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Design of Stair cased Square Fractal Antenna for Multiband Applications

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Abstract— **A novel design of fractal antenna is designed using Sierpinski carpet geometry and its various characteristics are investigated in this paper. Proposed antenna is designed on low cost easily available FR4 glass epoxy substrate with relative permittivity of 4.4 and a thickness of 1.6mm. The antenna is designed and simulated by using High Frequency Structure Simulator (HFSS) version 13. Basic structure of designed antenna is optimized by applying micro strip line feeding technique to achieve the high value of gain and return loss. Simulated results of proposed antenna revels that the antenna works on six frequency bands of operation such as 1.09GHz,3.63GHz,6.18GHz,7.18GHz and 9.18GHz with a value of return loss, gain and VSWR at acceptable level. Antenna is fabricated and tested using VNA (Vector Network Analyzer), which shows that the experimental results are in good agreement with the simulated results. Proposed antenna resonates at six different frequency bands including S band (2 – 4GHz) for WLAN and Bluetooth, High speed wireless Communications (5.92-8.5GHz) and X band (8-12GHz) for satellite Communications etc. The maximum gain of the proposed fractal antenna can reach 9.08dB.**

Keywords- fractal; VNA; HFSS; square

1. INTRODUCTION

The B.B Mandelbrot was the first French mathematician who developed the concept of fractal geometry in 1975 [1].In modern telecommunication system require antenna with wider bandwidth and smaller dimensions. To achieve multiband characteristics the fractal antenna geometry is used which are not possible to achieve by conventional micro strip patch antenna [2].The word fractal is defined as shape made of parts similar to the whole of same way. The fractal geometry is complex in structure and shape can be formed by sub dividing the whole antenna shape into different parts and each part is the copy of whole antenna [3].

The fractal antenna are designed by applying the two unique properties such as self similarity and space-filling property [4] which make fractal antenna to achieve many advantage like small size antenna, wideband characteristics, multiband characteristics and high efficiency. The self similarity property of antenna describes by the multiband nature and space-filling used to reduce size of antenna which lead to multiband and wideband applications like military and defense applications[12].

It is also used in UWB applications like WLAN, Wi-Max, Bluetooth, WI-Fi, satellite and ISM applications. Many fractal geometries has been designed to achieve the different parameters of antennas for various wireless applications such as Minkowski fractal [5], Sierpinski Gasket fractal [6], Koch Curves [7], Sierpinski Carpet fractal [8]. Multiband fractal antennas are more demanded because of many applications in the field of communication such as GPS, GSM, PCS, CDMA, RADAR etc [9]. The most commonly used fractal geometry which follows self similar and space filling property are sierpinski carpet and sierpinski gasket[10].

In this work a novel fractal antenna is designed by using square geometry and strip-line feed to enhance the performance of antenna like BW, return loss, gain and number of frequency bands. The details of designed antenna and its various performance parameters have been discussed in section II and section III respectively.

2. ANTENNA DESIGN AND CONFIGURATION

The Geometry of proposed antenna has been designed using low cost glass FR4 epoxy substrate with dielectric constant 4.4 and substrate thickness of 1.6mm.A square feed patch of side length 40mm is used along with finite ground plane of side length 50mm.A strip-line feed is used to excite the micro-strip patch antenna. HFSS (version 13) software based on method of moments has been used to simulate the proposed antenna design. The dimensions of micro strip patch antenna are as follows[11]:-

$$w = \frac{c}{2fo\sqrt{\frac{\varepsilon_r + 1}{2}}}$$

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

$$L_{eff} = \frac{c}{2fo\sqrt{\varepsilon_{reff}}}$$

$$\Delta L = 0.412\,h \frac{\left(\varepsilon_{reff} + 0.3\right)\left(\frac{w}{h} + 0.246\right)}{\left(\varepsilon_{reff} - 0.258\right)\left(\frac{w}{h} + 0.8\right)}$$

$$L = L_{eff} + 2\Delta L$$

Where,
c is the Velocity of light(in free space)
h is the Height of the substrate
Ɛr is the Relative permittivity of the substrate
W is the Width of patch
L is the Actual Length of patch
Leff is the Effective length
ΔL is the Length extension.
Ɛ eff is the Effective dielectric constant.

As shown in fig 1(a) basic shape of square fractal antenna and its parametric values are given in table 1, firstly side of patch of length 40mm is taken on ground plane of side 50mm. Further a square slot of side 20mm (half the size of basic square patch) has been imposed on in centre of the square feed patch.

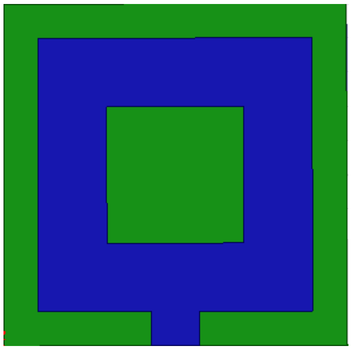


Figure 1(a) 0 th Iterations of Proposed Antenna

Figure 1(b) shows the first iteration of square fractal antenna. Four square slots, each side length 10mm (half the side of square slot of base shape) are employed in the centre of outer sides of the major square slot.

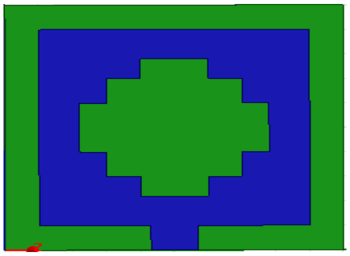


Figure 1(b) 1st Iterations of Proposed Antenna

Figure 1(c) shows the second iteration of square fractal antenna. Four square slots, each side length 6mm (half of side of square slot of first iteration) are employed in the centre of outer sides of foursquare slots of first iteration.

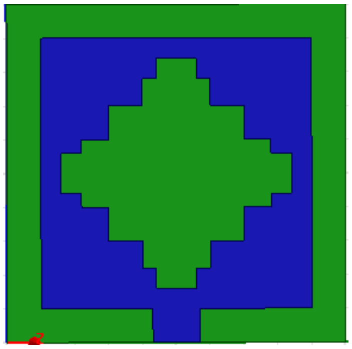


Figure 1(c) 2nd Iterations of Proposed Antenna

TABLE I. PARAMETRIC VALUES OF PROPOSED FRACTAL ANTENNA

S. No.	Parameters	Description	Values
1.	WS	Width of substrate	50mm
2.	LS	Length of substrate	50mm
3.	X	Width of Slot	20mm
4.	Y	Length of Slot	20mm
5.	WP	Width of Patch	40mm
6.	LP	Length of Patch	40mm

3. RESULT AND DISCUSSIONS

To understand the behavior and the performance of proposed antenna and to determine the different parameters, the proposed antennas are designed and simulated using HFSS V13 software. The designed antennas are then fabricated and tested using VNA (Vector Network Analyzer) to validate the simulated results with the experimental results. Fabricated structures of proposed antenna are shown in Figure 2 and the setup used for testing the proposed antennas is shown in Figure 3.

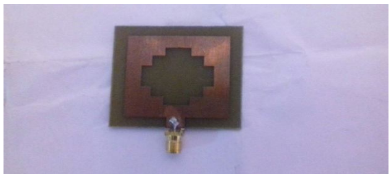


Figure 2. Fabricated Structures of proposed antennas

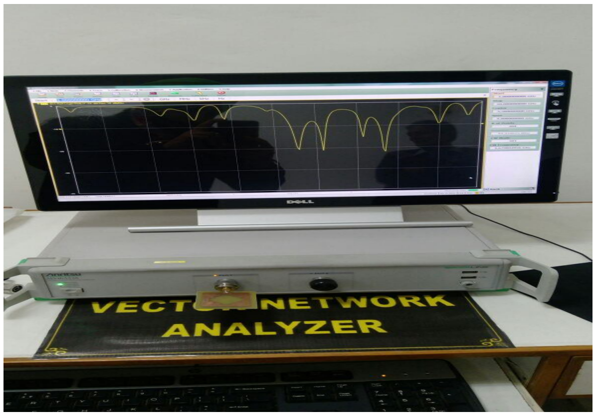


Figure 3. Testing setup of proposed fractal antennas

A. Return loss

Simulated results of proposed antenna with line feed shows the resonance peaks at six different frequency bands such as 1.27GHz, 3.63GHz, 6.27GHz, 7.18GHz ,8.54GHz and 9.36GHz with return loss -12.08,-11.42,-19.30,-14.28,-15.37 and -11.05. At all these frequency bands for both the antennas the value of return loss id ≤ -10dB , which are the acceptable values for an antenna to work efficiently for practical wireless applications. The comparison of simulated and measured curves of S_{11} (dB) for given fractal antenna with line feed is shown in Figure 4 and 5 respectively.

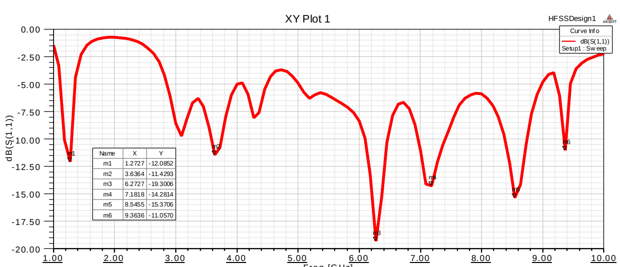


Figure 4. Return loss v/s frequency curves of proposed antenna with line feed

Measured results of proposed antenna with line feed shows that it resonates at four different frequencies with return loss -20.01,-20.2,-15.00 and -20.08 as observed from the Figure 5, there are some variations has been noted in the simulated and the measured results of the proposed antenna with line feed. This variation is due to the uncertainty in the electrical properties of the substrate and the reflection from the SMA connector. Simulated and measured values of return loss, and operating frequency bands are shown in Table 2.

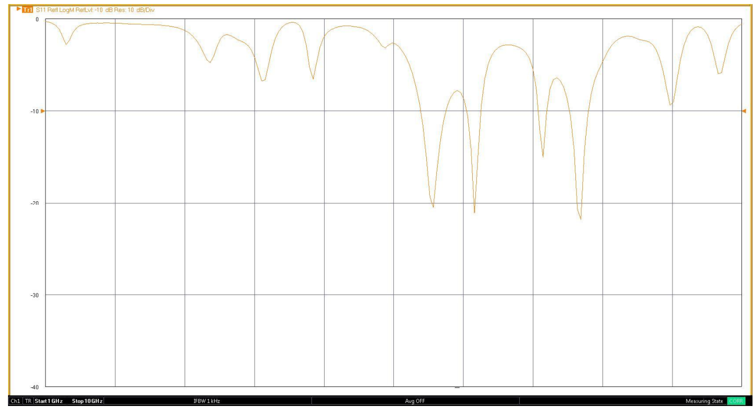


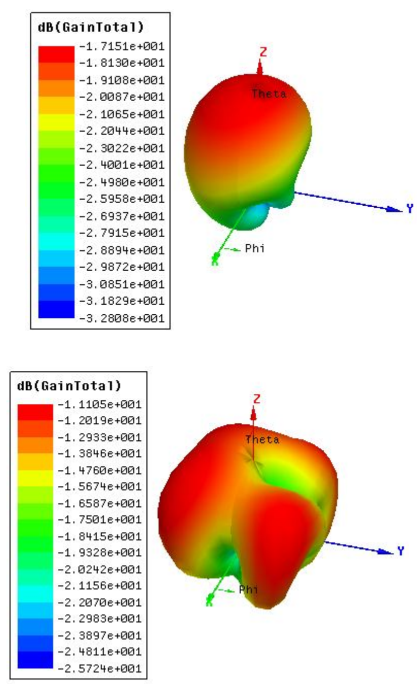
Figure 5. Return loss v/s frequency curves of proposed antenna with line feed

Table 2 Comparison of simulated and measured results of proposed fractal antenna

Antenna	Frequency (GHz)	Return loss (dB)
Simulated with line feed	1.27,3.63,6.27,7.18,8.54 and 9.36	-12.08,-11.42,-19.30,-14.28,-15.37 and -11.05
Measured with line feed	5.5,6.1,7.2 and 7.8	-20.01,-20.02,-15.00 and -20.08

B. Gain

The gain of proposed antenna with line feed shows the value of -1.71dB, -1.11dB, 7.5dB, -1.63dB and 9.08dB at Five frequency bands such as 1.09,3.63 ,6.18,7.18 and 9.18. The 3D plot for the maximum value of gain at 3.14GHz is shown in Figure 6.



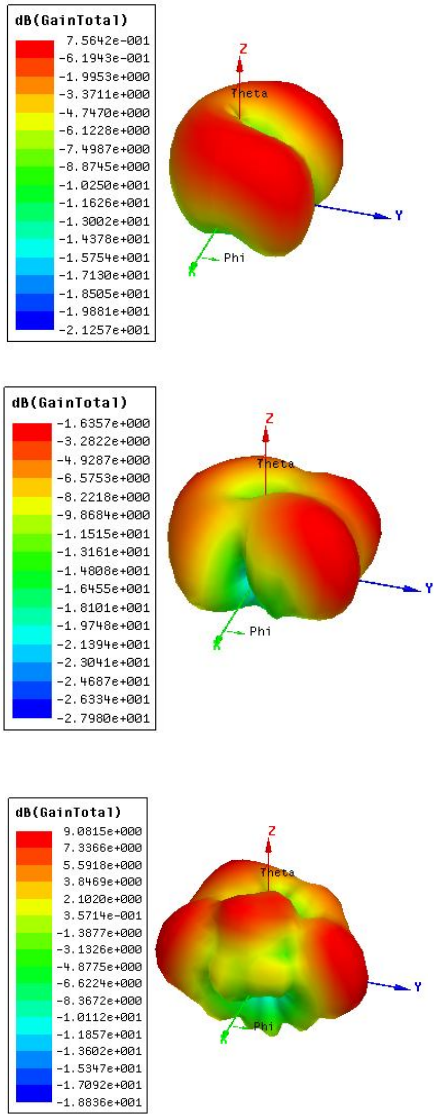


Figure 6. 3D Gain plot at 2nd iteration of proposed antenna

4. CONCLUSION

This paper presents the novel design of fractal antenna using Sierpinski carpet geometry for multiband applications such as S band (2 – 4GHz) for WLAN and Bluetooth, High speed wireless Communications (5.92-8.5GHz) and X band (8-12GHz) for satellite Communications etc. Proposed antenna is designed by using simple line feed to analyze the various performance parameters. Simulated and measured results of proposed antenna with line feed shows that it works on six and four resonant frequencies respectively. Antenna with line feed shows the value of gain 9.08dB at 9.18GHz frequency band .

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