optimized length of L1=8.9mm and L2=9.5mm. Optimized dimensions of ground slot are: t=13.4mm, b=0.8, g3=6.5mm and d=4.5mm.

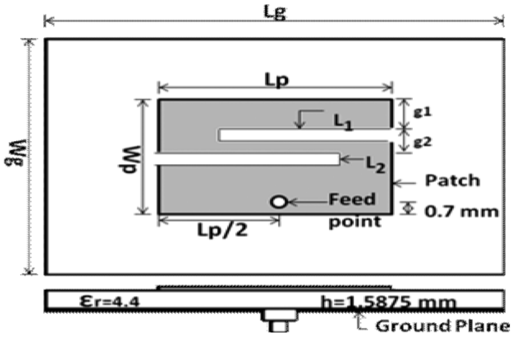


Fig 2. Configuration. of antenna6. Antenna dimensions are Lp=12mm, Wp=8mm, Lg=24mm, Wg=16mm, L1=8.9mm, L2=9.5mm, g1=2.1mm, g2=1.3mm and dimensions of ground slot are t=13.4, b=0.8mm, g3=6.5mm, and d=4.6mm.

## IV. SIMULATION RESULTS OF RMSA

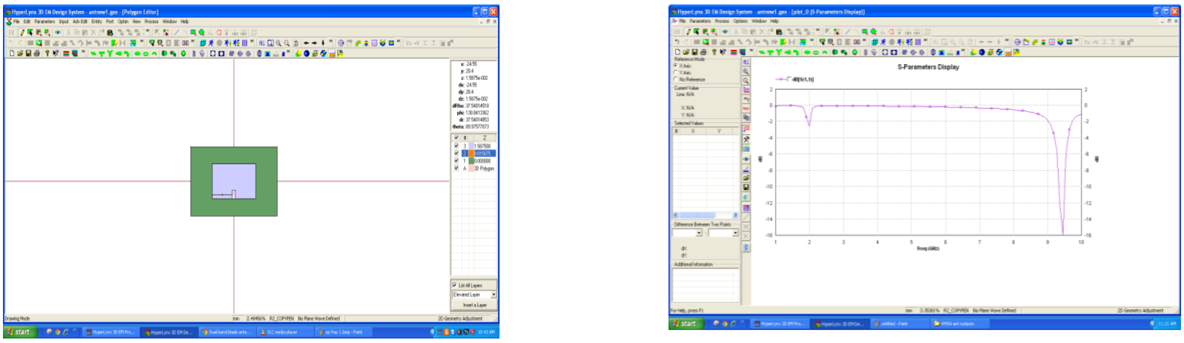


Fig 3. Antenna1 with simulated reflection coefficient vs. frequency plot.

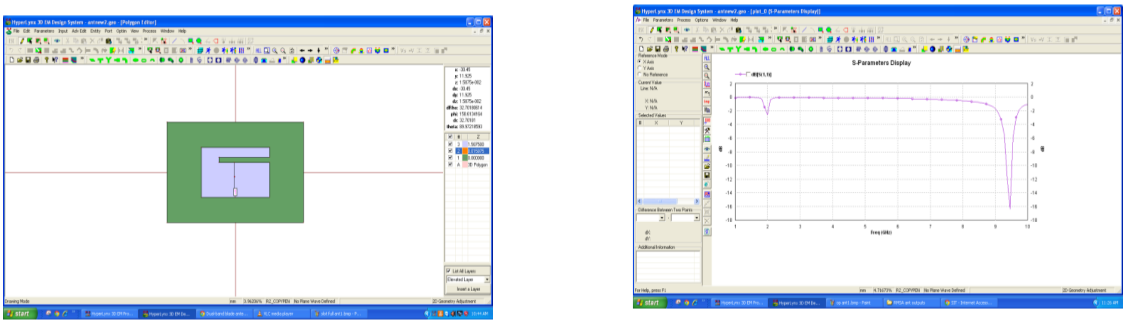


Fig 4. Antenna 2 with simulated reflection coefficient vs. frequency plot.

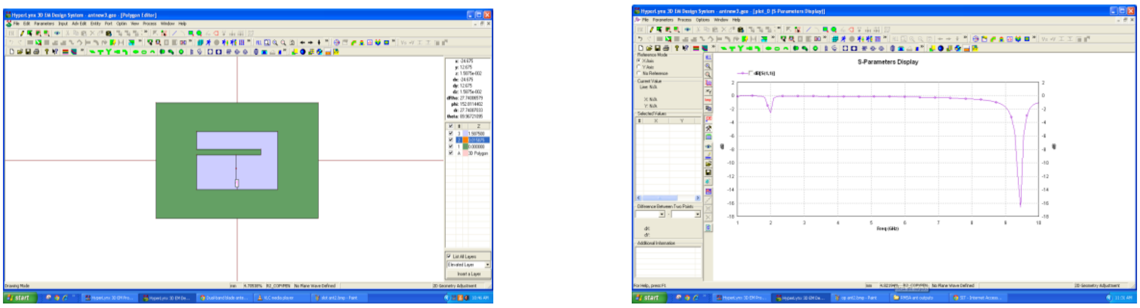


Fig 5.Antenna 3 with simulated reflection coefficient vs. frequency plot.

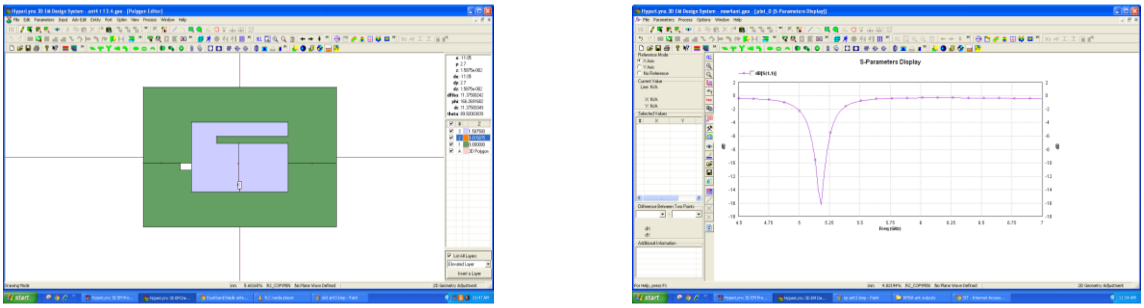


Fig 6. Antenna4 with simulated reflection coefficient vs. frequency plot.

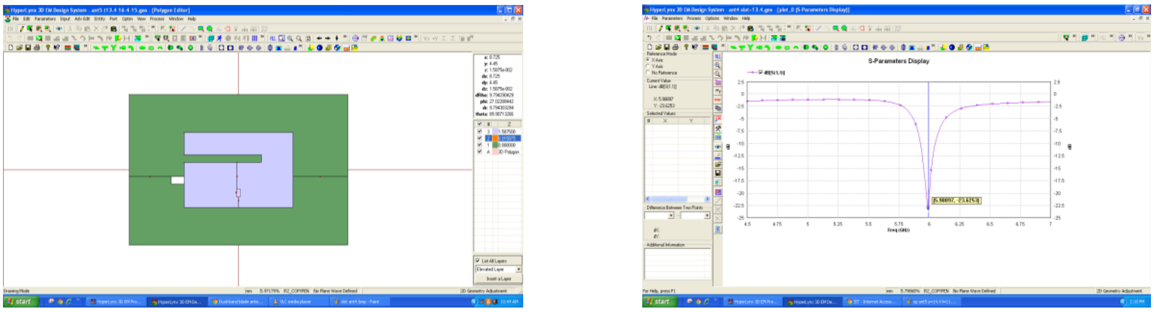


Fig 7.Antenna 5 with simulated reflection coefficient vs. frequency plot.

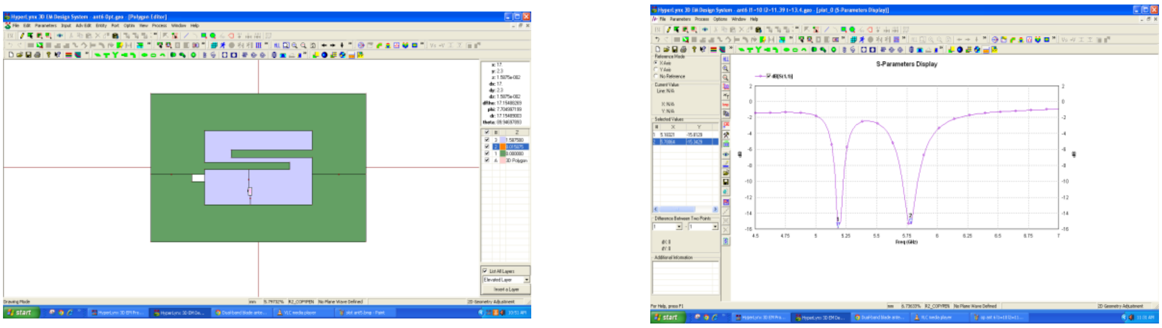


Fig 8. Antenna 6 with simulated reflection coefficient vs.frequency plot.

Table I: Resonant Frequency and simulated bandwidth of antennas 1-6.

| RMSAs | Resonant frequency (GHz) | Return loss (db) | Simulated bandwidth (MHz) |
|---|---|---|---|
| Antenna1 | 9.45 | -13.5 | 240 |
| Antenna2 | 9.36 | -14.2 | 350 |
| Antenna3 | 9.46 | -14.1 | 310 |
| Antenna4 | 5.19 | -16 | 265 |
| Antenna5 | 5.96 | -23.5 | 210 |
| Antenna6 | 5.15 and 5.82 | -16 and -16.89 | 225 and 350 |

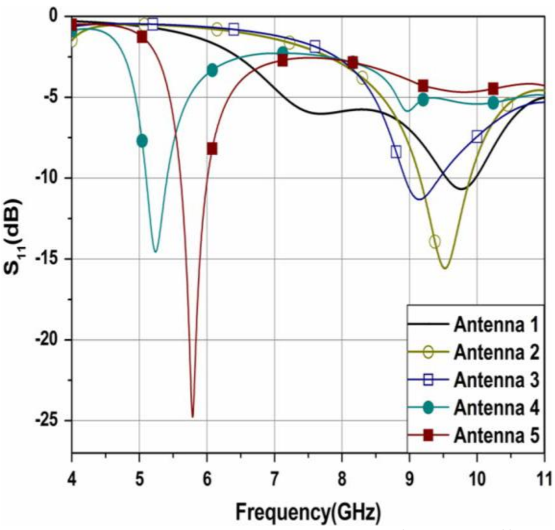


Fig 9.Simulated reflection coefficient vs. Frequency plot of Antennas 1-5.

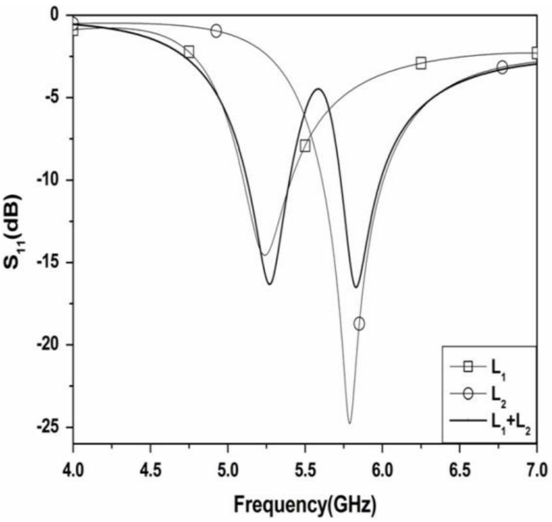
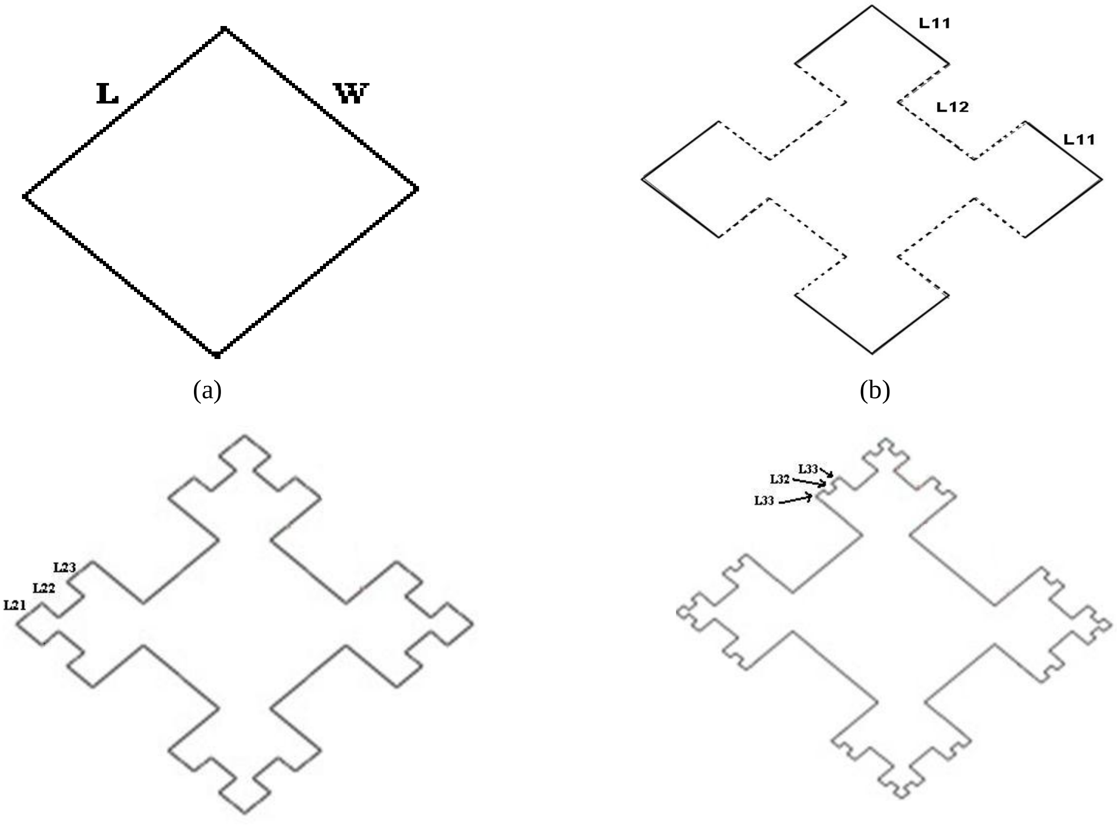


Fig 10.Simulated reflection coefficient vs. Frequency plot of Antennas 4-6.

## V. MINKOWSKI FRACTAL ANTENNA.

The proposed micro strip patch antenna which is based on minkowski fractal shape is constructed and fabricated by using FR4 epoxy as antenna substrate material. The analysis of these antennas is been performed with in the frequency range of dual band system. Execution of miniaturization technique by the geometry transformation from the square patch antenna is performed to achieve the dual band frequencies, which are for GPS and GSM systems in the first iteration, C-band applications in the second iteration and for ultra wide band applications in the third iteration. The basic antenna considered here for the design is minskowsi type. The dimension of the square which is the basic structure obtained by calculations will be used for the first, second and third iteration process to achieve the multiband behaviour of the patch. The proposed antennas are designed using Epoxy as substrate with dielectric constant of 4.3, loss tangent of 0.02 and thickness of the dielectric is 0.8mm. This substrate is used for the design because it is readily available, cheaper and easy to fabricate the designs. Since the basic structure is a square patch the width and length are of same dimension. The first iteration is obtained from the basic structure by creating the fractal structure. In this design, the value obtained after calculation is 39.28mm one third of this is 13mm which equals the values of L11, L12 or L13 in the first iteration. Hence L11=L12=L13 and L11+L12+L13=L. The values of L21, L22, L23 equals to 4.3mm in the second iteration therefore L21=L22=L23 and L21+L22+L23=L11 or L12 or L13. Applying the same for the third iteration L31, L32 and L33 are 1.4mm and hence L31=L32=L33 and L31+L32+L33=l21 or L22 or L23. For every iteration carried out, the side of the basic patch is reduced in a standard form however the area occupied by these antennas remains the same. The geometric construction of the minskowsi fractal curve is done by dividing the each side of the basic patch in to three equal parts. The middle part of each side of the patch is then replaced by a square projection inwards with two vertical and horizontal segments of equal length. Then the whole structure becomes first iteration patch. This procedure is repeated for the successive iterations maintaining the basic shape. The first iterated structure becomes the basic structure for the second iteration and the same logic is used for further iteration as shown in figure11



(a) (b)

(c) (d)

Fig 11. Minskowsi Curve modified by different iterations

The results shown in fig 12 to fig 15 reveal that the designed square patch antenna resonates at 1.8GHz. Further the first iteration fractal structure resonates at 1.5 and 1.75GHz which is used for GSM and GPRS systems, the second iteration fractal structure resonates at 4.5 and 6.5GHz which is used for c-band applications and the third iteration fractal structure resonates at 4.3 and 6.6Ghz which is used for ultra wide band applications. The tableII shows the performance characteristics of the designed antennas. All the values are observed values from the graph and all the frequencies are represented in gigahertz only. The return loss value indicates the reduction in the amplitude of the reflected energy, as compared with forward energy. For an antenna having a resonant frequency and range, the resonant frequency is measured at where the return loss (S11) is maximum negative.

## VI. SIMULATION RESULTS OF MINKOWSKI FRACTAL ANTENNA.

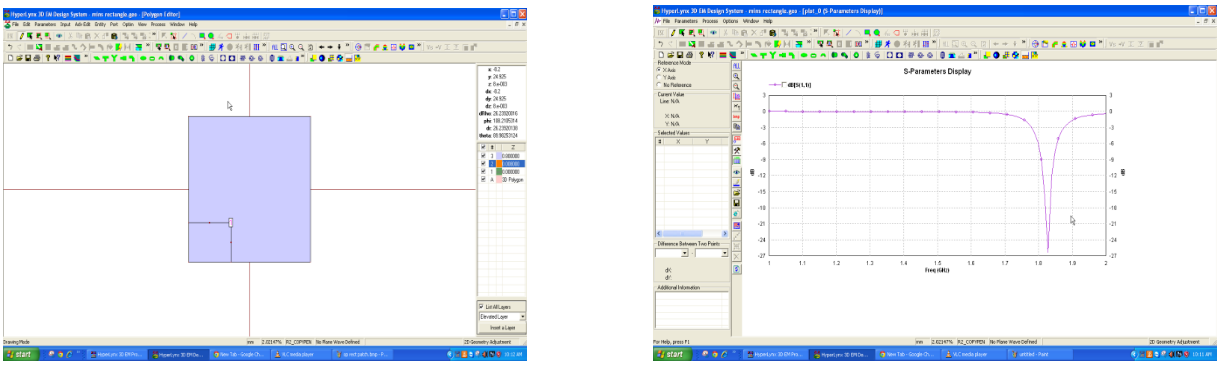


Fig 12. Basic Square Patch with S11 vs frequency plot.

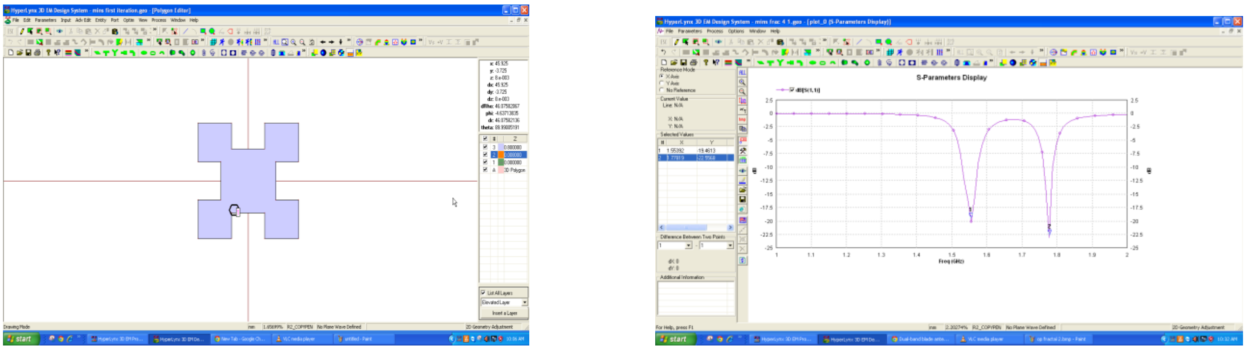


Fig 13. First Iteration Patch with S11 vs. frequency plot.

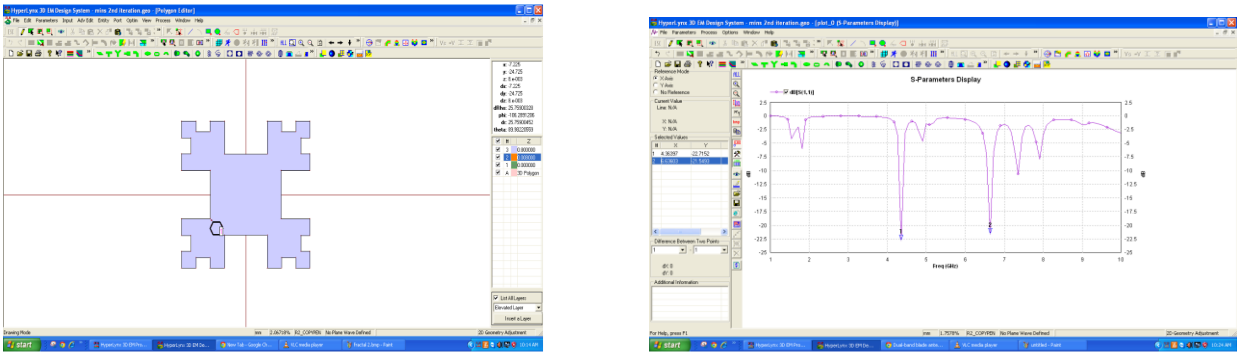


Fig 14. Second Iteration Patch with S11 vs. frequency plot.

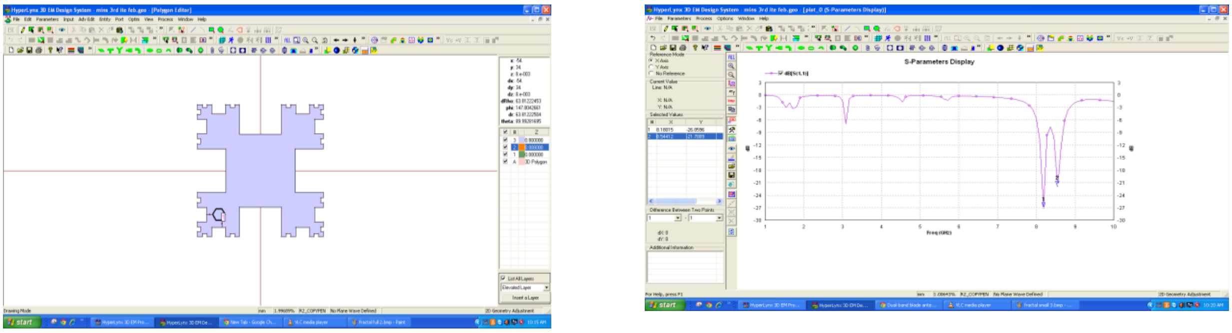


Fig 15. Third Iteration Patch with S11 vs. frequency plot.

Table II: Simulation results for minkowski fractal antenna.

| Patch Type | Resonate frequency (GHz) | Return loss (dB) | Simulated bandwidth (MHz) |
|---|---|---|---|
| Basic square | 1.82 | -26.5 | 330 |
| First iteration | 1.53 and 1.78 | -19.4 and -22.5 | 180 and 210 |
| Second iteration | 4.45 and 6.6 | -22.7 and -21.5 | 110 and 146 |
| Third iteration | 8.1 and 8.54 | -21 and -27 | 120 and 140 |

## VII. CONCLUSION.

A compact dual band microstrip patch antennas are designed and analyzed successfully. Primarily, in RMSAs two impedance bands of the dual band are generated separately by two separate designs of antennas with same dimensional slotted ground plane. Later these two designs are combined to form the design of dual band antenna. Similarly, minkowski fractal antenna from basic to third iteration along with simulation results is studied for different applications. Overall, the design technique used for double slotted dual band antenna using two separate single slotted RMSA's is successful for the application in WLAN band and the iterations carried out for minkowski fractal antenna using the basic square patch is successful for the applications in gsm, gprs,c-band and wideband systems.

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