DESIGN AND ANALYSIS OF GRAPHENE BASED YAGI UDA ANTENNA

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CANDIDATE'S DECLARATION

I, Rajesh Yadav, Roll No. 2K17/MOC/06 student of M.Tech. (MICROWAVE AND OPTICAL COMMUNICATION), hereby declare that the project Dissertation titled **"DESIGN AND ANALYSIS OF GRAPHENE BASED YAGI UDA ANTENNA"** which is submitted by me to the Department of ELECTRONICS AND COMMUNICATION ENGINEERING, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Master of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any degree, diploma associateship, fellowship or other similar title or recognition.

Place: Delhi **RAJESH YADAV**

Date: 25-07-2019

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CERTIFICATE

I hereby certify that the Project Dissertation titled **"DESIGN AND ANALYSIS OF GRAPHENE BASED YAGI UDA ANTENNA"** which is submitted by RAJESH YADAV, Roll No 2K17/MOC/06 Department of Electronics And Communication Engineering, Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of the degree of Master of Technology, is a record of the project work carried out by the students under my supervision. To the best of my knowledge this work has not been submitted in part or full for any degree or diploma to this university or elsewhere.

Place: Delhi **PROF. N. S. RAGHAVA**

Date: 25-07-2019 **SUPERVISOR**

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ABSTRACT

This thesis introduces two different application. The First application draws the attention towards 2 non-identical Yagi-Uda antenna based on hybrid metal-graphene materials. This Yagi-Uda antenna has been placed on the top of Rogers RT/duroid substrate. In the first proposed design, director, reflector, and dipole are made from a graphene material but the small length of a patch which has metal are attached to both ends of reflector and director. The second proposed design case is complementing of the first proposed design case. That means reflector, director and dipole are made from metal and patch is graphene on both ends of director and reflector. Now the two antennas have been compared by the estimated outcome. And it is signifying that Yagi-Uda antenna which is designed in the second proposed case is more efficient than the first proposed case. It is also superior in terms of gain, radiation efficiency, return loss, polarization, radiation pattern, front to back ratio and voltage standing wave ratio. The return loss of proposed design case 1 is -12.41 dB at resonating frequency 5.7 GHz, while in proposed case 2 it is -18.54 dB at 3.2 GHz. The Bandwidth and Gain of proposed case 1 are 70 MHz and 6.73 dB respectively which is lesser than proposed case 2. The Bandwidth and gain of proposed case 2 are 100 MHz and 7.11 dB respectively.

In second application draws the attention towards a rectangular box Yagi-Uda antenna based on the graphene materials. It consists of a rectangular box dipole antenna, rectangular box reflector, and rectangular box directors. Dipole, reflector, and directors are made from graphene materials. By altering the reflector, directors, and dipole the resonance frequency, gain, front to back ratio and efficiency can be maximized. The source provides in the antenna is a co-axial cable. Measure and compare the result from proposed Yagi-Uda antenna with graphene and conventional Yagi-Uda antenna without graphene. And it is conveying that a Yagi-Uda antenna with graphene is more compact and has superior characteristics in terms of 3D gain, efficiency, Front to Back Ratio than Yagi-Uda antenna without graphene. The exclusive antenna concept described is an efficient solution for graphene-based Yagi-Uda radiation pattern. the maximum gain of the proposed antenna is 6.32 dB at 6.6 GHz. In all the structure I used the material as a Graphene.it is an emerging material in the modern era. From this material, I got attractive characteristics. By the help of Yagi-Uda antenna Based on Hybrid Metal Graphene materials. we can use in project loon LLC, Li-Fi, etc. And these materials are also a key role in the Space Research. it is also used in the wireless network. These technologies used in GHz. Basically, these are used in the ruler area, remote area or hilly area, etc. Which is very important to relate or help to 4G or 5G technology.it is very important for future scope.

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LIST OF ABBREVIATIONS

Abbreviation	Full Form
HFSS	High-Frequency Structure Simulator
FEM	Finite Element Method
EM	Electromagnetic
BW	Bandwidth
EMI	Electromagnetic interference
EMC	Electromagnetic Compatibility
RF	Radio Frequency
2D	2 Dimensional
3D	3 Dimensional
5G	5^{th} Generation
THz	Terahertz
VSWR	Voltage Standing Wave Ratio
dB	Decibel
Mm	Millimeter
%	Percentage
GHz	Giga Hertz
CAD	Computer Aided Design
LAN	Local Area Network
TV	Television

FNBW	Full Null Beam Width
HPBW	Half power Beam Width
E-Field	Electric Field
H-Field	Magnetic Field
RFID	Radio Frequency Identification
LLC	Limited Liability Company
WI-FI	Wireless fidelity
WiMAX	Worldwide Interoperability for Microwave Access
MIMO	Multiple Input and Multiple Output

CHAPTER 1
INTRODUCTION

1.1 BACKGROUND

The Communication industry has noticed substantial growth of the antenna technology. There has been substantial growth in the field of Antenna technology in the last few years. The antenna will be important in the near future for realizing the project installation in the world. Antenna technology has been implemented in maximum present-day application and also it has upgraded the standard of human life. The applications such as wi-fi, Wi-max, loon LLC, 5G service, cell phones are constantly using the antenna technology.

An important classification which includes in the antenna technology is Graphene-Based Yagi-Uda antenna. It works on GHz range which is useful for S-band application. In the Yagi-Uda antenna, the important part is Graphene material. Graphene-Based Yagi-Uda antenna has spread over the last few years.in the last decade, many types of research were going on Graphene-Based Yagi-Uda antenna which is also a large interest in the modern years. So far, a huge number of Yagi-Uda antenna technology has been proposed for non-identical application including in small size, low return loss, more gain, high front to back ratio, high energy efficient, etc. The graphene-based Yagi-Uda antenna has many applications in wireless communication, satellite communication, radar, internet connectivity, etc.

Antenna technology is not restricted to simple theory as previously knowledgeable but will employ the various type of materials that build the new type of structure. Such as ones studied the construction and properties of Yagi-Uda antenna and graphene material. Now based on this if we use graphene in Yagi-Uda antenna, it will lead to the hybrid metal graphene Yagi-Uda antenna. Sometimes, director, the reflector is made from metal and patches are made from graphene. But in some cases, the patches are made from metal and director and reflector are made from graphene.

Furthermore, studies will be on the basis of feed, substrate, Ground, multiple directivities, Gain, etc. in every year new concept is used in antenna technology such as multiple-input multiple-output (MIMO), smart antenna, Nano-antenna, Graphene-Based antenna, metamaterial etc. the development has placed additional demand for low power consumption for device, small in size, need more output. Low power utilization in the antenna is also important for the working of such a network. High efficiency is necessary for acquiring higher signal strength.

An antenna is a necessary device for communication. Recently, multiple-input multiple-output (MIMO), Nano-antenna, the dual-polarized antenna has been studied for satellite and wireless communication. This antenna will be effective for the upcoming generation. We can conclude that the antenna technology is the future of advanced connectivity and additionally the upcoming of daily life application.

1.2 STATEMENT OF THE PROBLEM

There has been some difficulty in the graphene-based Yagi-Uda antenna application in modern time. Since Graphene-Based Yagi-Uda antenna has been designed for Loon LLC applications. Basically, the frequency range of loon LLC is in the range of 2.4- 6.8 GHz for the traditional metallic antenna but I have designed a hybrid metal-graphene antenna. We know that Graphene is a 2-dimensional material which leads to decrease its size and if the size of graphene gets reduced then the working frequency of antenna will automatically increase i.e.in the range of THz or above. But I have used this graphene material in the GHz range. So, it is a little difficult to use this material in the GHz range as compared to the THz frequency range. Also, Graphene is very costly so it is not easy to fabricate. This Research has relevant work to the antenna and propagation community as it has contributed its new approach towards loon LLC requirement and in S-Band applications.

1.3 OBJECTIVE

In this thesis, I focused on the prototype model and study of graphene-based Yagi-Uda technology for internet connectivity through loon LLC and communication. Basically, these applications are used in a rural area, remote area or hilly area in disaster, etc. to remember these applications I try to design alternate structure which is very compact and efficient and the structure is two proposed graphene-based Yagi-Uda antenna. Two proposed graphene-based Yagi-Uda antenna is designed. For first proposed design, a small length of a patch which are made of metals are attached on both ends of directors and reflectors while in the second proposed case, it is complementing the first proposed case, that means patches are made of graphene which is attached on both ends of directors and reflectors. After comparing these two antennas, we conclude that the graphene patches which are used in the second proposed case work better than the metal patches which are used in the first proposed case. Graphene has massive remarkable properties. Due to these graphene patches, the signal emission will improve because of side lobe and back lobe of the dipole. I simply reduced the traditional metallic antenna to the hybrid metal graphene antenna. It is also observed that hybrid-metal graphene-based antenna has higher efficiency, large front to back ratio, higher gain, less return loss.

1.4 LITERATURE REVIEW

Yagi-Uda antenna was discovered By Shintaro Uda and Hidetsugu Yagi in 1926. They published the first report on a directional antenna. If we know that gain-bandwidth product is constant. Now third parameter front to back ratio come into the picture. The three-parameter such as Front to Back Ratio, Gain and Bandwidth are trade off among them. According to the requirement, we have to design the Yagi-Uda antenna. Among the three one of them, we have to sacrifices. If the gain is high then bandwidth automatically will decrease or vice versa.

In [3] the author focused on the two different feed networks in the Yagi-Uda antenna. They proposed two different feed one of them is normally tapered microstrip balun and the other one is tapered microstrip balun but it converts unbalanced co-axial feed to balanced microstrip line feed. Both results have been compared. And they saw the effect on Yagi-Uda antenna.

In [4] an approach on beam-scanning microstrip Quasi-Yagi-Uda Antenna based on the Hybrid Metal-Graphene material. They design 7-element of Yagi-Uda with the help of metal and graphene and got the result of Beam scanning at a range of fixed angle. Graphene form Yagi-Uda antenna design and adjust in THz range which is very difficult in practical implementation.

Yagi-Uda antenna has been discussed in [1-14]. The intention of all the letter is to acquire a new structure that increases the Gain, Directivity, Front to Back ratio, efficiency, VSWR. advantage, disadvantage, and application of Yagi-Uda antenna.

Graphene material has been discussed in [15-39]. The Electronics Properties, Chemical Properties, Thermal Properties, Mechanical Properties has been analyzed. We got the important Specification from the above analysis and used in my project for designing purpose. Graphene material is a vital role to increase all parameter such as Gain, Directivity, efficiency, etc.

1.5 THESIS OUTLINE

The **FIRST** chapter started the discussion with antenna technology and graphene-based Yagi-Uda antenna. Later it discussed the problem and objective of Research work. A literature survey has written for the growth in the field of technology till now and how this project come into the picture.

The **SECOND** chapter dedicated the overview of antenna theory, mathematics, definition, and formula. Later some types of antenna have discussed in brief. It gives the idea of the term later in the thesis.

The **THIRD** chapter is based on the Yagi-Uda antenna and graphene material overview. The idea and concept of chapter third used in chapter fifth.

The **FOURTH** chapter is about the basics of HFSS software such as definition, parameter, flowchart, and how to find the results.

The **FIFTH** chapter is related to the Antenna description. The methodology followed by the development of the graphene-based Yagi-Uda antenna. Here explained all proposed antenna which I did in the project.

Finally, the **SIXTH** chapter concentrated on the simulation and results. Later compared all the simulate result among all the proposed antenna. the chapter ends with the Conclusion and Future scope.

CHAPTER 2

ANTENNA THEORY

2.1 INTRODUCTION

Since the last decade, an antenna has found broad application in the field of communication. In every coming year, it is very interesting to study the advanced theory, behavior and properties of the antenna. This field has experienced huge research and we got the result in a large body of theoretical and practical understanding. The German physicist Heinrich Hertz has originated antenna in the 19^{th} century. Its work was followed by exceptional conceptual research of the subject during the early 20^{th} century. This research proceeded with the growth of computer CAD tools between 1970s-2000s.

It has broad applications in the communication area. These include Satellites communication, TV and radio broadcasting, LAN application, RADAR, wireless communication, military communication, phones, RFID tags, etc. In antenna theory, we will see the fundamental concepts behind antennas' working and performance. Here we will see the antenna's operation, and the different parameters consisting of antenna specifications. The antenna theory starts with a short physical foundation to the subject followed by a large comprehensive and detailed analysis of the different antenna parameters.

2.2 FUNDAMENTAL CONCEPT OF ANTENNA

2.2.1 Antenna definition

An antenna is a device that gives a transformation of EM waves in wired to EM waves in free space. It is basically transforming the electromagnetic wave between transmitter and receiver. An antenna is also called reciprocal device because, during the transformation of the electromagnetic wave, it does not change the properties [1]. Or

An antenna is a device which changed the electrical energy into a radio wave and radio wave to electrical energy.

Many types of antenna are given below in Fig. 2.1: -

Reflector antenna, Microstrip antenna, Yagi-Uda, Dipole, Monopole, Loop, Short antenna, Helical, Log periodic antenna [1], etc.

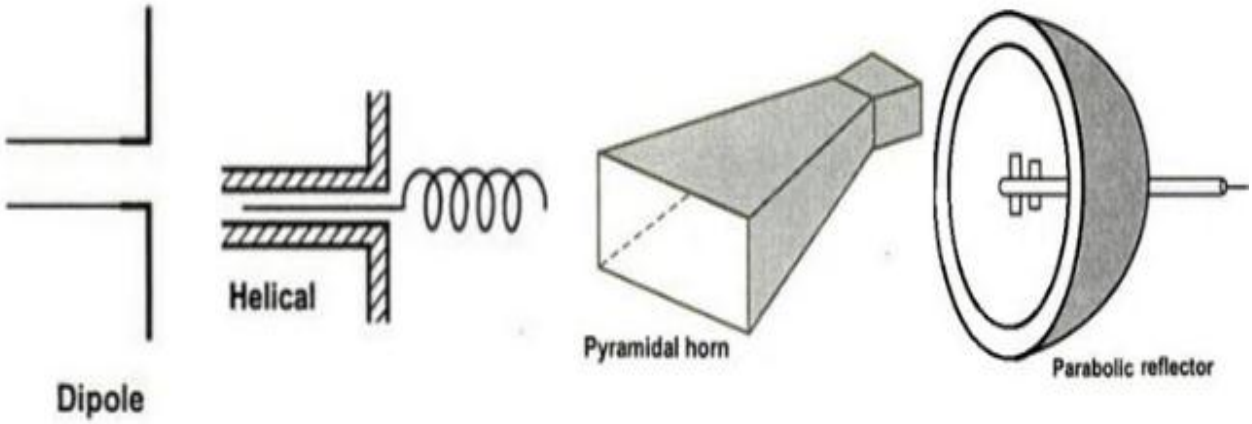


Fig. 2.1 Different type of antenna.

2.2.2 Radiation intensity

Radiate the electromagnetic power from the antenna. It is controlled by the direction of observation and distance from the antenna. Basically, The power of the antenna has differed in magnitude. The pattern is determined in the only far-field including distance from the antenna. Thus, we have to establish an EM power density function for the far-field region which doesn't depend on the distance. That refers to Radiation Intensity. To establish the mathematical expression of radiation intensity. First of all, we have to define two angles. One of them is called azimuth angle and it is represented by ϕ. The azimuth angle explains the antenna transverse in a zero-tilt state. While the other one angle is called Elevation angle which is represented by ɵ. The elevation angle explains the antenna tilt relative to the horizon [1]. A graphical representation is shown in figure 2.2

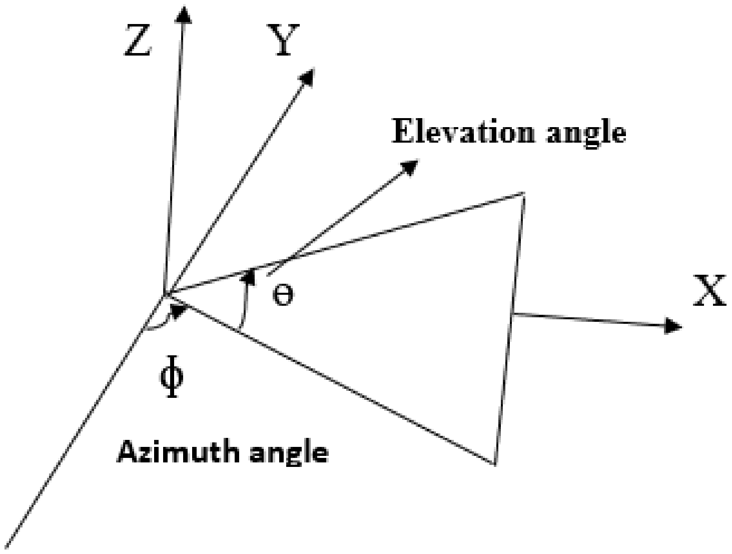


Fig. 2.2 Direction definition by ϕ and ϴ.

2.2.3 Radiation pattern

Radiation is related to emission and acceptance of EM wave. The radiation pattern is the strength of the radio wave as a function of direction. Basically, it indicates about the energy radiated into space. It is given in figure 2.3 which is shown below.

It is two types of pattern

Power pattern: - it is a function of the electric and magnetic field.

Field pattern: - filed pattern depends on the function of a square of magnitude.

It is classified into three categories which are discussed below

2.2.4 Isotropic radiation pattern: -

The antenna is radiate equally in all direction. In fact, it can be radiated in all entire sphere. However, there is no isotropic antenna exit as such. However, it is called a quasi-isotropic antenna. Or Equal in both azimuthal and elevation [1].

2.2.5 Omni-directional radiation pattern: -

Omnidirectional is defined as when the antenna is radiating the radio wave power uniformly in all direction in a single plane. Or

A pattern consisting of one main beam at only one plane and constant another plane.

Omni-directional has some Examples such as Dipole, monopole, slot, normal mode antenna, etc.

2.2.6 Directional radiation pattern

The pattern consisting of the main beam in both azimuthal and elevation planes.

2.2.7 Major and minor lobe

The radiation where there is maximum radiation known as the major lobe. And all other known as the minor lobe.

The minor lobe is again subdivided as

- **Sidelobe**: - the lobe which is adjacent to the main lobe
- **Back lobe**: - the lobe which is backside

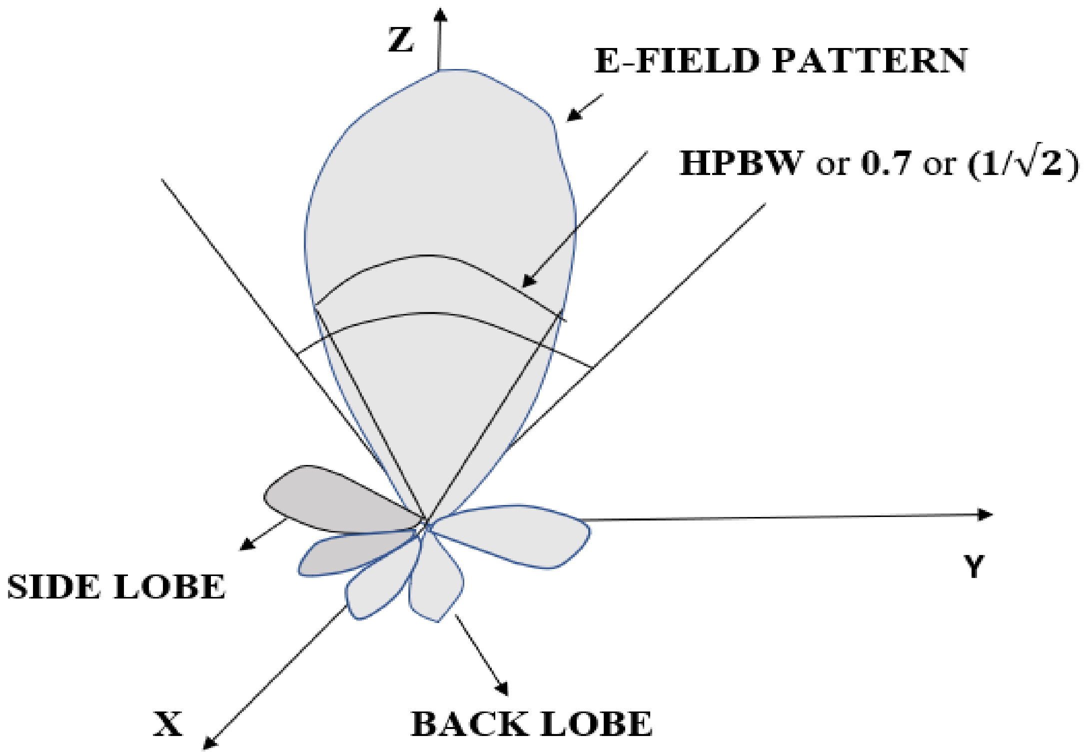


Fig. 2.3 Radiation pattern of an antenna

2.2.10 VSWR

The ratio of maximum current to the minimum current is called VSWR in terms of current. Or the ratio of maximum voltage to the minimum voltage in terms of voltage. The value of VSWR is varying from one to infinity. Basically, it explained about the mismatch between the transmission line to load impedance [1].

$$\text{VSWR} = \frac{Vmax}{Vmin} \text{ or } \frac{Imax}{Imin}$$

In terms of reflection coefficient, we can write as

$$\text{VSWR} = \frac{1+\Gamma}{1-\Gamma} \text{ where } \Gamma \text{ is reflection coefficient}$$

$$\Gamma = \frac{ZL-Z0}{ZL+Z0}$$

Where ZL= load impudence

Z0= characteristics impedance

2.2.11 Return loss

RF and circuit theory, the source impedance should be equal to load impedance than we say that the total power is transferred. If mismatched occur between these two impedances than some power is transferred back. Basically, the proportion of reflected power to the input power. This is called return loss.

In High-Frequency Simulator Structure, we consider as -10 dB. If it is more than the -10 dB then that is antenna is not suitable for application point of view.

$$\text{Return loss} = -20 \cdot \log(\Gamma)$$

Return loss represents in S (1,1) parameter. And it is in dB. One of return loss graph is shown in figure 2.4

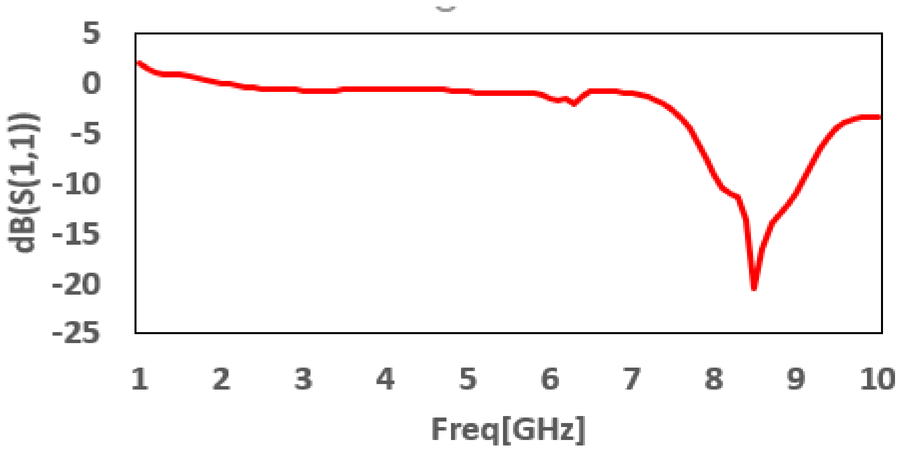


Fig. 2.4 Return loss of the antenna

2.2.12 Gain and Directivity

1.Gain

Total Electrical input power converts into radio wave in a specific direction then it is called a gain of the antenna. (for the transmitter)

If total radio wave converts into electrical power than it is called a gain of the antenna. (for the receiver)

$$\text{Gain} = \frac{4*\prod*Radiation\ intensity}{Total\ input\ power}$$

2. Directivity

Directivity is measuring the power when the signal is transmitted in a particular direction.it is the maximum gain in the required direction [1].

Directivity of an antenna can be found through HPBW in E and H plane.

$$\text{Directivity} = \frac{Max\ radiation\ intensity}{Radiation\ intensity\ of\ isotropic\ source}$$

$$\text{Directivity} = \frac{4*\prod*Umax}{Prad}$$

$$\text{Directivity}= \frac{41253}{\Theta_e*\Theta_h} \text{ where } \Theta_e \text{ and } \Theta_h \text{ should be in degree}$$

We can also write in terms of aperture are

$$D= \frac{4*\prod*A}{\lambda 2} \text{ where A is aperture area and } \lambda \text{ is wavelength}$$

If area increases continuously than directivity will also increase and if directivity increases than half-power beamwidth will decrease.

Gain=Efficiency* Directivity

Gain = η*D

If efficiency(η) is 100 % than Gain= Directivity

2.2.13 Front to Back Ratio

It is the ratio of forward radiation gain to backward radiation gain. in the directional antenna is nearly radiate some signal in a backward direction. And that is called back lobe and side lobe. Nearly It should be greater than 15 dB. So, we have minimized the sidelobe and back lobe. Our requirement in this project, the forward gain should be greater than backward gain [1].

If it is a greater value than we can say antenna is radiating efficiently in the required direction.

$$\text{Front to Back Ratio} = \frac{Forward\ power\ gain}{Reverse\ power\ gain}$$

2.2.14 Current density

Current density is defined as the current per unit area in a conductor. Its SI unit is amp/m^2.

$$\text{Current density} = \frac{current(I)}{Area(A)}$$

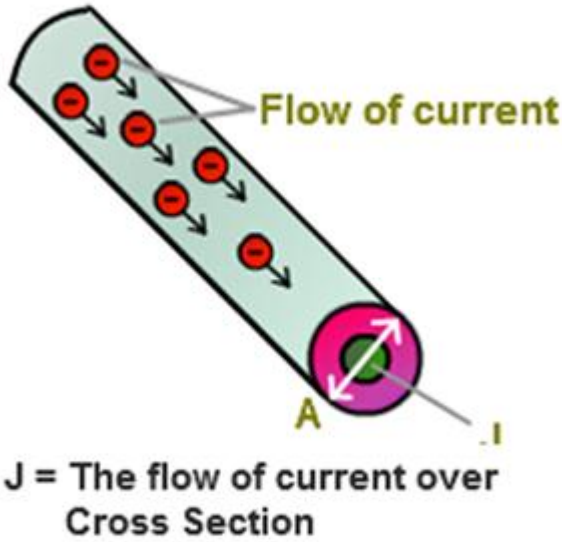


Fig. 2.5 Current Density

2.3 Types of antenna

2.3.1 Dipole antenna

The simplest antenna is dipole among all the antenna. Its directional pattern is like a doughnut. Dipole antenna required differential feed over here.so it required. The simple dipole antenna is shown in figure 2.5.

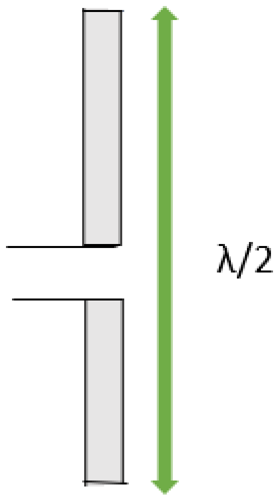


Fig. 2.6 Dipole antenna

Application of Dipole antenna

1. RFID (Radio-frequency identification)
2. RF harvesting chip.

2.3.2 Helical antenna

It is nothing but taking a wire and bent around. It is bent around the simple dielectric rod which can be hollow, solid or provide some support structure.

Three types of a helical antenna

1.Normal mode

2.Axial mode

3.Conical mode

Some helical can work in wither of the mode depending upon the frequency of operation. So, for normal mode circumference is ∏D. D is the diameter.

2.3.3 Pyramidal horn antenna

If pyramidal is flat in one plane only than it can be E-sectorial horn antenna or H-sectorial Horn Antenna but if Flat in both the direction than means width and length is extended. this is pyramidal horn antenna. Because it looks like a pyramidal. Here E-field is uniform in the vertical direction [1].

2.3.4 Reflector antenna

Three types of reflector antenna

1. Planer
2. Corner
3. Parabolic

Planer: - it is nothing but let's say a dipole antenna. Actually, dipole antenna radiating in all direction by putting a reflector. The wave which is incident on this particular plane will reflect and sending in the front direction.it acting like an omnidirectional.

Corner: -it is similar to the planer. But instead of planer reflector, we substitute conical reflector. the corner may be 30°, 60°, and 90°.

Parabolic: -to design very high gain, we will use a parabolic dish antenna. Parabola is defined as when rays which are coming from the far away, after the reflection concentrate at the focal point. And the same principle we will use a parabolic dish antenna.

The majority gain of a parabolic antenna is 30 dB to 50 dB. The shape can be different like a spherical antenna and cylindrical antenna.

2.3.5 Yagi-Uda antenna

Yagi-Uda antenna has Discovered by two japanis.it consists of a dipole, reflector, and director. Dipole provides the source. Balanced and unbalanced both feeds can be used. the size of dipole should be λ/2.reflector should be larger than the dipole antenna [1].

2.3.6 Log-periodic antenna.

The difference between log period antenna and Yagi-Uda antenna is the only use of the element.in case of a log-periodic antenna, we have multiple no of the dipole antenna. each of dipole antenna is fed. each of these elements experiencing a 180° phase shift. But in Yagi-UDA only single feed is used. In Log-periodic antenna, the length will vary in a logarithmic manner. even spacing between the element is in logarithmic [1].

CHAPTER 3

YAGI-UDA ANTENNA GRAPHENE MATERIAL OVERVIEW

3.1 YAGI-UDA ANTENNA

3.1.1 Structure and definition

The Yagi-Uda antenna contains a resonant dipole antenna with one or more parasitic element. These elements refer to a Reflector and Director. The director is kept on the right of the dipole and continuing on the right side of the element. The reflector is placed on the left of the dipole. Basically, TV was used over the last few years by Yagi-Uda antenna. It is very famous and simple to work this type of antenna with recommended performance, which is basically used for greater directivity, efficiency, power gain.

It includes driven elements, reflector, and director element. The driven element is a part of Yagi Uda antenna from which supply is being provided. Basically, it is considered to be a half-wave dipole. In reflector elements, total signals which are coming from driven element are reflected towards the directors. It is slightly greater than the driven element. It may be one element or more than one element behind the dipole. Director is also a section of Yagi-Uda antenna. It directs the beam on the way to require an angle. Usually, it is kept ahead of the driven element [1]. The Yagi-Uda is a generally Uni-directional antenna. Prior, it was designed by using different shapes of dipole like rectangular strip, cylindrical metallic dipole, etc and that's the reason the length and weight of Yagi-Uda antenna are larger [2-3]. Here dipole is designed by rectangular strip [4]. A typical antenna has straight forward construction, more directivity, small cost, easy to fabricate, and simple to feed the antenna. It is broadly used by Yagi-Uda antenna in wireless communication. In this paper, I have used the application of wireless communication which is discussed later. But it has some disadvantages like bandwidth is very limited. We already know that the three factors like bandwidth, front to back ratio and gain are the trade off among them. From many decades, lots of research are going on in this area especially on the prototype model and growth of Yagi-Uda antenna for wireless communication [5-10]. Yagi-Uda antenna has a key part in wireless technology, because of these results like high radiation efficiency, average gain, less cross-polarization, high co-cross polarization, high front to back ratio, etc [11-14]. The basic construction of the Yagi-Uda antenna shown in figure 3.1

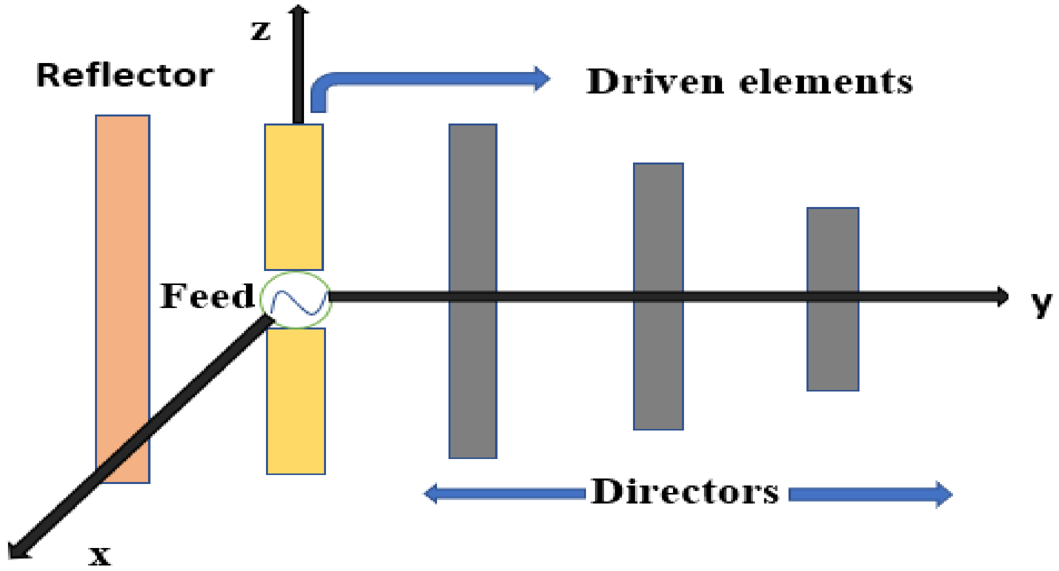


Fig. 3.1 Yagi Uda Antenna

3.1.2 Yagi-Uda antenna patterns.

The total radiation pattern of the Yagi-Uda antenna is the combined form of front to back ratio, power gain, beamwidth and unwanted side-lobes. The span of frequency above and below the design frequency in which the radiation pattern remains the same is called antenna radiation pattern bandwidth. The size of variation from the antenna design description that can be allowed is subjective. And the designer can be limiting the variation [39-43].

There are two reasons to enlarge the gain at fixed frequency first one, If the director element, dipole, and reflector element are an equal spaced and second one, Dimension of director, reflector, and dipole have equal but the bandwidth will narrower and More side lobe and back lobe will occur. If the spacing between the element is increased than bandwidth will increase but side lobe and back lobe will be more.

To varying the length, width and spacing between the element than bandwidth may be controlled. If we decrease the length of the director and increase the distance between the director element than we can get good pattern bandwidth [11-15]. The radiation pattern of Yagi-Uda antenna shown in figure 3.2 which is given below.

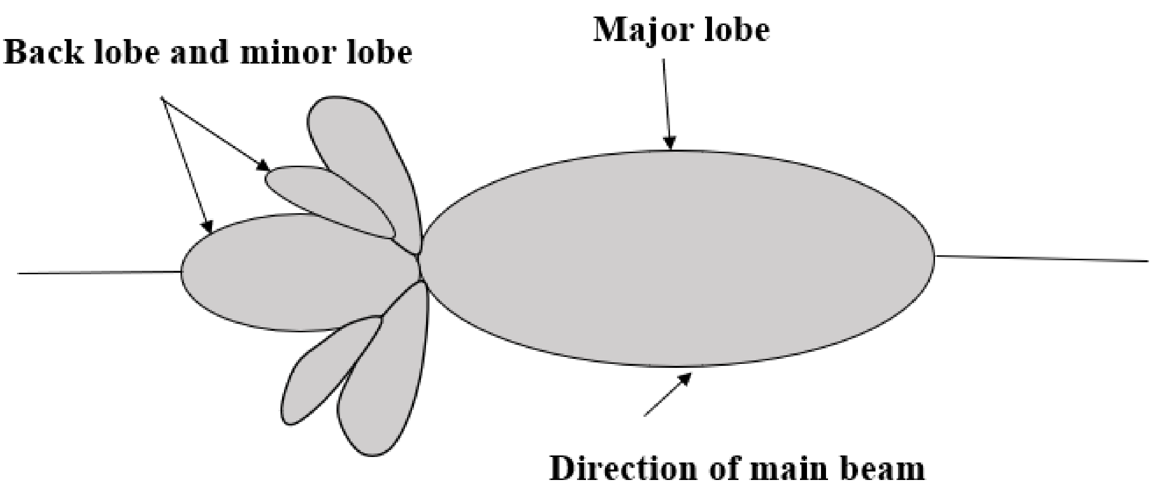


Fig. 3.2. Yagi-Uda radiation pattern.

3.1.3 Yagi- Uda Antenna Design

For this Yagi-Uda antenna to be constructed, the length and width of All the element of directors, reflectors, and dipole have some range and we should follow. All the length and width are depending on the frequency used in the antenna. But if it is a hybrid Yagi-Uda antenna than the length and width of the antenna can vary because it used the terahertz frequency range.

Basically, the following construction specification should be used which are given in table-3.1 and figure 3.3

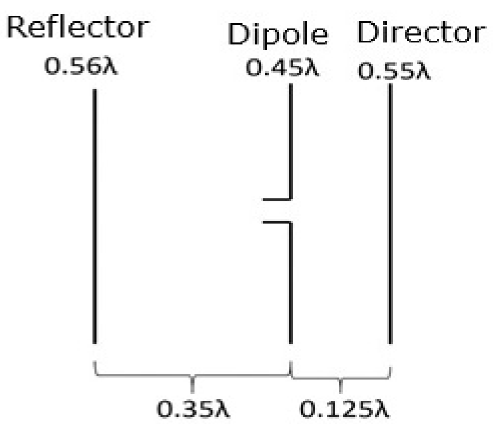


Fig. 3.3 Basic dimension of Yagi-Uda Antenna

TABLE-3.1 DIMENSION OF YAGI-UDA ANTENNA

Parameter	Description
Dipole Length	0.475λ
Reflector Length	0.575λ
Director 1 Length	0.45λ
Director 2 Length	0.42λ
Director 2 Length	0.37λ
Distance between directors	0.25λ
Distance between Reflector to the dipole	0.4λ
Distance between Dipole to director	0.225λ

3.1.4 Advantage & Disadvantage

Advantage

- It gives high gain or high directivity.
- Yagi-Uda can be easily handled and maintained.
- It will be large coverage of frequency.
- power wastage is very less.
- Front to Back Ratio can be adjusted.
- It can support both linear and circular polarization.
- It is very efficient in size and very less weight
- It is very efficient due to unidirectional
- It very easy to fabricate and very less cost.

Disadvantage

- Yagi-Uda antenna does not provide very high gain.it is very moderate. If antenna length increase than gain will increase which is costlier.
- It is very noisy.

- It can be affecting the atmosphere.
- Yagi-Uda antenna is very sensitive to frequency.
- Director element is increased for gain than bandwidth will reduce.

APPLICATION OF YAGI-UADA ANTENNA

- Yagi-Uda antenna basically used in the wideband system and ultra-wideband system.
- It is also used in reflector feed.
- Yagi-Uda antenna used in TV antenna.
- An application where gain doesn't matter but bandwidth requirement is high.

3.2 GRAPHENE

A few years back, the 2-dimensional matter was not popular but nowadays it has become outstanding in the field of nanotechnology due to extraordinary properties [15]. In two-dimensional matter, there is a movement of carrier in a sheet it means that the free carrier can move in two dimensions but it will be restricted in the 3rd dimensional [16-18]. One of the examples of 2-dimensional materials is graphene. It is only one sheet carbon-based allotropes substance. Graphene which consists of only one layer of the carbon atom, are put in order of a honeycomb lattice [19-20]. The benchmark for upcoming generation electronics device can the substitution of existing silicon-based industrial science with other new materials due to their magnificent properties. The initially found material is graphene material which is called 2-dimensional material. Graphene has contained a single layer sheet of SP2 hybridization carbon atom. It has been given a new outlook of the potential device among many analysts for its special electronic properties [25-31]. The structure of graphene is an atomic-scale honeycomb lattice made of the carbon atom. It is the fundamental construction of fullerenes, CNT and graphite [32-33]. It is very thin, strong, conductive, transparent which is given in figures 3.4

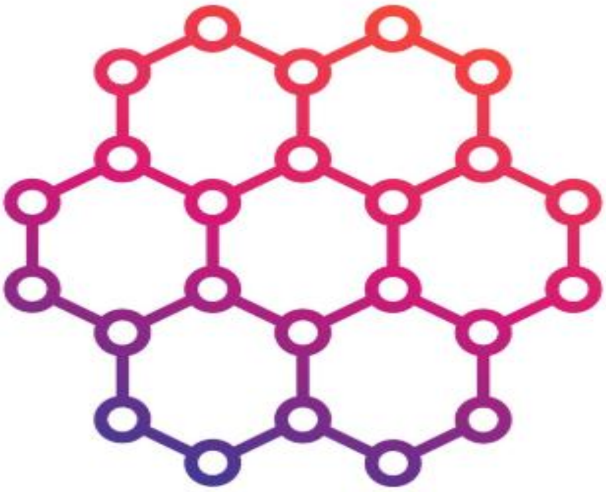


Fig. 3.4 Graphene carbon structure

3.2.1 Properties of graphene

Graphene has attracted huge observations from the recent few years due to its massive remarkable properties. It has special electrical & electronics properties, biological properties, mechanical properties, optical properties, thermal properties [25-39], etc. The mechanical, electronics or optical properties comprises of

- high mobility of charge carriers,
- high thermal conductivity,
- strongest materials,
- more young’s modulus,
- conduct heat,
- electrical efficient,
- transparent,
- mechanical strength.
- It is frequently known for its electronic characteristics such as it having excessive mobility (200000 cm2v-1s-1),
- larger specific area (2630 m2g-1).

ballistic transport at even room temperature and others. The properties of perfect graphene can be altered by generating a superlattice by locating a graphene sheet in the regular potential. Now to generate a graphene superlattice is to apply a sheet of 2 dimensional on a striped substrate [11-13]. Graphene is also called as a semimetal because it has no gap between valence and conduction band and due to this it gives us some extra properties like

- linear energy dispersion interconnection,
- Quantum hall effect etc.

3.2.2 APPLICATION OF GRAPHENE

Graphene has numerous applications in the field of electronics such as

- in antenna,
- radar,
- field-effect transistor, Sensor.
- In the last few decades, it has been noticed that graphene-based mixture has assigned for a huge part of energy storage materials,
- electromagnetic insulator products,
- chemical sensor and
- electronic device layer in cables.
- Graphene based combination have massive potential application in sensitive gas sensor,
- photovoltaic, space industry,
- electronics,
- biomedicals,
- automotive,
- spintronics and
- successor to the silicon device.

- battery current collector,
- sensor,
- transitor,
- detector device,
- capacitor etc.

Since it has very difficult to generate and tune the bandgap of this material to authorize its application in the no-identical device because the bandgap of graphene is zero [34-37]. Graphene has lots of advantage that make it sensible materials for applied in device utilize in terahertz range and if the frequency range is terahertz then the size will be in the scale of nanometer or micrometer including material depth in nanometer, relatively tuning of frequency of EM construction based on it. It has been more kinetic inductance and broadband amplification. Hence lots of research is going on the terahertz range, excluding the region of lower frequency [38-39].

CHAPTER 4
HIGH-FREQUENCY STRUCTURE SIMULATOR

High-Frequency Structure Simulator (HFSS) is a commercial finite element method solver for EM structure. The Maxwell equation has been used for the Finite element method (FEM).

- It is basically the design of high frequency and high-frequency component design.
- It is full-wave EM high-frequency structure simulator.

Common uses of Hfss are: -

- Package modeling
- PCB Board Modelling
- EMI/EMC
- Antenna design
- Connectors
- Waveguide
- Filters

4.1 Ansoft Terms

It consists of a different window which is used to construct a different type of model or structure. Basically, it is divided into five categories. Which is in the order of Project manager and so on.it is discussed below.

4.2 Project Manager

Project is created in the Project manager. Hfss model is called Design of the project.

The project manager is classified in three-part.

- Design
- Design setup
- Design result

Model, boundaries, excitation, mess operation, and analysis come under design set up. Basically, in the design setup, we draw the project and set the dimension, frequency, sources, range of frequency and finally boundary. All the process has to be before simulation. If all the parameter has taken correctly then it will be ready to run. Otherwise, it gives some error. And again, we have to change the dimension. And the process will happen many times. Simulation result depends on the design setup.

Design result gives the simulated value. Either it may be 2D Graph, 3D Graph or values. Here we can also check the distribution of electric field, magnetic field or current density. Also, we can get efficiency, front to back ratio, etc.

4.3 Property Window

Property window is a tool of HFSS. Whenever, we design the structure in hfss 3D modular than we focused on the following which is given below

- the shape of a structure,
- material,
- name,
- Orientation
- Model
- Display wireframe
- Color
- Transparent

Above are called a property table.

4.4 Three-Dimensional Modeler

It is a tool for HFSS which draws three-Dimension Devices. It has a 3-Dimensional design tree. By the help of the model, we can design like a waveguide, antenna, filter, etc. 3-Dimensional Draw the attention towards the real picture. We cannot imagine the total picture through 2-dimensional. Of course, the practical point of view, the size of 3-Dimensional is too large. But according to requirement, we have to use 3-Dimensional.

The relative position and coordinate system are a vital role in 3-Dimensional. Because whenever we draw the dimension of devices than we have to set the coordinate point at a fixed position.

4.5 Flow chart of simulating result in HFSS

The software provides an effortless-to-use interface for Growth instrument. Generating a diagram which assumes through the following flow chart. The Layout for simulating result is given in figure 4.1

To understand the processes, we have to see through the Flow chart which is shown below.

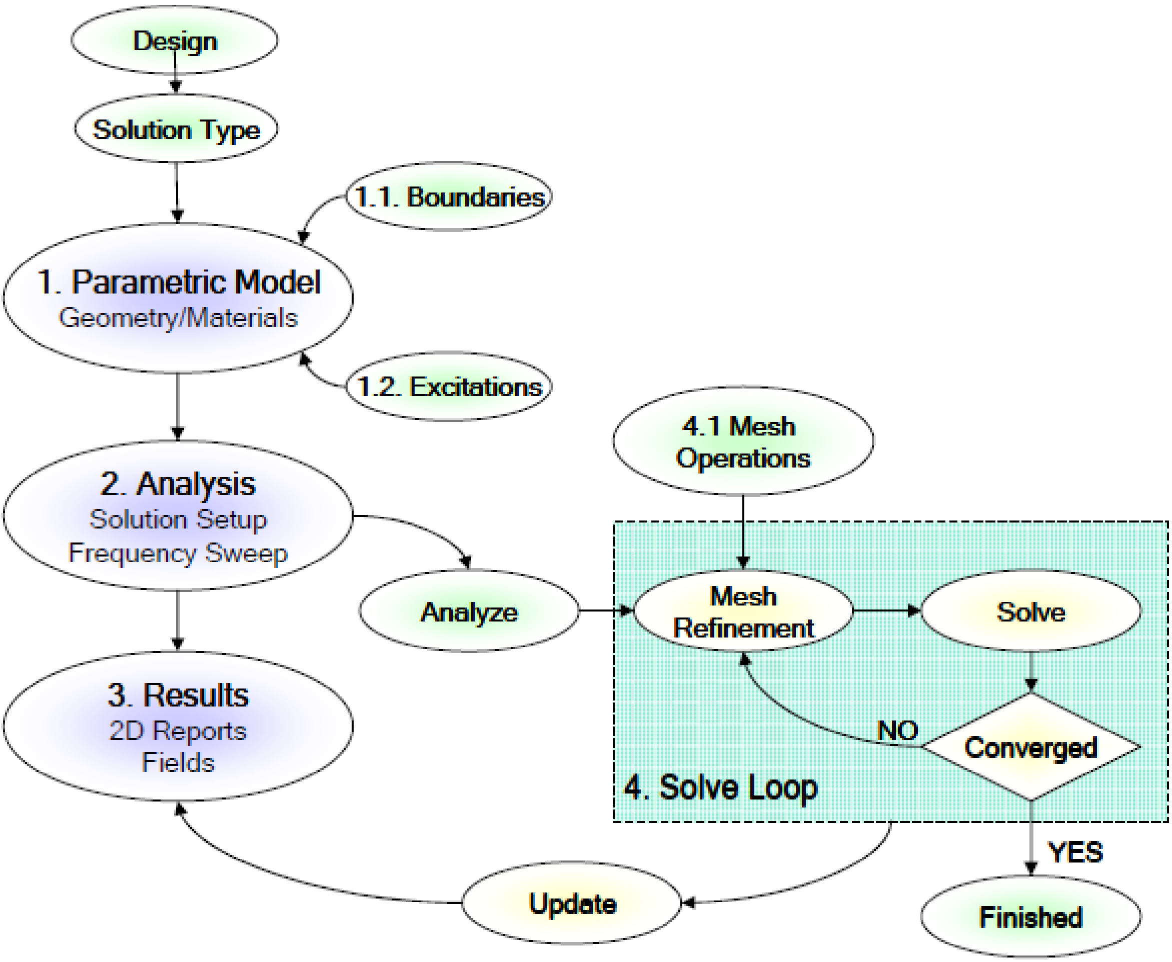


Fig. 4.1 flow chart diagram

4.6 Plotting data

Data plotting can have many forms. The most frequently used format is 2-Dimensional representing, but it can be drawn in 3-Dimensional. all the parameter that can be plotted on different graphs, is shown below.

- S-parameters
- Y-parameters
- Z-parameters
- VSWR
- Port Z etc.

CHAPTER 5

ANTENNA DESCRIPTION

5.1. Introduction

The design of Graphene-based Yagi-Uda antenna was convey through many research paper, Books, Magazine and internet [2-15], etc. This Structure has been concluded after a lot of analysis and experiment. The analysis has been done on the Graphene materials, Yagi-Uda antenna and antenna parameter. After all this analysis we get a new structure called Hybrid metal Graphene Yagi-Uda antenna. This design gives the advanced theory and properties of the antenna. It develops a new structure for different application in a certain range of frequency. Now my objective is to design an antenna which has a higher gain, higher front to back ratio, less loss and less VSWR for suitable applications.

An antenna which is design according to the above requirement, gives many advantages.

- Higher radiation efficiency.
- Ability to work with low SNR
- High performance in long-distance communication
- Radiate the signal in the hilly area and ruler area.
- Low transmit power
- The low signal transmits an unnecessary area.

To get higher gain, higher efficiency, we have to use a different technique for design such an antenna.

- Use Graphene material on the top and bottom of the director and reflector.
- Using the Ground under the substrate
- Increase the dielectric constant

Here antenna constructs new structure i.e. called Hybrid metal graphene Yagi-Uda antenna. So, if it is a hybrid metal graphene structure than Graphene will use in the top and bottom of the director and reflector. Which will give more advantage in the application. But if it is not hybrid metal Graphene then the total dimension of reflector and director should construct through either graphene or metal. The new structure gives many advantages but due to costlier of graphene, it has a disadvantage which is very difficult to design a practical antenna.

The Prototype model and simulation are done using HFSS. The alter the height, length, and width of the antenna. We got the best result using materials, substrate, and ground, etc.

5.2 Antenna design

5.2.1 Graphene-based Yagi-Uda antenna.

In this article, two non-identical design is based on the configuration of director, driver and reflector component of graphene-based Yagi-Uda antenna with co-axial feed construction are proposed in case-1. Basically, director, reflector, and dipole are made from graphene materials and the small patch which is especially used in the director and reflector are made from metal. While proposed antenna design 2 is just the complement of design 1 i.e. director, reflector and dipole are made from metal strip while a patch is made up of graphene. Both antennas are manufactured on a small cost, with Rogers RT/duroid substrate of relative permittivity 2.33, dielectric loss tangent 0.0012, substrate thickness 1.6 mm, substrate dimension (l and b) is 110.5 mm and 65 mm.

5.2.1.1 Proposed design case-1

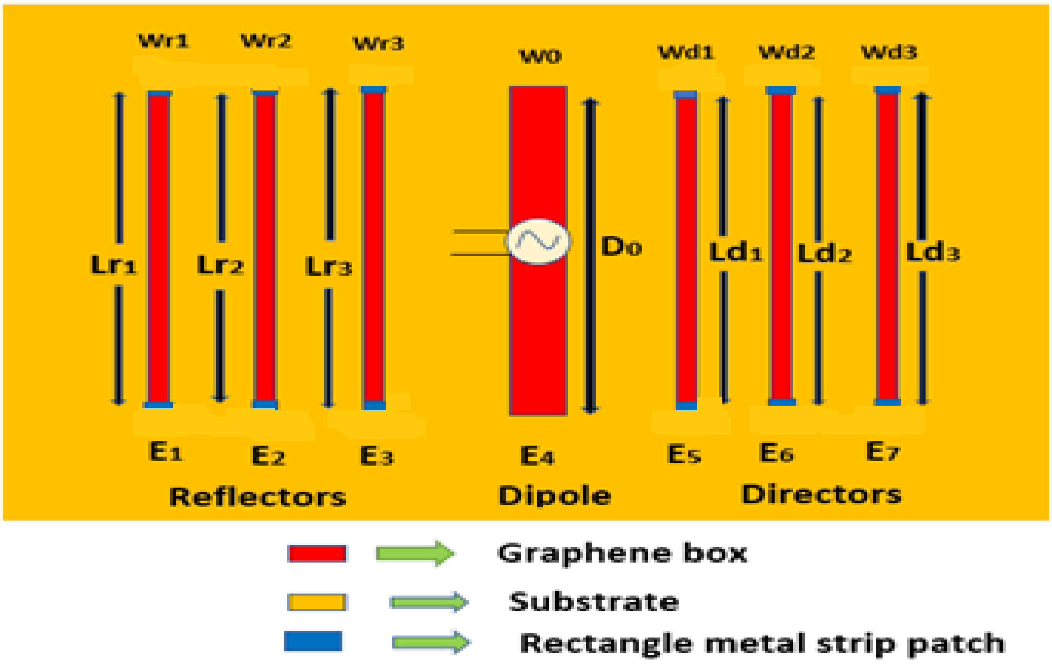


Fig. 5.1 Proposed graphene-based Yagi-Uda antenna design case-1

7-component of graphene-based Yagi-Uda antenna have proposed through graphene material box. And it is shown in figure 5.1. This graphene-based Yagi-Uda antenna comprises of three reflector elements, one driver, three directors [4]. There are some consequences of different variables like the distance between the element, length & width of the element, coaxial feed line size & shape, etc in the Graphene-based antenna. This antenna has been simulated using HFSS software. In this structure dipole, reflector and director has been fabricated from graphene material which has 0.2 mm thickness. Patches which are used in the top and bottom of director and reflector has been considered as a metal rectangular strip which is placed on YZ plane i.e. it has a width and height. The dimension of the dipole (length× width× height) is 31.07 mm ×5 mm × 0.2 mm respectively. The length of the reflector (Lr1=Lr2=Lr3) is 27.82 mm, the width of a reflector (Wr1=Wr2) is 0.8 mm and width of a reflector (Wr3) is 1 mm. Similarly, for director elements (E5, E6, E7) the length of the director is 27.82 and width is 0.65 mm. Since reflector and director are graphene materials, so it has a thickness of 0.2 mm and now finally the patches which are attached in this reflector have 0.2 mm height and width will adjust according to the respective reflector and director. All of the above theoretical analysis is summarized in the Table-5.1. Based on the study of this design, the different parameters are based on the solution frequency of 5.7 GHz.

TABLE-5.1 PROPOSED DESIGN CASE-1

Variable	Value (mm)
Substrate length	110.5
Substrate width	65
Substrate thickness	1.6
Dipole length (D0)	31.07
Dipole width (W0)	5
Dipole thickness	0.2
Reflector length [E1=E2=E3] i.e.	27.82
Reflector width [E1=E2] i.e. (Wr1=Wr2) (Lr1=Lr2=Lr3)	0.8
Reflector width (Wr3)	1
The reflector and Director thickness	0.2
Director length [E5=E7] i.e. (Ld1=Ld3)	27.82
Director length [E6]	27.82
Director width [E5=E6=E7] i.e. (Wd1=Wd2=Wd3)	0.65
Rectangle patch sheet Height	0.2
Rectangle patch sheet width	According to the width of respective reflector and director
Spacing between the element	13

5.2.1.2. Proposed design case 2

The performance of proposed design 1 can be enhanced by proposed design 2. Design-2 has seven components of graphene-based Yagi-Uda antenna. In this design graphene material box and some rectangle, metal strips are introduced. The three-reflector elements of proposed Yagi-Uda antenna are designed on the left side, followed by one driver and three director elements. The construction of Proposed Design case-2 is shown in figure 5.2

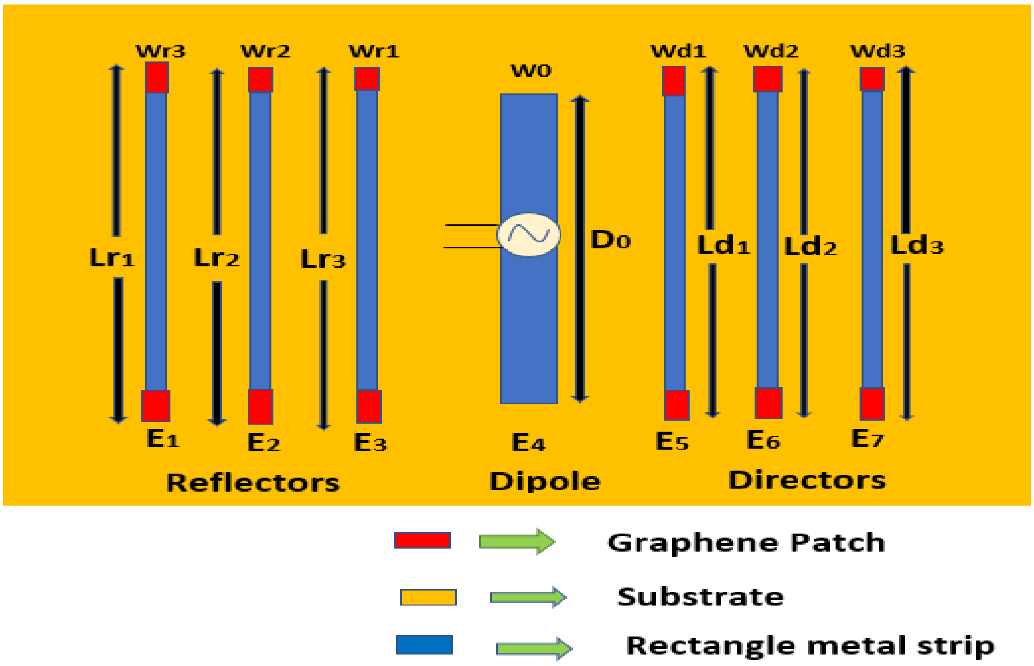


Fig. 5.2 Proposed graphene-based Yagi-Uda antenna design case-2

The length of the Dipole element should be lesser than the director and reflector element for the higher requirement of Gain. The Dipole element's length is 31.07 mm and width are 5 mm. The reflector element [E1, E2, E3] and director element [D1, D2, D3] comprises of two types of materials that are attached to each other. One of them is a metal sheet which is perfect electric & another one is graphene material which is attached to the top and bottom of the metal sheet and it is called as a patch. So total length of reflector [Lr1 = Lr2 = Lr3] is 31.33 mm (metal sheet length is 27.82 + two patches length is 3.51). The width of reflector (E1= E2) is 0.8 mm & E3 is 1mm. The width of patches will be equal according to the metal sheet. Similarly, for director element [E5, E6, E7], the length of director element (Ld1=Ld3) is 31.33 mm (metal sheet =27.82 + two patches=3.51) and Ld2 is 31.33 mm (metal sheet= 27.56 + two patches=3.77). The width of all director has been considered to be equal i.e. 0.65 mm. The spacing between the element is 13 mm. In this Yagi-Uda element, we used some patches as a graphene material so it has some thickness which is considered to be 0.2 mm. All of the above theoretical analysis is summarized in the table-5.2.

TABLE-5.2 PROPOSED DESIGN CASE-2

Variable	**Value (mm)**
Substrate length	110.5
Substrate width	65
Substrate thickness	1.6
Dipole length (D0)	31.07
Dipole width (W0)	5
Reflector length [E1=E2=E3] i.e. (Lr1=Lr2=Lr3)	31.33 (metal sheet is 27.82+ Two patches are 3.51)
Reflector width [E1=E2] i.e. (Wr1=Wr2)	0.8
Reflector width (Wr3)	1
Graphene patch thickness	0.2
Director length [E5=E7] i.e. (Ld1=Ld3)	31.33 (metal sheet is 27.82 + Two patches are 3.51)
Director length [E6]	31.33 (metal sheet is 27.56 + Two patches are 3.77)
Director width [E_5=E_6=E_7] i.e (W_{d1}=W_{d2}=W_{d3})	0.65
Spacing between the Element	13

5.2.2 Graphene form Yagi-Uda antenna with improved characteristics

5.2.2.1 Proposed Graphene-based Yagi-Uda antenna

In this paper, the proposed graphene base Yagi-Uda antenna is designed with co-axial feed. Director, Reflector, and Dipole are made from graphene material. This antenna is designed on slightly less cost with Rogers RT/duroid Substrate of relative permittivity 2.33. Substrate thickness 1.6 mm, dielectric loss tangent 0.0012. Substrate dimension (length × width) is 85 mm × 65 mm. five-component of graphene-based Yagi-Uda antenna have been presented through graphene materials box which is shown in figure 5.3.

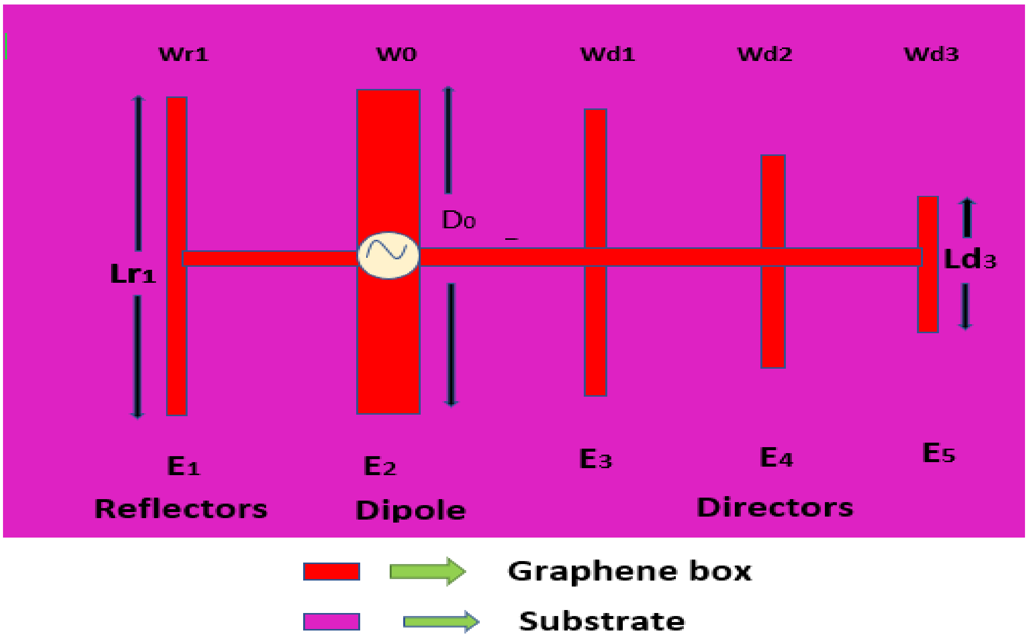


Fig. 5.3 Proposed graphene-based Yagi-Uda antenna

The above antenna has been designed on high-frequency structure simulator (HFSS) software. This graphene-based Yagi-Uda antenna includes one dipole, one reflector, and three director elements. Graphene-based Yagi-Uda antenna has been designed through graphene materials which have 0.2 mm thickness. In this structure, we considered the notation for the elements such as E_1 for reflector element, E_2 for dipole and E_3, E_4, E_5 for director elements. The dimension of a dipole (l×b×h) is 31.07 mm ×5 mm × 0.2 mm respectively. The length of the reflector element (Lr_1) is 37. The width of the reflector element (Wr1) is 0.8 mm and the thickness is 0.2 mm. Similarly for director E_3, E_4, E_5 are the same width and the width i.e (Wd_1=Wd_2=Wd_3) is 0.65 mm. the length of director E_3 i.e (Ld_1) is 27.82 mm. The length of director E_4 i.e (Ld_2) is 17.56 mm and the length of director E_5 i.e (Ld_3) is 13 mm.the lengths of the director is decreasing when we go away form the dipole because for the better radiation and maximum gain. The thickness of the director element is 0.2 mm. The spacing between reflector E_1 and dipole E_2 is 14 mm. the spacing between dipole E_2 to director element E_3 is 18 mm and finally, the spacing between the director element is 13 mm. a box is connected between E_1 to E_5 is 58 mm. the width of that box is 1.5 mm. and height is 0.2 mm. The center frequency for this antenna is 6.6 GHz. All of the above theoretical analysis is recap in the TABLE-5.3.

TABLE-5.3 PROPOSED GRAPHENE BASED YAGI-UDA

Parameter	**Value (mm)**
Substrate length, width, and height	85,65 and 1.6
Reflector length [E_1] i.e (Lr_1)	37
Reflector width [E_1] i.e (Wr_1)	0.8
Reflector thickness	0.2
Dipole length (D_0)	31.07
Dipole width (W_0)	5
Dipole thickness	0.2
Director [E_1] length i.e (Ld_1)	27.82
Director [E_4] length i.e (Ld_2)	17.56
Director [E_5] length i.e (Ld_3)	13
Director width i.e (Wd_1=Wd_2=Wd_3)	0.65
Director thickness	0.2
Spacing between E_1 and E_2	14
Spacing between E_2 to E_3	18
Spacing between E_3 to E_4	13
Spacing between E_4 to E_5	13
The length between E_1 to E_5	58

CHAPTER 6
RESULTS AND CONCLUSIONS

The simulation mechanism of the proposed antenna was carried out on HFSS Software. Some modification was made according to variation of length, width, height, source, and frequency. The final antenna has been designed after so many trails. The simulated was conducted for two different objectives.

In the first objective, Graphene-based Yagi-Uda antenna has been designed. In the first proposed design; director, reflector, and dipole are made up of graphene material but the small length of patches of metal are attached on both the ends of reflector and director. The second proposed design case is complementing the first proposed design case. That means reflector, director and dipole are made up of metal and patches of graphene on both ends of director and reflector.

In the Second objective, Simulation was conducted with or without graphene material in the Yagi-Uda antenna. The simulation result will be divided into two designs.

1. Design and analysis of graphene-based yagi-uda antenna for S-band.

    - In the first proposed design case-1;
    - In the second proposed design case-2;
    - Comparison between two proposed design case and with the simulation result

2. Graphene-based Yagi-Uda antenna with improved characteristics.

    - Yagi-Uda antenna with Graphene materials.
    - Comparision between proposed antenna and conventional antenna

6.1 Design and analysis of graphene-based yagi-uda antenna for S-Band

6.1.1 Proposed Design Case-1

Director, Reflector, and Dipole are made up of graphene material but the small length of patches of metal are attached on both the ends of reflector and director. Figure 6.1 shows the frequency response of simulated result S11 parameter of graphene-based Yagi-Uda antenna. The return loss(dB) of the proposed graphene-based Yagi-Uda antenna Design 1 is -12.41 dB at the resonant frequency of 5.7 GHz. With the help of return loss, we calculated the impedance bandwidth i.e. 70 MHz (5.74 GHz-5.67 GHz).

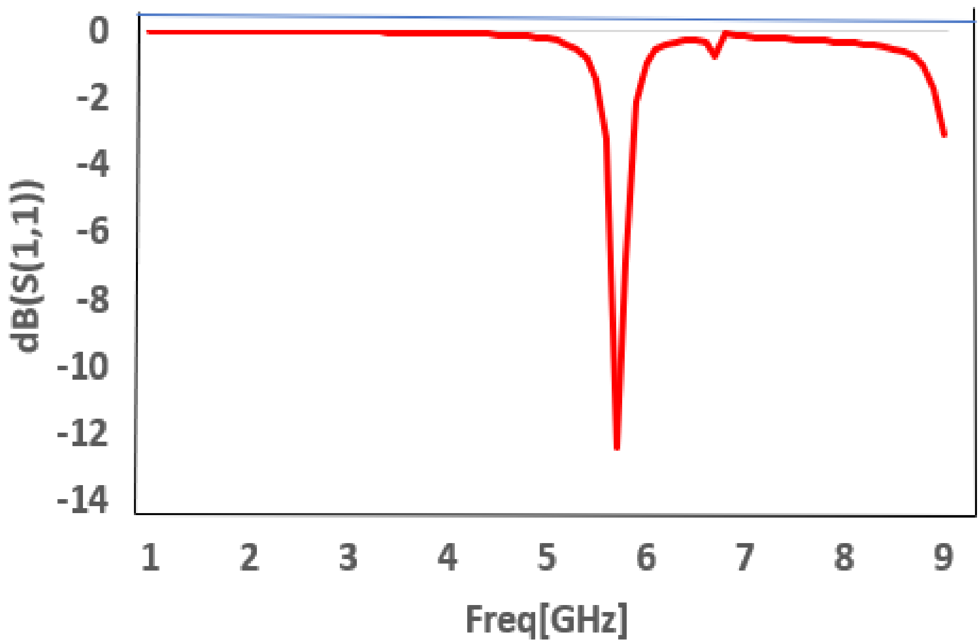


Fig. 6.1 Return loss (dB) of Proposed design case1

Fig. 6.2 and 6.3 Give the 3D and 2D Simulated Radiation pattern of proposed graphene-based Yagi-Uda antenna design 1 at the resonating frequency at 5.7 GHz. The gain achieved is 6.73 dB.

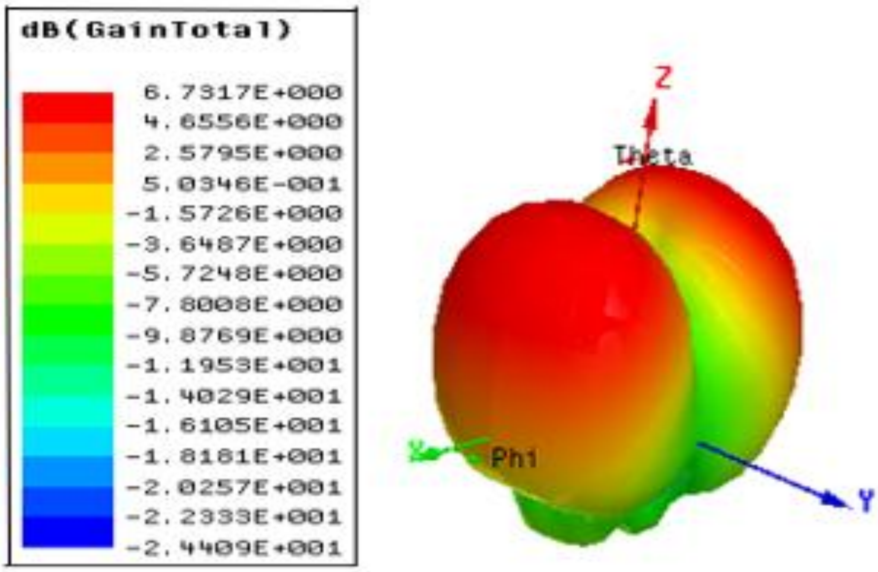


Fig. 6.2 3D polar gain

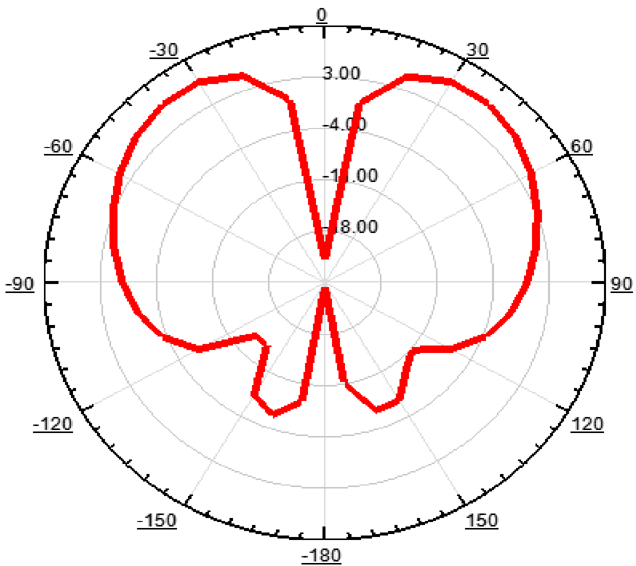


Fig. 6.3 2D radiation pattern

Figure. 6.4, 6.5 and 6.6 show the VSWR, Efficiency, and front to back ratio respectively with respect to frequency.

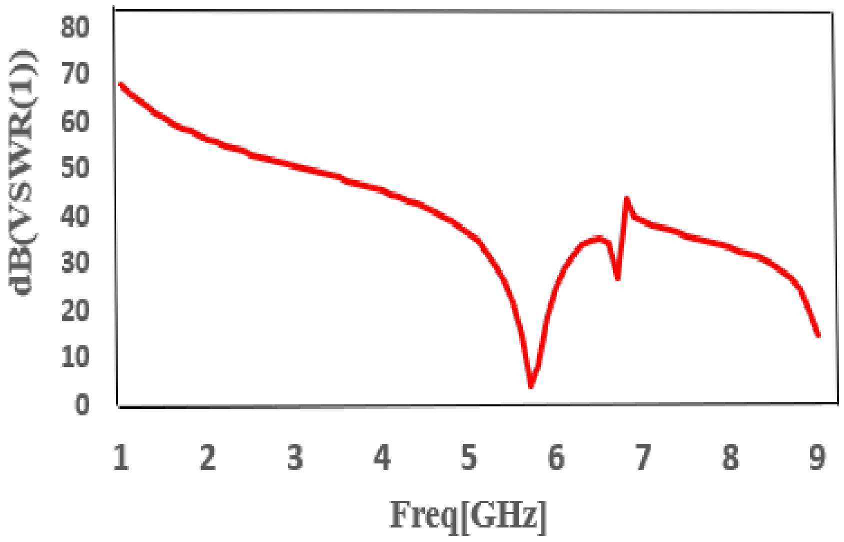


Figure. 6.4 VSWR of proposed design case-1

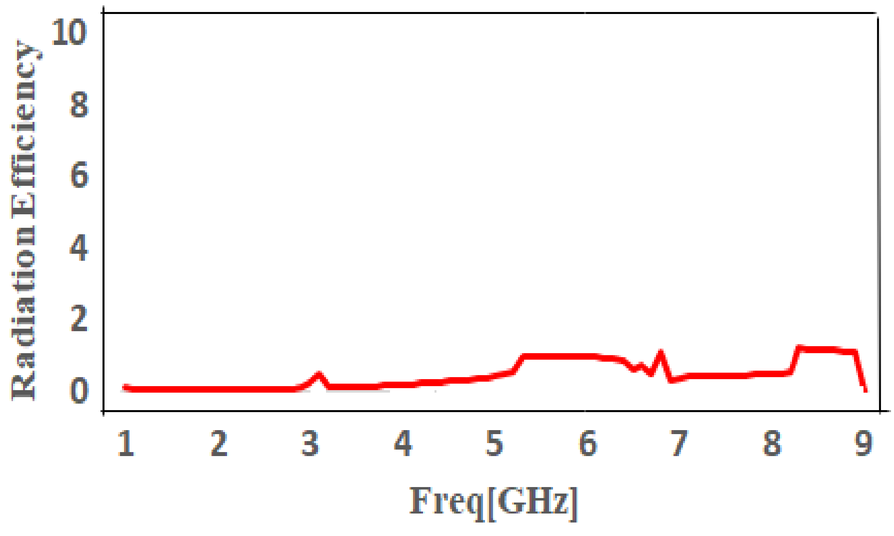


Fig. 6.5 Radiation Efficiency of proposed design case-1

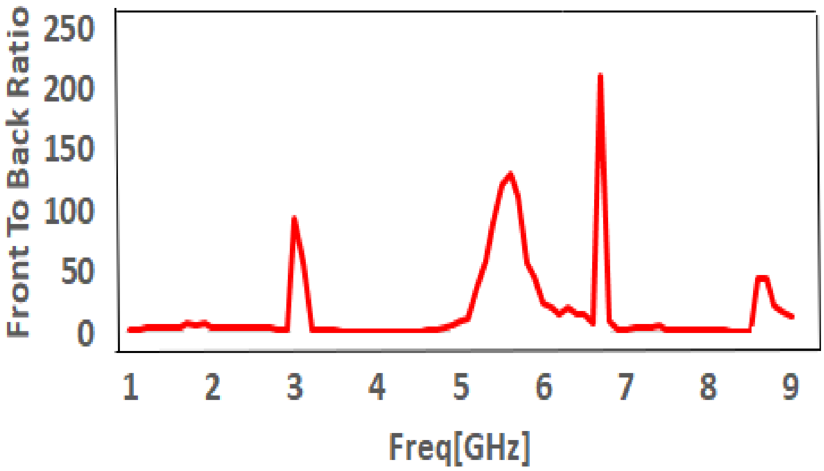


Fig. 6.6 Front To Back Ratio of proposed design case-1

We have also analyzed the electric field distribution in figure 6.7, magnetic field distribution in figure 6.8 and current distribution which is shown in figure 6.9 at (a) ϕ=0° and (b) ϕ=90°

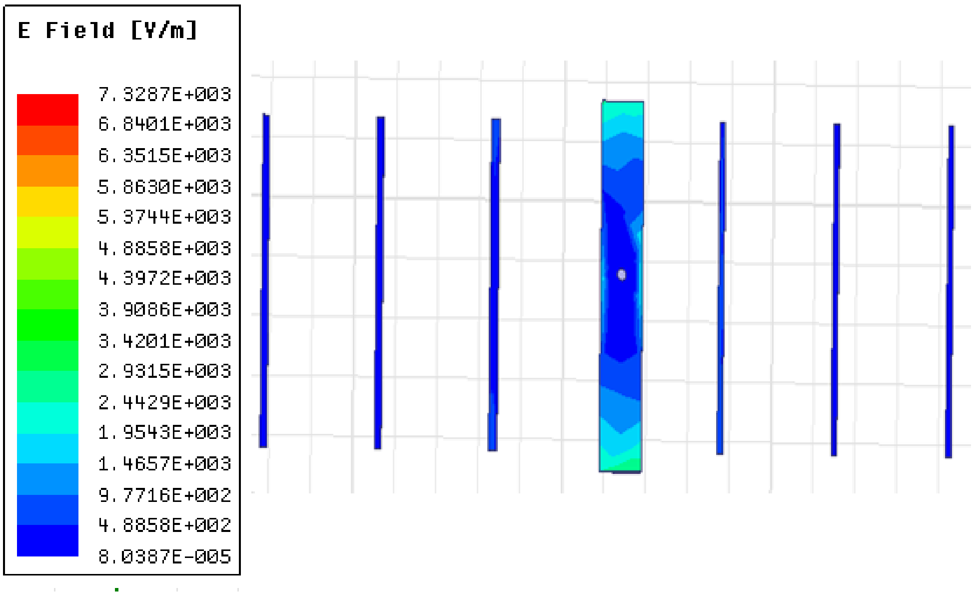


Fig. 6.7 Electric field distribution at an angle at ϕ=0°

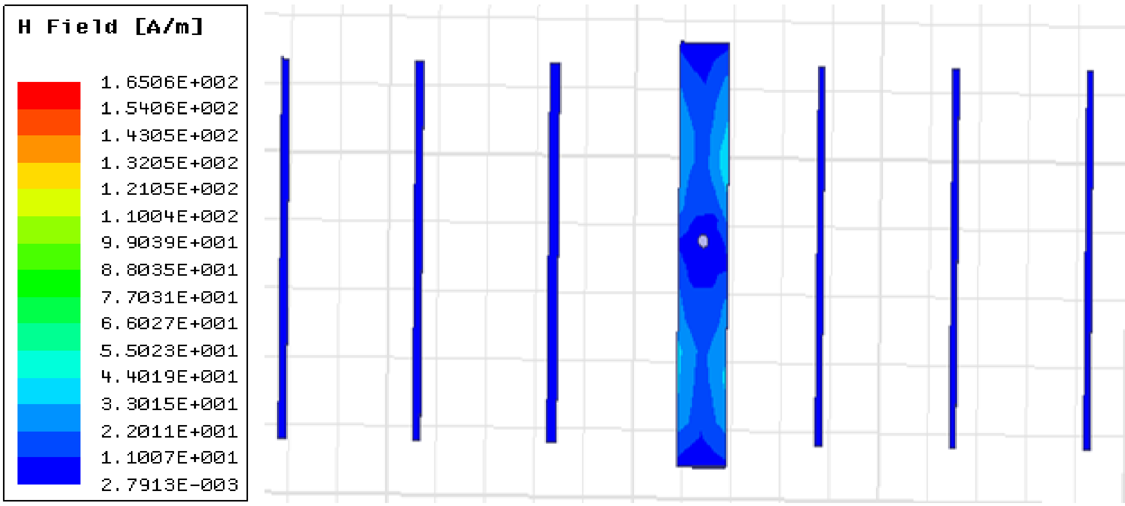
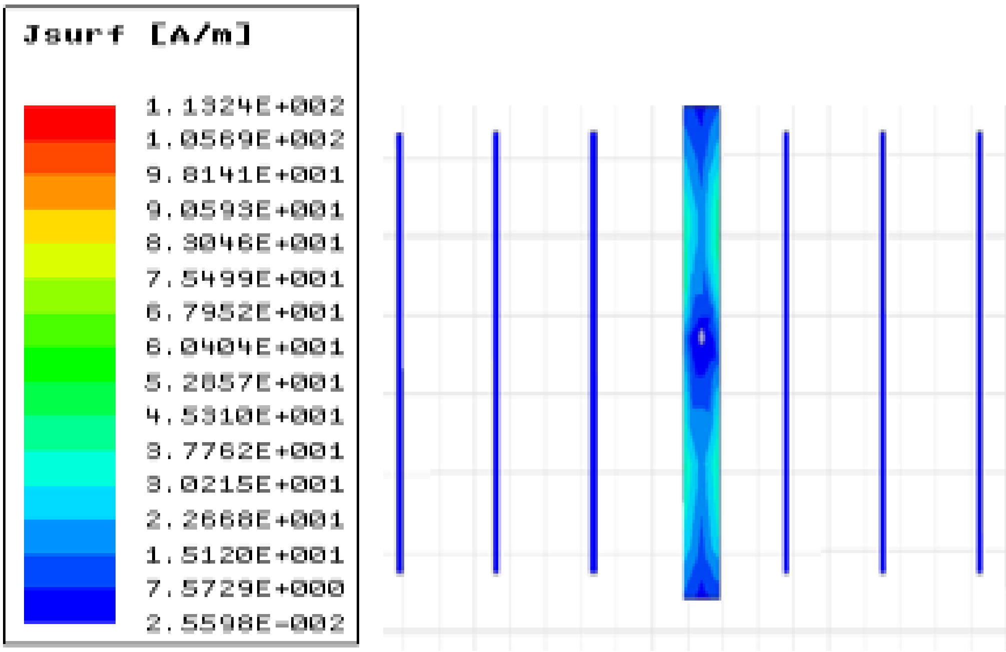
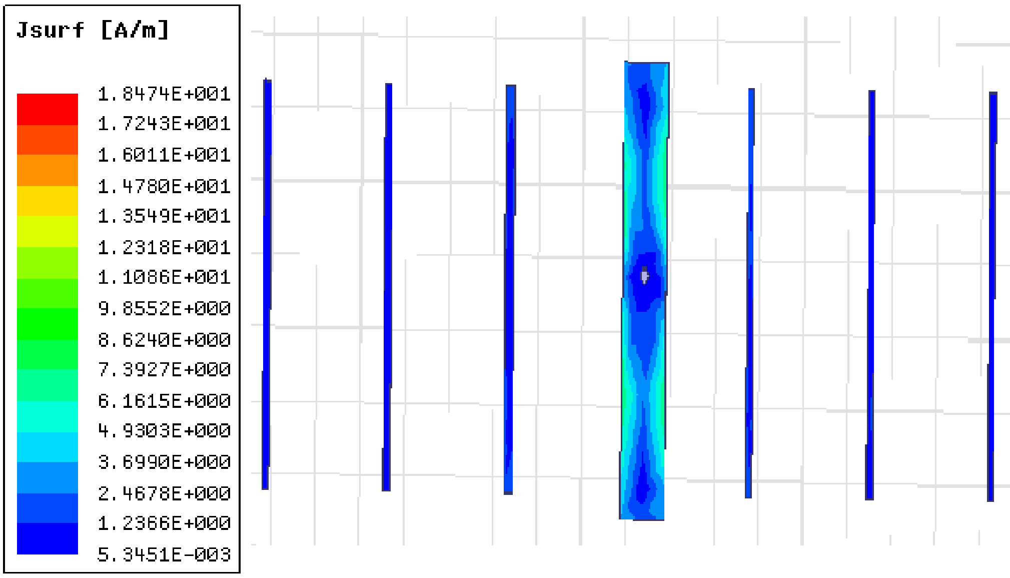


Fig. 6.8 Magnetic field distribution at an angle at ϕ=0°



(a) ϕ=0°



(b) ϕ=90°

Fig. 6.9 Current density distribution of proposed design case-1

6.1.2. Proposed Design Case-2

This branch outlines the simulation result of graphene-based Yagi-Uda antenna i.e. |S11| parameter, radiation efficiency, 3D polar gain, 2D radiation pattern, bandwidth, front to back ratio, VSWR, etc. Figure 6.10 shows a better S(1,1) of -18.54 decibel at resonating frequency 3.2 GHz and acquired bandwidth is approximately 100 MHz (3.25 GHz- 3.15 GHz).

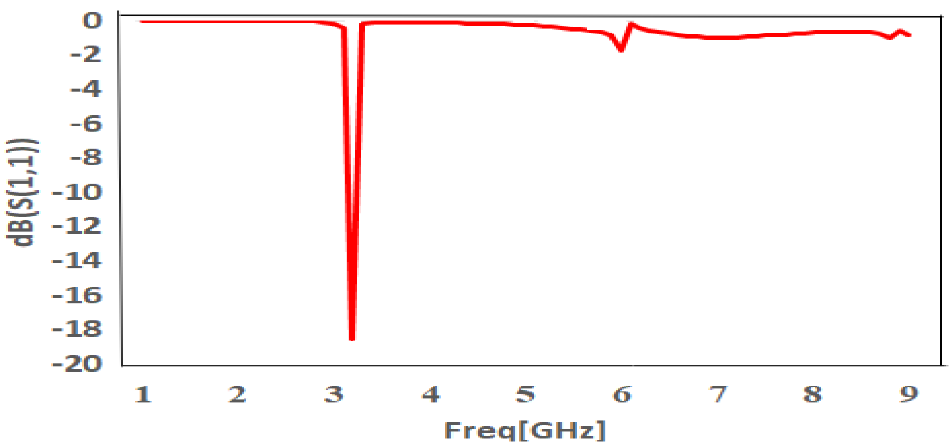


Fig. 6.10 simulated return loss (dB)

The maximum gain and directivity will be along the z-axis because the graphene patch is being used in the reflector and director. The highest gain obtained is 7.11 dB at resonate. frequency 3.2 GHz which is given in figure 6.11 as a Three-Dimensional Polar Plot Gain and in Figure 6.12 as a Two-Dimensional Radiation Pattern.

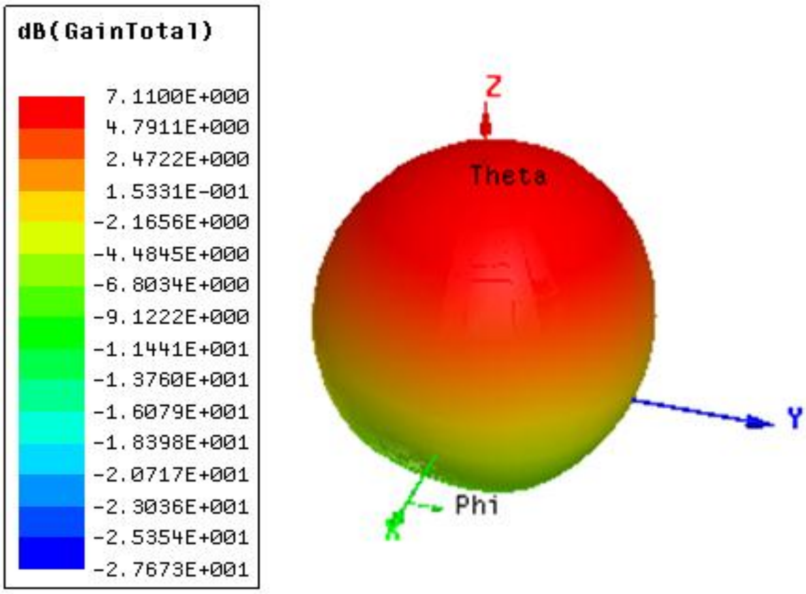


Fig. 6.11 Three Dimensional Polar Gain of Proposed Design case-2

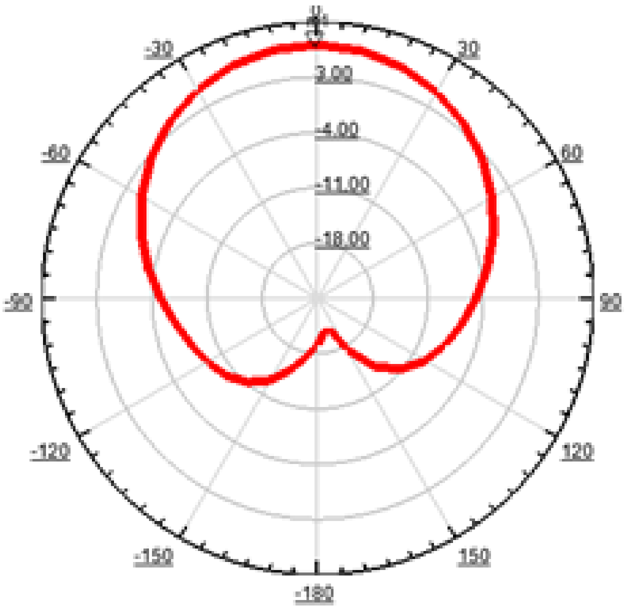


Fig. 6.12 Two-Dimensional Radiation Pattern

Fig. 6.13, 6.14 shows the Radiation Efficiency, VSWR respectively. Since, the Main Radiation is along the z-axis, it means that it is unidirectional. That's why the efficiency of graphene-form Yagi-Uda antenna is 100 %.

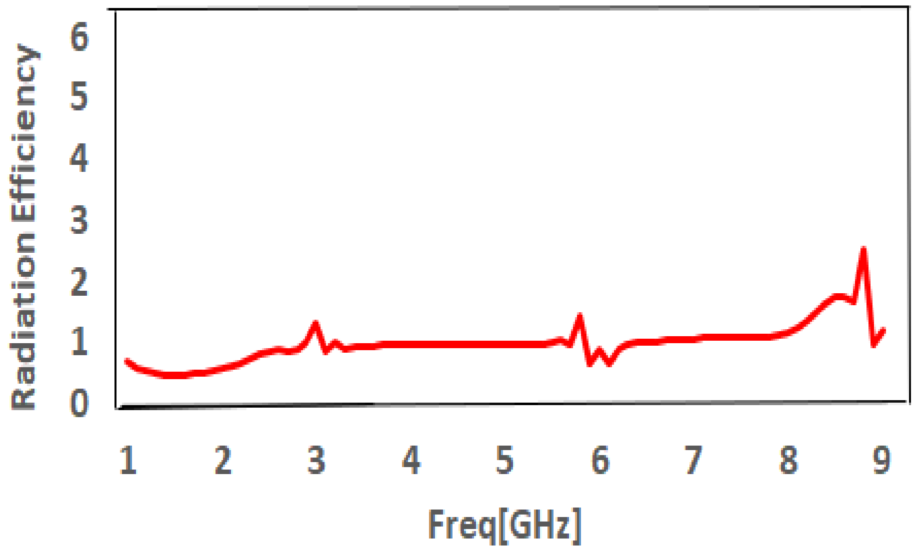


Fig. 6.13 Radiation Efficiency of proposed design case-2

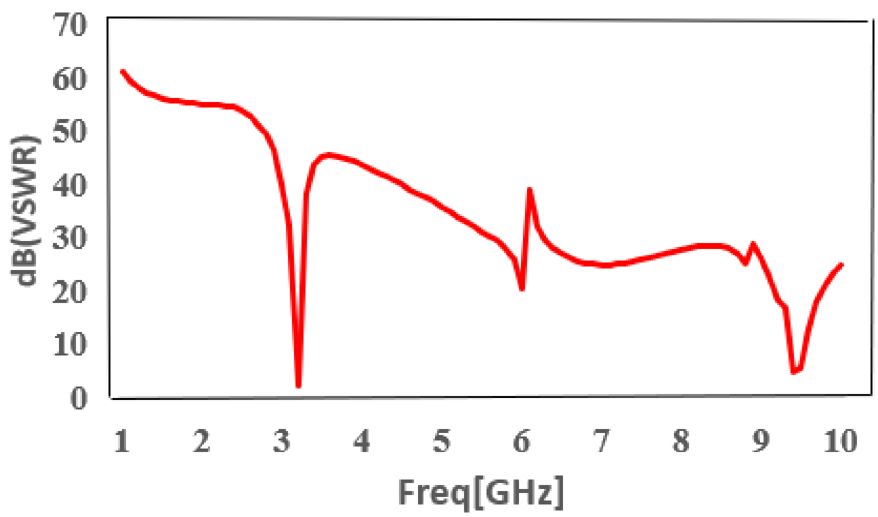


Fig. 6.14 VSWR

Figure 6.15 shows the front to back ratio. This notifies us the range of backward radiation and is normally indicated in dB. This variable is essential in circumstances where interference or coverage in the backward direction needs to be less. The front to back ratio is 407.

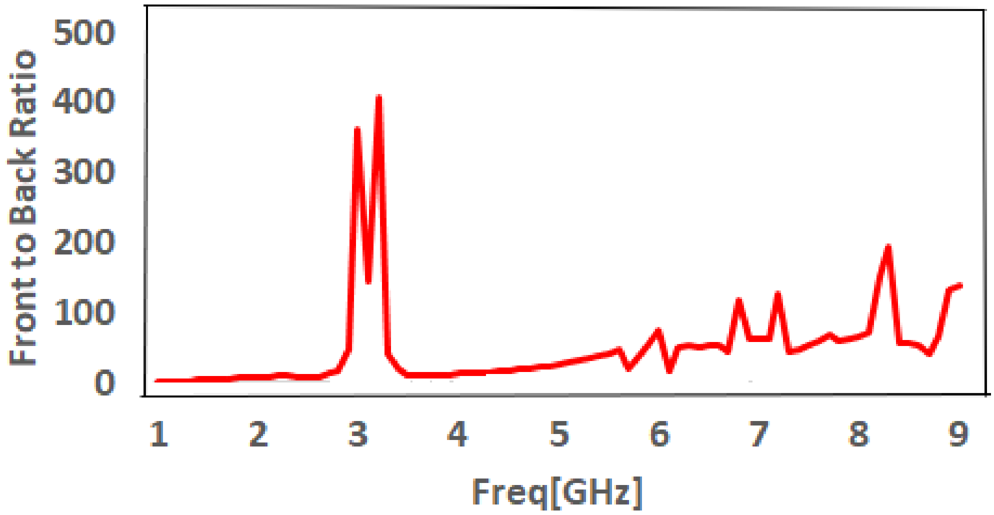


Fig. 6.15 Front To Back Ration

Electric field distribution and magnetic field distribution are shown in figure 6.16 and 6.17 at ϕ=0°

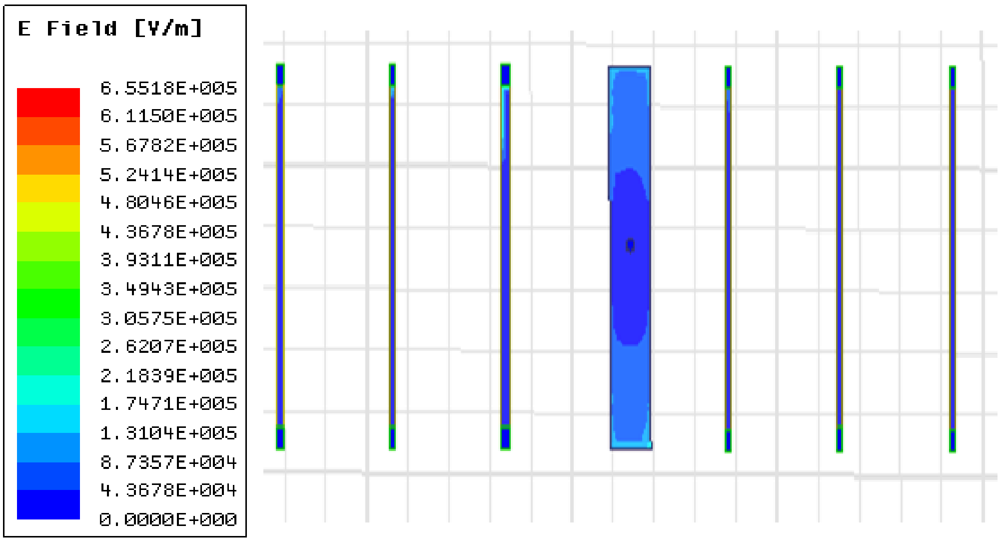


Fig. 6.16 Electric field distribution at an angle at ϕ=0°

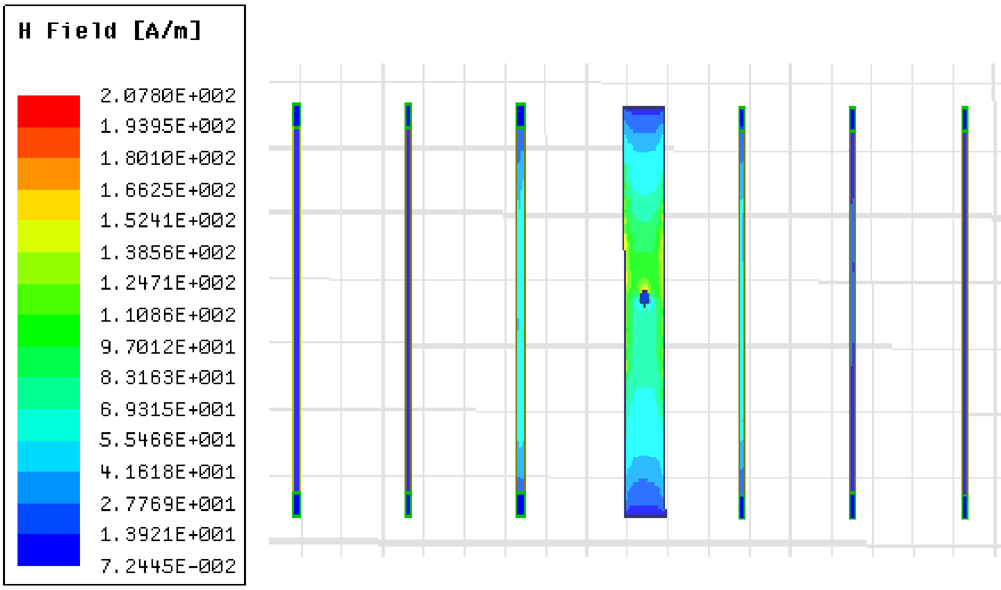
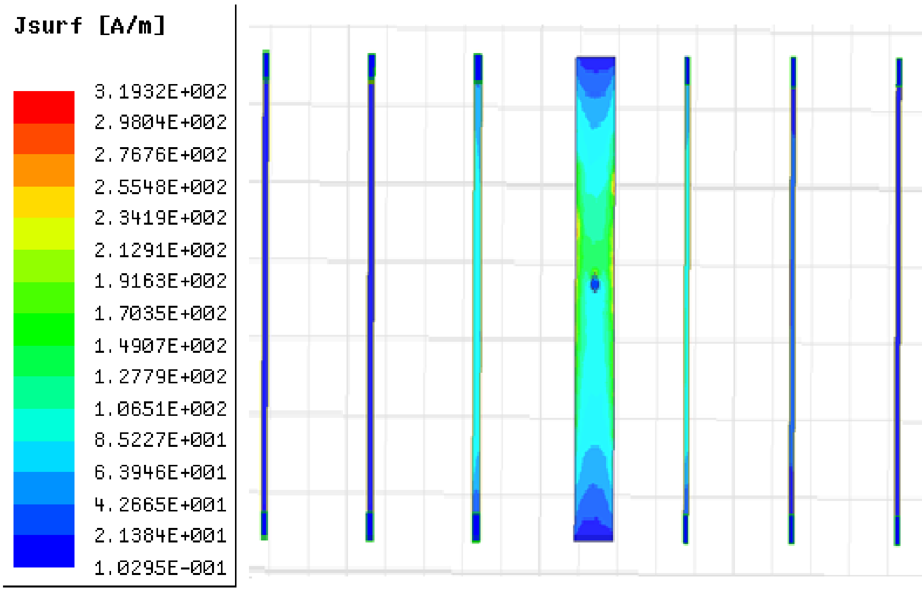
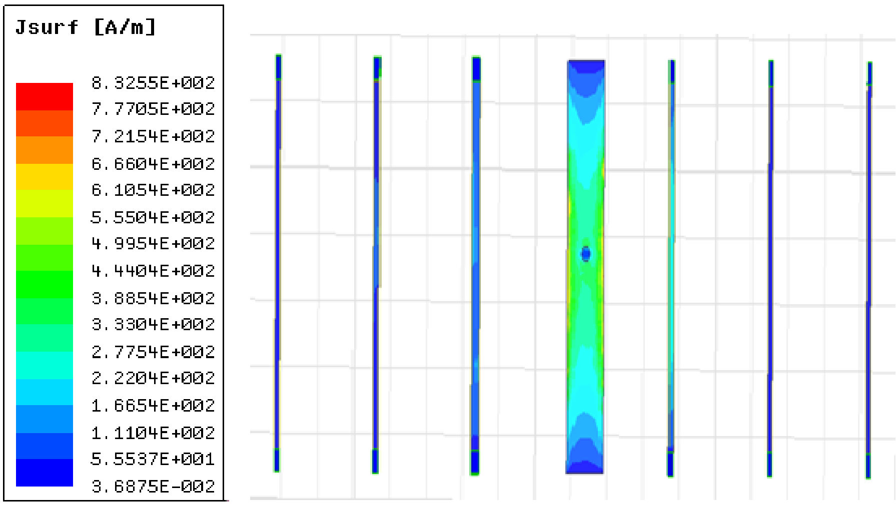


Fig. 6.17 Magnetic field distribution at an angle at ϕ=0°

Figure 6.18 shows the current distribution in the component of graphene-based Yagi-Uda antenna at (a) ϕ=0 degree and (b) ϕ= 90 degrees.



(a) ϕ=0°



(b) ϕ=90°

Fig. 6.18 Current density distribution of proposed design case-2 at (a) ϕ=0° degree and (b) ϕ=90°

6.2 Comparison between two proposed design case and with the simulation result

The two proposed design has been compared according to computed results of these two-graphene based Yagi-Uda antenna which are given in Figure 6.19, 6.20, 6.21 and 6.22. In the Proposed design 2, the graphene patches have been attached to both ends i.e. top and bottom of the reflector and director because Yagi-Uda antenna is normally made to have end-fire radiation so the direction of radiation should be along the single region which is called the unidirectional antenna. Due to this graphene patch, the radiation along the antenna will increase because side lobe and back lobe are also radiated along with the antenna. Graphene patch is not allowed to increase the radiation alongside lobe and back lobe. Now, rectangle metal strip patch is used in the proposed design case 1 which is not able to radiate along the axis of the antenna because it has some side lobe and back lobe. That's why the proposed design case 1 has some disadvantages as compared to the proposed design case 2. Design 2 gives a peak gain of 7.11 dB at a resonate frequency of 3.2 GHz while design 1 gives 6.73 dB at 5.7 GHz. That means design 2 has better gain and more radiation along with the antenna than design 1. The return loss of design 2 is -18.54 dB at 3.2 GHz while design 1 has -12.41 decibel at 5.7 Gigahertz. The proposed design case-2 has the bandwidth of 100 MHz which is more than design 1. The bandwidth of design 1 is 70 Megahertz Similarly, efficiency, VSWR, directivity and front to back ratio of design 2 has a far better result than design 1 for S-band application point of view. All the simulation results have been summarized in table 6.1. Both of the proposed antennas can be analyzed and compared from table 6.1.

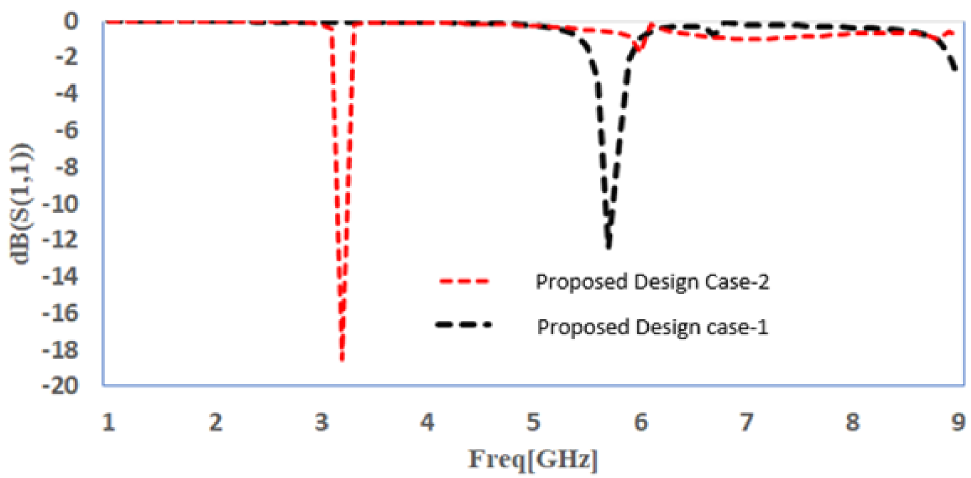


Fig. 6.19 Reflection coefficient

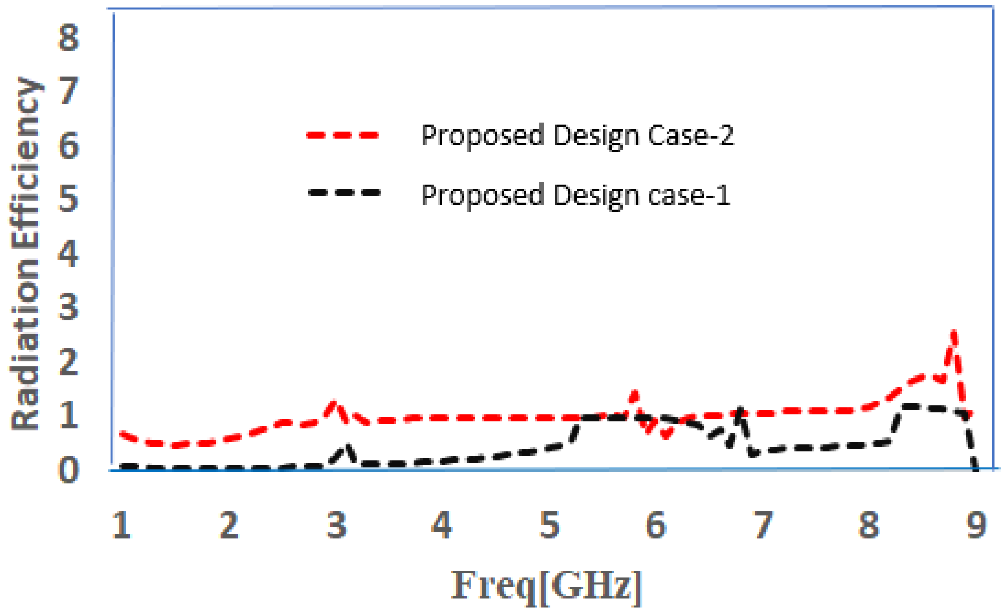


Fig. 6.20 Radiation efficiency,

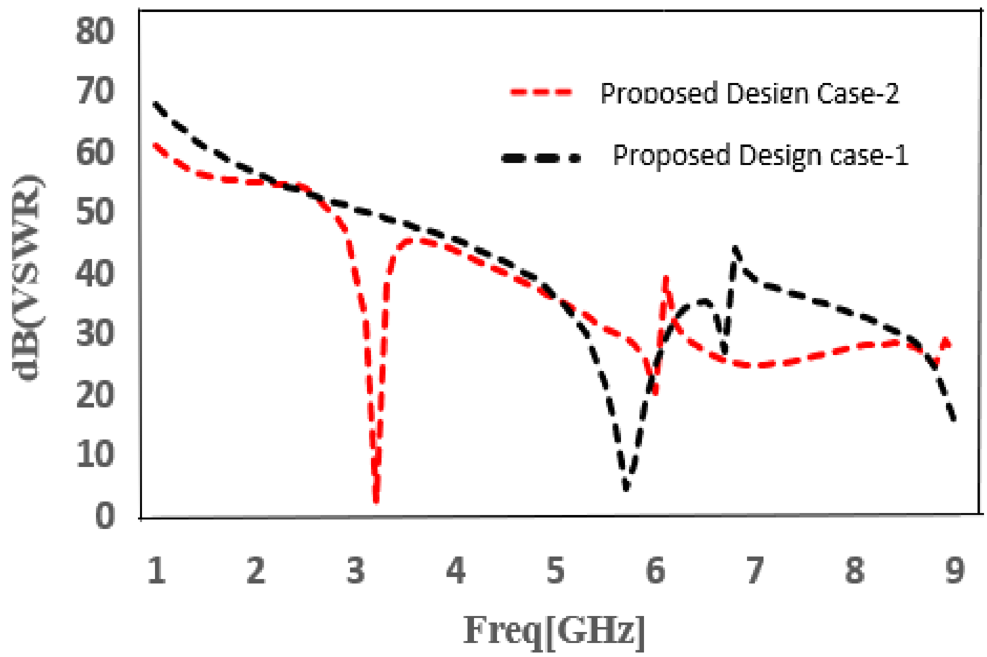


Fig. 6.21 VSWR

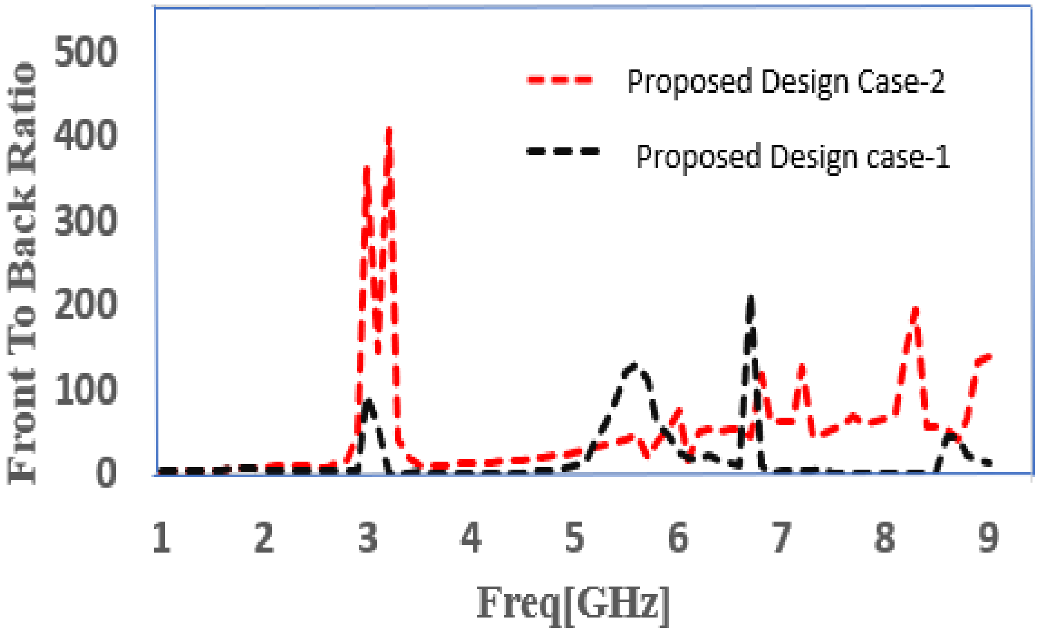


Fig. 6.22 Front to Back Ratio.

TABLE-6.1 COMPARISON OF PROPOSED DESIGN

Parameter	Propose design case-1	Propose design case-2
Centre Freq [GHz]	5.7 GHz	3.2 GHz
Return loss (S11(dB))	-12.41 dB	-18.54 dB
Bandwidth	70 MHz	100 MHz
Gain	6.73 dB	7.11 dB
Efficiency	0.98 (98 %)	1 (100 %)
VSWR	4.2	2.06
Directivity	6.8 dB	7.069 dB
Front to Back Ratio	111.63	407.63

6.3 Graphene-based Yagi-Uda antenna with improved characteristics

Compact Graphene-based Yagi-Uda antenna with graphene (proposed Prototype model) is better than without graphene in every parameter such as Gain etc. Graphene-based Yagi-Uda antenna has been designed at the center frequency of 6.6 GHz. Fig. 6.23 shows the frequency response of the simulated result S11 parameter. The return loss is -12.74 dB. In the frequency band 6.57 GHz to 6.62 GHz, S11<-10 dB.

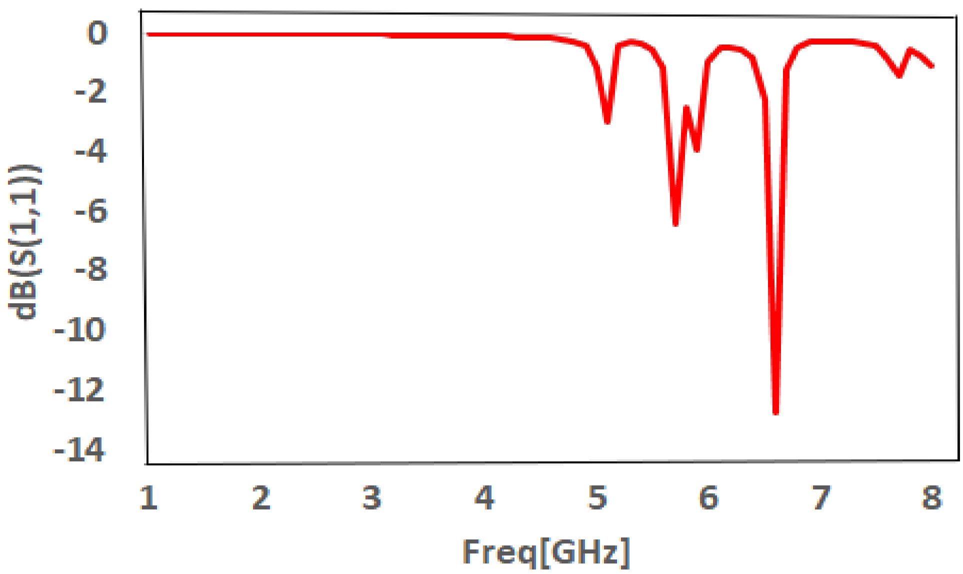


Fig. 6.23 simulation return loss (dB)

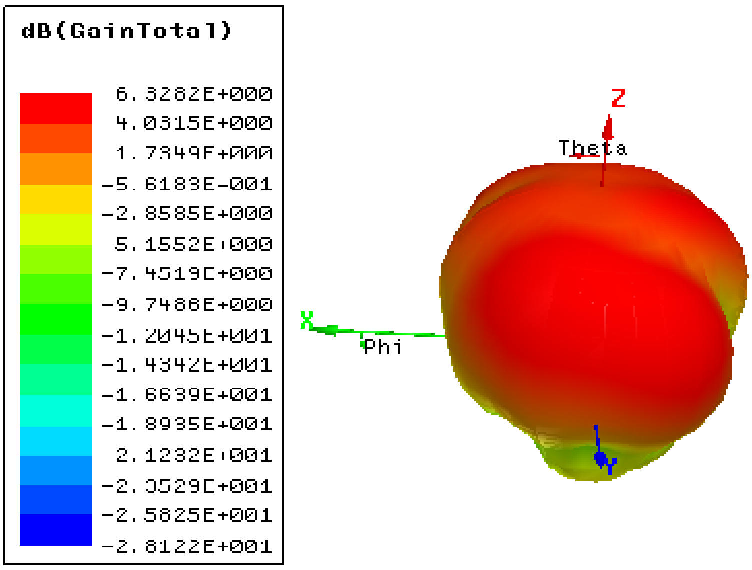


Fig. 6.24 3D polar gain

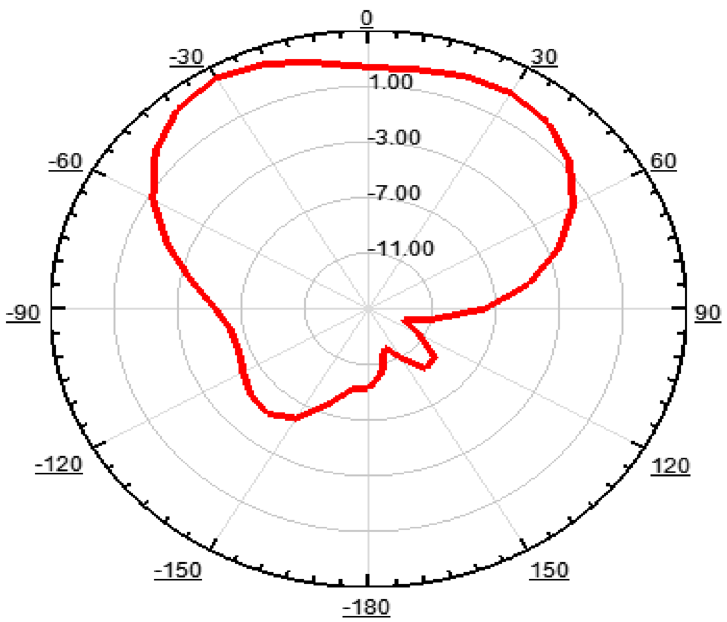


Fig. 6.25 2D radiation pattern

The 3-Dimensional realized gain at 6.6 GHz presented in figure 6.24 and 2-dimensional gain shown in figure 6.25 which are given in the above The total Gain of the graphene-based Yagi-Uda antenna is 6.32 dB.

Plot 6.26 Gives Radiation Efficiency. Total radiation efficiency is 99.82 % which is very superior for application point of view. It will totally convert radio frequency power to radiated power

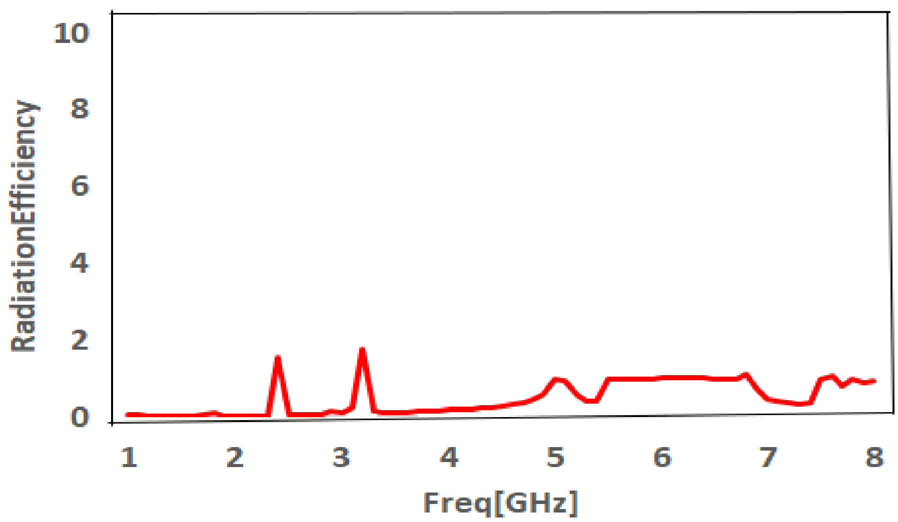


Fig. 6.26 Radiation Efficiency

Figure 6.27 shows the front to back ratio. Yagi-Uda antenna is normally made to have end-fire radiation so the direction of radiation is along unidirectional. The value of the front to back ratio is 15.33.

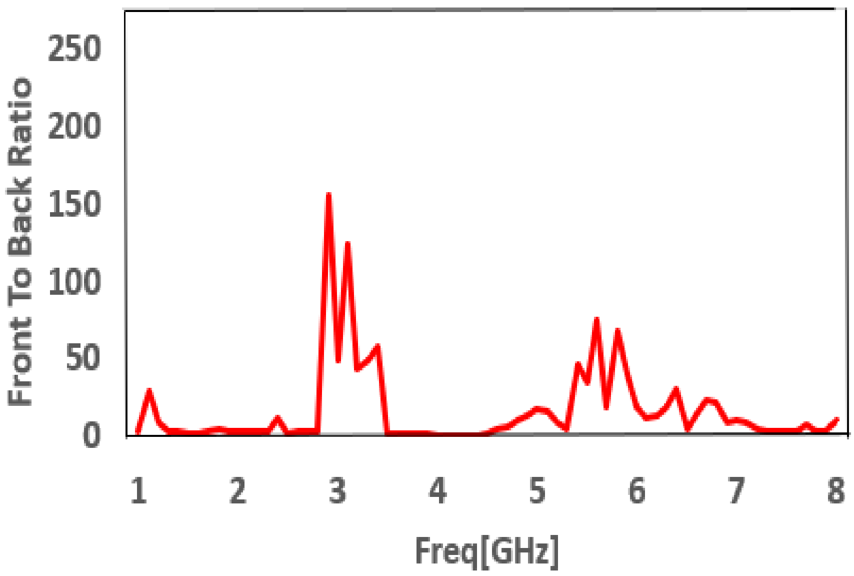


Fig. 6.27 Front to back ratio

Figure 6.28 shows the VSWR. The exact data of VSWR is 1.675 at 6.6 GigaHertz which is less than 2. If the value of VSWR is under 2 then it satisfactory for all antenna application because perfect match.

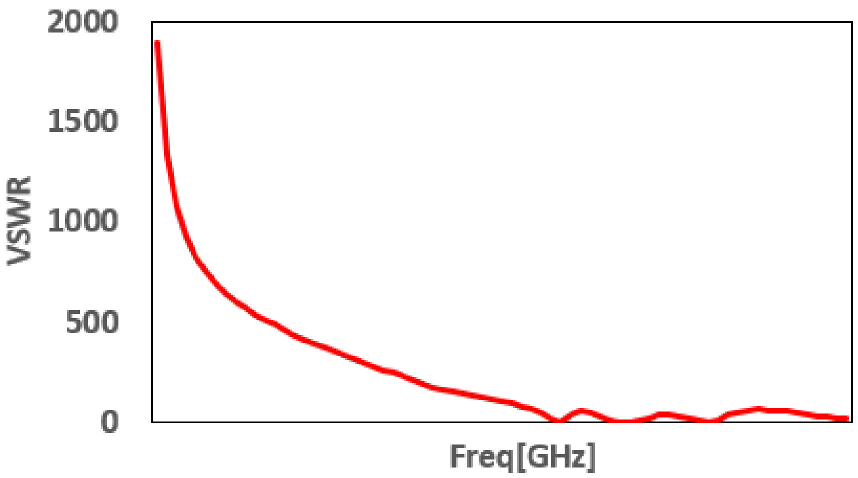


Fig. 6.28 VSWR

Figure 6.29, 6.30 and 6.31 shows the electric field distribution, magnetic field distribution, and current distribution in the graphene-based Yagi-Uda antenna at ϕ=0°.

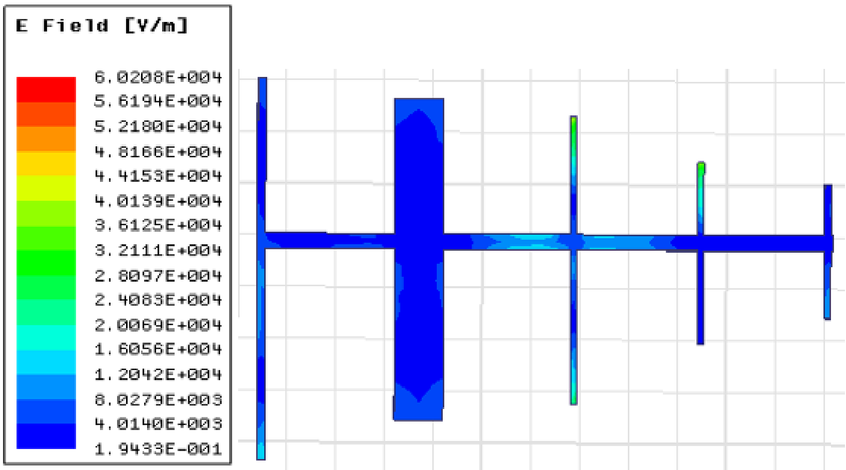


Fig. 6.29 Electric field Distribution at ϕ=0°

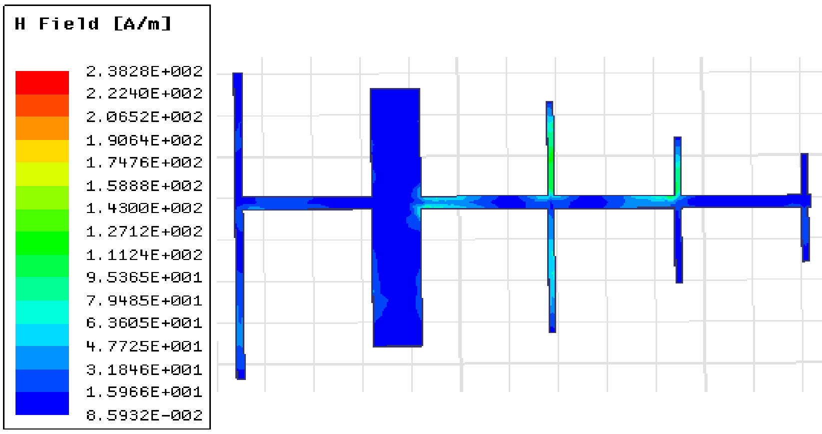


Fig. 6.30 Magnetic field distribution at ϕ=0°

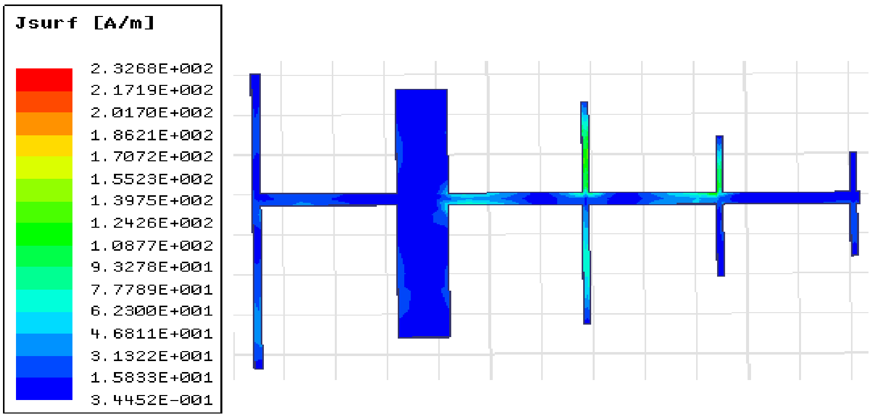


Fig. 6.31 Current density distribution at ϕ=0°

6.3.1 Comparison between proposed antenna and conventional antenna

TABLE-6.2 COMPARISION OF YAGI-UDA ANTENNA WITH OR WITHOUT GRAPHENE

Parameter	**With Graphene**	**Without graphene**
Resonant frequency [GHz]	6.6	5.7
Return loss (S11(dB))	-12.74	-7.7
Efficiency	0.9982 (99.82 %)	0.6844(68.44)
Gain	6.6	4.6
Front to Back Ratio	15.33	29.98
VSWR	1.675	1.82

6.4 Conclusion

The significance of this project was to design and Analysis of Graphen Based Yagi-Uda Antenna. From this project, we will get a new structure that supports a new application. Both antennae have been designed for different Application. Both have to work in Different Band, one of them working on S-Band and another one in C-Band.

For First Application, two complement case of graphene-based Yagi-Uda antenna has been designed based on the shape, size, and materials. Proposed design case 2 of graphene-based Yagi-Uda antenna has more gain, less S return loss in decibel, improved BW, higher Radiation Efficiency as compared to the proposed design case-1 of graphene-based Yagi-Uda antenna. The intention of this letter is to acquire a new structure that supports S-band applications like Loon LLC, Wi-max, etc.

In the second Application, the proposed graphene-based Yagi-Uda antenna has been designed. The reflector element is slightly larger than the driven element and all the element are connected to a single radiation box. After the simulation, it found that the Yagi-Uda antenna with graphene (proposed antenna) is better than without graphene in terms of every parameter such as Gain, etc. This structure can be applied in the application of radar, mobile communication, commercial wireless LAN.

6.5 Future Work

Every Research has some scope for development. In this thesis, many applications of Graphene-based Yagi-Uda antenna were discussed. But still, some portion will have to improve, for that required more research.

- Graphene material is very costly. Graphene cannot be used in any antenna due to costlier of graphene. So, in this area, we have to do more work to reduce the cost of graphene material so that we can use in any antenna without any hesitate.
- Our objective is to achieve a better performance of the antenna. For that human errors should be avoided during the Fabrication process. It has to be minimized. Hence, the fabrication field needs more Growth so that we get accurate results.
- Graphene-based Yagi-Uda antenna has low bandwidth and high gain. But our requirement is high in both cases. So, in this field, it can be a future scope so that we can get high gain and some range of bandwidth.
- Yagi-Uda antenna is not used in the modern era. But still, if we use any material like allotropes of carbon (Graphene, graphite ect.). Then it behaves like a Hybrid Yagi-Uda antenna which is very useful in modern application. So, our objective in the research is to find the application which supports Graphene-based Yagi-Uda antenna.

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