Design Simulation and Performance Analysis of Microstrip Patch Array Antenna using HFSS

SUBMITTED TO THE

DEPARTMENT OF

ELECTRONICS AND COMMUNICATION

ENGINEERING

EAST WEST UNIVERSITY

SUBMITTED BY

RIZVI AHMED

ID-2011-2-55-029

MD.RAKIBUL ISLAM

ID-2011-2-55-022

DECLARATION

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We declare that this proposal is our original work and has not been presented in any other university/institution for consideration of any certification. This research proposal has been complemented by referenced sources duly acknowledged. Where text, data (including spoken words), graphics, pictures or tables have been borrowed from other sources, including the internet.

RIZVI AHMED

ID-2011-2-55-029

MD.RAKIBUL ISLAM

ID-2011-2-55-022

Department of ECE

East West University

ACCEPTANCE

This research report presented of the department of Electronics and Communication Engineering East West University is submitted in partial fulfillment of the requirement for degree of BSC in Electronics and Telecommunication Engineering, under complete supervision of the undersigned.

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M. Mofazzal Hossain, PhD

Professor

Department of Electronics and Communication Engineering

____

Rizvi Ahmed

ID-2011-2-55-029

____

Md. Rakibul Islam

ID-2011-2-55-022

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Chapter 1

Fundamental of Antenna

1.1 Introduction

1.1.1 What is an Antenna?

An antenna is a device (usually metallic) for sending or receiving electromagnetic waves. The antenna is an important part of radio equipment. The antenna has to be tuned to the right frequency or the radio waves can neither be emitted nor captured efficiently. In transmission, a radio transmitter applies a radio frequency to the terminals of the antenna and then the antenna radiates the energy from the antenna as electromagnetic waves. In reception, an antenna intercepts some of the power of an electromagnetic wave to produce a radio frequency at its terminals that is applied to a receiver in order to be amplified and demodulated. In some cases the same antenna can be used for both transmitting and receiving.

1.2 Types of Antennas

There are several different kinds of antennas available at Future Electronics. We stock many of the most common types categorized by several parameters including operating frequency, power handling, gain, operating temperature range and type. These types include rubber ducky, embedded, conformal and weatherized.

1.3 Antenna parameters

The major parameters of an antenna are defined in the following subsection.

1.3.1 Antenna Gain

Antenna gain is defined as the radio between the radiation intensity in a given particular direction and total input power. The radiation intensity Unexpressed the power radiated per solid angle. IN terms of U the Antenna gain in a specified direction can be calculated.

$$G=\frac{U}{Pin/4\pi}$$

1.3.2 Antenna Efficiency

Antenna efficiency is defined by IEEE Std 145-1993 "Standard Definition of Terms for Antennas "as "The ratio of the total power radiated by an antenna to the net power accepted by the antenna from the connected transmitter". It is sometimes expressed as percentage (less than 100), and it is frequency dependent.

1.3.3 Antenna Effective Area

In electromagnetic and antenna theory. Antenna aperture of effective area is a measure of how effective an antenna is at receiving the power of radio waves. The aperture is defined as the area, oriented perpendicular to the direction of an incoming wave, which, would intercept the same amount of power from that waves as is produced by the antenna receiving it. At any point, a beam of radio waves has an irradiance or power flux density (PFD) which is the amount of radio power passing through a unit area.

1.3.4 Directivity

In electromagnetics, directivity is a figure of merit for an antenna. It measures the power density the antenna radiates in the direction of its strongest emission, versus the power density radiated by an ideal isotropic radiator (which emits uniformly in all directions) radiating the same total power.

An antenna's directivity is a component of its gain; the other component is its (electrical) efficiency. Directivity is an important measure because most emissions are intended to go in a particular direction or at least in a particular plane (horizontal or vertical); emissions in other directions or planes are wasteful (or worse).

1.3.5 Bandwidth

The properties of input impedance, polarization gain of an antenna do not necessary vary in the same manner, moreover there is no distinctive character of the bandwidth to calculate percentage of bandwidth: % of BW = $(f_2-f_1)/f_0*100\%$

1.3.6 Radiation Pattern

A radiation pattern defined as the variation of the power radiation from an antenna which is away from the antenna. The radiation pattern is a plot of the fare –field radiation properties of an antenna. The spatial coordinates which are specified by the elevation angle (ф) and the azimuth angle (Ɵ). It is a plot of the power radiated from an antenna per unit solid angle which is nothing but the radiation intensity. It can plotted as a 3D graph. It is an extremely important parameter as is show the antenna directivity as well as gain at various points in space.

1.3.7 Return Loss

In telecommunications, **return loss** is the loss of power in the signal returned/reflected by a discontinuity in a transmission line or optical fiber. This discontinuity can be a mismatch with the terminating load or with a device inserted in the line. It is usually expressed as a ratio in decibels (dB);

$$RL(\mathrm{dB}) = 10\log_{10}\frac{P_\mathrm{i}}{P_\mathrm{r}}$$

Where *RL* (dB) is the return loss in dB, P_i is the incident power and P_r is the reflected power.

Return loss is related to both standing wave ratio (SWR) and reflection coefficient (Γ). Increasing return loss corresponds to lower SWR. Return loss is a measure of how well devices or lines are matched. A match is good if the return loss is high. A high return loss is desirable and results in a lower insertion loss.

1.3.8 Beam Width

In an antenna pattern the half power beam width is the angle between the half power (-3dB) points of the main lobe, when referenced to the peak effective radiated power of the main lobe. A typical polar diagram showing beam width is as show below.

1.3.9 Input Impedance

The input impedance of an electrical network is the impedance from the source into the network being connected. In other words, the input impedance is the impedance, if placed across the input terminals that would produce the same voltage across and current through the input terminals as the electrical network being connected. Therefore, the input impedance of the network being connected and the output impedance of the source determines the transfer function from the source to the input terminals of the circuit.

1.3.10 Voltage Standing Wave Ratio (VSWR)

For a radio (transmitter or receiver) to deliver power to an antenna, the impedance of the radio and transmission line must be well matched to the antenna's impedance. The parameter VSWR is a measure that numerically describes how well the antenna is impedance matched to the radio or transmission line it is connected to.

1.4 UWB:

The word ‘ultra-wideband’ (UWB) commonly refers to signals or systems that either have a large relative, or a large absolute bandwidth. Such a large bandwidth offers specific advantages with respect to signal robustness, information content and/or implementation simplicity, but lead to fundamental differences from conventional, narrowband systems.

The bandwidth and VSWR level with band notch characteristics are optimized with slot length 5 mm, slot width 9.4 mm and slot thickness 1.25 mm, whereas other parameters are same as it is and the antenna is still working within UWB range. The input impedance of the presented antenna is given in the smith chart of Fig. 2. The resonant loops of the antenna are to be found close to the center of the smith chart, showing better matching to the input impedance. Few resonant frequencies are being stimulated. The small loop on the smith chart does not indicate true resonant frequencies as not crossing the real axis but the wideband impedance characteristic is visible from the impedance curve. It is important to mention that these intimately spaced multiple resonances which are harmonics of fundamental resonance overlap, resulting in ultra wide bandwidth. The simulated VSWR of the antenna with and without the band notch is depicted in Fig.3. It is observed in the result that the antenna has a wide bandwidth ranging from 3.4 GHz to 10.6 GHz with a band notch characteristics across 5 GHz to 6 GHz. This band notch characteristic is required to reduce the interference from WLAN systems.

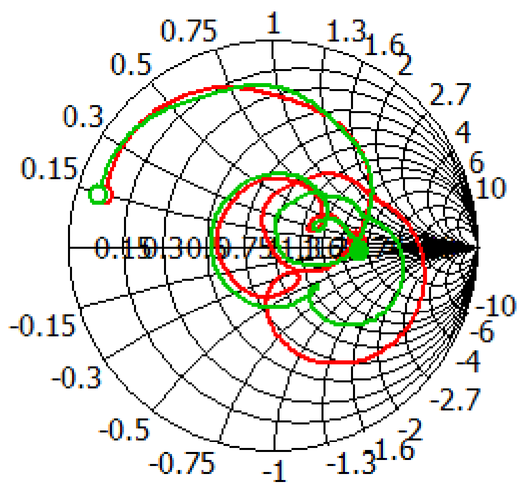


Figure 1.1: Input Impedance chart with notch (red) and without notch (green)

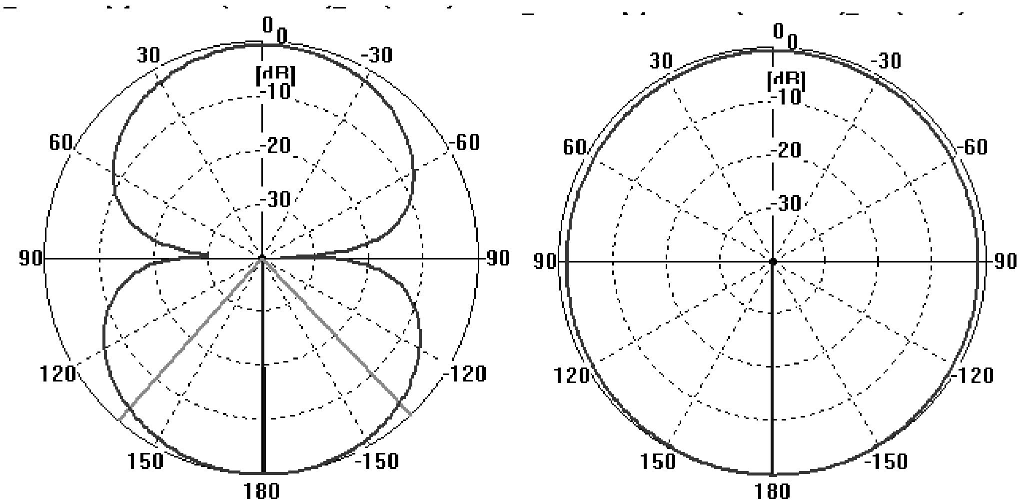


Figure1.2: Radiation pattern for proposed antenna at 3.8 GHz

1.5 What is Array Antenna?

An antenna array (often called a 'phased array') is a set of 2 or more antennas. The signals from the antennas are combined or processed in order to achieve improved performance over that of a single antenna.

An antenna array is a set of individual antennas used for transmitting and/or receiving radio waves, connected together in such a way that their individual currents are in a specified amplitude and phase relationship. This allows the array to act as a single antenna, generally with improved directional characteristics (thus higher antenna gain) than would be obtained from the individual elements. The resulting array in fact is often referred to and treated as "an antenna," particularly when the elements are in rigid arrangement with respect to each other, and when the ratio of currents (and their phase relationships) are fixed. On the other hand, a steerable array may be fixed physically but has electronic control over the relationship between those currents, allowing for adjustment of the antenna's directionality without requiring physical motion.

The array uses electromagnetic wave interference to enhance the radiative signal in one desired direction at the expense of other directions. It may also be used to null the radiation pattern in one particular direction, especially for a receiving antenna in the face of a particular interfering source.

1.6 Advantages and Disadvantages of Microstrip Patch Array antenna:

1.6.1 ADVANTAGES:

- Ease of manufacturing
- It has a low fabrication cost
- Microstrip patch antennas are efficient radiators
- It has a support for both linear and circular polarization
- Easy in integration with microwave integration circuits
- Unlike linear arrays, distortions in the array pattern of a circular array due to mutual coupling effect are same for each element and this makes it easier to deal with the mutual coupling effects.
- Capable of dual and triple frequency operations.
- High performance
- Supports both, linear as well as circular polarization.

1.7 APPLICATIONS OF MICROSTRIP PATCH ARRAY ANTENNA:

Microstrip antennas possess attractive features such as low profile, light weight, small volume and low production cost. In addition, integrating the microstrip feed structure with the radiating elements on the same substrate attains the benefit of a compact low cost feed network. However, losses in the microstrip feed network form a significant limit on the possible applications of microstrip antenna arrays in mm wave frequency range. However, in some applications the radiators in the array are not connected by an array feed network. In these applications we may benefit from the advantages of microstrip antennas. In this paper we describe the development and applications of mm wave microstrip arrays. MM wave microstrip antenna arrays may be employed in communication links, seekers and detection arrays. The arrays consists around 256 elements to 1024 elements. Design considerations of the antenna and the feed network are given in this paper. Optimization of the antenna and feed network allows us to design microstrip antenna arrays with high efficiency.

1.8Why Micro strip Patch Antennas is been used?

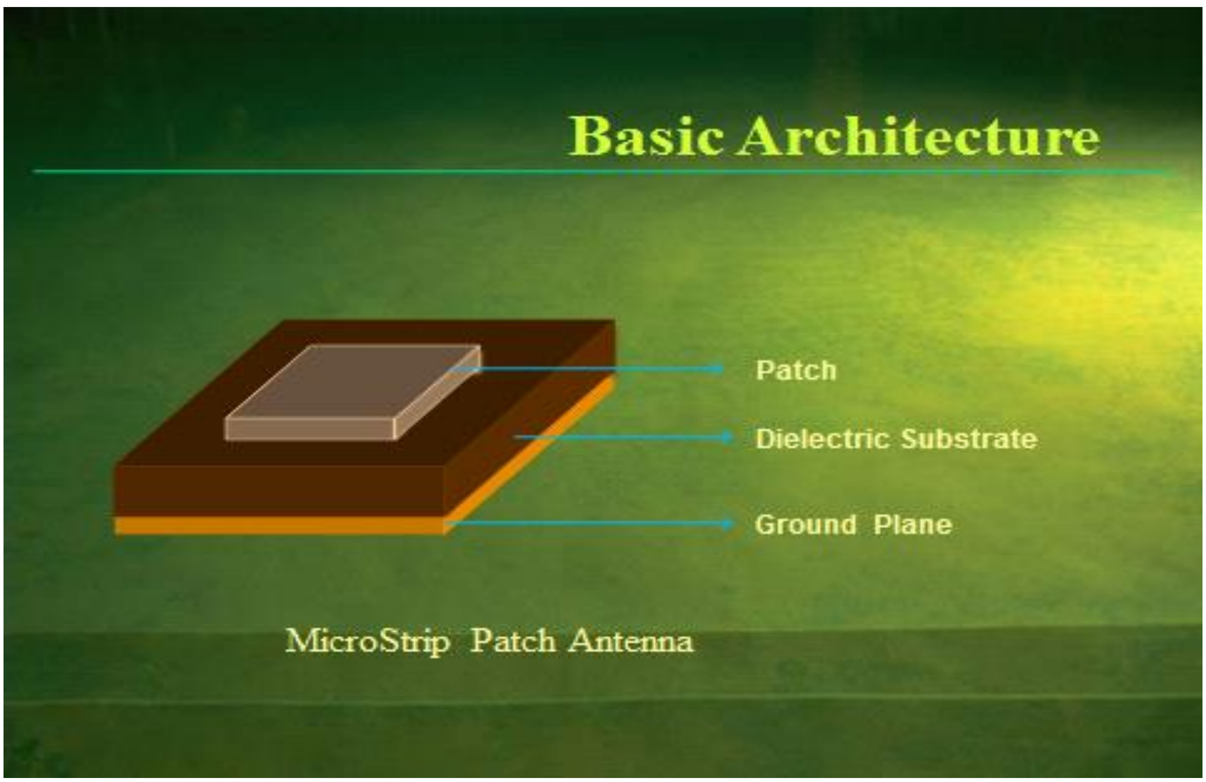
An antenna array (often called a 'phased array') is a set of 2 or more antennas. The signals from the antennas are combined or processed in order to achieve improved performance over that of a single antenna. The antenna array can be used to:

- increase the overall gain
- provide diversity reception
- cancel out interference from a particular set of directions
- "steer" the array so that it is most sensitive in a particular direction
- determine the direction of arrival of the incoming signals
- to maximize the Signal to Interference Plus Noise Ratio (SINR)

Chapter 2
Architecture of Patch Antenna

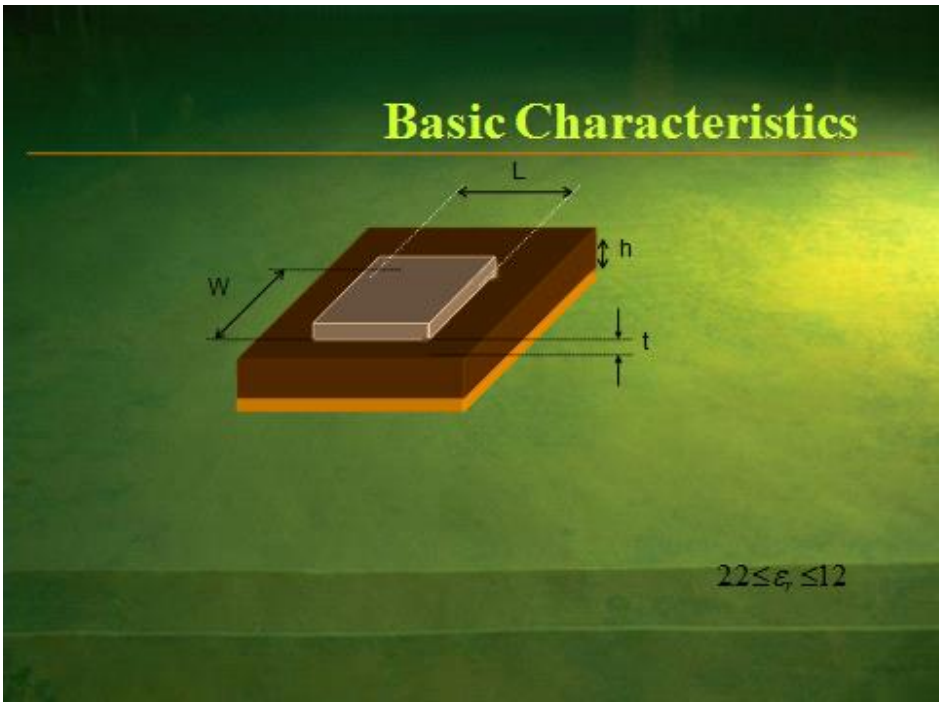
2.1 Basic Architecture

Microstrip patch antenna is vastly used where size, weight, cost, performance and simplicity of installation are constraints.



The basic configuration is a metallic patch etched on to an electrically thin and grounded dielectric substrate, as shown in Figure 2. The thickness of the substrate is much less than. In general, the patch element is fed asymmetrically by an unbalanced feed. The main dimensions of patches are of the order of where is an equivalent operating wavelength

2.2 Some basic characteristics:



- The patch should be a very thin metallic strip (t<<free space wavelength)
- dielectric constants are usually in the range of
- For good antenna performance, a thick dielectric substrate having a low dielectric constant is desirable since this provides better efficiency, larger bandwidth and better radiation.
- But this configuration leads to a larger antenna size.
- Higher dielectric constants may be used which are less efficient result in narrower bandwidth.
- In security system narrow bandwidth is expected.

2.3 Different shape of patch:

Square

Rectangular

Circle

Triangle

Circular Ring

Dipole

Elliptical

2.4 Fundamental specifications for Patch Antenna:

- Radiation Pattern
- Polarization
- Antenna Gain
- Bandwidth
- Directivity

2.5 Feeding Technique

There are many methods of feeding a micro strip antenna. The most popular methods are:

1. Micro strip Line.

2. Coaxial Probe (coplanar feed).

3. Proximity Coupling.

4. Aperture Coupling.

2.6.1 Micros trio Line feed

This method of feeding is very widely used because it is very simple to design and analyze, and very easy to manufacture. Previously, the patch antenna was fed at the end as shown here. Since this typically yields a high input impedance, we would like to modify the feed. Since the current is low at the ends of a half-wave patch and increases in magnitude toward the center, the input impedance (Z=V/I) could be reduced if the patch was fed closer to the center. One method of doing this is by using an inset feed (a distance R from the end) as shown in Figure 1.

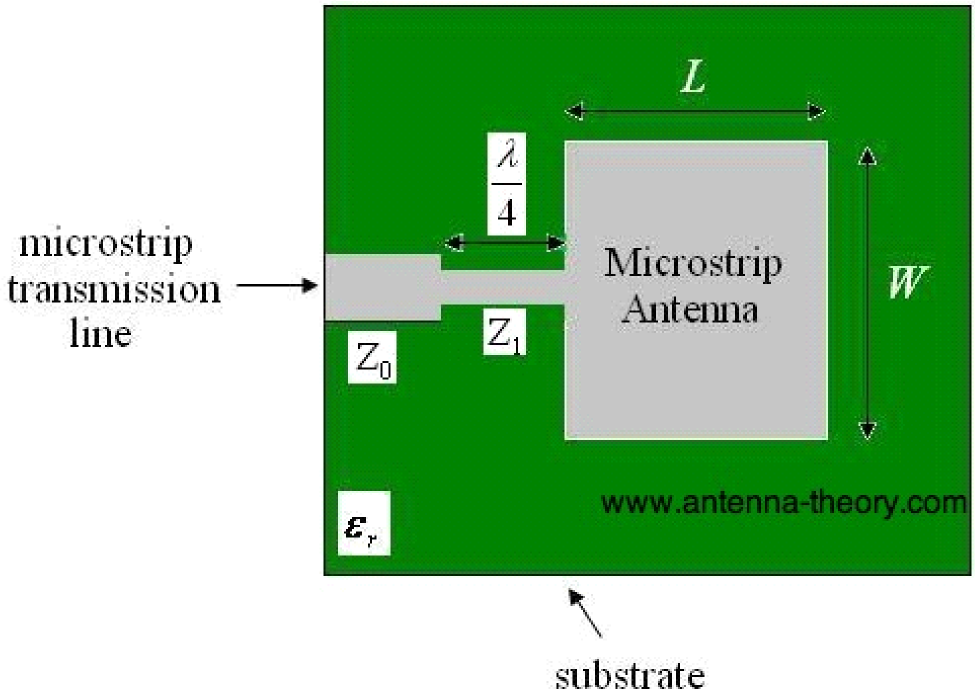


Figure 2.1. Patch Antenna with an Inset Feed.

2.6.2 Coaxial Probe (coplanar feed):

Micro strip antennas can also be fed from underneath via a probe as shown in Figure 3. The outer conductor of the coaxial cable is connected to the ground plane, and the center conductor is extended up to the patch antenna. The position of the feed can be altered as before (in the same way as the inset feed, above) to control the input impedance

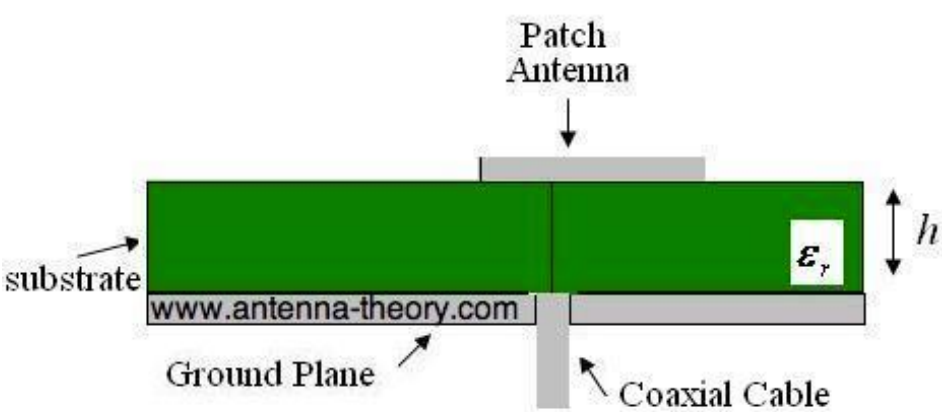


Figure 2.2. Coaxial cable feed of patch antenna.

2.6.3 Aperture coupled Feed:

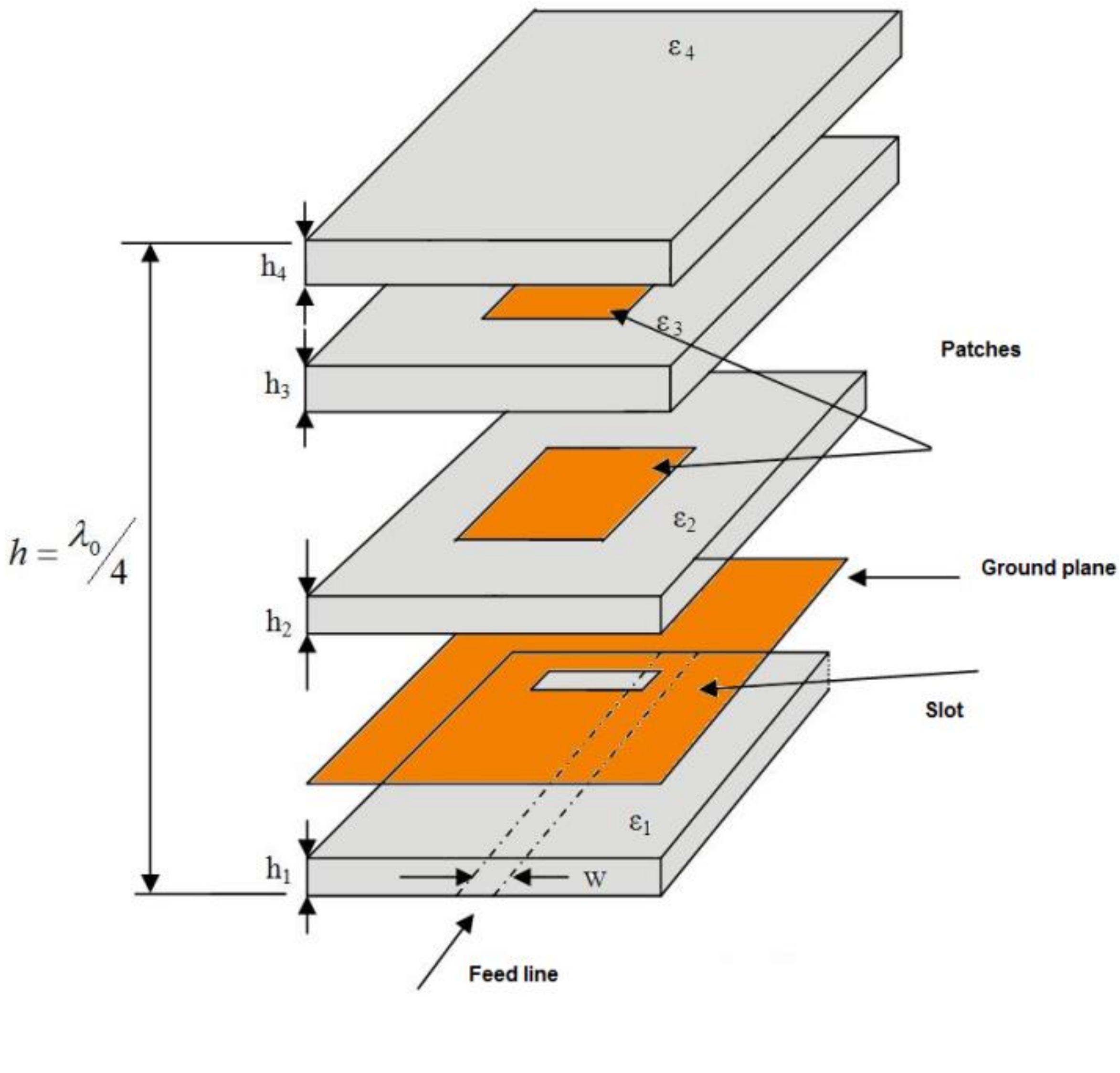


Figure 2.3: Aperture coupler feeding

2.7 Comparing the different feed techniques

Characteristics	Micro strip Line Feed	Coaxial Feed	Aperture Coupled Feed	Proximity Coupled Feed
Spurious feed Radiation	More	More	Less	Minimum
Reliability	Better	Poor due to Soldering	Good	Good
Ease of Fabrication	Easy	Soldering and drilling needed	Alignment required	Alignment required
Impedance Matching	Easy	Easy	Easy	Easy
Bandwidth (achieved with impedance matching)	2.5%	2.5%	2.5%	13%

2.8 Methods of Analysis

There are many methods of analysis for patch antenna, they are transmission line model, cavity model and full wave model. The transmission line model is the easiest of all, it gives good physical insight, but it is less accurate and it is more difficult to model coupling. Compared to the transmission line model, the cavity model is more accurate, but it is more complex.

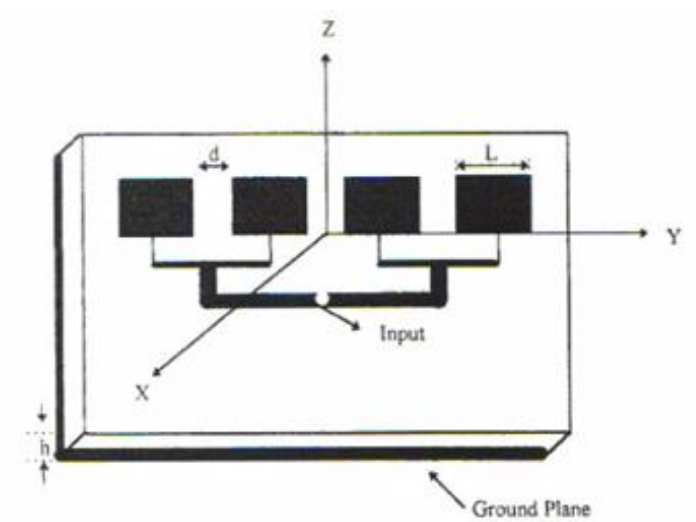


FIG. 1: Geometry and coordinate system of four element microstrip antenna array.

Chapter 3

Methodology

3.1 Introduction to HFSS

HFSS is a commercial finite element method solver for electromagnetic structures from Ansys. The acronym originally stood for high frequency structural simulator. It is one of several commercial tools used for antenna design, and the design of complex RF electronic circuit elements including filters, transmission lines, and packaging. It was originally developed by Professor Zoltan Cendes and his students at Carnegie Mellon University. Prof. Cendes and his brother Nicholas Csendes founded Ansoft and sold HFSS stand-alone under a 1989 marketing relationship with Hewlett-Packard, and bundled into Ansoft products. [1] After various business relationships over the period 1996-2006, H-P (which became Agilent EEs of EDA division) and Ansoft went their separate ways: [2] Agilent with the critically acclaimed [3] FEM Element and Ansoft with their HFSS products, respectively. Ansoft was later acquired by Ansys.

The Ansoft High Frequency Structure Simulator (HFSS) is a full-wave electromagnetic (EM) software package for calculating the electromagnetic behavior of a 3-D structure.

Using HFSS, you can compute:

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

3.2 Features of HFSS:

3.2.1 Capabilities:

- Accurate full-wave EM simulation
- Import/export of 3D structures
- Automatic adaptive mesh generation and refinement
- Adaptive Lanczos-Padé Sweep for fast frequency sweeps
- Inclusion of skin effect, losses
- Direct and iterative matrix solvers

- Eigen mode matrix solver

3.2.2 Solution Data (Visualization):

- S-, Y-, Z-parameter matrix (2D plot, Smith Chart)
- Port characteristic impedance
- Current, E-field, H-field (3D static and animated field
- plot in vector display or magnitude display)
- Far-field calculation (2D, 3D, gain, radiation pattern)
- Material losses, radiation losses.

3.3 Ansoft terminology

The Ansoft HFSS window has several optional panels

A. Project Manager

B. Message Manager

C. Property window

D. Progress window

E. 3D Modeler window

These above managers and windows are shown in fig. and their details are given in coming sections

3.4 HFSS window

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

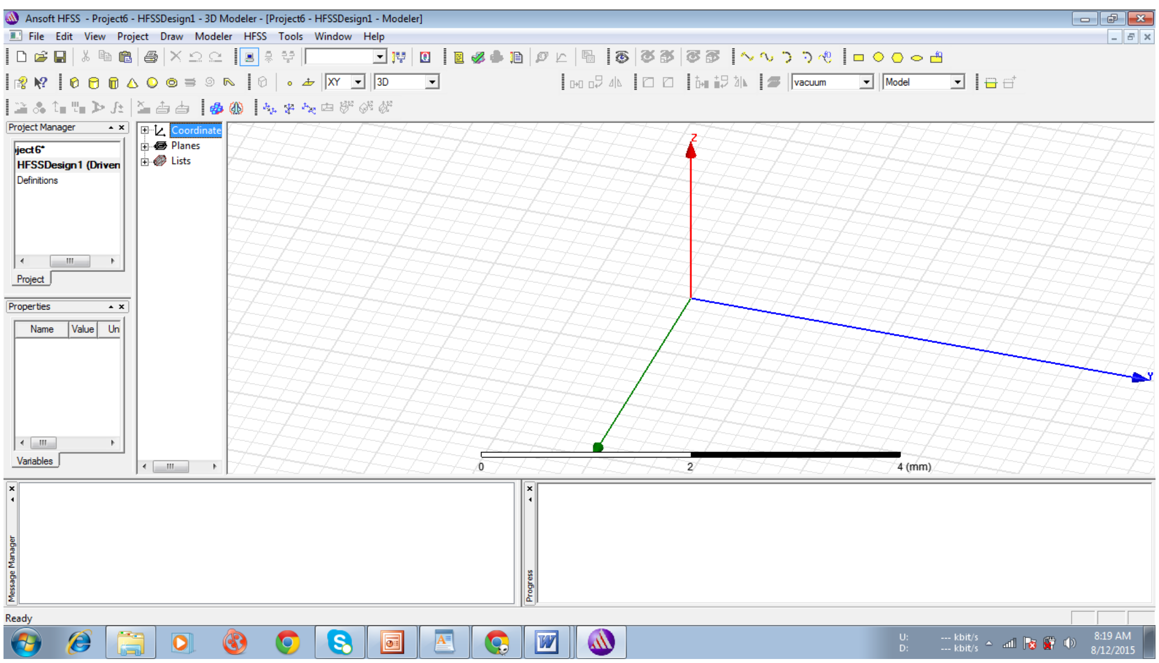


Figure 3.1 Ansoft HFSS window

3.5 Project Mangers

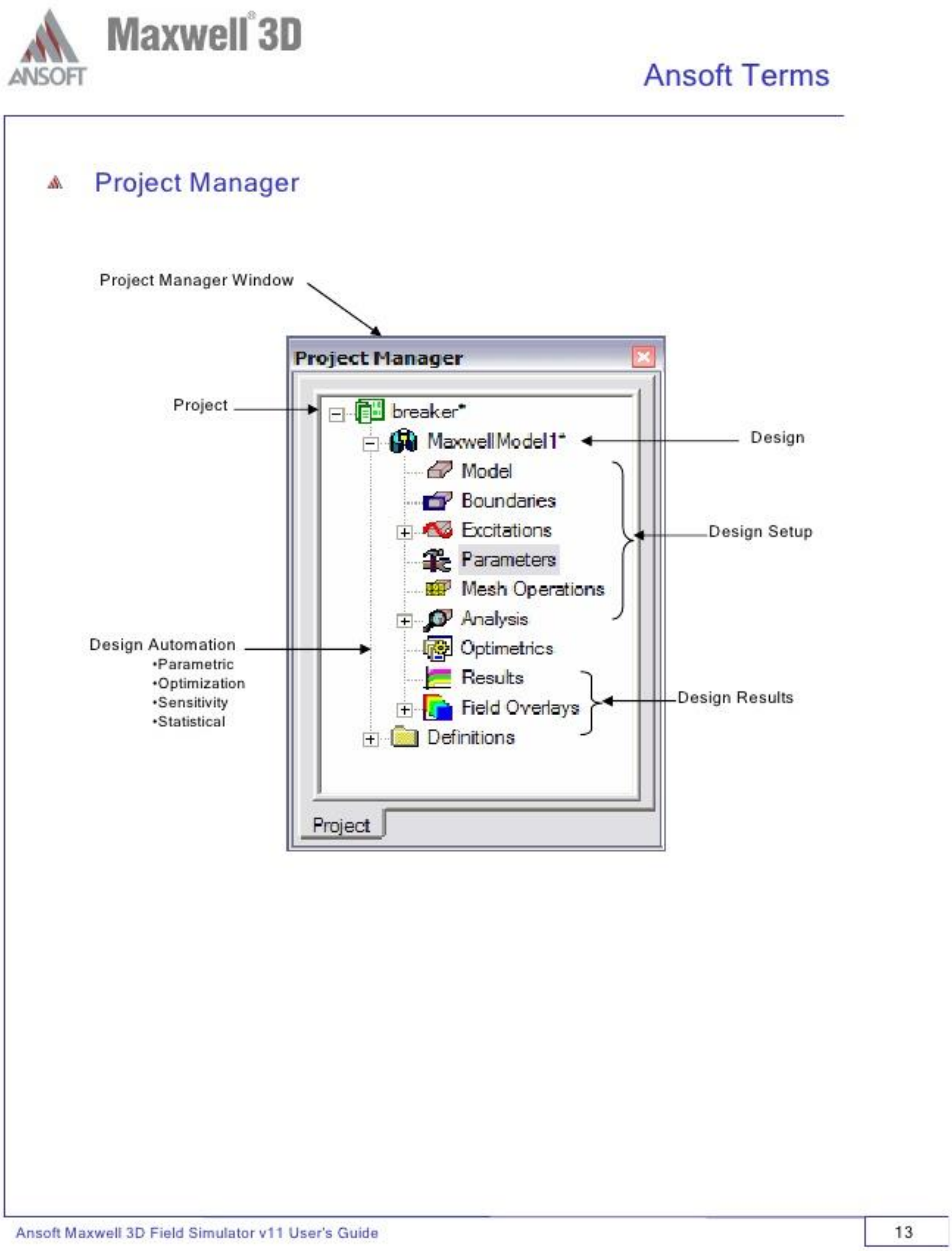


Figure 3.2: Ansoft project manager

3.5 Property window:

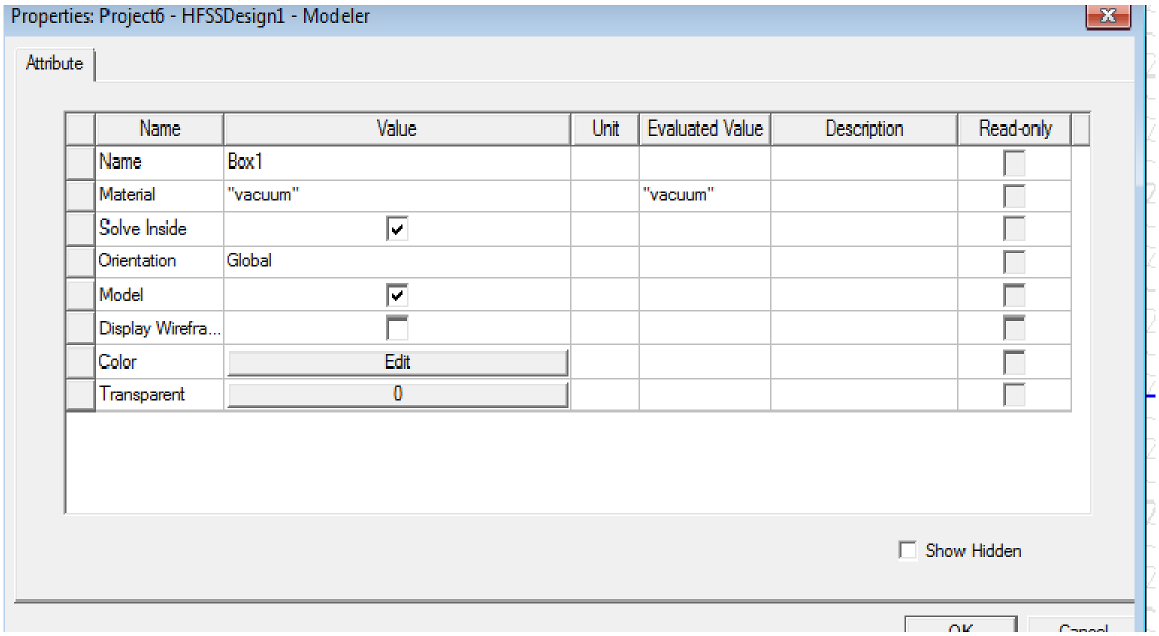


Figure 3.3: Ansoft property window

3.6 Modeler window

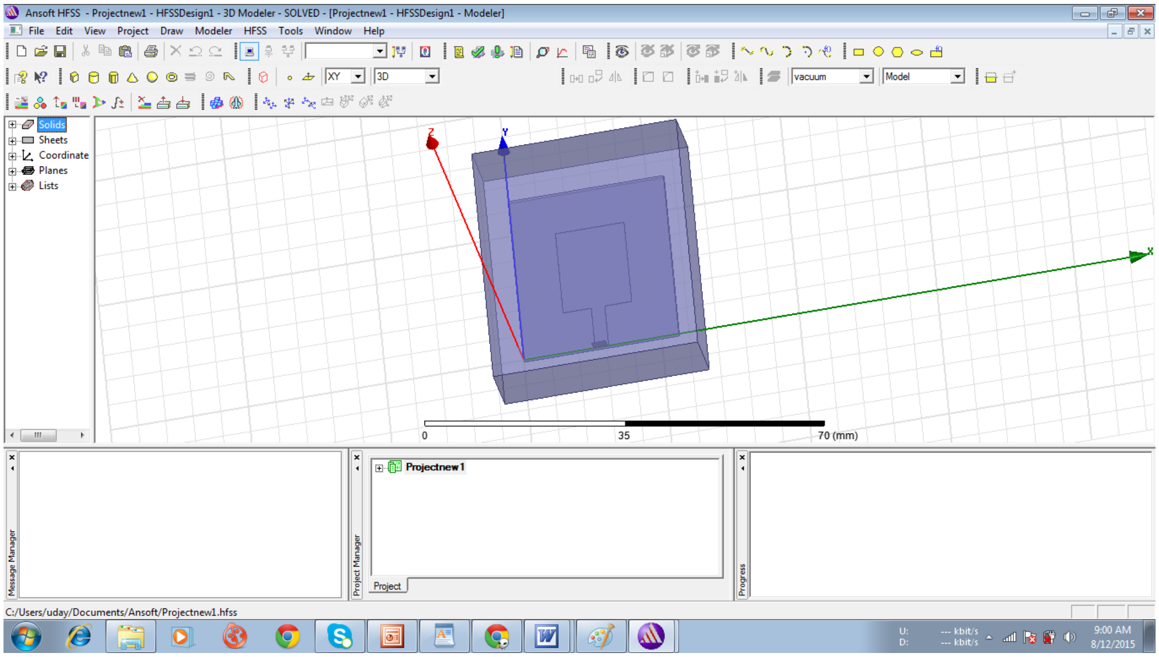


Figure 3.4 Ansoft HFSS window

3.8 Toolbars:

The toolbar 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.

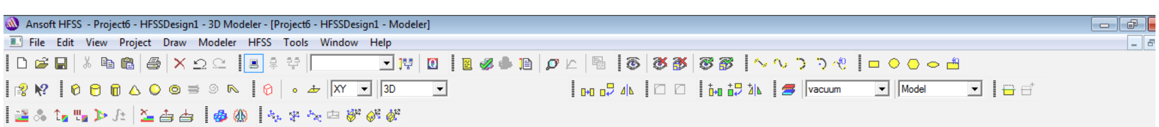


Figure 3.5 Toolbar

3.9 Ansoft HFSS Desktop

Ansoft HFSS Desktop provides an intuitive, easy-to-use interface for developing RF device models. Creating designs, involves the following:

A. Parametric Model Generation -creating the geometry, boundaries and excitations.

B. Analysis Setup -defining solution setup and frequency sweeps.

C. Results -creating 2D reports and field plots.

D. Solve Loop -the solution process is fully automated.

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

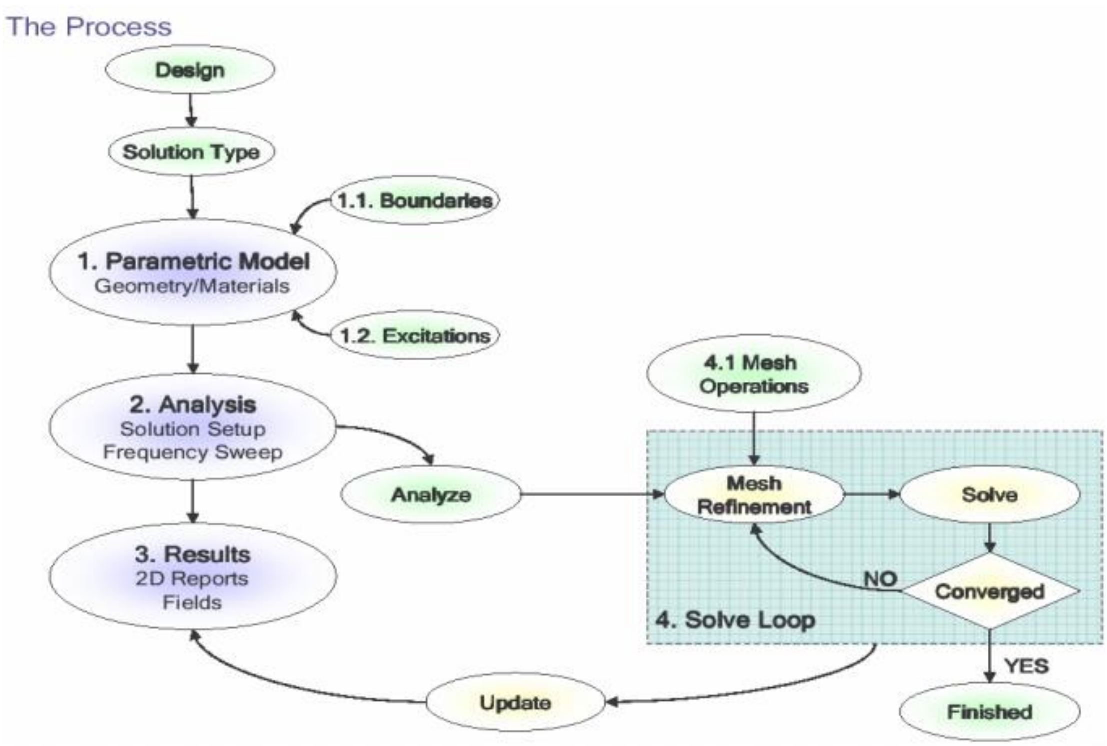


Figure 3.6: Flow chart illustration of Ansoft HFSS

3.10 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.

3.11 Opening a New project

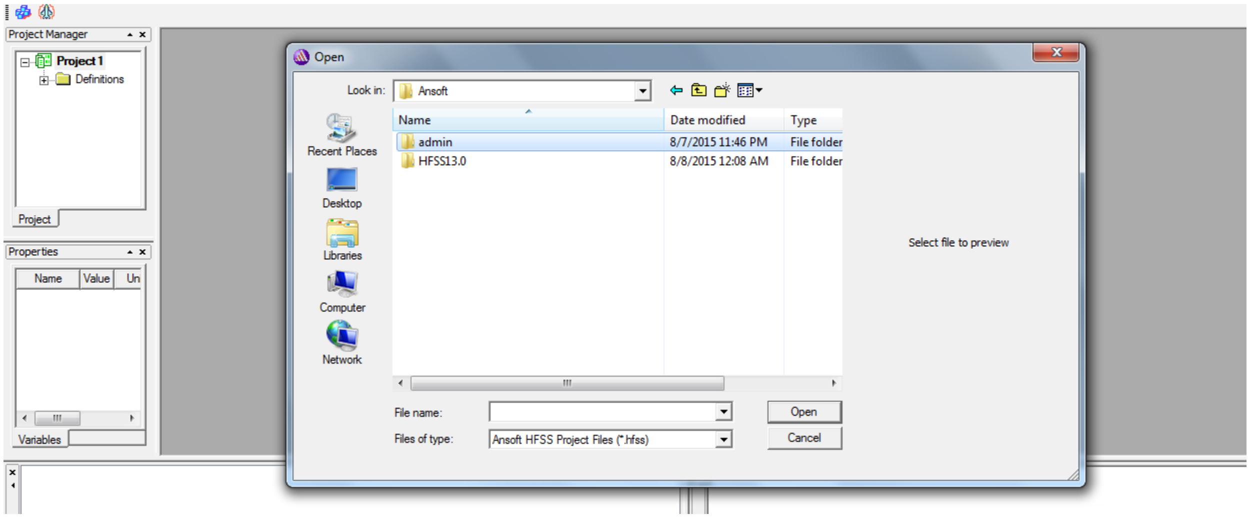
a. In an Ansoft HFSS window, select the menu item File. New.

b. Select the menu Project. Insert HFSS Design.

3.12 Opening an Existing HFSS project

To open an existing project:

a. In an Ansoft HFSS window, select the menu File > Open. Use, the Open dialog to select the project.
b. Click Open to Open the Project.



3.13 Set Solution Type

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

I. Driven Modal – calculates the modal-based S-parameters. The S-matrix, solution will be expressed in terms of the incident and reflected power of waveguide modes.

II. 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.

III. Driven Transient : It employs a time-domain ("transient") solver – Typical applications include, but are not limited to Simulations with pulsed excitations, such as ultra-wide band antennas, lighting strikes, electro – static discharge ; field visualization employing short-duration excitations; time-domain Reflectometry.

IV. Engine mode: Calculate the Eigen modes or resopnances, of a structure. The Eigen model solver finds the resopnant frequencies of the structure and the fiels at those resonant frequencies.

3.14 Convergence

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

II. Eigen mode- Delta F

II. Driven Terminal New – Delta S for the single –ended or differential nodal S-Parameters.

3.15 To set the solution type

Select the menu item HFSS > Solution Type

3.16 Solution Type Window

Choose one of the following:

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

3.17 Getting Help

If you have any questions while you are using Ansoft HFSS you can find answers in several ways:

3.18 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.

3.19 Ansoft Technical Support

1. To contact Ansoft technical support staff in your geographical area, please log on to the Ansoft corporate website, ansoft.com and select Contact.

2. Your Ansoft Sales engineer may also be contacted in order to obtain this information.

3.20 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

3.21 For Technical Support

The following link will direct you to the Ansoft Support Page. The Ansoft Support Pages Provide additional documentation, training and application notes.

Chapter 4

Results and discussion

In this chapter we will discuss about the effects of various shapes of a microtrip patch array antenna. We will also see that the bandwidth will be increased when we will used different types of patch array.

For design & simulation we used HFSS (High Frequency Structural Simulator).

4.1 Design and simulation of microstrip patch array antenna:

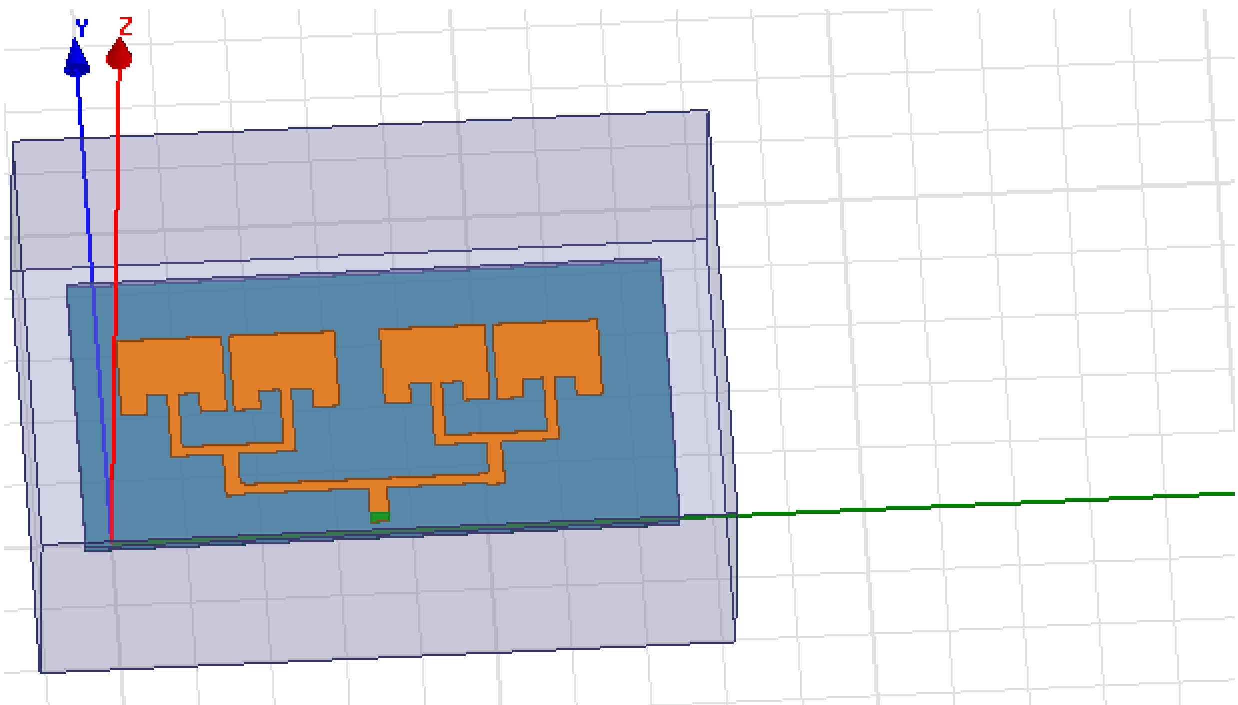


Figure 4.1Snapshot of the designed microstrip patch array antenna

Here substrate height is h= 1.6mm. Substrate length = 85mm at Y axis and width = 158mm at X axis. Here in patch, we use 'pec' material and substrate material use many type. Which have a different relative permittivity (ε_r) and that changes we get different result. Those result is show in simulated part.

The percentage bandwidth of the antenna is calculated using the formula-

% Bandwidth = $\frac{\int 2-f1}{f0}$100% (4.1)

Where f_1 and f_2 are the lower and upper cut off frequencies and f_0 is the center frequency.

4.2 Simulated results of a patch array antenna

After simulating the return loss of the optimized antenna from HFSS is shown in Figure 4.2 at7.5 GHz a return loss of -10 dB is achieved.

Now after taking Rogers ultralam1300(tm) as a substrate material, whose relative permittivity ε_r is 3.

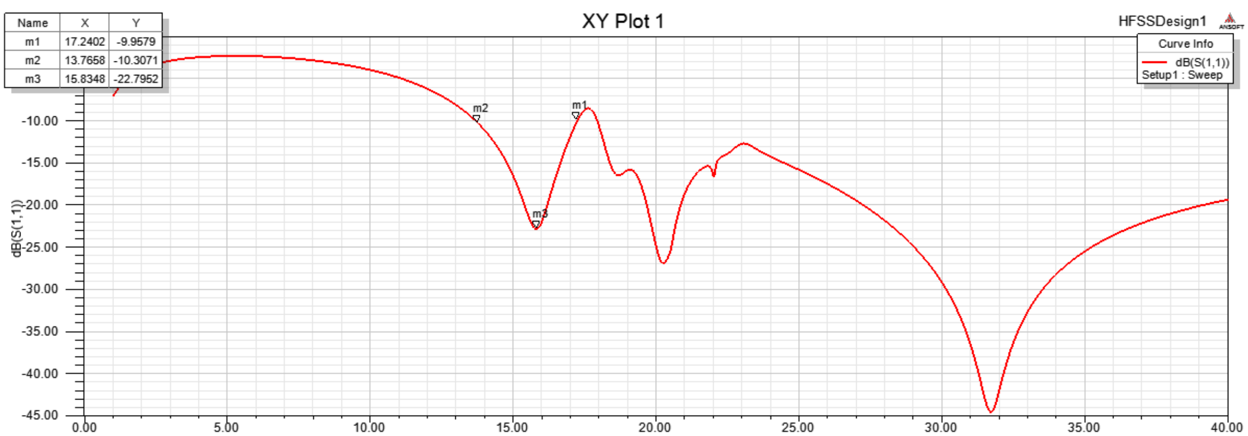


Figure 4.2: Return loss vs. frequency of an array antenna taking Rogers ultralam 1300(tm) as substrate.

Here after using equation 4.1 we get percentage bandwidth is 21.94%. We get array antenna for use"Rogers ultrlam 1300(tm)" substrate. That's substrate height 1.6 mm. Its relative permittivity is 3.

Figure 4.3: 3D polar plot of an array antenna for Rogers ultralam 1300(tm) as a substrate

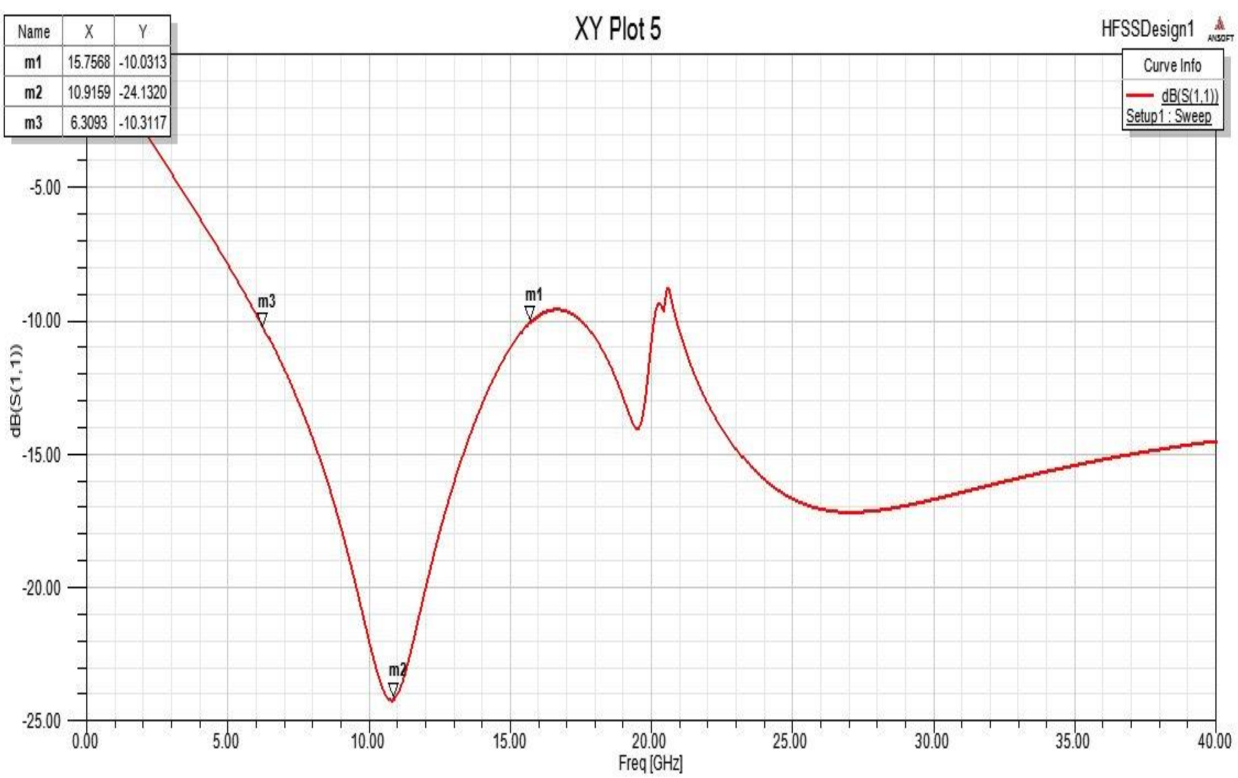


Figure 4.4 Return loss vs frequency of an array antenna for Rogers RT/duroid 6010/6010LM in HFSS.

From figure4.4, using equation (4.1) the calculated percentage bandwidth is 86.56%. The substrate thickness is 1.6 mm. The relative permittivity of Rogers RT/duroid 6010/6010LM is 10.2.

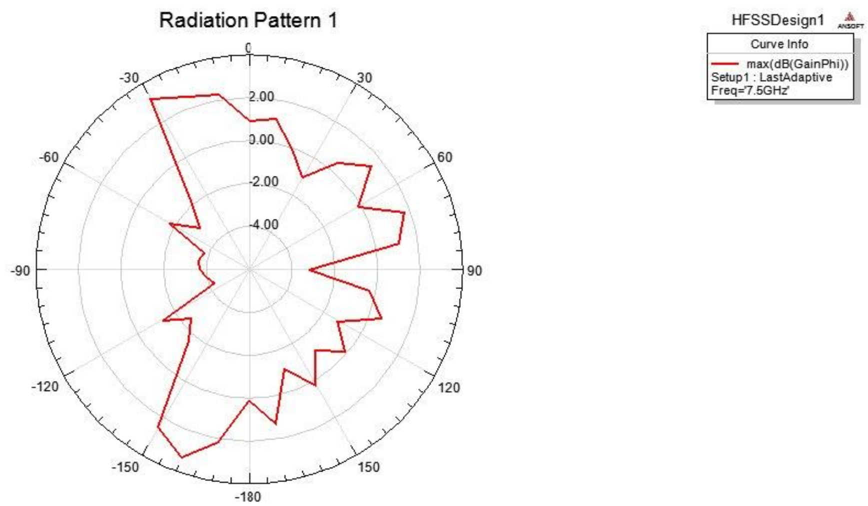


Figure 4.5 Radiation pattern for 2D for “Rogers RT/duroid 6010/6010LM(tm)” substrate

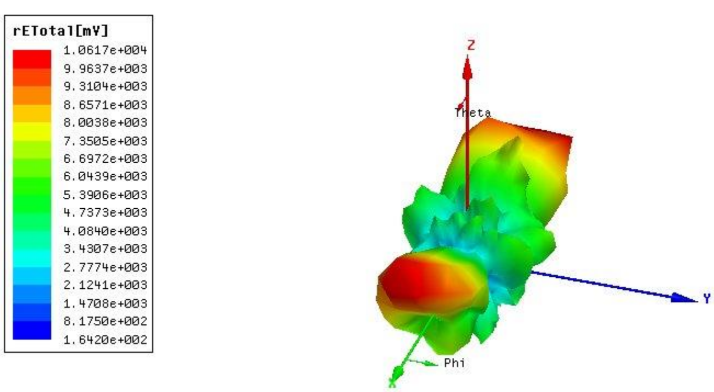


Figure 4.6 Radiation pattern for 3D for“Rogers RT/duroid 6010/6010LM(tm)” substrate

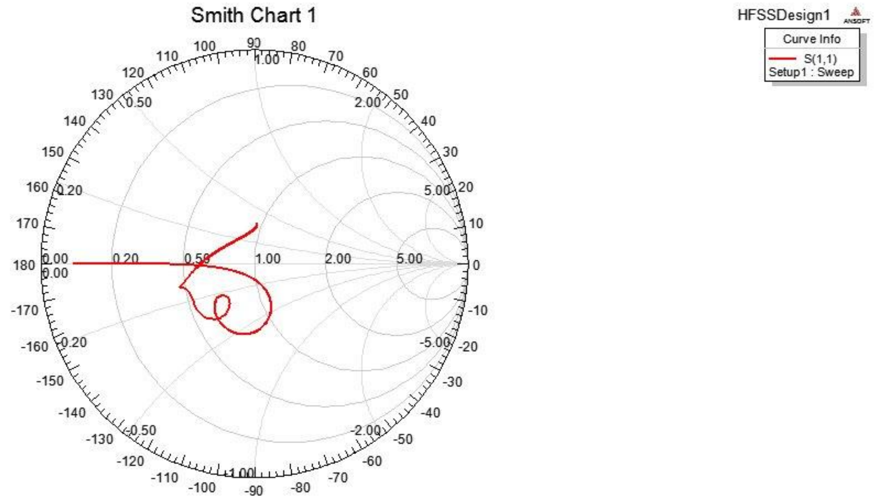


Figure 4.7 Smith chart

Table 4.1: Data sheet of relative permittivity (ε_r) of substrate material and percentage bandwidth

Substrate Material	Relative permittivity (ε_r)	f_2 (GHz)	f_1(GHz)	f_0 (GHz)	Bandwidth (%)
Rogers RTduroid 6002(tm)	2.94	17.27	13.41	16.22	23.83
Rogers ultralam 1300	3	17.2402	13.7698	15.8348	21.91
Rogers TMM 3(tm)	3.27	17.0660	13.973	14.9369	20.70
Rogers TMM 10(tm)	9.2	18.9184	13.5706	17.2796	30.94
Rogers RT/durioid 6010/6010LM(tm)	10.2	15.7588	6.3093	10.9159	86.56

4.3 Percentage bandwidth and permittivity

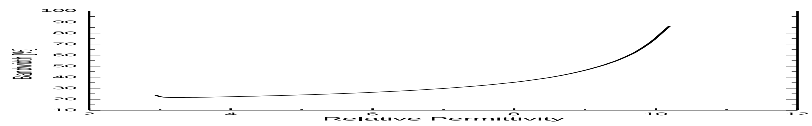


Figure 4.8 Dependence of percentage bandwidth on permittivity of substrate material

According to graph we see when permittivity is high that time % of bandwidth is increase array antenna at Rogers RT/duroid 6010/6010LM (tm) substrate. Here we get the maximun % of bandwidth on material Roger RT/duroid 6010/6010LM(tm) (ε_r= 10.2) is 86.56%.

4.4 Percentage Bandwidth and Substrate thickness

Table 4.2: Data sheet substrate thickness and percentage bandwidth

Substrate Material	Thickness (mm)	f_2 (GHZ)	f_1(GHZ)	f_0(GHZ)	Bandwidth (%)
Rogers RT/durioid 6010/6010LM(tm)	0.5				Not acceptable
Rogers RT/durioid 6010/6010LM(tm)	1				Not acceptable
Rogers RT/durioid 6010/6010LM(tm)	1.6	15.7588	6.3093	10.9159	86.56
Rogers RT/durioid 6010/6010LM(tm)	2	17.1231	121652	16.2643	30.48
Rogers RT/durioid 6010/6010LM(tm)	2.6	15.7568	14.3163	15.0931	9.54
Rogers RT/durioid 6010/6010LM(tm)	3.4	20.8138	19.8889	20.4416	4.52

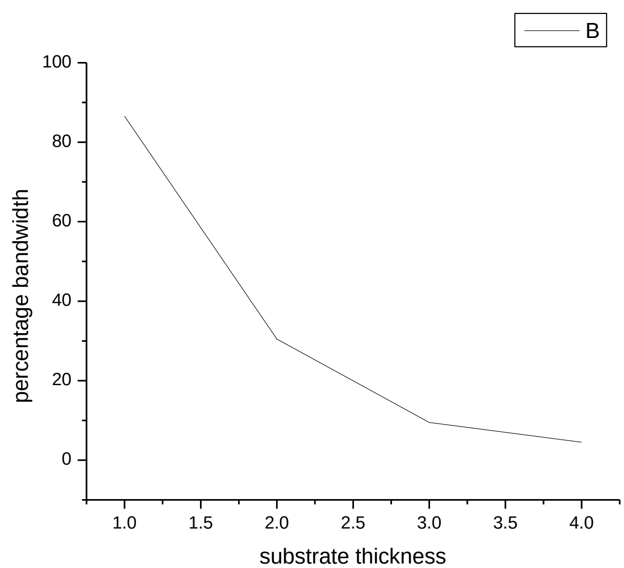


Figure 4.9: Dependence on percentage bandwidth and substrate thickness

4.5 Effects of feed position on percentage bandwidth

The effects of feed position on the percentage bandwidth of array antenna using Rogers RT/durioid 6010/6010LM(tm) as a substrate material is discussed in this section. Table 4.3 shows the data sheet.

Table 4.3: Percentage bandwidth and feed position of Rogers RT/durioid 6010/6010LM(tm)

Material name	Feed positon	Bandwidth (BW)%
Rogers RT/durioid 6010/6010LM(tm)	38,2,1.6	Not acceptable
Rogers RT/durioid 6010/6010LM(tm)	55,2,1.6	32.31
Rogers RT/durioid 6010/6010LM(tm)	60,2,1.6	Not acceptable
Rogers RT/durioid 6010/6010LM(tm)	66,2,1.6	55.34
Rogers RT/durioid 6010/6010LM(tm)	69,2,1.6	86.56
Rogers RT/durioid 6010/6010LM(tm)	72,2,1.6	16.57
Rogers RT/durioid 6010/6010LM(tm)	85,2,1.6	72.35
Rogers RT/durioid 6010/6010LM(tm)	92,2,1.6	3.36

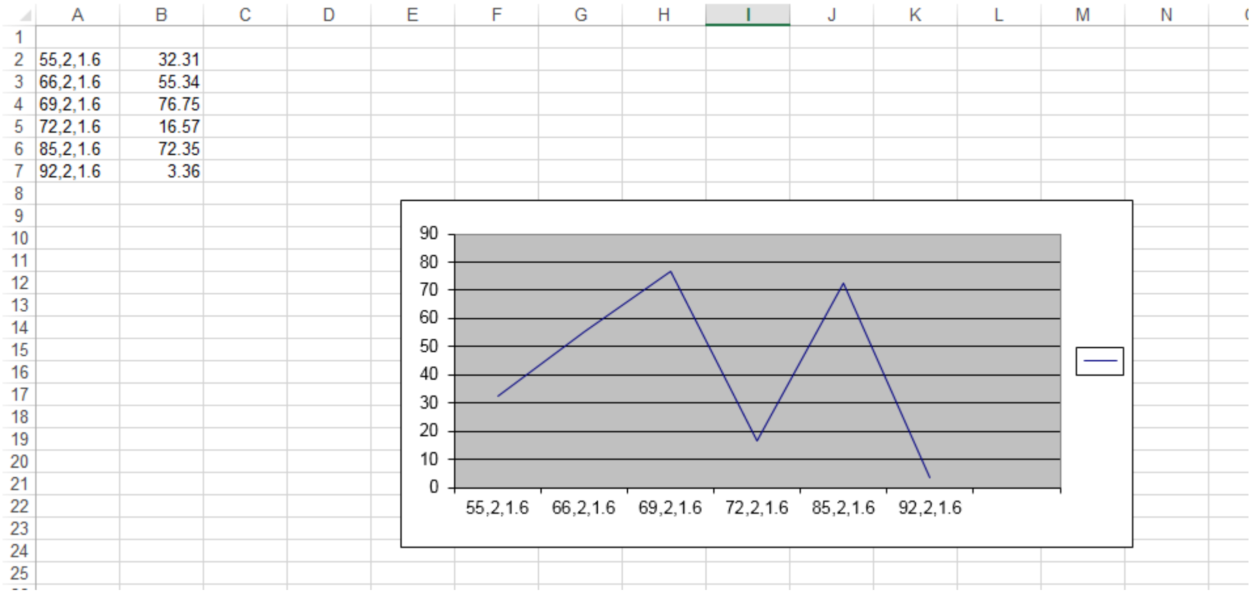


Figure 4.10 Dependence of percentage bandwidth on feed position

From figure 4.7, it is found that the percentage bandwidth is highly sensitive to the feed position.

Chapter 5

Conclusion

In this thesis we have designed a 4 patch microstrip array antenna using HFSS. After simulation 86.56 percentage bandwidth was found with substrate material Roger RT/duroid 6010/6010LM(tm) (ε_r= 10.2).

We have investigated the effect of substrate height and it is found that the maximum percentage bandwidth is available at a substrate height of 1.6 mm.

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