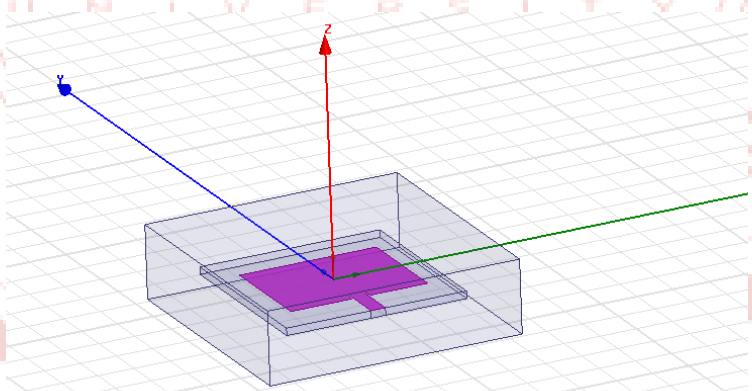
DELHI TECHNOLOGICAL UNIVERSITY

ELECTROMAGNETIC THEORY (EP 303)

PROJECT TOPIC : Antenna simulation



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INTRODUCTION

- In the field of communication systems, whenever the need for wireless communication arises, there occurs the necessity of an antenna. Antenna has the capability of sending or receiving the electromagnetic waves for the sake of communication, where you cannot expect to lay down a wiring system.

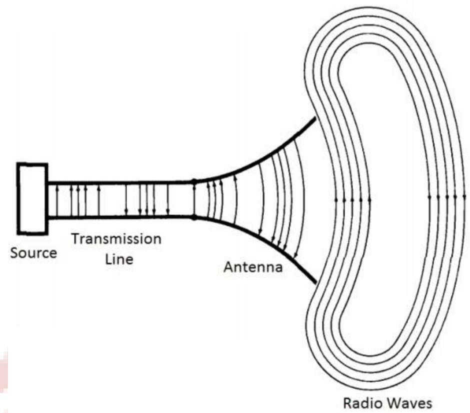
- An antenna is a device to transmit and/or receive electromagnetic waves.An antenna must be tuned (matched) to the same frequency band as the radio system to which it is connected, otherwise reception and/or transmission will be impaired.

- The half wave dipole is formed from a conducting element which is wire or metal tube which is an electrical half wavelength long. The half wave dipole is normally fed in the middle where the impedance falls to its lowest. In this way, the antenna consists of the feeder connected to two quarter wavelength elements in line with each other.

- Micro strip antenna is a printed circuit which consists of a very thin metallic strip placed on a ground plane with a dielectric material in-between.Microstrip antennas are relatively inexpensive to manufacture and design because of the simple 2-dimensional physical geometry. They are usually employed at UHF and higher frequencies because the size of the antenna is directly tied to the wavelength at the resonant frequency

Antenna: An Antenna is a structure affiliated with the region of transition between the "guided wave" and "free space", or we can say , An Antenna (sometimes called as an Aerial), is an electrical device that converts electric power into electromagnetic waves (or simply radio waves) and vice-versa.

A signal from a transmission line or the guiding device like a co-axial cable, is given to an antenna, which then converts the signal into electromagnetic energy to be transmitted through space.



Antenna can be used for both Transmission and Reception of electromagnetic radiation i.e. a Transmitting Antenna with collect electrical signals from a transmission line and converts them into radio waves whereas a Receiving Antenna does the exact opposite i.e. it accepts radio waves from the space and converts them to electrical signals and gives them to a transmission line.

Need of Antenna

In the field of communication systems, whenever the need for wireless communication arises, there occurs the necessity of an antenna. Antenna has the capability of sending or receiving the electromagnetic waves for the sake of communication, where you cannot expect to lay down a wiring system.

Radiation Mechanism

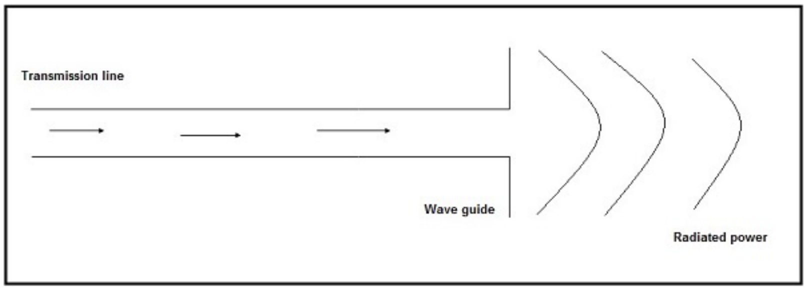
The sole functionality of an antenna is power radiation or reception. Antenna (whether it transmits or receives or does both) can be connected to the circuitry at the station through a transmission line. The functioning of an antenna depends upon the radiation mechanism of a transmission line.

A conductor, which is designed to carry current over large distances with minimum losses, is termed as a transmission line. For example, a wire, which is connected to an antenna. A transmission line conducting current with uniform velocity, and the line being a straight one with infinite extent, radiates no power.

For a transmission line, to become a waveguide or to radiate power, has to be processed as such.

- If the power has to be radiated, though the current conduction is with uniform velocity, the wire or transmission line should be bent, truncated or terminated.
- If this transmission line has current, which accelerates or decelerates with a timevarying constant, then it radiates the power even though the wire is straight.
- The device or tube, if bent or terminated to radiate energy, then it is called as waveguide. These are especially used for the microwave transmission or reception.

This can be well understood by observing the following diagram –



The above diagram represents a waveguide, which acts as an antenna. The power from the transmission line travels through the waveguide which has an aperture, to radiate the energy.

Different Types of Antennas

Some of the common types of antennas are mentioned below:

- Wire Antennas
  - Short Dipole Antenna
  - Dipole Antenna
  - Loop Antenna
  - Monopole Antenna

Log Periodic Antennas
  - Bow Tie Antennas
  - Log-Periodic Antennas
  - Log-Periodic Dipole Array

Aperture Antennas
  - Slot Antenna
  - Horn Antenna

Microstrip Antennas
  - Rectangular Microstrip Patch Antenna
  - Quarter-Wave Patch Antenna

Reflector Antennas
  - Flat-plate Reflector Antenna
  - Corner Reflector Antenna
  - Parabolic Reflector Antenna

Lens Antennas

Travelling-wave Antennas

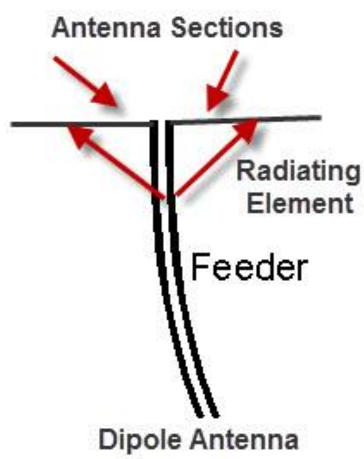
- Long Wire Antenna
- Yagi–Uda Antenna
- Helical Wire Antenna
- Spiral Antenna

Array Antennas

- Two-Element Array Antenna
- Linear Array Antenna
- Phased Array Antennas

Dipole antenna

The name 'di-pole' indicates that the dipole antenna consists of two poles or items – two conductive elements.



A dipole antenna is one of the most straightforward antenna alignments. This dipole antenna consists of two thin metal rods with a sinusoidal voltage difference between them. The length of the rods is chosen in such a way that they have quarter length of the wavelength at operational frequencies. These antennas are used in designing their own antennas or other antennas. They are very simple to construct and use.

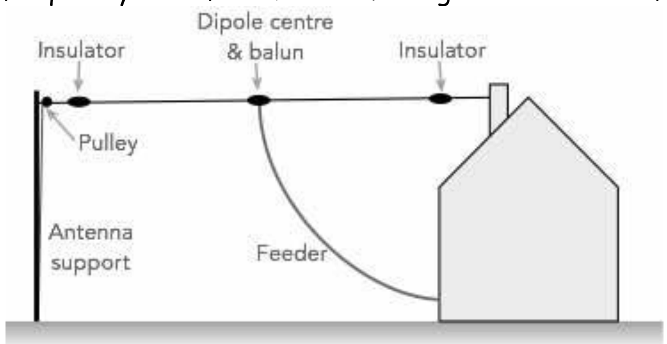
The dipole antenna consists of two metallic rods through which current and frequency flow. This current and voltage flow makes an electromagnetic wave and the radio signals get radiated. The antenna consists of a radiating element that splits the rods and make current flow through the center by using a feeder at the transmitter out that takes from the receiver.The different types of dipole antennas used as RF antennas include half wave, multiple, folded, non-resonant, and so on.

Dipole antenna applications

Dipole antennas are used in many areas, both on their own and as part of more complicated antennas where they can form the main radiating element. They are used in many forms of radio system from two way radio communications links, to broadcasting broadcast reception, general radio reception and very many more areas.

The dipole construction will depend upon the frequency, and also the way in which it will be used.

- ***HF wire dipole:*** The dipole was widely used as a wire antenna at MF and HF where its performance enabled signals to be transmitted and received on these frequencies. Even today the wire dipole is frequently used for HF transmitting as in the case of amateur radio etc



- ***Part of Yagi antenna:*** The dipole antenna forms the driven element within a Yagi antenna. Often a folded dipole is used because the 'parasitic' elements within the Yagi cause the dipole feed impedance to fall.
- ***As omni-directional vertical dipole:*** The dipole antenna is often used on its own as a vertically polarised antenna (in this case the dipole itself is vertical rather than the more usual horizontal format) to provide omnidirectional coverage.

- ***Driven element within a parabolic reflector:*** Parabolic reflector antennas need some form of driven element to radiate the antenna for the reflector to direct it in the required direction. Although a variety of radiating antenna types can be used, one option is the dipole antenna.
  These antennas are often used for satellite communications, radio astronomy as well as for radio communications links of various types. These parabolic reflector antennas are often seen on mobile phone antennas where they provide a radio communication link to the core network. Parabolic reflector antennas are also used for satellite TV reception.

The dipole antenna is a particularly important form of RF antenna which is very widely used for radio transmitting and receiving applications. The dipole is often used on its own as an RF antenna, but it also forms the essential element in many other types of RF antenna. As such it is the possibly the most important form of RF antenna.

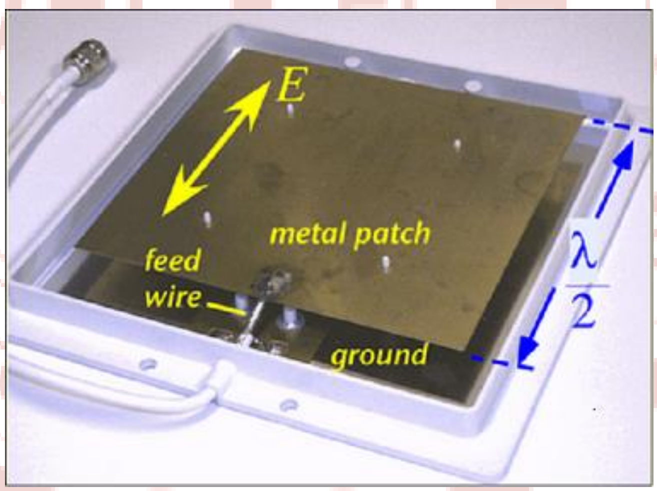
MICROSTRIP ANTENNA

Micro strip antennas are low-profile antennas. A metal patch mounted at a ground level with a di-electric material in-between constitutes a Micro strip or Patch Antenna. These are very low size antennas having low radiation.

The patch antennas are popular for low profile applications at frequencies above 100MHz

Construction & Working of Micro strip Antennas

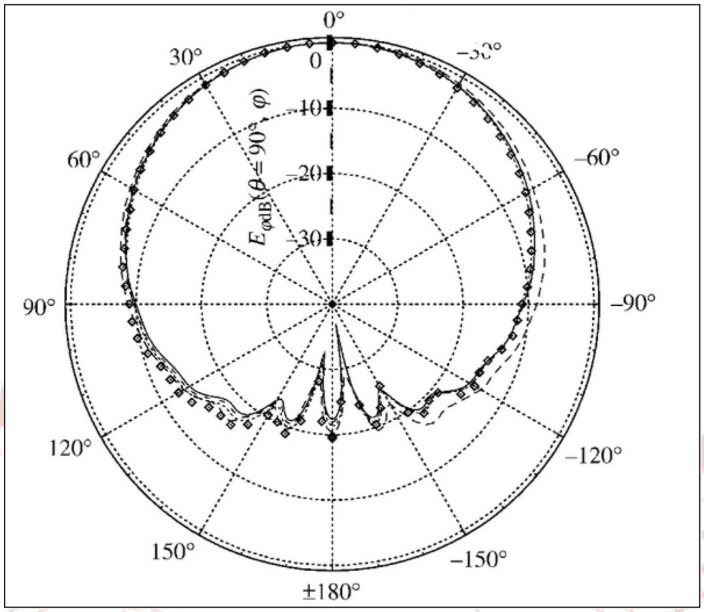
Micro strip antenna consists of a very thin metallic strip placed on a ground plane with a di-electric material in-between. The radiating element and feed lines are placed by the process of photo-etching on the di-electric material. Usually, the patch or micro-strip is choosen to be square, circular or rectangular in shape for the ease of analysis and fabrication. The following image shows a micro-strip or patch antenna.



The length of the metal patch is λ/2. When the antenna is excited, the waves generated within the di-electric undergo reflections and the energy is radiated from the edges of the metal patch, which is very low

Radiation Pattern

The radiation pattern of microstrip or patch antenna is broad. It has low radiation power and narrow frequency bandwidth.



The radiation pattern of a microstrip or patch antenna is shown above. It has lesser directivity. To have a greater directivity, an array can be formed by using these patch antennas.

<u>Advantages</u>

The following are the advantages of Micro strip antenna –

- Light weight
- Low cost
- Ease of installation

<u>Disadvantages</u>

The following are the disadvantages of Micro strip antenna –

- Inefficient radiation
- Narrow frequency bandwidth

<u>Applications</u>

The following are the applications of Micro strip antenna –

- Used in Space craft applications
- Used in Air craft applications
- Used in Low profile antenna applications

SOFTWARE DESCRIPTION

We simulated the antenna for the required applications using **ANSYS HFSS.**

Ansys HFSS is a 3D electromagnetic (EM) simulation software for designing and simulating high-frequency electronic products such as antennas, antenna arrays, RF or microwave components, high-speed interconnects, filters, connectors, IC packages and printed circuit boards. Engineers worldwide use Ansys HFSS to design high-frequency, high-speed electronics found in communications systems, radar systems, advanced driver assistance systems (ADAS), satellites, internet-of-things (IoT) products and other high-speed RF and digital devices.

HFSS stands for high frequency structure simulator and is finite element method solver for electromagnetic structure.

The finite element method is a tool for computing approximate solutions to complex mathematical problems. It is generally used when mathematical equations are too complicated to be solved in the normal way, and some degree of error is tolerable. The finite element method can be adapted to varying requirements for accuracy and can reduce the need for physical prototypes in the design process."

The basic concept of FEM can be thought of as splitting the computational domain into individual small patches and finding local solutions that satisfy the differential equation within the boundary of this patch. By stitching the individual solutions on these patches back together, a global solution can be obtained.
The finite element used by hfss are tetrahedra and entire collection of tetrahedral is called mesh. Solution is found for the fields within the finite element and these fields are interrelated so that Maxwell's equations are satisfied across inter-element edges , yielding a field solution for the entire original structure. Once the field solution has found the s matrix solution is determined.

SIMULATIONS

SIMULATION 1

We constructed a half wave **dipole antenna** at 1 GHz frequency with a frequency sweep between 0.8 GHz and 1.2 GHz .

Since the resonant frequency is 1 GHz the wavelength is given by

$$c = \lambda \nu$$

where c is speed of light and v is frequency.

Thus wavelength= $2.998*10^{\wedge 8}$ / $1*10^{\wedge 9}$ m

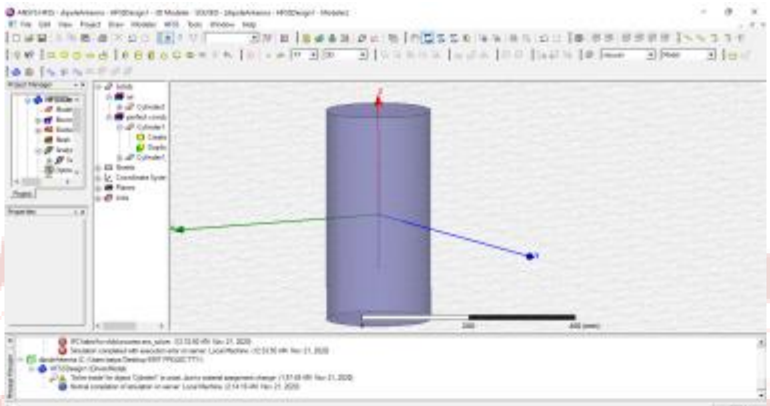
Wavelength= 299.8 mm =300 mm(approx)

Thus total length of the half wave dipole antenna is 150 mm .This makes each wire of the Dipole 75 mm.

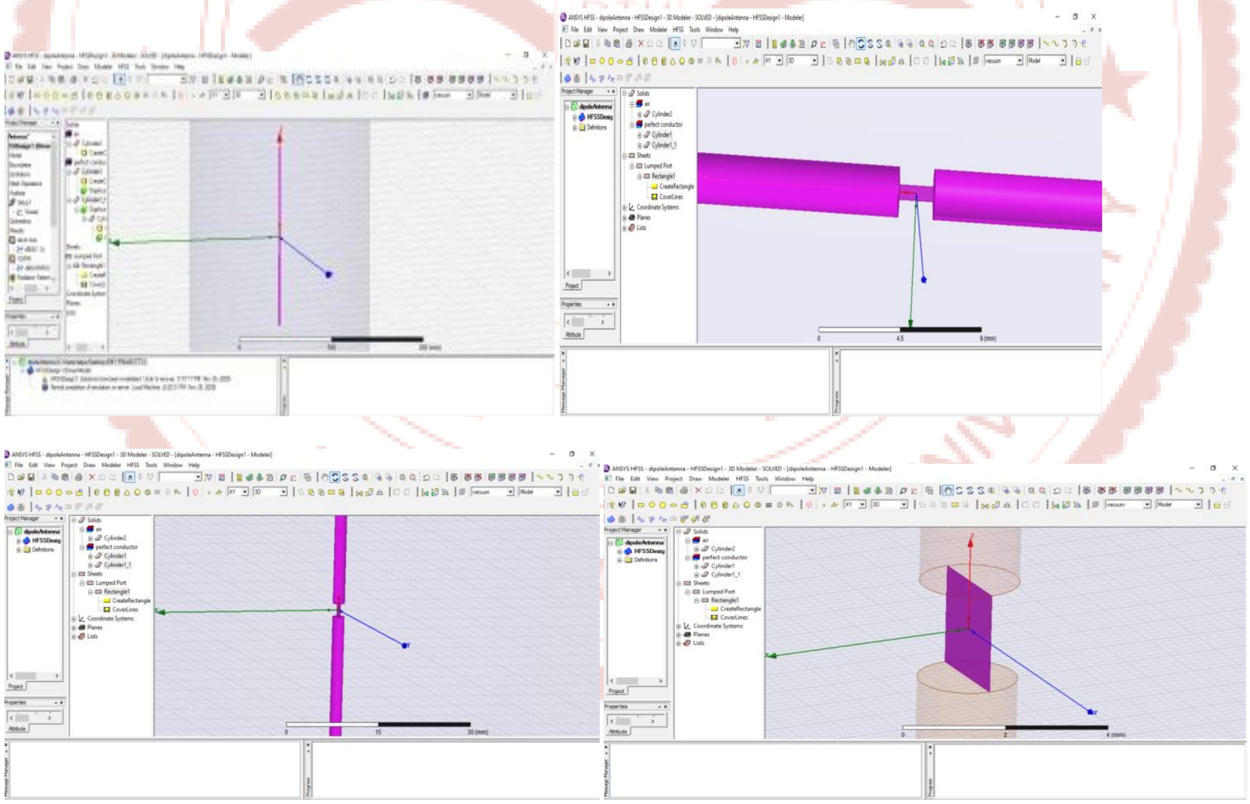
There is a 2mm gap between the two antennas to attach the excitation port to connect the two antenna to each other and to the feed line.

The dielectric used in the outer cylinder covering the antenna is air and the antenna is aligned along the z axis.

Antenna Design



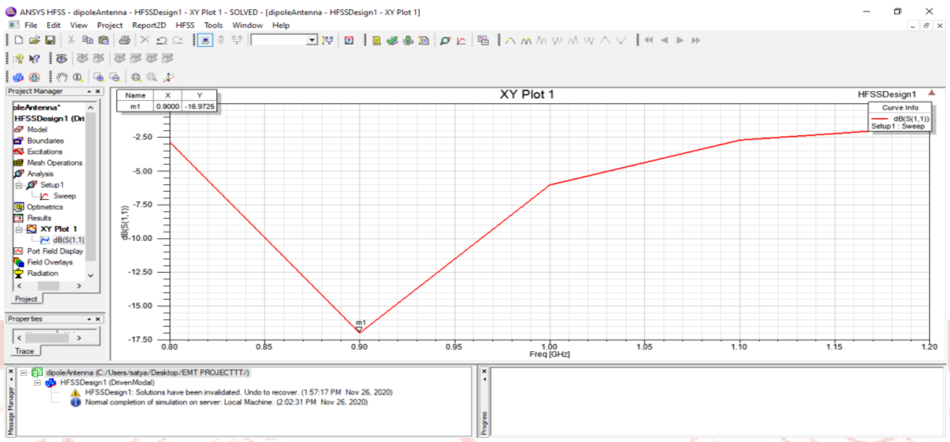
This picture depicts the whole antenna aligned along the z direction with the antenna inside the outer cylinder(represented by blue)



The antenna is represented by the pink cylinders and the excitation port by the pink rectangle.

Graphs

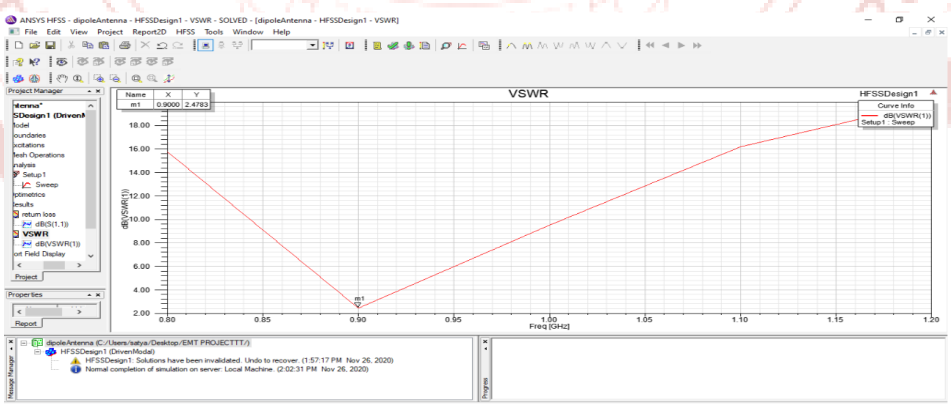
- Return loss Graph (S_{11})



The return loss is measure of the reflection coefficient of the antenna . If the value of return loss is 0 dB then antenna reflects back all the power and transmits nothing. Lower the value of the return loss(more negative) , higher will be the power transmitted by the antenna.

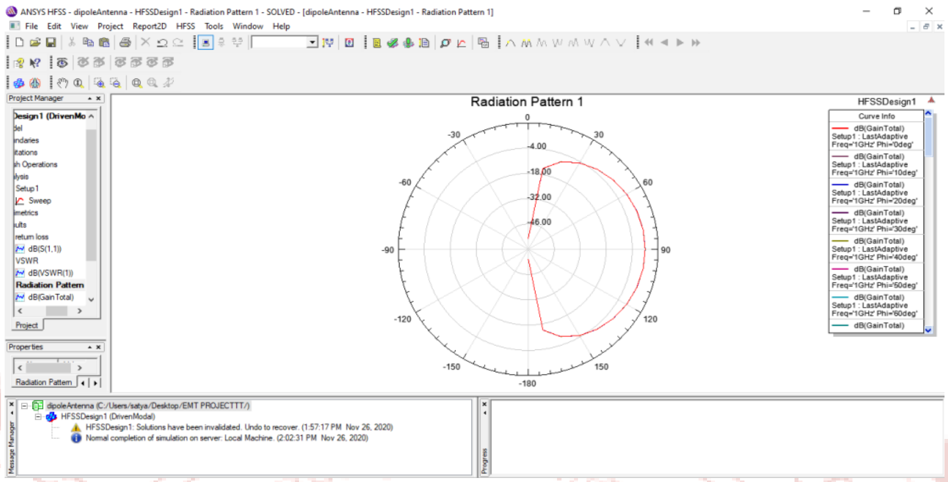
The return loss in this case was found to be at its lowest at 0.90 GHz (0.1 GHz lower than resonant frequency).This may be assigned to the different losses in the antenna or signaling that the antenna may be off resonance .

- VSWR plot



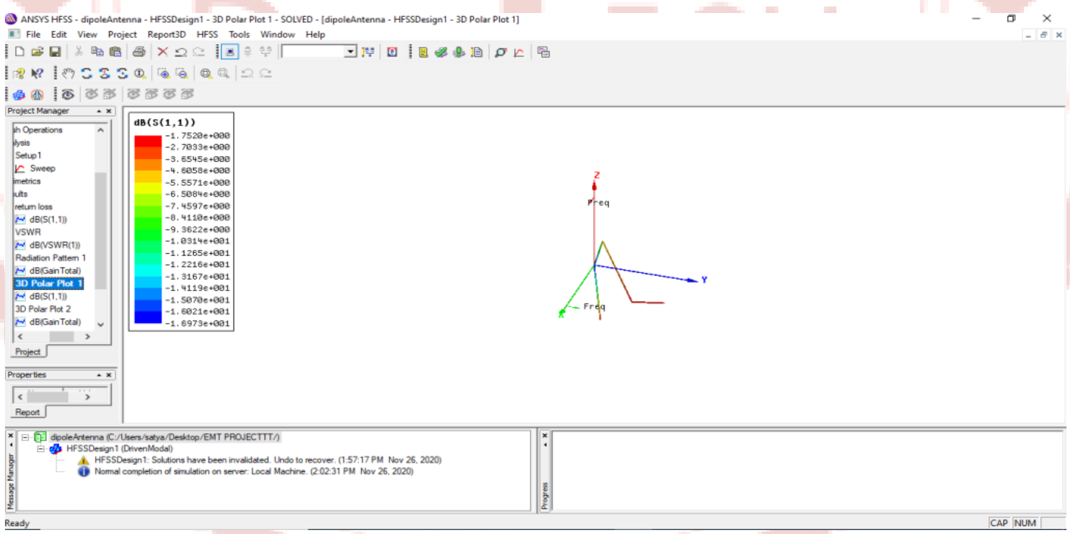
The VSWR plot is also at its lowest at 0.9 GHz as the return loss of the antenna is lowest at that point

• Radiation Pattern



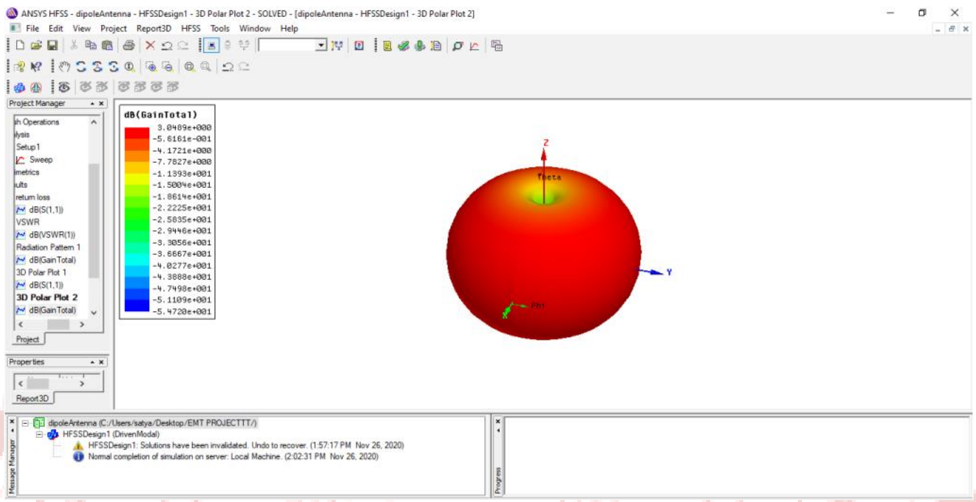
In the radiation pattern diagram we can see that the radiation is maximum perpendicular to the wire axis and minimum across the ends (although not zero here). The radiation is also found to only along one side of the antenna (which should be ideally omni-directional along the perpendicular plane)

• 3-D radiation



The 3-D radiation pattern is depicted to be only along a single side with its highest and lowest points and different values of the return losses depicted by different colours along different directions.

- 3-D Gain plot



The 3-D gain plot is omni-directional with the gain values depicting by different colours mentioned . The gain is found to be negative in middle signaling that the radiated power is less than the average value in the middle

Conclusion

After analyzing all the graphs it may be deduced that the antenna is working on a different resonant frequency than the value fed in the simulator. Although at the fed in frequency the antenna is working good but it is experiencing higher return loss than expected value.This may suggest that the antenna is off resonance due to some internal losses and effects(like end effect).

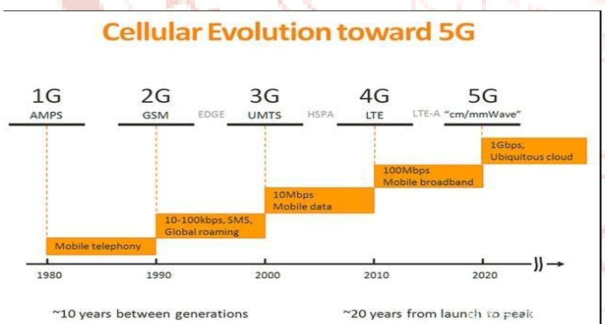
Simulation 2

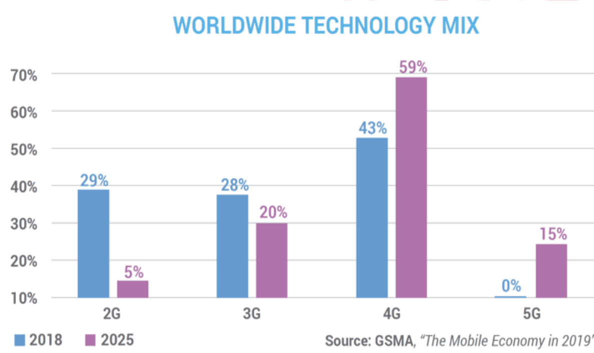
In this simulation we tried to design a **microstrip patch antenna for 5G** communication system.

Introduction to topic

In the past few years mobile wireless communication has experienced various generations from 0G to 4G technology. The 4G wireless communication systems has already been deployed in almost all countries. However 4G still cannot accommodate some challenges like spectrum crisis, high energy consumption, poor coverage, bad interconnectivity, poor Quality of Service (QoS) and flexibility . To address all these demands 5G wireless system are expected to be deployed in the future by 2020.To fulfill all the needs of fifth generation (5G) wireless system to facilitate higher data rate, better reliability, more connectivity, lower latency and improved security features wireless system designers need a new concept and design approach.

The millimeter wave (mm-wave) frequencies are likely to use by 5G.Millimeter wave radio frequency can provide the basic ground for the new Generation (5G).Millimeter wave have unexploited spectrum (3GHz-300GHz) to fulfill the new generation needs. The spectrum of 5G application is 20-90GHz.. 5G antennas are designed at frequencies 28Ghz, 38GHz, 72GHz having bandwidths of 500 MHz, 1 GHz, and 2 GHz as they are all suitable for high data rate and low latency system .They are highly directional and obstacle sensitive due to narrow beam width they can be used for cellular applications





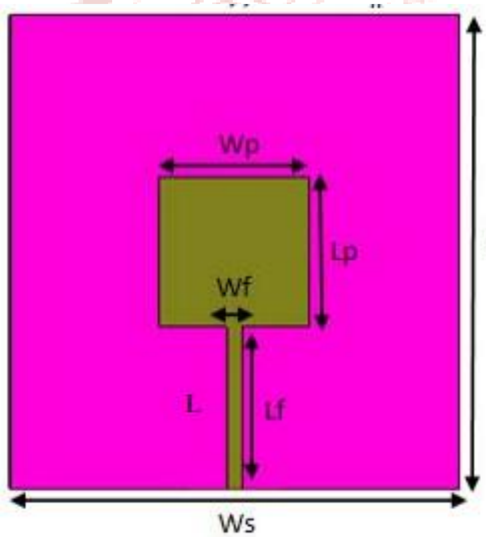
Since there is a huge rise in 5G consumers by 2025 thus a suitable antenna need to be designed to cater to the needs .

Antenna Design

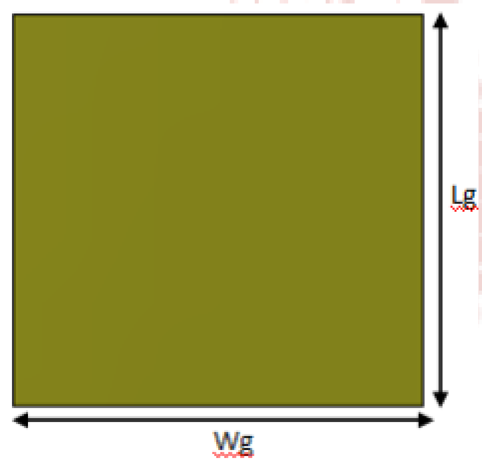
The frequency selected is 28 GHz with a frequency sweep between 10 and 40 GHz.

Micro strip patch antenna with substrate dimension of Ls×Ws with fr-4 epoxy material having dielectric constant of 4.40, loss Tangent of 0.02. Height of substrate is o Dimensions used for substrate is 5mm×6mm. The dimensions used for ground is same as the substrate 5mm×6mm. M-line feed is used to design proposed micro strip patch antenna. The width of the feed is Wf (0.3mm) and length Lf (2.2mm). The selected dimensions (Lp×Wp) for the radiating patch are (2.33 mm× 3.26 mm). Many Substrates are available but we have used fr-4 epoxy cause it is cost effective along with low dielectric constant. It has low moisture absorption and is easy to manufacture and widely available.

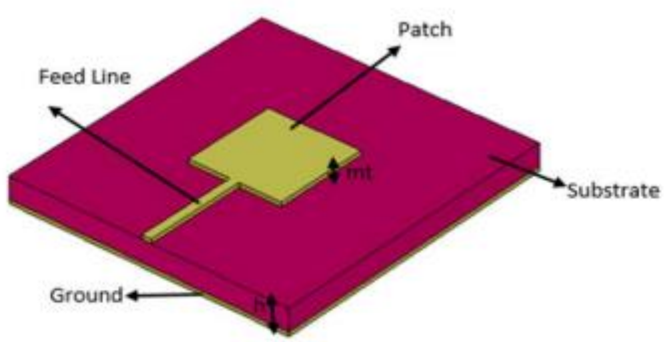
A different dielectric substance ROGER 5880 is also used in another version at similar frequency to determine which of these two is more efficient for mm wave transmission.

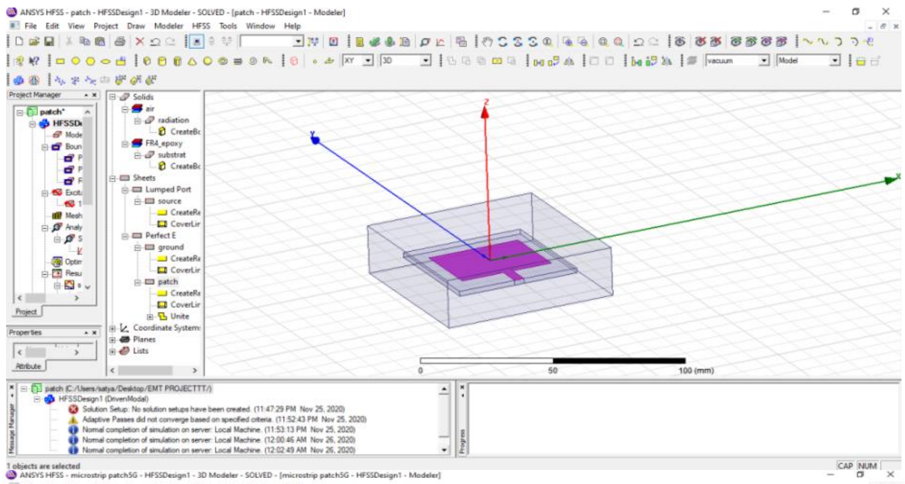


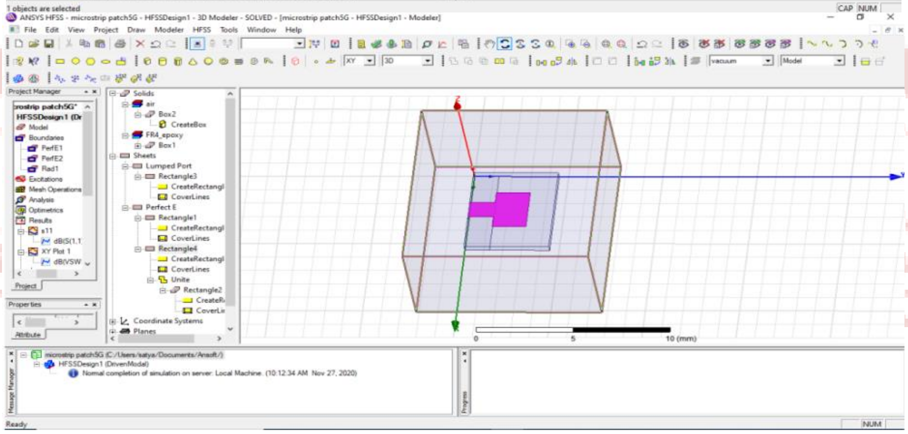
top view of antenna

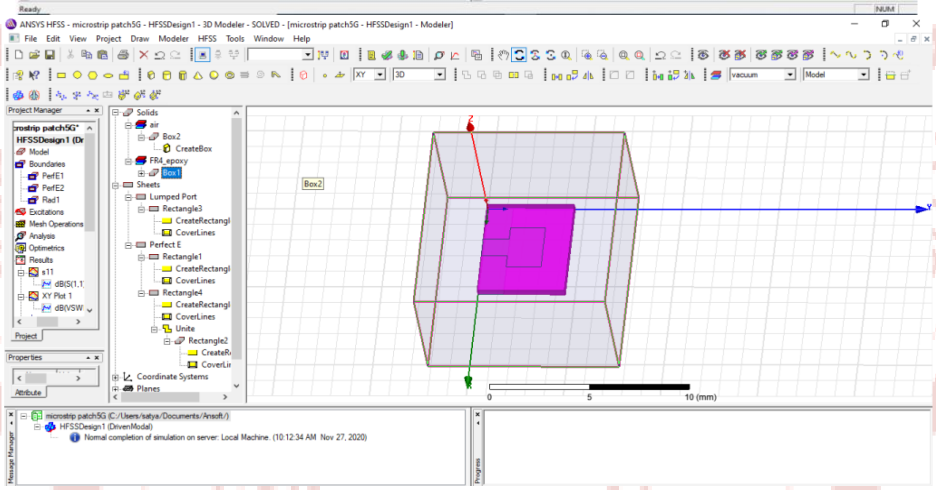


bottom view of the ground





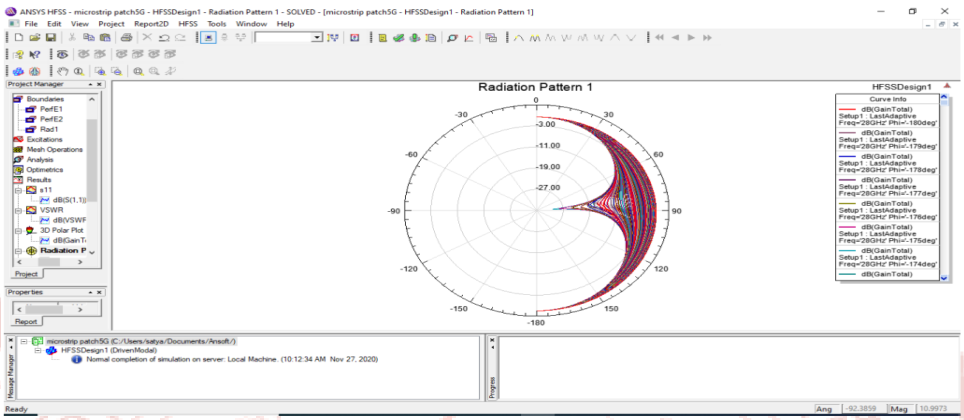




Parameters	Description	Value (mm)
Ls	Length of Substrate	5
Ws	Width of Substrate	6
H	Height of Substrate	0.508
Lp	Length of Patch	2.33
Wp	Width of Patch	3.26
Mt	Height of Patch	0.035
Wf	Width of Feed line	0.3
Lf	Length of Feed line	2.2
Wg	Width of Ground	6
Lg	Length of Ground	5

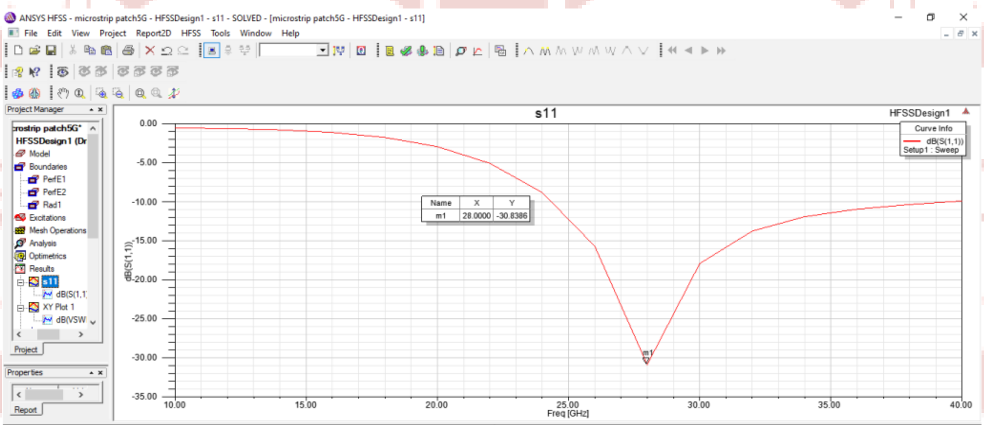
Graphs

- Radiation Pattern(2-D)



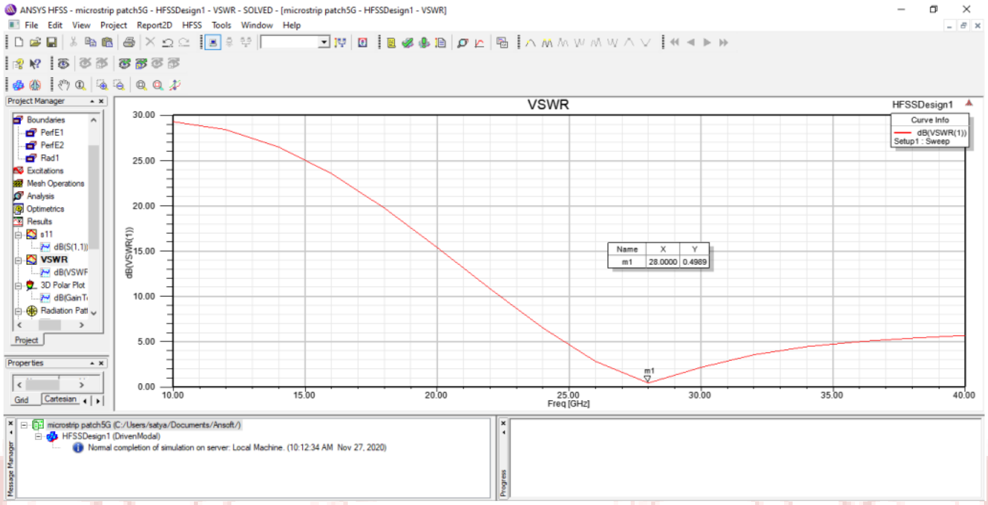
The radiation intensity graph is on expected lines of being quite broad and of narrow bandwidth

- Return loss Graph



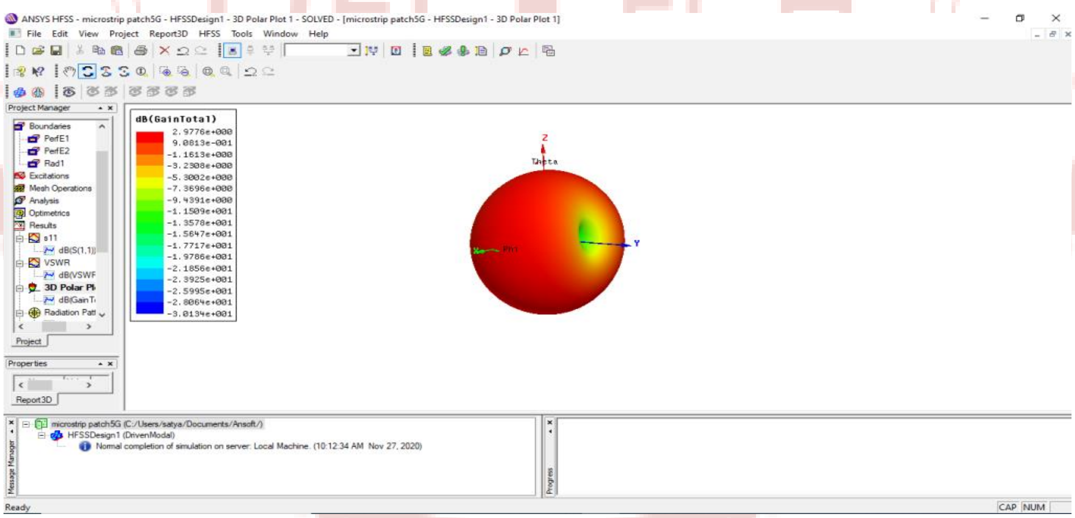
In this graph which depicts the return loss we can infer that the antenna function perfectly for the given resonant frequency (28 GHz) but has a narrow band in which the return loss is of appreciably low value. This proves that a patch antenna has a narrow bandwidth over which it can function smoothly.

• VSWR plot



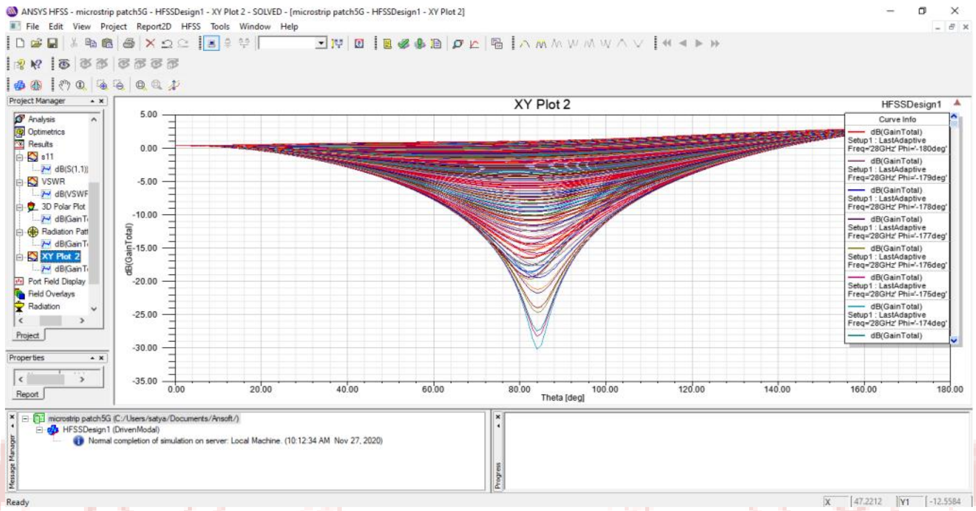
The VSWR plot depicts how efficient this antenna is at 28 GHz with its VSWR ratio being nearly zero and of quite low values between 20 and 40 GHz.

• 3-D Polar Gain Plot



Antenna is of best possible gain that can acquired by a single patch antenna. The gain plot is along the Y axis which is the axis of the feed line and is quite good in ZY plane implying it is great for mobile communications.

- 2-D Gain Plot



This graph depicts the gain values for 2-d plane (XY plane)

When the substrate was changed to ROGER 5880 and antenna size configured to that , it was found that the antenna performed with lower return losses and near – perfect VSWR . All the other parameters Analyzed were also improved with the new material for substrate.

This may be because fr-4 dielectric constant is frequency dependent(high with high frequency) and it can't support frequencies above 10 GHz quite appreciably whereas in case of ROGER 5880 it is designed for mm waves , has no moisture absorption and water retention and has quite low dielectric constant(2.2)

Conclusion

It was found that the designed antenna support mm waves very well for a resonant frequency of 28 GHz and can be effectively used for 5G mobile applications. It was also observed that ROGER 5880 is a better material for substrate than fr-4 epoxy for the above mentioned antenna because of its ability to transmit mm waves more effectively.

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The above project is made using help taken from the following mentioned sources

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