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Design and Analysis of Hexagonal Fractal Antenna Array for GPS and WLAN Applications

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***Abstract*—As per the need of growing demand for wireless communication a different standards are required, which provide mobility for end user and high speed of data transmission. Miniaturization of antenna led to develop a conformal, low profile and multiband characteristics antenna, hence fractal structure come into existence due to its self-similar geometry. This paper proposes the hexagonal fractal antenna array with three iteration. The proposed antenna is designed and simulated using HFSS software and fabricated using FR-4 material. Fabricated antenna is tested using vector network analyzer (VNA). Results of experimental and simulated are compared for parameters like; return loss, bandwidth, VSWR and directivity which are good in agreement. The designed and fabricated antenna is found to to suitable for multiband characteristics and satisfies the requirements of wireless applications like GPS, Bluetooth, and WLAN.**

***Index Terms*— Fractal, multiband, self-similarity, GPS, Bluetooth and WLAN.**

I. INTRODUCTION

In view of the progress of the recent wireless communication systems and its application, wider bandwidth, multiband and low profile antennas are in great demand for both commercial and military applications. The fast increase of wireless communications leads to a huge demand in designing of a multiband antenna [1][2]. Benoit Mandelbrot a mathematician was first used the term "fractal" in 1975[1][8]. A great scientist Rumsey developed an antenna with different shapes which depend upon angles which are called as frequency independent antenna, because its size and characteristics will not depend on wave length. With this geometry the antenna maximizes or increases its length of patch which is used for transmit or receive EM wave within a given volume or total surface area. Fractal is a concept with micro strip is used to have better Characteristics than micro strip antenna. In many fractal antennas, the self-similarity and plane-filling nature of fractal geometries are often quantitatively linked to its frequency characteristics. Fractals are self-similar geometrical shapes which repeat themselves at different scales. The geometry of fractals is important because the effective length of the fractal antennas can be increased while keeping the total area same 1975[3][6].

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There are many features of fractal geometries like infinite complexity, fractional dimension, and self-similarity. These characteristic features of fractals can be utilized in antenna design to get the better efficiency and fractals have sharp

Corners and edges that cause quick changes in the direction of current and hence improve radiation.

Therefore fractals are efficient radiators of electromagnetic energy [3]. Compact size compared to antennas of expected designs while maintaining good to exceptional efficiencies and gains. In this paper, the hexagonal fractal antenna is realized using corner fed technique.

II. Hexagonal Fractal Antenna Array and Its Design

The hexagonal fractal microstrip antenna array is simulated for three iterations. The proposed geometry of an antenna consists of eight hexagonal shapes which are constructed by sinking and combining. Then its shape will be one-third of its first iterations. This miniaturization procedure is known as the iterated function system (IFS) [4]. The designed antenna will maintain its conductivity and achieve self-similarity property.

The length and width of the designed antenna is 185mm^2 with the hexagon dimension is 29mm as shown in fig.1. An antenna designed with substrate height=1.6 mm, Loss tangent tan ɗ =0.019 and dielectric constant εr=4.4. A small hexagonal shaped slot has made at its center for 2nd iteration. Where as in the third iteration, further miniaturization creates eight smaller hexagons around a central hexagon. Because of this geometry in the radiator patch, surface current length enhanced and which results in increase in total conductivity and strong radiation in the patch. A signal is fed to the antenna through coaxial feeding with the probe diameter of 3.0mm. The results are observed at center frequency for 2.4GHz and around of it. A circular equation was used to calculate the actual distance, *"a"* of the hexagonal radiating patch antenna to match at 2.4GHz and around of it which is given below [4][7] and design values are calculated using standard formula and illustrated in table1 and simulation is carried out using HFSS software and we get the proposed antenna model as shown in fig. 2 and is fabricated using photolithographic technic and etching process as shown in fig.3.

$$a = \{(1 + 2h/ \pi \varepsilon r F)\ (lnF/ 2h + 1.7726)\}$$

where a and b = 29 and 59 mm

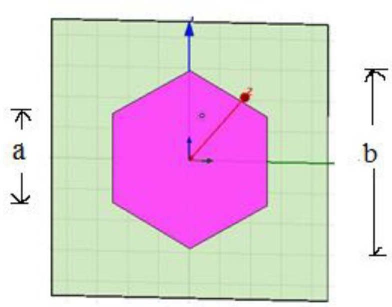

Fig.1 Micro strip hexagonal fractal antenna

TABLE I. DESIGN PARAMETERS OF HEXAGONAL FRACTAL ANTENNA

Particulars	**Value**
f_0	2.4GHz
ε_r	4.4
W	38mm
ε_{reff}	4.085
L_{eff}	30.91mm
ΔL	0.7388mm
H	1.6mm
L	29.44mm
Ls	48.64mm
Ws	57.23mm
X_f	7.5
Y_f	19.38

Proposed antenna model is:

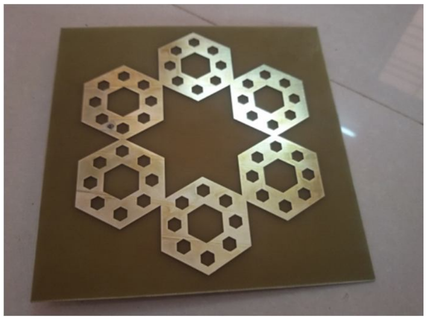

Fig.2 Simulated hexagonal fractal antenna array antenna array

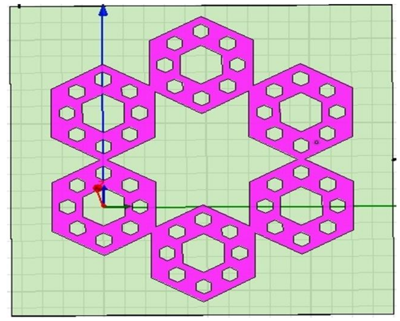

Fig.3 Fabricated hexagonal fractal

III. SIMULATION AND EXPERIMENTAL RESULTS OF HEXAGONAL FRACTAL ANTENNA ARRAY

The antenna is designed at a 2.4GHz frequency. The corner-fed hexagonal fractal antenna array is simulated by using HFSS software and results of simulated and experimental values are shown in fig 4 to fig 6. And experimental results are shown in fig 7 to fig.10.

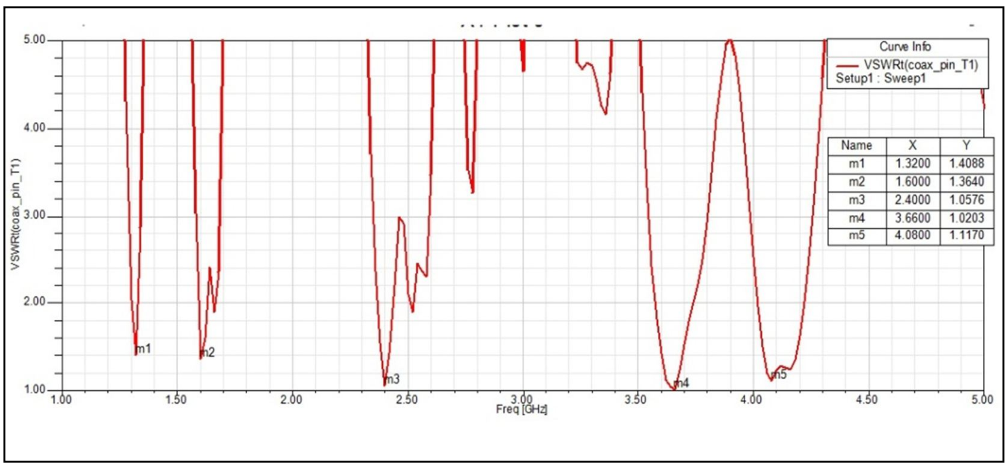

Fig.4: VSWR of Hexagonal Fractal Antenna Array

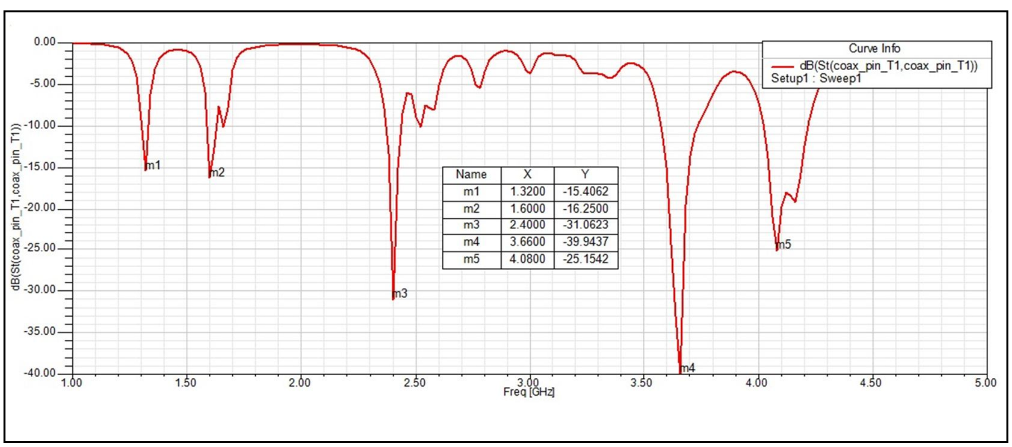

Fig. 5: Return Loss

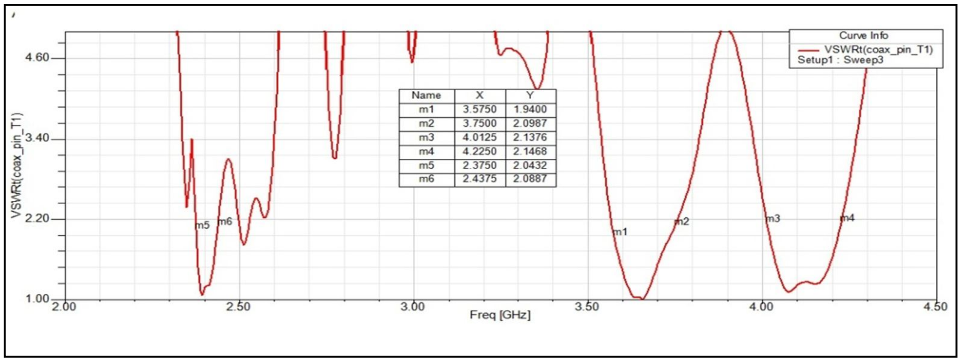

Fig. 6: Bandwidth

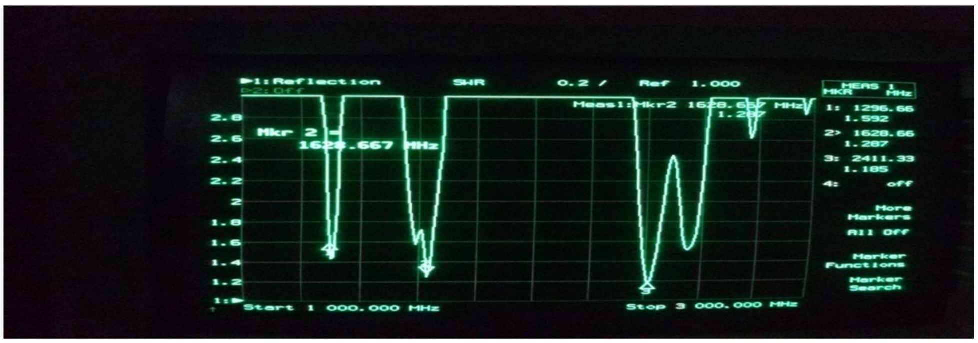

Fig. 7 Experimental VSWR of HFA

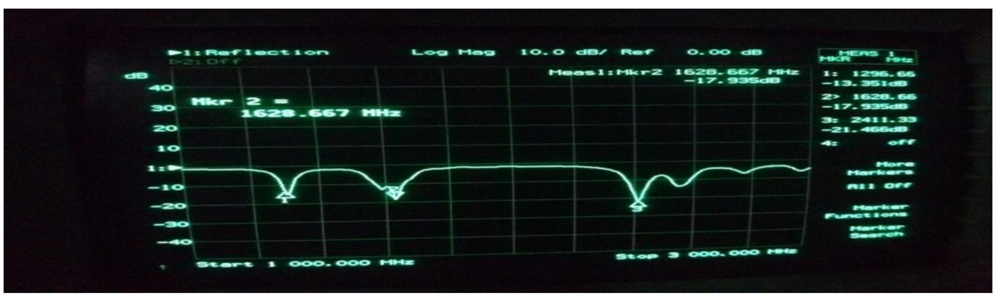

Fig. 8 Experimental Return loss of HFAA

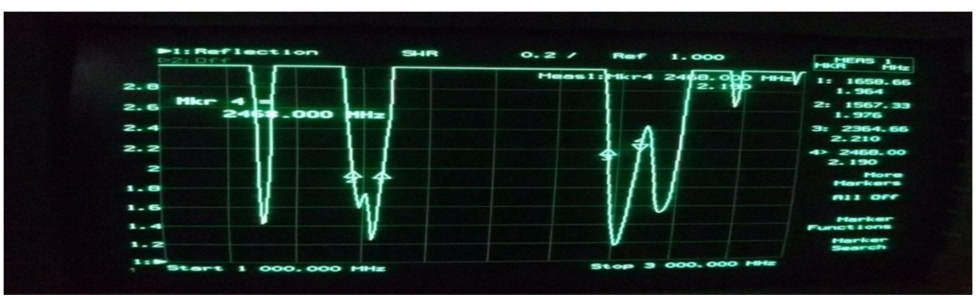

Fig. 9 Bandwidth of HFAA

In this paper presented a comparative analysis of simulated and experimental results of the hexagonal fractal antenna array with corner feeding technique. The overall working of antennas was understood. The major parameters such as VSWR, Return Loss, bandwidth, Directivity are analyzed as shown in table 2.

TABLE II. SIMULATED AND EXPERIMENTAL RESULTS OF THE HEXAGONAL FRACTAL ANTENNA ARRAY

Frequency (GHz)	Simulated results				Experimental Results		
	VSWR	**Return loss in (dB)**	**Bandwidth in (MHz)**	**Directivity in (dB)**	**VSWR**	**Return loss in (dB)**	**Bandwidth in (MHz)**
1.30	1.40	-15.40	30	2.32	1.59	-13.35	36
1.60	1.36	-16.25	60	3.01	1.28	-17.93	90
2.40	1.05	-31.06	62.5	6.83	1.18	-21.46	104
3.66	1.02	-39.94	175	9.60			

VSWR: Is a term which is used to find how the antenna is matched with cable impedance. The perfectly matched antenna will have a VSWR of 1:1 which indicates about the power reflected back or transferred into a cable. The ideal value of VSWR is lying in between 1 to 2. It has been observed that VSWR for the proposed antenna is as shown in table 2 are 1.40, 1.36, 1.05 at frequency 1.3GHz, 1.6GHz and 2.4GHz.

Return Loss: Is a term which is used to measure the amount of power that is lost to load and does not return as reflection. Return Loss is similar to VSWR and is generally preferred in the cable industry to a VSWR specification. The ideal value of return loss is < -10dB which corresponds to VSWR of < 2. In Simulated and Fabricated Hexagonal Fractal Antenna Array value of Return Loss at frequency 1.3GHz, 1.6GHz and 2.4GHz are -15.40, -16.25 and -31.06 respectively.

Bandwidth: The antenna bandwidth is defined as the range of operational frequencies on either side of the center frequency. This is used to analyze how efficiently an antenna is functioning over the essential range of frequencies. A VSWR less than or equal to 2 (-10dB ≥ RL) confirm good performance. It has been observed from table 2 that Bandwidth for Simulated and Fabricated Hexagonal Fractal Antenna Array is 36 MHz, 90 MHz and 104 MHz at 1.30 GHz, 1.60 GHz, and 2.40GHz respectively.

IV. CONCLUSION

Hexagonal fractal antenna array has been designed in this paper at resonant frequency 2.4GHz. Simulation is performed using HFSS, Fabricated and tested using Vector network analyzer (VNA). The simulation and experimental results presented a good radiation pattern and high directivity, compared to a conventional micro strip patch antenna. The return loss results show excellent rise and fall and appropriate bandwidth for the GPS and WLAN applications.

The hexagonal fractal antenna array possesses the multiband performance comparable to the Sierpinski gasket antenna. The working frequency band covers a large number of wireless communication applications including GPS (1.6GHz), Bluetooth (2.4 GHz) & WLAN (3.6GHz).

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