



EAST WEST UNIVERSITY

Project title

**Performance Analysis of Microstrip Patch Antenna For
Ultra Wide Band Application.**

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DECLARATION

This declaration is to clarify that all of the submitted contents of this project are original in its figure, excluding those, which have been admitted specifically in the references. All the work process involved is from my own idea and creativity. All contents of this project have been submitted as a part of partial fulfillment of Bachelor of Electronics & Communications Engineering. I hereby declare that this project is the work of my own excluded for the references document and summaries that have been acknowledge.

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ABSTRACT

The study of microstrip patch antennas has made great progress in recent years. Compared with conventional antennas, microstrip patch antennas have more advantages and better prospects. They are lighter in weight, low volume, low cost, low profile, smaller in dimension and ease of fabrication and conformity. Moreover, the microstrip patch antennas can provide dual and circular polarizations, dual-frequency operation, frequency agility, broad band-width, feedline flexibility, beam scanning omnidirectional patterning. In this paper we discuss the microstrip antenna, types of microstrip antenna, feeding techniques and application of microstrip patch antenna with their advantage and disadvantages over conventional microwave antennas.

Key Words: Microstrip Antenna (MSA), Microstrip patch antenna (MPA), Feeding techniques.

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Chapter-1

1.1 Introduction

Antenna is a transducer designed to transmit or receive electromagnetic waves. Microstrip antennas have several advantages over conventional microwave antenna and therefore are widely used in many practical applications. Microstrip antennas in its simplest configuration are shown in Fig1. It consists of a radiating patch on one side of dielectric substrate ($\epsilon_r \leq 10$), which has a ground plane on other side.

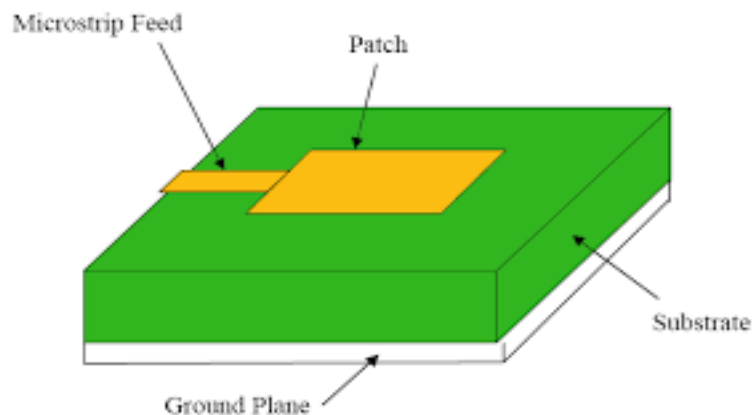


Fig 1.1: Microstrip antenna configuration

1.2 Antenna

Antenna is a transition device or transducer between a free-space wave and a guided wave and vice-versa. Transmission lines or waveguides are designed to minimize radiation whereas, antenna is designed to radiate or receive energy as efficiently as possible. Antenna (like the eye) converts electromagnetic photons into electric currents. Unlike the eye, antenna can also convert electric energy from a circuit into photons radiated into space.

An antenna is used to radiate electromagnetic energy efficiently and in desired directions. Antennas act as matching systems between sources of electromagnetic energy and space. The goal in using antennas is to optimize this matching

1.3 Classification of Antenna

On the basis of radiation there are three types of antenna. These are –

1. **Isotropic:** A hypothetical lossless antenna having equal radiations in all directions. These antennas don't exist in practice, but are sometimes discussed as a means of comparison with real antennas.
2. **Omnidirectional:** Some antennas may also be described as "omnidirectional", which for an actual means that it is isotropic in a single plane.
3. **Directional:** A directional antenna is one having property of receiving or radiating electromagnetic energy more effectively in some particular direction than in others.

On the basis of physical structure there are five types of antenna

1. Wire Antenna

- Dipole antenna
- Monopole
- Helix antenna
- Loop antenna (may be rectangular, circular, elliptical etc).

2. Aperture Antenna

- Horn antenna
- Rectangular waveguide

3. Planar Antenna

- Microstrip patch antenna,
- Planar Inverted F- Antenna
- Dual Inverted F-Antenna
- Planar L-Antenna

4. Reflector antenna

- High Gain Antenna
- Dimensions much larger
- Used for long distance (millions of miles) communication

5. Array antenna

- To achieve
- Desired radiation pattern
- High Directivity

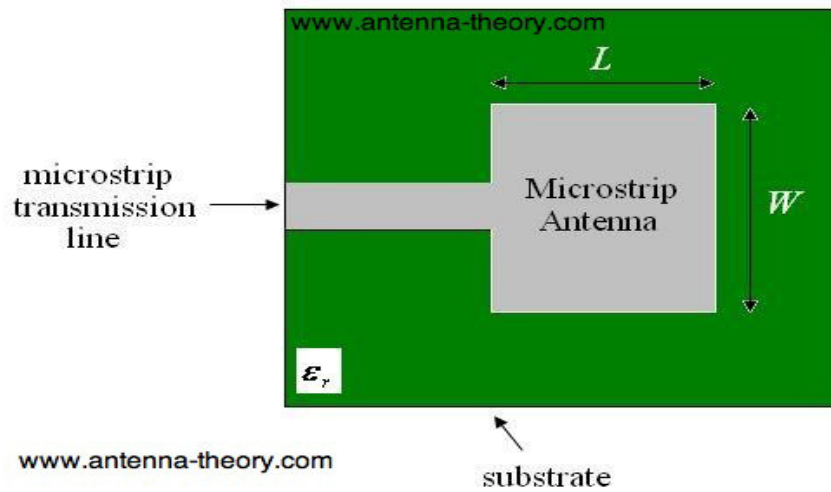
Chapter-2

Patch Antenna

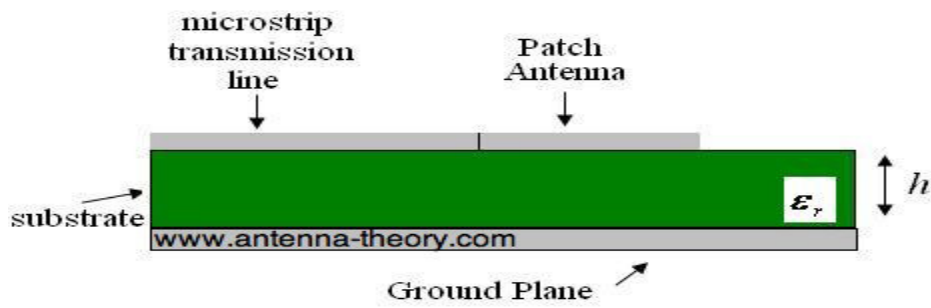
2.1 Patch Antenna: Microstrip patch Antennas (also just called *patchantennas*) are among the most common antenna types in use today, particularly in the popular frequency range of 1 to 6 GHz. This type of antenna had its first intense development in the 1970s, as communication systems became common at frequencies where its size and performance were very useful.

A microstrip patch antenna (MPA) consists of a conducting patch of any planar or nonplanar geometry on one side of a dielectric substrate with a ground plane on other side. It is a popular printed resonant antenna for narrow-band microwave wireless links that require semihemispherical coverage. Due to its planar configuration and ease of integration with microstrip technology, the microstrip patch antenna has been heavily studied and is often used as elements for an array. A large number of microstrip patch antennas have been studied to date. An exhaustive list of the geometries along with their salient features is available [1]. The rectangular and circular patches are the basic and most commonly used microstrip antennas. These patches are used for the simplest and the most demanding applications. Rectangular geometries are separable in nature and their analysis is also simple. The circular patch antenna has the advantage of their radiation

Microstrip or patch antennas are becoming increasingly useful because they can be printed directly onto a circuit board. Microstrip antennas are becoming very widespread within the mobile phone market. Patch antennas are low cost, have a low profile and are easily fabricated. Consider the microstrip antenna shown in Figure 2.1, fed by a microstrip transmission line. The patch antenna, microstrip transmission line and ground plane are made of high conductivity metal (typically copper). The patch is of length L , width W , and sitting on top of a substrate (some dielectric circuit board) of thickness h with permittivity ϵ_r . The thickness of the ground plane or of the microstrip is not critically important. Typically the height h is much smaller than



a) Top view of the patch antenna



b) Side view of the patch antenna

Fig 2.1: Geomtry of Patch Antenna

2.2 History of patch Antenna

Microstrip antenna was first introduced in the 1950s. However, this concept had to wait for about 20 years to be realized after the development of the printed circuit board (PCB) technology in the 1970s. Since then, microstrip antennas are the most common types of antennas with wide range of applications due to their apparent advantages of light weight, low profile, low cost, planar configuration, easy of conformal, superior portability, suitable for array with the ease of fabrication and integration with microwave monolithic integrate circuits (MMICs). They have been widely engaged for the civilian and military applications such as radio-frequency identification (RFID), broadcast radio, mobile systems, global positioning system (GPS), television, multiple-input multiple-output (MIMO) systems, vehicle collision avoidance system, satellite communications, surveillance systems, direction founding, radar systems, remote sensing, missile guidance, and so on.

2.3 Geomategy of Patch Antenna

Micro strip patch antenna consists of radiation patch, dielectric substrate and ground plan as shown in figure 2.2.

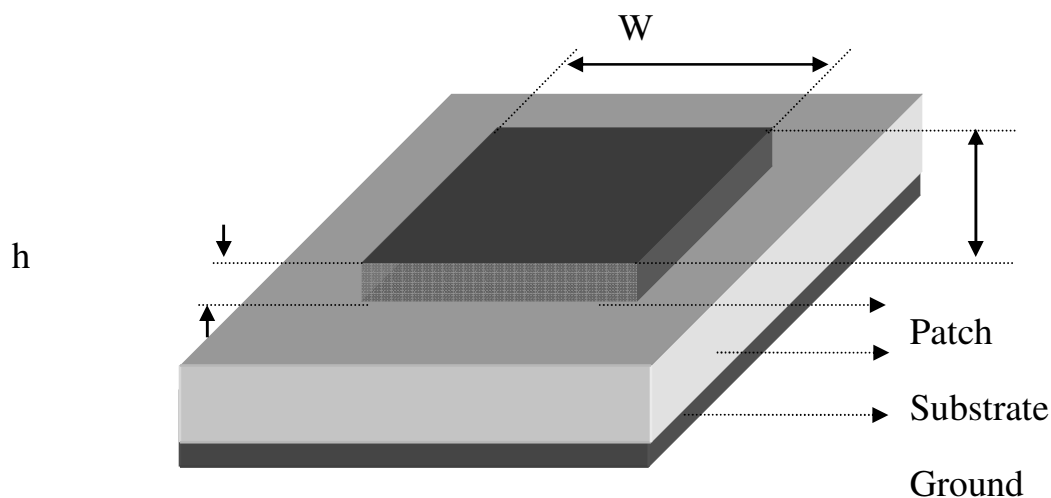


Fig 2.2: Structure of a Micro strip Patch Antenna.

The following figure shows a patch antenna in its basic architecture. The patch and the ground plane are separated by a dielectric material. A flat plate over a ground plane and

then the dielectric substrate at the center and the patch is at the top. The patch and the ground plane are generally conducting materials such as gold, copper and the patch can be any shape as the design specification. The feed line is used to feed the patch. There are many different types of feeding techniques. Usually, the patch and the feed line are photo etched to the substrate.

The radiating patch can be square, rectangular, circular, triangular, elliptical, circular ring and dipole and so on.

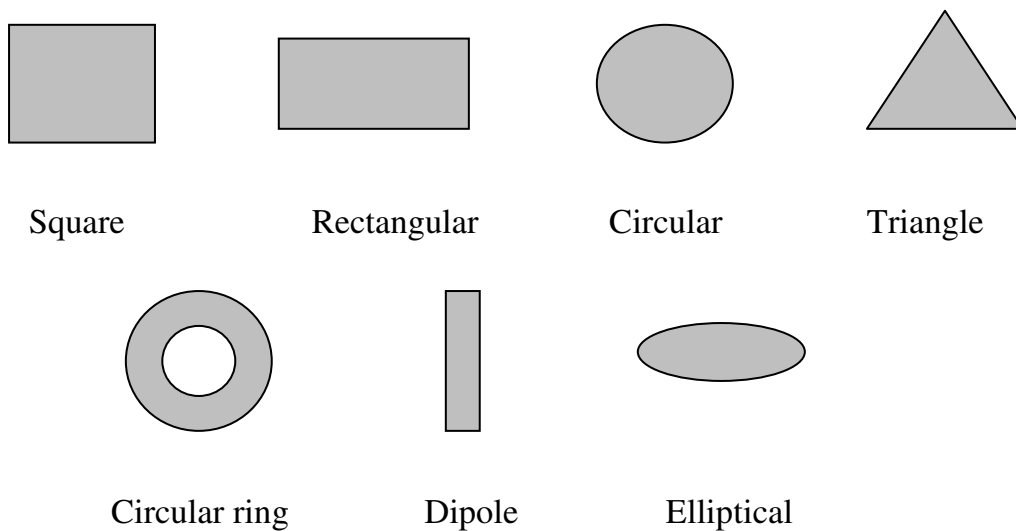


Fig 2.3: Common shapes of micro strip patch elements.

2.4 Advantage And Disadvantage of patch antenna

Microstrip Patch antennas are widely used in today's era. It is used in satellite communication, military purposes, GPS, mobile, missile systems etc as due to its compact shape and light weight, less complexity and easy to implement. Some of its advantages and disadvantages in the book by Waterhouse (2003) are as follows are given below.

A) Advantage

- Easy of manufacturing
- It has a very low fabrication cost
- Microstrip patch antenna is efficient radiator.
- It has a support for both linear and circular polarization
- Easy in integration with microwave integration circuit

B) Disadvantage

- Low impedance bandwidth
- Low Gain
- Extra radiation occurs from its feed and junctions
- Excitation of surface wave
- Size of micro strip antenna comes in both advantage and disadvantage but there are some application where the micro strip antenna size is too large to be used.

2.5 Applications

The microstrip patch antennas are famous for their performance and robust design. Microstrip patch antennas have applications in various fields such as in the medical field, satellites and even in the military systems just like in the rockets, aircrafts missiles and many more. Now they are booming in the commercial aspects due to their low cost of the substrate material and the fabrication. Microstrip patch antenna has a number of applications. Some of these applications are discussed as

- **Mobile and satellite communication application:** Mobile communication requires small, low profile, low cost antennas. Microstrip patch antenna meets all the necessities and a number of microstrip antennas have been designed for use in mobile communication systems. In case of satellite communication, circularly polarized radiation patterns are required and can be realized using either square or circular patch with one or two feed point.

- **Global positioning system applications:** Microstrip patch antennas having high permittivity sintered substrate material for global positioning system (GPS). These antennas are circularly polarized, very compact
- **Radio frequency identification (RFID):** RFID is used in different areas like mobile communication, logistics, manufacturing, transportation and health care. RFID system generally uses frequencies between 30 Hz and 5.8 GHz depending on its applications. Basically RFID system is a tag or transponder and a transceiver or reader.
- **Reduced size microstrip patch antenna for Bluetooth applications:** In this, the microstrip antenna operates in the 2400 to 2484 MHz ISM Band. Although an air substrate is introduced, microstrip antenna occupies a small volume of $33.3 \times 6.6 \times 0.8$.
- **Interoperability for microwave access (WiMax):** The IEEE 802.16 standard is known as WiMax. It can reach up to 30 mile radius theoretically and data rate 70 Mbps. Microstrip patch antenna generates three resonant modes at 2.7, 3.3 and 5.3 GHz and can, therefore, be used in WiMax compliant communication equipment. In the wireless communication, networking, aerospace & defense industries. For WiMAX, LTE, multi-gigabit per second data links, radar, & satellite applications, ADS provides full, standards-based design and verification with Wireless Libraries and circuit-system-EM co-simulation in an integrated platform.
- **Broadband microstrip S-shaped patch antenna for wireless communication:** This is a single-patch broadband microstrip S-shaped patch antenna. Microstrip Sshaped patch antenna is fed by a coaxial feeding. The antenna is designed by inserting two slots into rotated square patch then it look like English letter 'S'. Because of the slots and thick substrate, bandwidth of antenna is increased.
- **Radar application:** Radar can be used for detecting moving targets such as people and vehicles. The microstrip antennas are an ideal choice. The fabrication technology based on photolithography enables the bulk production of microstrip antenna with repeatable performance at a lower cost in a lesser time frame as compared to the conventional antennas.

Chapter 3

Feeding method of the patch Antenna

3.1 Feed Techniques

Microstrip patch antennas can be fed by a variety of methods. These methods can be classified into two categories- contacting and non-contacting. In the contacting method, the RF power is fed directly to the radiating patch using a connecting element such as a microstrip line. In the non-contacting scheme, electromagnetic field coupling is done to transfer power between the microstrip line and the radiating patch. The four most popular feed techniques used are the microstrip line, coaxial probe (both contacting schemes), aperture coupling and proximity coupling (both non-contacting schemes).

3.2 Coaxial Feed

The Coaxial feed or probe feed is a very common technique used for feeding Microstrip patch antennas. As seen from Figure 3.1, the inner conductor of the coaxial connector extends through the dielectric and is soldered to the radiating patch, while the outer conductor is connected to the ground plane.

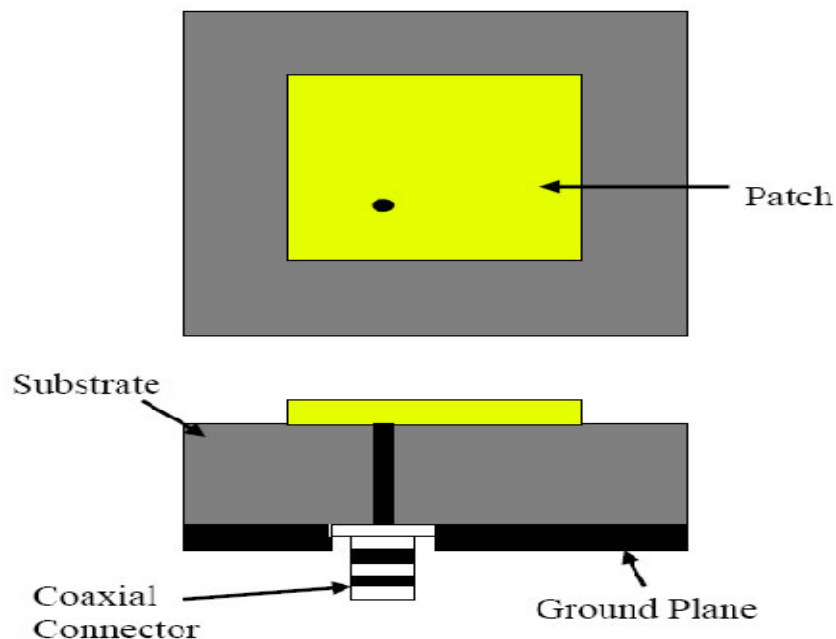


Figure 3.1 Probe fed Rectangular Microstrip Patch Antenna

The main advantage of this type of feeding scheme is that the feed can be placed at any desired location inside the patch in order to match with its input impedance. This feed method is easy to fabricate and has low spurious radiation. However, a major disadvantage is that it provides narrow bandwidth and is difficult to model since a hole has to be drilled in the substrate and the connector protrudes outside the ground plane, thus not making it completely planar for thick substrates ($h > 0.02\lambda_0$). Also, for thicker substrates, the increased probe length makes the input impedance more inductive, leading to matching problems. It is seen above that for a thick dielectric substrate, which provides broad bandwidth, the microstrip line feed and the coaxial feed suffer from numerous disadvantages. The non-contacting feed techniques which have been discussed below, solve these issues.

3.3 Aperture Coupled Feed

In this type of feed technique, the radiating patch and the microstrip feed line are separated by the ground plane as shown in Figure 3.2. Coupling between the patch and the feed line is made through a slot or an aperture in the ground plane

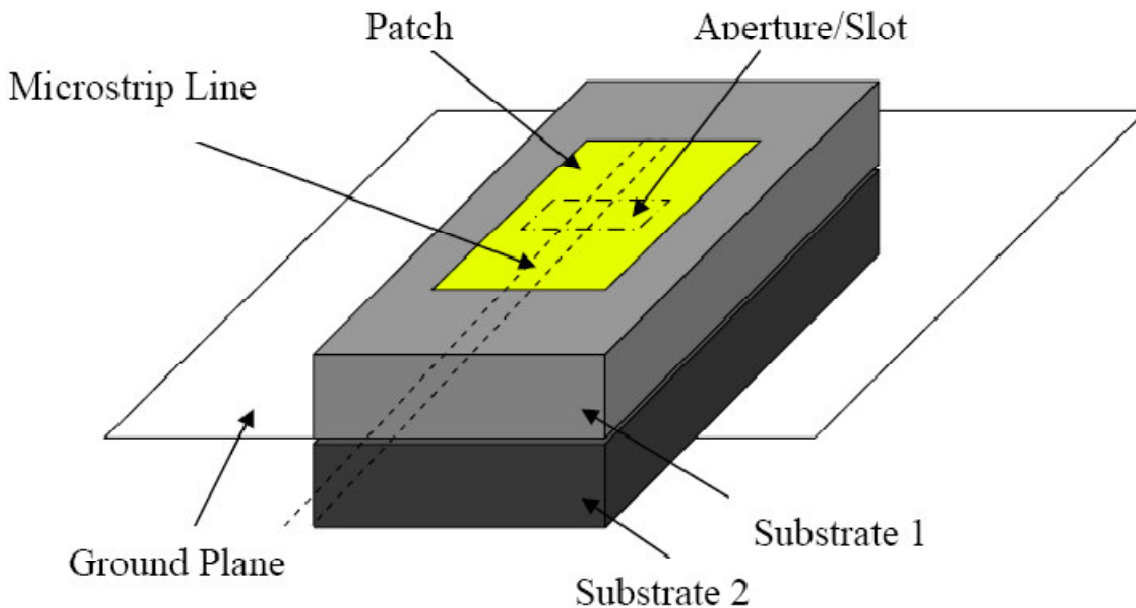


Figure 3.2 Aperture-coupled feed

The coupling aperture is usually centered under the patch, leading to lower cross polarization due to symmetry of the configuration. The amount of coupling from the feed

line to the patch is determined by the shape, size and location of the aperture. Since the ground plane separates the patch and the feed line, spurious radiation is minimized. Generally, a high dielectric material is used for bottom substrate and a thick, low dielectric constant material is used for the top substrate to optimize radiation from the patch. The major disadvantage of this feed technique is that it is difficult to fabricate due to multiple layers, which also increases the antenna thickness. This feeding scheme also provides narrow bandwidth.

3.4 Proximity Coupled Feed

This type of feed technique is also called as the electromagnetic coupling scheme. As shown in Figure 3.3, two dielectric substrates are used such that the feed line is between the two substrates and the radiating patch is on top of the upper substrate. The main advantage of this feed technique is that it eliminates spurious feed radiation and provides very high bandwidth (as high as 13%), due to overall increase in the thickness of the microstrip patch antenna. This scheme also provides choices between two different dielectric media, one for the patch and one for the feed line to optimize the individual performances.

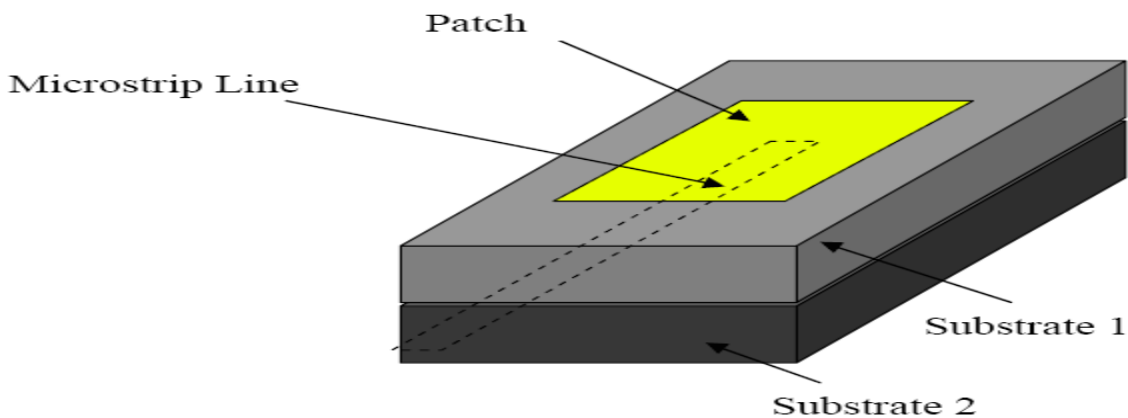


Figure 3.3 Proximity-coupled Feed

Matching can be achieved by controlling the length of the feed line and the width to-line ratio of the patch. The major disadvantage of this feed scheme is that it is difficult to fabricate because of the two dielectric layers which need proper alignment. Also, there is an increase in the overall thickness of the antenna.

CHAPTER 4

Patch Antenna parameter

Antenna Parameters

Antenna parameters are used to characterize performance of an antenna when designing and measuring antennas. In this Section, terms like bandwidth, radiation pattern, gain, polarization, and input impedance are explained.

4.1 Bandwidth: Bandwidth of an antenna can be defined as the range of frequencies within which the performance of the antenna, with respect to some characteristics conforms to a specific standard.

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: A radiation pattern defines the variation of the power radiated by an antenna as a function of the direction away from the antenna. This power variation as a function of the arrival angle is observed in the far field. 3- Dimensional radiation pattern in decibels.

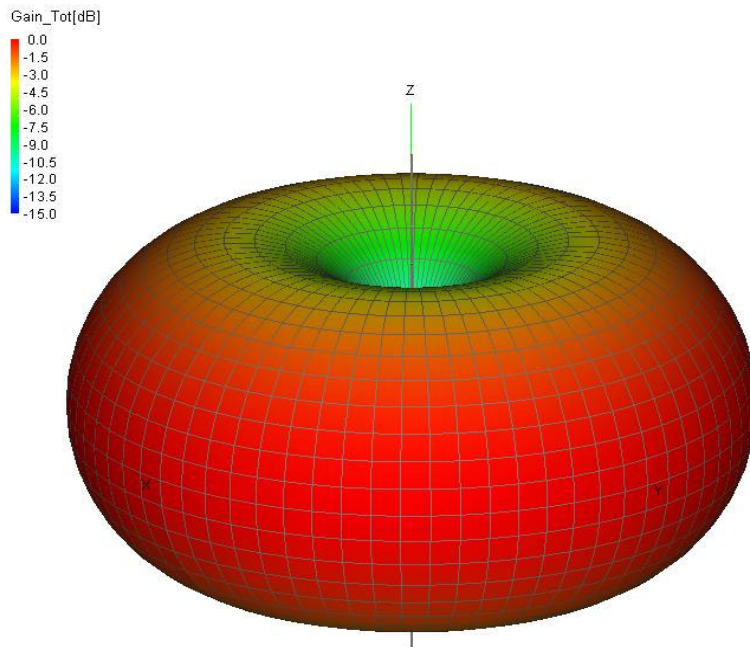


Figure 4.1 3D Radiation Pattern

Along the z-axis, which would correspond to the radiation directly overhead the antenna, there is very little power transmitted.

In the x-y plane (perpendicular to the z-axis), the radiation is maximum.

The radiation patterns are plotted in 2D. In this case, the patterns are given as "slices" through the 3D plane. Standard spherical coordinates are used, where θ is the angle measured off the z-axis, and ϕ is the angle measured counterclockwise off the x-axis.

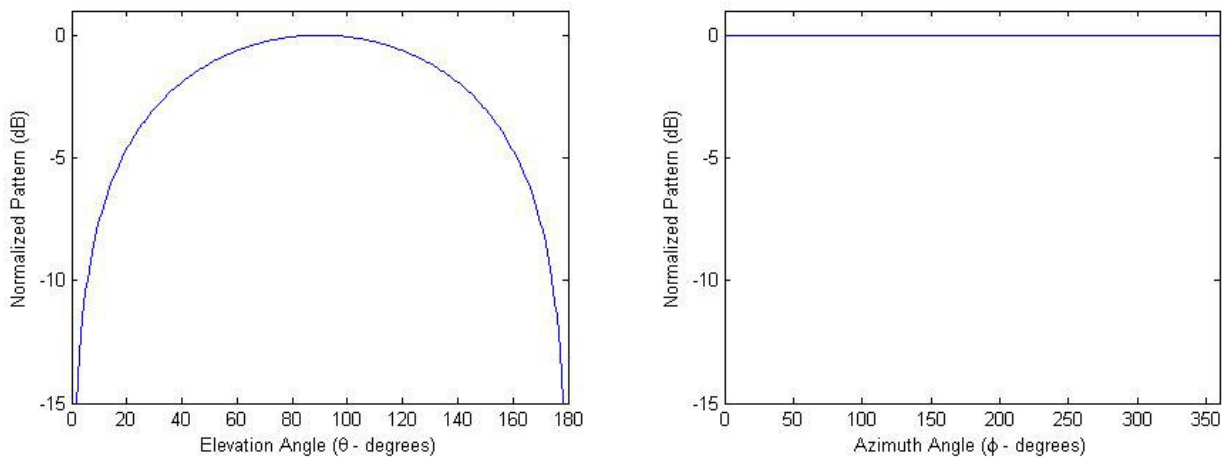


Figure 4.2 2D Radiation Pattern

4.3 Radiation Intensity

It is defined as the power radiated from an antenna source in a given direction per unit solid angle. It is a far field parameter and it can be obtained by multiplying the radiation density by square of distance from the antenna.

$$U = r^2 W_{rad} = \frac{P}{4\pi}$$

where

r : distance from the antenna (m)

W_{rad} : Radiation density (W/m^2)

U : Radiation intensity/ Poynting vector (W/sr)

P : Radiated power (W)

$$W_{rad} = \frac{1}{2} \text{Re}[\bar{\mathbf{E}} \times \bar{\mathbf{H}}] = \frac{P}{4\pi r^2}$$

4.3 Directivity

Directivity is defined as the ratio of radiation intensity in a given direction (maximum radiation intensity) from an antenna to the radiation intensity averaged over all directions.

The average radiation intensity is equal to the total power radiated by the antenna divided by 4π .

$$D = \frac{U_{\max}}{U_{\text{avg}}} = \frac{U_{\max}}{P/4\pi}$$

$$D = \frac{4\pi U_{\max}}{P_{\text{rad}}} \text{ (dimensionless)}$$

P_{rad} : Average radiated power (W)

4.4 Antenna Gain

Gain is defined as the ratio of radiation intensity in a given direction to the radiation intensity that would be obtained if the power accepted by the antenna were radiated isotropically.

$$G = 4\pi \frac{\text{radiation intensity}}{\text{total input power}} = 4\pi \frac{U}{P_{\text{in}}}$$

$$P_{\text{rad}} = \eta P_{\text{in}}$$

$$G = 4\pi \frac{\eta U}{P_{\text{rad}}} = \eta D$$

Where

η : Antenna efficiency

4.5 Input Impedance

The input impedance of an antenna is defined as “the impedance presented by an antenna at its terminals or the ratio of the voltage to the current at the pair of terminals or the ratio of the appropriate components of the electric to magnetic fields at a point”.

4.6 VSWR/Return loss

VSWR or Return Loss determines the matching properties of antenna. It indicates that how much efficiently antenna is transmitting/receiving electromagnetic wave over particular band of frequencies.

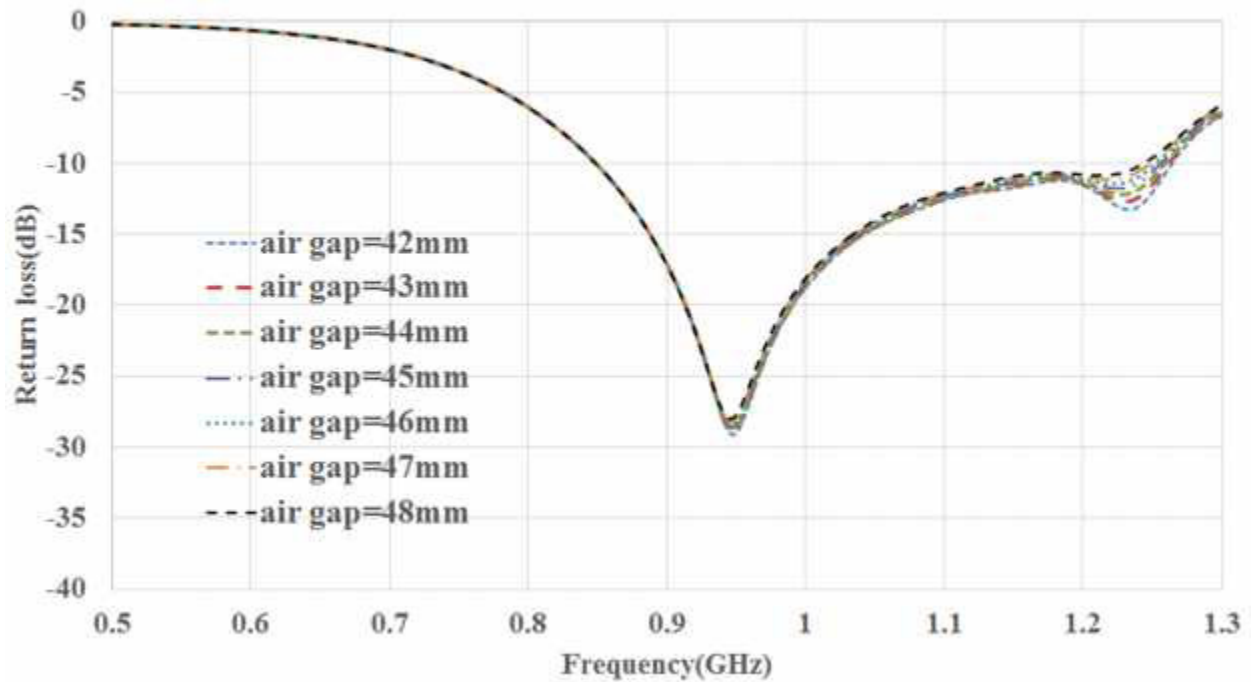


Figure 4.3 Frequency VS Return Loss

CHAPTER 5

Methods of Analysis

The preferred models for the analysis of Microstrip patch antennas are the transmission line model, cavity model, and full wave model (which include primarily integral equations/Moment Method). The transmission line model is the simplest of all and it gives good physical insight but it is less accurate. The cavity model is more accurate and gives good physical insight but is complex in nature. The full wave models are extremely accurate, versatile and can treat single elements, finite and infinite arrays, stacked elements, arbitrary shaped elements and coupling. These give less insight as compared to the two models mentioned above and are far more complex in nature.

5.1 Transmission Line Model

This model represents the microstrip antenna by two slots of width W and height h , separated by a transmission line of length L . The microstrip is essentially a nonhomogeneous line of two dielectrics, typically the substrate and air.

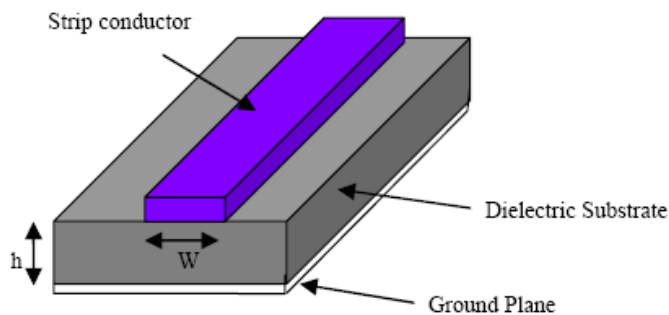


Figure 5.1: Microstrip Line

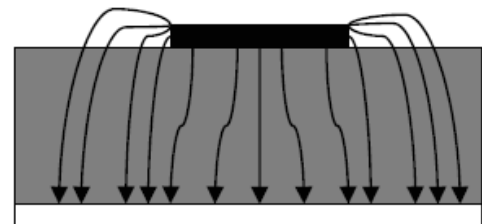


Figure 5.2: Electric Field Line

Hence, as seen from Figure 5.1, most of the electric field lines reside in the substrate and parts of some lines in air. As a result, this transmission line cannot support pure transverse-electric-magnetic (TEM) mode of transmission, since the phase velocities would be different in the air and the substrate. Instead, the dominant mode of propagation would be the quasi-TEM mode. Hence, an effective dielectric constant (ϵ_{eff}) must be

obtained in order to account for the fringing and the wave propagation in the line. The value of ϵ_{reff} is slightly less than ϵ_r because the fringing fields around the periphery of the patch are not confined in the dielectric substrate but are also spread in the air as shown in Figure 3.8 above. The expression for ϵ_{reff} is given by Balanis as:

$$\epsilon_{reff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left[1 + 12 \frac{h}{W} \right]^{-\frac{1}{2}} \dots\dots\dots 5.1$$

Where ϵ_{reff} = Effective dielectric constant
 ϵ_r = Dielectric constant of substrate
 h = Height of dielectric substrate
 W = Width of the patch

Consider Figure 5.3 below, which shows a rectangular microstrip patch antenna of length L , width W resting on a substrate of height h . The co-ordinate axis is selected such that the length is along the x direction, width is along the y direction and the height is along the z direction.

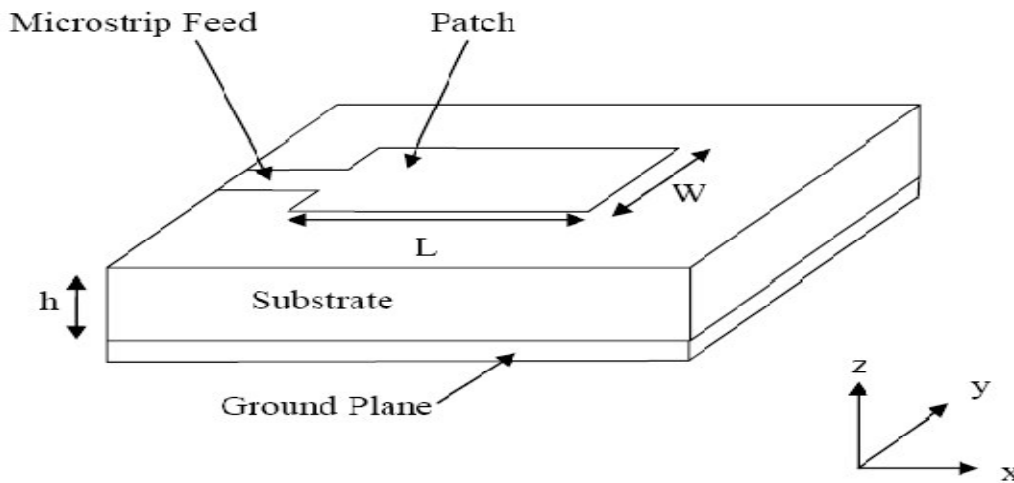


Figure 5.3 Microstrip Patch Antennas

In order to operate in the fundamental TM_{10} mode, the length of the patch must be slightly less than $\lambda/2$ where λ is the wavelength in the dielectric medium and is equal to $\lambda_0/\sqrt{\epsilon_{reff}}$ where λ_0 is the free space wavelength. The TM_{10} mode implies that the field varies one $\lambda/2$ cycle along the length, and there is no variation along the width of the patch. In the Figure 5.4 shown below, the microstrip patch antenna is represented by two

slots, separated by a transmission line of length L and open circuited at both the ends. Along the width of the patch, the voltage is maximum and current is minimum due to the open ends. The fields at the edges can be resolved into normal and tangential components with respect to the ground plane.

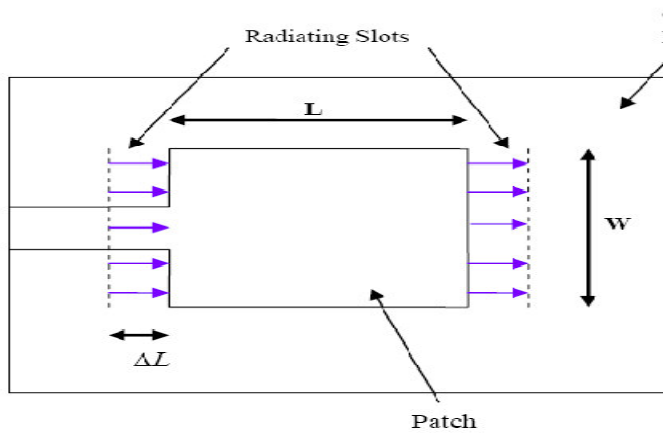


Figure 5.4 Top View of Antenna

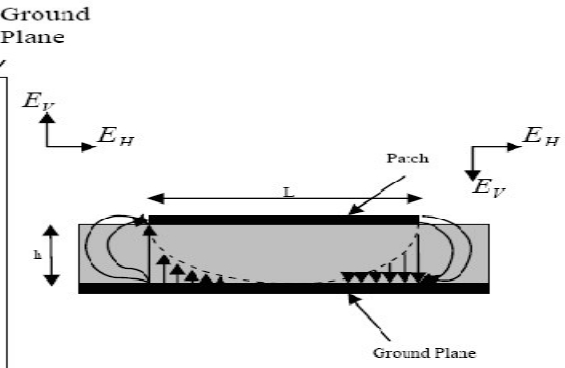


Figure 5.5 Side View of Antenna

It is seen from Figure 5.5 that the normal components of the electric field at the two edges along the width are in opposite directions and thus out of phase since the patch is $\lambda/2$ long and hence they cancel each other in the broadside direction. The tangential components (seen in Figure 5.5), which are in phase, means that the resulting fields combine to give maximum radiated field normal to the surface of the structure. Hence the edges along the width can be represented as two radiating slots, which are $\lambda/2$ apart and excited in phase and radiating in the half space above the ground plane. The fringing fields along the width can be modeled as radiating slots and electrically the patch of the microstrip antenna looks greater than its physical dimensions. The dimensions of the patch along its length have now been extended on each end by a distance ΔL , which is given empirically by Hammerstad as:

$$\Delta L = 0.412h \frac{(\epsilon_{r_{eff}} + 0.3) \left(\frac{W}{h} + 0.264 \right)}{(\epsilon_{r_{eff}} - 0.258) \left(\frac{W}{h} + 0.8 \right)}$$

..... 5.2

The effective length of the patch L_{eff} now becomes:

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

For a given resonance frequency f_o , the effective length is given by [9] as:

$$L_{eff} = \frac{c}{2f_o\sqrt{\epsilon_{reff}}}$$

For a rectangular Microstrip patch antenna, the resonance frequency for any TM_{mn} mode is given by James and Hall as:

$$f_o = \frac{c}{2\sqrt{\epsilon_{reff}}} \left[\left(\frac{m}{L} \right)^2 + \left(\frac{n}{W} \right)^2 \right]^{\frac{1}{2}}$$

Where m and n are modes along L and W respectively.

For efficient radiation, the width W is given by Bahl and Bhartia [15] as:

$$W = \frac{c}{2f_o\sqrt{\frac{(\epsilon_r + 1)}{2}}}$$

Cavity Model

Although the transmission line model discussed in the previous section is easy to use, it has some inherent disadvantages. Specifically, it is useful for patches of rectangular design and it ignores field variations along the radiating edges. These disadvantages can be overcome by using the cavity model. A brief overview of this model is given below. In this model, the interior region of the dielectric substrate is modeled as a cavity bounded by electric walls on the top and bottom. The basis for this assumption is the following observations for thin substrates ($h \ll \lambda$).

- Since the substrate is thin, the fields in the interior region do not vary much in the z direction, i.e. normal to the patch.

- The electric field is z directed only, and the magnetic field has only the transverse components H_x and H_y in the region bounded by the patch metallization and the ground plane. This observation provides for the electric walls at the top and the bottom.

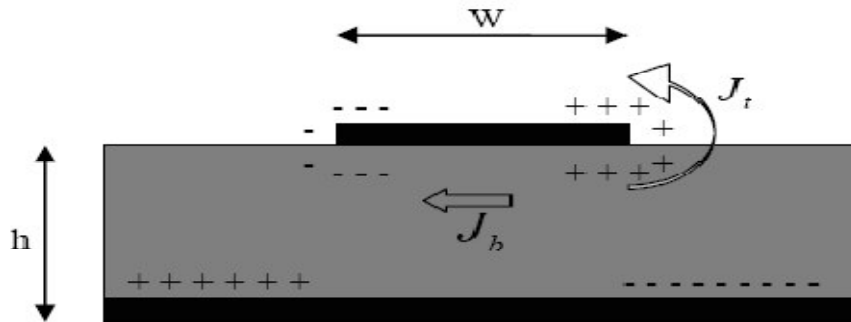


Figure 5.6 Charge distribution and current density creation on the microstrip patch

Consider Figure 5.6 shown above. When the microstrip patch is provided power, a charge distribution is seen on the upper and lower surfaces of the patch and at the bottom of the ground plane. This charge distribution is controlled by two mechanisms—an attractive mechanism and a repulsive mechanism as discussed by Richards. The attractive mechanism is between the opposite charges on the bottom side of the patch and the ground plane, which helps in keeping the charge concentration intact at the bottom of the patch. The repulsive mechanism is between the like charges on the bottom surface of the patch, which causes pushing of some charges from the bottom, to the top of the patch. As a result of this charge movement, currents flow at the top and bottom surface of the patch. The cavity model assumes that the height to width ratio (i.e. height of substrate and width of the patch) is very small and as a result of this the attractive mechanism dominates and causes most of the charge concentration and the current to be below the patch surface. Much less current would flow on the top surface of the patch and as the height to width ratio further decreases, the current on the top surface of the patch would be almost equal to zero, which would not allow the creation of any tangential magnetic field components to the patch edges. Hence, the four sidewalls could be modeled as perfectly magnetic conducting surfaces. This implies that the magnetic fields and the electric field distribution beneath the patch would not be disturbed. However, in practice, a finite width to height ratio would be there and this would not make the tangential magnetic fields to be completely zero, but they being very small, the side walls could be approximated to be perfectly magnetic conducting. Since the walls of the cavity, as well as the material within it are lossless, the cavity would not radiate and its input impedance would be purely reactive. Hence, in order to account for radiation and a loss mechanism, one must

introduce a radiation resistance RR and a loss resistance RL . A lossy cavity would now represent an antenna and the loss is taken into account by the effective loss tangent δ_{eff} which is given as:

$$\delta_{eff} = 1/Q_T$$

Q_T is the total antenna quality factor and has been expressed by [4] in the form:

$$\frac{1}{Q_T} = \frac{1}{Q_d} + \frac{1}{Q_c} + \frac{1}{Q_r}$$

- Q_d represents the quality factor of the dielectric and is given as :

$$Q_d = \frac{\omega_r W_T}{P_d} = \frac{1}{\tan \delta}$$

where ω_r is the angular resonant frequency.

W_T is the total energy stored in the patch at resonance.

P_d is the dielectric loss.

$\tan \delta$ is the loss tangent of the dielectric.

- Q_c represents the quality factor of the conductor and is given as :

$$Q_c = \frac{\omega_r W_T}{P_c} = \frac{h}{\Delta}$$

where P_c is the conductor loss.

Δ is the skin depth of the conductor.

h is the height of the substrate.

- Q_r represents the quality factor for radiation and is given as:

$$Q_r = \frac{\omega_r W_T}{P_r}$$

where P_r is the power radiated from the patch.

Substituting equations (3.8), (3.9), (3.10) and (3.11) in equation (3.7), we get

$$\delta_{eff} = \tan \delta + \frac{\Delta}{h} + \frac{P_r}{\omega_r W_T}$$

Chapter 06

Methodology

6.1 Introduction

A patch antenna (also known as a rectangular micro strip antenna) is types of radio antenna with allow profile, which can be mounted on a flat surface. It consist of flat rectangular sheet Or “patch” of metal, mounted over a larger sheet of metal called Ground plan. The assembly is usually contained inside a plastic redone, which protects the antenna structure from damag .Patch antennas are simple to fabricate and easy to modify and customize. They two metal sheets together from a resonant piece of micro strip transmission line with a length of approximately one-half wavelength of the radio waves. A patch antenna is usually constructed on a dielectric substrate, using the same materials to make printed circuit board.

6.2 High Frequency Simulator Structure (HFSS)

HFSS is a commercial finite element method solver for electromagnetic strictures from Ansys. The acronym originally stood for high frequency structure simulator. It is one of several commercial tools used for antenna design, and the design of complex RF electronic circuit elements including filter, transmission lines, and packaging. It was originally developed by Professor Zoltan Cendes and his students at Carnegie Mellon University.

HFSS is a high performance full wave Electromagnetic field simulator for arbitrary 3D volumetric positive device modeling that takes advantage of the familiar Microsoft Windows graphical user interface.

Using HFSS, we can compute:

Basic electromagnetic field quantities and, for open boundary problems, radiated near and afar fields; THeeigenmodes, or resonances, of a structure; port characteristic impedances and propagation constants; Generalized S-parameters and S-parameters renormalized to specific port impedance.

6.2 Application of HFSS

Ansoft HFSS can be used to calculate parameters such as S-Parameter, Resonant Frequency, and Fields. Typical uses include:

- Package Modeling- BGA, QEP, Flip-Chip
- PCB Board Modeling- power/Grounds plane, Mesh grid Ground, Backplanes.
- Silicon/GaAs-Spiral Inductors, Transformer, EMC/EMI-Mobile Communications-patched, dipoles, horns Conformal Cell Phone Antenna, Infinite Arrays, Radar Section, and Frequency Selective Surface (FSS).
- HFSS is an interactive simulation system whose basic mesh element is a tetrahedron. This allows solving any arbitrary 3D geometry, especially those with complex curves and Shapes, in a fraction of the time it would take other techniques.
- Ansoft pioneered the use of the Finite Element Method (FEM) for EM simulation by developing /implementing technologies such as tangential vector finite elements, adoptive meshing, and Adoptive Lanczos-pade Sweep (ALPS).

6.3 Features of HFSS

6.3.1 Capabilities:

- Accurate full-wave EM simulation
- Import/Export of 3D structures
- Automatic adaptive mesh generation and refinement
- Inclusion of skin effect, losses
- Direct and iterative matrix solvers
- Eigen mode matrix solver

6.3.2 Solution Data (Visualization):

- S-, Y-, Z-, parameters matrix (2D plot, smith chart)
- Port characteristic impedance
- Current, E-field, H-field
- Far field calculation (2D,3D, gain, radiation pattern)
- Material losses, radiation losses.

6.4 Ansoft Terminology

The Ansoft HFSS window has several optional panels

- i. Project Manager
- ii. Message Manager
- iii. Property Window

- iv. Progress Window
- v. 3D Modeler Window
- vi. These above managers and windows are shown in fig. and their details are given in coming sections.

6.5 HFSS Window

- From Windows **Start** menu, open the **control Panel**
- Select **System**
- From the left panel, select **Advanced system settings**
- Click **Environmental Variables**
- Under **User variables**, click **New**
- Set the variable **LM_LICENSE_FILE** and click **OK**
- When the initial setup is completed, start the tool.

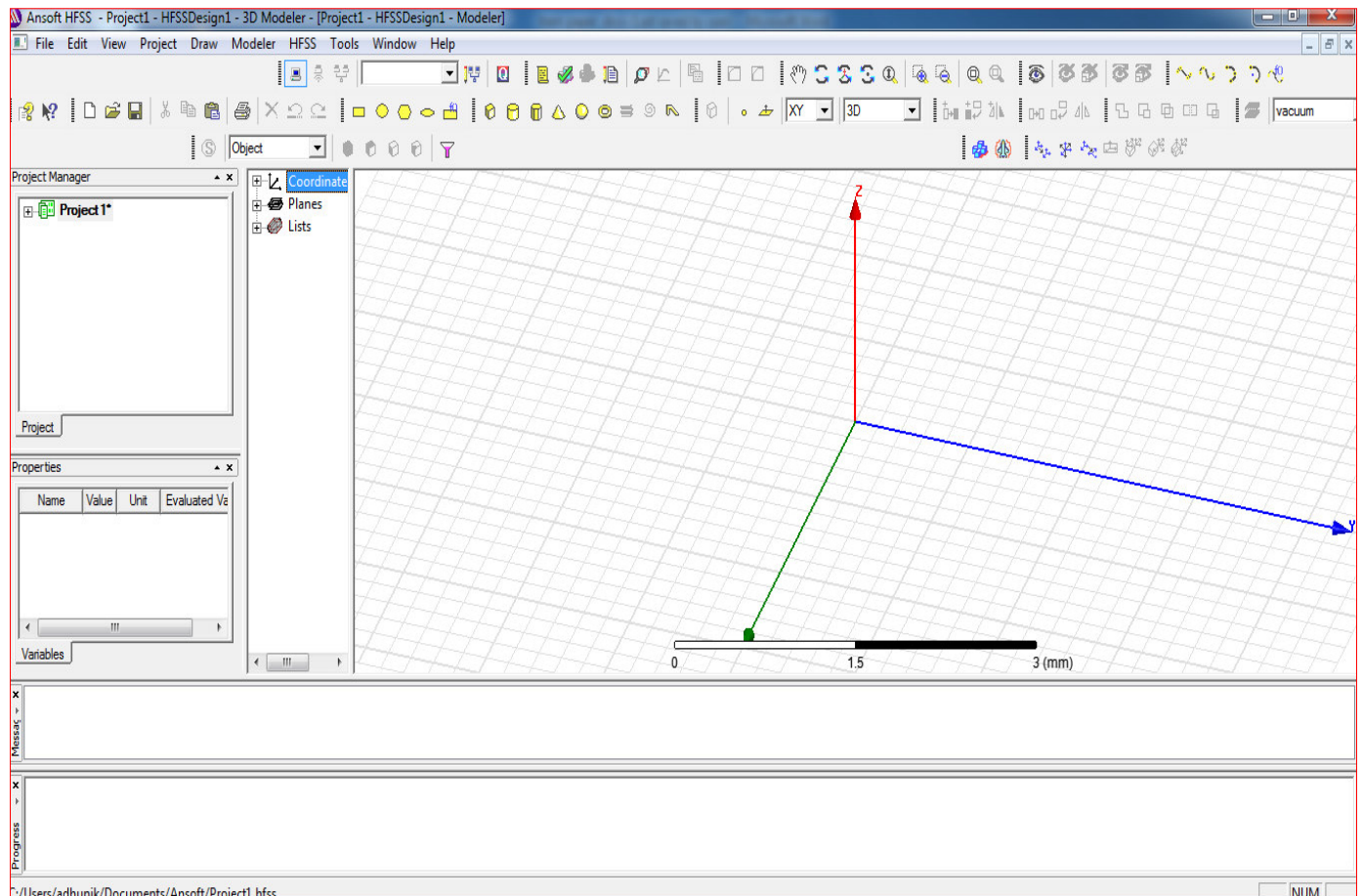


Figure 6.1 Ansoft HFSS Window

6.6 Project Managers

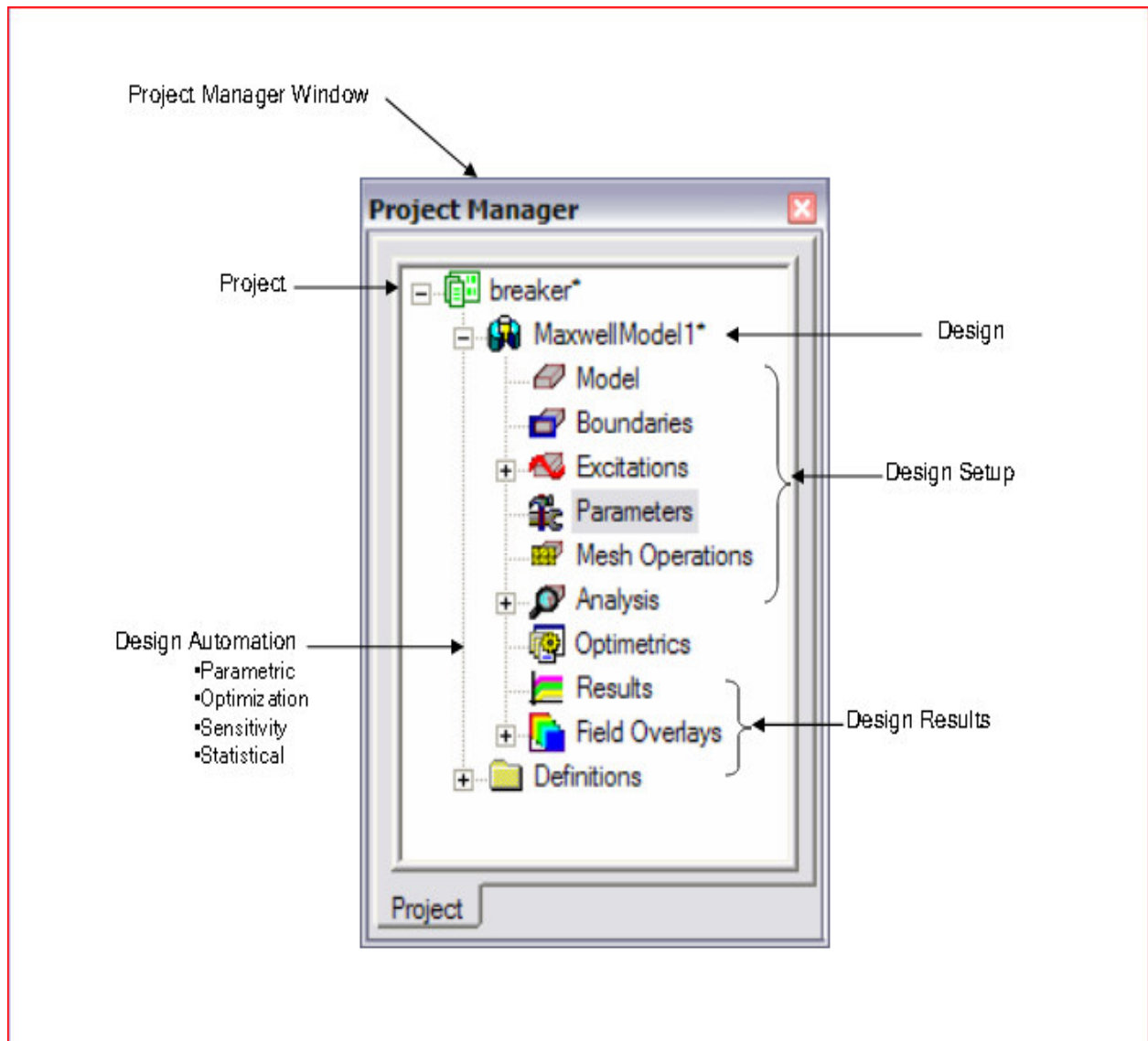


Figure 6.2 Ansoft Project Manager

6.7 Property Window

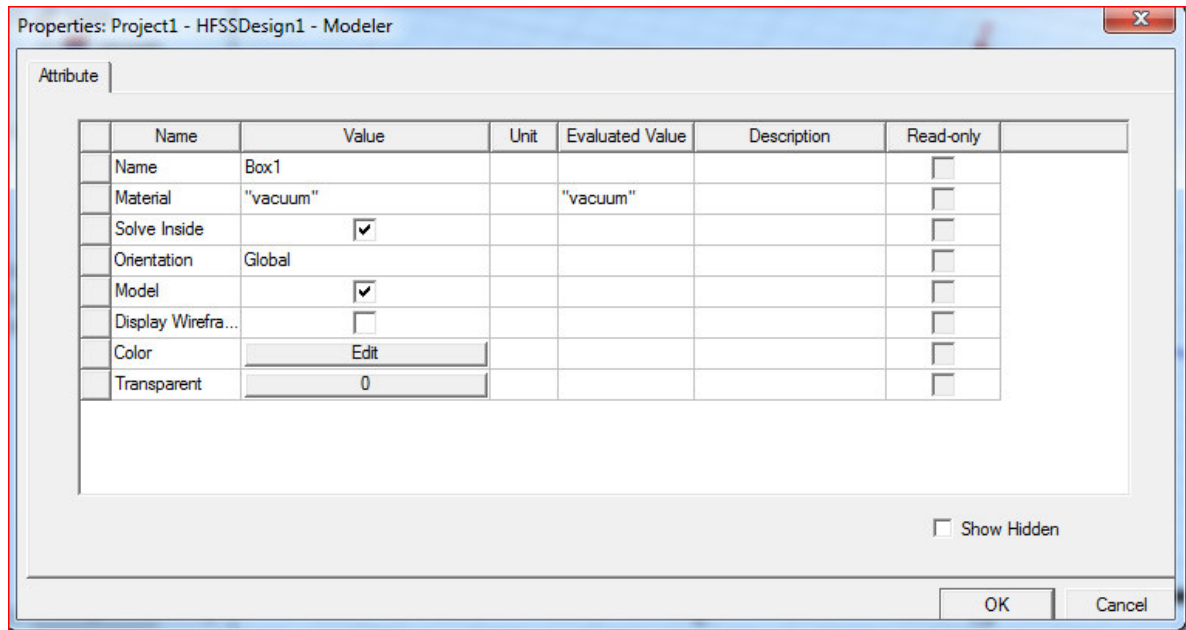


Figure 6.3 Ansoft Property Window

6.8 Modeler Window

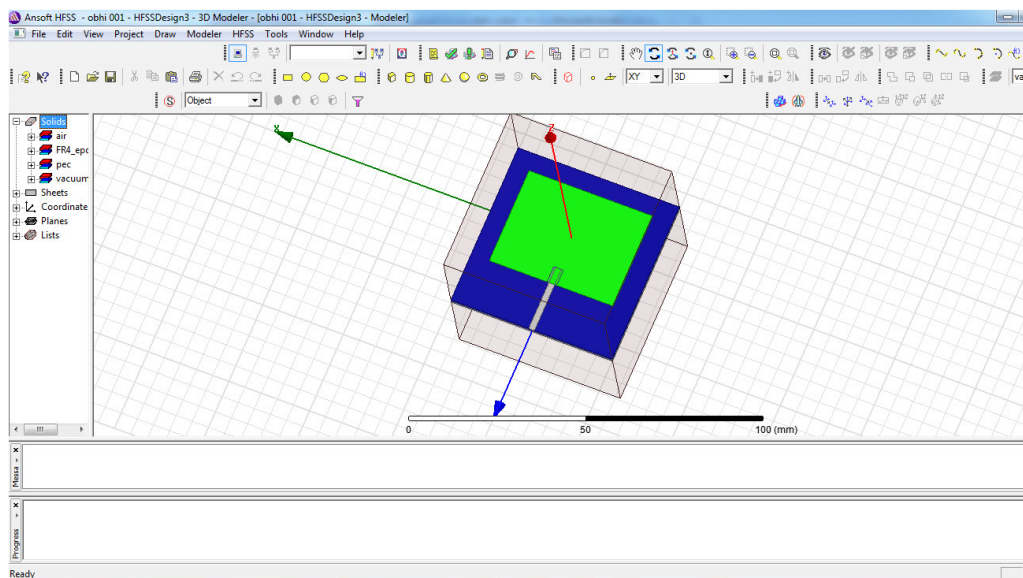


Figure 6.4 Ansoft HFSS Window

6.9 Toolbars:

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

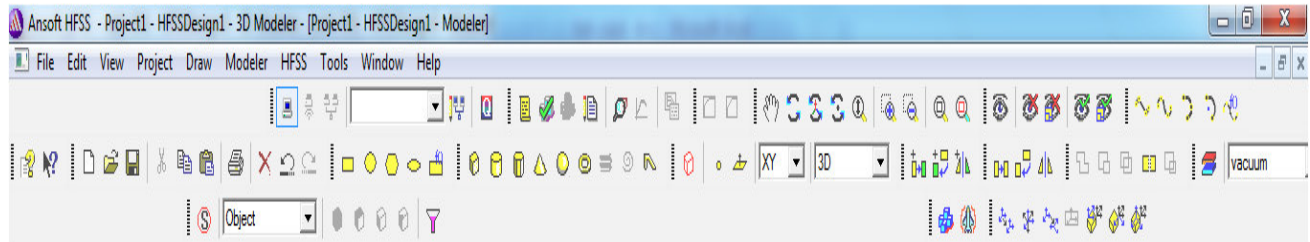


Figure 6.5 Toolbar

6.10 Ansoft HFSS Desktop

Ansoft HFSS Desktop provides an intuitive, easy-to-use interface for developing RF device model, creating designs, involves the followings:

- i. Parameters Model Generation-creating the geometry, boundaries and excitations.
- ii. Analysis Setup_ defining solution setup and frequency sweeps.
- iii. Results-creating 2Dreports and fields plots.
- iv. Solve Loop- the solution process is fully automated.

To understand how these process Co-exist, determine the illustration shown here,

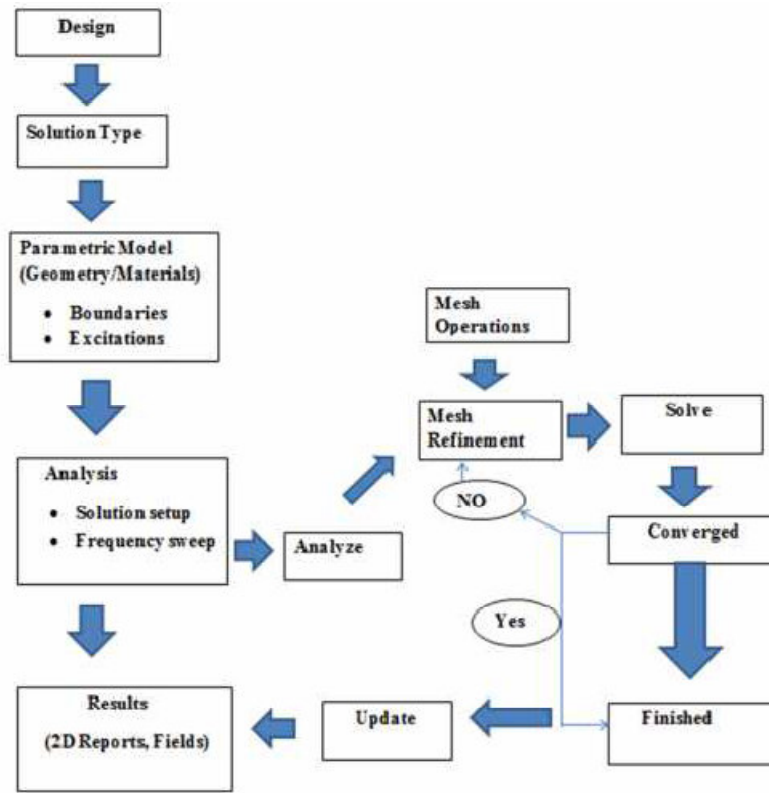


Figure 6.6 Flow Chart Illustration of Ansoft HFSS

6.11 Opening an HFSS Project

This section describes how to open a new or existing project. First, go the HFSS software and click to open. Then go file and click open file. And select desired file and open it.

6.12 Opening a New Project

- i. In an Ansoft HFSS window, select the menu item file. New.
- ii. Select the menu project. Insert HFSS Design.

6.13 Opening an Existing HFSS project

To open an existing project:

- i. In an Ansoft HFSS window, select the menu File> Open. Use, the Open Dialog to select the project.
- ii. Click Open to open the project.

6.14 Set Solution Type

This section describes how to set the Solution Type. The solution defines the type of results, how the excitations are defined and the convergence. The following solution Types are available.

- I. **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.
- II. **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 is ualization, employing short-duration excitations; time domain reflection.
- III. **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.

6.15 Convergence

- I. Driven Model- Delta S for model S- parameters. This was the only convergence method available for Driven Solutions in previous versions.
- II. Eigen Mode-Delta F
- III. Driven Terminal New- Delta S for the single – ended or differential nodal S-Parameters

6.16 To Set the Solution Type

Select the menu item HFSS> Solution Type

6.17 Solution Type Window

Choose one of the following:

- Driven modal
- Driven Terminal
- Driven Transient
- Eigen Mode

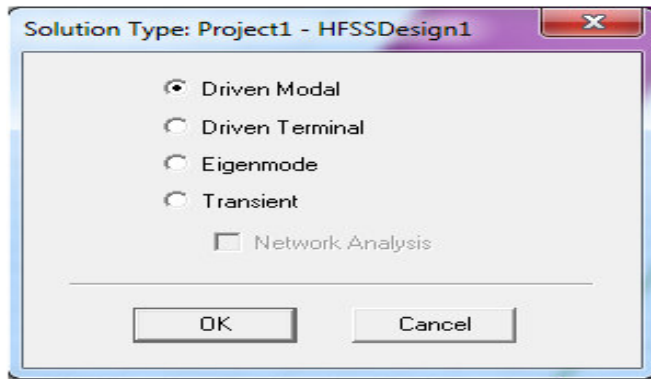


Fig 6.7: Solution Type.

6.18 Ansoft HFSS Online Help

Provides Assistance while you are working.

- To get help about a specific, active dialog box, click the Help button in the dialog box or press the F1 key.
- Select the menu item Help>Contents to access to online help system.
- Tooltips are available to provide information about the tools on the toolbars or dialog boxes. When you hold the pointer over a tool for a brief time, a tooltip appears to display the name of the tool.
- As you move the pointer over a tool or click a menu item, the Status Bar at the bottom of the Ansoft HFSS window provides a brief description of the function of the tool or menu item.
- The ansoft HFSS Getting Started guide provides detailed information about using HFSS to create and solve 3D EM projects

6.19 Ansoft Technical Supports

- I. To contact Ansoft technical support staff in your geographical area, please log on to the Ansoft corporate website, ansoft.com and select Contact.
- II. Your Ansoft Sales engineer may also be contacted in order to obtain this information.

6.20 Visiting the Ansoft web Site

If your computer is connected to the internet, you can visit the Ansoft web site to learn more about the Ansoft Company and Products.

- From the Ansoft Desktop Select the menu item Help>Ansoft Corporate Website to access the online technical support (OTS) system.
- From Your Internet browser Visit-www.ansoft.com or visit www.youtube.com/ansoft.hfss

6.21 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 07

Patch Antenna Design and Analysis

In our Thesis Paper we utilize Rogers Rogers R03010(tm) material as the Substrate in Ansoft HFSS (13) to have the yearning pick up at - 10 db. We make another Microstrip patch Antenna ellipse H shape to have our craving pick up for the extensive band application. Here we will examine about the aftereffect of the state of the patch.

7.1 RO3000® Series Circuit Materials RO3003™, RO3006 , RO3010™ and RO3035™ High Frequency Laminates:

RO3000 ®high frequency circuit materials are ceramic-filled PTFE (Polytetrafluoroethylene) composites intended for use in commercial microwave and RF applications. This family of products was designed to offer exceptional electrical and mechanical stability at competitive prices

RO3000 series laminates are ceramic-filled PTFE based circuit materials with mechanical properties that are consistent regardless of the dielectric constant selected. This allows the designer to develop multi-layer board designs that use different dielectric constant materials for individual layers, without encountering warpage or reliability problems.

RO3000 materials exhibit a coefficient of thermal expansion (CTE) in the X and Y axis of 17 ppm/oC. This expansion coefficient is matched to that of copper, which allows the material to exhibit excellent dimensional stability, with typical etch shrinkage (after etch and bake) of less than 0.5 mils per inch. The Z-axis CTE is 24 ppm/°C, which provides exceptional plated through-hole reliability, even in severe thermal environments. The dielectric constant versus temperature for RO3003™ and RO3035™ materials is very stable.

RO3000 series laminates can be fabricated into printed circuit boards using standard PTFE circuit board processing techniques, with minor modifications as described in the application note “Fabrication Guidelines for RO3000Series High Frequency Circuit Materials.”

RO3000 laminates are manufactured under an ISO 9001 certified system.

Table 7.1 Data Sheet of Rogers Rogers R03010(tm)

Property	Typical Value ⁽²⁾				Direction	Unit	Condition	Test Method
	R03003	R03035	R03006	R03010				
Dielectric Constant, ϵ_r , Process	3.00 ± 0.04	3.50 ± 0.05	6.15 ± 0.15	10.2 ± 0.30	Z	-	10 GHz 23°C	IPC-TM-650 2.5.5.5 Clamped Stripline
⁽²⁾ Dielectric Constant, ϵ_r , Design	3.00	3.60	6.50	11.20	Z	-	8 GHz - 40 GHz	Differential Phase Length Method
Dissipation Factor, tan δ	0.0010	0.0015	0.0020	0.0022	Z	-	10 GHz 23°C	IPC-TM-650 2.5.5.5
Thermal Coefficient of ϵ_r	-3	-45	-262	-395	Z	ppm/°C	10 GHz -50 to 150°C	IPC-TM-650 2.5.5.5
Dimensional Stability	-0.06 0.07	-0.11 0.11	-0.27 -0.15	-0.35 -0.31	X Y	mm/m	COND A	IPC-TM-650 2.2.4
Volume Resistivity	10 ⁷	10 ⁷	10 ⁸	10 ⁸		MΩ•cm	COND A	IPC 2.5.17.1
Surface Resistivity	10 ⁷	10 ⁷	10 ⁸	10 ⁸		MΩ	COND A	IPC 2.5.17.1
Tensile Modulus	900	1015	2068	1500	X, Y	MPa	23°C	ASTM D638
Moisture Absorption	0.04	0.04	0.02	0.05	-	%	D48/50	IPC-TM-650 2.6.2.1
Specific Heat	0.9		0.86	0.8		J/g/K		Calculated
Thermal Conductivity	0.50	0.50	0.79	0.95	-	W/m/K	50°C	ASTM D5470
Coefficient of Thermal Expansion	17 16 25	17 17 24	17 17 24	13 11 16	X Y Z	ppm/°C	-55 to 288°C	ASTM D3386-94
Td	500	500	500	500		°C TGA		ASTM D3850
Density	2.1	2.1	2.6	2.8		gm/cm ³	23°C	ASTM D792
Copper Peel Strength	12.7	10.2	7.1	9.4		lb/in	1 oz. EDC After Solder Float	IPC-TM-2.4.8
Flammability	V-0	V-0	V-0	V-0				UL 94
Lead Free Process Compatible	YES	YES	YES	YES				

Typical Applications:

- Automotive radar applications
- Global positioning satellite antennas
- Cellular telecommunications systems – power amplifiers and antennas
- Patch antenna for wireless communications
- Direct broadcast satellites
- Data link on cable systems
- Remote meter readers
- Power backplanes

7.2: Ellipse Rectangular Elliptical-shaped 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 ultra wide band frequency.

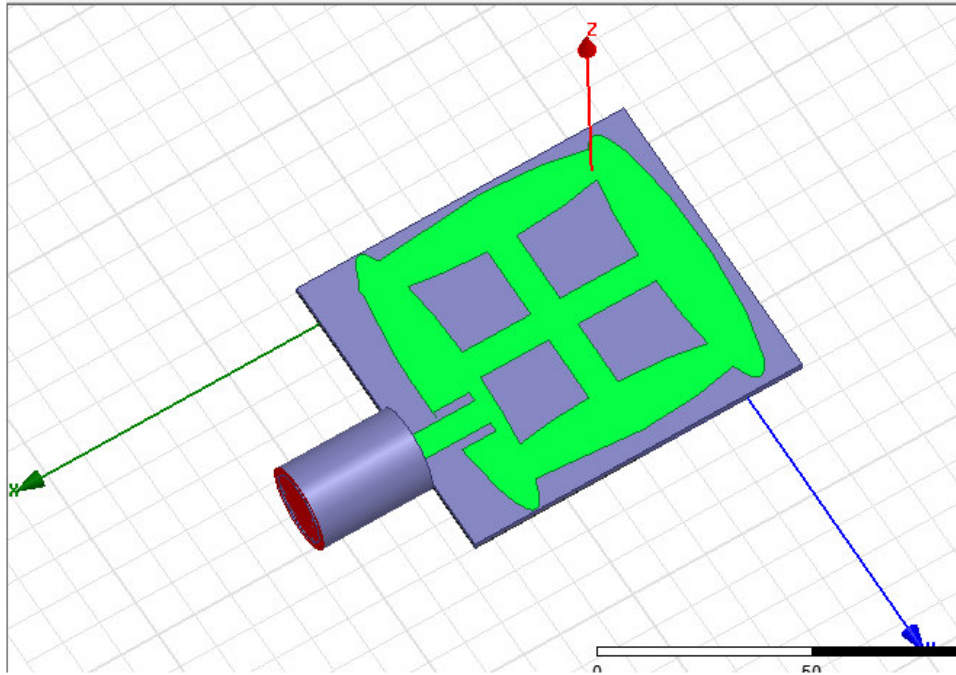


Fig 7.1: Snapshot of the designed microstrip patch antenna.

Here substrate height is $h=5\text{mm}$. Substrate length= 80mm at Y axis and width = 90mm at X axis. Here in patch, we use 'pec' material and substrate material use many type. Which have a different relative permittivity (**) and that changes we get different result. Those results are shown in simulated part.

The percentage bandwidth of antenna is calculated using the formula-

$$\% \text{Bandwidth} = \frac{f_2 - f_1}{\frac{f_2 + f_1}{2}} 100\% \quad (7.1)$$

Where f_1 and f_2 are lower and upper cut off frequencies.

Table 7.2: Antenna Design Parameters

Name	Material	Length(mm)	Width(mm)	Height(m)	axis	Position
Substrate	Rogers R03010(tm)	80	90	5	X,Y,Z	-15,-10,0
Ground	Sheet	-80	-45	---	Z	75,70,0
Feed line	Sheet	7	22	-----	Z	53,37.5,5
Rectangular (Substrate with feed line)	Sheet	12	-10		Z	65.1,35,5
Radiation Box	air	80	90	120	X,Y,Z	-15,-10,-45
		Radios		Height	Axis	Position
Cylinder 1	Vacuum	11		30	X	75,40,5
Cylinder 2	pec	9		30	X	75,40,5
Wave Port		11		-----	X	105,40,5

Table 7.3: Antenna Design Parameters (Patch)

Name	Major Radios	Ratio	Axis	Center position
Patch	7.5	5	Z	-5 ,30 ,5
Ellipse 01	7.2	5.5	Z	58,30 ,5
Ellipse 02	35	.2	Z	28,-1.5,5
Ellipse 03	35	.2	Z	28,58 ,5
	Length	Width	Axis	Position
Rectangular 01	55	8	Z	55 ,25 ,5
Rectangular 03	60	8	Z	24 ,-1 ,5

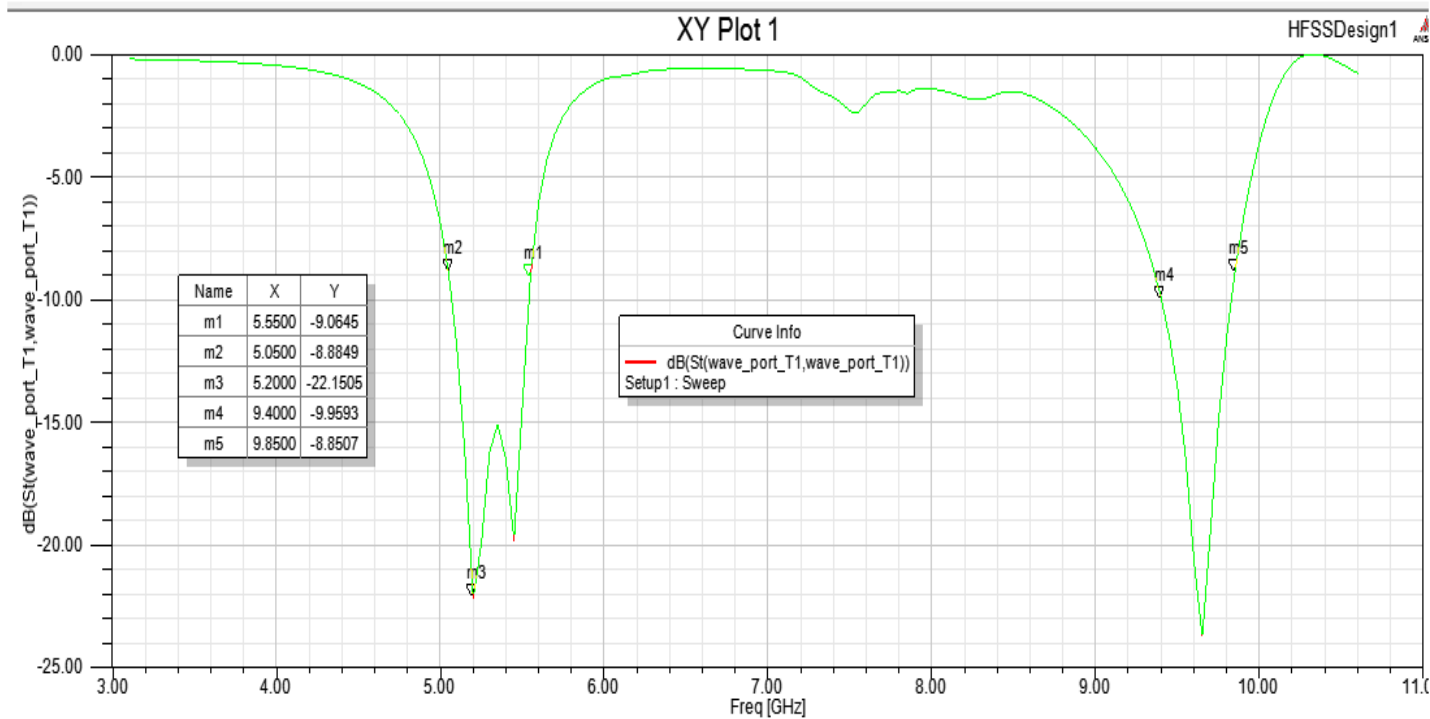
7.3: Simulated Results of Microstrip Patch Antenna

Fig 7.2: Return Loss vs Frequency of a Patch Antenna taking Rogersrltralam R03010(tm) as substrate.

Here after using equation 7.1 we get percentage bandwidth is 10.47%. we get patch antenna for use ' Rogers R03010(tm)' substrate. That's substrate height 5 mm. its relatively permittivity is 10.2.

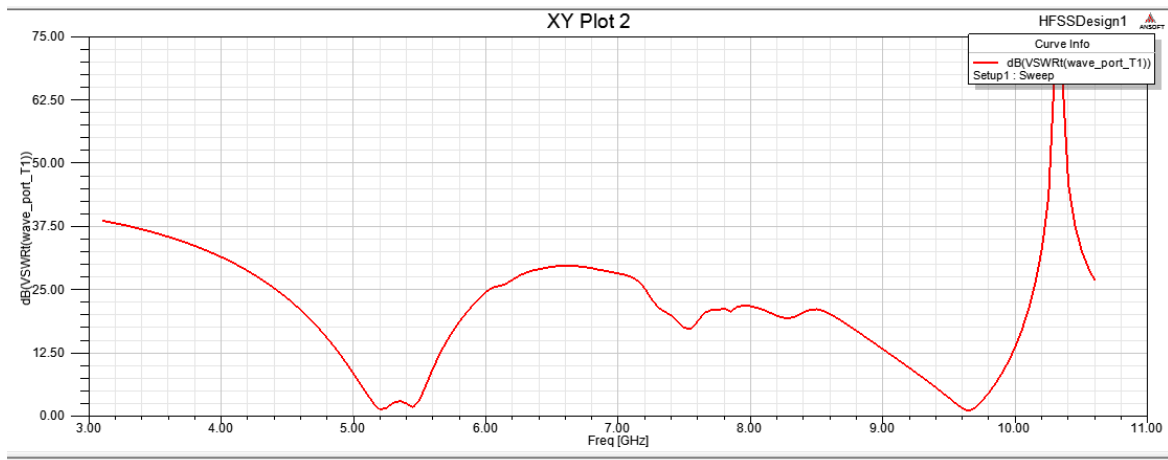


Fig 7.3: VSWR vs Frequency of Microstrip Patch Antenna.

Radiation Pattern

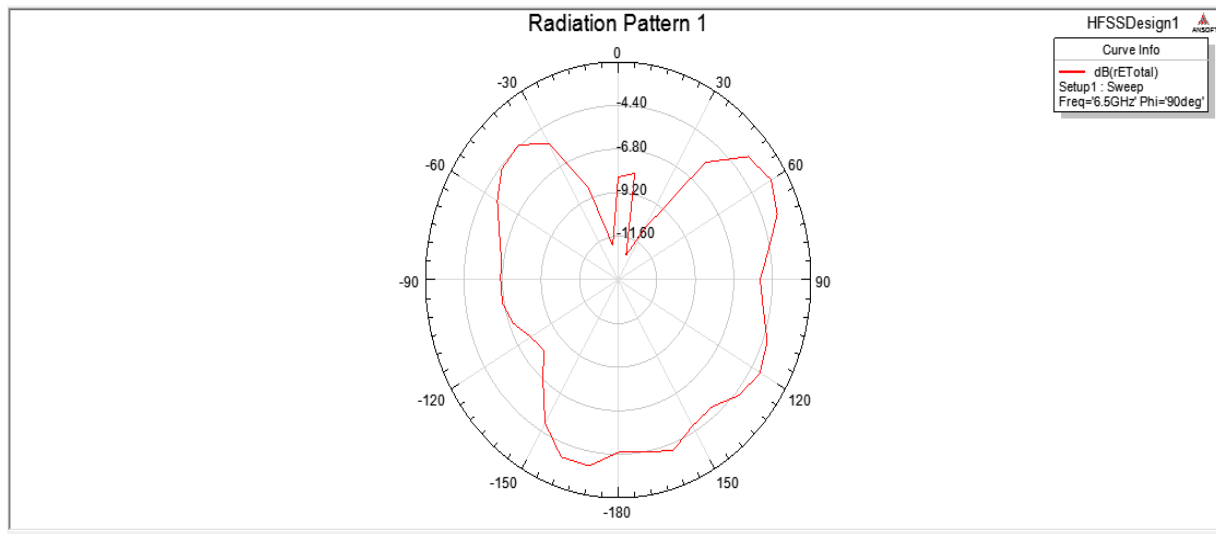


Fig 7.4: Radiation Pattern.

Gain

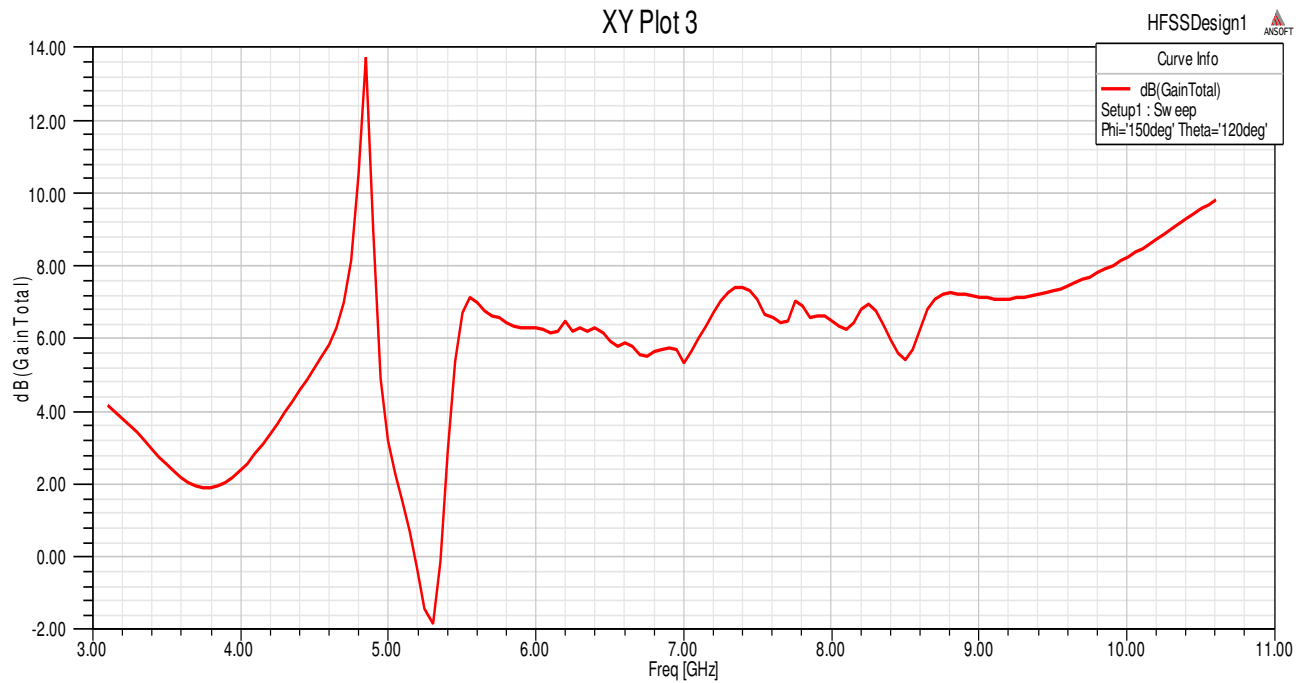


Fig 7.5: Simulation Result of Gain vs Frequency.

Table 7.4: Percentage bandwidth for Different Substrate Thickness:

Material Name	Substrate Thickness (mm)	f1(GHz)	f2(GHz)	%Bandwidth $= \frac{f_2 - f_1}{\frac{f_2 + f_1}{2}} 100\%$
Rogersrltralam R03010(tm)	1.8	5.35	5.55	3.6%
Rogersrltralam R03010(tm)	2	5.35	5.60	4.50%
Rogersrltralam R03010(tm)	3	5.25	5.55	5.55%
Rogersrltralam R03010(tm)	4	5.25	5.60	6.48%
Rogersrltralam R03010(tm)	5	5.20	5.60	10.47%

Table 7.5 Percentage bandwidth for Different Ground Position:

Material Name	Length(L) (mm)	Width(W) (mm)	Ground position	f1 (GHz)	f2 (GHz)	%Bandwidth = $\frac{f2-f1}{\frac{f2+f1}{2}} \times 100\%$
Sheet	90	80	75 ,70 ,0	5.05	5.60	10.47%
Sheet	70	80	75,70,0	5.05	5.60	10.47%
Sheet	50	80	75,70,0	5.05	5.60	10.47%
Sheet	40	80	75,70,0	5.05	5.55	9.43%
Sheet	40	80	60 ,70 ,0	9.60	9.80	2.06%
Sheet	50	80	65 ,70 ,0	9.60	9.80	2.06%
Sheet	50	80	50,70,0	0	0	0
Sheet	50	70	40,70,0	0	0	0

Table 7.6: Percentage bandwidth for Different Substrate Material:

Material Name	Relative Permittivity	f1(GHz)	f2(GHz)	%Bandwidth $= \frac{f_2 - f_1}{\frac{f_2 + f_1}{2}} \times 100\%$
"Rogers RO3003 (tm)"	3	0	0	0
"Rogers RO3203 (tm)"	3.02	5.20	5.55	6.51%
"Rogers RO4003 (tm)"	3.55	5.20	5.55	6.51%
"Rogers RO4350 (tm)"	3.66	5.20	5.55	6.51%
"Rogers RO3006 (tm)"	6.15	5.15	5.55	7.47%
"Rogers RT/duroid 6006 (tm)"	6.15	5.15	5.55	7.47%
"Rogers TMM 10 (tm)"	9.2	5.10	5.55	8.45%
"Rogers TMM 10i (tm)"	9.8	5.10	5.55	8.45%
"Rogers RO3010 (tm)"	10.2	5.05	5.60	10.47%
"Rogers RT/duroid 6010/6010LM (tm)"	10.2	5.05	5.60	10.47%
"silicon"	11.9	0	0	0

Chapter 08

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 R03010(tm) is given us a good result of dual band frequency at 5.06.-5.55 with maximum % of BW is 10.47 % . 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 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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