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Analysis of effects of height of substrate on Minkowski based fractal patch antenna

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Abstract
In this paper a Minkowski algorithm based antenna has been designed. The proposed antenna has been designed in three steps. In the first part no iteration has applied as shown in fig 2.The configuration of the antenna are having FR4 substrate with relative permittivity €sub=4.4 and thickness t=1.59mm having dimensions L× W=80 mm×80mm. In this paper a height analysis has been experimented where height of substrate changed and simulated results are Obtained return loss minimized up to -50 dB and bandwidth obtained up to 1GHz. Designed simulated on HFSS tool.
Keywords: Microstrip line; Dielectric loading; fractal antenna; multi frequency antenna; slot antenna

I. INTRODUCTION

In today world of wireless communication, small, compatible and cheap microstrip patch antennas are required. A microstrip patch antenna is used to process ultra high frequency signals. Microstrip patch antenna is a wideband, narrow beam, occupy less space antenna placed over an insulating material such as FR4, glass, ceramic etc whose dielectric constant lies between $2.2\leq \varepsilon r\leq 12$ The microstrip antenna mainly consist of Ground , Substrate , patch and feed line. The base of the antenna is known as ground plane. Just above the ground with the same dimension a substrate is placed. A substrate is the intermediate part of the antenna having different dielectric constant. The patch in the antenna is made of a conducting material CU (copper) or Au (gold) and this can be in any shape rectangular, circular, triangular, and elliptical or some other common shape. Microstrip antennas are used mostly in many applications such as WIMAX (worldwide interoperability microwave access), WI-FI(Wireless fidelity), USB dongle, satellite radio or cell phone receiver or is mounted on an aircraft or spacecraft due to their compact size, less weight, low cost on mass production, ease of installation with multi-frequency bands. The disadvantages of patch antenna are narrow B.W., lower gain and surface waves. High dielectric constant is the simplest solution but it cause narrow B.W. and poor efficiency For obtaining multiband, wideband characteristics different techniques such as stub loading, cutting a resonant slot inside the patch, fractal geometry is used. This technique is used to reduce the size of patch antenna. Stacking of patches is the common technique to introduce multiple bands. The primary aim of this paper is to design a multiband antenna confirming to multiple wireless standard. One major disadvantage of etching multiple slots on a patch antenna is that it reduces the overall gain of the antenna as major portion of the antenna as major portion of the antenna is etched out. FRACTAL means broken or irregular fragments. They do not have a predefined size or shape and composed of multiple copies of themselves. In this paper we are using two iterations on patch antenna also known as Minkowski Fractal Island.

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II ANTENNA DESIGN AND IMPLEMENTATION

Multiband fractal patch antenna has been designed using Minkowski fractal geometry. Square shaped fractal patch antenna is obtained by three iterations of fractal geometry to form self-similar geometry. The proposed antenna has been designed in three steps. In the first part no iteration has applied as shown in Figure 2.The configuration of the antenna are having FR4 substrate with relative permittivity €sub=4.4 and thickness t=1.59mm having dimensions L× W=80 mm×80mm. The 50Ω CPW feed line is designed to have a center conductor with of s=6mm and a gap with of 1mm. The antenna has been designed by using transmission line model which is most accurate method.

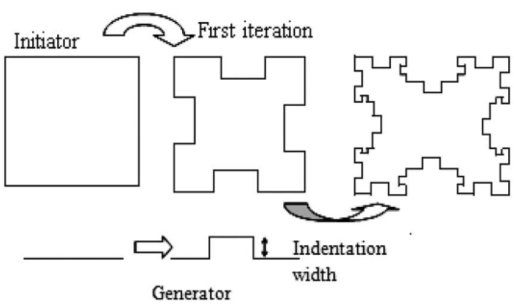

Figure 1: Generation of Minkowski Fractal Island.

In this paper all the dimensions get changed with respect to the reference paper [14] and work has been carried out to obtain improved results in respect to return loss and gain.

Table-1: Design parameter and corresponding values

Subject	Dimensions
Ground Size	80×80mm
Patch Size	50×50mm
Loss Tangent	.02
Feed line size	6×15 mm
Substrate Used	FR4
Thickness	1.59 mm
Feed line Technique	Microstrip line feed.
Feed point	(37,65,1.64)
Length of 1st iteration Fractal cut	15mm
Length of 2nd iteration fractal cut	5mm

Minkowski fractal geometry algorithm has been applied to square patch and different fractal geometry iterations are shown by Figure 2 (a), 2 (b), and 2 (c). In these geometries ground plane configurations remains same. Here square patch having a length of 50 mm is taken as shown in Figure 2 (a) and microstrip feed line has been given at (37,65,1.64). Feed point has been chosen in such a way that impedance matching of 50Ω take place. Square patch as shown in Figure 2(b) is made by using concept of fractal geometry. Vertical length of 50 mm is divided into 3 parts, each of length 15 mm. Two cuts are made in vertical direction i.e. along x-axis.and one cut along y-axis. This square shaped patch is example of microstrip patch antenna with slot cut inside it. Now to make square shaped fractal square cuts of length 5 mm are made in each square of dimension 15mm. This design is made using HFSS13.0 simulation software.

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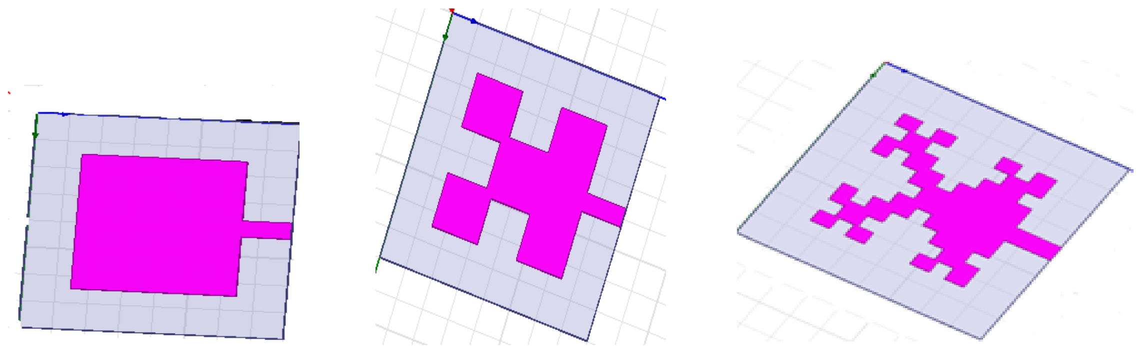

(a) (b) (c)

Figure 2: Square shaped **(a)** 0th Iteration, **(b)** 1st Iteration, and **(c)** 2nd Iteration

From these geometries, it is found that self-similar characteristics are obtained. From Figure 2, it is clear that size of Square shape patch antenna is goes on decreasing but resonant length goes on increasing and area goes on decreasing.

III. RESULTS OF SQUARE SHAPED FRACTAL ANTENNA

square fractal patch antenna design are discussed and comparisons between results of different antenna designs using change in thickness of substrate and using different dielectric materials are made. By making a square antenna with 0^{th} iteration, 1^{st} iteration and by 2^{nd} iteration Fractal technique results are analyzed. All simulations were carried out in HFSS simulation software and tested results of fabricated antenna are compared. Return loss vs. frequency curve for different fractal geometry iterations are shown in Figure 3

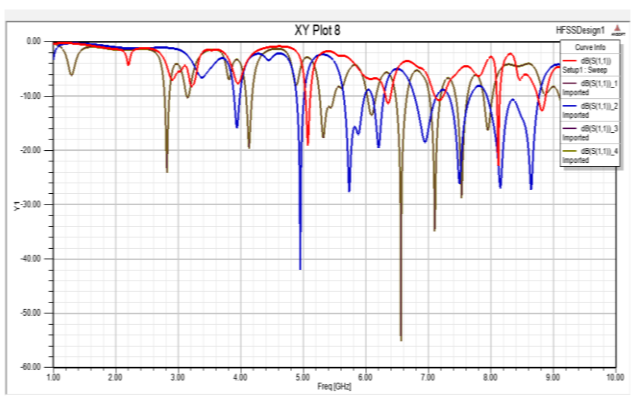

Figure 3: Return Loss Vs. Frequency for Different Fractal Iterations of Square-Shaped FWPA

For 0^{th} iteration the antenna resonates at 6.55, 7.08, 7.52,9.2 GHz with return loss -55,-34.78,-28.82,-17.5 db. By applying 1^{st} iteration antenna resonate at 6.18,6.93,7.50,8.64GHz with return loss -19.53,-18.49,-26.18,-27.32 dB. when next iteration that is 2^{nd} iteration have been applied to fractal antenna it will resonate at 8.8 and 9.42 GHz with return loss -12.81 and -21.189 dB

IV Parametric analysis

The geometry of basic design antenna is in square shape. It is a conventional design which is simulated in HFSS 13.0 software. It has a square patch and FR4 substrate which is feeding by microstrip line for mobile and wi-Max applications.

SIMULATION RESULTS OF SQUARE- SHAPED FRACTAL PATCH ANTENNA USING SUBSTRATE HEIGHT H=1, 2.

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Since by applying fractal geometry, characteristics of antenna improved but bandwidth needs to improve. In this section effects of varying height of substrate of fractal antenna for all iterations are analyzed in term of the antenna characteristics.

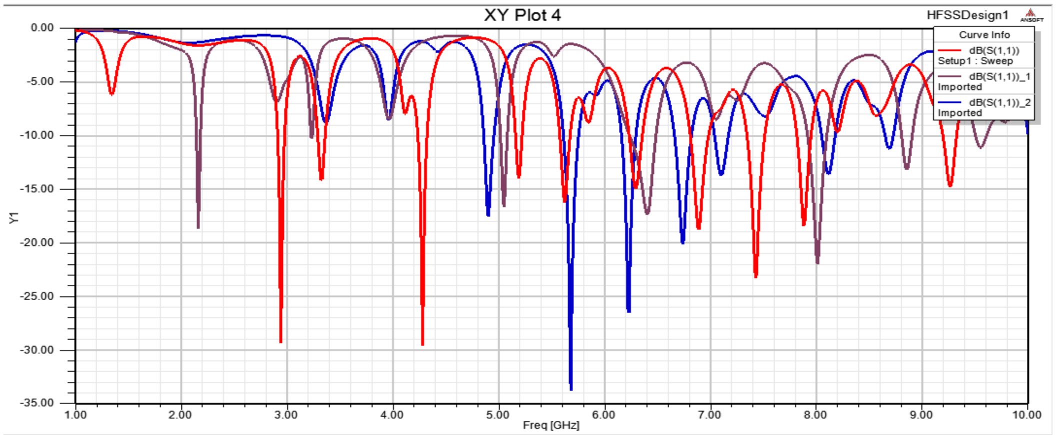

Figure 4: Return Loss Vs Frequency for Antenna with height (h=1)

By changing the height of dielectric constant FR4 from 1.59mm to 1mm the frequencies, return loss and their gain get changed. By changing the height of substrate for 0^{th} iteration the antenna resonate at 5.22,5.55 with return loss -14.82,-52.51dB,gain 9.52 and 3.78 and having B.W. 50,55 respectively. When iteration factor increased to one the antenna resonates at 7.08,8.09 GHz with return loss of -13.74,-13.57,gain with 1.84,2.82 dBi having B.W 150 ,100 respectively similarly when 2^{nd} iteration has been applied antenna resonate at 6.39,9.54 MHz ,with return loss of -17.30,-11.06 dB,gain of 2.67,4.55 having B.W of 266 and 110 respectively.

- **Effect Of Height On Square –Shaped Patch Antenna When H=1**

The antenna resonate at different frequencies are listed in table 2

Table 2: characteristics of square-shapes antenna when substrate height h=1.

Iteration number	**Resonance frequency (GHz)**	**Return loss (dB)**	**Gain (dBi)**	**Bandwidth (MHz)**
0^{th}	**5.22**	**-14.82**	**9.52**	**50**
	5.55	**-52.51**	**3.78**	**55**
	6.03	-23.69	1.51	70
	6.5	-18.01	-9.34	90
	6.99	-18.98	1.90	100
1^{st}	4.89	-17.54	1.88	101
	5.67	-33.78	1.17	150
	6.22	-26.5	-1.61	135
	6.73	-20.20	1.26	160
	7.08	**-13.74**	**1.84**	**150**
	8.09	**-13.57**	**2.82**	**100**
	8.68	-11.31	2.89	80
2^{nd}	2.13	-18.70	-9.32	28
	5.04	-16.68	-4.64	55
	6.39	**-17.30**	**2.67**	**266**
	7.99	-22.02	2.65	185
	8.84	-13.14	2.19	101
	9.54	**-11.06**	**4.55**	**110**

Further from analysis shown in table 2 it is found that by changing the height of substrate Fr4 antenna gain get increased to 9.52 dBi.

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- **Effect Of Height On Square –Shaped Patch Antenna When H=2**

Simulated results of varying height of FR4 substrate (when h=2) have been shown in figure 6.4 in which for 0^{th} iteration fractal antenna resonates at 7.00,7.47,8.11,8.59,GHz with return loss -24.94,-19.74,-31.26,-31.09dB and gain of 3.19,5.88,2.55,4.24 having B.W 890and 755 MHz respectively. For 1^{st} iteration when h=2 the antenna resonate at 7.00,7.47,8.11,8.59 GHz with return loss -24.94,-19.74,-31.26,-31.09 bB, gain of 3.19,5.88,2.55,4.24 having B.W. of 890 and 755 MHz When we are changing the height of 2^{nd} iteration the antenna resonate at 7.8, 7.82,9.36 GHz, with return loss -40.01,-34.50,-28.26 dB and gain of 3.90,3.88,4.96 dBi having B.W 578,349,330 MHz all the antenna parameters are listed in table 2.

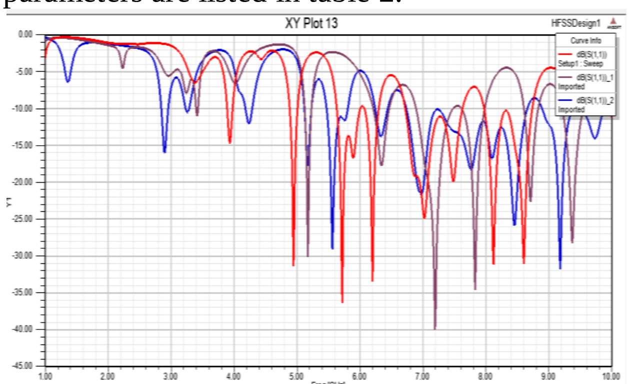

Figure 5: Return Loss Vs Frequency for Antenna with height (h=2)

When we are changing the height of the antenna h=2 the B.W. get increased unto 1424 MHz that is the Wideband. Thus we can use this antenna for wideband applications. From these, it is found that, as number of iterations increases, results improves but complexity increases.

Table 3: characteristics of square-shapes antenna when substrate height h=2

Iteration number	**Resonant frequency(GHz)**	**Return loss (dB)**	**Gain (dBi)**	**Bandwidth (MHz)**
0^{th}	2.87	-16.08	-4.12	110
	4.22	-12.12	1.005	120
	5.16	-17.86	-3.77	120
	5.55	-29.09	4.20	331
	6.32	-13.82	-4.85	211
	6.96	**-21.66**	**4.87**	**496**
	7.75	**-18.26**	**1.81**	**1424**
	8.44	**-25.9**	**6.5**	
	9.17	**-31.76**	**1.11**	**524**
1^{st}	3.92	-14.63	4.19	74
	4.93	-31.26	3.30	130
	5.70	-36.37	1.89	358
	6.19	-33.34	1.33	212
	7.00	**-24.94**	**3.19**	**890**
	7.47	**-19.74**	**5.88**	
	8.11	**-31.26**	**2.55**	**755**
	8.59	**-31.09**	**4.24**	
2^{nd}	5.16	-30.03	-2.27	110
	6.32	-17.7	4.28	257
	7.8	**-40.01**	**3.90**	**578**
	7.82	**-34.50**	**3.88**	**349**
	8.7	-22.50	3.17	230
	9.36	**-28.26**	**4.96**	**330**

V Results and discussion

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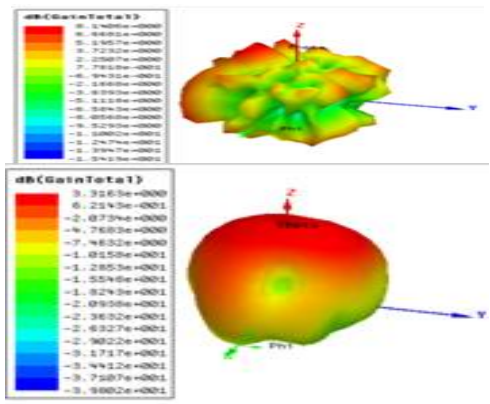
In this paper results of proposed square microstrip patch antenna design are discussed. By making a square antenna with 1st iteration and by using Minkowski Fractal techniques results are analysed. All simulations were carried out in HFSS simulation software.The gain of these different resonant frequencies are listed below:



(a) (b)

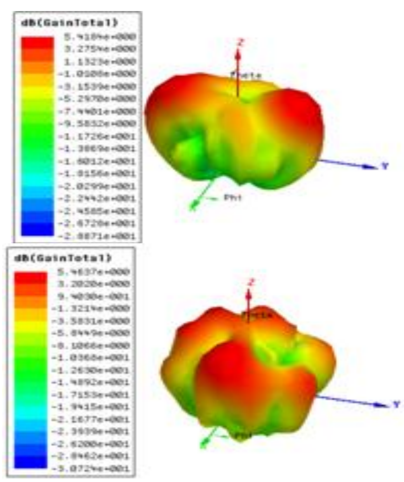


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Figure.6: Radiation pattern of conventional patch antenna for (a) 8.14GHz (b) 8.16GHz(c) 5.46 (d) 5.41GHz

Conclusion

Antenna has been designed using HFSS simulation software. The configuration of the antenna are having FR4 substrate with relative permittivity €sub0=4.4 and thickness t=1.59mm having dimensions L× W=80 mm×80mm^2. The 50Ω CPW feed line is designed to have a center conductor with of s=6mm and a gap with of 1mm. The antenna has been designed by using transmission line model which is most accurate method. Antenna at Zeroth iteration resonates at seven frequencies 4.11,6.07,6.55,7.08,7.52,7.94,9.2 GHz with return loss of -19.67,-13.5,-55.0,-34.73,-28.82,-16.3,-17.5dB,gain of 1.95,1.34,2.14,4.03,4.19,2.28,8.14 and bandwidth of 100.7,146.9,174.5,183.7,192.8,146.9,248. This antenna had been used forWi-MAX, WLAN and defence and secures communication application.

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