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# Design and Performance Evaluation of Ultra Wide Band Triangular Patch Antenna for Wireless Communication

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**ABSTRACT:** In this paper, we have found a compact multiband fractal antenna based on fractal geometry. The simulation of the proposed antenna is done by CST Microwave Studio EM simulation software. The fractal antenna proves that it is capable to create multiband frequencies. There are four resonant frequencies between 9.1-11GHz, with resonate frequency of 10.30 GHz. Simulated results indicates that the return loss is better than 15 dB, the VSWR is less than 1.4,the directivity is greater than 6dBi & the gain is more than 3dB in each band. So this fractal antenna can be suitable for fixed microwave & aviation applications.

**KEYWORDS:** Fractal Antenna, CST, IFS, Multiband

## I. INTRODUCTION

Antennas are regarded as the largest components of integrated, conformal & low-profile wireless communication systems. Therefore, it is desired for the antenna miniaturization in achieving an optimal design for wireless communications. It is well known that the dimension of the antenna is function of its operating wavelength (in small size, it becomes inefficient because its radiation resistance, gain, directivity and bandwidth are insolvent. Fractal geometry provides a pleasant solution for this problem on account of its two major characteristics: self-similarity and space filling. So, fractal theories have become a pioneering approach for designing & characterizing wideband and multiband antennas.

### 1.1 Antenna Theory

I he smart antennas play an important role in today's wireless communication, such as Mobile and satellite communication. Global Positioning System (GPS), WiMAX, Radio Frequency Identification (RFID), Wireless Local Area Networking(WLAN) and medicinal applications. The requirements of the antenna for Wireless communication applications are small, low cost, and low profile. Micro-strip patch antenna meets all this requirements. So most antenna designers preferred micro-strip patch antenna for various wireless communication applications (Balanis. 1997). Today Micro-strip patch antennas are the widely used type attic antennas due to their advantages such as low volume, low cost, light weight and compatibility with integrated circuits and easy to install on the rigid surface (Marotkar et al.. 2015).

Recently micro-strip patch antennas are widely used often in antenna designs for their simplicity and compatibility. Wireless technology has experienced an incredible progress and growth because of an ever-increasing demand of wireless devices in communication systems. In 4G LTE, several devices and networks are interconnected to provide an ultra-fast, efficient and high-speed communication for the users. With the massive up gradation of networks, the current spectrum assigned for wireless communication has theoretically reached its maximum system utilization. Millimetre-waves (MMWs) are anticipated as a promising candidate for the upcoming wireless solutions (Rappaport, 2013). Unused available spectrum at MMWs frequencies has a potential to compete with the requirements of next generation where high capacity and last speed are the distinguishing features to achieve (Rappaport, 2011) and (Khan, 2011).

In this trade of technology various demands of microwave and wireless communication systems in many types of applications resulting in an interest to improve antenna parameters performances. Therefore, the selection of micro-strip antenna is suitable and useful to apply in various fields such as medical application, telecommunication, satellite and military system (Tariqul *et al.*, 2009).

A 'Fractal' is a repeated generated structure having a fractional dimension which provides wide flexibility in antenna design & analysis. Fractal antenna engineering is the field, which utilizes fractal geometries with IFS for antenna design. Presently, it has become one of the budding fields of antenna engineering due to its advantages over conventional antenna design. Most of the fractal geometries have the following characteristic features: infinite complexity and detail, fractional dimension self-similarity, space filling & frequency independent.

Recently, the self-filling in space curves like Hilbert and Peano fractals were used to obtain high-impedance ground plane EBG, so-called meta materials, used to design high performance, low profile, conformal antennas with enhanced radiation characteristics and improved power gain of various communication and radar applications.

Fractal geometry has many applications in life and open up new research directions in many fields such as biology and economics. In many EM devices, the self-similarity and plane-filling nature of fractal geometries are often qualitatively linked to its frequency characteristics, i.e. multi-frequency operation, or small size in low frequency bands.

**Here are some properties, which most fractals have**:

- They are made up of elements with any small scale,
- They are usually defined by a simple recursive processes,
- They are too irregular to be described using traditional Euclidian geometry,
- They have some type of self-similarity,
- They have fractal dimensions

**Why use the antenna of fractal geometry?**

Antennas are generally narrowband devices. Their properties depend on the size of the referenced to the wavelength. This means that for fixed antenna sizes, its parameters: power gain, input impedance, the radiation patterns, the side lobe level and distribution of surface currents will be continued strong changes when the operating frequency will change. Frequency dependency also means that the antenna should retain the minimum size in relation to the wavelength of operation, to work effectively. This means that for a given frequency, the antenna cannot be arbitrarily small, usually of the minimum size level of a quarter wavelengths. These well-known rules for antenna engineers are:

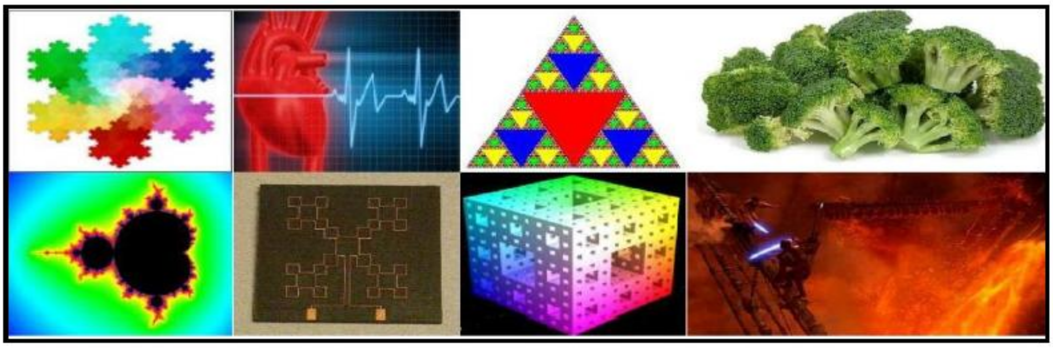


**Fig1.1:- The original inspiration for the development of fractal geometry**

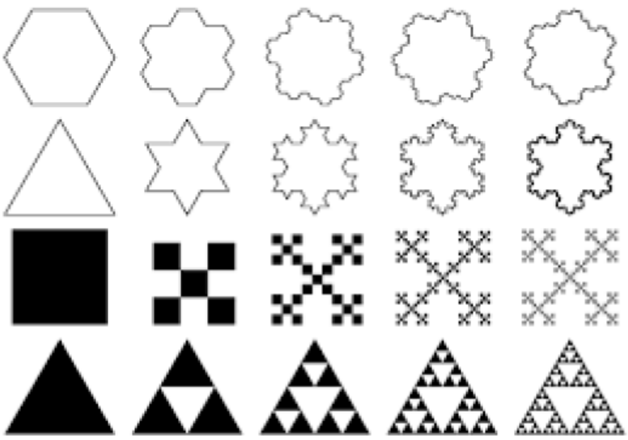


**Fig. 1.2: The fractal geometry shapes (FG)**

## II. MIMO ANTENNAS

In modern wireless communication systems, multiple-input-multiple-output (MIMO) technology has attracted attention. A significant increment in the channel capacity is achieved without additional transmit power or bandwidth by developing multiple antennas for transmission. MIMO can achieve an array gain and diversity gain, there by improves the spectral efficiency and reliability. MIMO antenna system should he highly decoupled between antenna ports and a compact size for application in portable devices.

### 2.1 MIMO system:

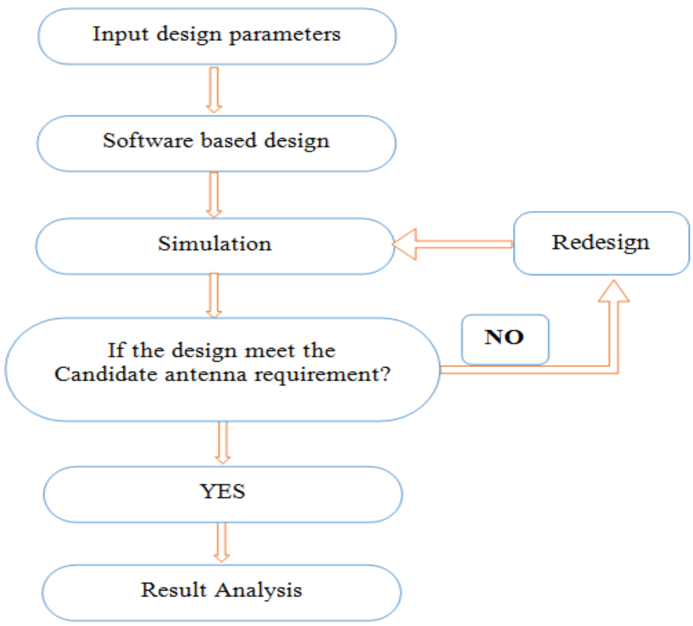
Multiple-input multiple-output (MIMO) uses multiple antennas on both the transmitter side and the receiver side. MIMO has dual capability of combining the MISO and SIMO technologies. MIMO can also increase capacity by using Spatial Multiplexing (SM). The MIMO method has some cleat- advantages over Single input Single-output (SISO) methods. The lading is greatly eliminated by spatial diversity; low power is required compared to other techniques in MIMO.

The proposed antenna is designed with dimension 59 x 69 $mm^2$ to resonate at 9.1GHz and 11GHz frequencies. Complementary improves the isolation, gain and specific absorption rate. A partially extended ground has been inserted between the radiators to control the degrading factors of MIMO system performance. The designed MIMO antenna system with 50 Ω ports is designed using computer simulation tool (CST Microwave Studio 2015) version 12.0. All the simulation and measurement results of designed MIMO antenna are given below:

## III. SIMULATION OF DESIRED ANTENNA

The design triangular shaped antenna using for wireless applications were simulated and fabricated also. The proposed research work started with the detailed literature survey of MIMO antenna design for wireless applications. The MIMO antenna has high gain and low losses. The triangular shaped radiator system with 50 Ω ports is designed using computer simulation tool (CST Microwave Studio 2015) version 12.0 and assembled on lower cost FR4 dielectric substrate (thickness of 1.524 mm, the permittivity of 4.3, and loss tangent of 0.02) of size 59× 69 $mm^2$. Particle swarm optimization is used for optimization of designed MIMO antenna for wireless applications. The particle swarm optimization (PSO) used with min-max algorithm was set to achieve the best design objectives for essential frequency operating band, compactness and for desired antenna parameters. The proposed design behind the selection of the proposed antenna element is the minimums return loss, low mutual coupling (high port to port isolation), compact size, higher gain, low ECC, low SAR (specific absorption rate) and essential bandwidth for wireless application. This section contains the research methodology used in this thesis objective of proposed antenna. For this purpose following steps are followed

### 3.1 Antenna Design Methodology



### 3.2 Theoretical Calculation for Antenna Design:

#### A. Design of Antenna

**Fig. 3.1 : Front View**

**Fig. 3.2 : Back View**

I. For an efficient antenna, a practical width is given by this formula and the calculated width is $w_1$ = 34.62mm and $w_2$= 16.13mm.

$$W = \frac{1}{2\, f_r\sqrt{\mu_0\epsilon_0}}\sqrt{\frac{2}{\epsilon_r + 1}} = \frac{\upsilon_0}{2f_r}\sqrt{\frac{2}{\epsilon_r + 1}}$$

Where,$\upsilon_{0is}$ the free-space velocity of light.

II. Determine the effective dielectric constant of the micro strip antenna using relation and the practical value of $\epsilon_{reff}$is 3.77.

$$W/h > 1$$

$$\epsilon_{reff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-1/2}$$

III. Once $W$ is found, determine the extension of the length $3L$ by formula and $\Delta_L = .7017$

$$\frac{\Delta_L}{h} = 0.412\frac{(\epsilon_{reff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\epsilon_{reff} - 0.258)\left(\frac{W}{h} + 0.8\right)}$$

IV. The actual length ($L$)of the patch is 12.12mm and determined by this formula

$$L = \frac{1}{2f_r\sqrt{\epsilon_{reff}}\sqrt{\mu_0\epsilon_0}} - 2\Delta_L$$

V. Effective Length is 13.53mm determined by given formula

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

### 3.3 CST Microwave studio 2015 Software introduction:

CST integrates features such as Perfect Boundary Approximation (PBA), the Thin Sheet Technique and True Geometry Adaptation which goes a long way in improving the efficiency of its time domain and frequency calculation metrics thereby improving design accuracy.


**Figure 3.3: CST Microwave studio 2015 LOGO**

**Open microwave studio after opening CST:**

- After opening dimension box first of all enter units that involves the dimension.
- Base material needs to be found.
- By using Boolean operators different shapes and size need to be defined.
- The range of frequency must be entered.
- Location of the port must be defined.
- Boundary conditions must be defined.
- Field monitors value should be entered.

**3.4 Methodologies for design of MIMO antenna system:**

The proposed research work start with the detailed literature survey of MIMO antenna design for wireless applications. A sufficient frequency spectrum should be available in order to achieve requirements. CST integrates features such as Perfect Boundary Approximation (PBA), the Thin Sheet Technique and True Geometry Adaptation which goes a long way in improving the efficiency of its time domain and frequency calculation metrics thereby improving design accuracy.

**Flowcharts:**

1. Flowchart for antenna design using Meta material.

- Flowchart for the design of MIMO Antenna System

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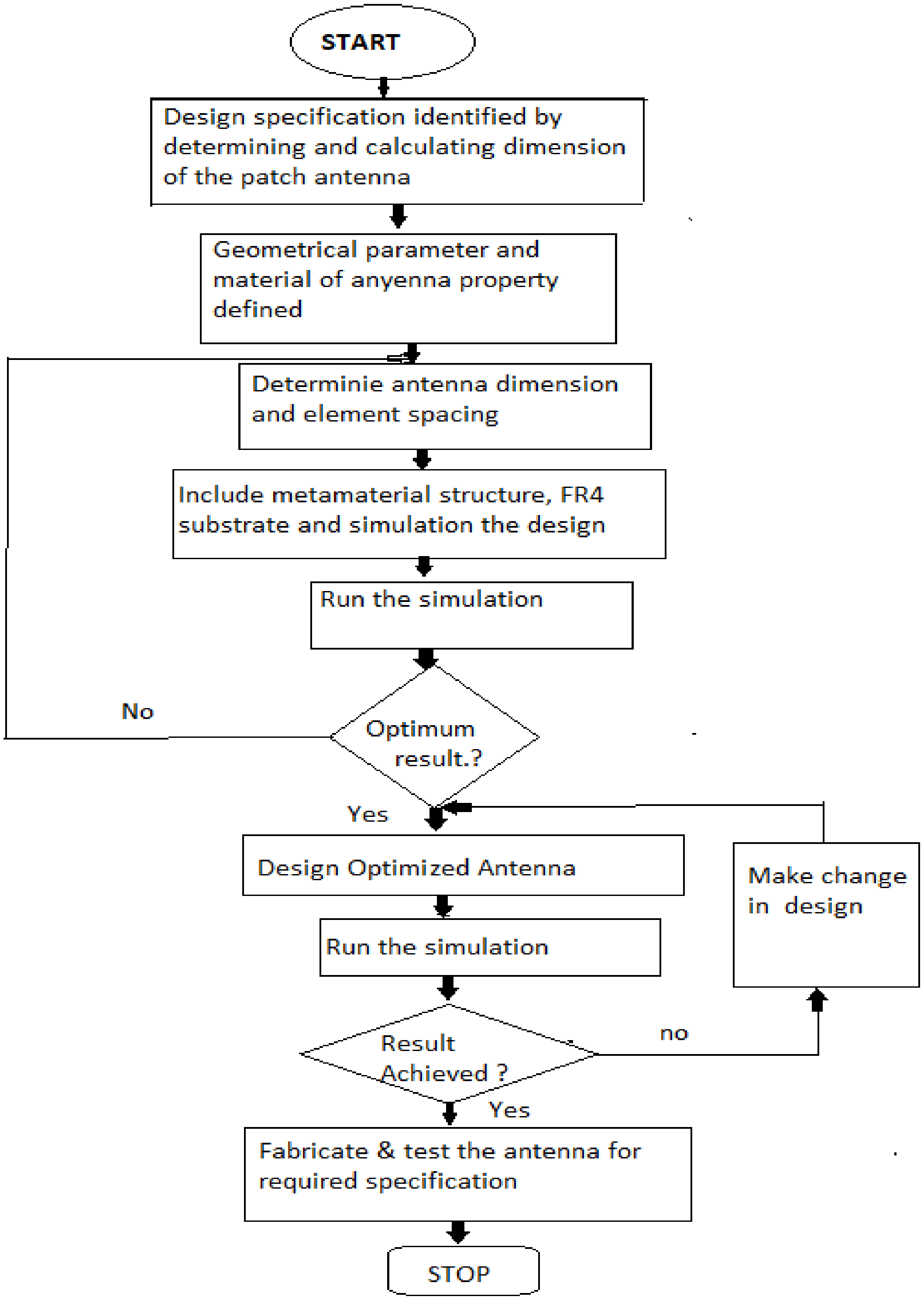


Fig. 3.4 : Flow chart for antenna design using meta material

## IV. RESULTS AND DISCUSSION

The proposed antenna is designed with dimension 59 x 69 $mm^2$ to resonate at 9.1GHz and 11GHz frequencies. Complementary improves the isolation, gain and specific absorption rate. A partially extended ground has been inserted between the radiators to control the degrading factors of MIMO system performance. The designed MIMO antenna system with 50 Ω ports is designed using computer simulation tool (CST Microwave Studio 2015) version 12.0. All the simulation and measurement results of designed MIMO antenna are given below

### 4.1 Return Loss and S parameter

To obtain low return loss and least possible mutual coupling between the linearly polarized antennas, the antenna parameters are optimized using PSO. The resultant simulated S parameter for return loss or reflection coefficient and bandwidth range is shown in fig. 4.1 (i.e.9.1251-11.012 GHz) that is resonating at 9.1GHz and 11GHz frequencies. The designed dual-band MIMO antenna has simulated -10dB impedance bandwidth. The effectiveness or success of designed MIMO system in terms of return-loss and isolation can be distinguished here. We got return loss approximately 18.48dB. All the measured and simulated S parameters are represented in graphical form which is given below:

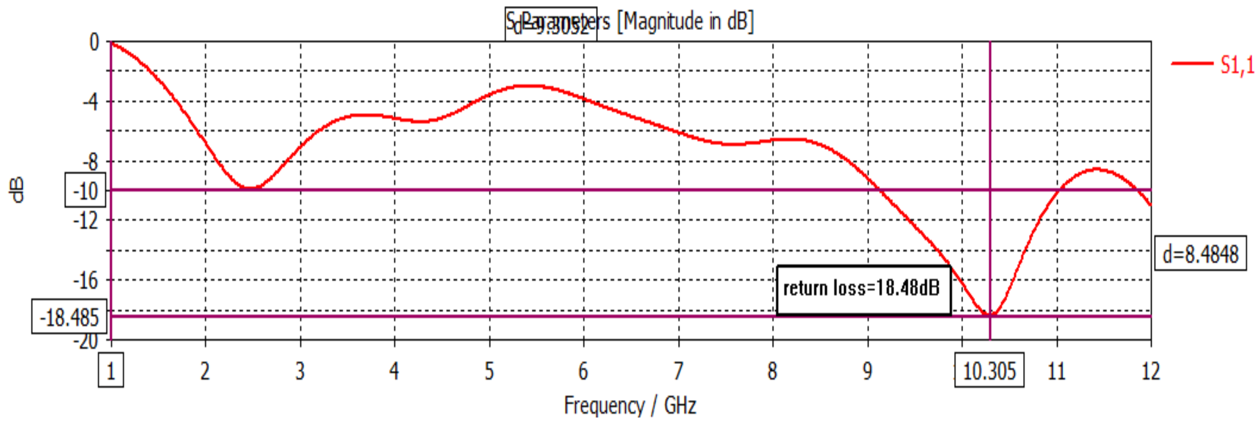


**Fig. 4.1: Plot between Reflection coefficient & frequency**

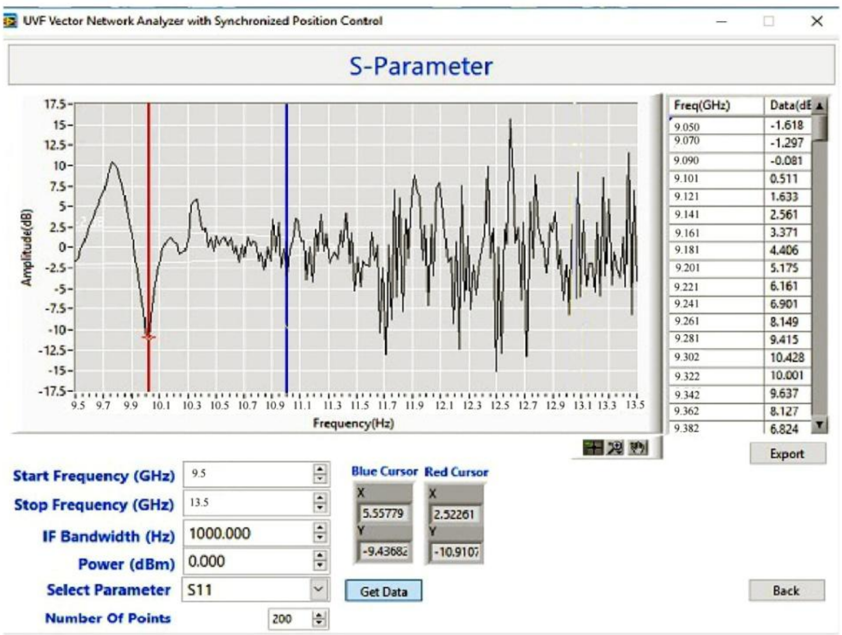


**Fig.4.2 : Measured $S_{11}$ parameter of Designed MIMO antenna**

**4.2 Radiation patterns**

Gain can be defined as the ratio of radiation intensity of practical antenna with respect to radiation intensity of idea antenna. It is stated in dB and dBi. The 3D gain plot determines the antenna efficiency. The designed patch antenna achieved moderate gain of 3 dBi which is considered good in terms of a compact antenna design. Fig 4.3 shows the 3D omni directional pattern of the antenna .In 3D pattern we obtained gain is 3dBi in range of frequency is 9.1-11 GHz

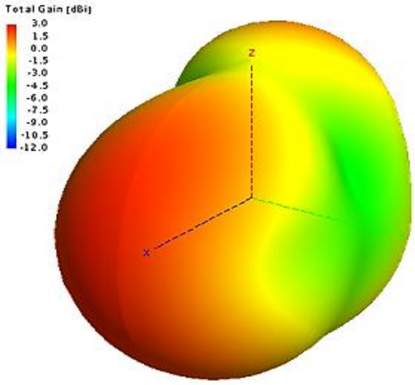


**Fig. 4.3: 3D radiation pattern of patch antenna**

Fig 4.4 shows the 3D Omni directional pattern of the proposed antenna. In 3D pattern we obtained Theta gain is 5dBi in range of frequency is 9.5-10.5 GHz.

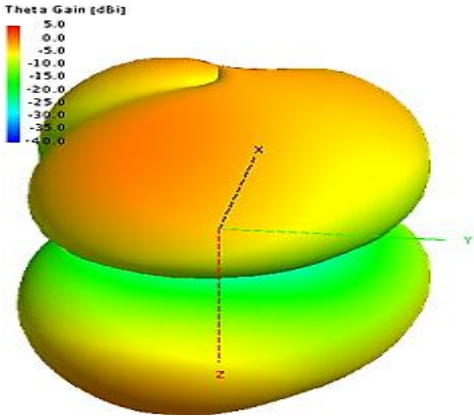


**Fig. 4.4: 3D radiation pattern of patch antenna (Gain in Theta)**

Fig 4.5 shows the 3D Omni directional pattern of the DGS antenna. In 3D pattern we obtained Phi gain is 4dBi in range of frequency is 10.3-11.5.5GHz.

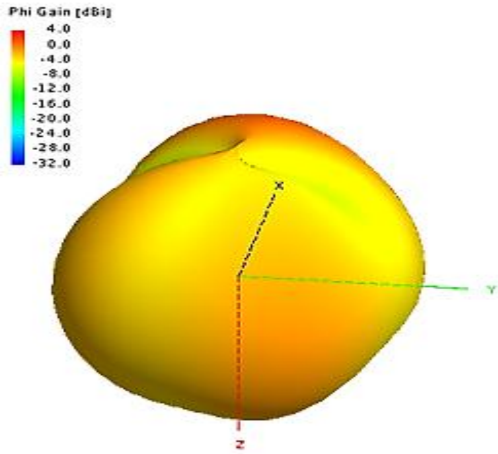


**Fig. 4.5: 3D radiation pattern of patch antenna (Gain in Phi)**

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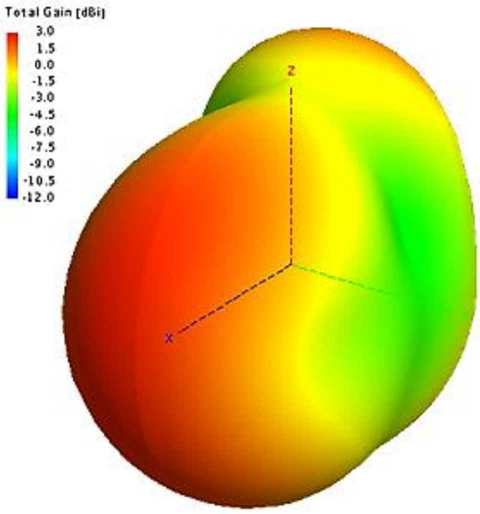
**4.3 Current Distribution:**




## 4.4 Voltage Standing Wave Ratio (VSWR)

VSWR is a function of the reflection coefficient, which describes the power reflected from the antenna. If the reflection coefficient is given by Γ, then the VSWR is defined by the following formula:

$$\text{VSWR} = \frac{1 + |\Gamma|}{1 - |\Gamma|} \qquad ..18$$

The reflection coefficient is also known as $S_{11}$ or return loss. Since VSWR is given by-

$$VSWR = \frac{10^{\frac{RL(dB)}{20}} + 1}{10^{\frac{RL(dB)}{20}} - 1}$$

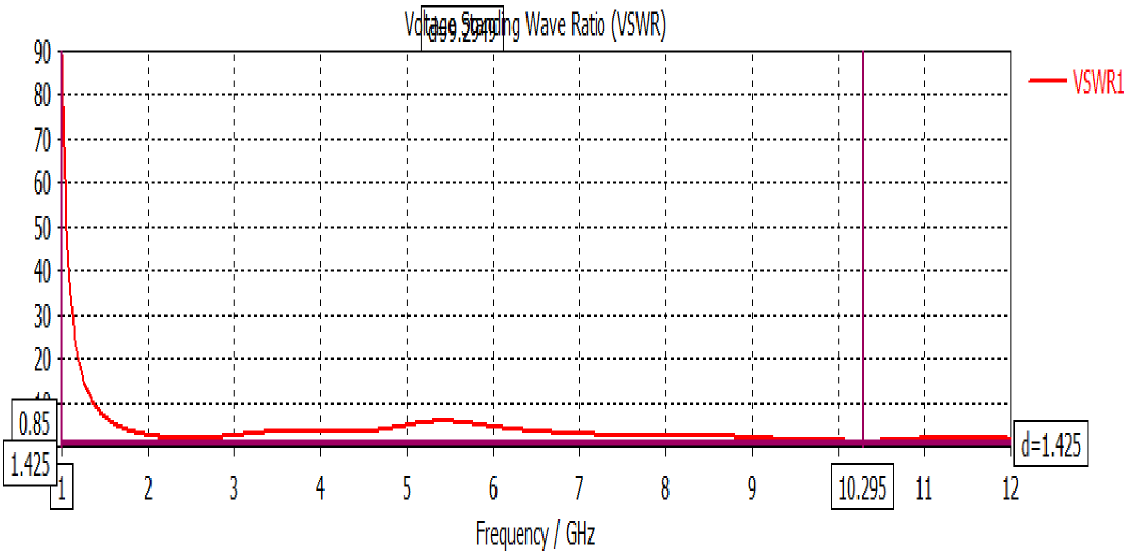



Fig 4.7 VSWR

**4.5 Antenna Efficiency:**

Fig 4.7 shows the graph between Power Efficiency and Frequency. The efficiency for DGS antenna in range of 41-42GHz is above 90-91%.

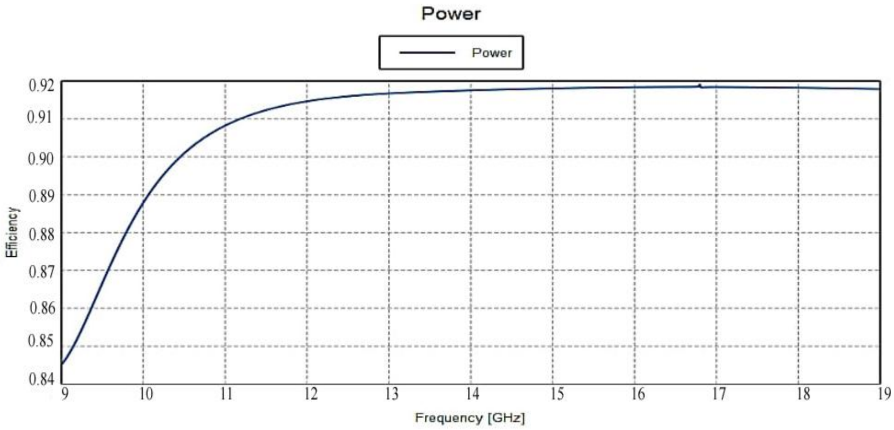



**Fig. 4.8 Plot between Power Efficiency and frequency of patch antenna**

**4.6 Antenna Impedance:**

Antenna impedance is a way of measuring the level of resistance to an electrical transmission in an antenna. A large number of factors have an impact on an antenna's capability to transmit a transmission signal such as the environment that the antenna is in and the design and structure of the antenna. Understanding antenna impedance is important when designing components that connect an antenna to a receiver or transmission device.

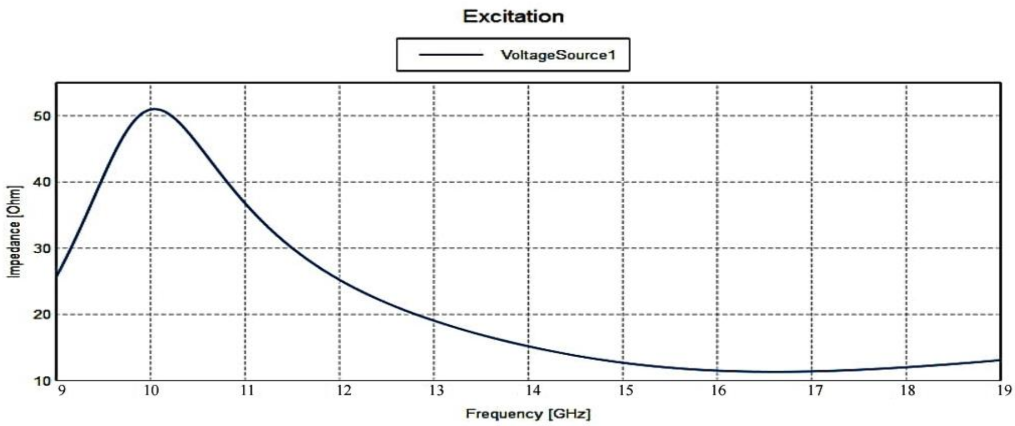



**Fig. 4.8 Plot between Frequency and Impendence**

**4.7 Comparative Studies:**

In this section we are discuss about comparisons of thesis work to other reference base papers.

Table 4.1 Shows simulation results of the Designed antenna

**Table 4.1: Simulation results of the Designed antenna**

| **Parameter** | **Simulated Result** |
|---|---|
| Frequency range | 9.1 to 11 GHz |
| Return loss | 18.48GHz |
| Gain | 3dB |
| Impedance | 50 Ω |
| VSWR | Less than 2 |
| Radiation pattern | Omni-directional |
| Size | 59 x 69 $mm^2$ |
| Efficiency | 90-91% |
| Impedance Bandwidth | 1.88GHz |

**Table 4.2 Results from Base (Yadava*et.al.* 2010)**

| Parameter | Simulated Result |
|---|---|
| Frequency | 9.6 GHz |
| Return loss | -21.89dB |
| Gain | 1.6634dBi |
| Impedance | 48.6 Ω |
| VSWR | Less than 2 (1.2) |
| Radiation pattern | Omni-directional |
| Size | 65.046 x 65.046 $mm^2$ |
| Efficiency | 74.39% |
| Impedance Bandwidth | 0.25GHz |

From this Reference paper we got antenna size is compact and the efficiency is smaller than our proposed antenna In the Reference paper the size of the antenna is 65.046 x 65.046 $mm^2$ on II$^{nd}$ iteration at frequency 9.6GHz but in my designed work got the size of the antenna is 69 x 59$mm^2$ on frequency range 9.1GHz to 11GHz on resonate frequency 10.30 GHz.

## V. CONCLUSION

It is concluded that found results of proposed antenna design covers the frequency range of 9.1 to 11 GHz. This Report presents an efficient antenna design at resonate peak frequency of 10.30GHz. The compact Patch antenna is designed using a technique simulating the design by Thin sheet Technique by CST (Computer Simulation Tool). Simulation had been done in the ground Plane. The top geometry of the suggested antenna consists of a Triangular-shaped radiating patch with T Slot. The proposed antenna has demonstrated a high impedance bandwidth of 1.88 GHz and a gain of 3dBi. Moreover, the numerically calculated efficiency is above 90-91% in operating range.

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