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Design And Analysis Of Square Fractal Antenna For Satellite Applications

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Abstract— **In this paper , a simple, multiband square molded microstrip patch antenna based on fractal geometry for satellite application has been presented. The proposed antenna comprises of three iterations. The antenna has measurements 24x24sq.mm. The composite material of FR4 as a substrate of relative permittivity of εr=4.3 and 1.6mm thickness. The antenna is feed with microstrip feed line. The proposed antenna work in X band (8 to 12GHz) and in lower Ku band (12 to 14GHz). It has resonance frequency of 10.1GHz which is appropriate for satellite applications. By utilizing fractal geometry the proposed antenna emanates on various frequencies like 8.5GHz, 10.1GHz, 12GHz, and 13.4GHz. The reenactment results demonstrate the return loss, radiation pattern, VSWR, directivity and gain of the antenna. The software used for simulation is CST microwave studio2017 (student version).**

Index Terms— **fractal geometry, multiband, satellite application, CST microwave studio.**

I. INTRODUCTION

Use of such antenas incorporate, however are not constrained to, personal communication framework, small satellite correspondence terminals, unmanned arial vehicle, and some more. Fractal idea has been connected to numerous braches of science and building, included fractal electrodynamics for radiation, proliferation, and dissipating. The term fractal infers eccentric or broken segments. It was portrayed by Benoit Mandelbrot which was gotten from Latin word 'fractus' which infers split or broken. Fractal recieving wire are moved ordinarily. Fractal recieving wire has two essential properties which are space-filling and self-likeness. The multiband radio wire is intended to work at various recurrence band by using fractal geometry thought into the fix of microstrip recieving wire, we can diagram multiband reception apparatus. With fractal reception apparatus, we can achive full frequencies that are multiband and these frequencies are not hormonics. A fractal is an unpredictable example worked from the repletion of a simple shape.

This square fractal antenna results to different unequivocal renonant frequency bands alongside great radiation qualities. As the quantity of fractal expands, the activity of recurrence band likewise increments with coordinating of impedance for assortment of satellite applications. The examination of square fractal antenna for various frequencies have been investigated. The X-band and Ku band, as translate by an IEEE standard, ranges from 8-12GHz and 12-18GHz individually. This application includes different various extension in the field of long distance communication, satellite communication, radar, teristrial broadband.

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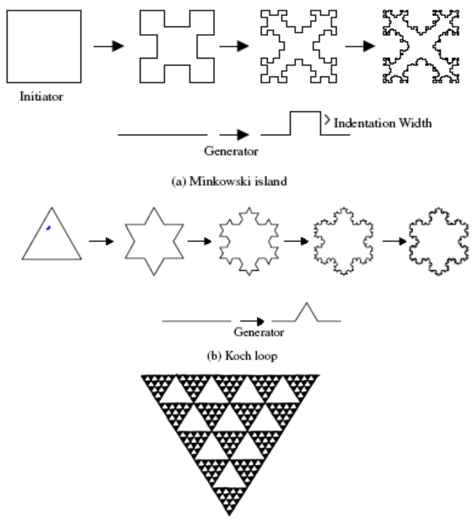


Sierpinski Gasket

Fig1. Various types of Fractal designs.

II. ANTENNA DESIGN:

To start with the design of antenna we have to calculate the effective dielectric constant, length and width of the patch, and feed line dimensions.

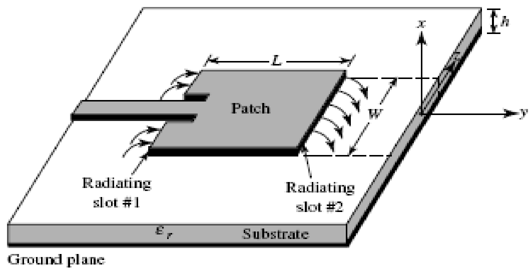


Fig 2. Microstrip Patch Antenna

The width of patch can be calculated as

$$W = \frac{1}{2fr\sqrt{\varepsilon\mu}}\sqrt{\frac{2}{\varepsilon r+1}} = \frac{\upsilon}{2fr}\sqrt{\frac{2}{\varepsilon r+1}}$$

The effective dielectric constant can be calculated as

$$\varepsilon reff = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2}\left[1+\frac{12h}{w}\right]^{-1/2}$$

Where h is the height of substrate, W is the width of patch.

The length of patch can be calculated as

$$\frac{\Delta L}{h} = 0.412\frac{(\varepsilon reff+0.3)(\frac{W}{h}+0.264)}{(\varepsilon reff-0.258)(\frac{W}{h}+0.8)}$$

Resonating frequency

$$fr = \frac{1}{2L\sqrt{\varepsilon r\sqrt{\mu\varepsilon}}} = \frac{\upsilon}{2L\sqrt{\varepsilon r}}$$

Actual length of patch

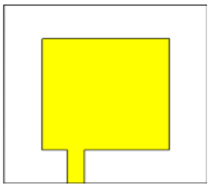
$$L = \frac{1}{2fr\sqrt{\varepsilon reff\sqrt{\mu\varepsilon}}} - 2\Delta L$$

Design of proposed antenna:

The proposed antenna includes a FR4 (lossy) glass epoxy dielectric substrate with dielectric constant 4.3. Resonant frequency of 10.1GHz is chosen for this antenna. Microstrip feed line is used for feeding. In this paper a square shaped fractal antenna is designed on a microstrip patch. The design of proposed antenna has three iterations.

Base shape of Antenna

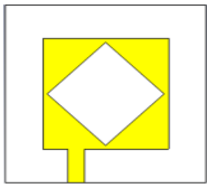
Base shape is a simple patch antenna with microstrip feeding at (-2.5,-4.5). The length and width of patch is 15x15mm, therefore the area of the patch is 225sq.mm and perimeter of the patch is 60mm. After carrying out the iterations the area of the patch decreases. As a result the antenna radiates on multiple bands. The basic patch antenna radiates on 8.7GHz and 10GHz.



(a)

First iteration

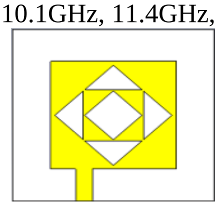
In the first iteration geometry another square is removed from the patch . The length and width of the removed square is approximately 10x10mm, having area of about 100sq.mm and perimeter 40mm. In this iteration frequency on which the antenna radiates are 8.5GHz and 10.2GHz.



(b)

Second iteration

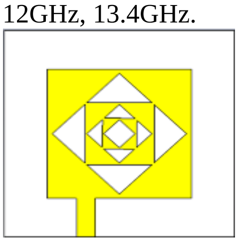
In the second iteration another square of area 25sq.mm is removed from the patch. After second iteration the antenna radiates at 8.5GHz, 10.1GHz, 11.4GHz, 13.5GHz.



(c)

Third iteration

Similarly in the final iteration the square of area 5sq.mm is crop from the patch. After last iteration he antenna radaites at 8.5GHz, 10.1GHz, 12GHz, 13.4GHz.



(d)

Fig 3. Geometry of Proposed Antenna (a) base shape (b) 1st iteration (c) 2nd iteration (d) 3rd iteration

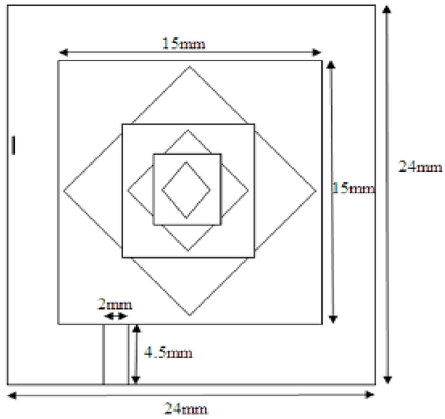
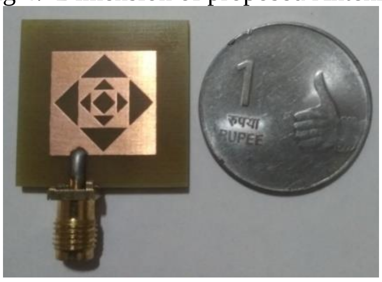


Fig 4. Dimension of proposed Antenna



(a)

(b)

Fig 5. (a) Top view (b) Bottom view of designed antenna

Parameters	Values
Patch length	15mm
Patch width	15mm
Substrate height	24mm
Substrate width	24mm
Substrate height	1.6mm
Ground thickness	0.035mm
Feed location	(-2.5,-4.5)
Dielectric constant	FR4 glass epoxy
Dimension of the basic patch	Length=15mm Width=15mm
Dimension of patch of 1st iteration	Length=10mm Width=10mm
Dimension of patch of 2nd iteration	Length=5mm Width=5mm
Dimension of patch of 3rd iteration	Length=2.5mm Width=2.5mm

Table 1. Showing Antenna Dimensions

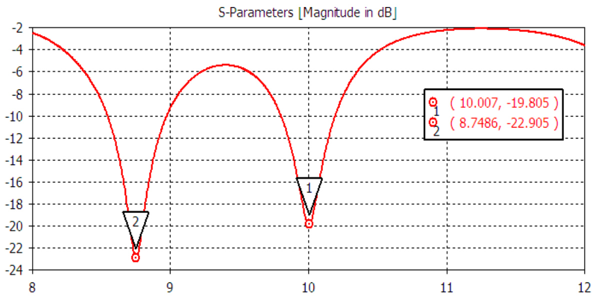
III. RESULTS AND ANALYSIS:

The design of the square fractal slot and three iteratives were studied and simulated by using CST microwave studio

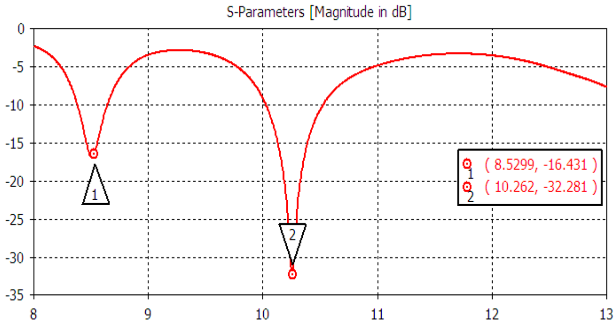
2017(student edition). The results are measured by Microwave Analyzer. In this part we discuss some illustrative results like Return loss, VSWR, Radiation pattern and gain.

Return Loss or S11 parameter

Return loss is the amount of signal that is reflected back towards the signal source by the device due to an impedance mismatch. It is the measure of hoe well device or line are matched. It is measured in dB. If the value of S11 parameter is 0dB, it means all the power is reflected from the antenna and nothing is radiated. Return loss of various iterations is shown in fig 6.In the third iteration the values of return loss are 8.5GHz, 10.1GHz, 12GHz, and 13.4GHz.



(a)



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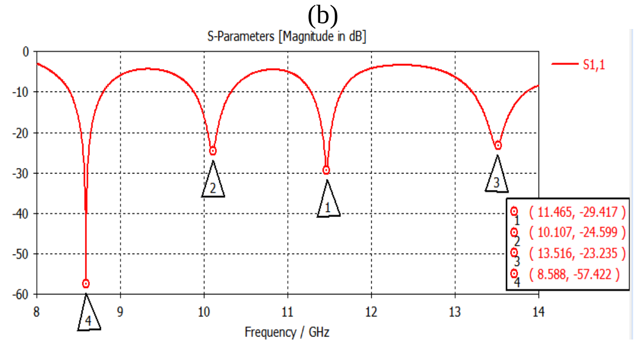
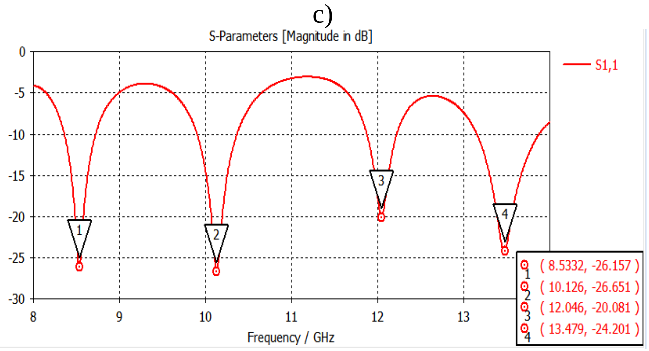


c)



(d)

Fig 6. Return Loss Plot of (a)base shape, (b)1st , (c) 2nd and (d) 3rd iteration

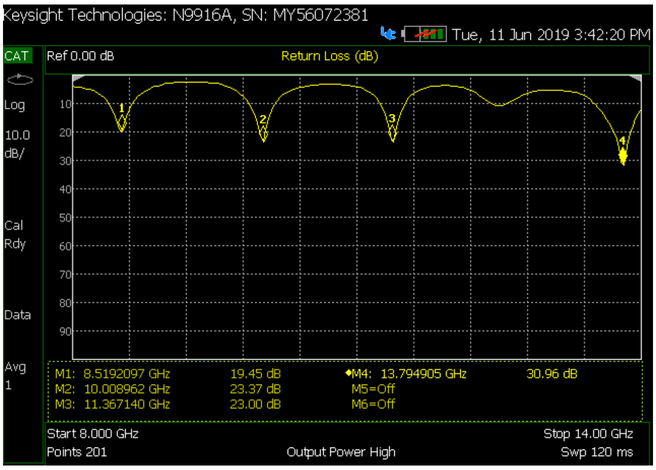
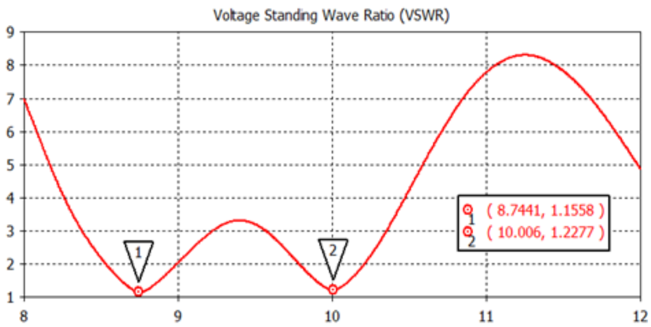


Fig 7. Measured Return Loss

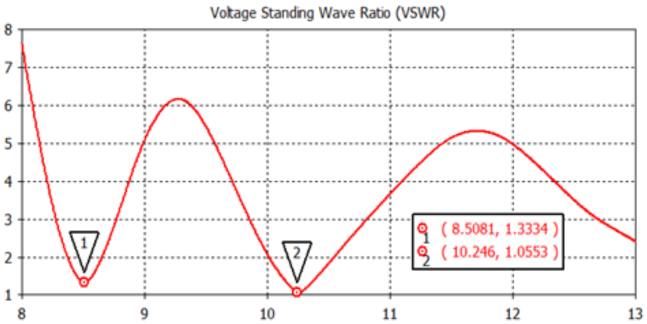
As shown in fig 5. the measured values of return loss are -19.45dB, -23.37dB, 23dB, 30.96dB at 8.5GHz, 10GHz, 11.3GHz, 13.7GHz respectivily.

VSWR

VSWR stands for voltage standing wave ratio. It is the measure of Impedance matching of load to the characteristics impedance line or waveguide. Simply it shows the amount of mismatching between antenna and the feedline connecting to it. The range of values for VSWR is from 1 to ∞. A value under 2 is consided suitable for most antenna applications. Fig8 shows VSWR plots of designed antenna for various iterations. As shown in figure the value of VSWR is less than 2 for every iteration at all radiating frequencies. For base shape VSWR is 1.1 and 1.2 at 8.7GHz and 10GHz. For first iteration it is 1.3 and 1.05 at 8.5GHz and 10.2GHz. For second iteration it is 1.02, 1.1, 1.07, 1.1 at 8.5GHz, 10GHz, 11.4GHz, 13.4GHz. For final iteration it is 1.08, 1.09, 1.2, 1.1 at 8.5GHz, 10.1GHz, 12GHz, 13.4GHz.



(a)



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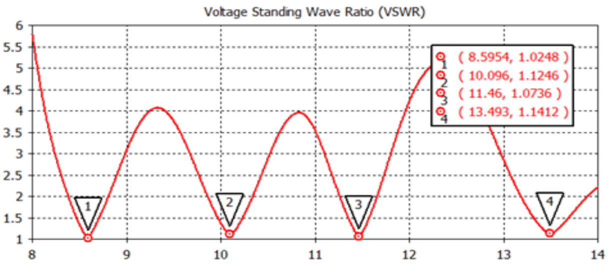

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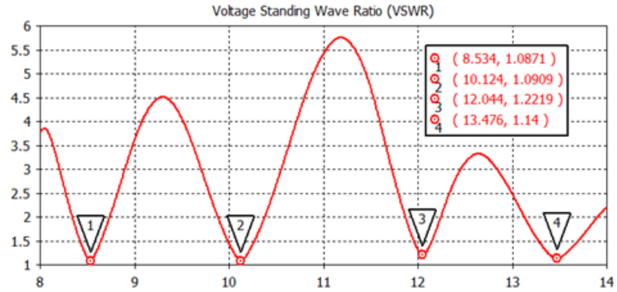


(d)

Fig .8 VSWR Plot of (a) Base Shape , (b)1st , (c) 2nd and (d) 3rd iteration

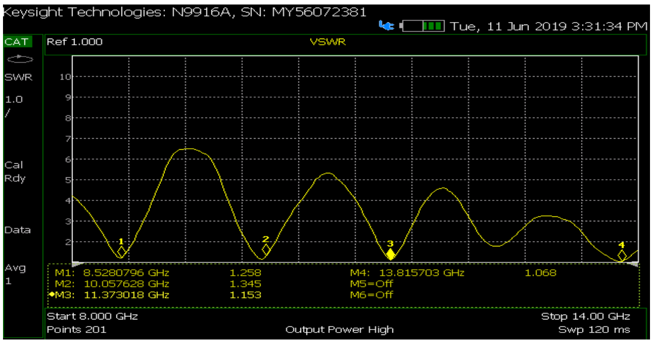
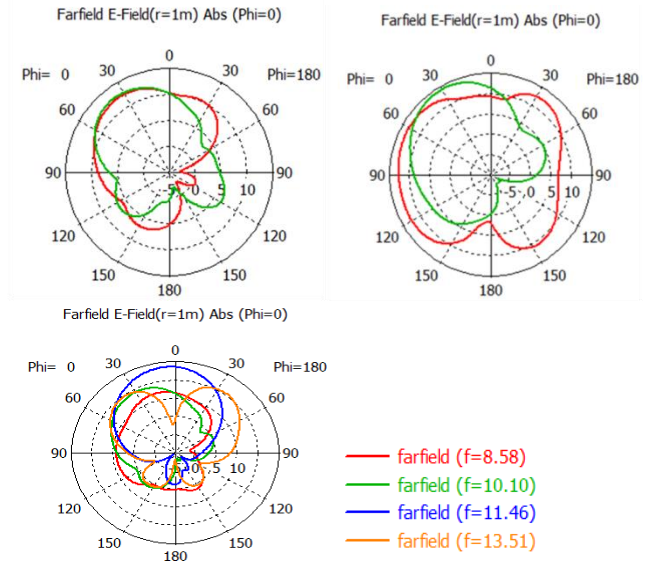


Fig 9. Measured VSWR

Radiation pattern

Radiation pattern is the graphical representation of the radiation properties of the antenna as a function of space coordinates. Various parts of a radiation pattern are referred to as lobes which may be subclassified into major or main, side and back lobes. The E-field pattern of all the iterations at different frequencies are shown in fig 10. It is shown that the proposed atenna is radiating in +Z direction and some amount of back radiation.



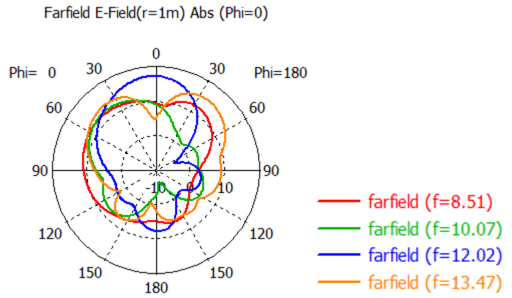


Fig 10. E-Field pattern of Base Shape, 1st,2nd,3rd iterations

Gain

Gain of the antenna is defined as the ratio of the intensity in a given direction , to the radiation intensity that would be obtain if the power accepted by the antenna were radiated istropically. Although the gain of the antenna is closly related to the directivity, it is a mearure that takes into account the efficiency of the antenna as well as its directional capabilies. Fig 11 shows the gain vs frequency plotof third iteration. The value of gain is 2.9dBi, 2.5dBi, 2.6dBi, 2.6dBi at 8.5GHz, 10GHz, 12GHz, 13.4GHz respectivily. The maximum gain occur at 8.5GHz of about 2.9dBi.

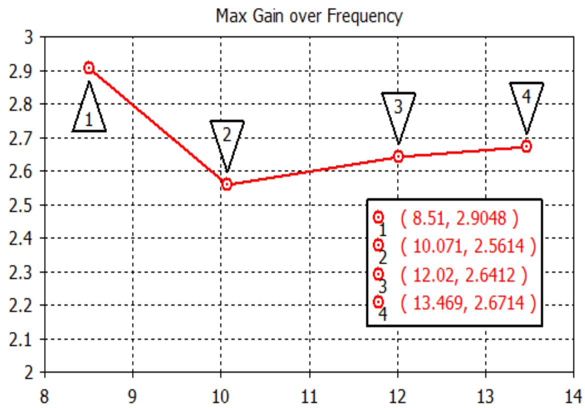


Fig 11. Gain plot at different frequencies of third iteration

Comparison Table:

A comparative study of different performance parameter of the fractal patch antenna has been given in Table 2.

Iteration No.	Freq. (GHz)	Return Loss (dB)	VSWR	Gain (dB)	Directiv-ity(dBi)
Base shape	8.7	-22.9	1.15	4.5	7.74
	10	-19.8	1.22	3.2	7.07
Iteration 1	8.5	-16.4	1.33	0.97	5.12
	10.2	-32.2	1.05	2.16	6.37
Iteration 2	8.5	-57.4	1.02	3.87	7.73
	10.1	-24.5	1.12	3.46	7.52
	11.4	-29.4	1.07	3.87	9.19
	13.5	-23.2	1.14	2.34	7.1
Iteration 3	8.5	-26.1	1.08	2.77	6.57
	10.1	-26.6	1.09	2.49	6.4
	12	-20	1.2	2.39	7.91
	13.4	-24	1.14	2.52	7.18

IV. CONCLUSION:

The proposed antenna has measure 24x24x1.6mm^3. For impedance matching microstrip feeding is utilized. The proposed antenna is intended to execute X and lower Ku band range applications with minimum antenna size and better impedance matching. The multiband capacity of proposed antenna is accomplished by fractal idea. Simulation result demonstrate that proposed antenna works on resonant frquency of 10.1GHz. This is a multiband antenna. Great outcomes has been found at X-band and lower Ku band. The antenna is utilized for satellite, radar, space, terrestrial communication application like telecom satellite, administration for sea, aeronautical or land application. The distinctive parameters of proposed antenna like Return loss,VSWR, Gain, Directivity, Radiation Pattern have adequate esteem.

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