Term Paper Report
On
Performance Analysis of Microstrip Patch Antenna For Ultra Wide Band Application.

Submitted to partial fulfillment of the Requirements for the award of the degree Of

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IN
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EAST WEST UNIVERSITY
DHAKA, BANGLADESH

Declaration

It is hereby declared that this thesis or any part of it has not been submitted elsewhere for the award of any degree or diploma.

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Approval

The project report entitled " Performance Analysis of Microstrip Patch Antenna using HFSS" submitted by Syeda Sanjida Afrin, ID: 2011-3-55-026 & Pinky Rani Dev, ID: 2011-3-55-002 to the Department of Electronics & Communication Engineering, East West University, has been accepted as satisfactory for the partial fulfillment of the requirements for the degree of Bachelor of science in Electronics and Communication Engineering and approved as to its style and contents.

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We extend our gratitude to *EAST WEST UNIVERSITY* for giving us this opportunity.

We also acknowledge with a deep sense of reverence, our gratitude towards our parents, who have supported us morally as well as economically.

At last but not the least gratitude goes to all of our friends who directly or indirectly helped us to complete this thesis report.

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SYEDA SANJIDA AFRIN
PINKY RANI DEV

ABSTRACT

In this Thesis paper we propose the antenna geometry to design a very compact microstrip patch antenna for ultra-wide band application using thin dielectric substrate having low dielectric constant. This antenna provides better efficiency, better band-width without any enhancement in the weight, volume or cost. HFSS high frequency simulator is employed to analyze the proposed antenna and simulated results on return loss, gain, radiation pattern is presented. The antenna parameter in frequency domain analysis has been investigated to show its capability as an effective radiating element. Our new shape of antenna which is D over D shape can operate at 4.78-8.48 GHZ frequency range. Due to low-profile structure it can be used in the WLAN (wireless local area network), Router, WI-FI, Modem and other wireless application using this frequency range.

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Chapter one
Introduction To Microstrip (Patch) Antenna

1.1 Introduction

This chapter basically introduces the normal concepts of patch antennas. We use a simple rectangular, half wave long, probe-fed patch operating in its fundamental mode as an example.

Topics include principles of operation, impedance matching, radiation patterns, circular polarization, bandwidth, efficiency, alternative feed types, stacked patches and higher mode behavior.

1.2 Patch Antenna:

Modern wireless communication systems and increasing of other wireless applications require low cost and high performance multiband antennas. The demand for high performance multi standard communication system has led the antenna research and studies in various directions. One of them the design of the multiband microstrip(patch) antennas.

Microstrip or patch antennas are becoming increasingly useful because they can be printed directly onto a circuit board. Microstrip (patch) antennas are becoming very widespread within the mobile phone market. Patch antennas have become quite popular due to their low cost; have a low profile design and ease of manufacturing.
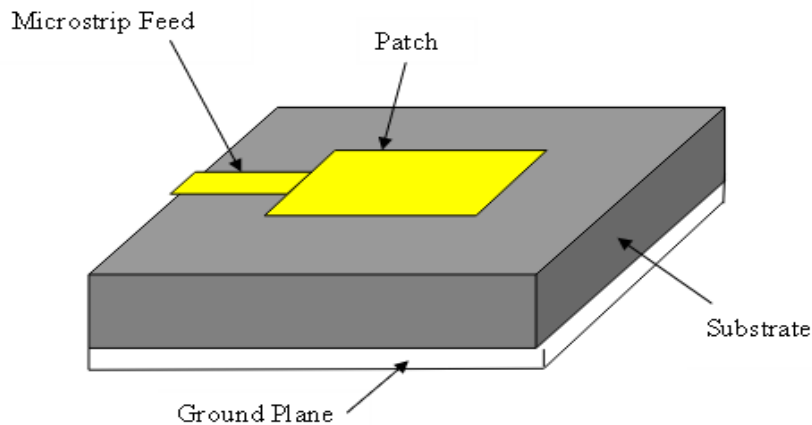
Fig 1.1: view of Patch Antenna

1.3 History of Microstrip Antenna

The microstrip antenna was first proposed by G.A. Deschamps in 1953, but didn't become practical until the 1970s when it was developed further by researchers such as Robert E. Munson and others using low-loss soft substrate materials that were just becoming available.

1.4 Motivation for this study

The size of a microstrip antenna is inversely proportional to its frequency. At frequencies lower than microwave, microstrip patches don't make sense because of the sizes required. At X-band a microstrip antenna is on the order of 1 centimeter long (easy to realize on soft-board technology). If you wanted to make a microstrip antenna to receive FM radio at 100 MHz it would be on the order of 1 meter long (which is a very large circuit for any type of substrate) For AM radio at 1000 KHz, the microstrip patch would be the size of a football field, basically impractical. One everyday application where microstrip patches are used is in satellite radio receivers. Here the antenna is often mounted in a vehicle, where the angle in the X-Y plane relative to the satellite is not fixed (like it is for the satellite television dish mounted to your house.) Thus circular polarization is employed for satellite radio, and the angle that the patch is with respect to the satellite doesn't matter.

Chapter 2

Basic Architecture of Patch Antenna

2.1 Antenna Architecture

The following drawing show a patch antenna in its basic form: a flat plate over ground plane shown in figure 2.1
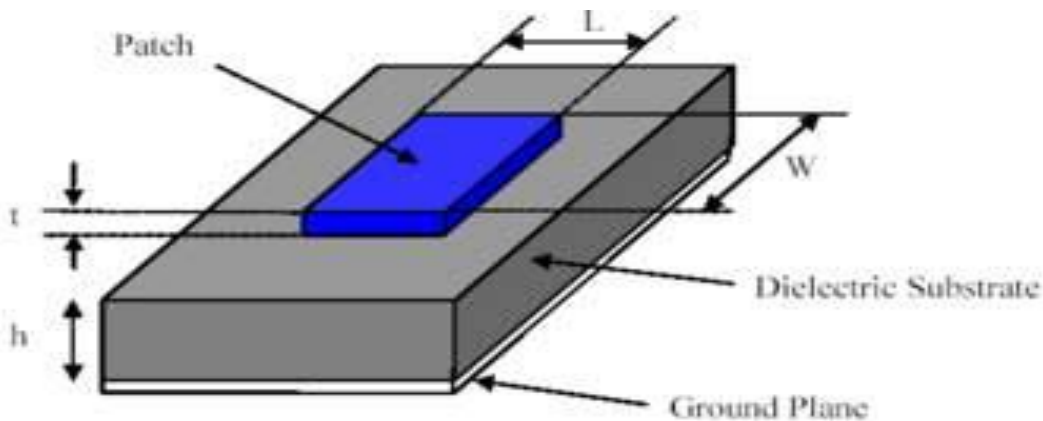
Fig 2.1: structure of microstrip antenna.

Consider the microstrip antenna shown in figure 2.1,the patch and the ground plane are made of high conductivity metal(typically copper).The patch is of length L, width W and on the top if a substrate(some dielectric circuit board) of thickness h with permittivity. The thickness of the ground plane or of the microstrip is not critically important. Typically the height h is much smaller than the wavelength of operation but should not be much smaller than 0.025 of a wavelength for an efficient antenna. And the feed line is used to feed the patch.

2 .2 Antenna Geometry

The radiating micro strip antenna can be Dipole or can be square, circular, elliptical, dipole, triangle or rectangular etc. Rectangular and circular microstrip patch antennas are most widely used antenna in wireless communication.

Different Shapes of
Micro strip Antenna
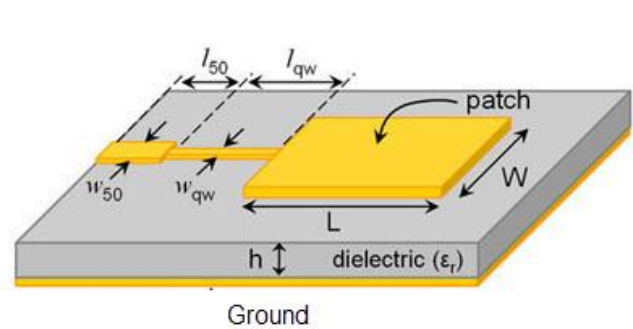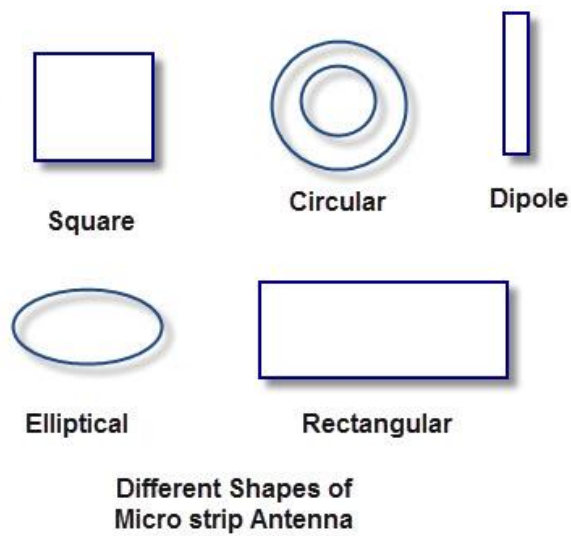
Rectangular Microstrip
Antenna

2.3 Dimensions

The resonant length determines the resonance frequency and is about $\lambda_d/2$ for a rectangular patch excited in its fundamental mode where λ_d is the wavelength in the PCB material. The patch is actually a bit larger electrically than its physical dimensions due to the fringing fields and the difference between electrical and physical size is mainly dependent on the PC board thickness and dielectric constant of the substrate.

A good approximation for the resonant length is:

$L \approx 0.49$

$\lambda_d = 0.49\ \lambda 0/\sqrt{\epsilon_r}$

This formula includes a first order correction for the edge extension due to the fringing fields with:

- L = resonant length
- λ_d = wavelength in PC board
- λ_0 = wavelength in free space
- ϵ_r = dielectric constant of the printed circuit board material

Other parameters that have less influence on the resonant frequency include:

- Ground plane size
- Metal (copper) and dielectric thickness
- Patch (impedance) width.

2.4 Advantages and Disadvantages

Advantages of micro strip antennas include:

- ➢ Low cost to fabricate
- ➢ Conformal structures are possible(it's easy to form curved surfaces as long as the curve is in one direction only)
- ➢ Light weight
- ➢ Supports linear and circular polarization
- ➢ Low volume
- ➢ The unique property of micro strip antenna is its two dimensional structure
- ➢ Easy to manufacture
- ➢ The effective wavelengths are much smaller.

Disadvantages include:

- ➢ Limited bandwidth(usually 1to 5% but much more is possible with increased complexity
- ➢ Low power handling
- ➢ Low frequency
- ➢ Small polarization
- ➢ Poor gain

Chapter 3
Analysis of feeding methods

Different feeding techniques of micro strip patch antennas with different spiral defected ground structures are presented in this chapter. In the analysis of the impact of feeding on the parameters of the antennas will be considered work bandwidth antennas, impedance matching and shape of the radiation pattern. We try sought a solution that will give the wideband of work while maintaining a directional radiation patterns. The most popular types are micro strip line feed, coaxial feed, aperture coupled, proximity coupled, probe feed patch and so on. A number of feed mechanisms have been developed for micro-strip antennas. Most often it is the feed mechanism that determines the complexity of the antenna design. Popular feed techniques can be classified into four broad categories are as follows.

3.1 Micro strip feed line

This method of feeding is very widely used because it is very simple to design and analyze and very easy to manufacture. Figure-3.1 shows a patch with microstrip line feed from the side of the patch. It is widely used in both one patch antenna and multi-patches (array) antennas. Micro strip feed line is a conducting strip and it is directly connected to the edge of the micro strip patch. The advantage of this structure is the ability to place circuitry near the elements on the same substrate and avoid a multi-layer board. Also elements can be connected in parallel in the same plane to form an array. With this type of feed, impedance transformation to a useful value is needed as the impedance near the edge of the patch is quite high (a couple hundred Ω typical).
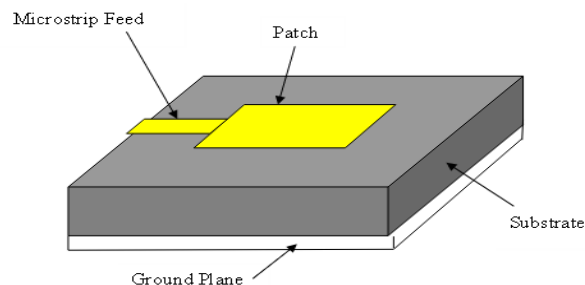

Fig 3.1: micro strip line feed

3.2 Aperture coupled feed

An aperture-coupled design is proposed for Micro strip slot antenna to improve its radiation pattern as well as bandwidth. It is based on coupling of an aperture between the patch antenna and Micro strip slot line. The first aperture coupled micro strip antenna was introduced in 1985 by D M Pozer. The geometry of an aperture coupled micro strip antenna is shown in Fig. 3.2. It consists of two substrates bonded together, with a ground plane in between. The radiating patch is printed on the top (antenna) substrate; while a microstrip feed line is printed on the bottom (feed) substrate. A small non resonant aperture in the ground plane. The impedance bandwidth of a basic patch is a couple % at best. The radiation bandwidth is usually much larger and can be up to 50%. Aperture coupling to a patch is a classic impedance bandwidth enhancement technique. The microstrip fed aperture coupled patch may suffer from a reduced front to back ratio. A strip line feed avoids this: the feed line is 'captured' between two ground layers.
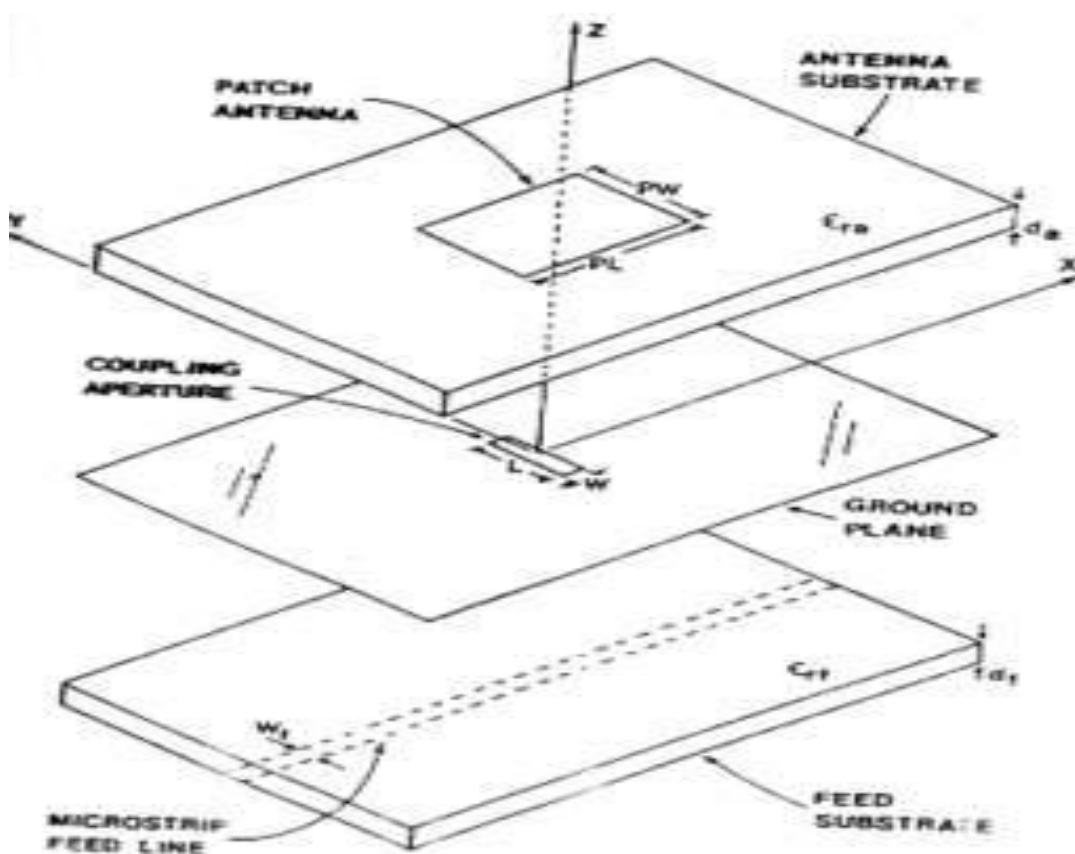

Fig 3.2: Aperture coupled feed.

3.3 Coaxial Feed Line

A classic way to feed a patch antenna is by using a coaxial probe or connector mounted at the appropriate impedance point and we will look at a couple of alternate ways to connect to a patch. Since in most patch antennas, the impedance bandwidth is much smaller than the radiation bandwidth, we will also look at some techniques to increase the bandwidth.

While the probe feed discussed so far has a bandwidth of only a couple %, it is still very useful for a lot of applications like GPS and WLAN. The coaxial feed cable has two conductor-inner conductor and outer conductor. In figure the coaxial feed line is connected to the radiating patch and the outer conductor is connected to the ground.
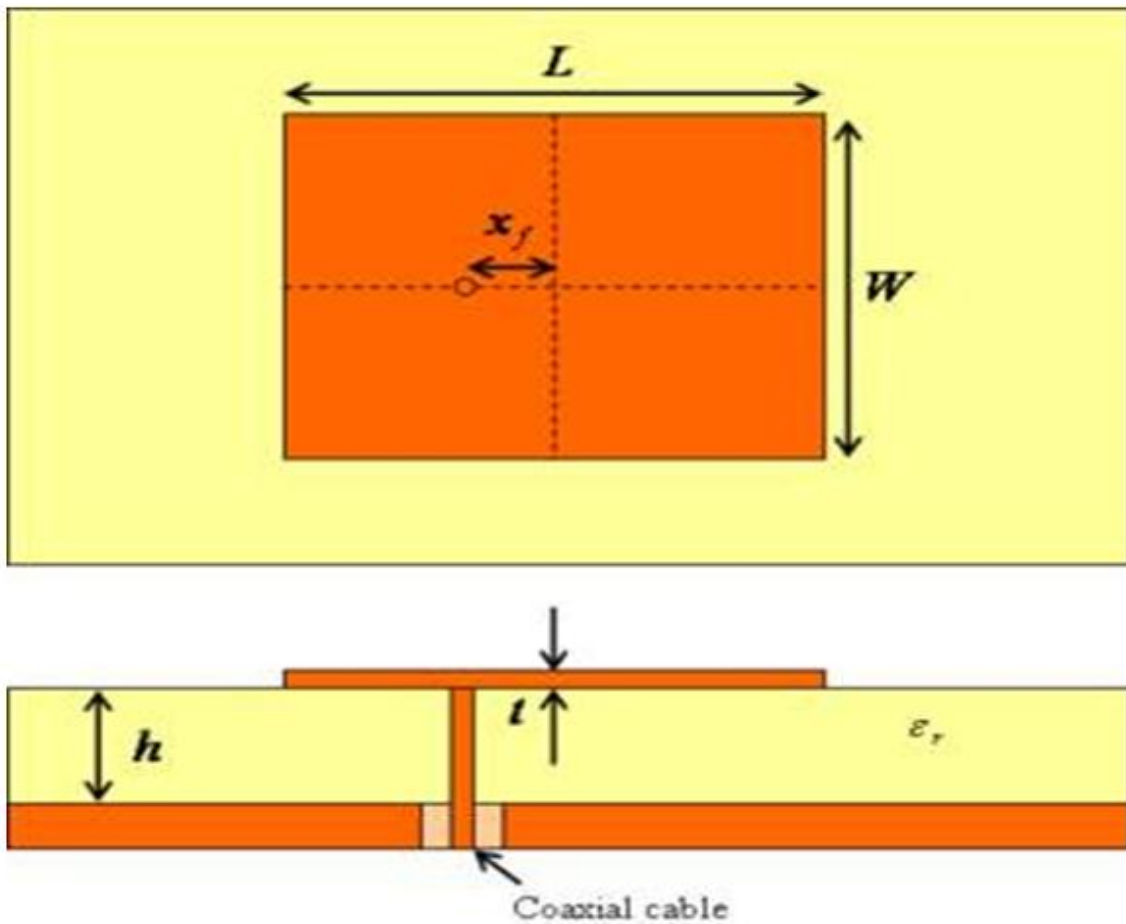

Fig 3.3: Probe feed rectangular micro strip antenna

Chapter 4

Antenna Design

Antenna parameters are used to characterize performance of an antenna when designing and measuring antenna. This chapter we discuss bandwidth, polarization, radiation pattern, gain, input impedance that is related to antenna design.

4.1 Bandwidth

The most important parameter of an antenna is the bandwidth it covers. Most of the time only impedance or return loss bandwidth is specified. However, it is important to realize that several other definitions of bandwidth exist: directivity bandwidth, polarization bandwidth and efficiency bandwidth. Directivity and efficiency are often combined to gain bandwidth.

Equation of Bandwidth is f_2-f_1/f_0 and % $BW=f_2-f_1/f_0 * 100\%$, where $f_0=f_2+f_1/2$

4.2 Radiation pattern

The radiation pattern of an antenna is the power radiated or received by an antenna. The patch's radiation at the fringing fields results in a certain far field radiation pattern. This radiation pattern shows that the antenna radiates more power in a certain direction than another direction. The antenna is said to have certain directivity. This is commonly expressed in dB; if the antenna had 100% radiation efficiency then all directivity would be converted to gain. Typical half wave patches have efficiencies well above 90%.

Radiation pattern of an antenna can be defined as the locus of all points where the emitted power per unit surface is the same.

A plot through which it is visualizes where the antenna transmits or receives power. The microstrip antenna radiates normal to its patch surface. So, the elevation pattern for $\varphi= 0$ and $\varphi= 90$ degrees are important for the measurement.

The rectangular patch excited in its fundamental mode has a maximum directivity in the direction perpendicular to the patch
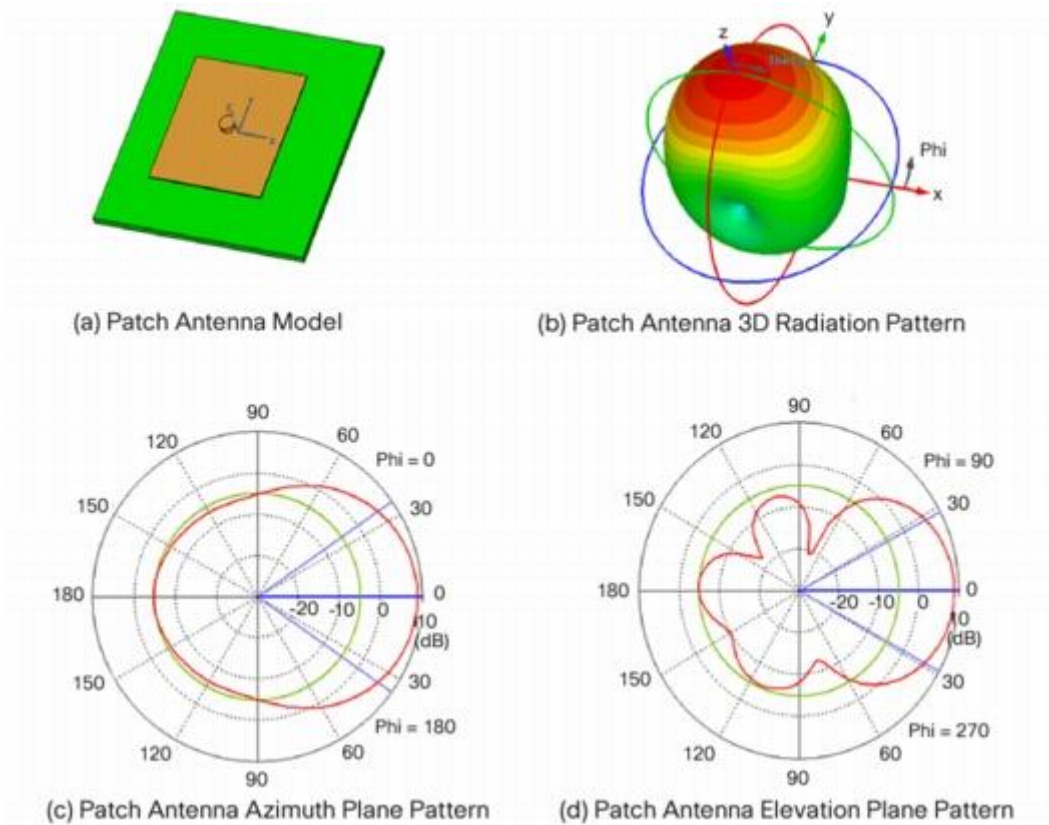
(a) Patch Antenna Model

(b) Patch Antenna 3D Radiation Pattern

(c) Patch Antenna Azimuth Plane Pattern

(d) Patch Antenna Elevation Plane Pattern

Fig4.1: Radiation pattern of patch antenna

Assuming all radiation occurs in one half of the hemisphere, this results in a 3 dB directivity. This case is often described as a perfect front-to-back ratio; all radiation towards the front and no radiation towards the back. This front-to-back ratio is highly dependent on ground-plane size and shape in practical cases. Another 3 dB can be added since there are 2 slots. The slots are typically taken to have a length equalto the impedance width (length according to the y-axis) of the patch and a width equal to the substrate height. Such a slot typically has a gain of about 2 to 3 dB (simple dipole). This results in a total gain of 8 to 9 dB.

.

4.3 Antenna Gain

Antennas do not have gain because they are passive structures. Antenna gain is defined as antenna directivity times a factor representing the radiation efficiency. Antenna gain defined as the efficiency of the ratio of the radiated power and to the input power. Due to isotropic as ideal antenna we take dB as reference unit.

Antenna gain can also be specified using the total efficiency instead of the radiation efficiency only. This total efficiency is a combination of the radiation efficiency and efficiency linked to the impedance matching of the antenna. Radiation efficiency is always lower than 100% so the antenna gain is always lower than antenna directivity.

Antenna gain can also be specified using the total efficiency rather than just the radiation efficiency. This total efficiency is a combination of the radiation efficiency and efficiency linked to the impedance matching of the antenna.

It is defined as the ratio of the intensity (power per unit surface) radiated by the antenna in a given direction at an arbitrary distance divided by the intensity radiated at the same distance by an hypothetical isotropic antenna. Gain is a key performance figure which combines the antenna's directivity and electrical efficiency.

Fig 4.2: Gain in dB

4.4 Directivity
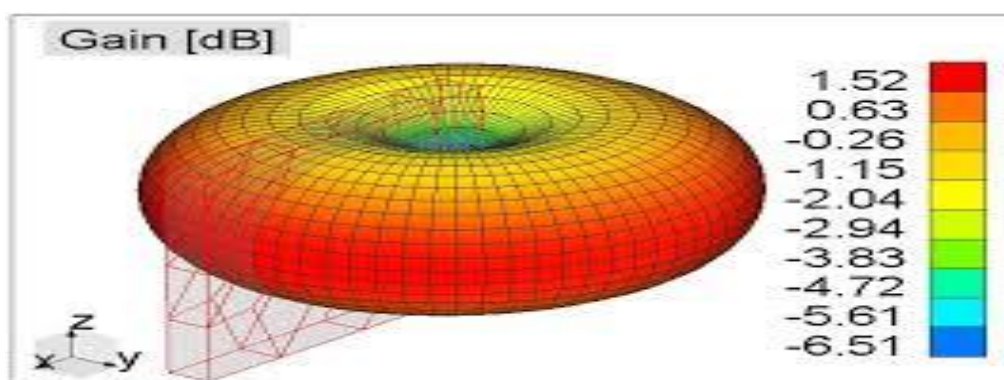
The ratio of the radiation intensity in a pre-arranged direction from the antenna to the radiation intensity averaged over all directions.

This is the frequency range wherein the antenna meets a certain directivity/gain requirement (1 dB gain flatness). The average radiation power intensity is equivalent to the radiated power by the antenna divided by 4π.
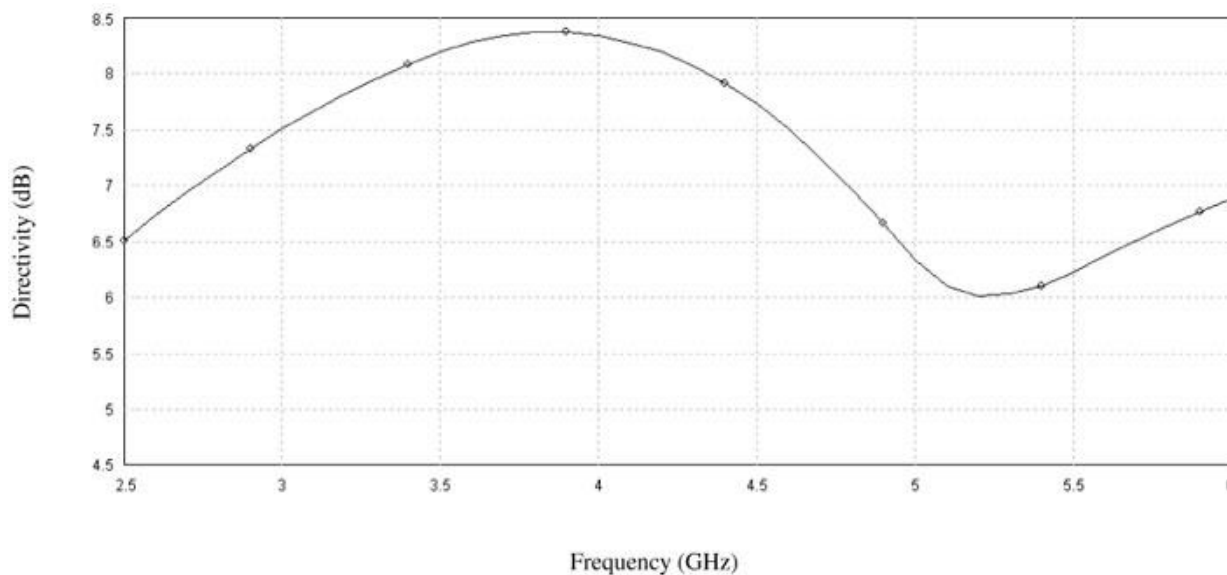
Fig 4.3: Directivity in dB

4.5 Return loss

This can be defined as difference in dB between the forward and reflected power measured at a given point in an RF system. Return Loss is a measure of how much power is delivered from the source to a load and measured by 11 parameters. Bandwidth is the range of frequencies over which the antenna can operate effectively. Bandwidth can be calculated by going 10 dB down in return loss. Equation of Return Loss is $-20\log S_{11}$, here S_{11} is Return loss value.

Fig 4.4: Return loss

4.6 Polarization

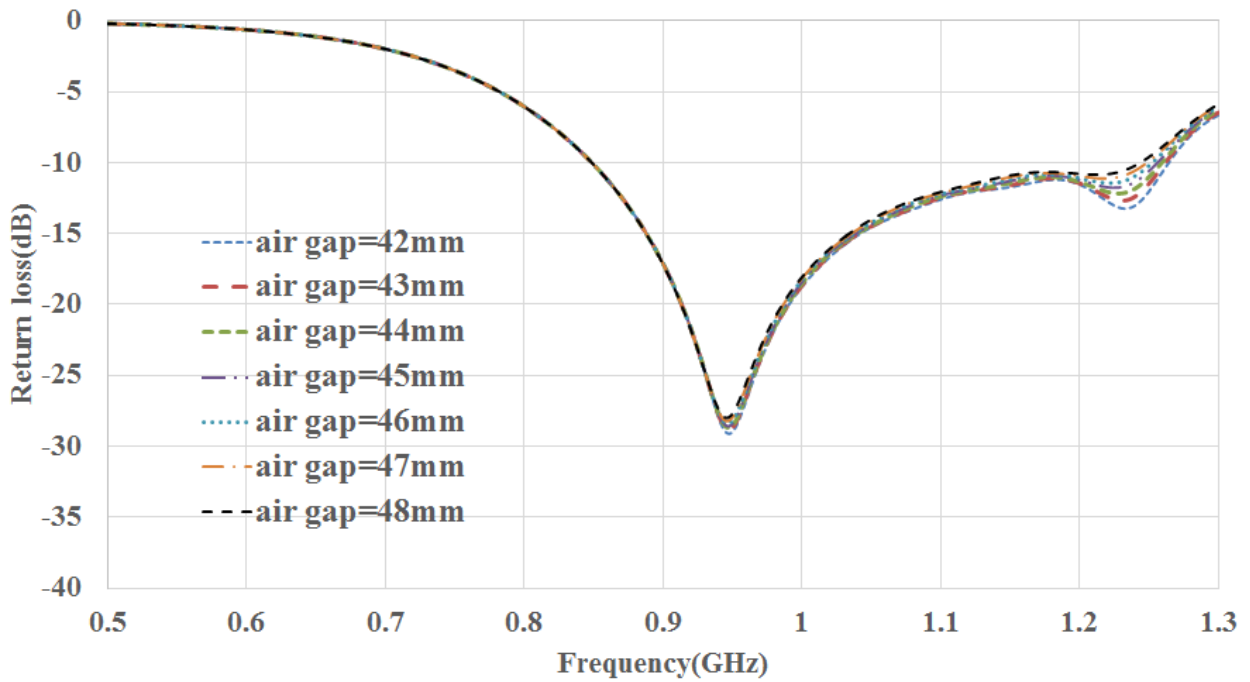In last few years, researchers have looked into the designing of circular polarized antennas. Circular- polarization enables to receive or transmit through antennas without significantly changing the output voltage. In many applications, these antennas operating at low power density, when the transmitting power is low and the transmission distance is long.The advantage of this antenna over a linearly polarized antenna is that it has nearly constant dc output and it can achieve the retina's rotation angle, relative to the transmitter changes.

The plane wherein the electric field varies is also known as the polarizatio n plane. The basic patch covered until now is linearly polarized since the electri c field only varies in one direction.A large number of applications, including sat ellite communication, have trouble with linear polarization because the orientati on of the antennasis variable or unknown. Luckily, there is another kind of polar ization -- circular polarization. In a circular polarized antenna, the electric field varies in two orthogonal planes (x and y direction) with the same magnitude and a 90degree phase direction.

4.7 Voltage Standing Wave Ratio (VSWR)

The **VSWR** is defined Voltage Standing Wave Ratio. VSWR is a measure of the reflected power on a transmission line. It is an important specification for all communication devices. It measures how well an antenna is matched to the cable impedance.

4.8 Applications of the Micro Strip Antenna

- ➢ Satellite Communication:

  - ▪ Satellite communication requires circularly polarized radiation patterns, which can be realized using either square or circular patch micro strip antenna.

- ➢ Global Positioning Satellite (GPS) system:

  - ▪ In circularly polarized micro strip antenna are used. They are very compact in size and quite expensive due to their positioning.

- ➢ RFID:

  - ▪ Micro strip antennas are also used in the fields of RFID (radio frequency identification), mobile communication and healthcare. Basically, an RFID system consists of a tag and a reader. Generally, it uses frequencies between 30 Hz and 5.8 GHz.

- ➢ Medical applications:

  - ▪ In the treatment of malignant tumors, microwave energy is said to be the most effective way of inducing hyperthermia. The radiator to be used   for this purpose should be light-weight, easy to handle and rugged. Only a patch radiator fulfills these requirements.

- ➢ Medical Application with textile:

  - ▪ There are some applications at present where antennae are used to continuously monitor biometric data of the human body. In order to do this, they need to be so close to the human body all the time that they can continuously monitor

the biometric data and send the information to the outside world. If the antenna is hard, it cannot be kept always attached with the human body. An antenna made of textile material will not harm the human body and can be worn for extended periods. Wearable antennae will find use in healthcare, recreation, fire-fighting, etc.

- Textile materials are increasingly being used for development of flexible wearable systems due to the recent miniaturization of wireless devices. For flexible antennae, textile materials form interesting substrates, because fabric antennae can be easily integrated into clothes.
  In this special type of patch antenna, the radiating patch and the ground plane are made up of conductive textile material. The substrate too is a textile material with specific dielectric constant. As everything is made up of textile material, it is called textile antenna.

➢ Mobile communication:

- Mobile communication requires small, low-cost, low-profile antennae. In some mobile handsets, semiconductor-based diodes or detectors are used as antennae. They are much like p-n diode photo-detectors but work at microwave frequency. Many times Omni directional antenna is used in mobile phones. There are different kinds of antennae like planar inverted-F antenna, folded inverted conformal antenna and mono pole. Also retractable whip antenna is commonly used in handsets.

  The phone is subdivided into roughly 60 components, each consisting of hundreds or even thousands of individual facets.

> Some communication-based applications of micro strip patch antennae are radio altimeters, command and control systems, remote sensing and environmental instrumentation, feed elements in complex antennae, satellite navigation receivers, mobile radio, integrated antennae, biomedical radiators and intruder alarms, Doppler and other radars, and satellite communication and direct broadcast services.

4.9 Ultra Wide Band (UWB)

Ultra wideband (also known as UWB or as *digital pulse wireless*) is a wireless technology for transmitting large amounts of digital data over a wide spectrum of frequency bands with very low power for a short distance. Ultra-wideband is a technology for transmitting information spread over a large bandwidth >500 MHz ultra-wideband transmissions can legally operate in the range 3.1 GHz up to 10.6 GHz, at a limited transmit power of -41dBm/MHz Additionally the transmissions must occupy a bandwidth of at least 500 MHz, as well as having a bandwidth of at least 20% of the center frequency. To achieve this last requirement, a transmission with a center frequency of 6 GHz, for example, must have a bandwidth of at least 1.2 GHz. Consequently, UWB provides dramatic channel capacity at short range that limits interference.

4.9.1 Ultra Wideband Application:

Ultra Wide Band has two types application:

✓ Applications involving radar, in which the signal penetrates nearby surfaces but reflects surfaces that are farther away, allowing objects to be detected behind walls or other coverings.

✓ Voice and data transmission using digital pulses, allowing a very low powered and relatively low cost signal to carry information at very high rates within a restricted range.

Chapter 5
Overview OF HFSS

Ansoft HFSS (High Frequency Structural Simulator) is an interactive software package for calculating the electromagnetic (EM) behavior of a 3D structure. The software also includes post-processing commands for analyzing the electromagnetic behavior of a 3D structure in more detail. Ansoft HFSS software contains the technology, solvers and capabilities needed to model RF and microwave as well as signal- and power-integrity issues.

Using Ansoft HFSS, you can compute:

- It integrates simulation, visualization; solid modeling and automation in a stress free situation which gives solutions to your 3D EM difficulties are fast and exactly found.

- Basic electromagnetic field quantities and, for open boundary problems, radiated near and far fields.

- Generalized S-parameters and S-parameters renormalized to specific port impedances.

- Characteristic port impedances and propagation constants.

You are expected to draw the structure, specify material characteristics for each object and identify ports and special surface characteristics. The system then generates the necessary field solutions, resonant frequency and associated port characteristics and S-parameters. It employs the Finite Element Method (FEM), adaptive meshing and brilliant graphics that give you unparalleled performance and insight to all your 3D EM problems

5.1 HFSS Capabilities:

HFSS stands for "High frequency structure simulator", it is a Finite element code capable of solving a variety of EM problems:

- IC packages, PCB interconnects, and high-frequency components such as Antennas, RF/microwave components.
- Material properties such as ferrites as well as surface properties can be readily modeled.
- Tangential vector basis functions enabled the highly accurate finite element method for electromagnetic field solution.
- Transfinite element method for fast and accurate multimode.
- S-parameter extractions.
- Automatic mesh generation and adaptive refinement for reliable, repeatable and efficient results.
- Typically HFSS is used for the simulation of Antenna's and circuit boards. However it can and is used by several laboratories around the world for cavity design (CERN, FNAL, DESY to name a few).

HFSS is a cooperative simulation system whose mesh element is a tetrahedron. It will permit you to solve any arbitrary 3D geometry, mainly for those with complex curves and shapes, in a fraction of the time it would take using other techniques. Ansoft founded the use of the FEM (finite element method) for EM (electromagnetic) simulator by implementing technologies such as tangential vector finite elements, adaptive meshing, and adaptive lanczos-pade sweep (ALPS). Ongoing process of HFSS to lead the industry with improvements such as Modesto-nodes and full wave spice.

Ansoft HFSS have changed over a period of choice for high-productivity research, development and virtual prototyping.

5.2 Helping Procedure

If you are facing any problem or having any questions while using Ansoft HFSS then you can have the solution in such ways:

5.2.1 Online Help

It will provide guidelines while you are working:

- To get the help of specific active dialog box, click the help option in the dialog box or press F1 key.
- Select the menu item help > contents to have the online help system.
- Options are available there to provide information about every tool on the toolbars or dialog boxes. You have to hold the pointer over a tool for a brief time; a tool trip will display the name of the tool.
- If you click a menu item the status bar at the bottom of the Ansoft HFSS window will provide a brief description of the function of the menu item or tool.
- Ansoft HFSS getting started guide provides detailed information and solution of problems that faced through using it to create and solve 3D EM projects.

5.2.2 Technical support

- To contact the Ansoft technical support staff in your geographical area you have to log on to the Ansoft corporate website, ansoft.com and select content.
- Your Ansoft sales engineer may also be connected in order to provide this information.

5.2.3   Ansoft Web Site Visit

If you are connected through the internet then you can easily visit Ansoft web site to learn more about the Ansoft Company and products.

- From the Ansoft desktop select the menu item > Ansoft corporate website to access the Online Technical Support (OTS) system.
- Now from your internet browser visit ansoft.com

5.2.4 Procedural Support

The following link will direct you to the Ansoft support page. It will provide additional documentation, training and application notes.

5.3   HFSS Main Portions

Ansoft HFSS window has several optional panels:
  i. Project Manager
  ii. Message Manager
  iii. Property Window
  iv. Progress Window
  v. 3D Modeler Window

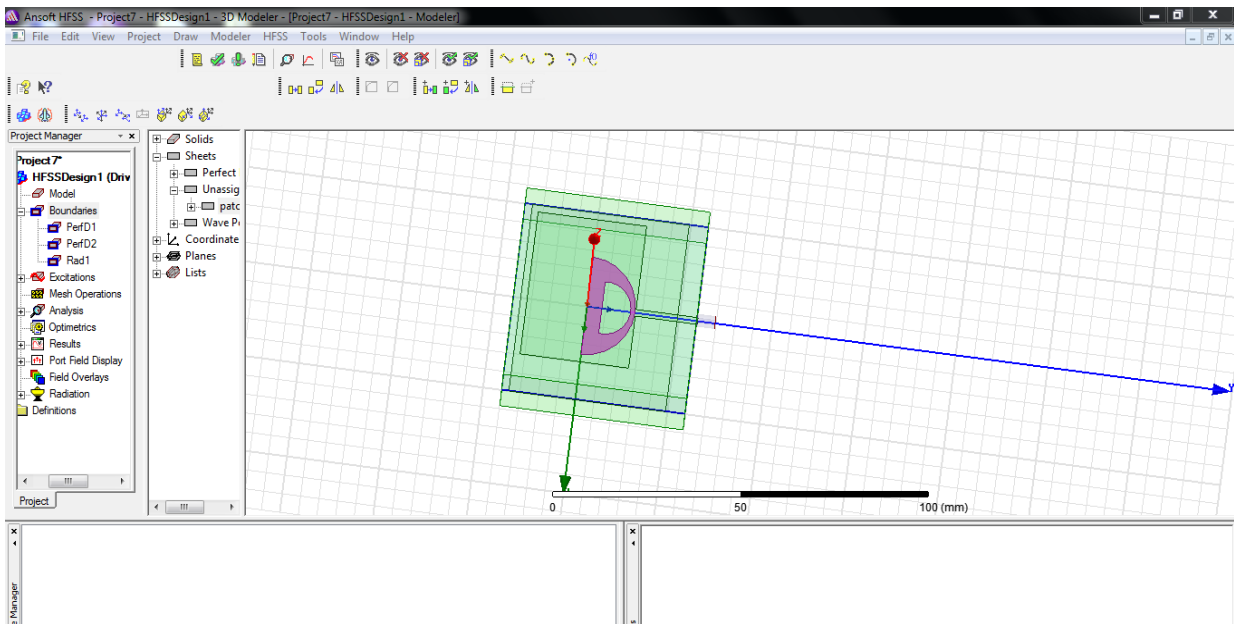Above Managers and windows are shown in fig 5.1 and their details are given in approaching sections

Fig.5.1: Ansoft HFSS window

5.3.1 Project Manager

The project you have done in Ansoft HFSS, the project manager will show you the creations of your own project structure design tree are shown below in Fig.5.2
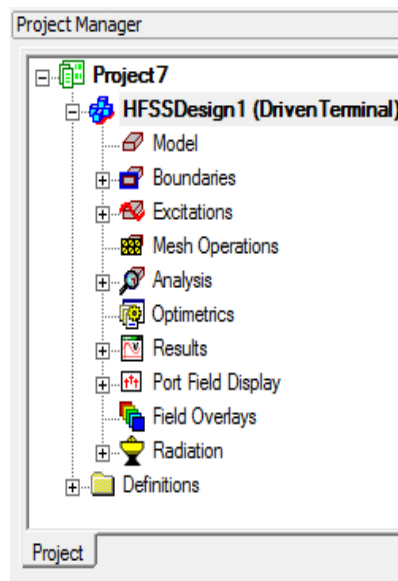

Fig 5.2: Ansoft HFSS project Manager

5.3.2 Massage Manager

After creating the project the massage manager will give you the information about you project like you have an error or any warnings it will mention on the massage manager that occur before simulation and after simulation it will deliver the project report on screen of it that is shown by Fig 5.3
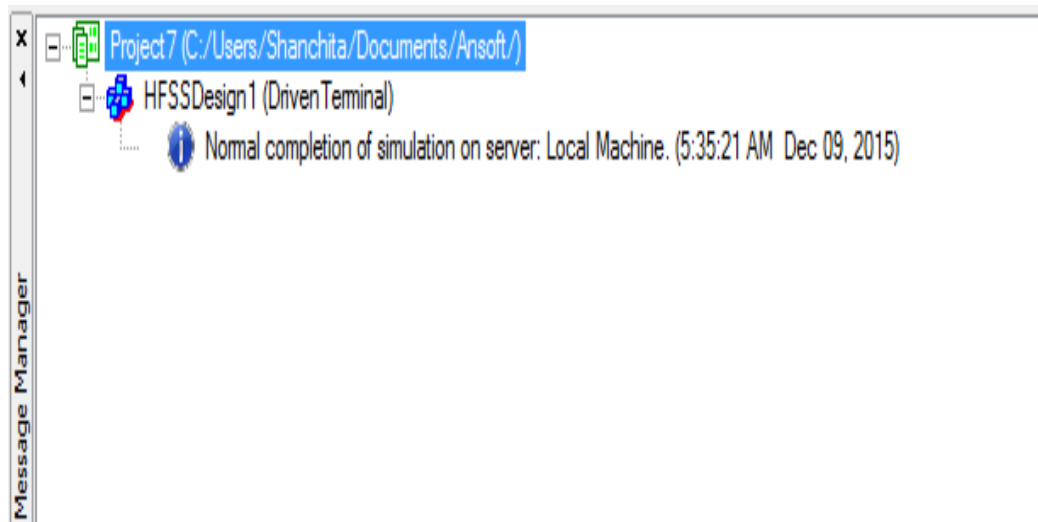

Fig 5.3: Ansoft HFSS Massage Manager

5.3.3 Properties window

Properties window will show u the command or the value you put on your design will provide on this window is given below by the Fig.5.4
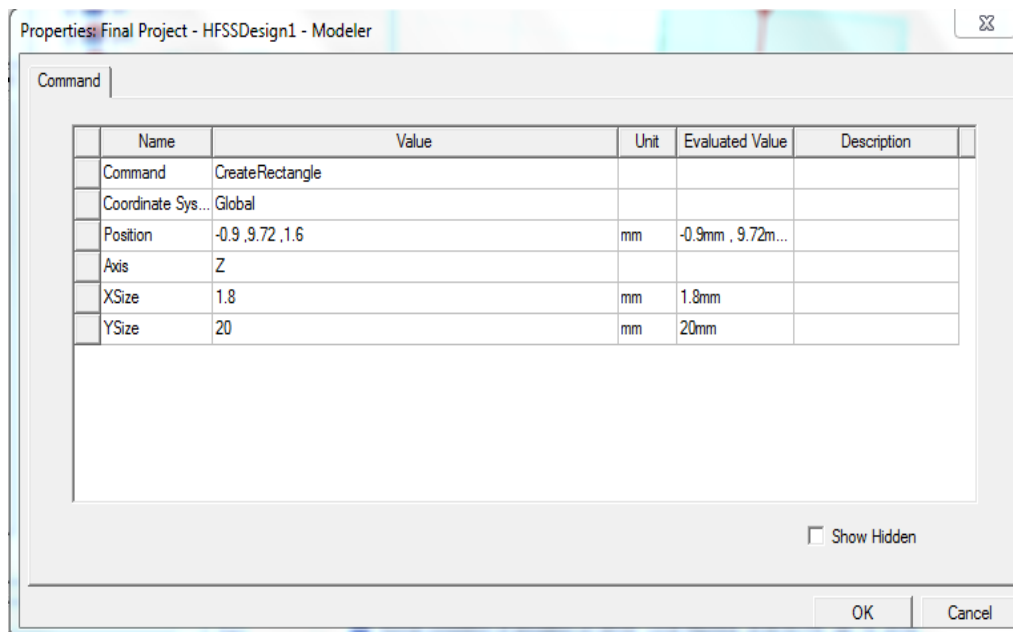

Name	Value	Unit	Evaluated Value	Description
Command	CreateRectangle			
Coordinate Sys...	Global			
Position	-0.9 ,9.72 ,1.6	mm	-0.9mm , 9.72m...	
Axis	Z			
XSize	1.8	mm	1.8mm	
YSize	20	mm	20mm	

Fig 5.4: Ansoft HFSS Progress Window.

5.3.4 Progress Window

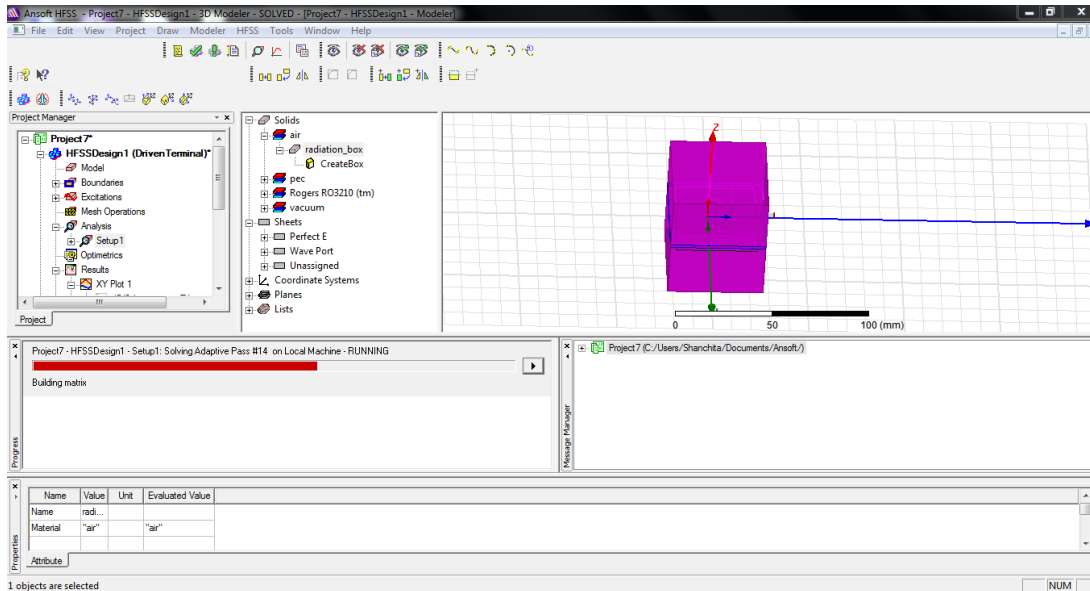Progress window shows the solution progress is shown below in Fig 5.5

Fig.5.5: Ansoft HFSS Progress Window.

5.3.5 3D Modeler Window

3D Modeler Window in this is area where you cancreate the model geometry. This window consists of the model view area (or grid) and the history tree as shown in **Figure 5.6, 5.7, 5.8.** The history tree documents the actions that have been taken in the model view area, and provides an alternative way to select objects in the model view area.

A 3D Modeler window contains the model and the model tree for the active design is give below in **Fig.5.6 and 5.7, 5.8:**
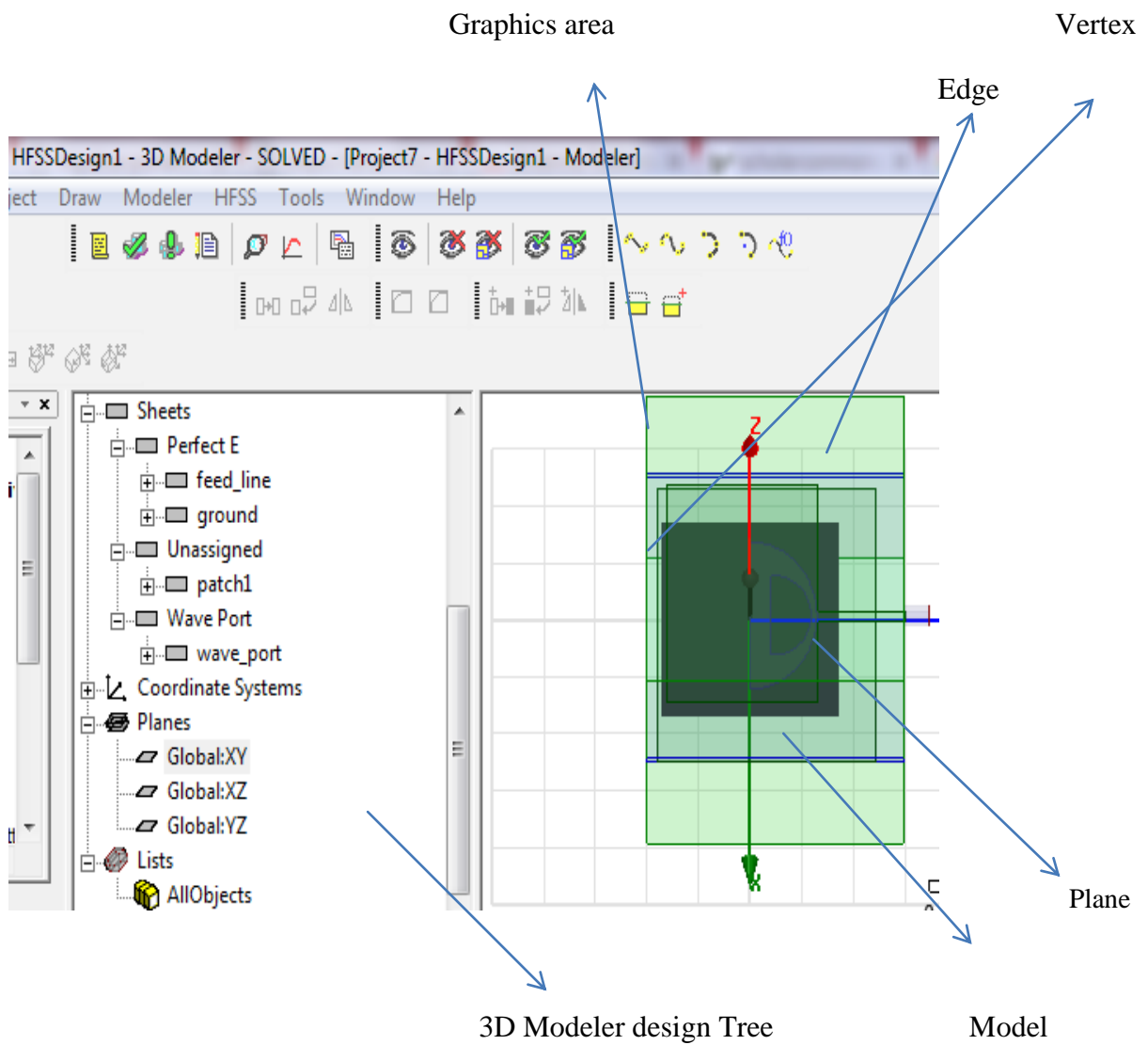
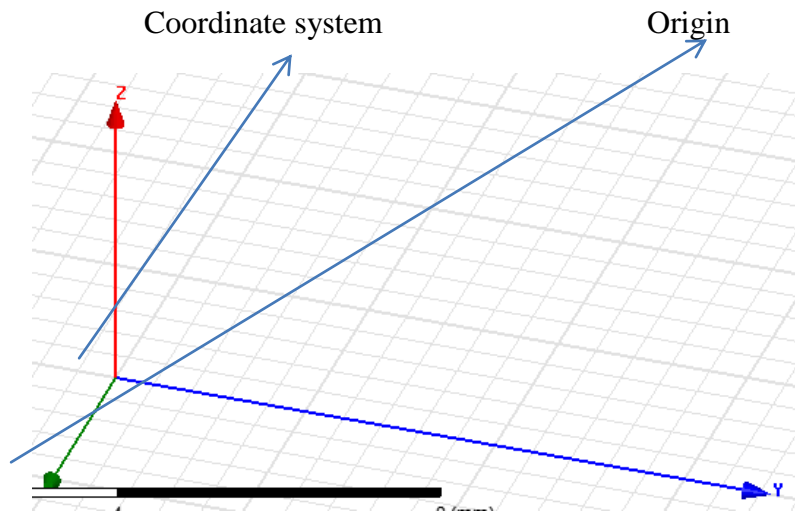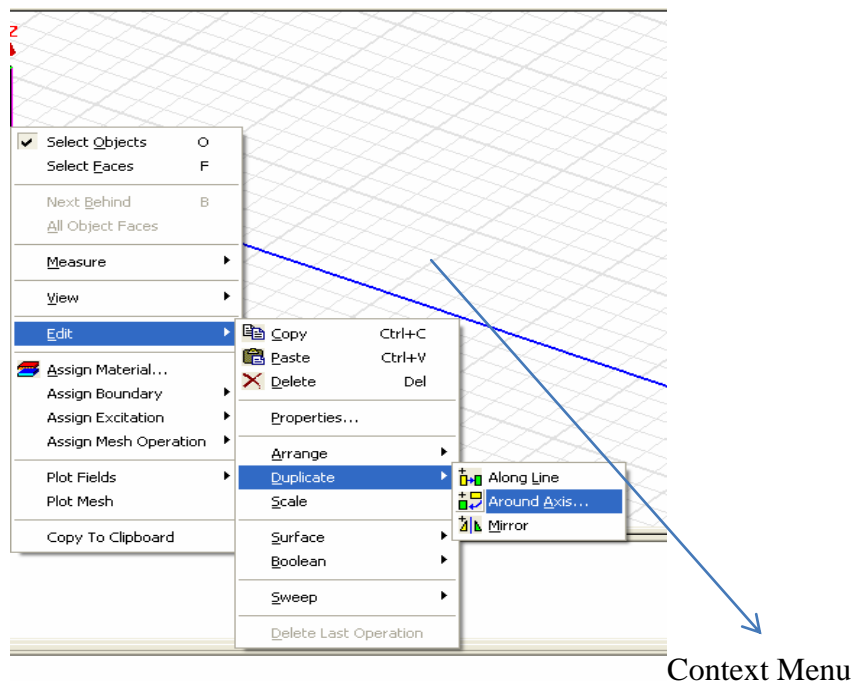**Fig.5.6:** Ansoft HFSS 3D Modeler Window with Model.

Coordinate system   Origin

Fig: 5.7: Coordinate System (CS).
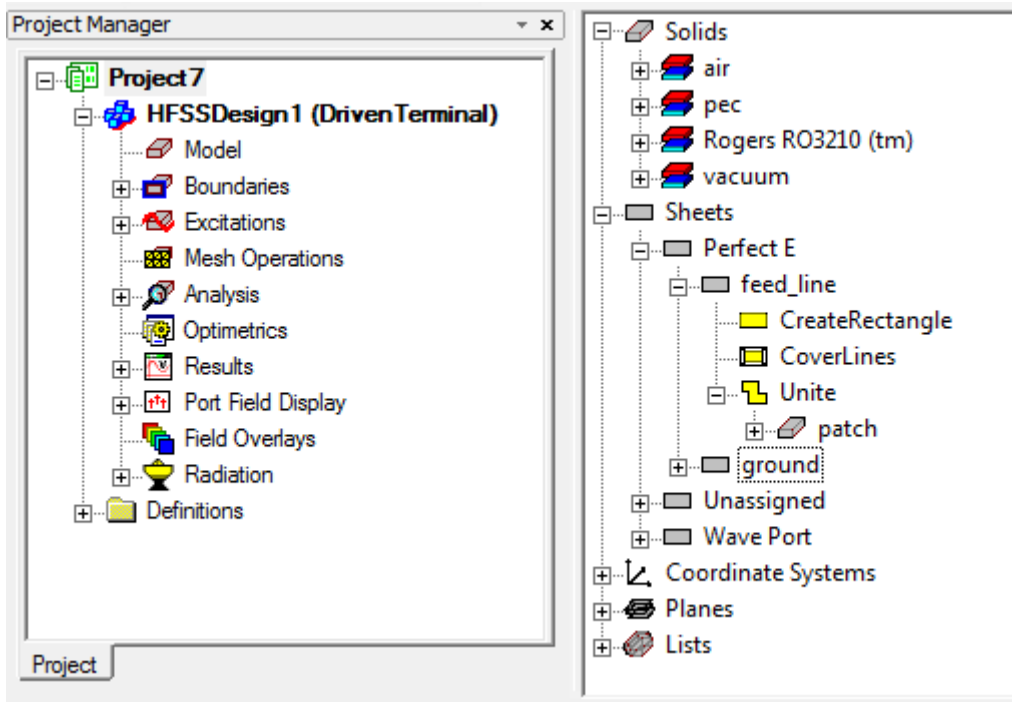

Context Menu

Fig.5.8: 3D Modeler design tree

5.4 Toolbars

The toolbar buttons are shortcuts for frequently used commands. Most of the available toolbar are displayed in this illustration of the Ansoft HFSS initial screen, but your Ansoft HFSS window probably will not be arranged this way.

You can customize your toolbar display in a way that is convenient for you. Some toolbars are always displayed; other toolbars display automatically when you select a document of the related type. For example, when you select a 2D report from the project tree, the 2D report toolbar displays, as shown in Fig 5.9:
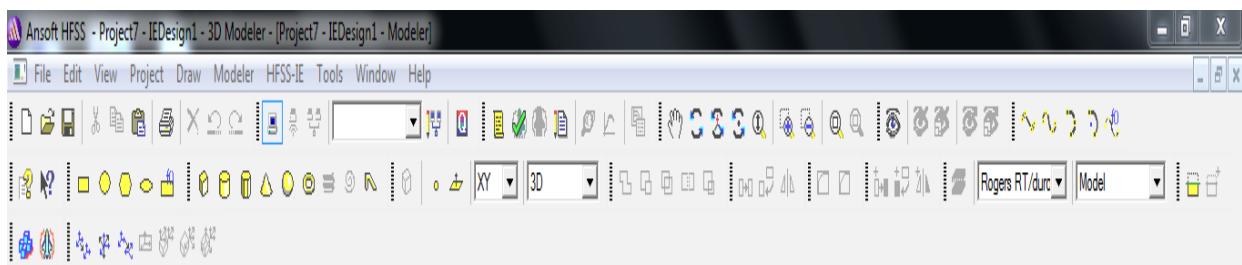

Fig 5.9: Ansoft HFSS Toolbars.

5.4.1 To display or hide individual toolbars

- Right-click the Ansoft HFSS window frame,
    - A list of all the toolbars is displayed. The toolbars with a check mark beside them are visible; the toolbars without a check mark are hidden. Click the toolbar name to turn its display mood on or off.
- To make changes to the toolbars, select the menu item Tools > Customize.
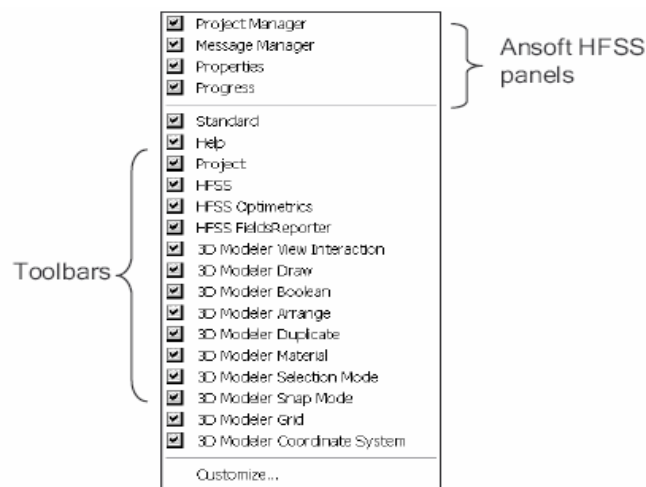
5.5 Ansoft HFSS Process:

The Ansoft HFSS Desktop Provides an easy way of interfacing to develop passive RF device models. Creating designs, involves following:

Parametric Model generation: producing the geometry, boundaries and excitations.

Analysis setup: Creating solution Setup and frequency sweeps.

Results: Creating 2D reports and field plots.

Solve Loop: The solution process is fully automated by analyzing it.
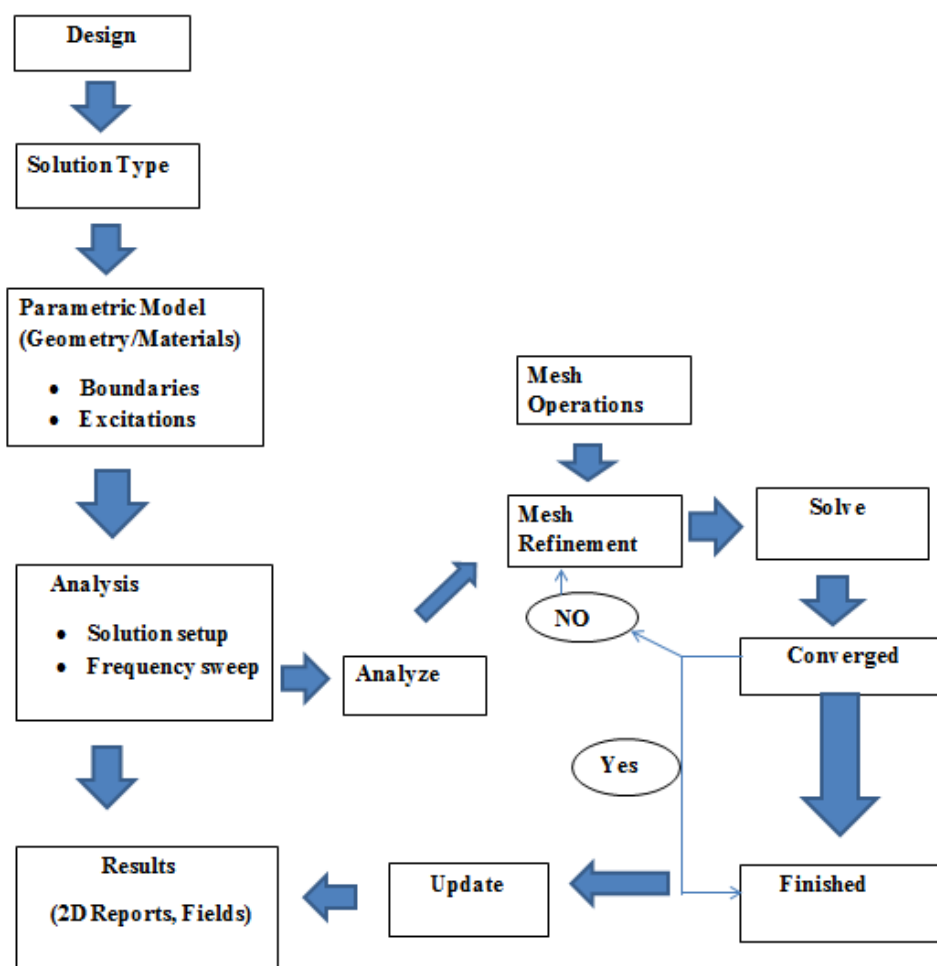
How this Process exists is given below:

Fig.5.10: Ansoft HFSS Procedure Flow Chart.

5.6 Functioning a HFSS Project

This part will describe how to create a new or existing project.

5.6.1: Functioning a New Project

To create a new project procedure is given below:

- In a Ansoft HFSS window , first you have to select the menu File >New
- Then you have to press the Project > Insert HFSS design.
- Now by giving a file name, you have to press File > save button to create a project.

5.6.2 Functioning an existing HFSS Project

To open up an existing project:

First you have to open up the menu File > Open, use the open button   to select the project,

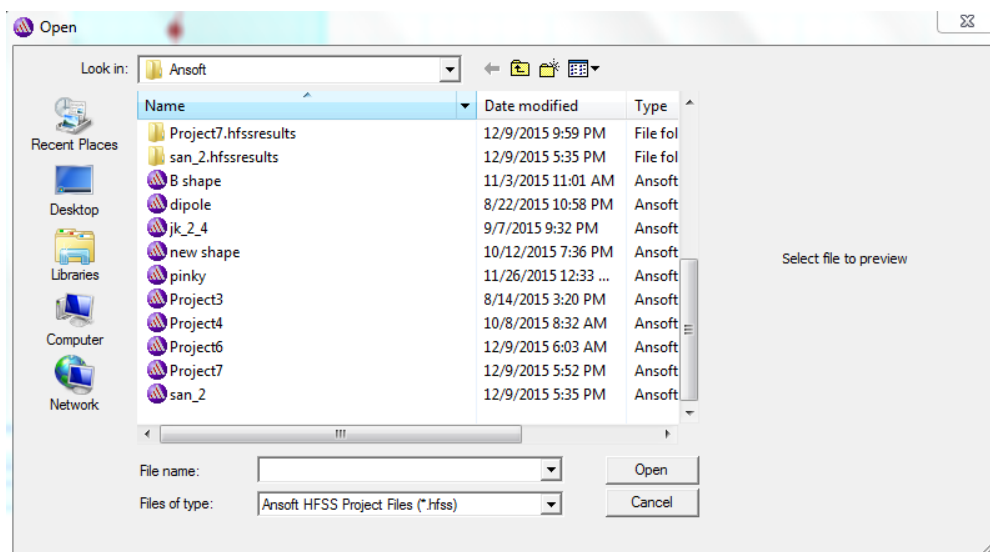Now select the project name to open the desire file you want to work with.

Fig 5.11: Opening a HFSS Project

5.7 Basic Type

Solution type is containing how the excitations and convergences are defined. The following solution types are available In Ansoft HFSS:

Driven Modal: Calculates the modal-based S-parameters. The S-matrix solutions will be expressed in terms of the incident and reflected powers of waveguide modes. Driven Modal is used for problems where the transmission line supports a non-TEM mode such as microstrip, waveguides, CPW, etc. Driven Terminal is used when your problem involves multiple and closely coupled transmission lines each supporting quasi-TEM modes such as a signal integrity problem. You can also use Driven Terminal when your structure supports a TEM mode like feed line, coax. If you are simulating just a microwave component (i.e., antenna, waveguide, filter, coupler, etc...) use the Driven Model Solution type.

Driven Terminal: calculates the terminal-based S-parameters of multi conductor transmission line ports. The S-matrix solutions will be expressed in terms of terminal voltages and currents.

Driven transient: It employs a time domain solver. Distinctive applications are included but don't have any limitations with pulsed excitations, thus Ultra wide band antennas, lighting strikes, electro static discharge, field visualization, employing short-duration excitations; time domain reflection.

Eignemode: calculate the Eigen modes, or resonances, of a structure. The Eigen mode solver finds the resonant frequencies of the structure and the fields at those resonant frequencies.

5.8 Conjunction

i. **Driven Modal** – Delta S for modal S-Parameters. This was the only convergence method available for Driven Solutions in previous versions.

ii. **Driven Terminal New** – Delta S for the single-ended or differential nodalS-Parameters.

iii. **Eigenmode** - Delta F

5.9 Solution Type

Select menu item HFSS>solution type to choose one of the following terminal

- Driven Modal
- Driven Terminal
- Driven Transient
- Eigen Mode

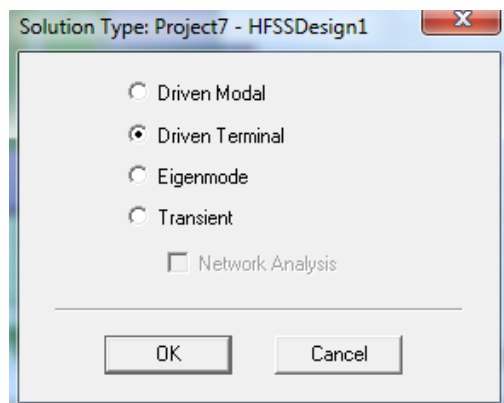Click the ok button to have the desire terminal is shown below by Fig 5.12

Fig 5.12: Solution Type.

Parametric and Optimization Using Ansoft HFSS

Optometric is a powerful new feature in Ansoft HFSS that provides parametric and optimization capabilities for 3-D RF and microwave design problems. The approach used is very general and allows any design quantity to be parameterized and optimized. It even allows outside programs such as MatLab to be used to drive the optimization. Significant applications of Optometric include fine-tuning preliminary designs, searching the design space for acceptable designs and the possibility of creating excellent designs from scratch. All of these applications provide good productivity improvements for designers and allow precision designs to be created with minimal cost and time.

HFSS Design Setup

In Ansoft HFSS introduction you know about how to create project and all the solution type. Creating a project and when you have to start work in it, you have to draw the dielectric part, substrate, feedline and in design procedure you have to select boundary, Excitations , validation check, Analysis, Analyze and finally you get Result after simulation.

5.10 Boolean Function:

In Ansoft HFSS when you create project to design an antenna, first you have to select substrate material then creating a patch you have to and port you want for your design. Now to create your desire design you need the Boolean function to subtract then unite that to Boolean function is mostly used to create a desire on any shape of antenna. Procedure with **Fig 5.13.1** is given below,

> ➢ If you select faces or variable of shape to point out the menu Edit> Object> desire item (like select patch and feedline)
> ➢ Then click on select button
> ➢ Then select the menu Modeler > Boolean > subtract
> ➢ When you need to unite desire item same procedure repeat just when you point out Modeler > Boolean > Unite

Now you have the desire shape to select Boundary which is the next design procedure to create a microstrip patch antenna on Ansoft HFSS.
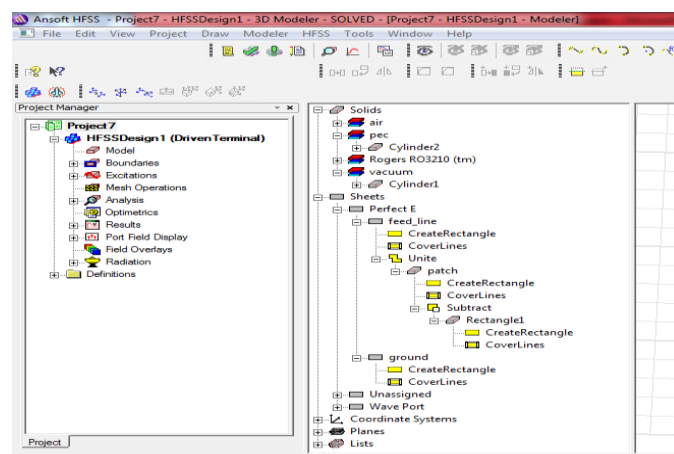

Fig 5.13.1: Selection of Boolean function in design tree of HFSS.

5.10.1Boundary Condition:

The following boundary conditions must be applied while creating a project of patch antennas:

- Perfect E boundary on the top of the dielectric (simulates a metal layer)
- Perfect E boundary on the bottom of the dielectric (simulates a metal layer)
- Perfect E boundary on the trace (simulates a metal layer)

Radiation boundary on the long sides of the dielectric (simulates the material extending to inanity in that direction) .To applies these boundary conditions,

- ➢ Right click in the 3D modeler window and click Select>assign boundaries.

- ➢ For selecting boundaries you have to select the faces first which faces you want in the boundaries ,for this you have to open the Edit> select>faces.

- ➢ Now, select perfect E1 shape for substrate, perfect E2 shape for ground and after creating Radiation Box it will also have to assign in rad1 boundary and click ok for all this procedure. You can change the name of the E1, E2 to your desire shape name that you created on your HFSS Project.

- ➢ To check that the boundaries are created correctly, expand the \Boundaries" item in the Project Tree, and you should see PerfE1, PerfE2 and Rad1 or similar.

- ➢ Highlight PerfE1, PerfE2 and you should see hash marks indicating which regions of the model apply to this boundary. Highlight Rad1 to see the same information for the radiation boundary.
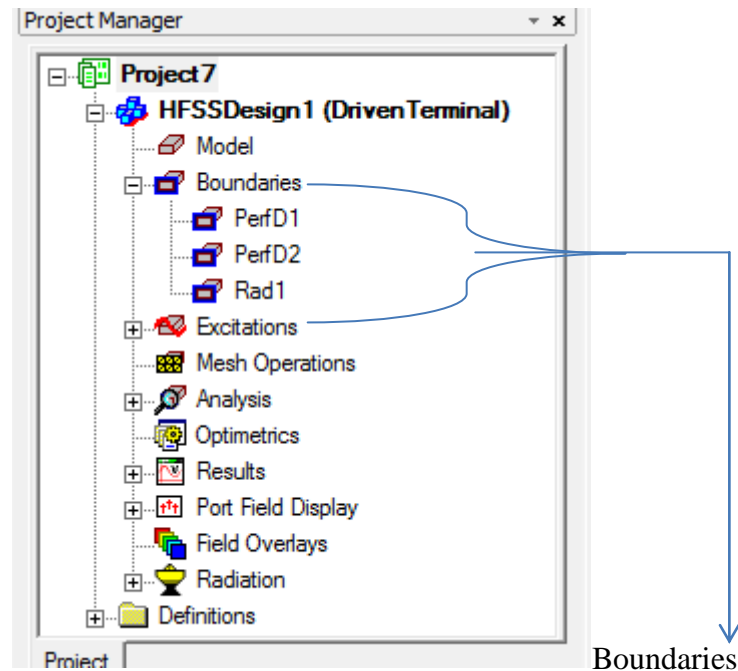
Following **Fig5.13.2** is given below

Boundaries

Fig: 5.13.2

5.10.2 Excitations

We will create a wave port excitation at each end of the circuit. To do so, we perform the following steps:

➢ Select the face of the nearest end of the circuit
➢ First you have to change the solution type > driven Terminal
➢ Right click in the 3D modeler window and select Assign Excitation => Wave Port
➢ Click Next
➢ Then select the Terminal Naming > Use Port Object Name.
➢ Press OK and then change the grid line to XY axis.

The same steps should be performed to create a wave port at the other end of the circuit. Following **Fig 5.14** is given below
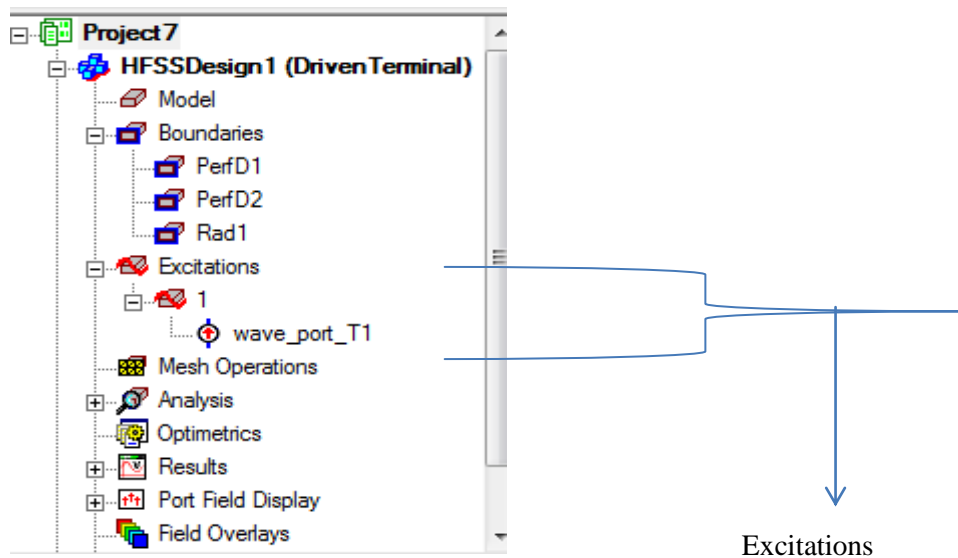
Excitations

Fig: 5.14

5.11 Analysis

Perform the following steps to set up the analysis options:

- ➢ Right click on Analysis in the Project Tree, and select >Add Solution Setup.
- ➢ Under the General tab:
- ➢ Set the solution frequency 2.4 GHz
- ➢ Set the maximum number of passes to 20
- ➢ Set maximum Delta S to 0.02

Perform the following steps to set up the frequency sweep:

Under the Analysis item in the Project Tree, right-click on Setup1

- ➢ Select Add Frequency Sweep.
- ➢ Set start frequency to 3 GHz
- ➢ Set stop frequency to 10 GHz
- ➢ Set step size to 0.01 GHz
- ➢ Click OK

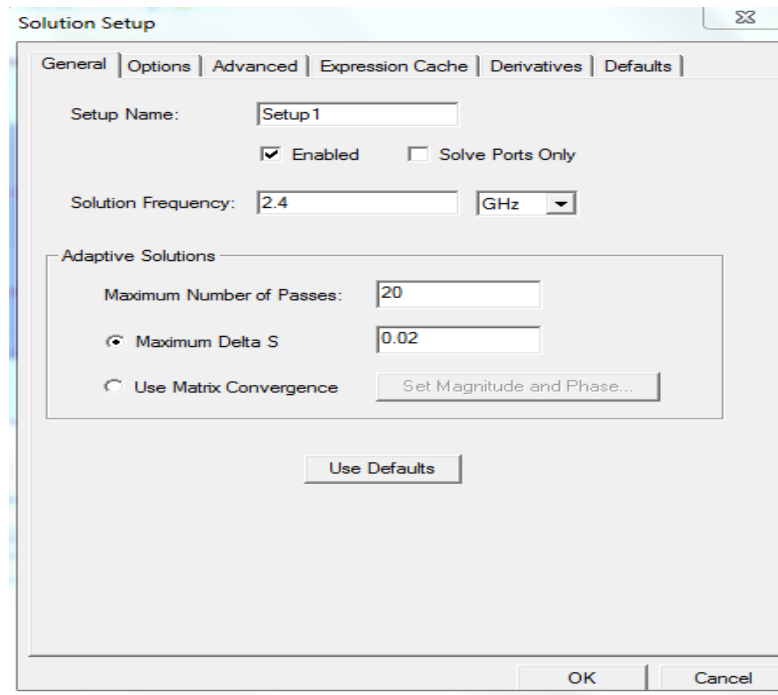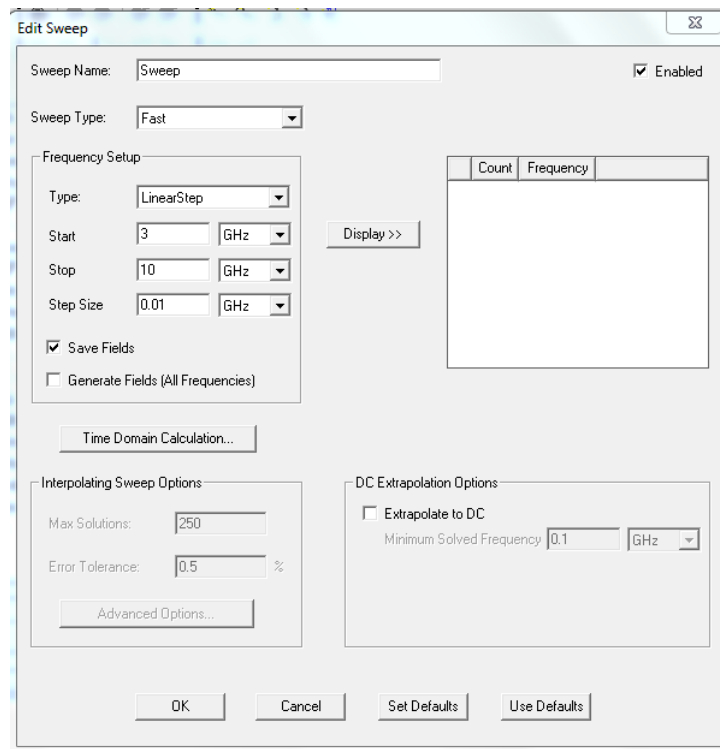Following **Fig 5.15.1 and Fig 5.15.2** will show the procedure.

Fig 5.15.1

Fig 5.15.2

5.12 Final validate Checks and Running the Simulation

The procedure is given below

- ➢ Select HFSS > Validation Check to ensure the project is prepared for simulation (Click-close).

- ➢ Save the project by clicking on the save icon at the top of the screen.

- ➢ Right-click setup1 under Analysis in the project tree, select Analyze to begin the simulation. At this point the progress window should show the progress of the simulation, beginning with the mesh generation.

Showing by **Fig 5.16.1**
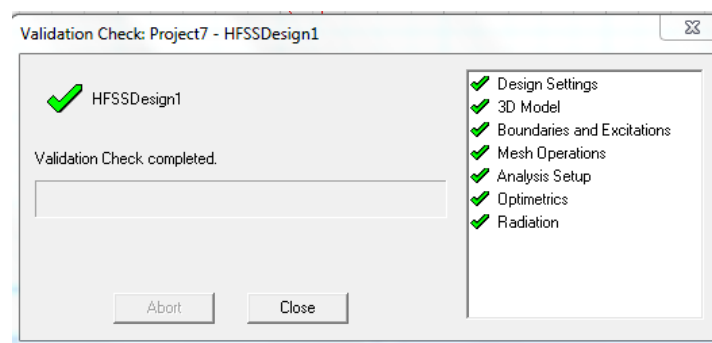
5.12.1 Simulation Results

To view the results of the simulation, perform the following steps:

- ➢ Right click on the results item in the Project Tree.
- ➢ Click Create Modal Solution Data Report =>Rectangular Plot.
- ➢ Under the trace tab, select the S-Parameter that you wish to view and click New Report.
- ➢ Add additional S-Parameters by highlighting them and clicking Add trace
- ➢ Click close.
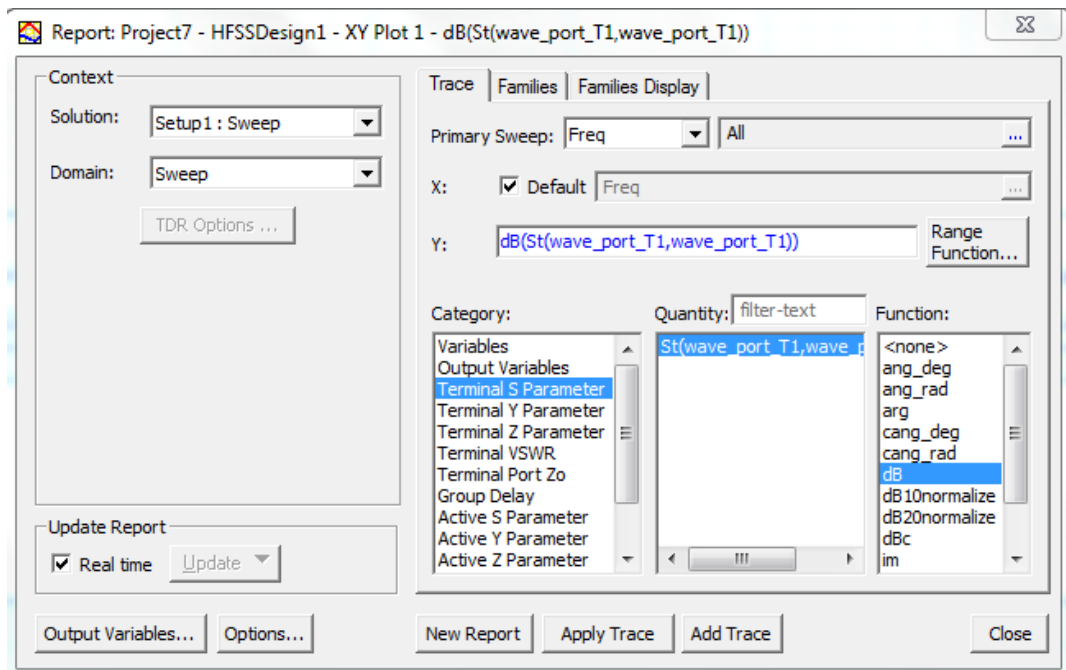
Following **Fig 5.16.2** will show this,

Fig: 5.16.2

Creating the radiation pattern, procedure is given below:

- First select Menu HFSS>Far fields>Infinite sphere1
- Then editing the phi> start with 0, Stop with 360 others values will remain same.
- Then press Ok
- Again click the Result > Create Far Fields> Radiation Pattern
- Then it will show the result.

Other results VSWR, Gain graph, Total gain in 3D or other varieties, similar procedure you have to follow.

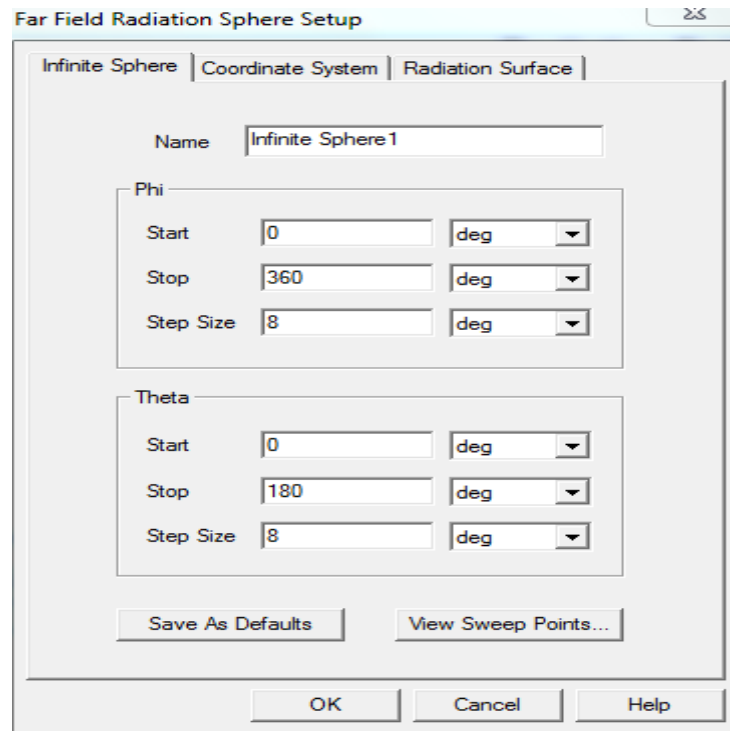Following **Fig 5.16.3and Fig 5.16.4** will explain the procedure properly,

Fig 5.16.3: creation of infinite sphere
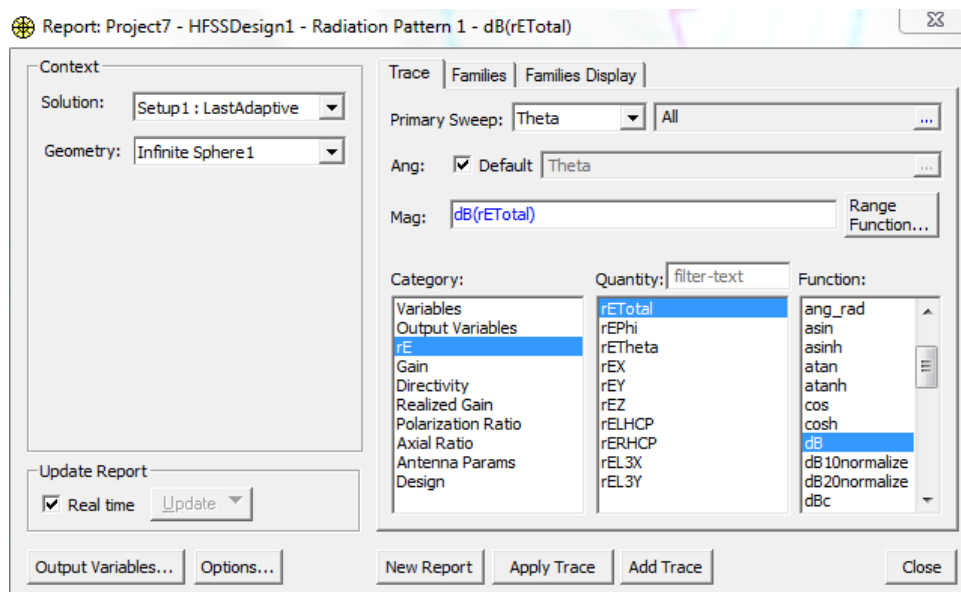
Fig 5.16.4: Creation of radiation pattern procedure.

5.13 Advantages of HFSS:

Ansoft HFSS is given below:

- Advanced Layout Capabilities

  - ➢ Improved Extraction
  - ➢ Enhanced Frequency Sweep techniques
  - ➢ New Broadband SPICE model generation

- Ansoft Designer

  - ➢ Advanced Simulation Technology
  - ➢ IBIS AMI
  - ➢ Full Channel for Compliance

- Productivity Enhancements

  - ➢ HPC for Speed
  - ➢ Distributed Solve for Design Space Characterizations for designing Antennas.

Chapter 6

Patch Antenna Analysis

In our Thesis Paper we use Rogers RT/druid 5880™ material as the Substrate in Ansoft HFSS (13) to have the desire gain at -10 db. We create a new Microstrip patch Antenna D over D shape to have our desire gain for the ultra-wide band application. Here we will discuss about the result of the shape of the patch.

6.1: Rogers RT/duroid 5880™ High Frequency Circuit Material

RT/duroid® 5880 high frequency laminates are PTFE composites reinforced with glass microfibers. These microfibers are randomly oriented to maximize the benefits of fiber reinforcement in the direction most valuable to circuit producers and in RT/duroid 5880 high frequency laminates are PTFE composites reinforced with glass microfibers. The final circuit applications.

The dielectric constant of these high frequency laminates is the lowest of all products, and low dielectric loss make them well suited for high frequency/ broad band applications where dispersion and losses need to be minimized. Because of its extremely low water absorption characteristics, RT/duroid 5880 laminates are ideal for applications in high moisture environments.

RT/duroid 5880 laminates are easily cut, sheared and machined to shape, and resistant to all solvents and reagents normally used in etching printed circuits or plating edges and holes. RT/duroid 5880 laminates have the lowest electrical loss of any reinforced PTFE material, low moisture absorption, are isotropic, and have uniform electrical properties over frequency.

When ordering RT/duroid5880 laminates, it is important to specify dielectric thickness, tolerance, rolled, electrodeposited or reverse treated copper foil, and weight of copper foil required

Fig 6.1 Rogers RT/duroid 5880™

Table 6.1 Data Sheet of Rogers RT/duroid 5880™

PROPERTY	TYPICAL VALUE			DIRECTION	UNITS	CONDITION	TEST METHOD
Dielectric Constant, ε_r	2.20 2.20 ± 0.02 spec.			Z Z	---	C24/23/50 C24/23/50	1 MHz IPC-TM-650 2.5.5.3 10 GHz IPC-TM-650 2.5.5.5
Dissipation Factor, tan δ	0.0004 0.0009			Z Z	---	C24/23/50 C24/23/50	1 MHz IPC-TM-650 2.5.5.3 10 GHz IPC-TM-650 2.5.5.5
Volume Resistivity	2 X 10⁷			Z	Mohm cm	C93/35/90	ASTM D257
Surface Resistivity	3 X 10⁸			Z	Mohm	C93/35/90	ASTM D257
Tensile Modulus	Test at 23 C 1070 (156) 860 (125)	Test at 100 C 450 (65) 380 (55)		X Y	MPa (kpsi)	A	ASTM D638
ultimate stress	29 (4.2) 27 (3.9)	20 (2.9) 18 (2.6)		X Y	MPa (kpsi)		
ultimate strain	6.0 4.9	7.2 5.8		X Y	%		
Compressive Modulus	710 (103) 710 (103) 940 (136)	500 (73) 500 (73) 670 (97)		X Y Z	MPa (kpsi)	A	ASTM D695
ultimate stress	27(3.9) 52 (7.5)	22 (3.2) 21 (3.1) 43 (6.3)		X Y Z	MPa (kpsi)		
ultimate strain	8.5 7.7 12.5	8.4 7.8 17.6		X Y Z	%		
Deformation Under Load	Test at 150 C 1.0			Z	%	24 hr/14 MPa (2kpsi)	ASTM D621
Water Absorption Thickness = 0.8 mm (0.031) Thickness = 1.6 mm (0.062)	0.9 (0.02) 13 (0.015)				mg (%)	D24/23	ASTM D570
Specific Gravity	2.2						ASTM D792
Heat Distortion Temperature	>260 (>500)			X,Y	C (F)	1.82 MPa (264 psi)	ASTM D648
Specific Heat	0.96 (0.23)				J/g/K (BTU/lb/ F)		Calculated
Thermal Conductivity	0.20			Z	W/m/K		ASTM C518
Thermal Expansion	X	Y	Z	<<<	mm/m		ASTM D3386 (10K/min)
	-6.1	-8.7	-18.7			-100 C	
	-0.9	-1.8	-6.9			15	(Values given are total change from a base temperature of 35 C)
	-0.5	-0.9	-4.5			25	
	1.1	1.5	8.7			75	
	2.3	3.2	28.3			150	
	3.8	5.5	69.5			250	

6.1.1: Features and benefits Of Rogers RT/duroid 5880™

- Lowest electrical loss for reinforced PTFE material.
- Low moisture absorption.
- Isotropic
- Uniform electrical properties over frequency.
- Excellent chemical resistance.

6.1.2: Uses

Rogers Rogers RT/duroid 5880™high frequency laminates are used in:

- Commercial airline broadband antennas.
- Microstrip and strip line circuits.
- Millimeter wave applications.
- Military radar systems.
- Missile guidance systems.
- Point-to-point digital radio antennas.

6.2: D over D shape Microstrip patch Antenna:

The objective of this chapter is to know about this new shape for how you can create, simulate and analyze a microstrip Patch antenna resonating at a dual ultra-wide band frequency ranging 4.78-8.48 GHZ is given below:
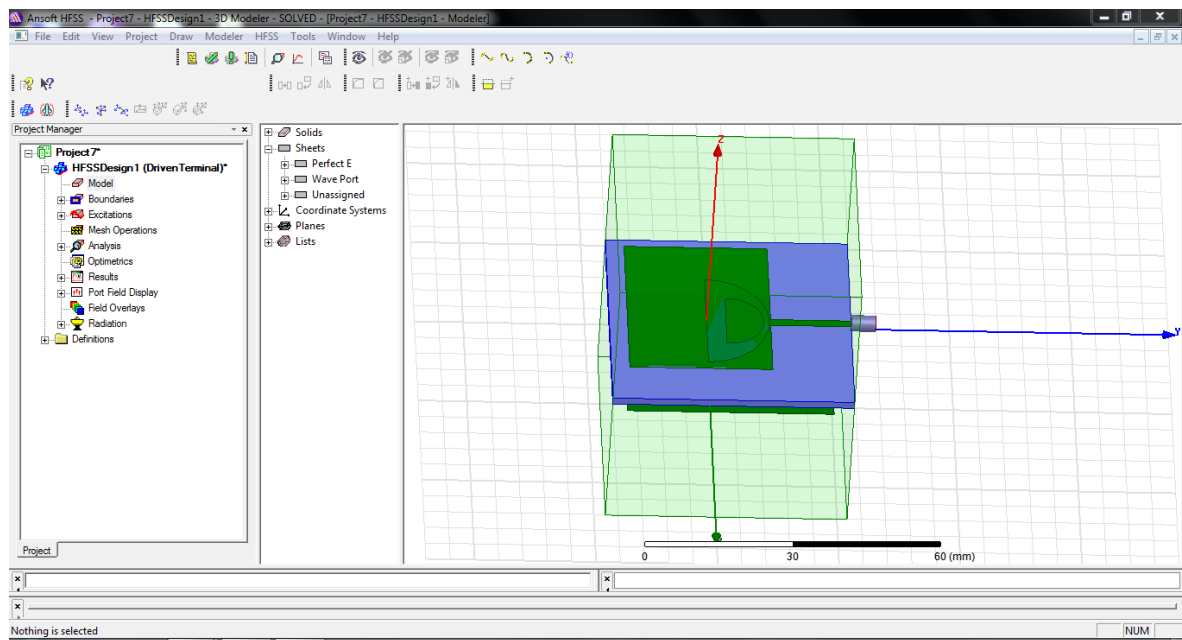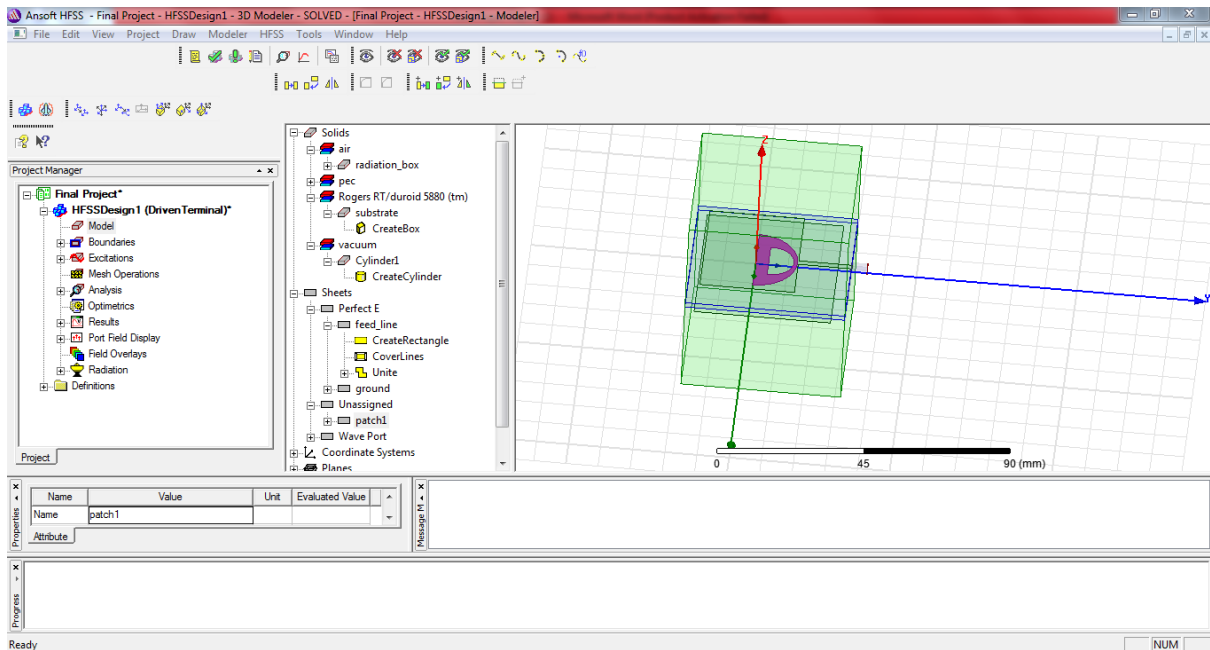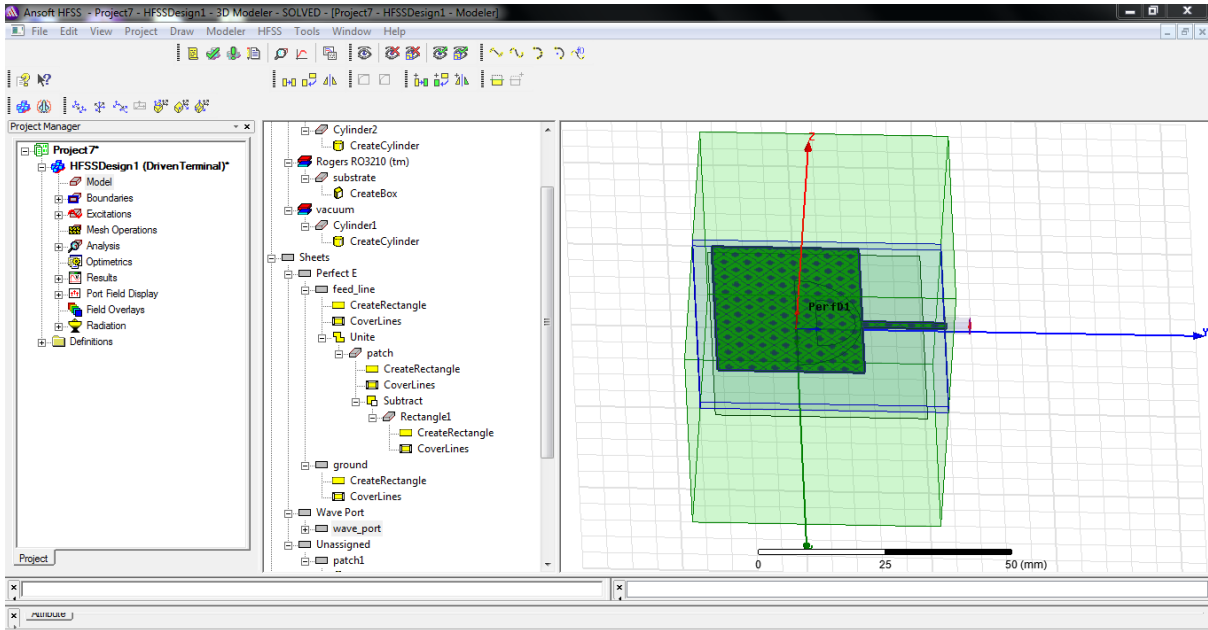

Fig: 6.2: Design Window.

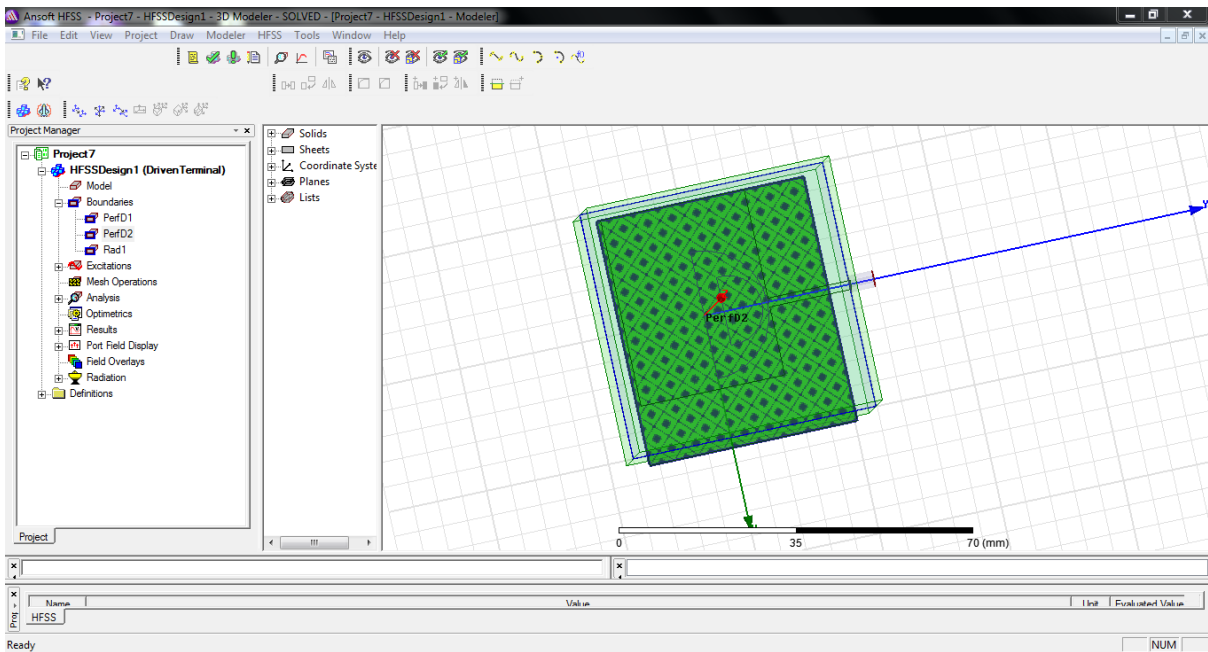**Fig.6.2.1:** Microstrip Patch Antenna (perfect D1).

Fig.6.2.2: Microstrip Patch Antenna (perfect D2)

HFSS Design Model:

In HFSS design Model will show the necessary Properties which are essential to design the D over D shape of Microstrip patch antenna. Here the command window of HFSS Design Model:
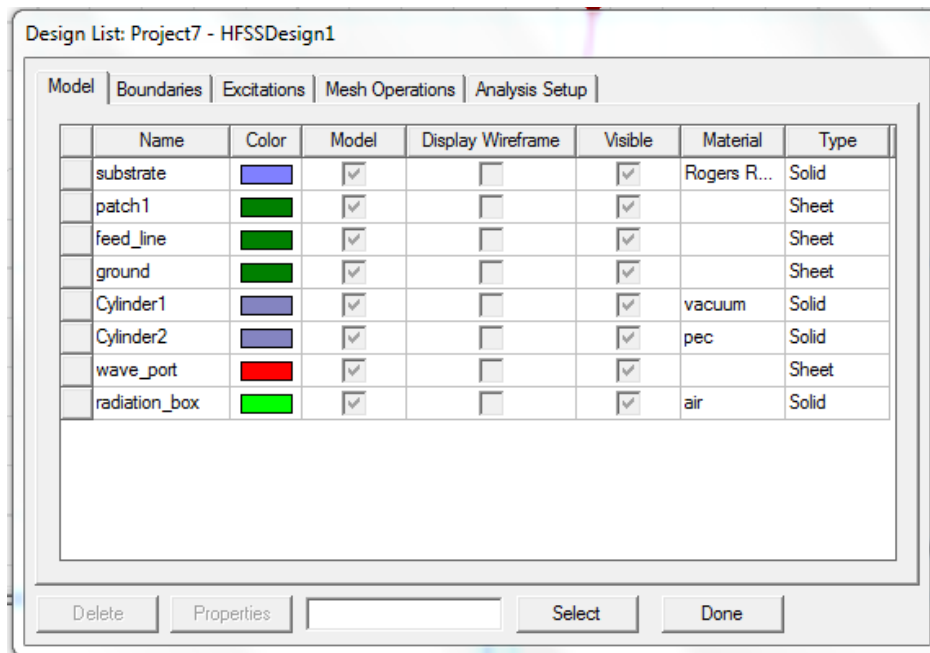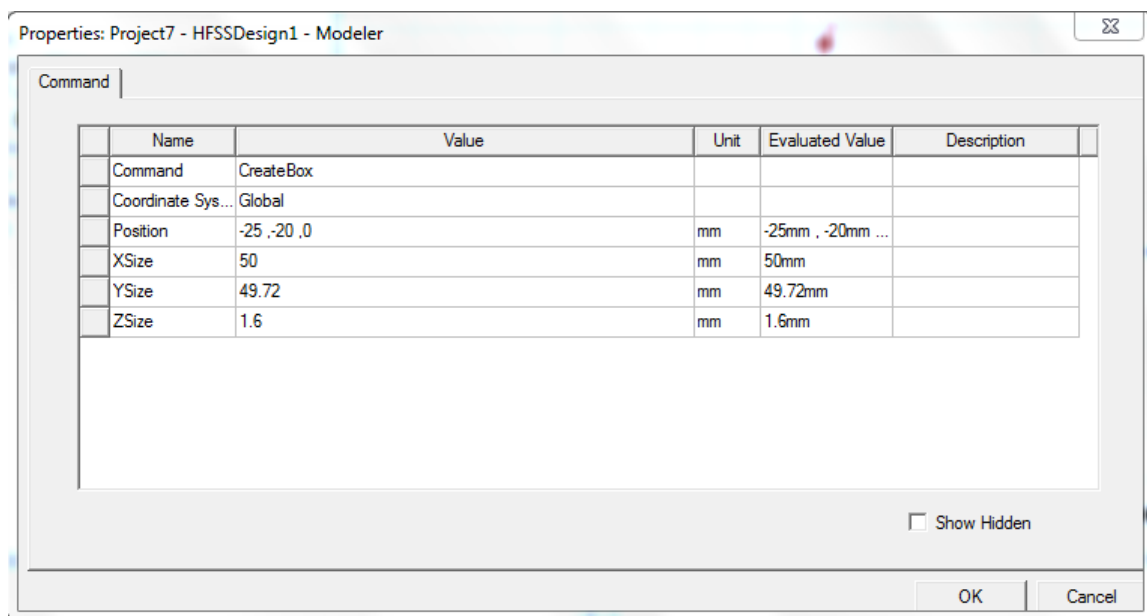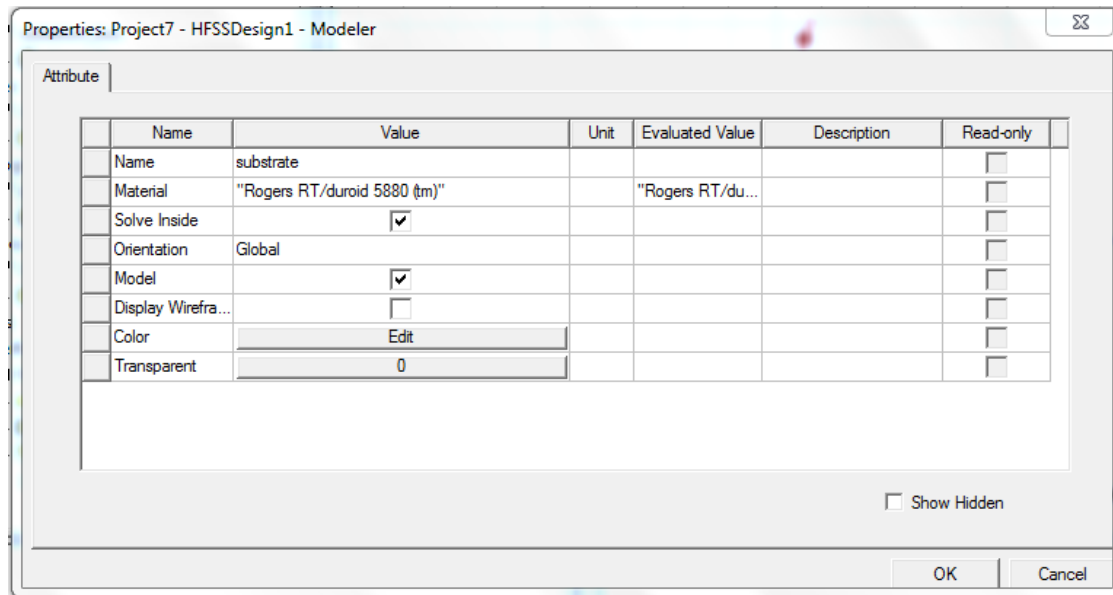
Design List: Project7 - HFSSDesign1

Model | Boundaries | Excitations | Mesh Operations | Analysis Setup

Name	Color	Model	Display Wireframe	Visible	Material	Type
substrate		✓	☐	✓	Rogers R...	Solid
patch1		✓	☐	✓		Sheet
feed_line		✓	☐	✓		Sheet
ground		✓	☐	✓		Sheet
Cylinder1		✓	☐	✓	vacuum	Solid
Cylinder2		✓	☐	✓	pec	Solid
wave_port		✓	☐	✓		Sheet
radiation_box		✓	☐	✓	air	Solid

Delete   Properties   [   ]   Select   Done

Table 6.2: Antenna Design Parameters

Name	Material	Length(L)mm	Width(W)mm	Height (h)mm	Axis	Position
Substrate	Rogers RT/duroid 5880 ™	50	49.72	1.6	X,Y,Z	-25,-20,0
Patch1	Sheet	38.04	29.44		Z	-23,-16.25,1.6
Ground	Sheet	50	42.5		Z	-23,-17,0
Feedline	Sheet	20	1.8		Z	-0.9,9.72,1.6
Radiation Box	Air	50	49.72	60	X,Y,Z	-25,-20,-30
		Radius	Height		Axis	Position
Wave Port	Sheet	1.7			Y	0,34.72,1.6
Cylinder1	Vacuum	1.7	5		Y	0,29.72,1.6
Cylinder2	Pec	0.7	5		Y	0,29.72,1.6

HFSS Attribute and Command Window for Substrate:

Properties: Project7 - HFSSDesign1 - Modeler — Attribute tab

	Name	Value	Unit	Evaluated Value	Description	Read-only
	Name	substrate				☐
	Material	"Rogers RT/duroid 5880 (tm)"		"Rogers RT/du..."		☐
	Solve Inside	☑				☐
	Orientation	Global				☐
	Model	☑				☐
	Display Wirefra...	☐				☐
	Color	Edit				☐
	Transparent	0				☐

☐ Show Hidden

OK   Cancel

Properties: Project7 - HFSSDesign1 - Modeler — Command tab

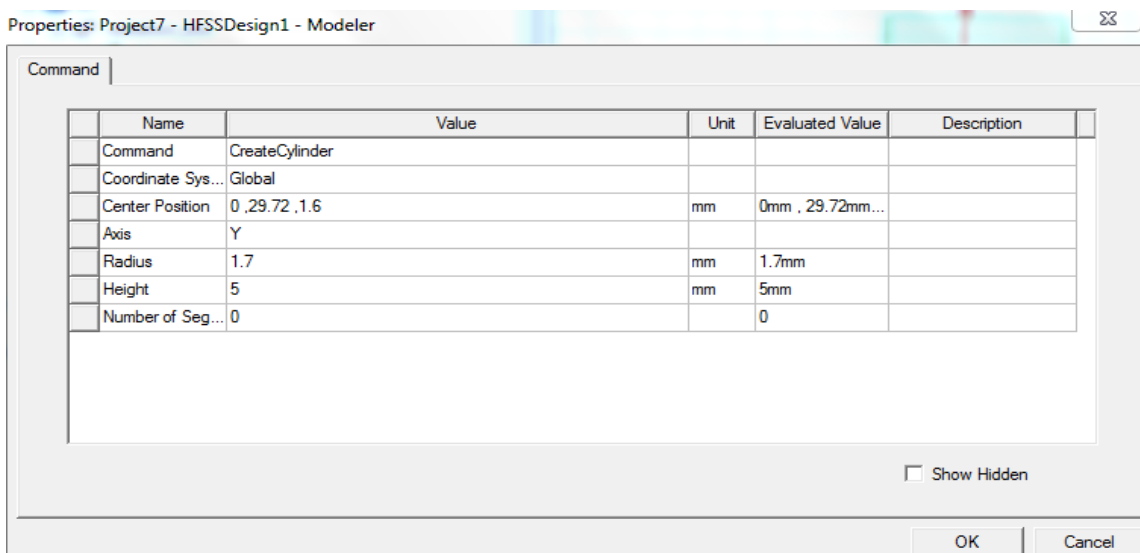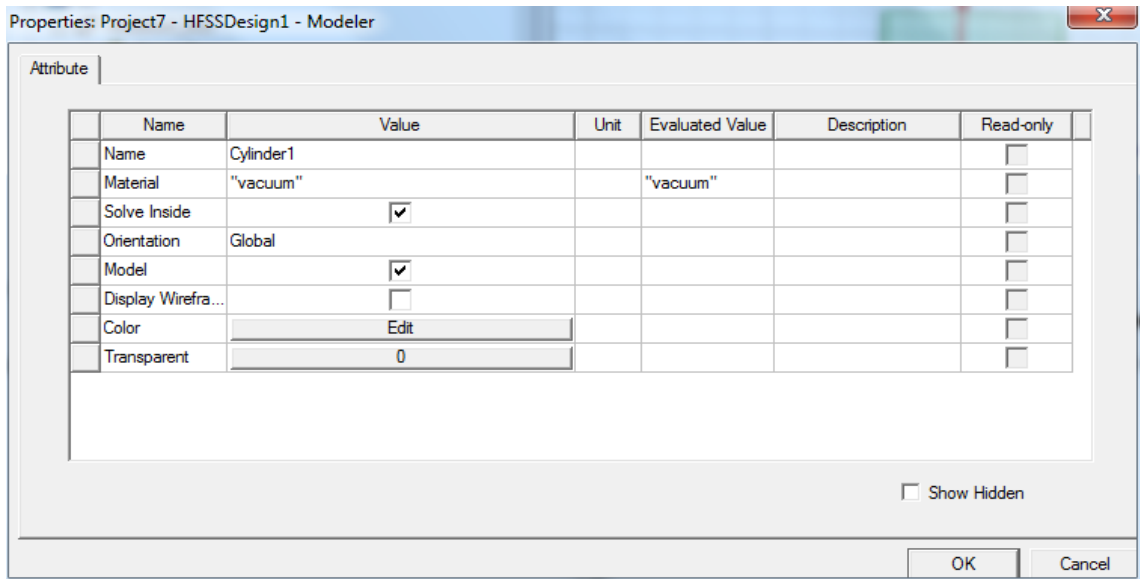|	Name	Value	Unit	Evaluated Value	Description	
	Command	CreateBox				
	Coordinate Sys...	Global				
	Position	-25 ,-20 ,0	mm	-25mm , -20mm ...		
	XSize	50	mm	50mm		
	YSize	49.72	mm	49.72mm		
	ZSize	1.6	mm	1.6mm		

☐ Show Hidden

OK   Cancel

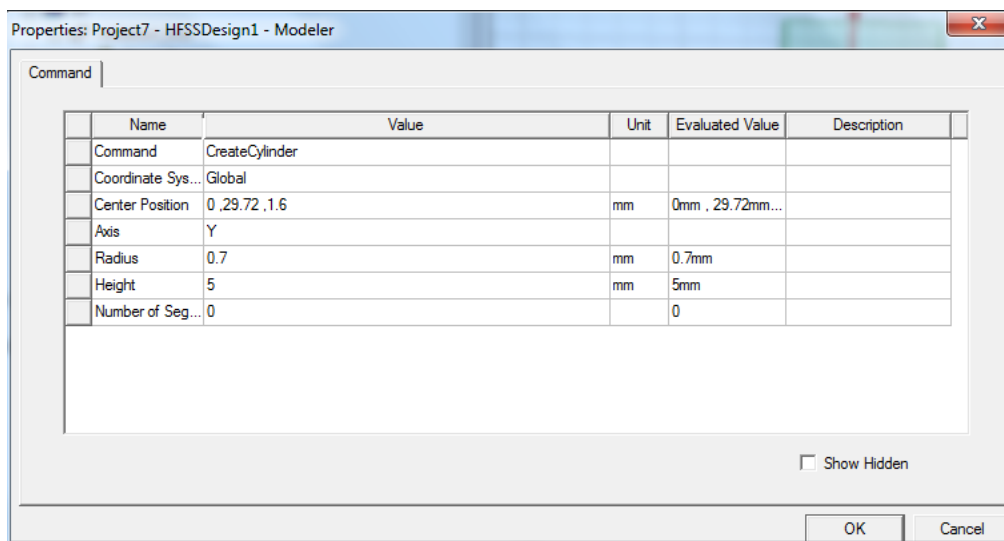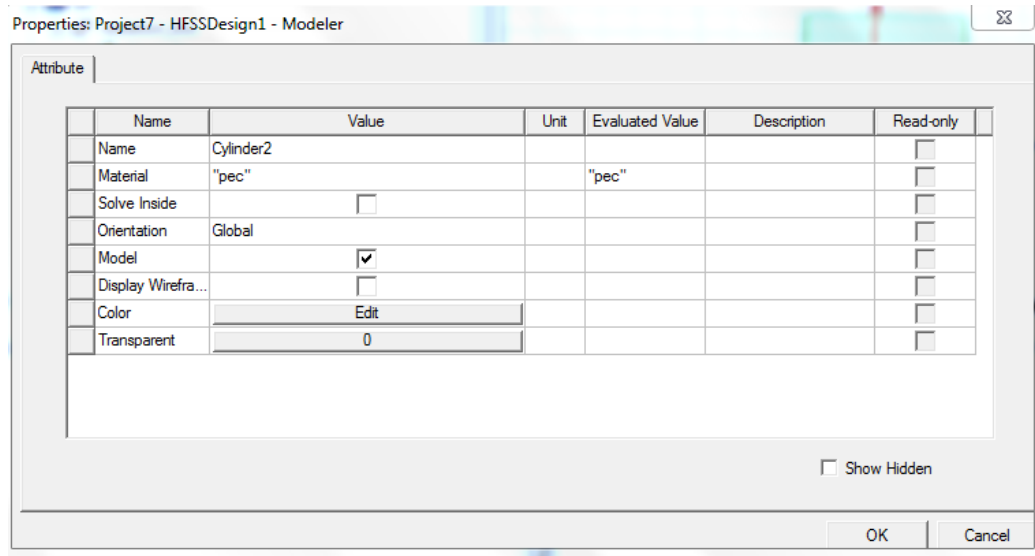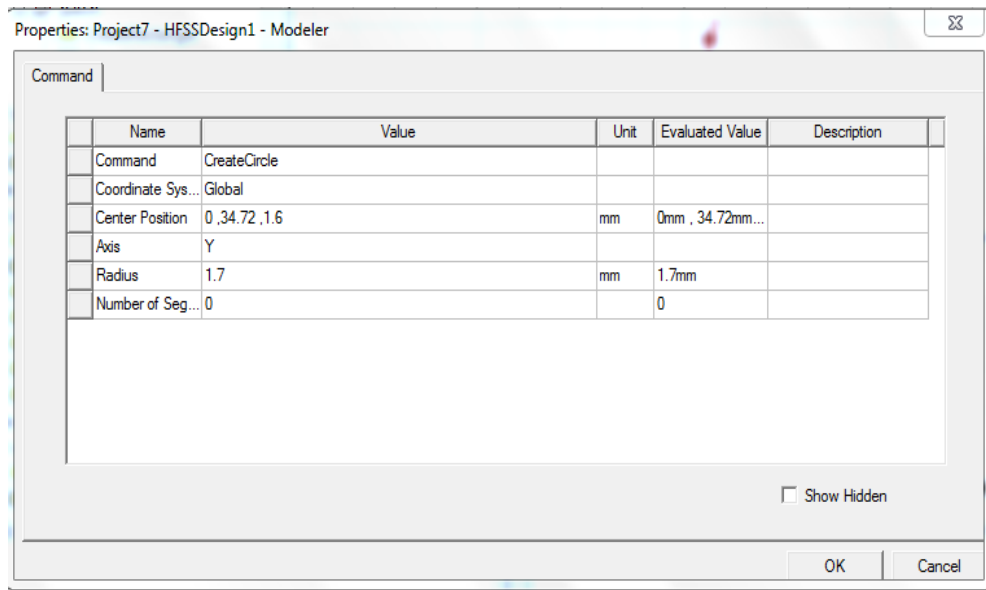## HFSS Command window For Patch:

HFSS Command Window for Feedline:
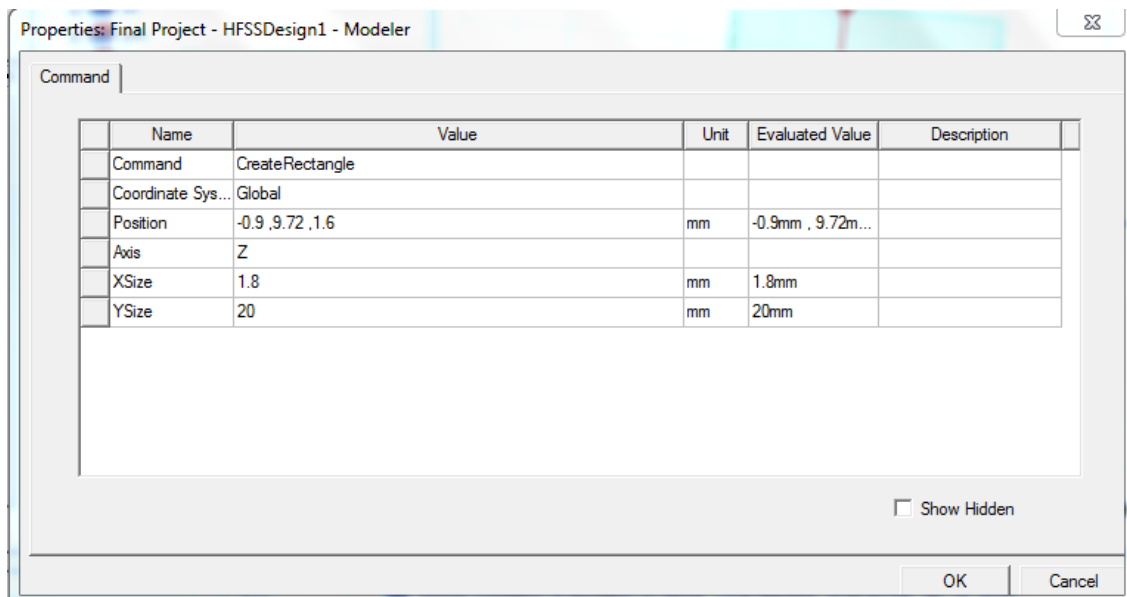
HFSS Attribute and Command Window for Cylinder 1:

HFSS Attribute and Command Window for Cylinder 2:

HFSS Command Window for Waveport:
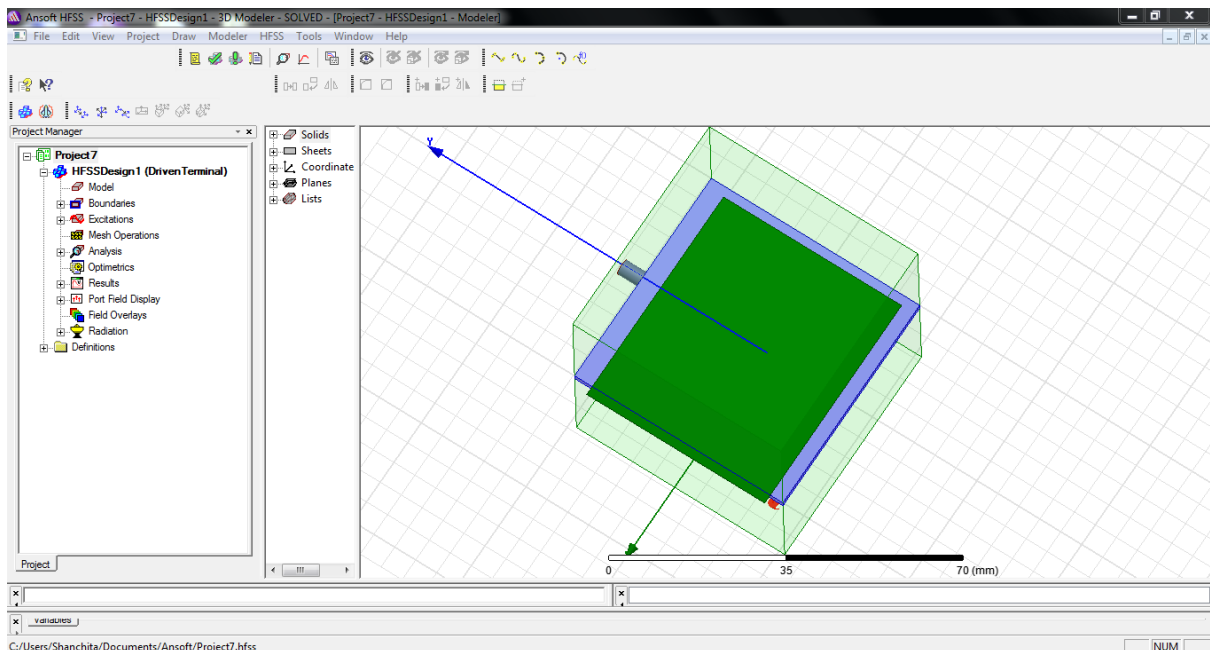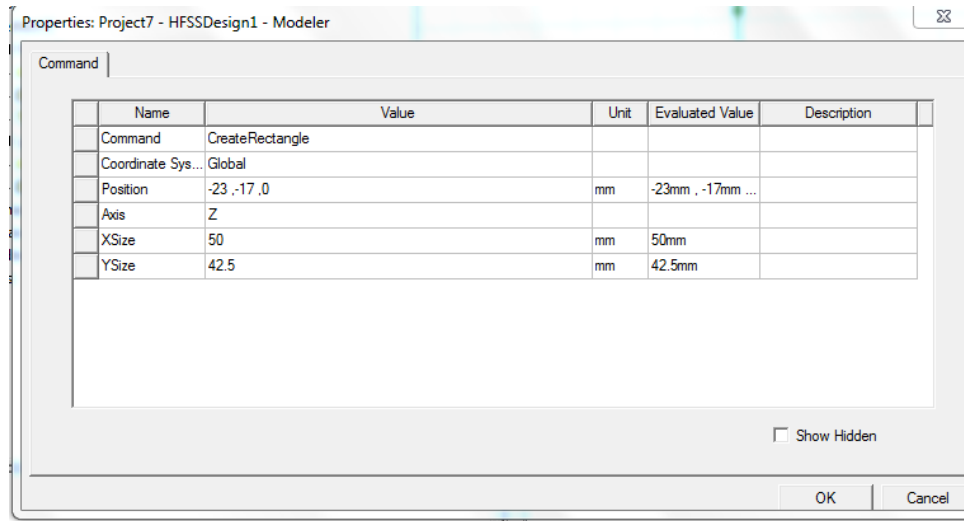

Ground Image:

Fig 6.2.3: Ground View

HFSS Command Window for Ground:
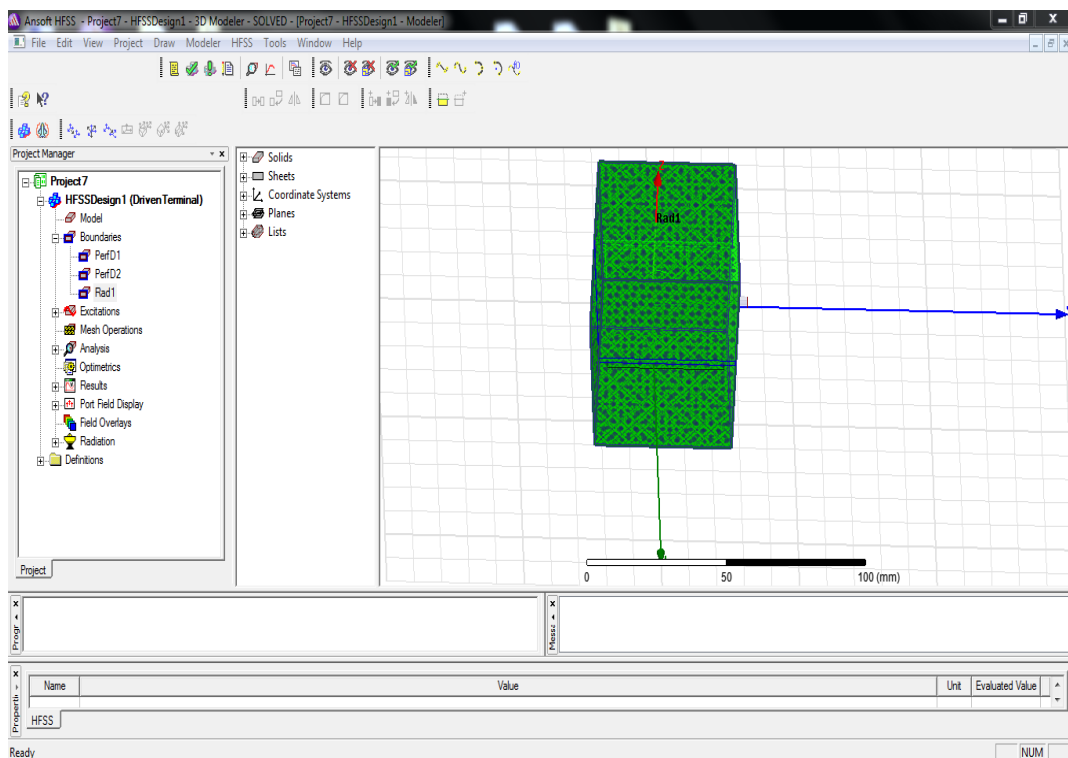

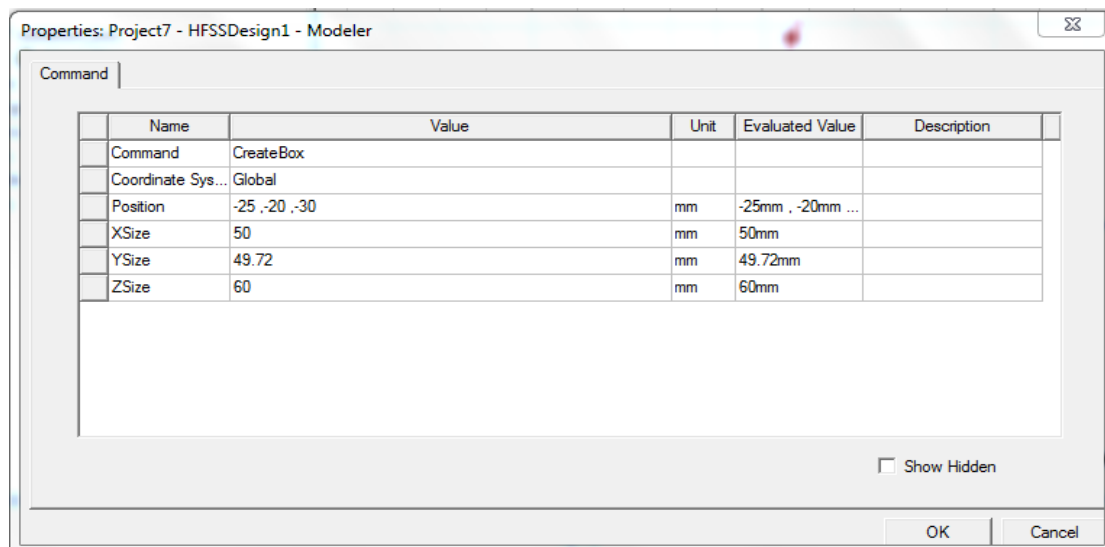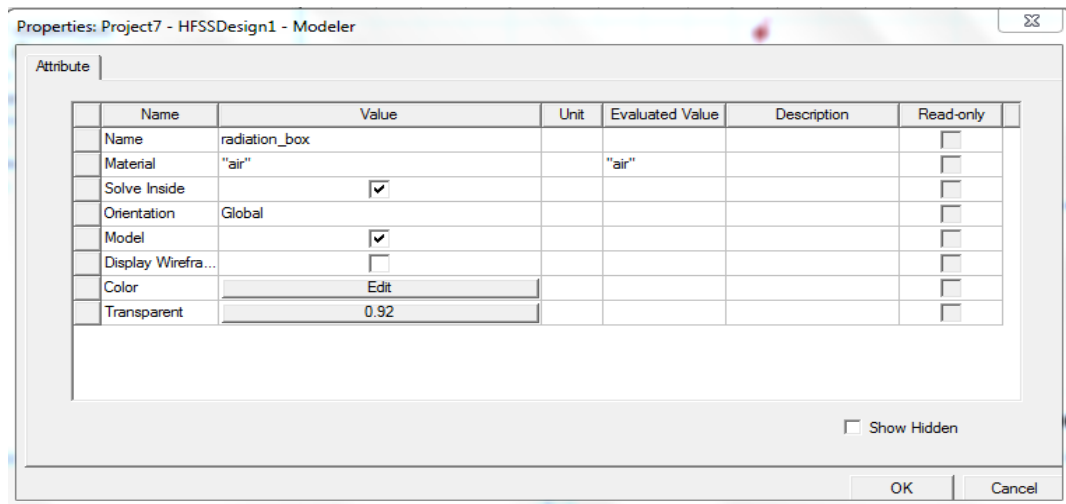
Radiation BOX Image:

Fig 6.2.4: Radiation Box (RAD1)

HFSS Attribute and Command Window for Radiation Box:

Using this require value we can get the perfect D over D shape Microstrip Patch Antenna for ultra-wide band application.

6.3: Simulated Results of Microstrip Patch Antenna:

6.3.1: Return Loss

During this simulation procedure you will get the microstrip patch antenna with dual band frequency for ultra-wide Band application. Here the Return loss graph on Ansoft HFSS shown in Fig 6.3
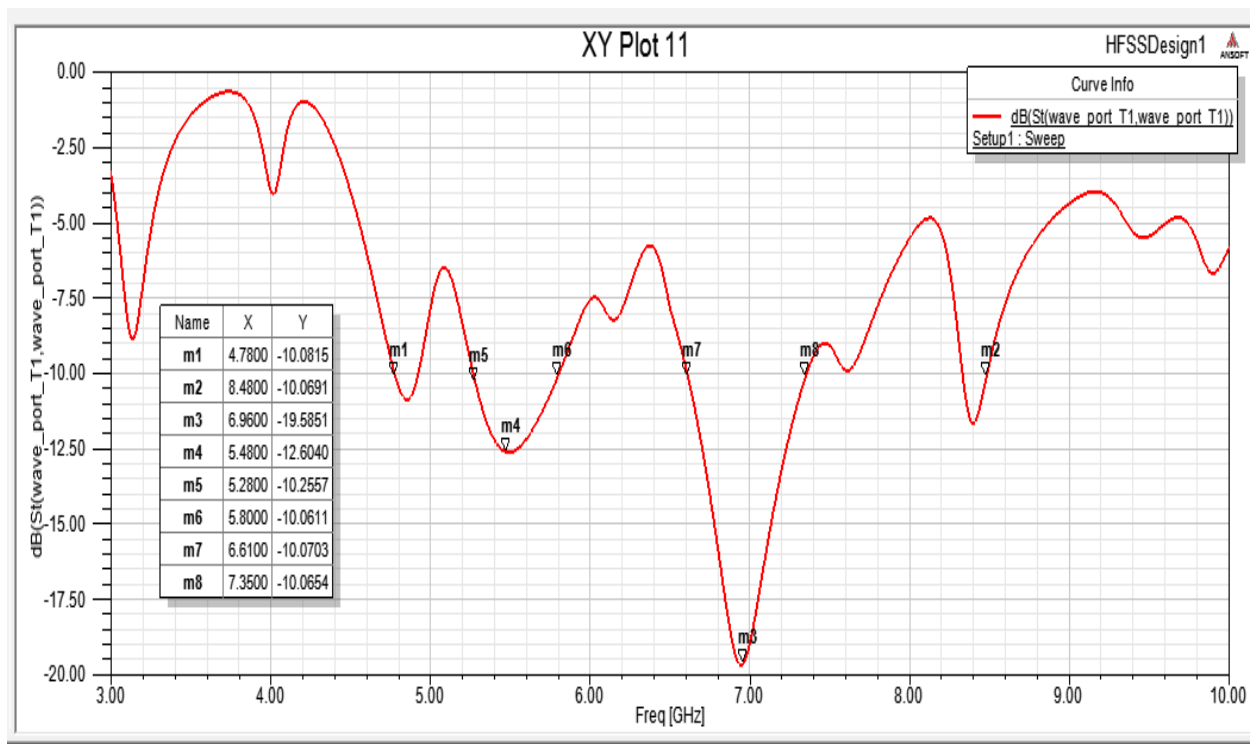

Fig 6.3.1: Return Loss of Microstrip Patch Antenna.
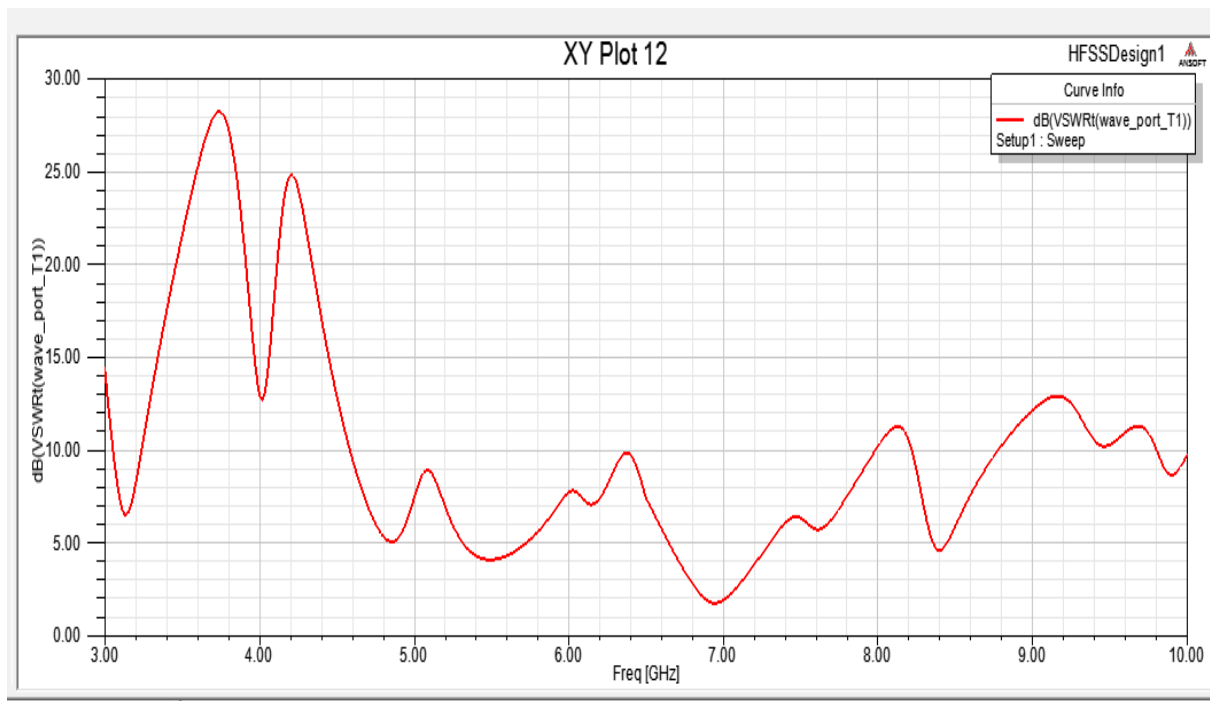
Here having the **Fig 6.3.2** of VSWR

Fig 6.3.2: Simulation Result of VSWR

Using the given equation in chapter-4 of Return Loss equation is -20log S_{11} of dual-band frequency for ultra-wide band application for this desire antenna are -25.83and 22.01 and we also can have the % of Bandwidth of this dual-band frequency of ultra-wide band application that is f_2-f_1/f_0*100 where f_2 is maximum frequency range,f_1 is minimum frequency range,f_0 is center frequency of both this maximum and minimum frequency range below -10 return loss curve is accepted, where f_0=f_1+f_2/2 .By using this equation we have the maximum Bandwidth (BW) which is 55.81% where $f_{1=}$4.78,f_2=8.48 and $f_{0=}$6.63.

The comparison of changing substrate thickness, Ground position and Feedline position we get this result from this desire antenna, the tables are given below to show how the changing of substrate thickness, feed position and ground position can effect to have this result:

Table 6.3: Data Sheet of Different Substrate Thickness of Rogers RT/duroid 5880 ™ for % of BW:

Material Name	Substrate Thickness (mm)	f_0	f_1	f_2	% of BW=$(f_2$-$f_1)$/f_0*100
Rogers RT/duroid 5880(tm)	0.5	8.2	7.02	9.1	25.8%
Rogers RT/duroid 5880(tm)	0.75	7.8	6.75	8.8	26.3%
Rogers RT/duroid 5880(tm)	1	7.4	6.36	8.4	27.6%
Rogers RT/duroid 5880(tm)	1.26	7.1	6.1	8.1	28.2%
Rogers RT/duroid 5880(tm)	1.6	6.62	4.79	8.44	55.14%
Rogers RT/duroid 5880(tm)	2	6.61	4.77	8.43	55.37%
Rogers RT/duroid 5880(tm)	2.26	5.78	4.77	6.79	34.87%

Table 6.4: Data sheet of Different ground position for % of BW

Material	Length(L)	Width(W)	Ground position	f_0	f_1	f_2	% Of BW=$(f_2-f_1)/f_0*100\%$
Sheet	25	25	-25,-20,0	6.61	7.1	8.45	17.74%
Sheet	45	22.5	-25,-20,0	7.7	7.18	8.28	15.33%
Sheet	45	42.5	-25,-20,0	6.32	5.5	7.14	25.94%
Sheet	50	49	-25,20,0	7.055	5.61	8.5	40.96%
Sheet	50	45	-23,-18,0	6.645	4.79	8.5	55.80%
Sheet	50	40	-22,-15,0	6.71	4.76	8.60	50%
Sheet	45	40	-21,15,0	7.73	4.70	8.67	51.36%
Sheet	50	42.5	-23,-17,0	6.63	4.78	8.48	55.81%

Table 6.5: Data Sheet of Different Feed Position for % BW

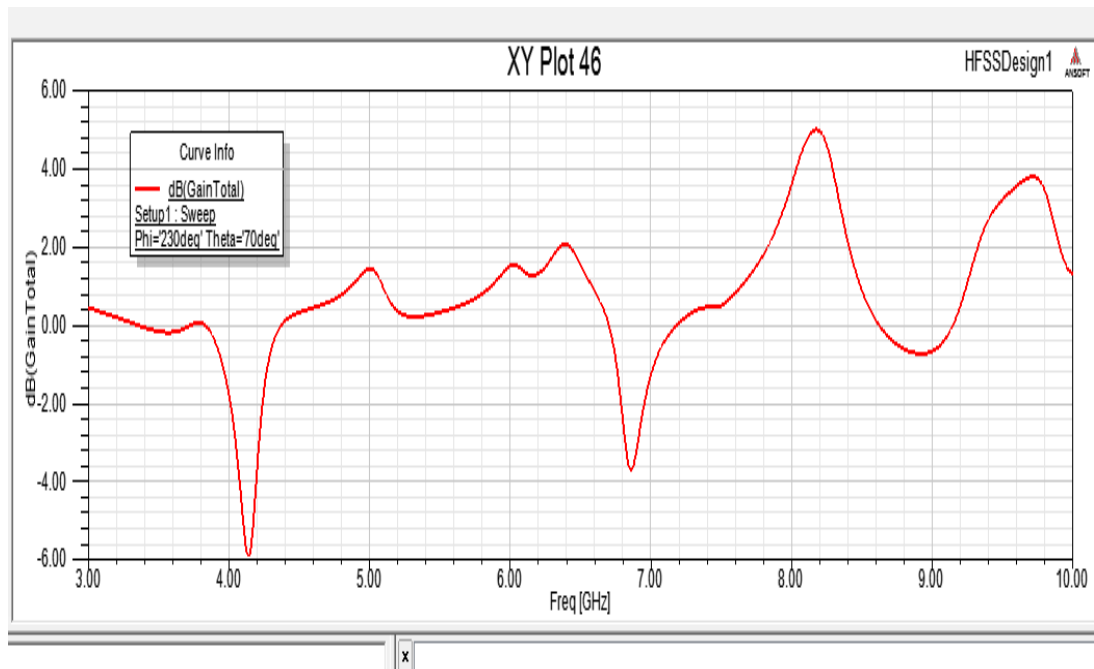| Material Name	Feed Position	f_0	f_1	f_2	% of BW=(f2-f1/f$_0$)*100
Pec	-1.55,11.5,1.6	6.635	5.35	7.38	31.8%
Pec	-1.5,10.5,1.6	6.635	4.8	8.47	55.31%
Pec	-1.25,11.5,1.6	6.68	4.84	8.52	55.09%
Pec	-1.25,10,1.6	6.79	4.92	8.66	55.08%
Pec	-1,9.9,1.6	6.64	4.79	8.49	55.72%
Pec	-0.9,9.72,1.6	6.63	4.78	8.48	55.81%
Pec	-0.7,10,1.6	6.62	4.79	8.45	55.14%

Gain:

Fig.6.3.3: Simulation result of gain.
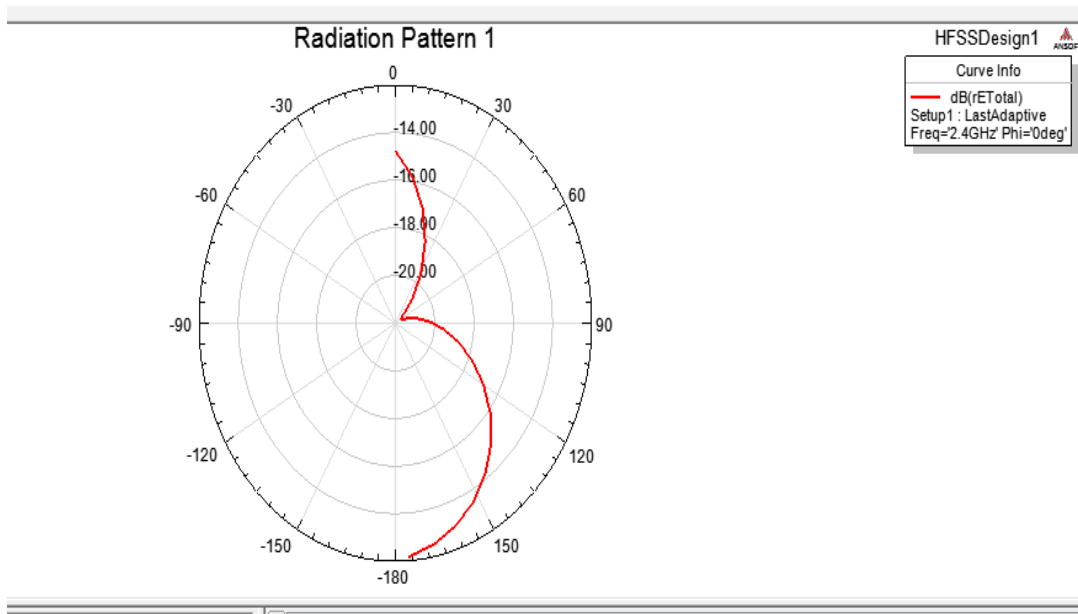
6.3.2: Radiation Pattern:

Fig.6.4: Radiation Pattern.
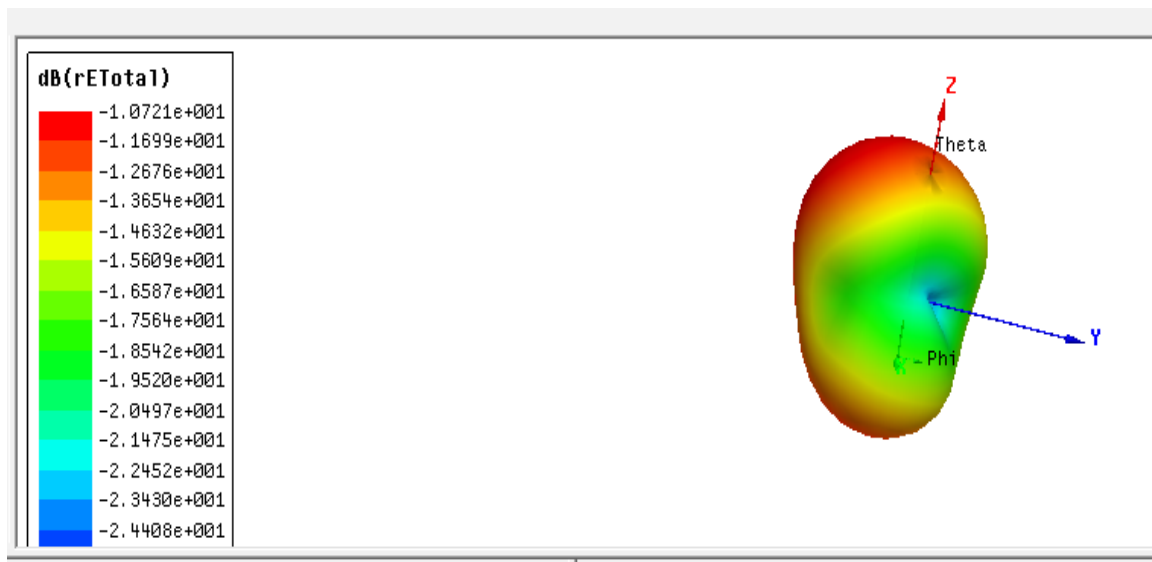
6.3.3: 3D radiation Pattern:

Fig.6.5: 3D polar plot for radiation Pattern on HFSS.
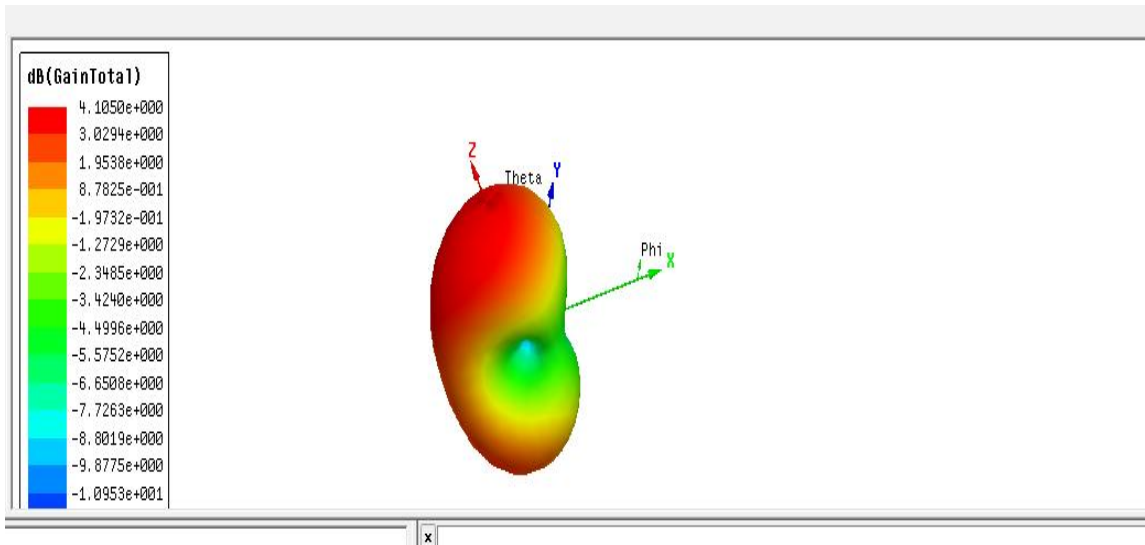
6.3.4: 3D Gain Total:

Fig 6.6: 3D Polar plot for Gain on HFSS.

This is the final output results of simulation having the clear concept of every material that is used to create this Microstrip Patch Antenna for ultra – wide band application for this D over D shape Antenna. Here the maximum % of Bandwidth is 55.81% ,return losses are 25.83-22.01 for its dual band nature, gain is around 2-5 dB and VSWR (voltage standing wave ratio) is ≤ 2 in its frequency range, so we can considered it as a good design of antenna having dual band .

Chapter 7

Conclusion

In This Thesis Paper we want to create a new shape to have better efficiency, better bandwidth, Return loss, gain to create an Antenna that will have every possible facility to give an excellent output using Ansoft HFSS. We use several materials to have a desire output that we have finally Rogers RT/duroid5880™ is given us a good result of dual band frequency at 4.78-8.48 having the Return loss at 25.83-22.01 with maximum % of BW is 55.81 % and gain is about 2-5 dB. During this Antenna design we have faced a lot of problems to have this output. We have to oversee several things like we have to change the thickness of substrate, feed line position, Ground position and parameters of Antenna to have this desire Result. Major parameters such as Return loss,VSWR, Radiation Pattern, Gain, and Bandwidth is good enough to create this D over D shape Antenna having Performance analysis of Microstrip Patch Antenna for ultra-wide band Application which can be used in several wireless application like Router,WI-FI,Modem,WLAN and many other.

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