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Formation of Fractal Antenna Array for Multiband Applications

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***Abstract*: *Antennas play a vital role in wireless communication; a thirst of excellence in this area is unending. Proposed work describes a concept of fractal multiband antenna designed in the hexagon shape. Basically fractal is the concept used in Microstrip antenna for giving better results than conventional Microstrip antenna. By using hexagonal fractal antenna we can possibly achieve the radiation pattern with high gain. The coaxial feeding is used and multiple hexagons are interconnected in array for maintaining conductivity and to preserve electrical self similarity. Hexagonal antenna is used for different wireless applications. The proposed antenna frequency band covers a large number of wireless communication applications including GPS (1.6GHz), Bluetooth (2.4 GHz) & WLAN (3.6GHz). Antenna design has been designed and simulated by using the software Ansoft's HFSS and parameters like bandwidth return loss, directivity, VSWR are analyzed. Fabrication of the antenna is done by using wet-etching method, on FR-4 dielectric substrate material. Experimental results are taken on Vector Network Analyzer (VNA) and those obtained results were compared with simulated results. The hexagonal fractal antenna array is found to possess predictable multiband characteristics*.**

Keywords: Fractal antenna, FR4, Microstrip, VNA.

I. INTRODUCTION

In the last few decades, wireless communication has gained a lot of importance. The devices used in wireless communication, respond at the high-frequency range. Much of the researches were done to minimize the circuit complexity of these devices without losing the characteristics and signal propagation in wireless communication. As the wireless communication is vital in many areas like military applications, satellite communication, etc. so, this has initiated the antenna research in various directions and one of them is using fractal shaped antenna arrays.

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An antenna is a metallic structure that sends or receives electromagnetic waves, such as radio waves, microwaves etc. In other words, antennas convert radiofrequency fields into electrical currents. In old times antennas used were operating at a single or dual frequency band. So, different antennas were needed for different applications [1]. So the limited place and space problem arises.

To overcome this problem, the multiband antenna can be used where a single antenna can operate at many frequency bands. One technique to construct a multiband antenna is by applying fractal shape into antenna geometry [3]. Proposed work presents the hexagonal antenna array where this famous shape, antenna behaviors are investigated The antennas have been analyzed and designed by using the software Ansoft's HFSS A fractal antenna is nothing but an antenna that is used for the multiband application. Fractal is a concept that is being implemented in Microstrip antenna to have better characteristics than the Microstrip antenna. The frequency characteristics of fractal antenna are linked to the self similarity and plane filling nature of fractal geometry. Fractals are self-similar geometrical shapes that repeat themselves at different scales [8]. Because of fractal geometries many areas of science and engineering have been impacted, and one of them is antennas. Some of the geometries are already available in market for telecommunication applications. And it has shown the improvement in several antenna features.

As the fractal geometries have been known for a long time but the study of fractal antenna is totally a new area. The fractal term was created in 1975 by the French mathematician, Benoit B. Mandelbrot [11]. The area of Fractal electrodynamics and its applications have been studies by Mandelbrot. This area combines the electromagnetic theory and fractal geometry which results in new radiation patterns, propagation and scattering problems. The studies included showed that fractals have good electromagnetic radiation patterns and advantages over traditional antennas. A fractal antenna is a rough or fragmented geometric shape that can be separated into parts which are an approximation to the whole geometry but in reduced size. Fractals are complex because of their similarity at all levels of magnification. There are only two types of fractals, natural and mathematical [10]. Fractal geometries, to a certain level, can be found all around us, even though we are not aware of that, these are the natural fractals. Examples of natural fractals are shown below: fig.1) coastlines , fig.2) Lightning , fig.3) Snowflakes All these examples have fractal geometry.


fig.1[10]


fig.2[10]


fig.3 [10]

Fractal geometries, to a certain level, can be found all around us, even though we are not aware of that, these are the natural fractals. Each fractal is combination of multiple iterations of a single elementary shape. The iterations can continue infinitely, thus forming a shape within an infinite boundary but of infinitely length or area [2].

This compactness property is highly desirable in mobile wireless communication applications because smaller receivers could be produced. Use of fractals is an approach to antenna design is relatively new development in the field of antenna research. Before undertaking the design of both antennas, it is farsighted to establish a general design plan and to determine the constraints imposed on that plan. Simulations of the design will be done before hardware fabrication to obtain the expected outcome and the dimensions of the antenna. HFSS will be used for simulation and the design will be tested using Vector Network Analyzer (VAN).

II. DESIGN OF FRACTAL ANTENNA

The block diagram of general overview of design of fractal antenna is as shown in following diagram

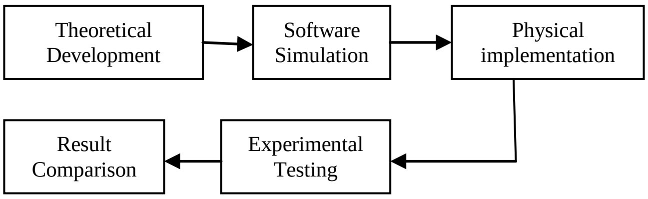

Fig.4: General overview of design of fractal antenna

The design plan includes the following phases:

Step 1: Theoretical development rough calculations of antenna parameters as well as develop a general idea of the physical implementation of the antenna.

Step 2: Software simulation Perform software simulations in order to verify the theoretical design and adjust any parameters to predict the desired antenna performance. Software simulation is done by using HFSS software.

Step3:Physical implementation Undertake physical construction of the antennas based on simulation confirmed parameters. Antenna is manufactured on FR-4 dielectric material.

Step 4: Experimental testing antenna performance is measured with the help of vector network analyzer (VAN). Here, the different antenna parameters are measured like VSWR, return loss, bandwidth.

Step 5: Comparison of Results: Finally, compare the results obtained from software simulation and experimental testing of antenna.

III. SIMULATION AND EXPERIMENT RESULTS

This section describes the simulation and experiment results of the proposed work.

1. High Frequency Simulator Structure (HFSS)

This is a high performance full wave Electromagnetic Field simulator for erratic 3D volumetric passive device modeling which takes the advantage of the familiar Microsoft windows GUI. HFSS combines simulation, visualization, solid modeling and automation in an easiest environment where solutions to our 3D Electromagnetic problems are quickly and accurately obtained. Ansoft HFSS engages the finite Element Method (FEM), adaptive meshing and brilliant graphics that gives unparalleled performance and understanding of all 3D EM problems. It can be used to calculate parameters such as S-Parameters, Resonant Frequency, and Fields.

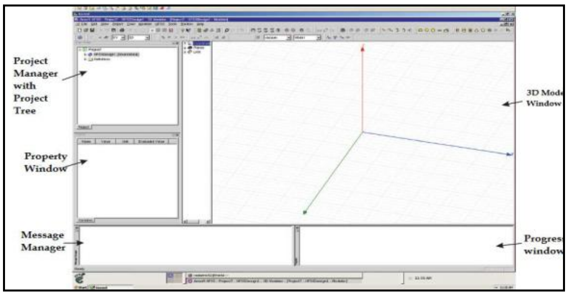

Fig.5: HFSS window

Iteration wise structure of hexagonal fractal antenna is as follows

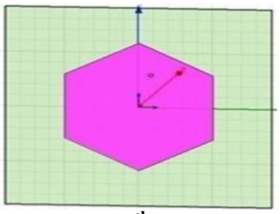
Fig.6: 0th iteration

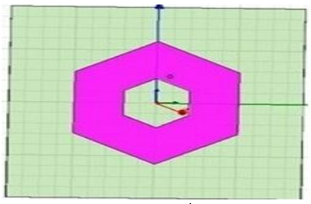
Fig.7:1st Iteration

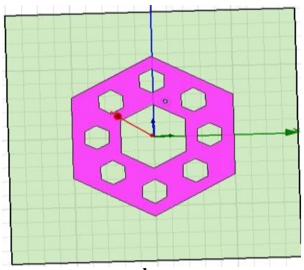
Fig.8:2nd Iteration

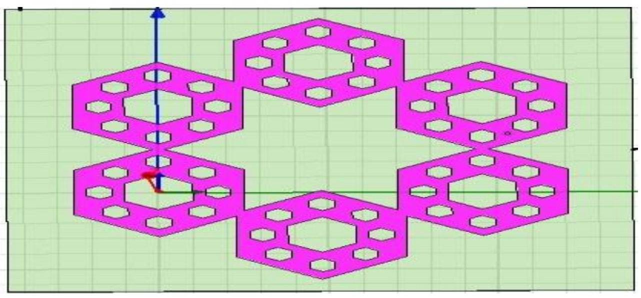
Fig.9: Hexagonal fractal antenna array

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2. Simulated Results by using HFSS software

2.1. Simulated Results of VSWR

Voltage Standing Wave Ratio is the ratio of maximum radio-frequency voltage to minimum radio-frequency voltage on a transmission line [4]. It is given by,

$$VSWR = \frac{V_{max}}{V_{min}}$$

The best performance of an antenna is achieved when the VSWR under 2 or the return loss is -10dB or lower.

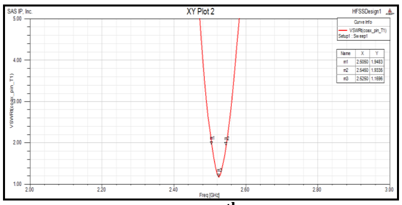

Fig.10: VSWR of 0th Iteration for Hexagonal Fractal Antenna

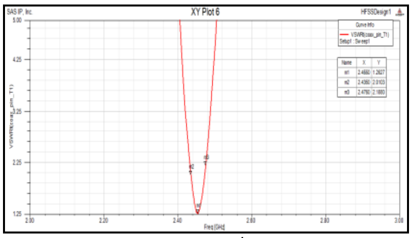

Fig.11 : VSWR of 1st Iteration for Hexagonal Fractal Antenna

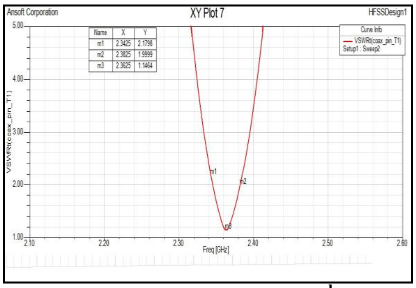

Fig.12: VSWR of 2nd Iteration for Hexagonal Fractal Antenna at 2.36GHz

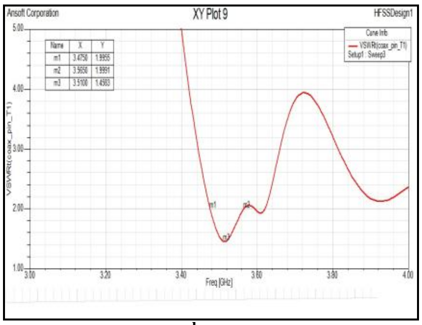

Fig.13: VSWR of 2nd Iteration for Hexagonal Fractal Antenna at 3.51GHz

Sr. No.	Frequency (GHz)	VSWR
0th Iteration	2.52	1.12
1st Iteration	2.45	1.26
2nd Iteration	2.36	1.09
	3.51	1.17
Antenna Array	1.30	1.40
	1.60	1.36
	2.40	1.05
	3.66	1.02
	4.08	1.11

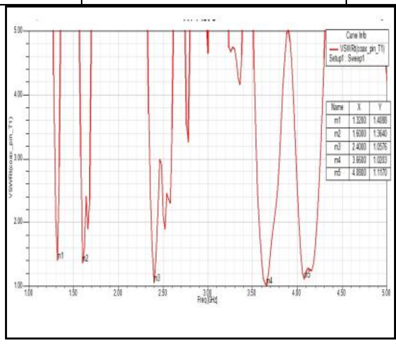

Fig.14: VSWR of Hexagonal Fractal Antenna Array

TABLE I: Simulated results of VSWR

2.2 Simulated Results of Return Loss

It indicates the amount of power that is lost to load and does not return as reflection. Return loss is a parameter similar to VSWR to indicate how well the matching between transmitter and antenna has taken place. Ideal value of return loss is around -13dB which corresponds to VSWR of less than 2.The first three iterations of the corner-fed hexagonal fractal antenna and hexagonal fractal antenna array are simulated by using HFSS software. The Return Loss (reflection coefficients) for the first three iterations and array of the hexagonal fractal antenna are plotted in below figures. It shows that the Hexagonal fractal Antenna produced a high return loss compared to the Sierpinski Carpet Fractal Antenna.

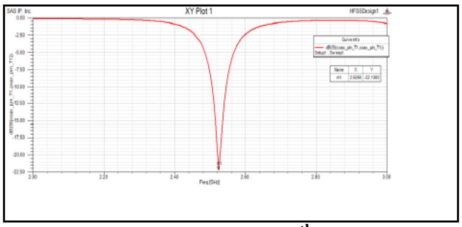

Fig.15: Return Loss of 0th Iteration for Hexagonal Fractal Antenna

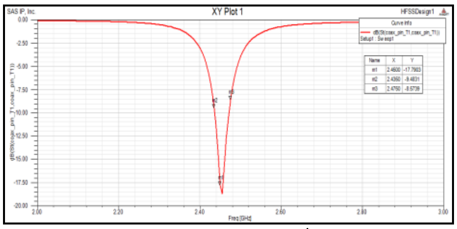

Fig.16: Return Loss of 1st Iteration for Hexagonal Fractal Antenna

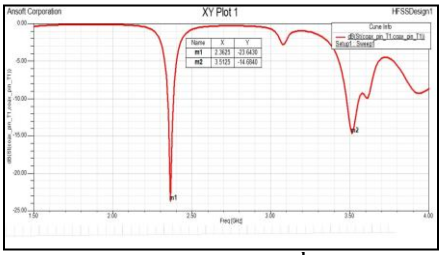

Fig.17: Return Loss of 2nd Iteration for Hexagonal Fractal Antenna

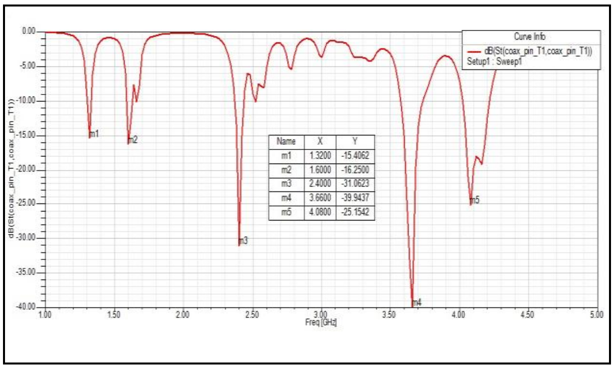

Fig.18: Return Loss of Hexagonal Fractal Antenna Array

TABLE II: Simulated results of Return Loss

Sr. No.	Freq (GHz)	Return Loss (dB)
0th Iteration	2.52	-22.13
1st Iteration	2.45	-17.81
2nd Iteration	2.36	-23.64
	3.51	-14.68
Antenna Array	1.30	-15.40
	1.60	-16.25
	2.40	-31.06
	3.66	-39.94
	4.08	-25.15

2.3 Simulated Results of Bandwidth

The bandwidth of a broadband antenna can be defined as the ratio of the upper to lower frequencies of acceptable operation.

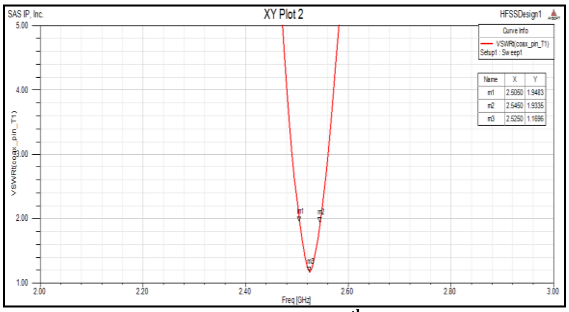

Fig.19: Bandwidth of 0th Iteration for Hexagonal Fractal Antenna

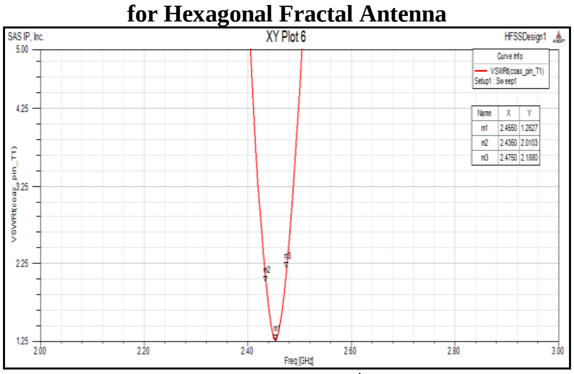

Fig.20: Bandwidth of 1st Iteration for Hexagonal Fractal Antenna

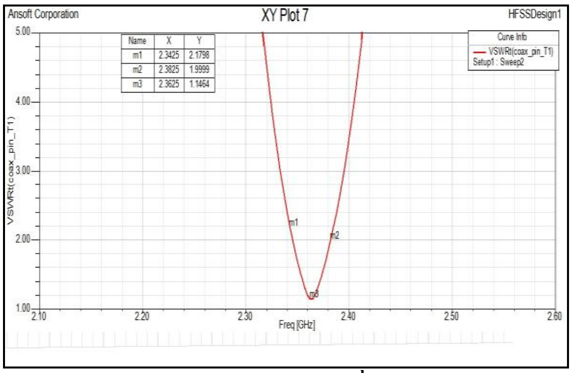

Fig.21: Bandwidth of 2nd Iteration for Hexagonal Fractal Antenna at 3.6GHz

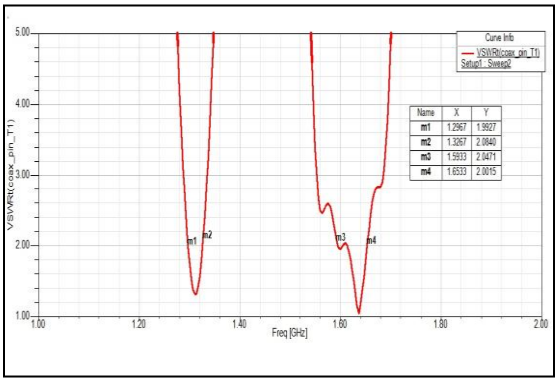

Fig.22: Bandwidth of Hexagonal Fractal Antenna Array at 1.3GHz and 1.6GHz

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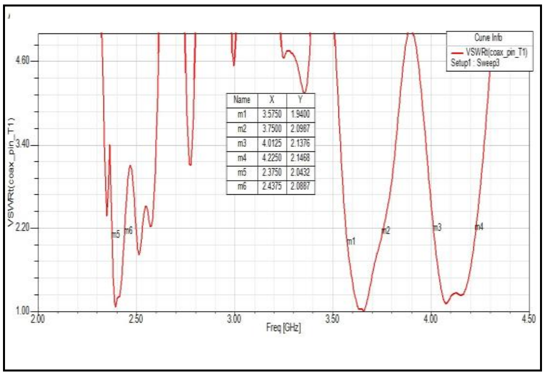

Fig.23: Bandwidth of Hexagonal Fractal Antenna Array at 2.4GHz, 3.66GHZ and 4.08GHz

TABLE III: Simulated results of Bandwidth

Sr. No.	Frequency (GHz)	Bandwidth (MHz)
0th Iteration	2.52	40
1st Iteration	2.45	40
2nd Iteration	2.36	40
	3.51	90
Antenna Array	1.30	30
	1.60	60
	2.40	62.5
	3.66	175
	4.08	212

TABLE IV: Simulated results with different parameters

Sr. No.	Freq. (GHz)	VSWR	Return Loss (dB)	BW (MHz)
0th Iteration	2.52	1.12	-22.13	40
1st Iteration	2.45	1.26	-17.81	40
2nd Iteration	2.36	1.09	-23.64	40
	3.51	1.17	-14.68	90
Antenna Array	1.30	1.40	-15.40	30
	1.60	1.36	-16.25	60
	2.40	1.05	-31.06	62.5
	3.66	1.02	-39.94	175
	4.08	1.11	-25.15	212

It can be observed from table, VSWR for iteration wise and antenna array is in limit. The value of the return loss and bandwidth are better for antenna array than the iteration wise results. The directivity of antenna can be improved by adding array to the antenna

3. Experiment Results

The Vector network analyzer (VNA) has been used to measure the Return loss, VSWR and Bandwidth

Fig.24: Experimental set up with Vector Network Analyzer (VAN)

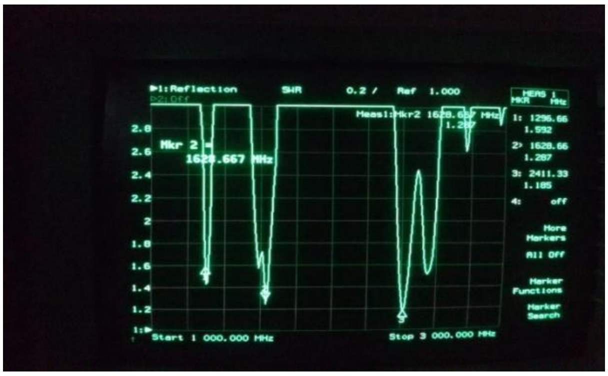

Fig.25: VSWR of Hexagonal Fractal Antenna Array

TABLE V: Experimental results of VSWR

Sr. No.	Frequency (GHz)	VSWR
Antenna Array	1.3	1.59
	1.6	1.287
	2.4	1.185

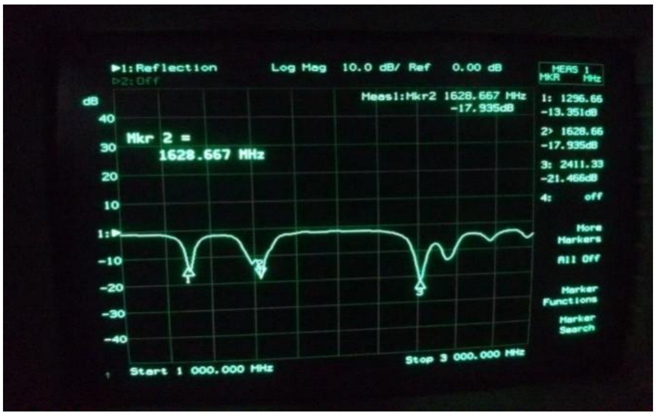

Fig.26: Return loss of antenna array

TABLE VI: Experimental results of Return Loss

Sr. No.	Frequency (GHz)	Return Loss (dB)
Antenna Array	1.3	-13.35
	1.6	-17.93
	2.4	-21.46

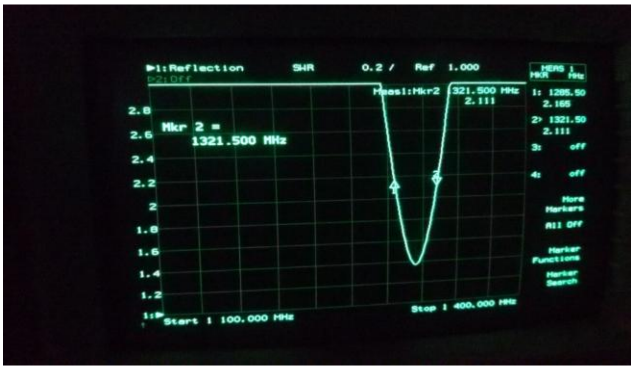

Fig.27: Bandwidth of Hexagonal Fractal Antenna Array at 1.3GHz

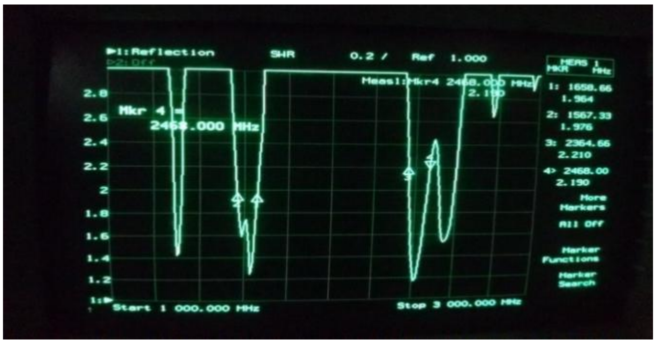

Fig.28: Bandwidth of Hexagonal Fractal Antenna Array at 1.6GHz and 2.4GHz

TABLE VII: Experimental results of Bandwidth

Sr. No.	Frequency (GHz)	Bandwidth (MHz)
Antenna Array	1.3	36
	1.6	90
	2.4	104

TABLE VIII: Experiment results with different parameters

Sr. No.	Freq(Hz)	VSWR	Return loss	Bandwidth
Antenna Array	1.3	1.59	-13.35	36
	1.6	1.287	-17.93	90
	2.4	1.185	-21.46	104

4. **Comparison between simulated and experiment results**

TABLE IX: Simulated and experimental results of Bandwidth

Sr. No.	Freq (GHz)	VSWR		Return loss		Bandwidth	
		Sim	Expt	Sim	Expt	Sim	Expt
Antenna Array	1.30	1.4	1.59	-15.4	-13.35	30	36
	1.60	1.36	1.287	-16.25	-17.93	60	90
	2.40	1.06	1.185	-31.06	-21.46	62.5	104

From the above table parameters are illustrated as follows:

VSWR:

VSWR is a measure of how well matched an antenna is to the cable impedance. A perfectly matched antenna would have a VSWR of 1:1. This ratio indicates how much power is reflected back or transferred into a cable. Ideal value of VSWR is lies in between 1 to 2.It have been observed that VSWR for Simulated and Fabricated Hexagonal Fractal Antenna Array is in between 1 to 2 at frequency 1.3GHz, 1.6GHz and 2.4GHz.

Return Loss:

It indicates the amount of power that is lost to load and does not return as reflection. Return loss is a parameter similar to VSWR to indicate how well the matching between transmitter and antenna has taken place. Ideal value of return loss is less than -10dB which corresponds to VSWR of less than 2. In Simulated and Fabricated Hexagonal Fractal Antenna Array value of Return Loss at frequency 1.3GHz, 1.6GHz and 2.4GHz are below -10dB and nearly equal.

Bandwidth:

The bandwidth of an Antenna is defined as the range of usable frequencies on either side of the center frequency. One method of judging how efficiently an Antenna is operating over the required range of frequencies is by measuring its VSWR and Return Loss. A $VSWR \leq 2$ ($-10dB \geq RL$) ensures good performance. It has been observed that Bandwidth for Simulated and Fabricated Hexagonal Fractal Antenna Array is better for higher frequencies value.

IV. CONCLUSION

The hexagonal fractal antenna array through its different iterations like, 0^{th} iteration, 1^{st} iteration, 2^{nd} iteration and array structure has formed. The simulation has been carried out by using High Frequency Structure Simulator (HFSS) software. The performances parameter considered in this study includes VSWR, Return loss and Bandwidth. The antenna is designed and fabricated on FR-4 dielectric material by wet etching method. The hexagonal fractal antenna array is observed to possess multiband behavior similar 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).The antenna is tested by using Vector Network Analyzer (VAN). The simulated results and experimental results are compared

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