DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

ANIL NEERUKONDA INSTITUTE OF TECHNOLOGY AND SCIENCES
(UGC AUTONOMOUS)

(Permanently Affiliated to AU, Approved by AICTE and Accredited by NBA & NAAC with 'A' Grade)

Sangivalasa, Bheemili mandal, Visakhapatnam dist.(A.P)

PRAGNANAM BRAHMA

ANITS

CERTIFICATE

This is to certify that the project report entitled **"BAND SWITCHABLE MICROSTRIP PATCH ANTENNA FOR COGNITIVE RADIO"** submitted by **G.S.N.Hari Priya (317126512075), T.Dheeraj Kumar (317126512115), P.Swarna Latha (317126512095), S.T.V.S.S.Pavan (317126512107)** in partial fulfillment of the requirements for the award of the degree of **Bachelor of Technology** in **Electronics & Communication Engineering** of Andhra University, Visakhapatnam is a record of bonafide work carried out under my guidance and supervision.

Project Guide

Ms.P.Chaya Devi

Assistant Professor
Department of E.C.E
ANITS

Assistant Professor
Department of E.C.E.
Anil Neerukonda
Institute of Technology & Sciences
Sangivalasa, Visakhapatnam-531 162

Head of the Department

Dr. V.Rajyalakshmi
Professor&HOD
Department of E.C.E
ANITS

Head of the Department
Department of E.C.E
Anil Neerukonda Institute of Technology & Sciences
Sangivalasa - 531 162

ACKNOWLEDGEMENT

We would like to express our deep gratitude to our project guide **Ms.P.Chaya Devi,** Assistant Professor, Department of Electronics and Communication Engineering, ANITS, for her guidance with unsurpassed knowledge and immense encouragement. We are grateful to **Dr. V. Rajyalakshmi**, Head of the Department, Electronics and Communication Engineering, for providing us with the required facilities for the completion of the project work.

We are very much thankful to the **Principal and Management, ANITS, Sangivalasa,** for their encouragement and cooperation to carry out this work.

We express our thanks to all **teaching faculty** of Department of ECE, whose suggestions during reviews helped us in accomplishment of our project. We would like to thank **all non-teaching staff** of the Department of ECE, ANITS for providing great assistance in accomplishment of our project.

We would like to thank our parents, friends, and classmates for their encouragement throughout our project period. At last but not the least, we thank everyone for supporting us directly or indirectly in completing this project successfully.

PROJECT STUDENTS

G.S.N.Hari Priya(317126512075),
T.Dheeraj Kumar(317126512115),
P.Swarna Latha(317126512095),
S.T.V.S.S.Pavan(317126512107)

ABSTRACT

Now a days with increasing use of communication devices, signal trafficking over a particular band increasing. In order to overcome these kind of issues, cognitive radio was introduced. A cognitive radio is a radio that can be programmed and configured dynamically to use the best wireless channels in its surroundings to avoid user interference and congestion. It will scan throughout the spectrum and find the free slots over any particular bands and start transmission or receiving signal the proposed work is focused on achieving Spectrum sensing and signal transmission or reception over a single band through switching technique. So, we introduce a six-switch integrated ultrawideband (UWB) frequency reconfigurable system. Switching property can be achieved by inserting pin diodes or RF-MEMS switches. This design mainly finds the applications of cognitive radios such as cellular networks, medical purposes and aviation etc.,

CONTENTS

LIST OF SYMBOLS

a	Channel thickness
E_C	Conduction energy band
E_V	Valence energy band
E_F	Fermi energy
E_g	Energy gap
E_i	Intrinsic Fermi energy
E_{crit}	Critical Electric Field
eV	electron volt
I_D	Drain current
I_{Dmax}	Maximum drain current
I_{Dsat}	Drain saturated current
J_n	Electron current density
J_p	Hole current density
k	Thermal conductivity
L	Channel length
L_a	Length of upper gate in L-gate structure
L_b	Length of lower gate in L-gate structure
L_D	Length of the drain region

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVATIONS

CR	channel-recessed
CR_BG	channel-recessed buried-gate
CR_LG	channel-recessed L-gate
EHP	electron-hole pair
MESFET	Metal Semiconductor Field Effect Transistor
NR_BG	non-recessed buried-gate
NR_LG	non-recessed L-gate
NR	non-recessed
RF	Radio Frequency
SiC	Silicon Carbide
I-V	Current-Voltage

CHAPTER 1

SWITCHABLE MICROSTRIP PATCH ANTENNA

1.1 INTRODUCTION

Microstrip antennas received considerable attention starting in the 1970s, although the idea of microstrip antenna can be traced to 1953 [1] and a patent in 1955 [2]. One of the major benefits of microstrip antenna is that they are very comfortable to planar and non-planar surfaces. This was the main reason that the microstrip antenna acquired the serious attention to the researchers in early 1970s when high performance application such as aircraft, spacecraft, missile, satellite communication put the motivation for researchers to investigate on usefulness of conformal microstrip antennas. After about 2 years Howell introduced a basic rectangular shape microstrip antenna that was fed using the microstrip transmission line. In that days microstrip antenna was a major focus for investigators. Researchers introduced many various designs. But it was difficult to get the better radiation efficiency that was limited up to 90%. Narrow bandwidth was also a severe problem for microstrip antenna.

1.2 STRUCTURE:

In a most basic form a microstrip antenna comprises of two thin metallic layers (t $<<\lambda_0$, where λ_0 is wavelength in free space) one as radiating patch and second as ground plane and a dielectric substrate is placed between them. The conductor patch is placed on the dielectric substrate and used as radiating element. On the other side of the substrate there is a conductive layer used as ground plane as represented in Fig.1.2. Copper and gold is used normally as a metallic layer. Radiating patch can be of any shape but simple shapes are used to design a patch because patches basic shapes are easy to analysis by the available theoretical models and it is easy to predict the performance. Square, rectangular, dipole, triangular, elliptical, circular are some basic shapes. Circular, rectangular and dipole are the most often used shapes because of easy of analysis and fabrication. A variety of dielectric materials are available for the substrate with dielectric constants $2.2 \leq \varepsilon_r \geq 12$. The height of substrate plays an important role in antenna characteristics generally are in the range $0.003\lambda_0 \leq h \geq 0.05\lambda_0$

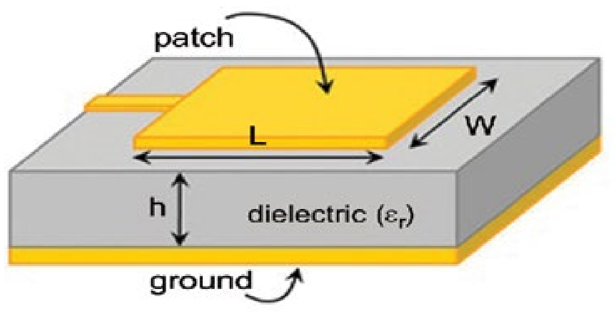


Fig.1.1: Basic Microstrip Antenna

An antenna characteristics is not only depends on the antenna element but also be influenced by the TX-line and antenna combination. Generally the input impedance of microstrip antenna is complex and the characteristic impedance of TX-line is real (usually 50 ohm). This will results in impedance mismatching and causes a voltage standing wave pattern on transmission line results in low impedance bandwidth. One way to overcome this problem is use of impedance matching networks between antenna and transmission line. There are several impedance matching techniques are available, Circuit theory deals with the impedance matching techniques.

Microstrip antenna suffers from very Narrow frequency bandwidth. However some application where narrow bandwidth is essential such as government security systems, microstrip antennas are useful. Bandwidth of microstrip antenna is directly proportional to height of substrate. There are two main techniques two improve the Structural technique deals with the modification of substrate properties such as height and dielectric constant. By increasing the height we can increase the bandwidth. But it will also introduce surface waves which increases loss of the power and leads to performance and characteristics degradation. Various types of methods are introduced by the researchers such as stacking, defected ground plane, parasitic patches and improvement of bandwidth of microstrip antenna is still an interesting topic for investigation. By choosing a particular shape one can easily design an antenna with desired resonance frequency radiation pattern, polarization. It is easy to design a microstrip antenna with reconfigurable polarization, resonance frequency and radiation patterns just by adding loads like PIN diode, Varactor diodes.

1.3Configurations:

Since the early development of microstrip antenna until now, variety of configurations have been produced and investigated to improve the performance of microstrip antenna as shown in Fig. 1.2. Some of the common shapes are rectangle; triangle and circular are shown in figure. Several shapes such as pentagon and ellipse are known to give circular polarization [3].

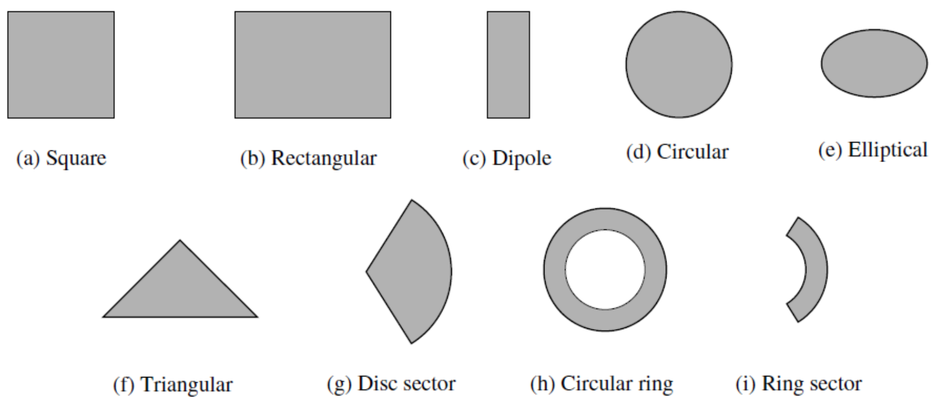


Fig 1.2 Different shape of microstrip patch antenna

1.4 Advantages and Disadvantages:

Microstrip antenna is a low profile antenna that has light weight and is very easy to installation due to which it is very popular in handheld wireless devices such as cell phones, pagers and in some high performance communication systems such as in satellite, missile, spacecraft, aircraft etc. Some of the major advantages of microstrip antenna as discussed by Ramesh Garg [4] are given below:

- Inexpensive and easy to fabricate.
- Can be planted easily on any surface.
- Can easily get reconfigurable characteristics.
- Can easily design antenna with desired polarization.
- Mechanically robust, Resistant against vibration and shock.
- Suitable to microwave integrated circuits (MICs).
- For high gain and directivity Array of antennas can be easily formed.

Conversely microstrip antennas also have a number of disadvantages and limitations when compared to other antennas. Some of the major disadvantages of microstrip antennas are written below:

- High quality factor.
- Cross polarization.
- Poor polarization efficiency.
- Suffers from spurious feed radiation.
- Narrow impedance bandwidth (5% to 10% without any technique)

There are various methods to overcome this limitations, bandwidth of microstrip antenna can be increase by using some special methods like defected ground plane strategy, stacked patches, slotted patches, parasitic patch. Gain and the power handling ability of antenna can be improved by making an antenna array. Use of Electromagnetic Band Gap (EBG) structure and met material also results in the improvement of the antenna characteristics [4]

1.5 Feeding Techniques:

Feeding methods can be dividing in two categories one is contacting feeds and other one is non contacting feeds or electromagnetic coupled feed. In contacting feeds the feed line is directly connected to radiating element. The main drawback of contacting feeds are that it shows inherent asymmetry which produces the higher order modes that leads to increase in cross polarization level. To minimize these non-contacting feeds are used. Microstrip line feed and coaxial probe feeding are two mainly used direct contact feedings and aperture coupled and proximity coupling are two non-contacting couplings which are described in brief below:

1.5.1 Microstrip probe feed:

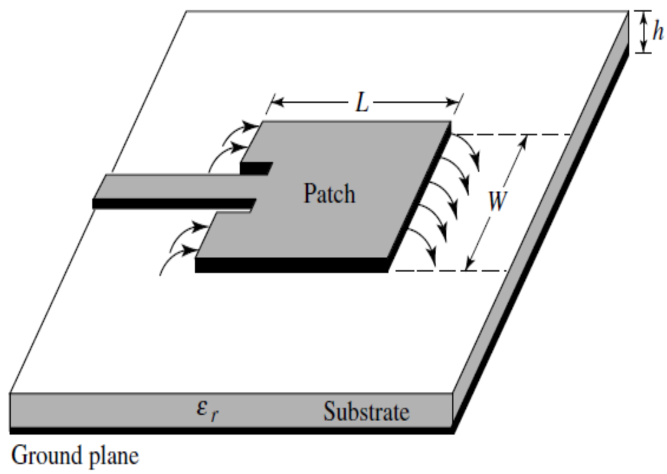


Fig. 1.3: Microstrip linefeed

In this type of feeding the radiating patch is directly fed by the microstrip feed line has a narrow width as compare to patch as shown in Fig. 1.4. It is the simple and mostly used feeding method. Because microstrip line can be treated as extended part of radiating patch and fabricated on the same substrate on the board. This feeding simple to fabricate and it's easy to impedance matching techniques are very compatible with this type of feed. But this feed also have some drawbacks, suffers from spurious feed radiation and surface wave losses also has low bandwidth

1.5.2 Coaxial probe feed:

One of the widely used feeding for microstrip antenna. In this type of feeding core of coaxial cable is directly connected to the patch using the soldering and the outer cable are connected to the ground. Core conductor is inserted in the substrate via a hole. The main advantage of this feeding is that we can directly feed or connect the inner conductor to the feed point where the input impedance is equal to the characteristic impedance of the feed line as shown in Fig. 1.4.

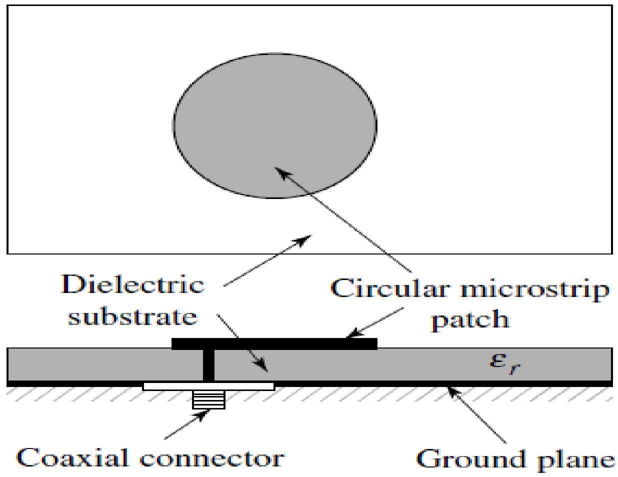


Fig. 1.4: Probe Feed

1.5.3 Proximity coupled feed:

Two types of dielectric substrates are used in this type of feeding. Microstrip line is not directly connected to patch and left open ended and is sandwiched between the substrates. Energy from feed line is coupled electromagnetic to the radiating patch. The microstrip line can be extended as stub to increase the bandwidth. Substrates dielectric constants play a lead role and selected to increase the bandwidth and decrease the spurious feed radiations from the feed line. Structural view of this type of feeding is shown in Fig. 1.5.

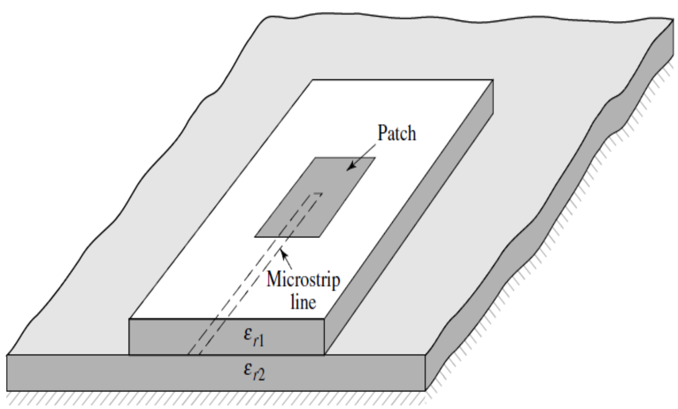


Fig. 1.5: Proximity-Coupled feed

Thick Material with low dielectric constant is selected for Upper substrates because lower the dielectric constant more the fringing field and more the radiations from patch and thin substrate with high dielectric constant is selected for lower substrate. This type of feeding has largest bandwidth as compared to others. It is easy to model and has low spurious feed radiation however its fabrication is more difficult because the exact alignment of feed line is required. The length of the extended stub and width to line ratio of patch can be optimized to control the antenna characteristics.

1.5.4 Aperture coupled feed:

Structural view of this type of feeding is shown in Fig. 1.6. As shown this feeding also uses two type of substrate ground plane is placed between them and microstrip line is used generally to feed which is placed below the lower substrate.

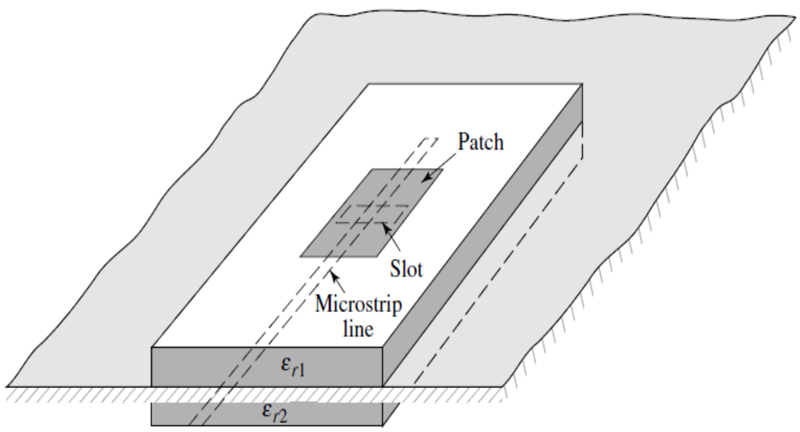


Fig. 1.6: Aperture-Coupled feed

Aperture coupling feeding the energy is electromagnetically coupled to the patch through an aperture or slot made in the ground plane. Different types of aperture shapes are used generally rectangular and circular shapes are widely used. Cross shaped and annular ring shape slots are used for exciting the circular polarization. The parameters of slots are used to improve the antenna characteristics. As in proximity coupled feeding substrates dielectric constant is selected to get better radiation and bandwidth. Thick substrate with low dielectric constant is used for the upper substrate to get the good radiation and bandwidth. While thin and high dielectric constant material is used for the upper substrate to for efficient transfer of energy from feed line to patch. To get the maximum coupling between feed structure and the patch slot should be located at the place where the magnetic field is maximum. We know that from the current and voltage distribution along the patch length, electric field is maximum at the ends and magnetic field is maximum at the centre of the patch. The microstrip feed line is extended a length extra and is used as a stub. Stub works as an open circuited transmission line has admittance is in parallel to that of the slot. By optimizing the extended length of feed line (stub) the reactive components of slot can be cancelled out to that of the stub that will result in better impedance matching.

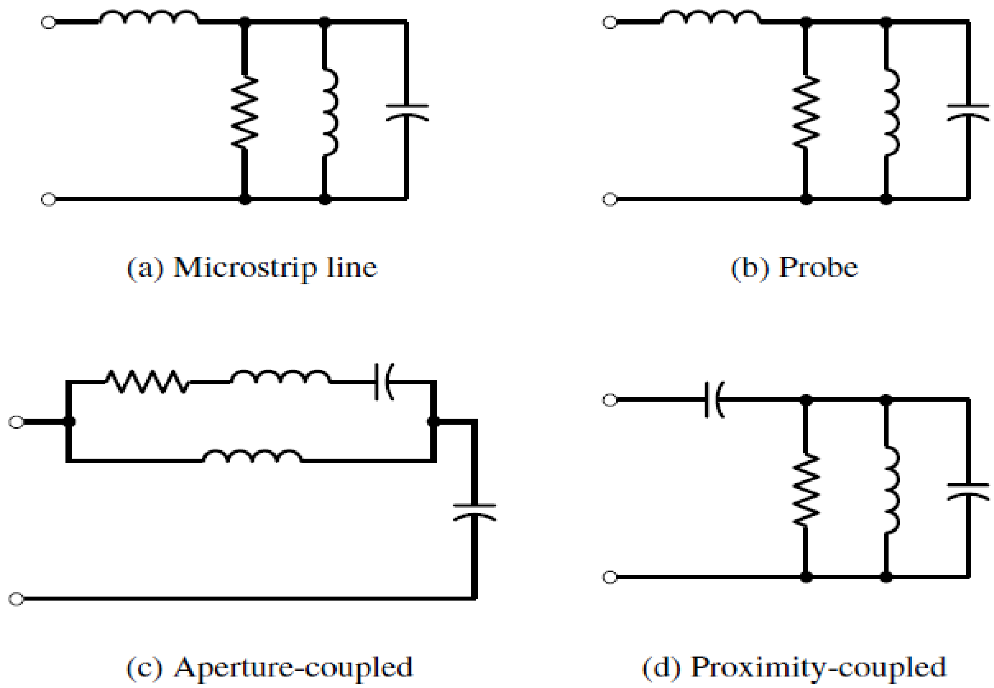


Fig. 1.7: Equivalent Circuits for Feeding Techniques

The area of slot is kept small to minimize the radiation below the ground plane. This type of feeding has better polarization purity, low spurious feed radiation and large bandwidth as compared to microstrip and coaxial probe feeding. The equivalent circuit for each of them is shown in Fig. 1.7 above.

1.6 Methods of Analysis:

There are many methods of analysis for microstrip antennas. The most popular models are the transmission model [5] and cavity model [6] and full wave [7] (which include primarily integrations/moment methods). The transmission line model is the easiest of all, it gives good physical insight, but is less accurate and it is more difficult to model coupling. Compared to transmission line model, the cavity model is more accurate at the same time more complex. However it gives also physical insight and is rather difficult to model coupling, although it has been used successfully. In general, when applied properly, the full wave models are accurate, very versatile and can treat single elements, finite and infinite arrays, stacked elements, arbitrary shaped elements, and coupling. However they are the most complex models and usually give less physical insight. In this section we will cover the transmission-line and cavity models only.

1.6.1 Rectangular Patch Antenna:

The rectangular microstrip patch is by far the most widely used configuration. It is very easy to analyze using both the transmission-line and cavity models, which are most accurate for thin substrates. We begin with the transmission-line model because it is easier to illustrate.

1.6.1.1 Transmission Line Model:

The transmission line model treated rectangular microstrip as a part of transmission line. As the rectangular microstrip antenna consists two radiating slots, transmission line model represents each radiating slots by an equivalent admittance which are separated by a distance equal to the length. The resistive part of them represents the radiation loss from the each slot. At the resonance the reactive part of the input impedance cancelled out and the input impedance become pure resistive. Transmission line model consider the effects of various parameters described below.

a. Fringing Field:

The fringing field in rectangular microstrip antenna as shown in Fig. 1.9 arises from the radiating edges shown in the figure below. Fringing field are mainly depends on the dielectric constant and length L to height h ratio. Since in most of the cases the L/h ratio is << 1 therefore the fringing fields are less.

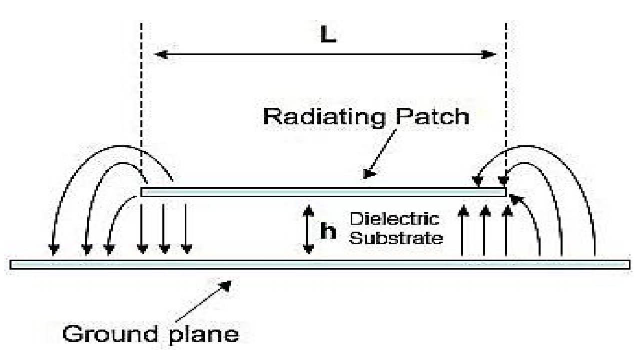


Fig. 1.8: Fringing Field Effect

Higher dielectric constant substrate leads to bounded electric fields more enclosed in the substrate as used in the microstrip lines. While the lower dielectric constants substrates results in loosely bounded electric fields means they will go more further from the patch. Lesser the dielectric constant material used in substrate more bowed the fringing fields. We know that the fringing fields are responsible for the radiations from microstrip antenna. Therefore lower dielectric constant more the fringing fields and more the radiations leads to better efficiency and better antenna performance. From figure it can be seen that fringing fields lines are not only enclosed in substrate but also go further out in the air. As the field lines travels in substrate and air also we have to calculate an Effective Dielectric constant by taking the air also in account as shown in Fig. 1.9.

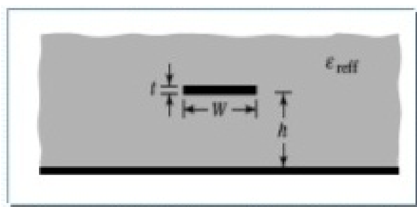


Fig. 1.9: Effective Dielectric constant

The effective dielectric constant is a dielectric constant of the material for which the antenna characteristics are same as for the real one. The range of effective dielectric constant varies from 1> ε_{reff}< ε_r . In most cases the ε_{reff} value is close to ε_r . If the air is used as a substrate then the effective dielectric constant is equal to dielectric constant ε_{reff} =ε_r. The ε_{reff} is also depends on frequency. As the operating frequency increases the value of effective dielectric constant reaches to the real value of dielectric material used. Fig. 1.10 below showing the variation of effective dielectric constant with the frequency below.

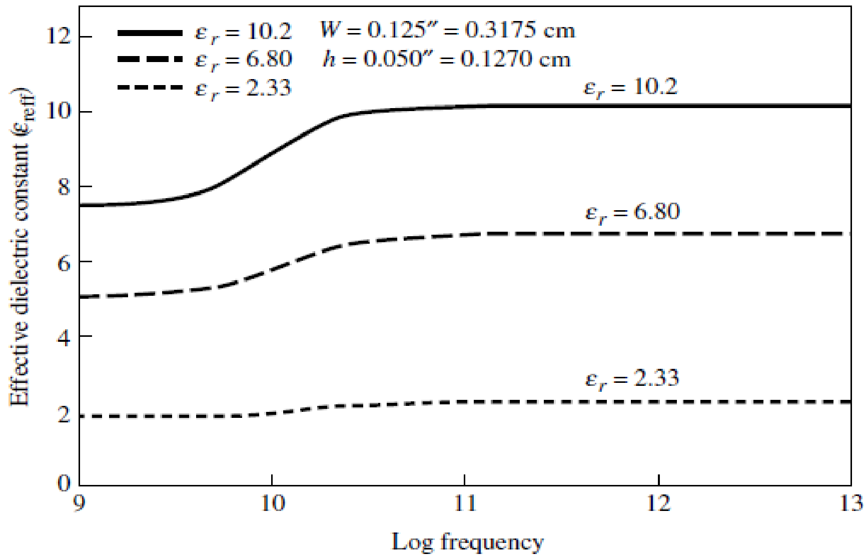


Fig. 1.10: Effective Dielectric constant Vs Frequency

For the lower frequency the effective dielectric constant does not varies but as the frequency increases the effective dielectric constant approaches towards the actual dielectric constant of substrate material.

The ε_{reff} for W/h>1 can be given by equation 1.1

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\,(1 + 12h/W)^{\frac{-1}{2}} \qquad \text{....1.1}$$

b. Effective Length, Resonant Frequency, and Effective Width:

Because of the fringing effects, electrically the patch of the microstrip antenna looks greater than its physical dimensions. Where the dimensions of the patch along its length have been extended on each end by a distance ΔL, which is a function of the effective dielectric constant $\in_{reff}$ and the width-to-height ratio (W/h). A very popular and practical approximate relation for the normalized extension of the length is given by equation 1.2

$$\frac{\Delta L}{h} = 0.412\frac{(\varepsilon_{reff} + 0.3)(\frac{W}{h} + 0.264)}{(\varepsilon_{reff} - 0.258)(\frac{W}{h} + 0.8)} \qquad \text{....1.2}$$

Since the length of the patch has been extended by ΔL on each side, the effective length of the patch as shown in Fig. 1.11.

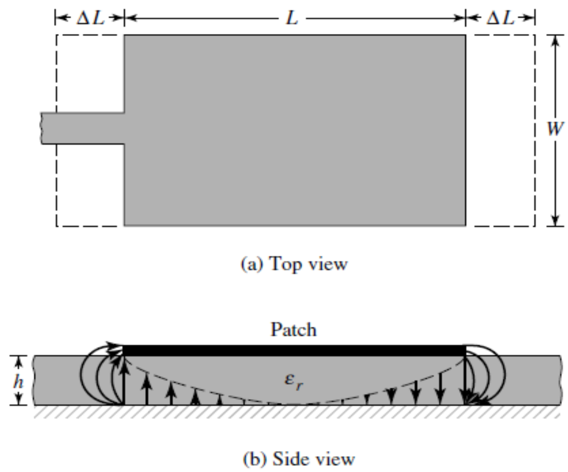


Fig. 1.11: Length Extension

This ΔL value mainly depends on the effective dielectric constant and the width to height ratio. Due to this length extension length of patch is about 0.48λ rather than 0.5λ. Therefore to get the actual physical length of the patch equal to λ/2 we have consider the extension on both the ends and that is, the length of the patch is given by equation 1.3

$$L = L_{eff} - 2\Delta L \qquad \ldots .1.3$$

As we know for dominant mode the length of patch is equal to λ/2 therefore the L_{eff} is given by equation 1.4, 1.5

$$L_{eff} = \frac{c}{f_r} \qquad \ldots .1.4$$

$$L_{eff} = \frac{C_0}{2f_r\sqrt{\varepsilon_{eff}}} \qquad \ldots .1.5$$

Where C_0 is the velocity of light in free space and f_r is the resonance frequency for which antenna is to be design.

For the dominant mode TM_{010} there is no fringing fields along the width therefore there is no need to consider the effective dielectric constant. Width of the patch can be calculated by this formula is given by equation 1.6.

$$W = \frac{C_0}{2f_r}\left(\frac{\varepsilon_r+1}{2}\right)^{\frac{-1}{2}} \qquad \ldots .1.6$$

For the dominant mode TM_{010} the antenna resonates (without taking fringing into account) at the frequency given by equation 1.7.

$$f_r = \frac{C_0}{2L\sqrt{\varepsilon_{reff}}} \qquad \text{....1.7}$$

And when considering the effective length and effective dielectric constant the antenna will radiate at the frequency.

c. Input impedance:

It is important for the perfect impedance matching to find the point along with the patch dimension where the input impedance is equal to that of that of the feed line referred as Feed point or Driving point. The input impedance at feed point or driving point is known as Driving Point Impedance. The current and voltage distribution over the patch length is shown in figure. Voltage is maximum at the corners and current is maximum at the centre. As we know that the resistance is the ratio of voltage and current. Therefore the resistance will be maximum at the corners and minimum at the centre.

Input impedance of the rectangular patch antenna along the centre line at any point can be determined by the transmission line model. The transmission line model for rectangular patch antenna is shown in figure. Each radiating edge is shown by parallel equivalent admittance y_e and is separated by a distance equal to length L =λ/2. The edge admittance consist equivalent conductance G_e and susceptance B_e. The feed point is located L1 distance away from edge. Input admittance y_{in} at the end of a L length long transmission line with characteristic admittance y_o can be given by equation 1.8.

$$y_{in} = y_o \frac{y_l + jy_o \tan(BL)}{y_o + jy_l \tan(BL)} \qquad \text{....1.8}$$

Where β is the phase constant. Using the above equation the input impedance at the driving point can be expressed by equation 1.9

$$y_{drivingpoint} = y_o \left(\frac{y_e + jy_o \tan(BL_1)}{y_o + jy_e \tan(BL_1)} + \frac{y_e + jy_o \tan(BL_2)}{y_o + jy_e \tan(BL_2)} \right) \qquad \text{....1.9}$$

The total input admittance at the corner of patch is given by equation 1.10-1.14

$$y_{in} = 2y_e \quad ....1.10$$

Where,

$$y_e = B_e + G_e \quad ....1.11$$

Approximated values of G_e and B_e can be given by

$$G_e = 0.00836\frac{w}{\lambda_0} \quad ....1.12$$

$$B_e = 0.01668\frac{\Delta L}{h}\frac{w}{\lambda_0}\ \varepsilon_{reff} \quad ....1.13$$

At the resonance the imaginary parts of the edge admittance are equal and out of phase and they will cancel out each other. So the total input admittance at the edge at resonance become real and is equal to

$$y_{in} = 2G_e \quad ....1.14$$

So at the resonance the total input impedance become pure real, the equation given by equation 1.15

$$R_{in} = 1/2G_e \quad ....1.15$$

When we consider the mutual conductance into account then the input impedance will become as in equation 1.16-1.17

$$R_{in} = 1/(2G_e \pm G_{12}) \quad ....1.16$$

$$G_{12} = \frac{1}{120\pi^2}\int_0^{\pi}\left[\frac{\sin(\frac{k_0 w}{2}cos\theta)}{cos\theta}\right]^2 J_0(k_0 Lsin\theta)sin^3\theta d\theta \quad ....1.17$$

Using the model expansion analysis the input resistance at a point y_0 away from the edge of patch along the centre line can be calculated by the equation1.18.

$$R_{in(y=y_0)} = \frac{1}{(2G_e \pm G_{12})}cos^2\left(\frac{\pi}{L}y_0\right) \quad ....1.18$$

The Fig. 1.12 represents the graph below shows that the input impedance of the rectangular patch antenna varies according to square of cosine.

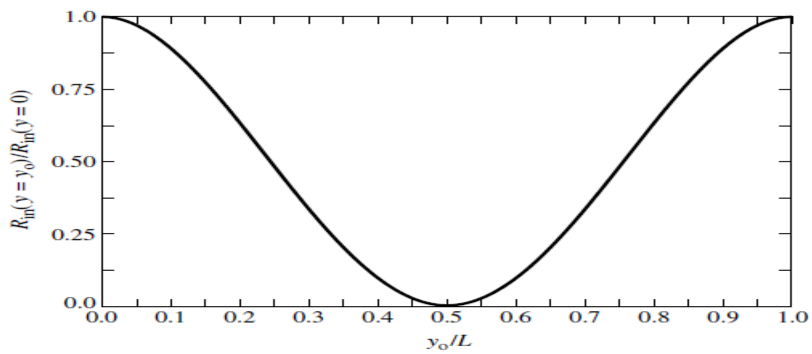


Fig. 1.12 Normalized input Resistance

1.6.1.2 Cavity Model:

The cavity model first described by Lo et al. in. late 1970s. As the name says cavity model treated the rectangular patch antenna as a cavity with electric walls above and below at metallic patch and ground plane, and magnetic walls along the edges of patch.

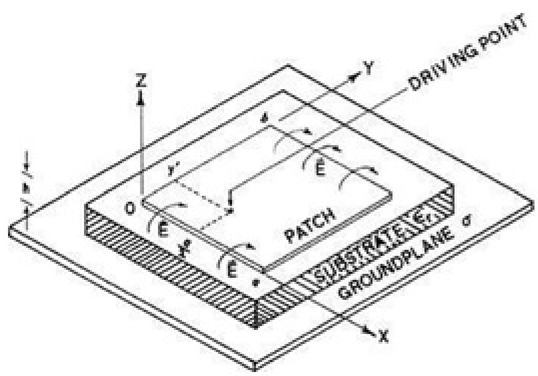


Fig. 1.13: Rectangular patch for cavity model

The field under the patch is the summation of the resonance modes created by these radiating walls. The cavity model based on the assumption that only z-axis component of electric field and x and y-axis components of magnetic field exist. A simple rectangular antenna used for the calculation in cavity model is shown in Fig. 1.13.

1.7 DESIGN EQUATIONS

The three important parameters while designing the antenna are

1. Operating frequency (f_r)
2. Dielectric constant (ε_r)
3. Substrate thickness (h)

By using above three parameters, the dimensions of an antenna can be determined by using the below equations

Width of the patch (W) is given by equation (2.1)

$$W = \frac{C_0}{2f_r}(\frac{\varepsilon_r + 1}{2})^{\frac{-1}{2}} \quad \text{....(2.1)}$$

The length of the patch is given by equation (2.2)

$$L = L_{eff} - 0.824\frac{(\varepsilon_{reff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{W}{h} + 0.8\right)} \quad \text{....(2.2)}$$

Where L_{eff} is the effective length of the patch.

ε_{eff} is the effective dielectric constant.

The effective length of the patch (L_{eff}) is given by equation (2.3)

$$L_{eff} = \frac{C_0}{2f_r\sqrt{\varepsilon_{eff}}} \quad \text{....(2.3)}$$

Where C_0 is the velocity of light in free space

f_r is the resonance frequency for which case is to be design.

The effective dielectric constant (ε_{eff}) is given by equation (2.4)

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\ (1 + 12h/W)^{\frac{-1}{2}} \quad \text{....(2.4)}$$

Example: Design a microstrip patch with dimension w and l over a single substrate, whose center frequency is 10GHZ. The distance constant of the substrate is 10.2 and the height of the substrate is 0.127cm.

Given that

Fr = 10GHz, Er = 10.2 & H = 0.127cm

Find w and l:

$W = (\lambda_0/2) * \sqrt{(\epsilon_r + 1)/2}$

$= 6.33cm$

And $\epsilon_{eff} = (\epsilon_r + 1)/2 + ((\epsilon_r - 1)/2 * (1/\sqrt{1 + 12(H/W)})$

$= 8.09$

$\Delta L = [0.412H*(\epsilon_{eff}+0.3)*(W/H+0.264)] / [(\epsilon_{eff}-0.258)*(W/H + 0.8)]$

$= 5cm$

Where:

$$L_{eff} = \frac{C}{2 fr \sqrt{\varepsilon_{eff}}}$$

$= 5.2$ cm

Then

$L = L_{eff} - 2\,\Delta L$

$= 4.2cm$

CHAPTER 2

WORKING ON HFSS SOFTWARE

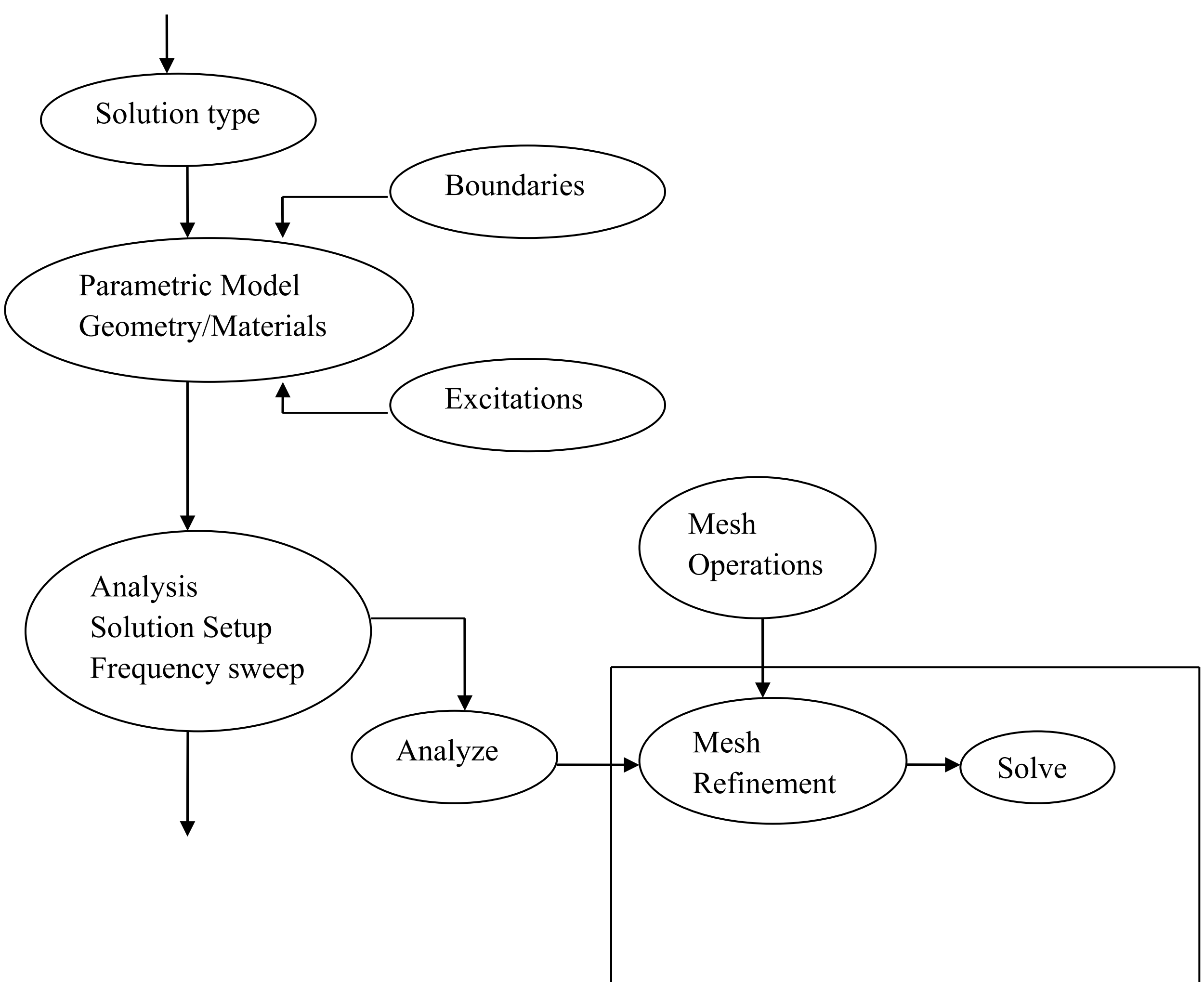
2.1 INTRODUCTION

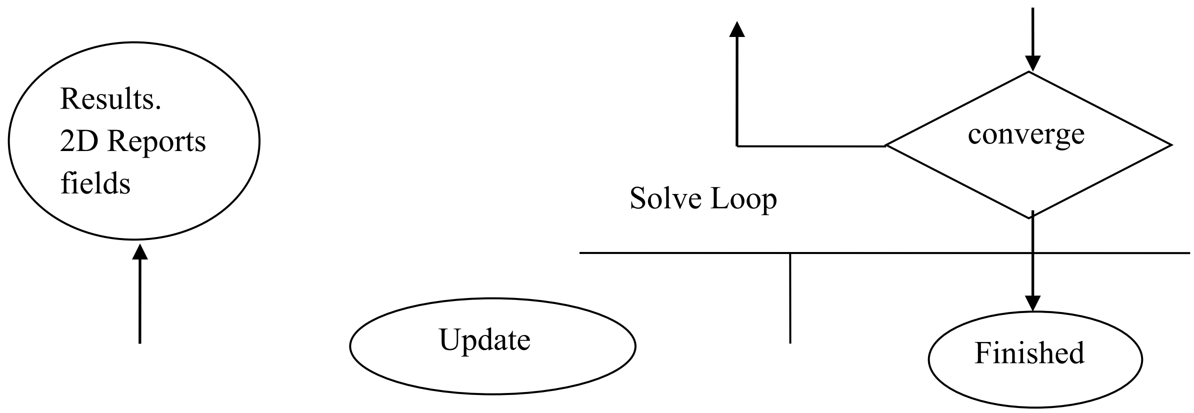
HFSS stands for stands for high frequency structure simulator. This software basically teardowns a structure into multiple tiny substructures, Hence the name Finite Element Method (FEM). With its user friendly environment, it's very easy to understand right from out of the box. HFSS can be used to calculate parameters such as S-Parameters, Resonant Frequency, and Fields. HFSS can also be used for solving 3D EM problems with ease and results are obtained with high accuracy.

SIMULATION WORKFLOW

The figure given below depicts the design process in HFSS. these are the six steps required to resolve a proper HFSS simulation.

Design workflow:





2.1.1 Create model/geometry:

The primary step in creating an HFSS model is to make a physical model of our choice. Using 3D modeller built-in in HFSS, we can design a structure with desired dimensions and material properties. We can also import 3D structures into HFSS. Nevertheless, these imported projects do not hold on to any history of their creation. Hence the parameters are unmalleable unless its modified manually.

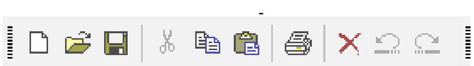
In order to use HFSS, one has to initially specify the type of solution that needs to calculated. There are three types of solutions:

1. Driven model
2. Driven Terminal
3. Eigen mode

Exploring User Interface:

At first glance, we will find a design workspace along with windows., like project manager. At the top of the toolbox, we will find systematically grouped icons according to their specific job. The tool box contains the following sections

File managing section:



This section, user will find basic operations such as creating a new file, save file, open, cut, copy, paste and print etc.

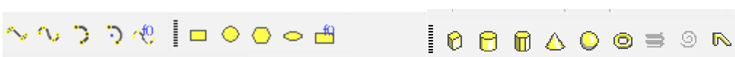
Analysis and relsult section:

In this section, user has all the necessary functions required to run and simulate the model. It consists of operations such as analyse, validate,solution setup. It also consists of functions capable of plotting the resultd using frequency sweep.

Interfacing section:

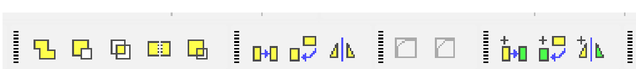
In this section we will get access to the tools required to move, transform according to planes, rotate, hide, zoom in, zoom out, fit contents in a singe view etc.

Geometric section:



This is one of the most important sections. It holds all the necessary tools required to generate a geomterical shape. The shapes can be of 2D or 3D. shapes such as stright line, curved line, 3 point arc, square(or rectangle), cube, cylinder etc.

Transformation tools:



This section consists of tools requird to tranform the components of the model such as unite,substract,intersect,imprint,move,rotate,etc.

Let us take an example of a microstrip patch antenna of frequency 5.8GHz to understand the deigning steps.

Creating a ground plane using geometric section tools.

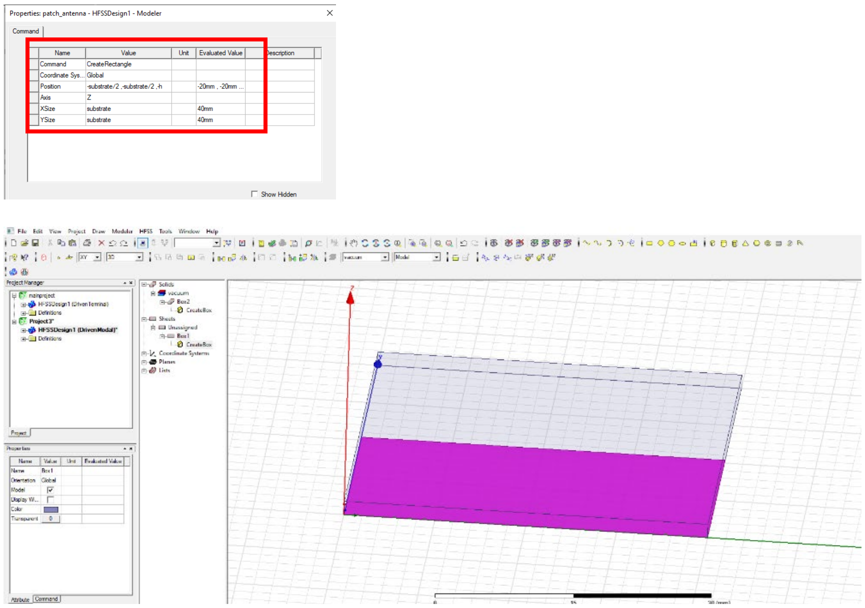


Fig 2.1 ground plane

User can enter the dimensions and position in the properties dialoag box and obtain the desired structure.

Creating a slot:

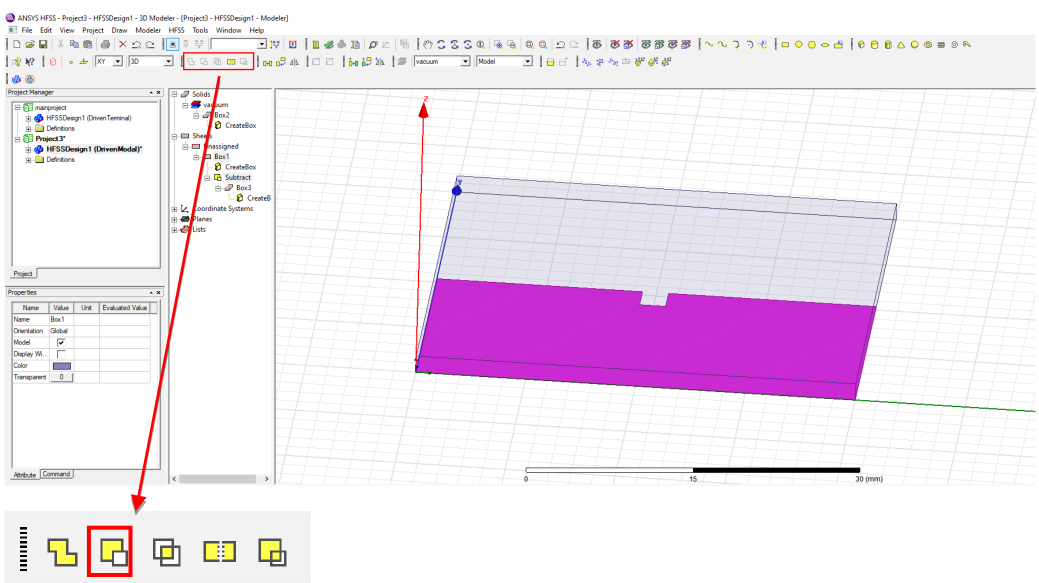


Fig 2.2 create a slot

Enter the required dimensions of the slot and use the subtract option in the transform tools section to obtain a slot.

Use the same step to create a substrate and also to cteate rectangular microstrip patch antenna.

After designing the microstrip patch, we will add an excitation.

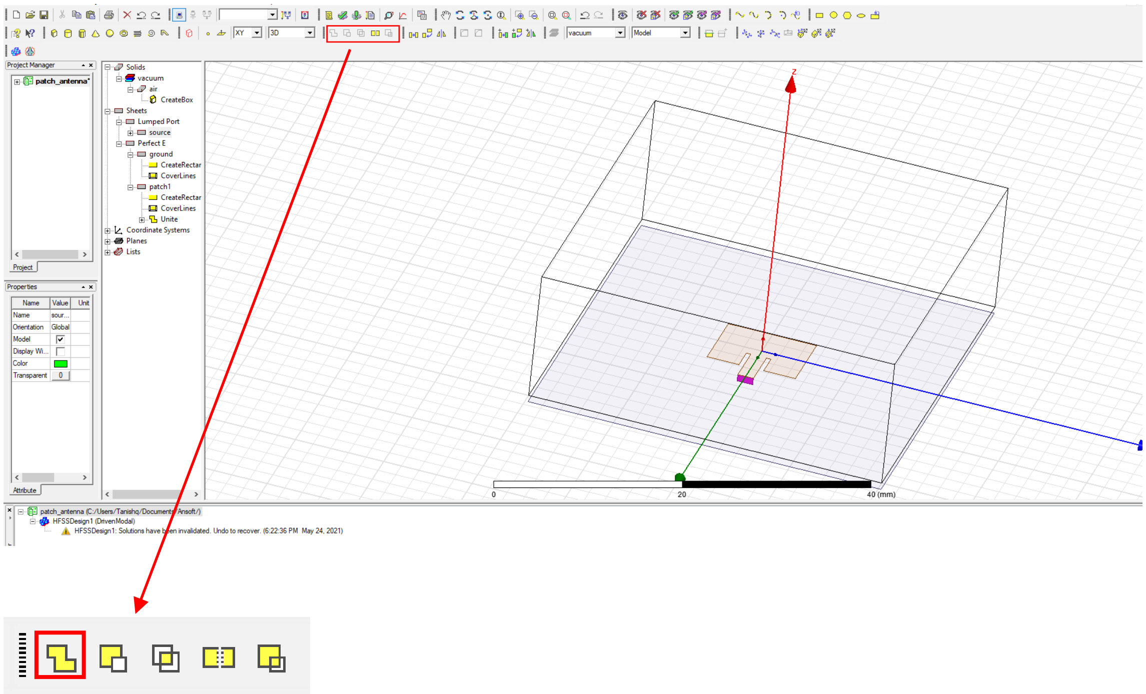


Fig 2.3 blend excitation

In order to blend the excitation and feedline we use the tool option in the transform section and click on the unite tool.

2.2 Boundary Assignment:

The boundaries are usually assigned in this step. Boundaries are applied to specifically create 2D sheet objects, or surfaces of 3D objects. The twelve boundaries are:

1. Perfect Electric Conductor (PEC): Built-in HFSS boundary surrounds the solution space and constructs a closed model
2. Radiation: open model is fabricated by this.
3. Perfectly Matched layer (PML): favored by antenna simulations, these are used to generate open model
4. Finite Conductivity: used for building single layer conductors
5. Layered Impedance: allows construction of multilayer conductors and thin dielectrics
6. Impedance: used to create ohm per square material layers
7. Lumped RLC: allows creation of ideal lumped components
8. Symmetry: used to enforce a symmetry boundary

9. Master: used in concurrence with Slave Boundary to replicate infinitely large repeating array structures
10. Slave: used in association with Master Boundary to facsimile large infinitely repeating array structures
11. Screening Impedance: used to make large screens or grids
12. Perfect H: allows fabrication of a symmetry plane

In order to assign boundary conditions, we have to right click on the required material and select the desired condition.

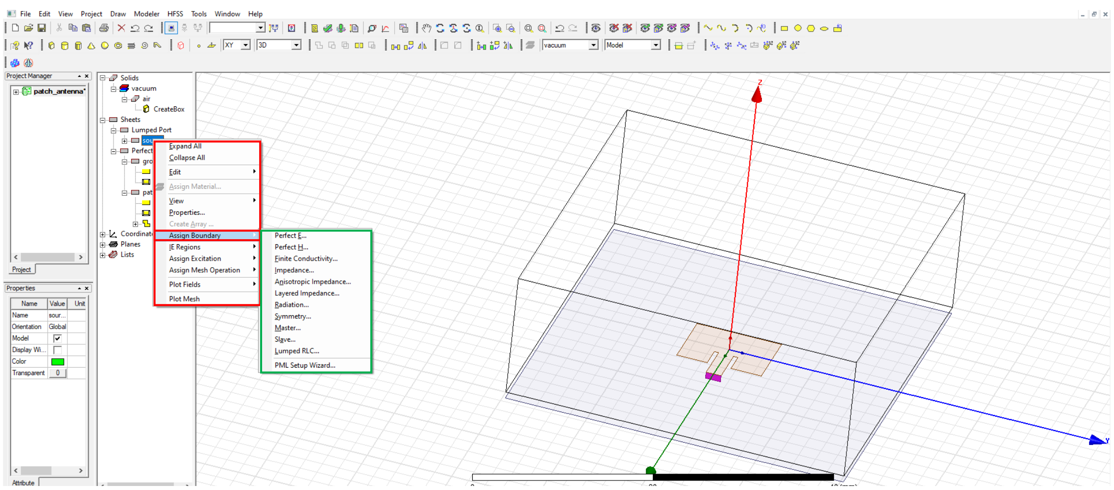


Fig 2.4 assigning boundary

2.3. Assign excitations:

Following the boundary assignment, excitations are allocated. Corresponding to boundaries, the excitations also make a direct impact on the standard of the results that HFSS will impart for a given model. Thereupon, an appropriate design and use of excitations is a foremost to obtain HFSS results with peak accuracy.

To assign excitation, we should right click on the required material and select desired excitation.

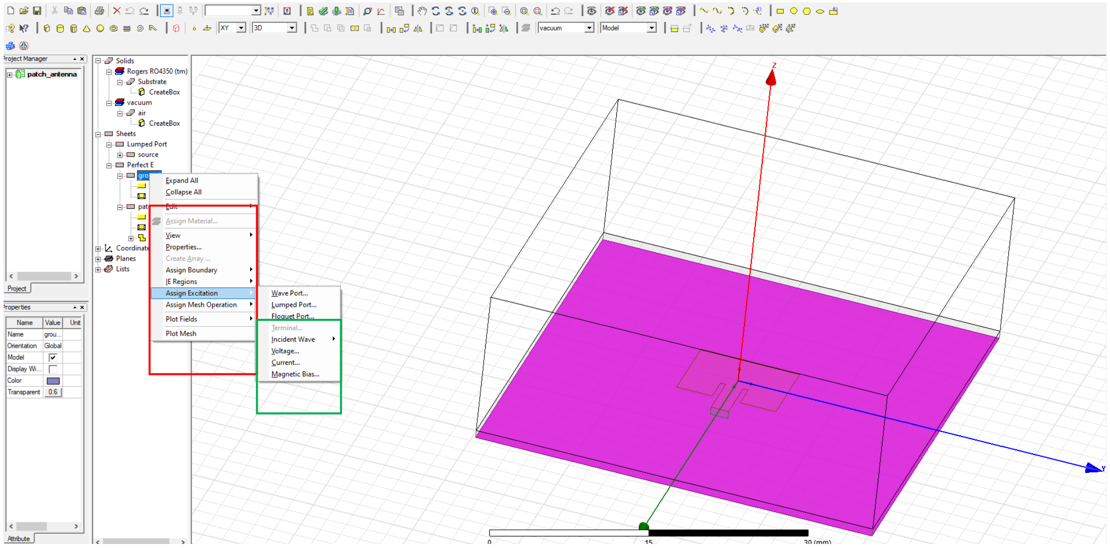


Fig 2.5 assigning excitation

2.4. Set up the solution:

Next step succeeding the excitation is to create a solution setup. Throughout this process, a solution frequency, the desired convergence criteria, utmost number of adaptive steps to perform, a frequency band over which solutions are desired, and which particular solution and frequency sweep method to use are to be created.

To obtain solution setup, we should click on the HFSS option in the toolbar and select the analysis setup and choose solution setup in the dialog box

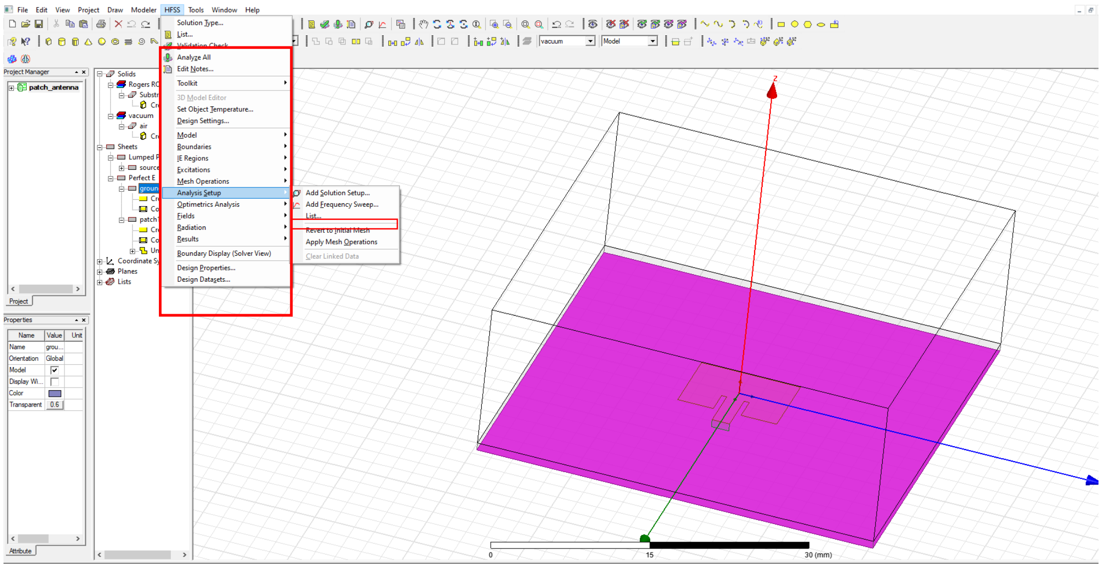


Fig 2.6 solution setup

After selecting solution setup., type your desired frequency in the dialog box as shown below.

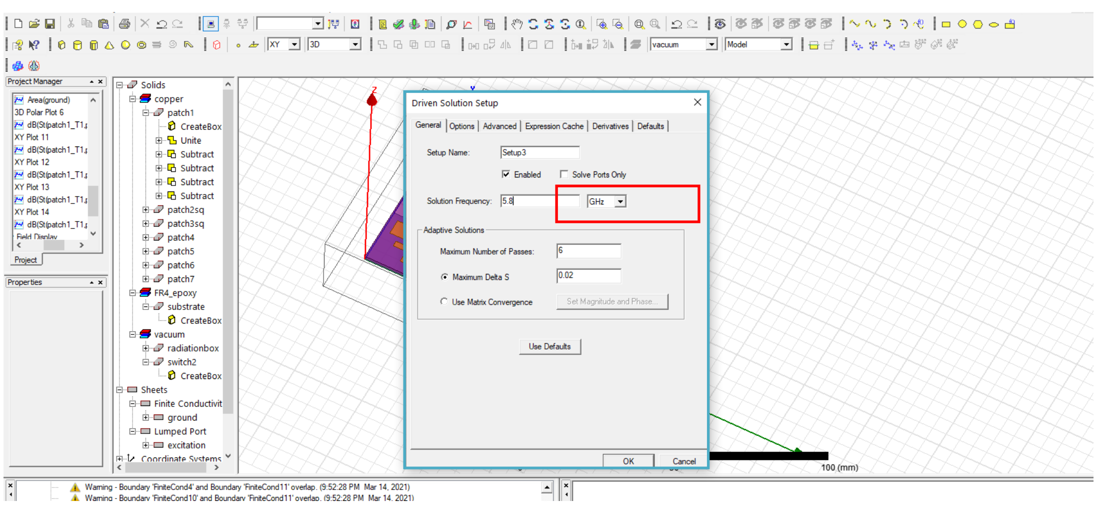


Fig 2.7 frequency input

2.5. Solve:

After completing four steps by an HFSS, we can analyse the model. The time taken to complete the analysis is directly proportional to geometrical model, the solution frequency, and available computer resources.

Click on the validate and analyse all to run the designed model.

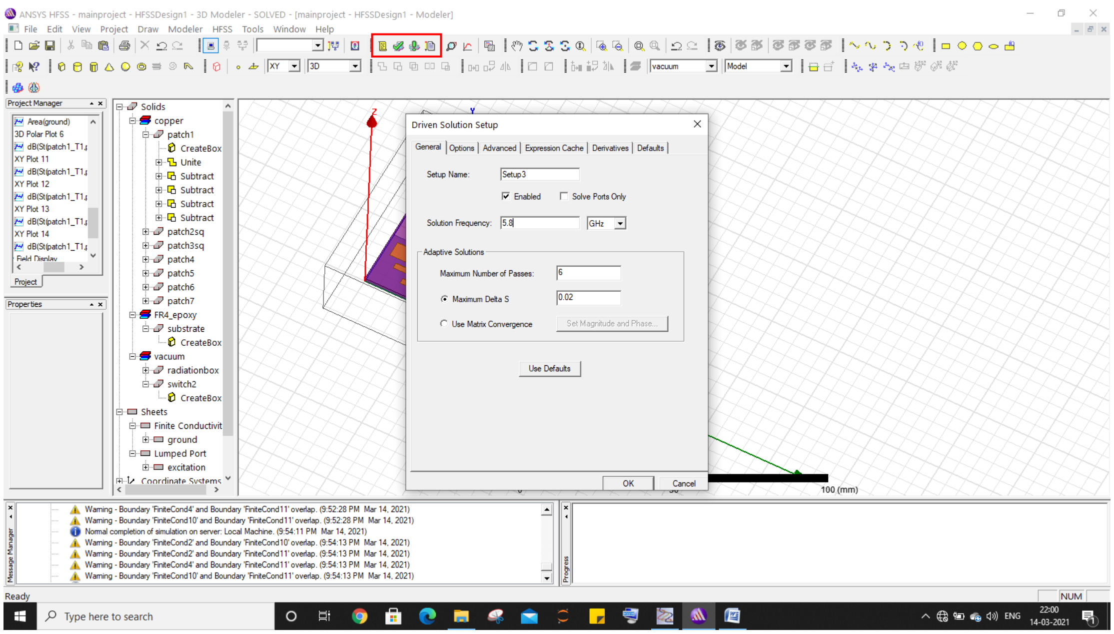


Fig 2.8 validate and analyse

2.6. Post-process the results:

User can post-process the results after completing their analysis. Post-processing of result includes scrutinizing the S-parameters or plotting the fields surrounding the structure. Users can also inspect the far fields created by an antenna. Substantially, any field quantity or S, Y, Z parameter can be plotted in the post-process.

User can obtain the results in the project manager dialog box and click on the results section to get your desired plots.

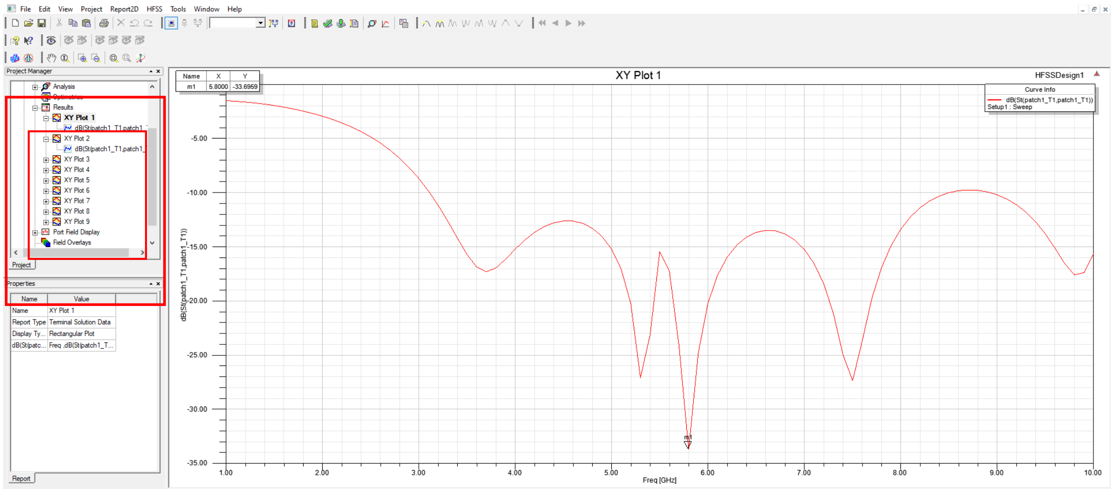


Fig 2.9 result graph

CHAPTER 3

SWITCHABLE MICROSTRIP PATCH ANTENNA USING PIN DIODES

3.1 INTRODUCTION

Antennas which are capable of modifying certain characteristics such as frequency, polarization and radiation pattern are called reconfigurable antennas. Antennas once fabricated cannot be modified normally in operating bands. But with this design, switching between bands is possible using frequency reconfiguration with six pindiodes as switches. This proposed design incorporates an ultra wideband section for frequency sensing and same design is frequency reconfigured using pindiodes as switches to get narrow bands for communicating within the spectrum. The switches are inserted between the main feed line and extended transmission lines. The frequency range of this design is 3.1 to 10.6 GHz. The antenna design,results,conclusion of proposed designed are explained in following section.

3.2 COGNITIVE RADIO

The advancement in wireless communication applications and the rise in demand on new protocols have created an unbalance in the spectrum allocation. It is determined that there is a need for a communication protocol that can detect the various free spaces that exist in the spectrum, as well as communicate over these white spaces. For this there is a report issued by the Federal Communications Commission (FCC) that identifies 70% of the spectrum as underutilized and mostly idle. These idle gaps are also known as white spaces.

The identification of white spaces and the communication over these idle gaps requires a communication device to be able to continuously monitor the spectrum, identify idle frequencies, process such information, communicate over these discovered white spaces and adapt for future use. This device is then required to possess processing potential and cognition ability. Such a device was proposed by Dr. Mitola in 1999 and was called a cognitive radio device.

3.2.1 OPERATION OF COGNITIVE RADIO

The operation of a cognitive radio system is divided mainly into two tasks. In the first task, a cognitive radio device searches and identifies any part of the spectrum that is idle which is called as spectrum sensing. The second task consists of achieving a good mode of communication by allocating the appropriate channel to be used, this is called as signal transmission. The cognitive radio antenna systems must operate around the heavily congested spectrum and broadcast over underutilized bands to access various wireless standards set by FCC. Therefore, cognitive radio systems are considered a good solution for unbalanced spectrum occupancies and constitute the future of efficient wireless communication systems.

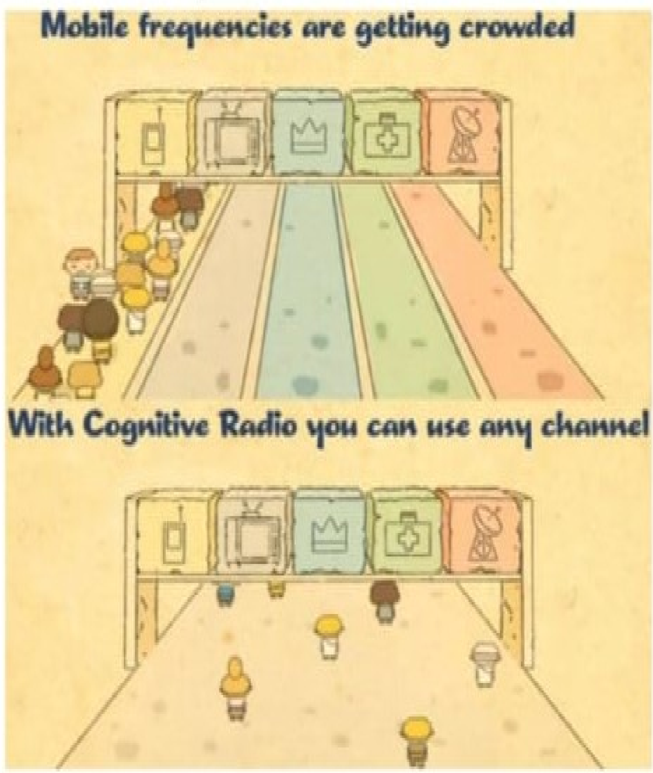


Fig 3.2.1 Cognitive radio mechanism

The radio spectrum is divided into licensed and unlicensed frequencies. The licensed spectrum is for the exclusive use of designated users. For instance, it includes the UHF/VHF TV frequency bands. The unlicensed spectrum can be freely accessed by any user, with certain rules such as by not exceeding a defined limit for transmission power. In order to share the spectrum with licensed users without disturbing them, and meet the better quality of service requirement of applications, each CR user in a CR network must determine the portion of spectrum that is available, which is known as Spectrum sensing. Select the best available channel, which is called Spectrum decision. Coordinate access to this channel with other users, which is known as Spectrum sharing. Vacate the channel when a licensed user is detected, which is referred as Spectrum mobility.

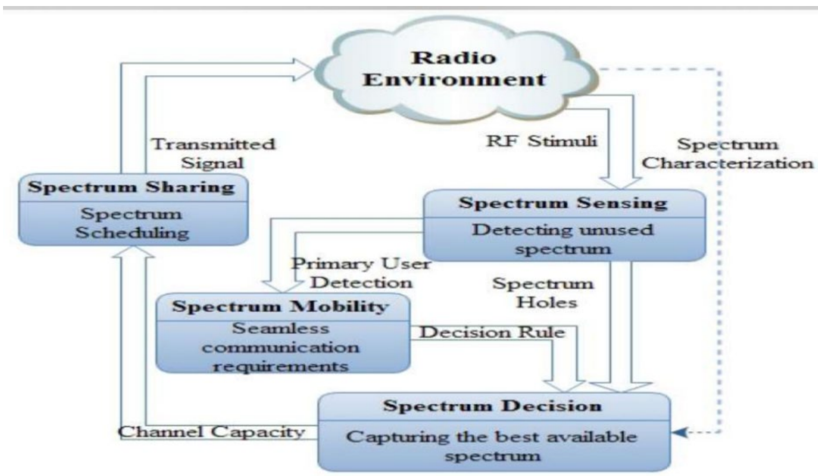


Fig 3.2.2 Cognitive cycle

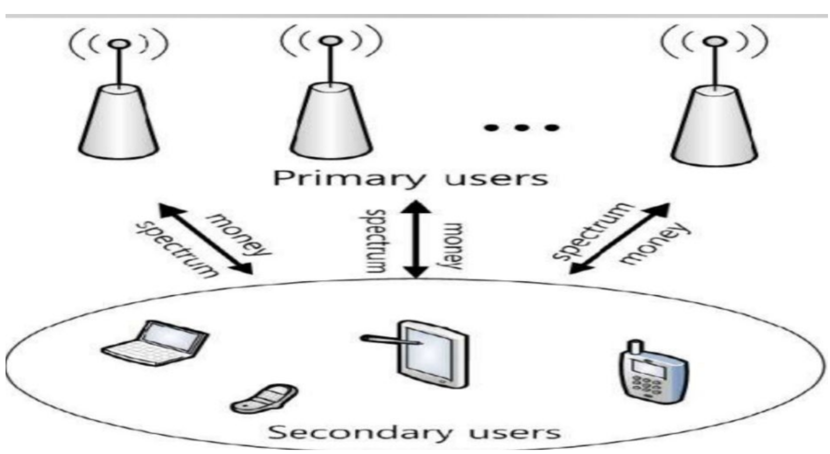


Fig 3.2.3 Primary and Secondary users

So, a cognitive radio antenna system has access to the software-controlling processor of a cognitive radio device and reconfigures its operation based on observations made by the sensing antenna.

3.3 PINDIODES

A microwave PIN diode is a semiconductor device that operates as a variable resistor at RF and Microwave frequencies. It is a current controlled device. The microwave PIN diode's small physical size compared to a wavelength, high switching speed, make it an ideal component for use in miniature, broadband RF signal control circuits. The PIN diode has the ability to control large RF signal power while using much smaller levels of control power.

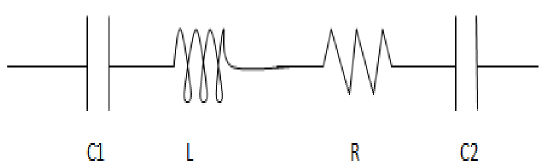


Fig 3.3.1 pindiode as forward bias

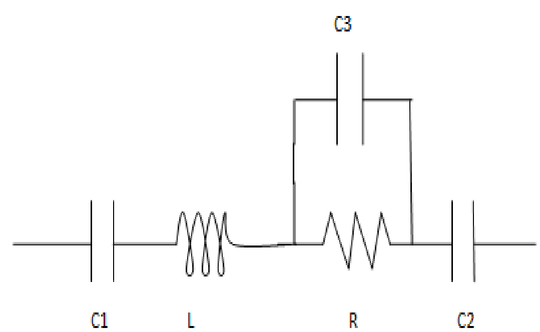


Fig 3.3.2 pindiode as reverse bias

When the forward bias control current of the PIN diode is varied continuously, it can be used for attenuating, leveling, and amplitude modulating an RF signal. When the control current is switched on and off, or in discrete steps, the device can be used for switching, pulse modulating, and phase shifting an RF signal. The microwave PIN diode's small physical size compared to a wavelength, high switching speed, and low package parasitic reactances, make it an ideal component for use in miniature, broadband RF signal control circuits. In addition, the PIN diode has the ability to control large RF signal power while using much smaller levels of control power.

The performance characteristics of the PIN diode depend mainly on the chip geometry and the processed semiconductor material in the intrinsic or I - region, of the finished diode. When the diode is forward biased, holes and electrons are injected into the I-region.

If the PIN diode is reverse biased , there is no stored charge in the I-region and the device behaves like a Capacitance (CT) shunted by a parallel resistance (RP).

3.4 DESIGN OF MICROSTRIP PATCH ANTENNA USING PINDIODES

The antenna is designed in Ansoft HFSS software tool. The design is simulated for five cases based on required configurations. The following are the required dimensions for the design.

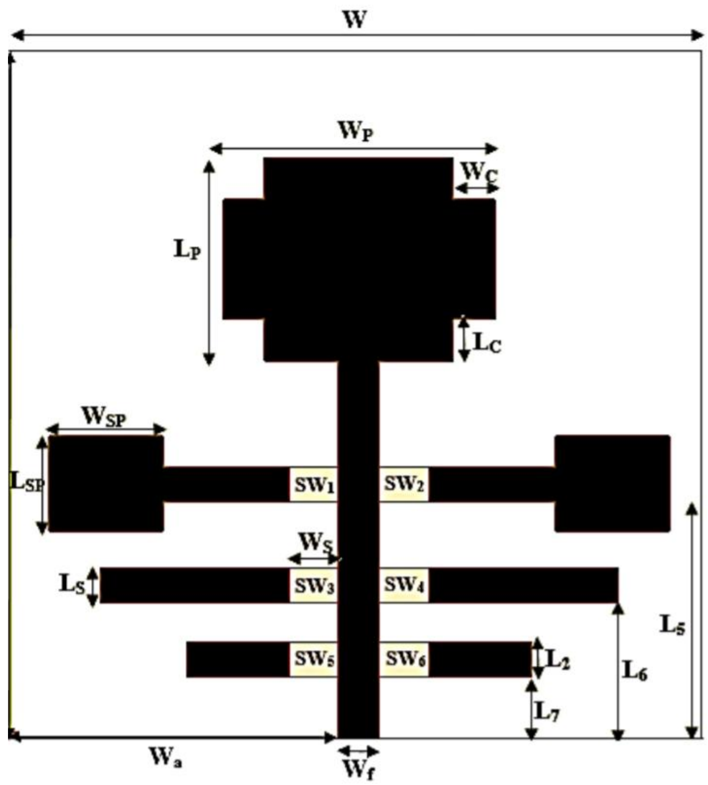


Fig 3.4.1: structure of switchable microstrip patch antenna

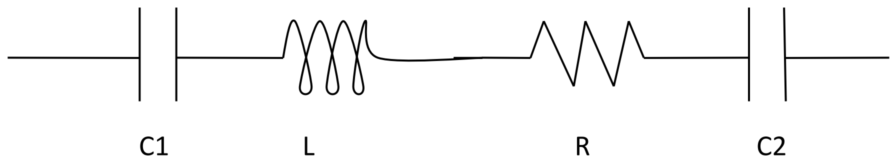
Table 3.1: Switching Configurations

C	SW1	SW2	SW3	SW4	SW5	SW6
C-I	OFF	OFF	OFF	OFF	OFF	OFF
C-II	ON	OFF	OFF	OFF	OFF	OFF
C-III	OFF	OFF	OFF	ON	OFF	OFF
C-IV	OFF	ON	OFF	ON	ON	OFF
C-V	OFF	OFF	OFF	OFF	ON	OFF

Table 3.2: Dimensions of switchable microstrip patch antenna using pindiodes.

S. NO	PARAMETER	DESCRIPTION	DIMENSIONS
1	L	Length of the substrate	40.00mm
2	L1	Length of main feed line	22.07mm
3	L2	Length of transmission line 5,6	2.00mm
4	L3	Length of slot cut in ground	2.90mm
5	L4	Length of the ground	20.75mm
6	L5	Length to transmission line 1,2	14.00mm
7	L6	Length to transmission line 3,4	8.16mm
8	L7	Length to transmission line 5,6	3.86mm
9	Ls	Length of transmission lines 3,4	2.00mm
10	Lp	Length of patch 1	11.75mm
11	W	Width of the ground and substrate	40.00mm
12	Wf	Width of main feed line	2.36mm
13	Wc	Width of corner slot	2.40mm
14	Ts	Thickness of substrate	1.6mm
15	Ws	Width of switch	2.90mm
16	Wp	Width of patch 1	15.74mm
17	Wsp	Width of patch 2	6.61mm
18	Lsp	Length of patch 2	5.53mm
19	Lc	Length of corner slot	2.40mm

Pindiode as forward bias:

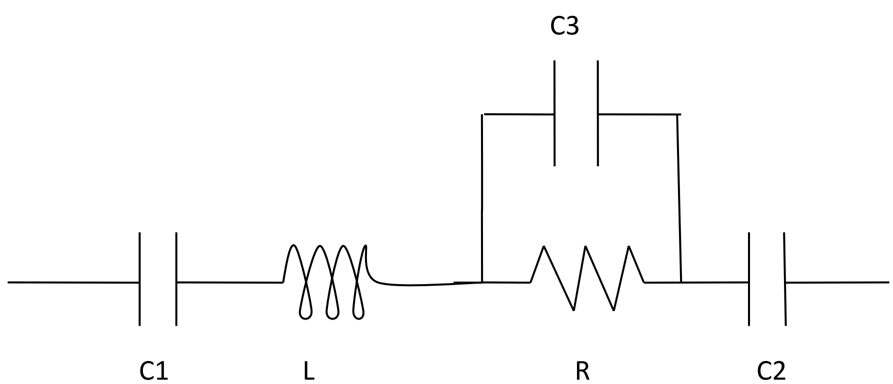


C1 , C2 = 1μF

L = 0.6 nH

R = 1 Ὠ

Pindiode as reverse bias:



C1 , C2 = 1μF

C3 = 0.5 pF

L = 0.6 nH

R = 1 KὨ

3.4.1 Design steps:

The antenna is simulated for configuration-1. In this configuration all switches are in off condition, ie., all the pindiodes are in reverse bias. All the required dimensional measurements for antenna design are calculated.

Step 1: Launch the HFSS software.

Step 2: In the HFSS window, from menu item click file and select new.

Step 3: From project menu, select insert HFSS Design.

Step 4: Select the menu item HFSS > Solution Type > Driven Terminal.

Select the menu item 3D Modeler > Units > mm

Step 5: Now go to menu and Click on rectangle. Windows pops up and define all the specifications of ground plane and name it as ground and subtract a slot of required dimensions from it.

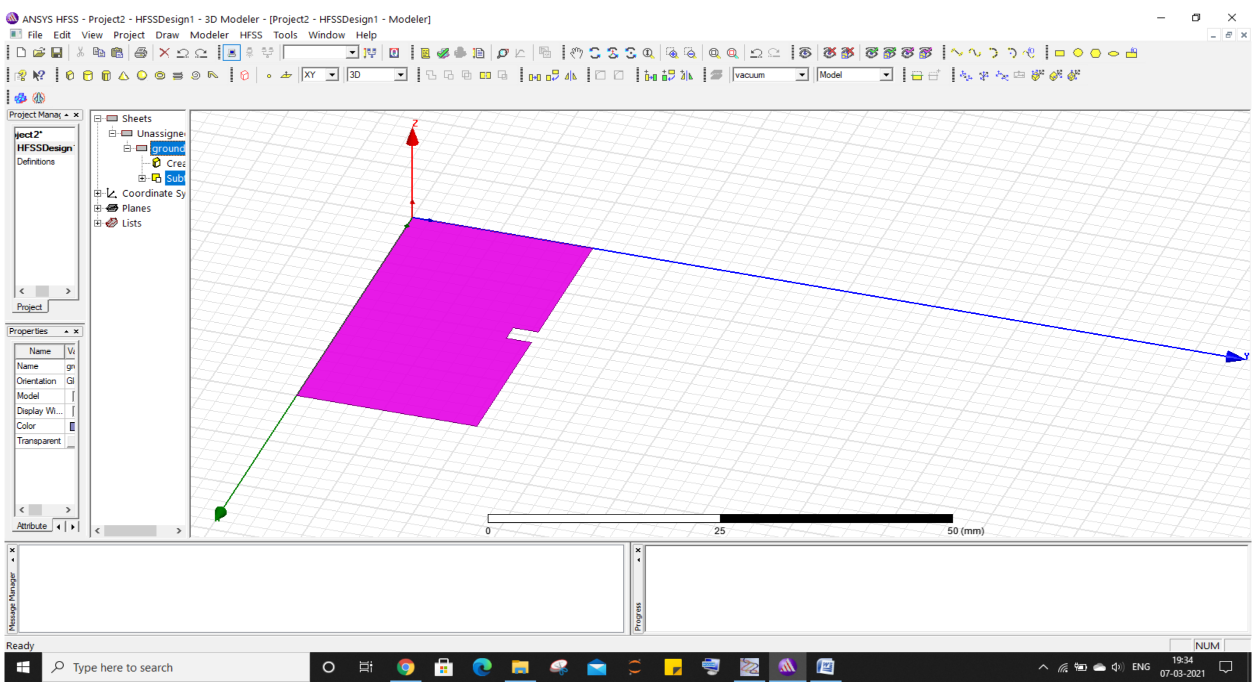


Fig 3.4.2: Ground plane in HFSS window

Step 6: From menu, click on box (for substrate).A window pops up and defines all the specifications of the box. Name the box as substrate and define its dimensions.

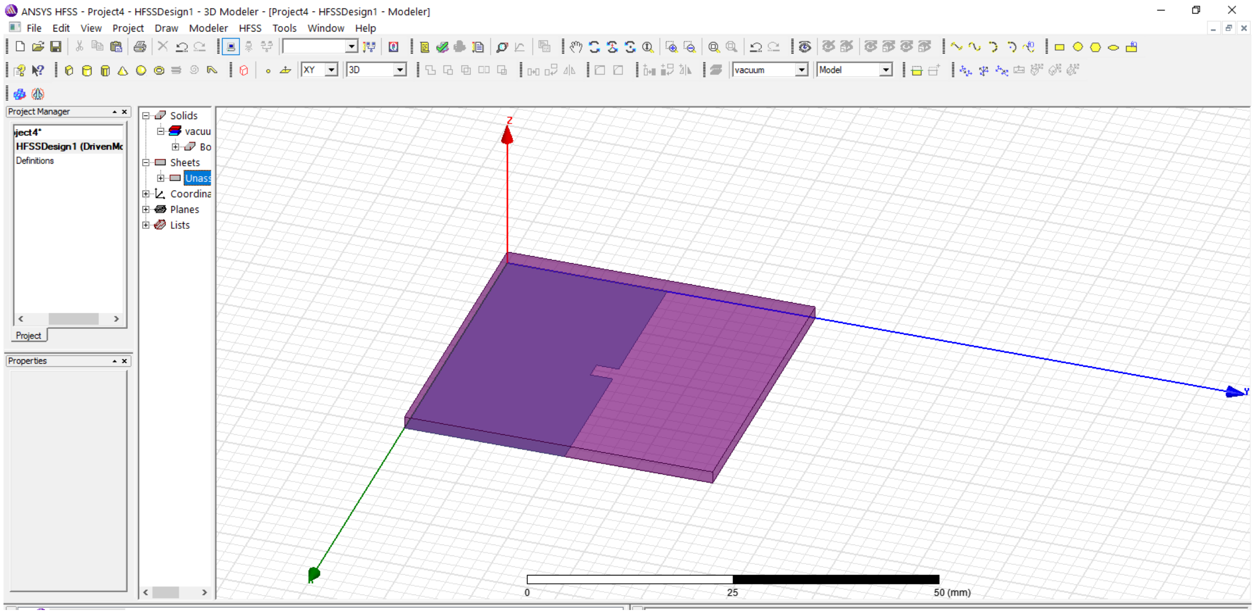


Fig 3.4.3: After placing substrate

Step 7: Now place the vertical patch by specifying all its dimensions.

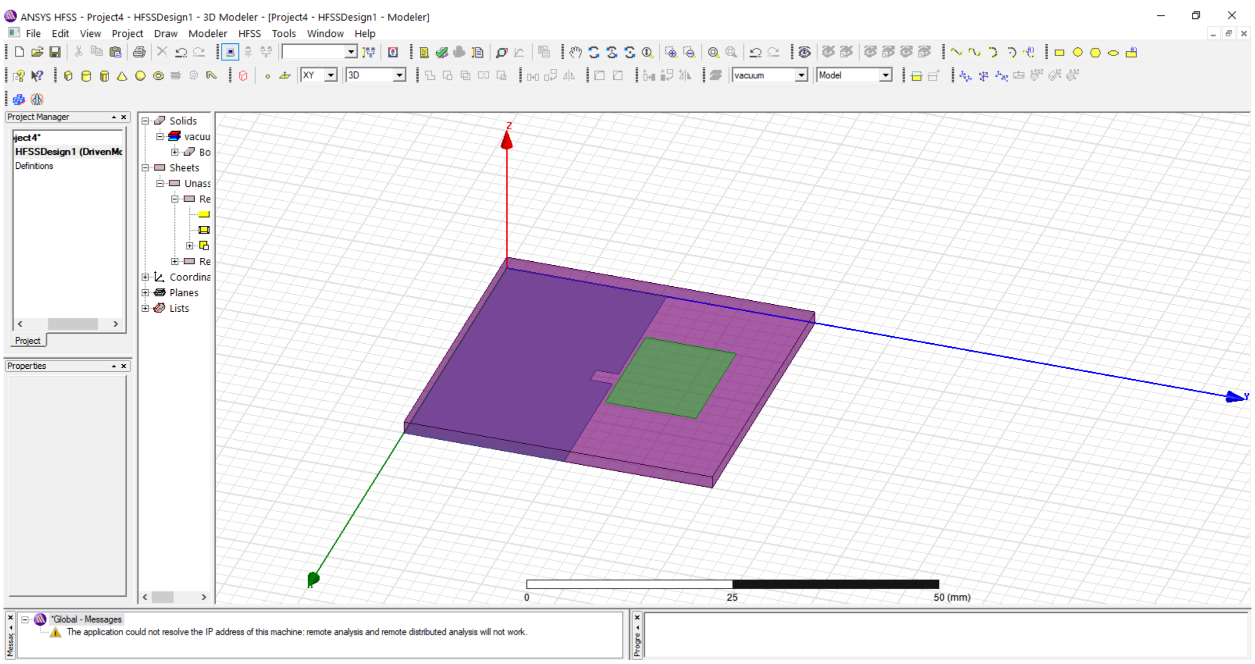


Fig 3.4.4: After placing main patch

Step 8: Insert main feed line with specified dimensions and join the patch and transmission line.

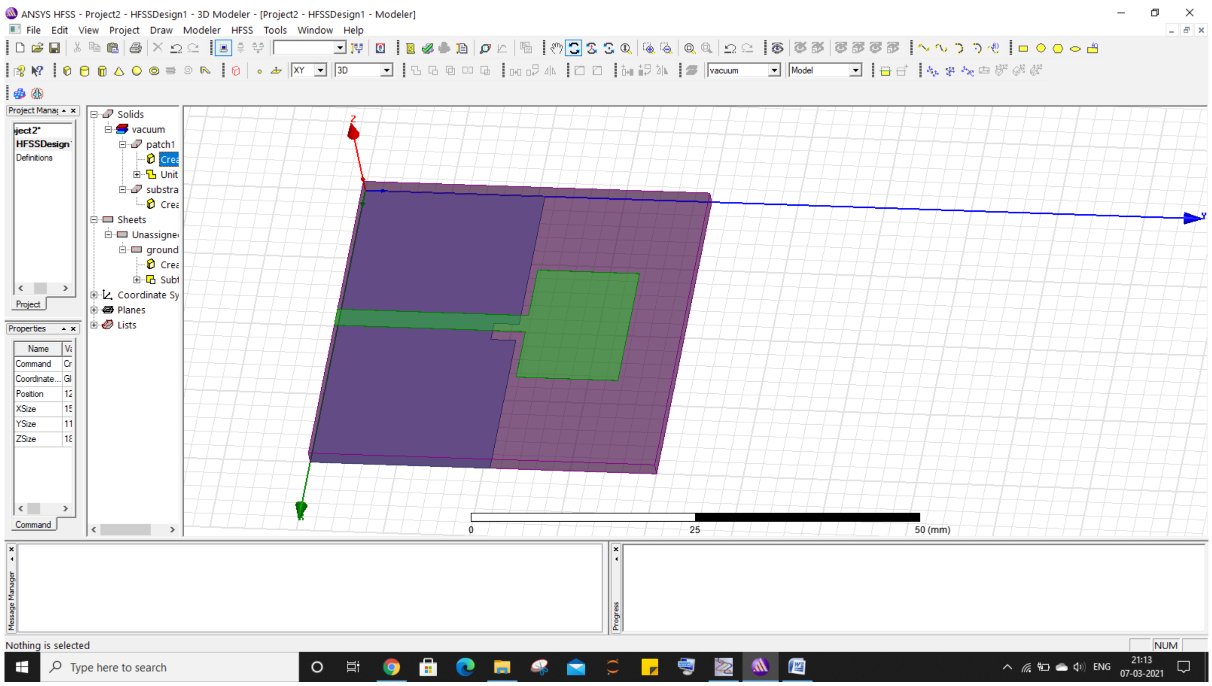


Fig 3.4.5: After placing main patch

Step 9: Now subtract the 4 slots with specified dimensions at the corner of the main patch.

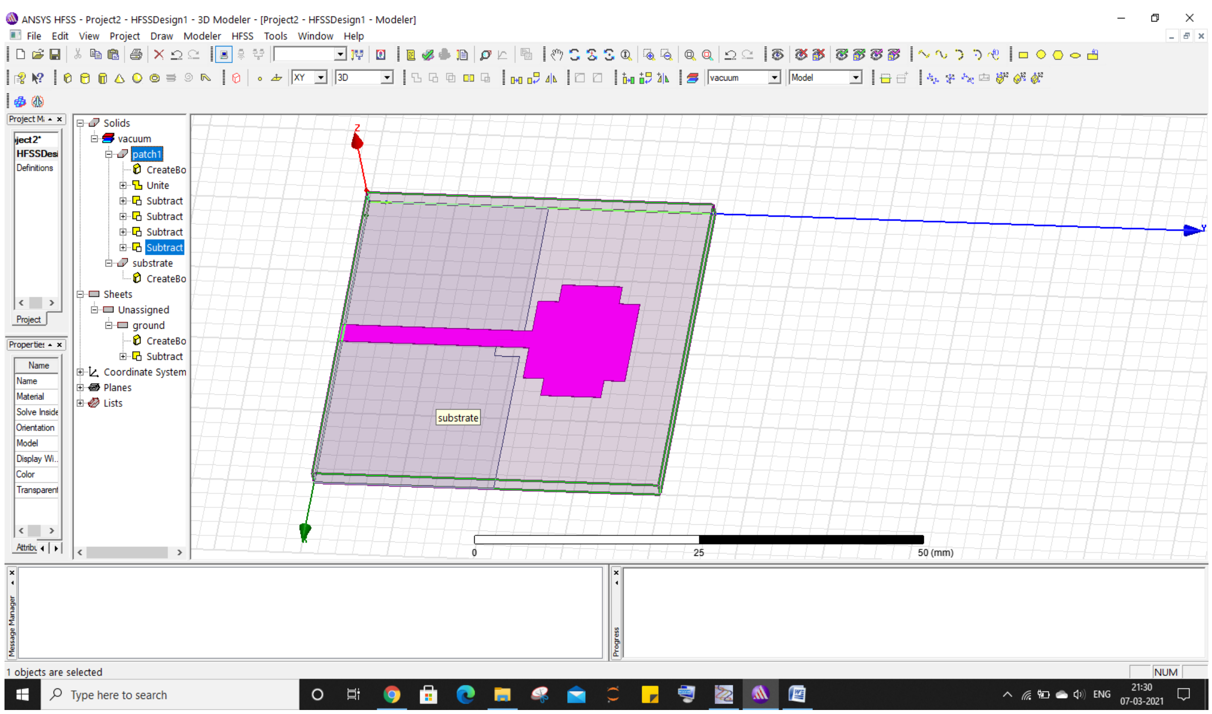


Fig 3.4.6: After cutting slots from main patch

Step 10: Now insert the first transmission line with specified dimensions by selecting rectangle from item menu.

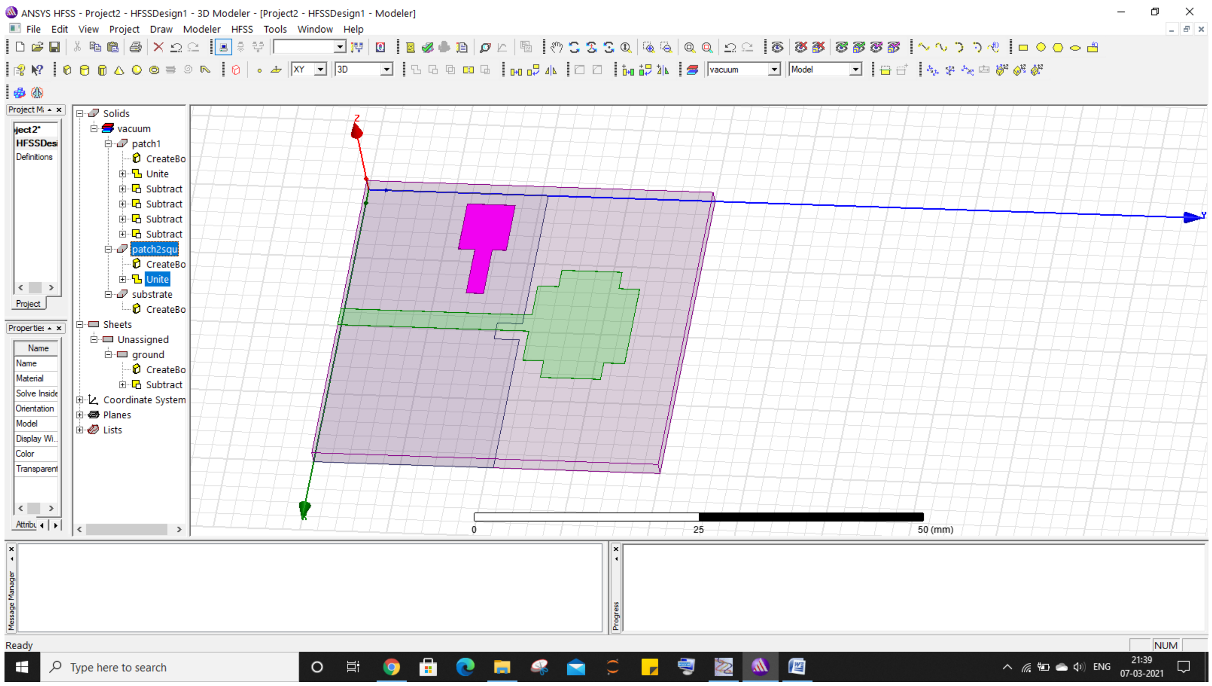


Fig 3.4.7 First extended transmission line

Step 11: similarly insert all other 5 transmission lines with specified dimensions.

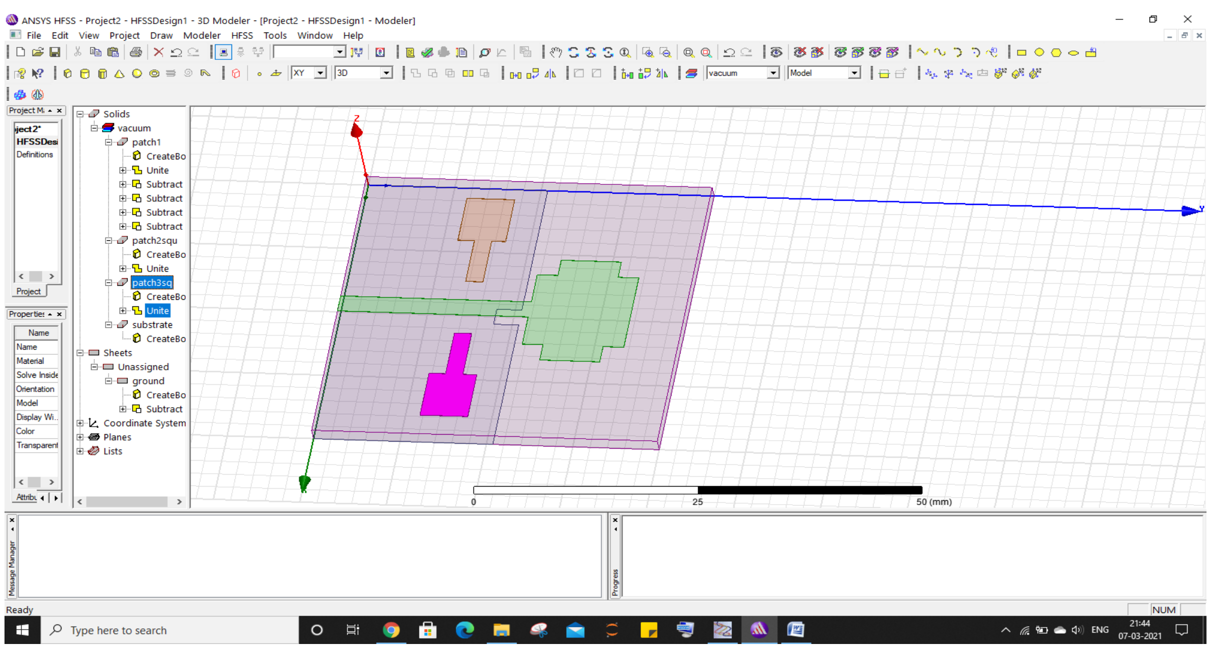


Fig 3.4.8.1 Second extended transmission line

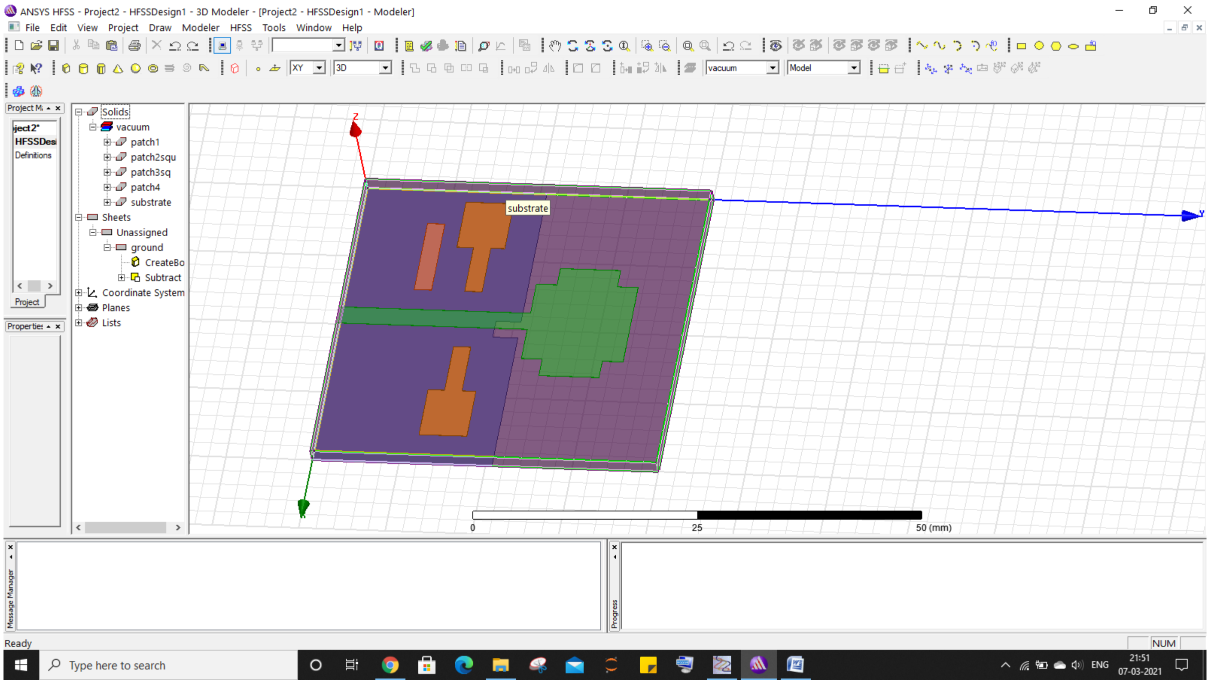


Fig 3.4.8.2 Third extended transmission line

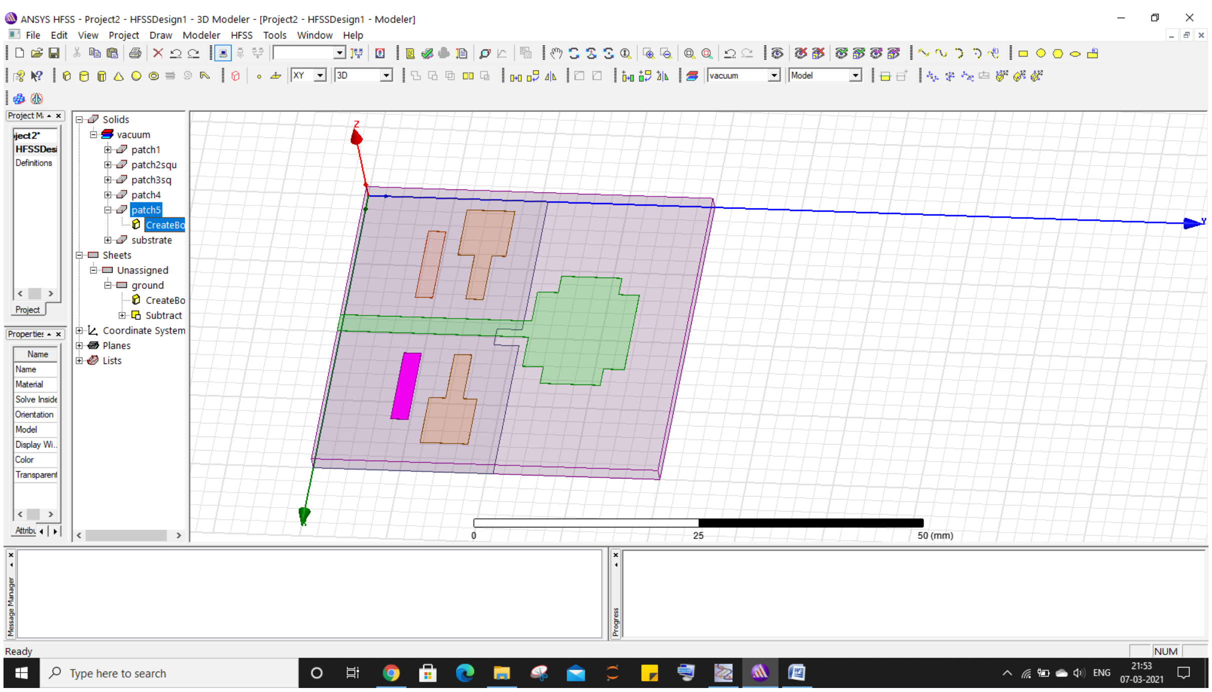


Fig 3.4.8.3 Forth extended transmission line

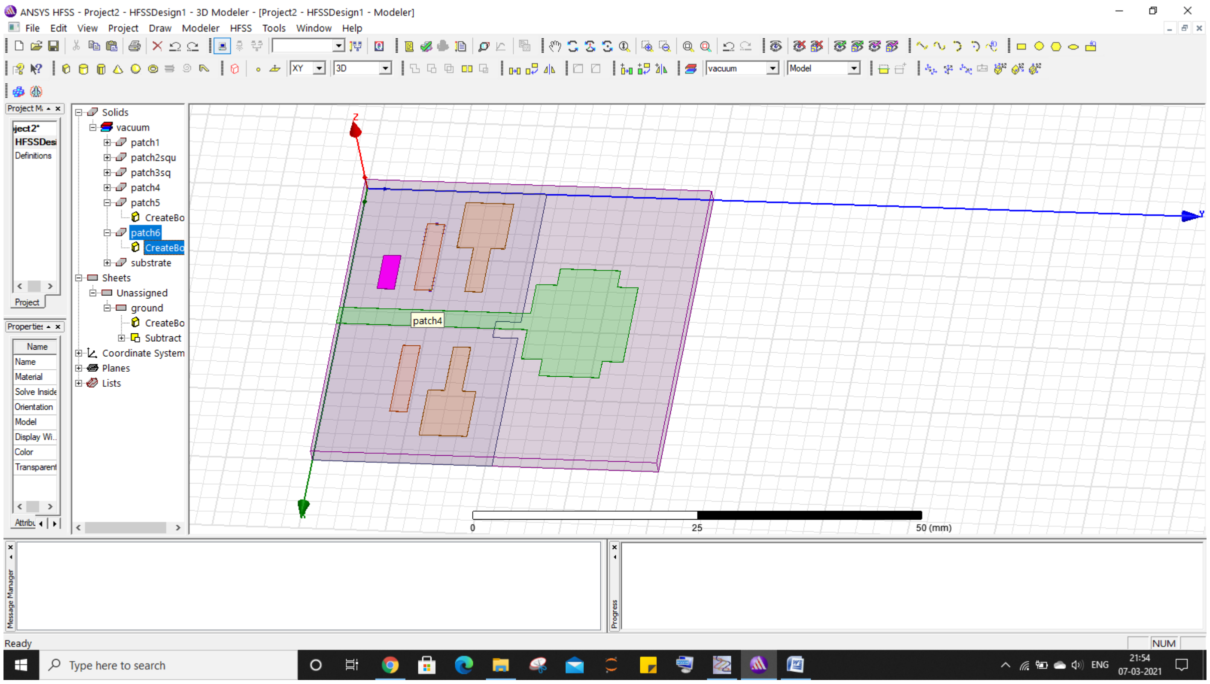


Fig 3.4.8.4 Fifth extended transmission line

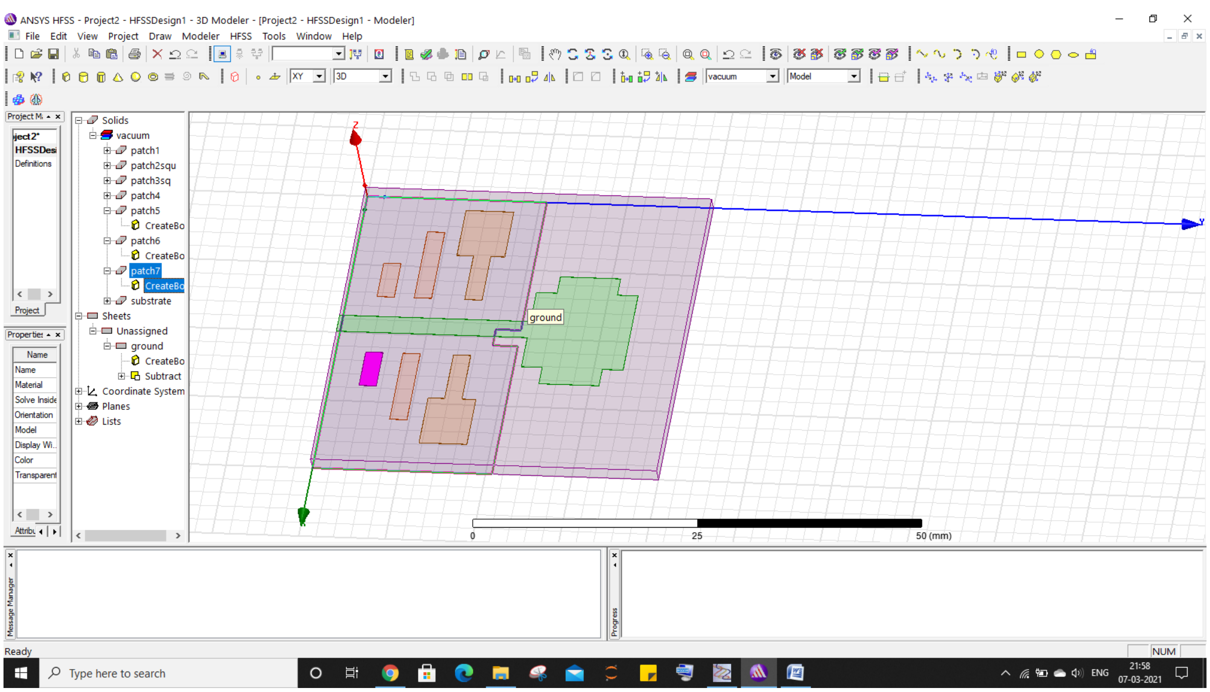


Fig 3.4.8.5 Sixth extended transmission line

Step 12: Now create feed point with required dimensions by changing drawing plane to ZX direction.

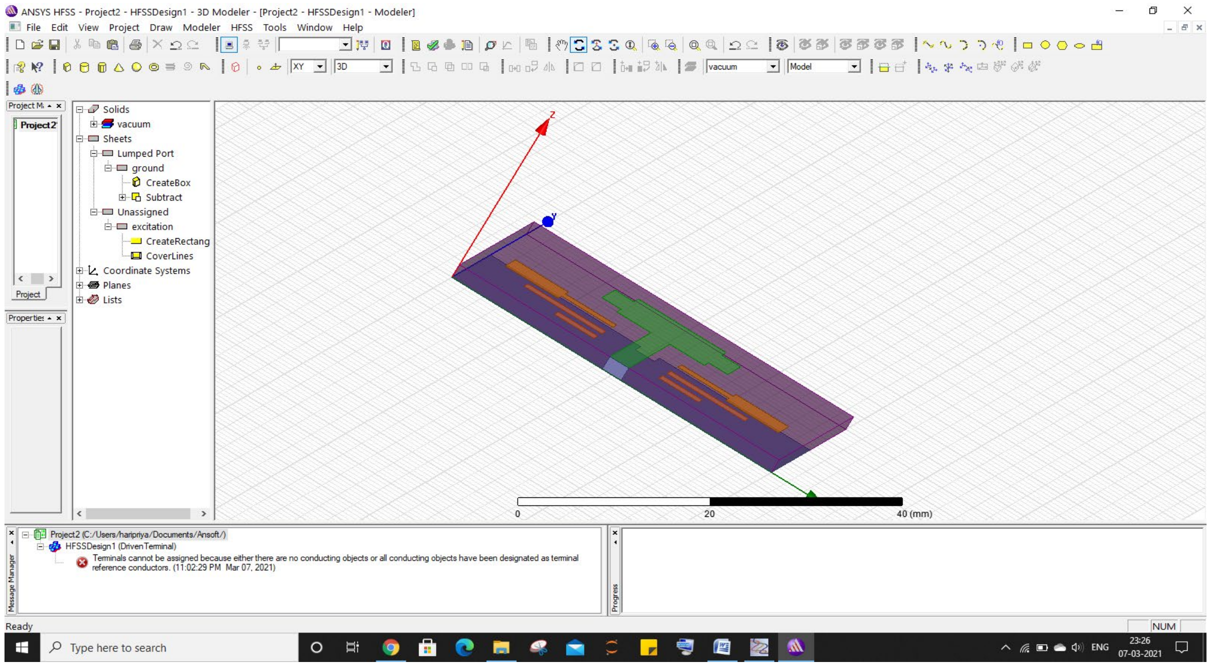
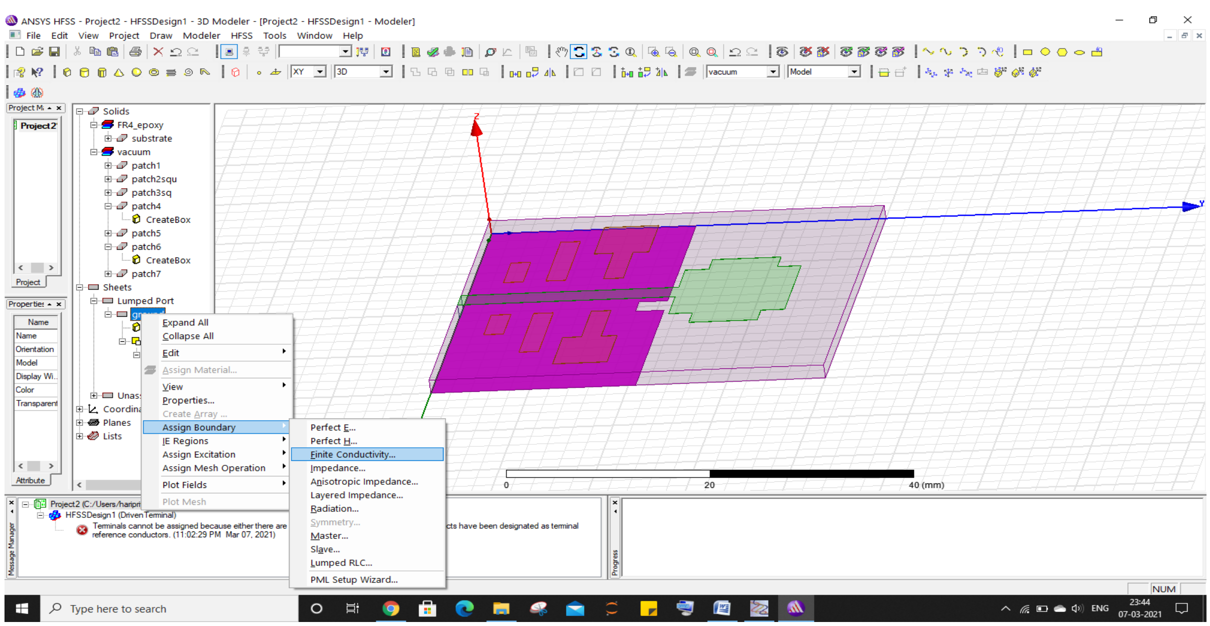


Fig 3.4.9: After creating feed point

Step 13: Assign boundary to ground as finite conductivity and use material as copper.

Right click on ground > assign boundary > finite conductivity > use material > copper



. Fig 3.4.10: After assigning boundaries

Step 14: Similarly assign boundary to all patches as finite conductivity and use material as copper.

Step 15: Assign FR4 material to substrate.

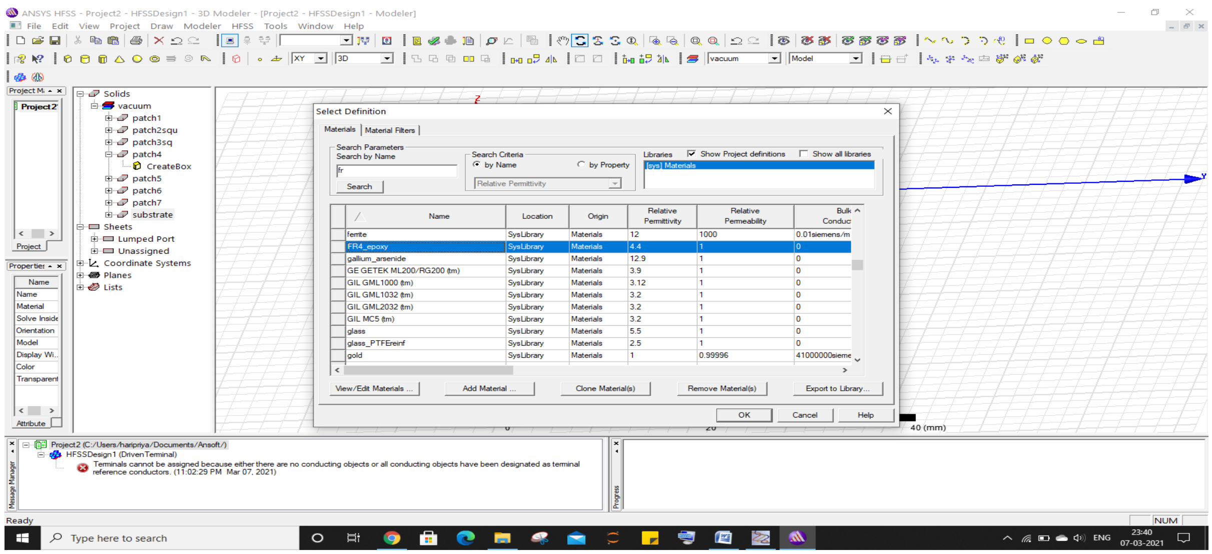


Fig 3.4.11: Assigning material for substrate

Step 16: Add lumped port for excitation with reference to ground.

Right click on feed point > assign excitation > lumped port > ground(use as reference).

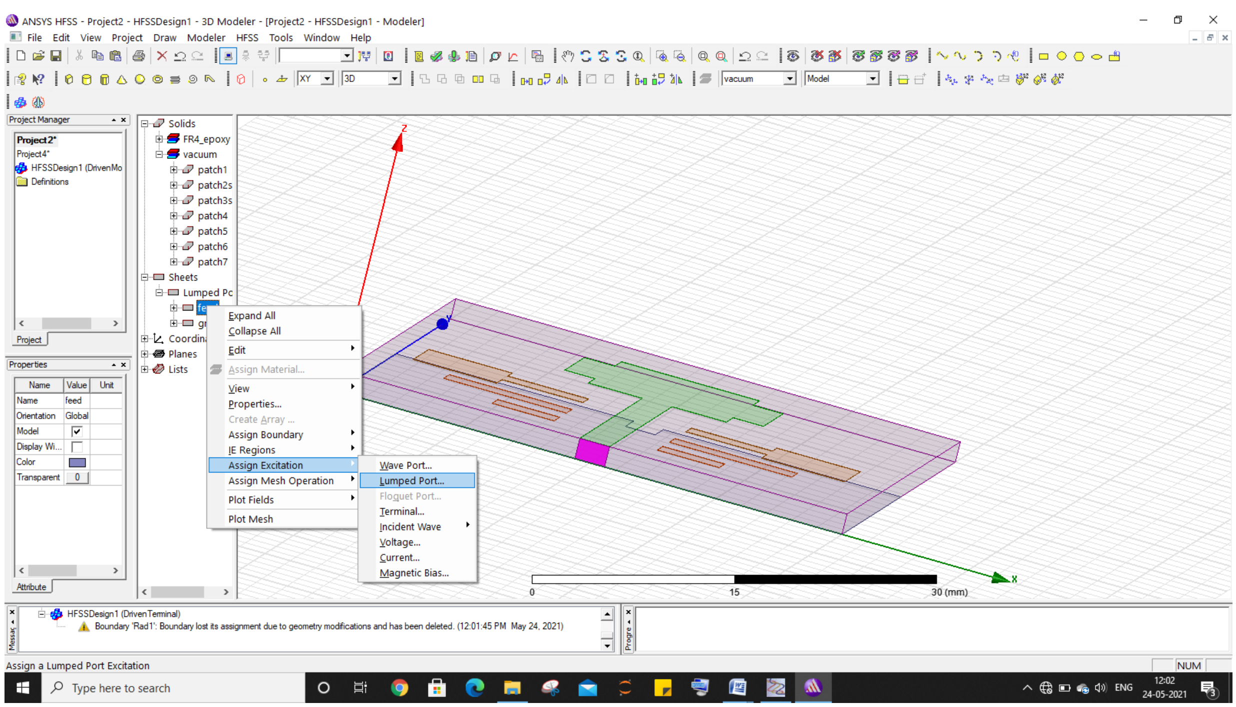


Fig 3.4.12: After assigning Excitation

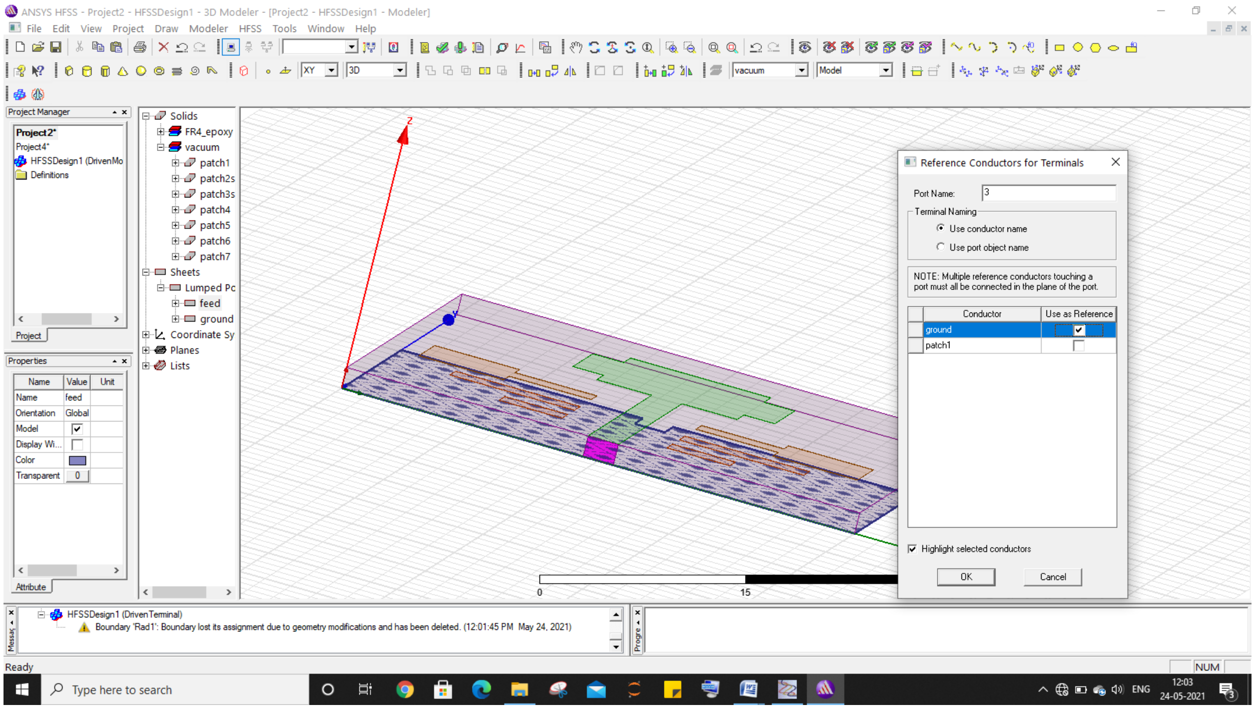


Fig 3.4.13: After assigning Excitation

Step 17: Insert radiation box with specified dimensions such that the design such lie inside the radiation box.

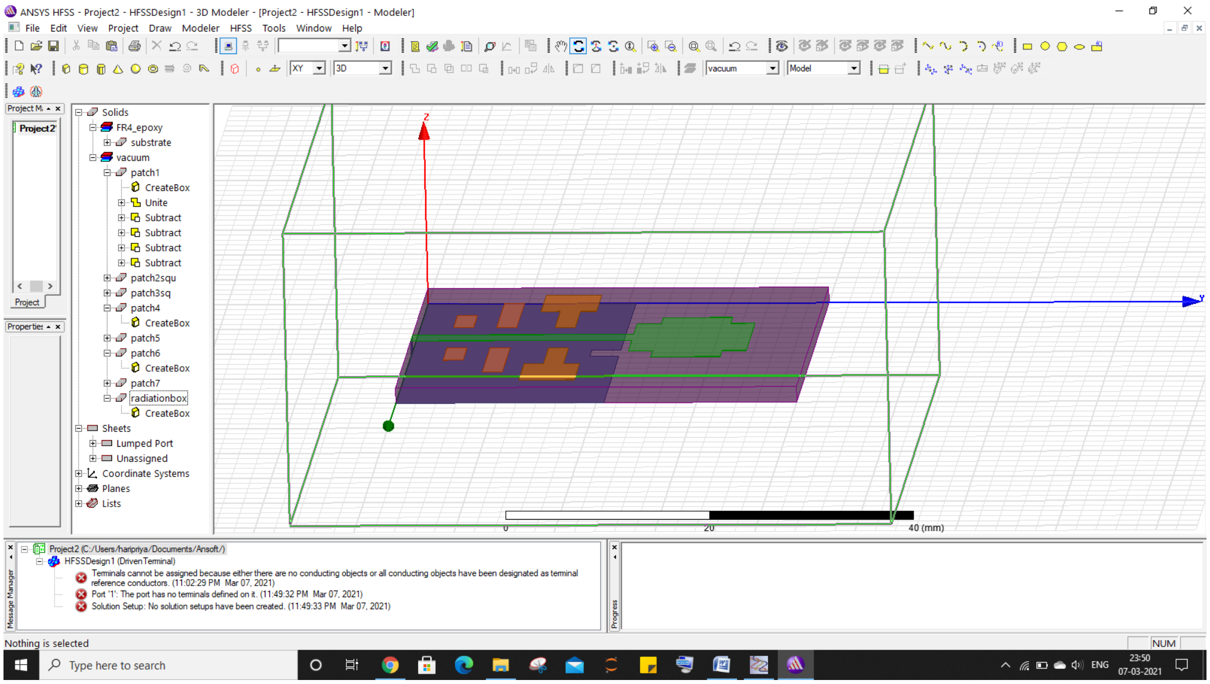


Fig 3.4.14: Assigning radiation box for designed antenna

Step 18 : Assign radiation characteristics to radiation box.

Right click on radiation box > assign boundary > radiation

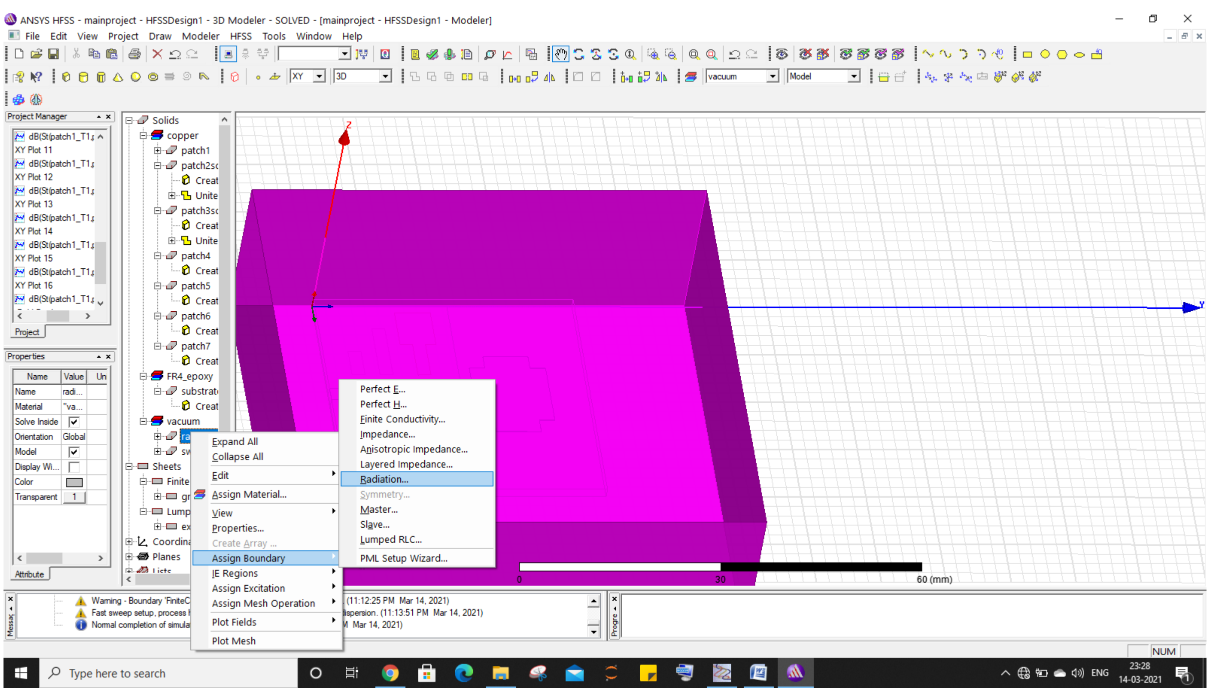


Fig 3.4.15: Assigning boundary for radiation box

Step 19: Now insert switches (pindiodes) and assign the resistance, inductance, capacitance values as per off condition.

Right click > assign boundary > lumped RLC > select resistance/ inductor/ capacitor > define current flow with new line.

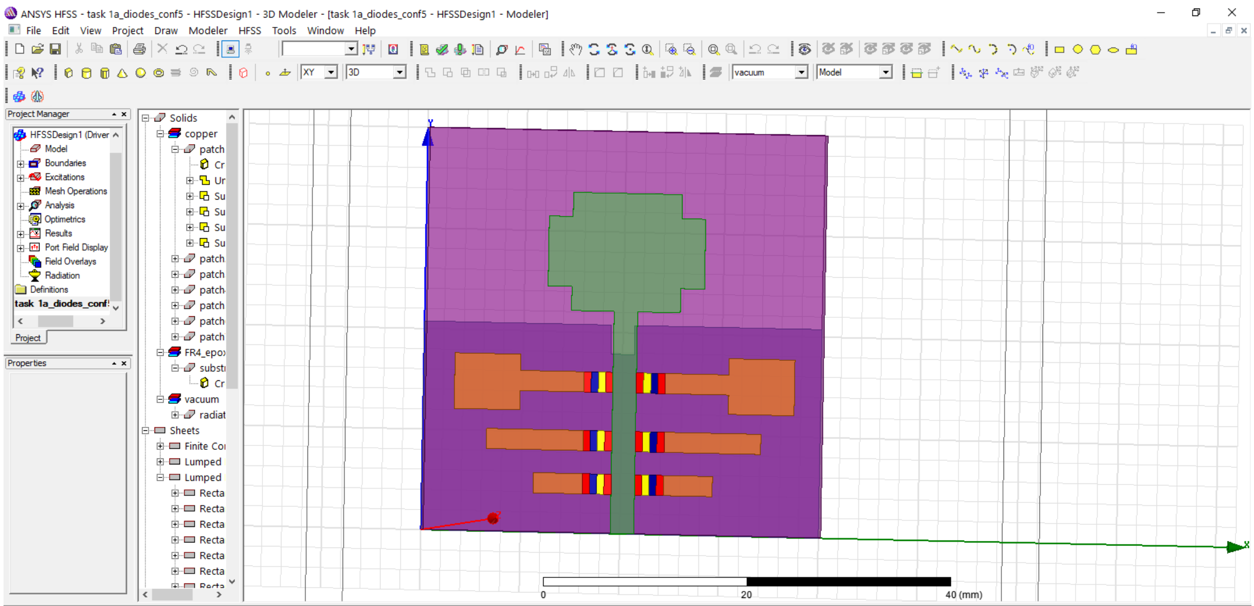


Fig 3.4.16.1: inserting pindiodes

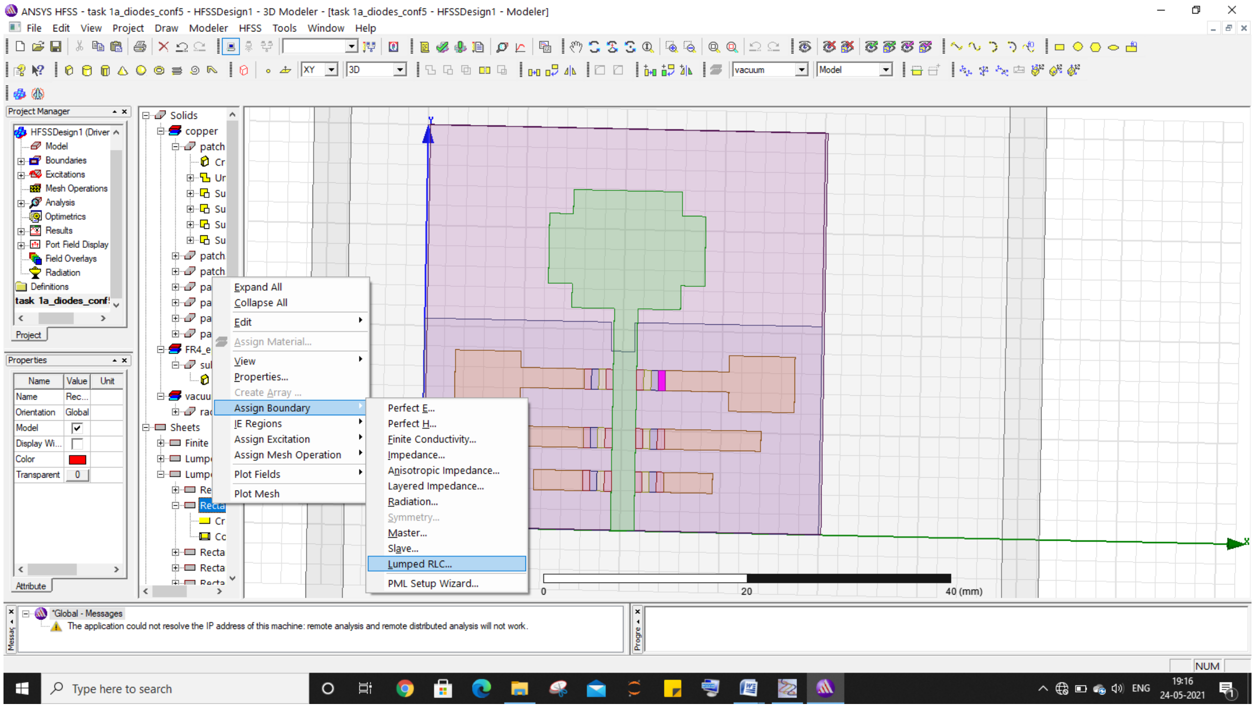


Fig 3.4.16.2: assigning properties for pindiodes

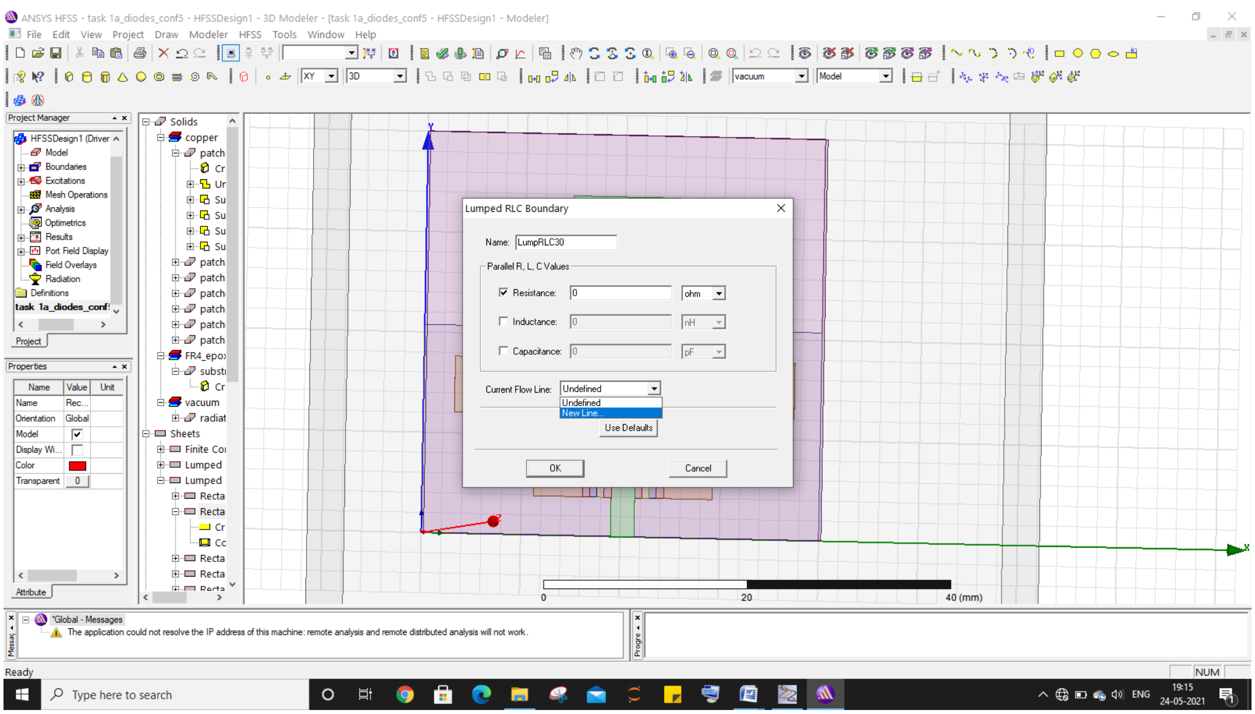


Fig 3.4.16.3: assigning values and defining current flow for lumped RLC

Step 20: Assign operating frequency.

HFSS > analysis setup > add solution setup

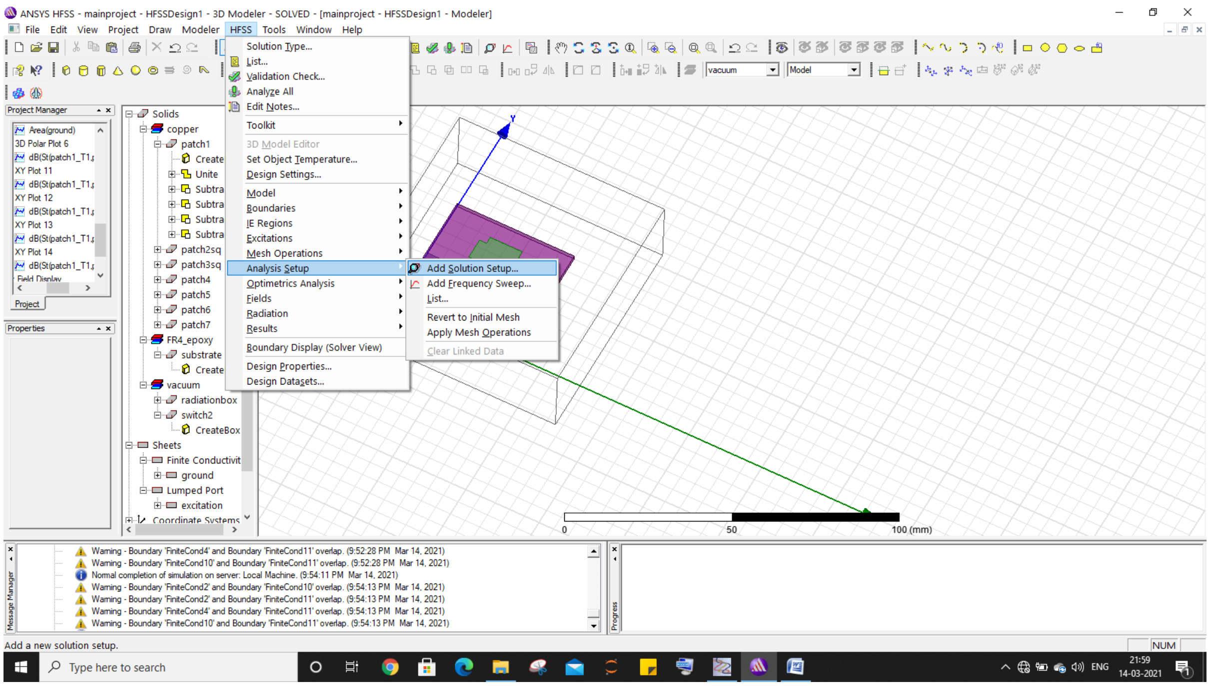


Fig 3.4.17.1: adding solution frequency

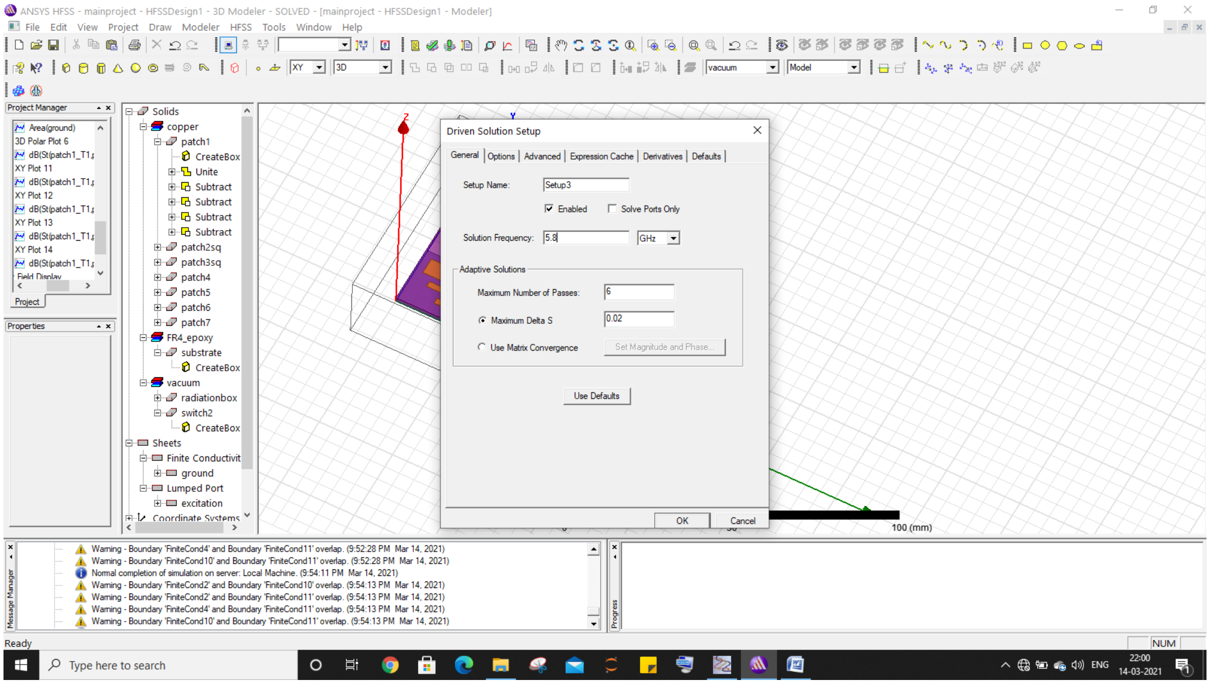


Fig 3.4.17.2: After adding solution frequency

Step 21: To specify the start and stop frequency of the plot select HFSS> Analysis set up > Add Frequency Sweep.

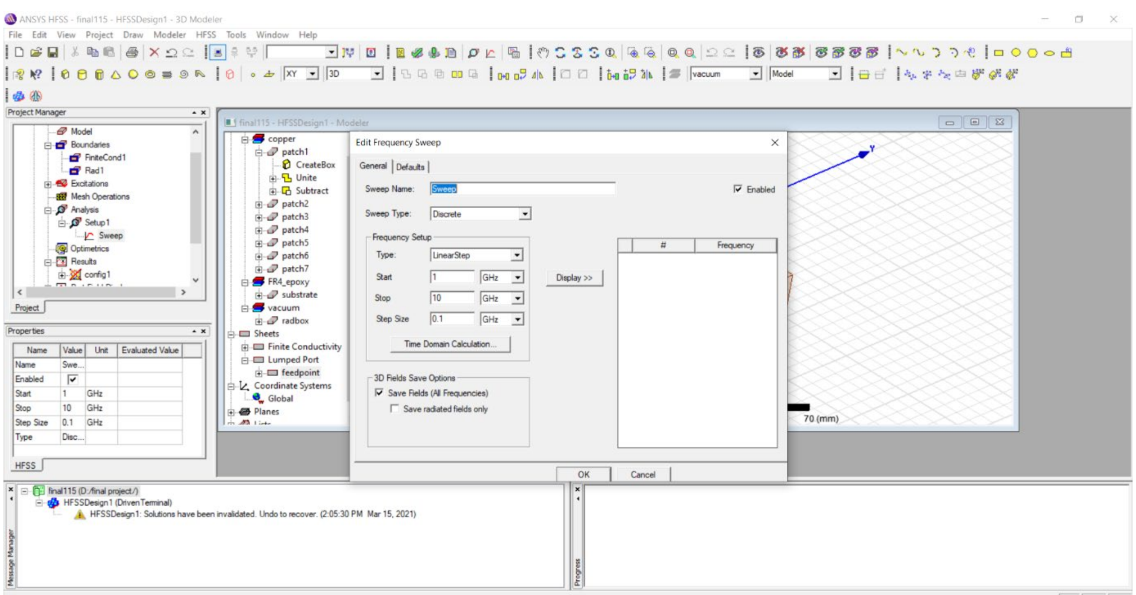


Fig 3.4.18: Assigning Sweep setup

Step 22: To view any errors in the design, click on HFSS > Validation Check and then to analyze the design click on HFSS > Analyze all.

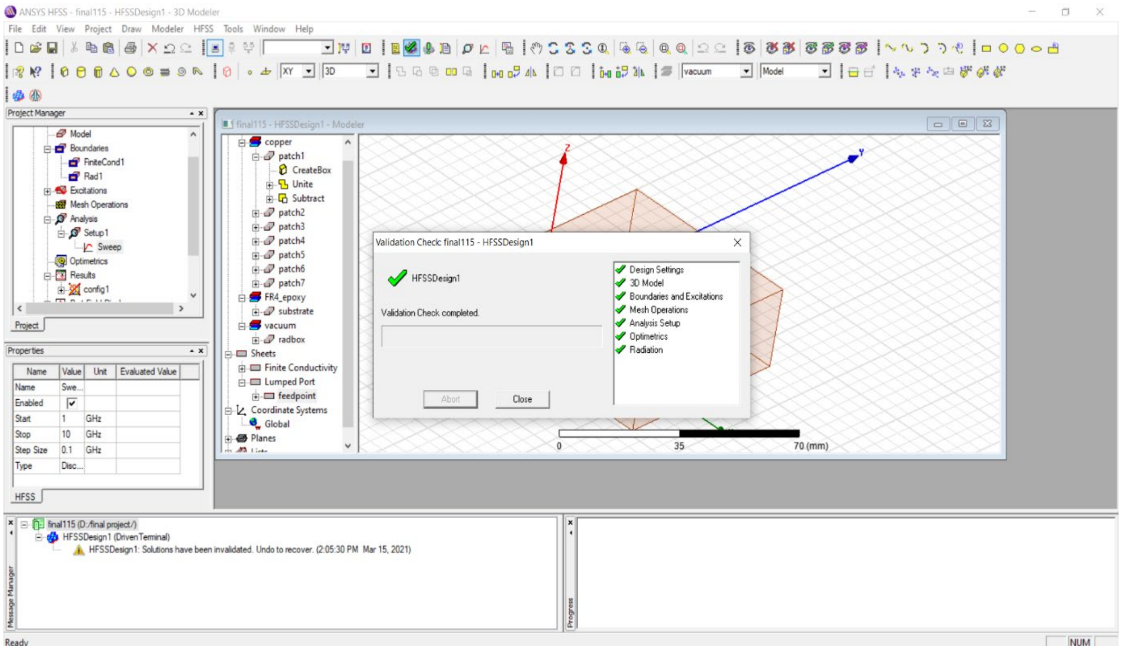


Fig 3.4.19: Validation check and Simulation

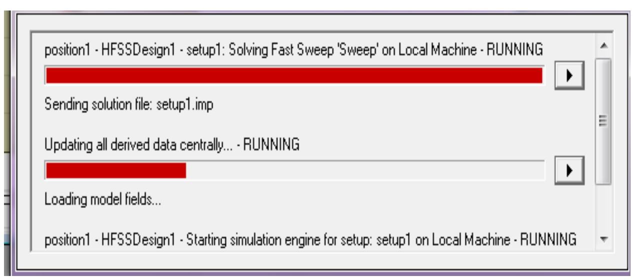


Fig 3.4.20: Analysis setup

Step 23: After completion of the simulation process, the results are observed through select HFSS > Results. These are the results for configuration1 when all switches in OFF condition .**Step 24**: To observe the results for remaining four configurations follow the same above steps and additionally change the configuration of RLC circuit of pindiode for forward bias as per the configuration ON conditions.

3.5 RESULTS:

Here we obtain two main parameters (Return loss and Gain) as results.

Return loss (S_{11}) is a measure of how much power is reflected back at the antenna port due to mismatch from the transmission line.

Antenna gain is the ability of the antenna to radiate more or less in any direction compared to a theoretical antenna.

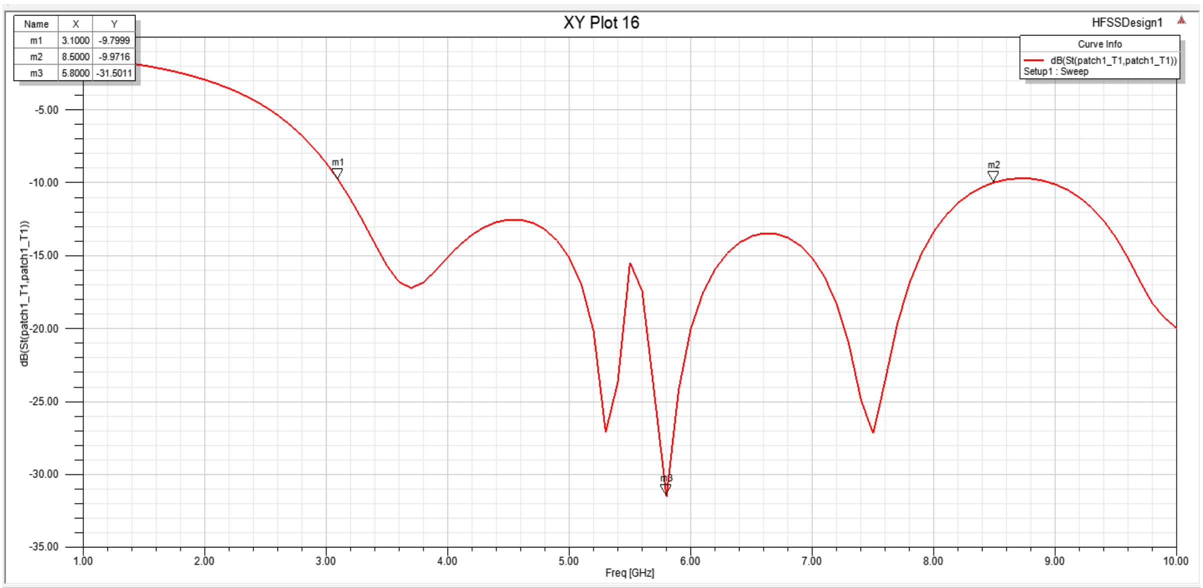


Fig 3.4.21.1: Return loss of configuration1 (-31 dB)

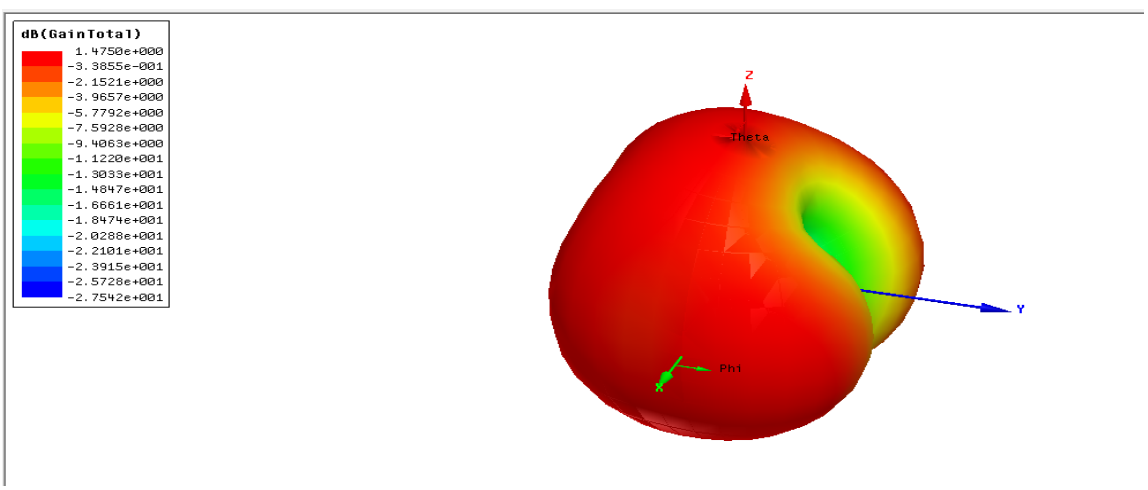


Fig 3.4.21.2: Gain of configuration 1 (1.4 dB)

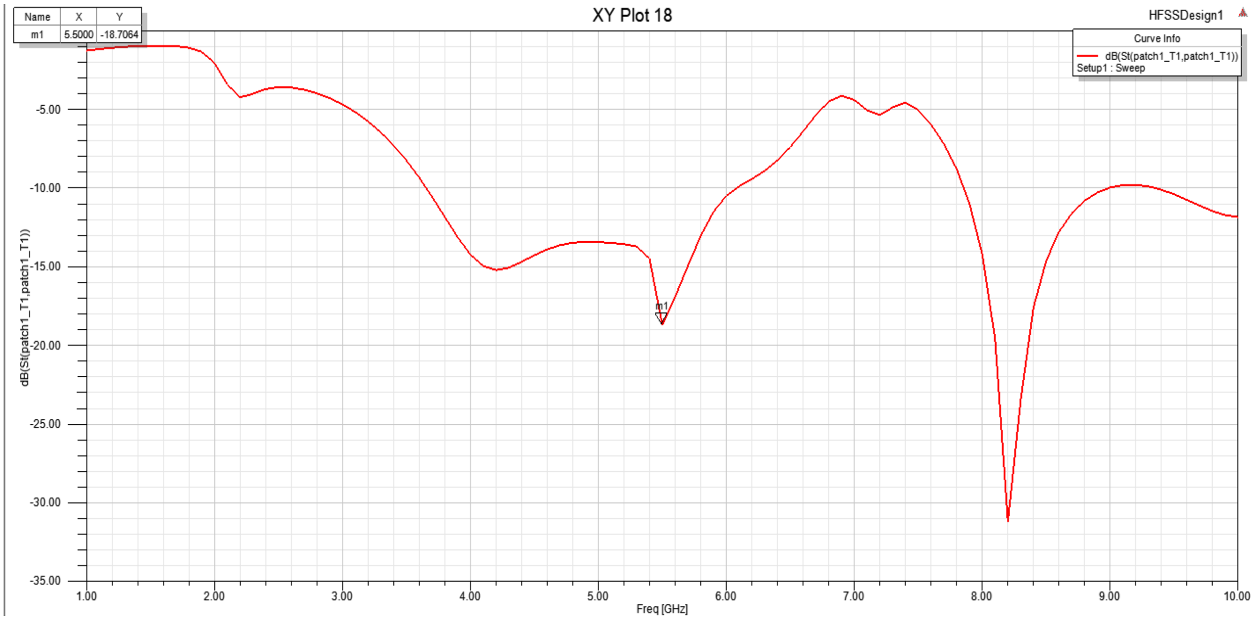


Fig 3.4.22.1: Return loss of configuration 2 (-18.7 dB)

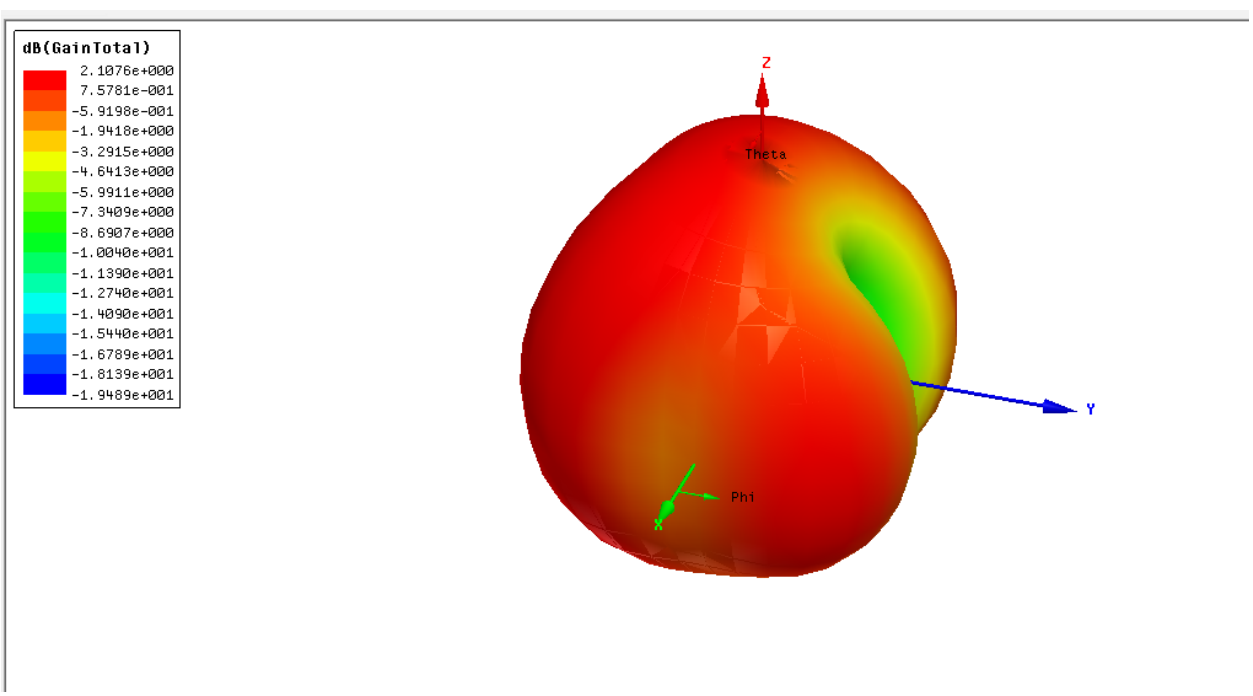


Fig 3.4.22.2: Gain of configuration2(2.1 dB)

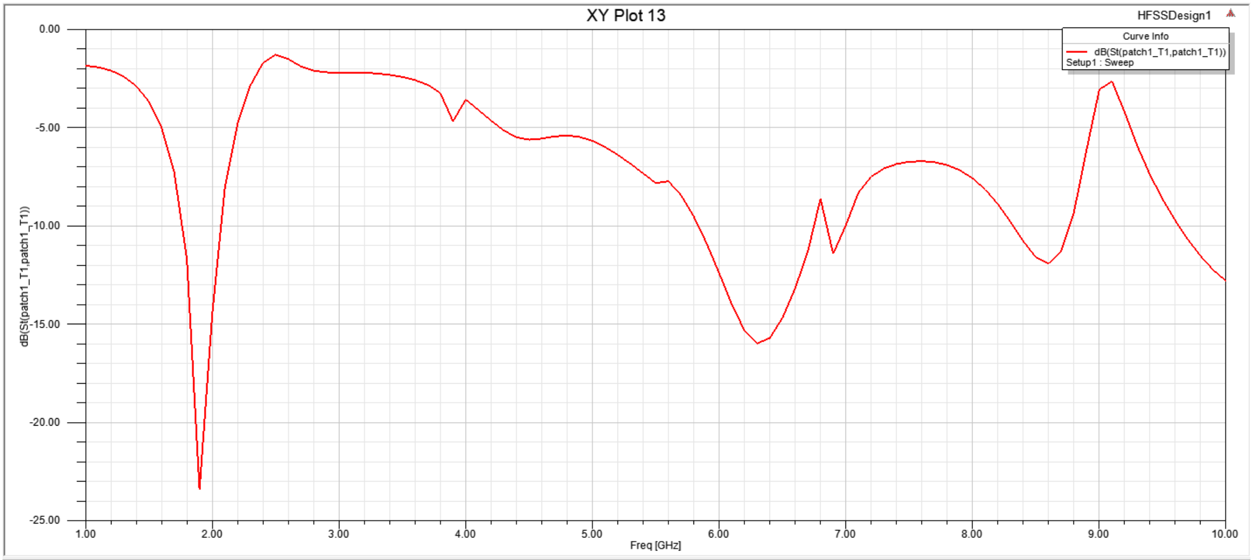


Fig 3.4.23.1: Return loss of configuration 3 (-15.52 dB)

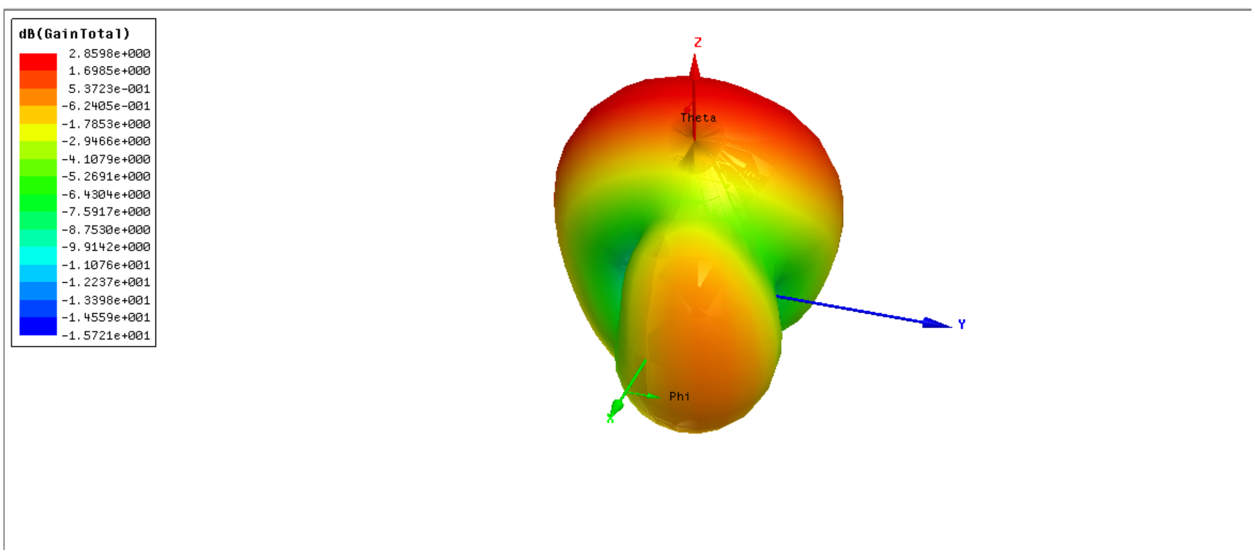


Fig 3.4.23.2: Gain of configuration 3 (2.8 dB)

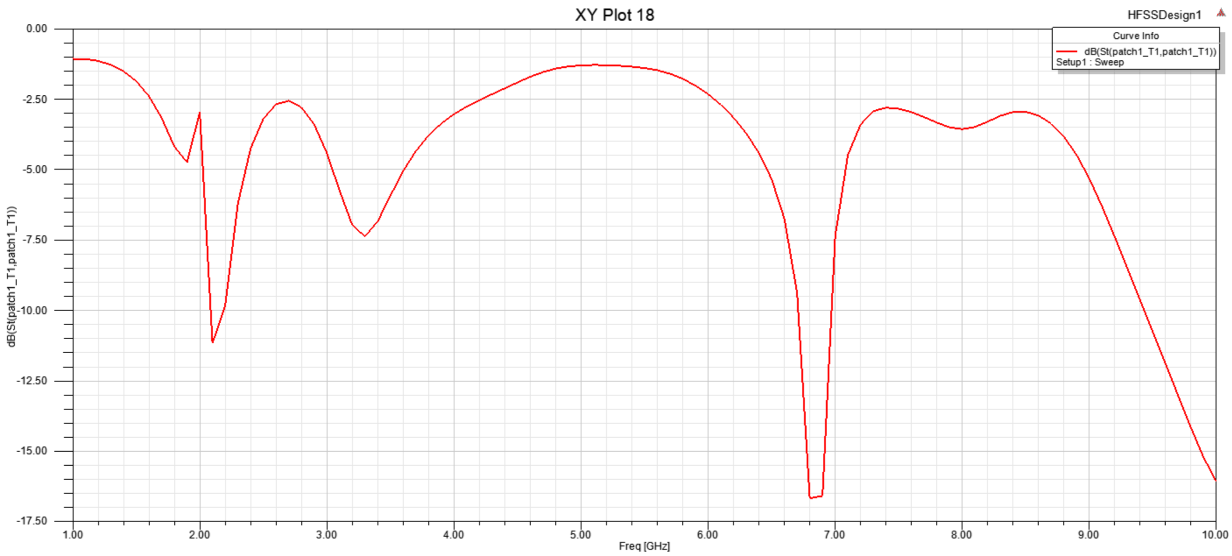


Fig 3.4.24.1: Return loss of configuration 4(-16.6 dB)

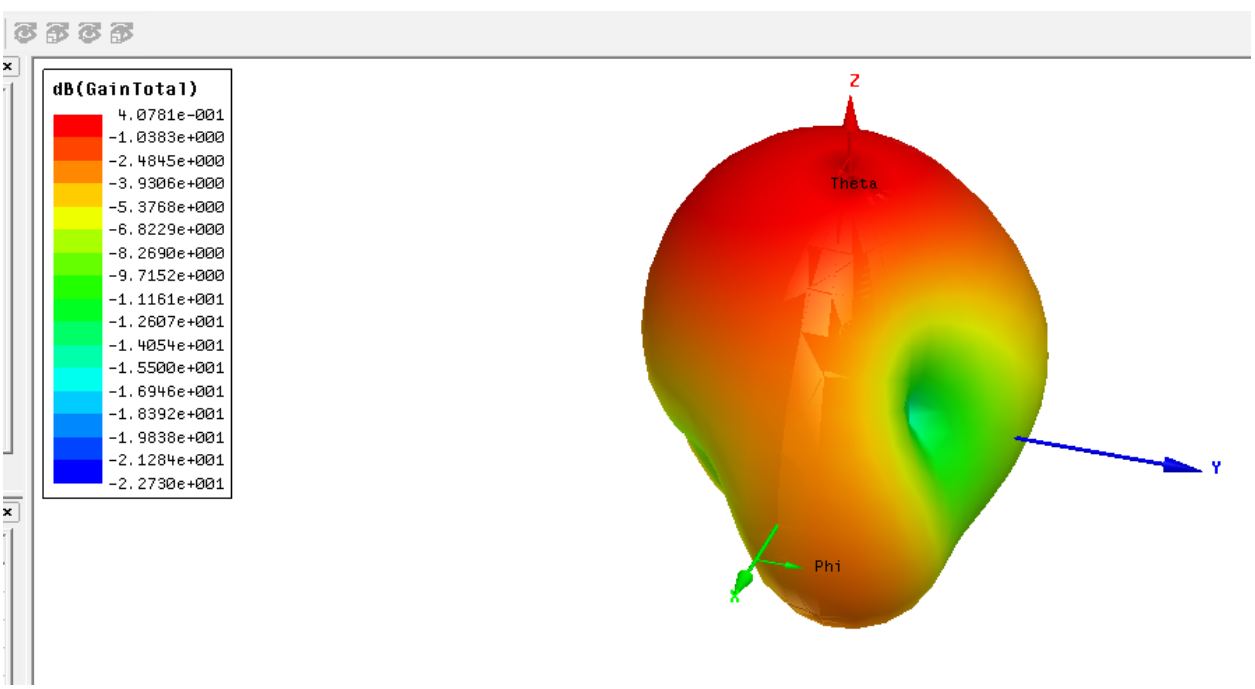


Fig 3.4.24.2: Gain of configuration 4 (4.07 dB)

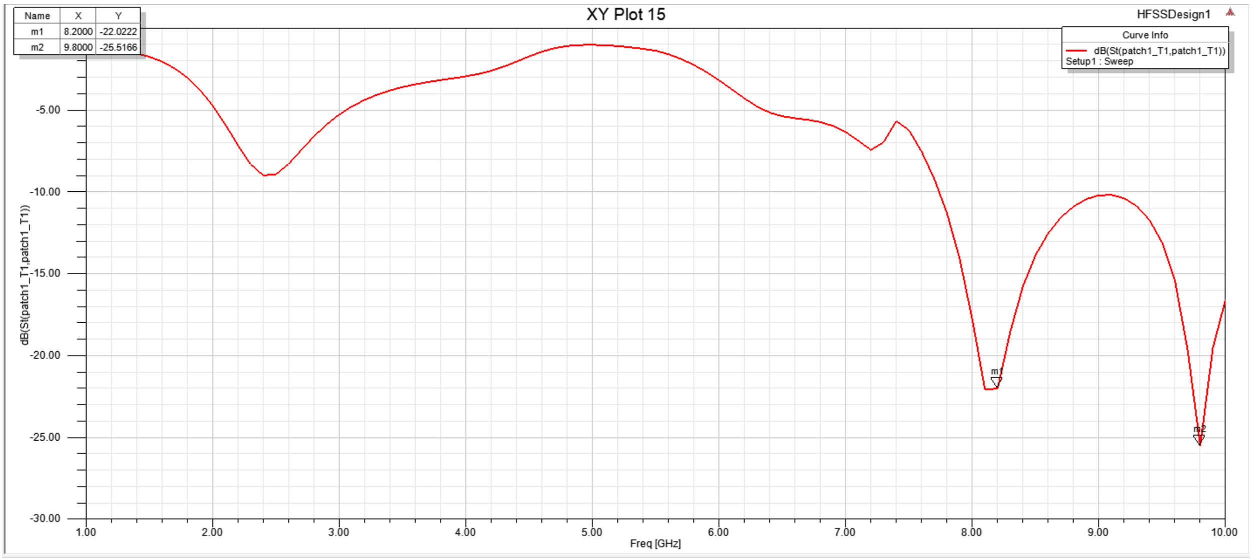


Fig 3.4.25.1: Return loss of configuration 5 (-22.02 dB)

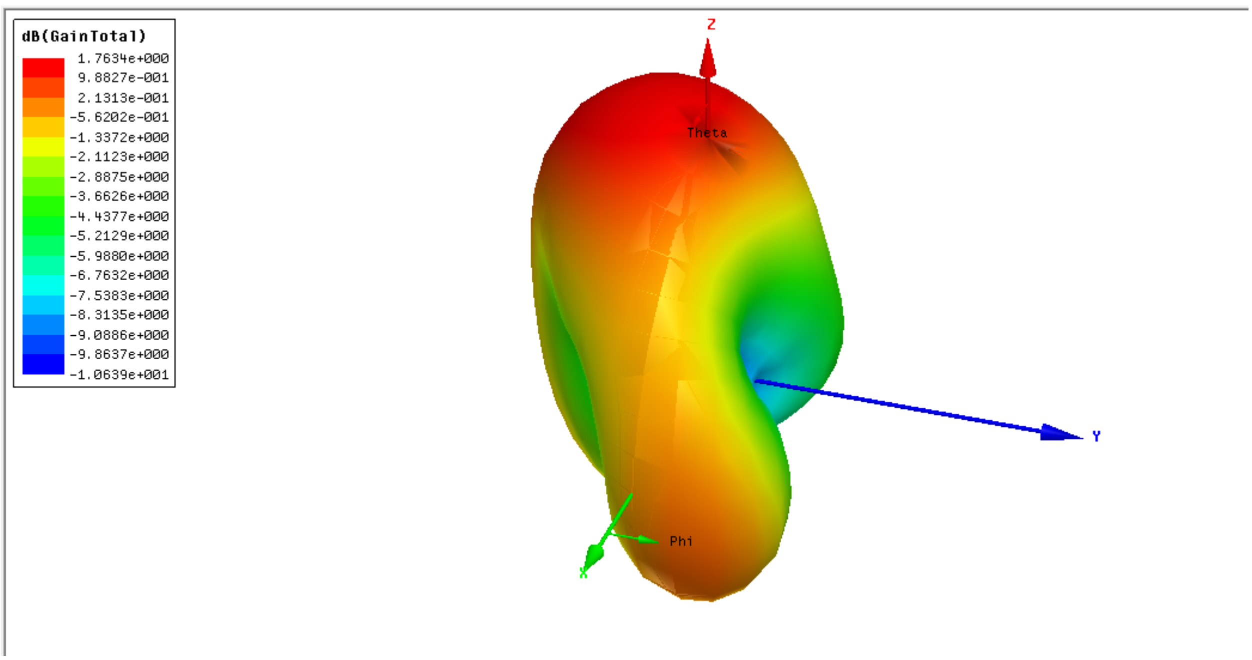


Fig 3.4.25.2: Gain of configuration 5 (1.7 dB)

Table 3.3: Summary of results obtained for the proposed design.

Configuration	Return loss(db)	Gain (db)	Frequency (GHz)
I	-31	1.4	3.2 – 8.5
II	-18.7	2.1	3.6 – 6.2
III	-15.52	2.8	5.2 – 8.2
IV	-16.6	4.07	6.6 – 7
V	-22.02	1.7	7.8 – 10.2

3.6 CONCLUSION:

This work reports a frequency reconfigurable antenna that can be reconfigured as an UWB antenna and narrow band antennas .Here we use pindiodes as switches. Configuration I with all switches OFF combination allows the antenna to operate in the UWB (3.2 to 8.5 GHz).Configuration II, III, IV, and V, collectively allow the antenna to operate from 3.6 to 10.2 GHz as five narrow bands. Configuration I makes the antenna suitable for spectrum sensing part of Cognitive Radio, and Configurations II to V allow the antenna to be used for communicating within the UWB spectrum. So, from the obtained results we can conclude that signal transmission in narrow and widebands can be achieved through switching using pindiodes.

CHAPTER 4

SWITCHABLE MICROSTRIP PATCH ANTENNA DESIGN AND SIMULATION RESULTS USING MEMS

4.1 INTRODUCTION

Reconfigurable antennas have attained much attention in recent years. These antennas are able to modify themselves with respect to the frequency, Bands, polarization, characteristics, radiation pattern, and combinations of the above. A single reconfigurable antenna is capable of accommodating the features of a number of antennas. This proposed antenna is designed to achieve Band reconfigurability. The reconfigurability of the antenna is obtained by inserting switches like RF-MEMS. RF-MEMS Switches are found to be dependable over microwave and milli meter-wave range applications with rapidness in switching, higher linearity and isolation, excellent adaptability, lower distortion rates.

The proposed work can achieve both spectrum sensing and signal transmission using same design. Here, the UWB and Narrow band characteristics are obtained by presenting rectangular patch band reconfigurable antenna in this design using various switching configurations. These configurations are considered as per the Federal Communications Commission (FCC) regulations for the UWB technology and assigned the unlicensed spectrum from 3.1 to 10.6 GHz for Cognitive radio applications. Gain, Return loss, Frequency bands are obtained through switching in between the bands of preferred configurations. The antenna design, results, conclusion about the results of the proposed design are explained in the following sections.

4.2 MEMS

Micro electro mechanical Systems (MEMS) have been developed since the 1970s for pressure and temperature sensors, accelerometers and other sensor devices. The one main criterion of MEMS is Sort of mechanical functionality whether or not these elements can move. These actually refer to miniature mechatronic systems which are fabricated using VLSI technology

4.2.1 Functionality of MEMS:

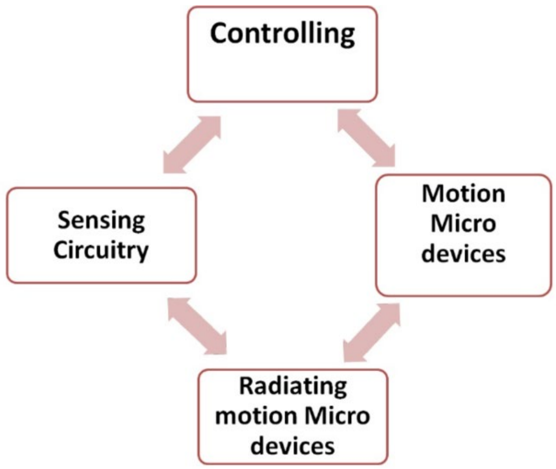


Fig 4.2.1.1 Basic function of MEMS

MEMS Converts physical stimuli, events and parameters to Electrical, Mechanical, and optical signals and vice versa. Performs actuation, sensing and other functions.

4.2.2 Features and Benefits of MEMS:

MEMS are used for Sensing, Actuation (passive micro-structures), Cost reduction, Increase functionality, Improve reliability, Small in size as in the range of micrometer to millimeter, Techniques and processes to design and create miniature systems and miniature embedded system, Fewer defects per chip, Reduce noise and improve sensitivity.

MEMS introduced many benefits of size reduction on the electrical domain and also in terms of Speed for High Frequency, Low Thermal time const. Power Consumption for less Actuation Energy & Heating power. Complexity for High Integration density & functionality, Faster switching, Low loss, Larger networks and Fast Analysis speed.

4.3 DESIGN OF SWITCHABLE MICROSTRIP PATCH ANTENNA

The switchable microstrip patch antenna is designed by using RF MEMS and also by using the Ansoft HFSS simulation tool. The design is simulated for five cases based on the required configurations.

4.3.1 Design steps:

The antenna design is simulated for configuration 1 when all the switches in OFF condition. Simulation steps are shown in Fig 5.1-5.13 are as follows

Step1: Launch the Ansoft HFSS.

Step2: In an HFSS window, from the menu click file>New.

Step3: From the Project menu, select insert HFSS Design.

Step4: Select the menu item HFSS > Solution Type > Driven Terminal.

Select the menu item 3D Modeler > Units > mm

Step5: Now go to menu and Click on rectangle. Windows pops up and define all the specifications of ground plane and name it as ground

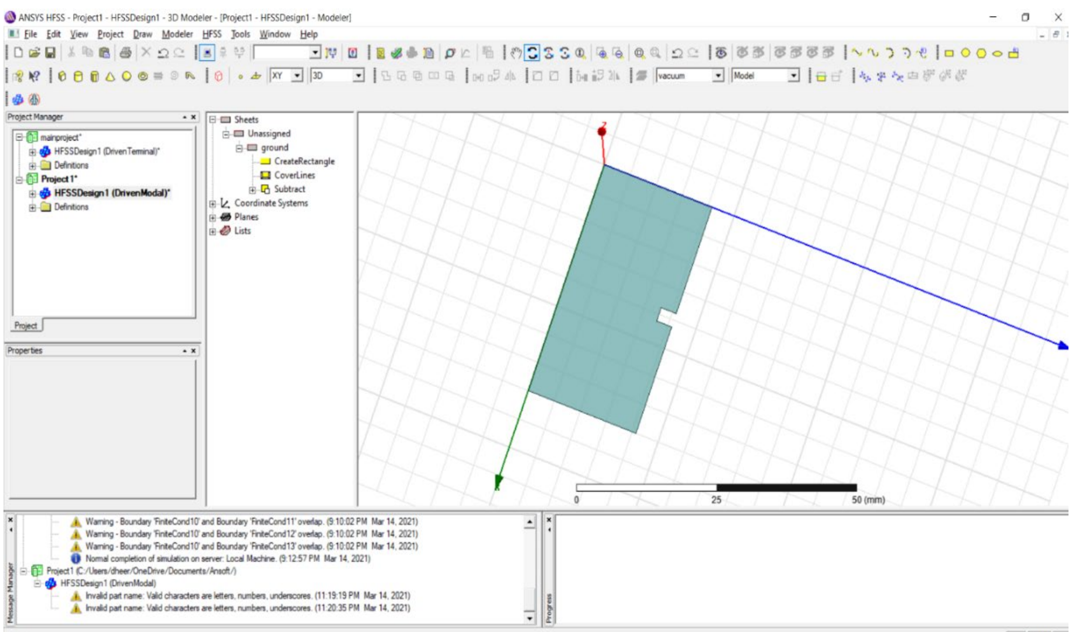


Fig 4.1: Ground plane in HFSS window

Step6: Now go to menu and Click on box. A window pops up and defines all the specifications of a substrate. i.e. type of substrate and the dimensions. Name the box as substrate. Also place vertical patch by defining all the specified dimensions.

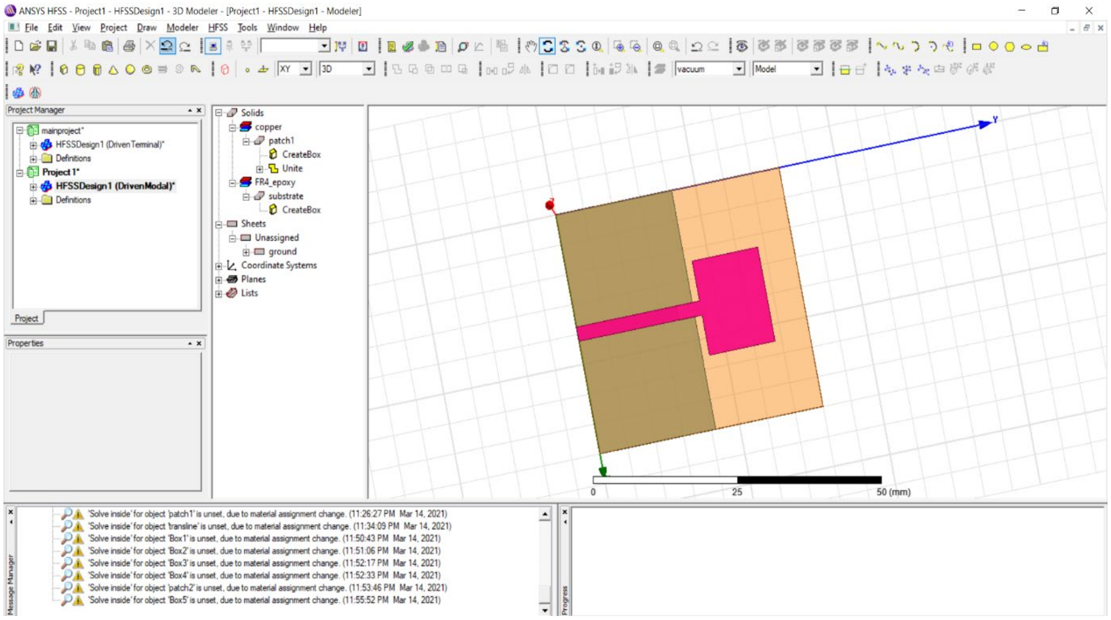


Fig 4.2: After placing substrate and main patch

Step7: Now cut the four slits from the edges of Rectangular patch (main patch) using specified dimensions by clicking on main patch.

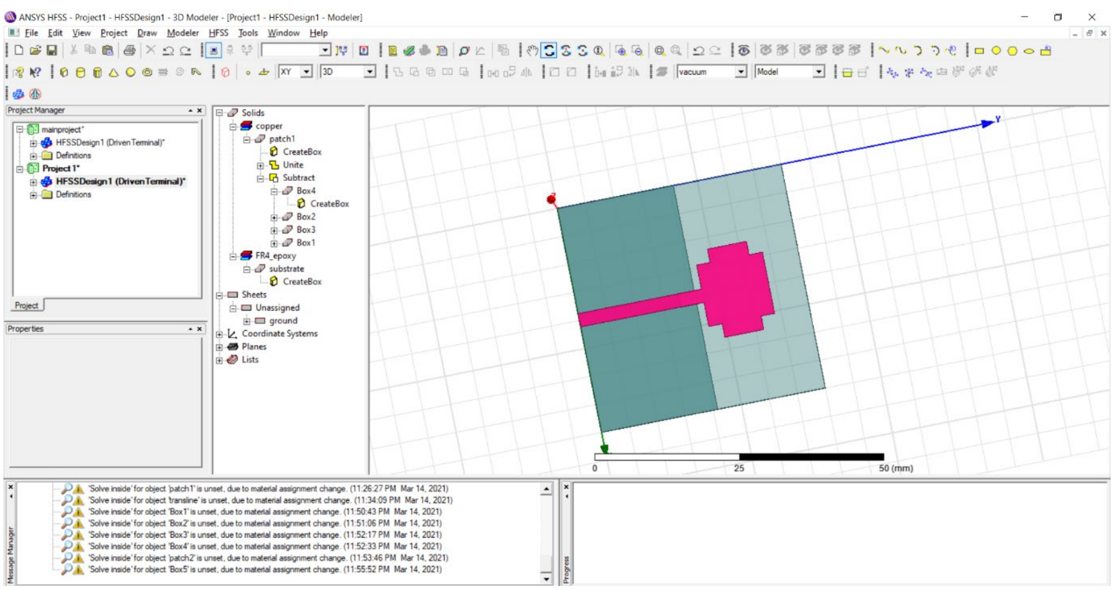


Fig 4.3: After cutting edge slots of main patch

Step8: Assign perfect E to ground, vertical patch and horizontal patch

Select Edit > Select > By Name > patch1.

Select HFSS> Boundaries > Assign > Perfect E

Step9: Now insert all the 6 extended transmission lines by using specified dimensions which were obtained from the calculations.

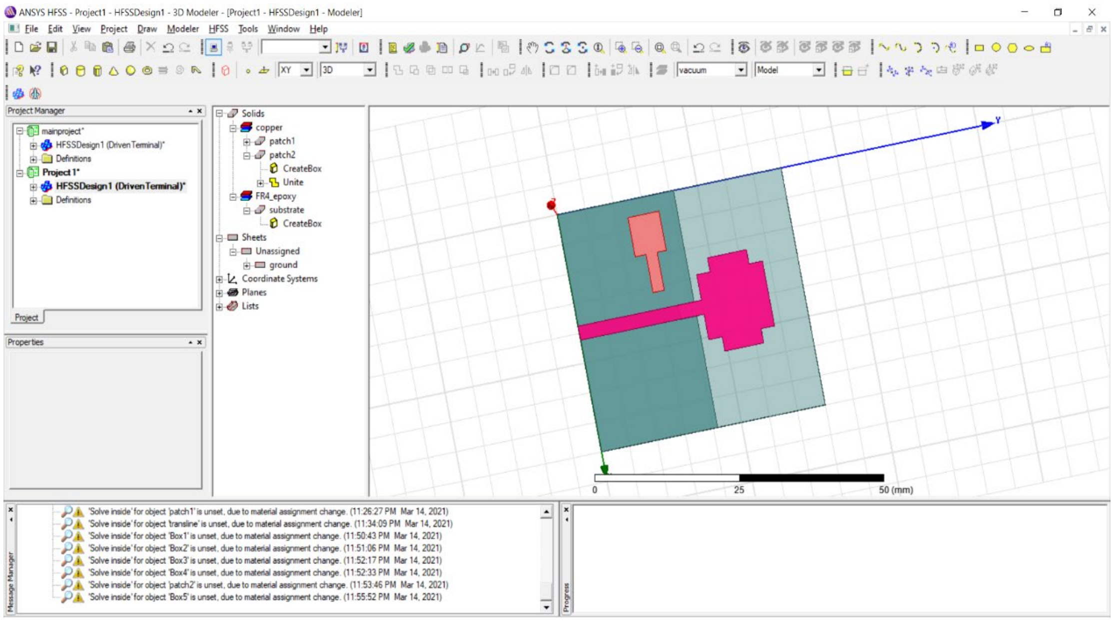


Fig 4.4.1 First extended transmission line

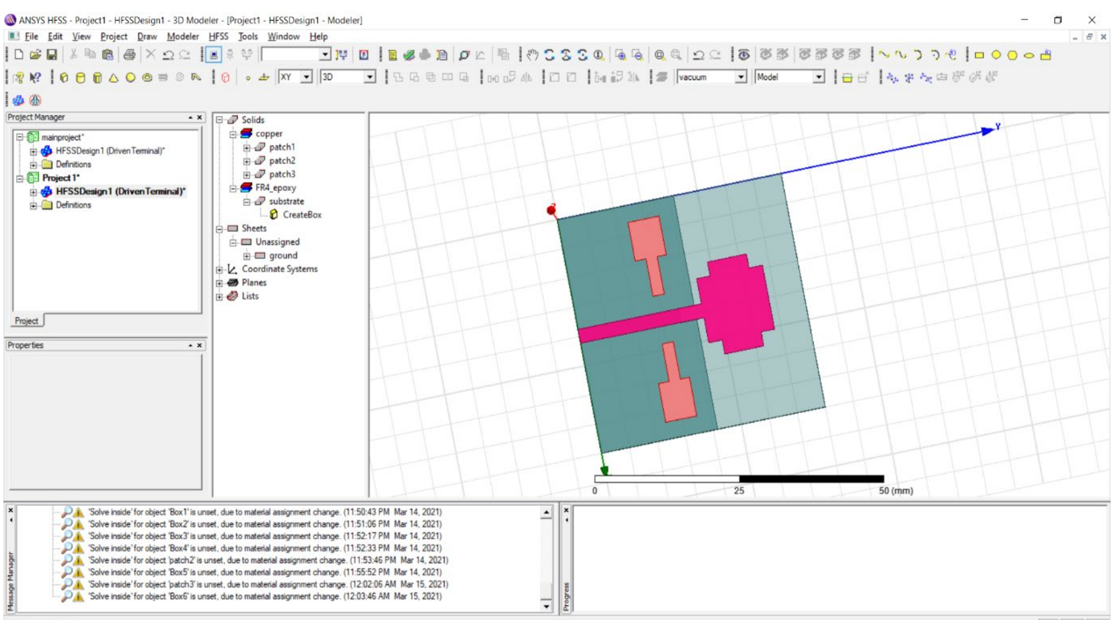


Fig 4.4.2 Second extended transmission line

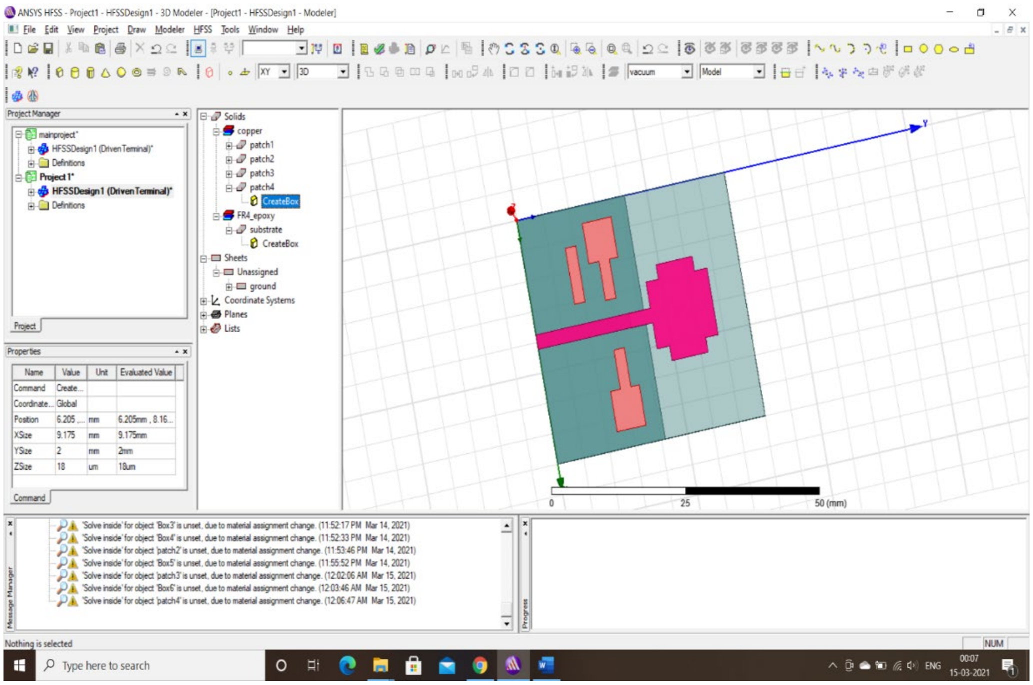


Fig 4.4.3 third extended transmission line.

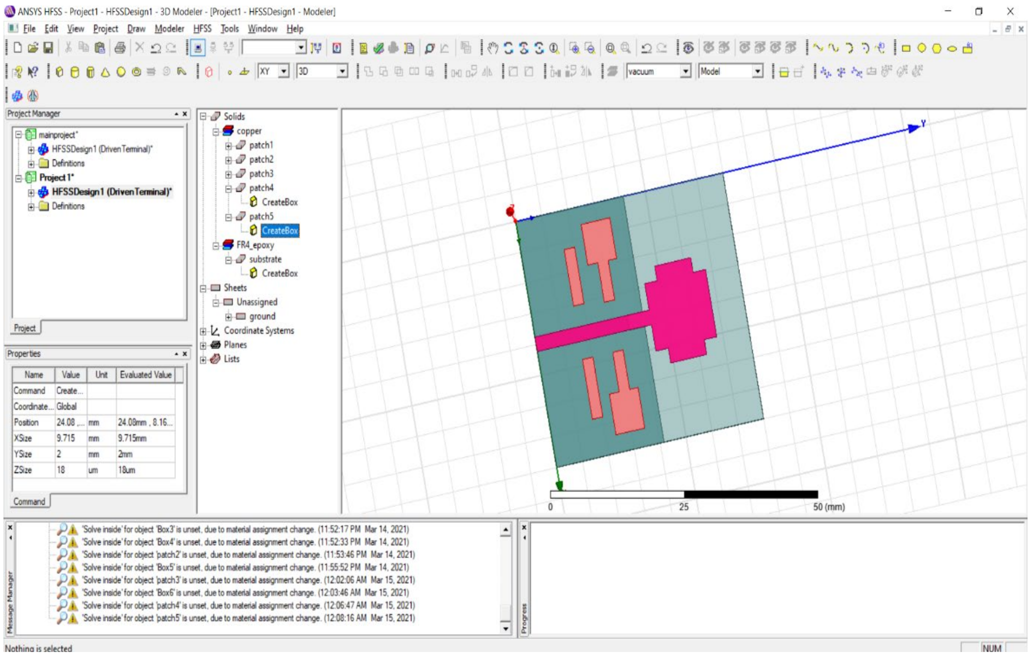


Fig 4.4.4 Fourth extended transmission line

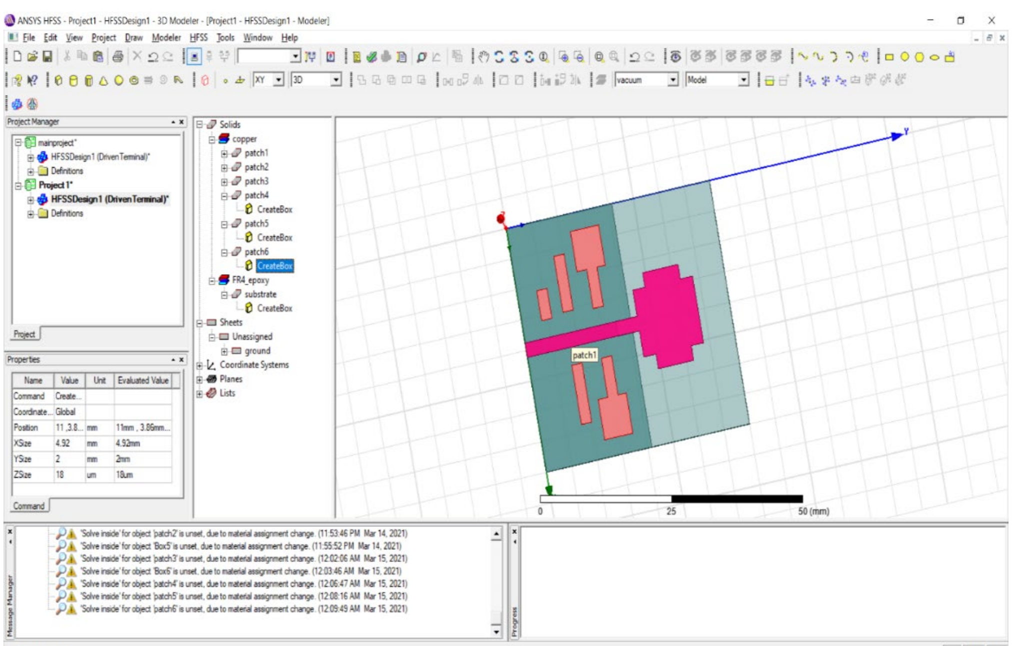


Fig 4.4.5 Fifth extended transmission line

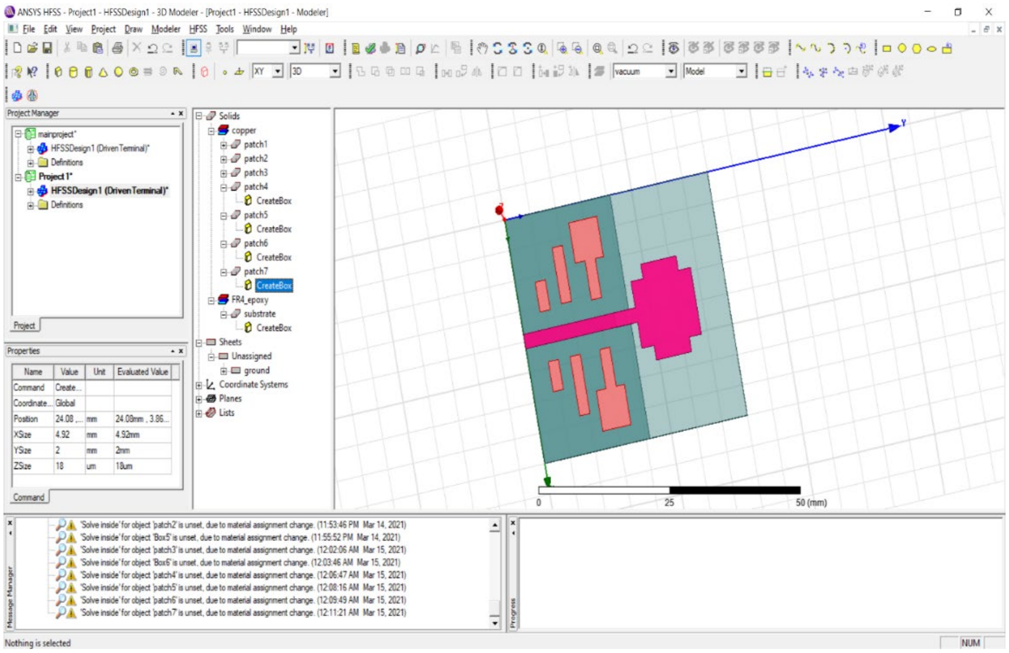


Fig 4.4.6 Sixth extended transmission line

Step10: Now assign the specified dimensions and create a feed point. Then assign excitation to the feed point.

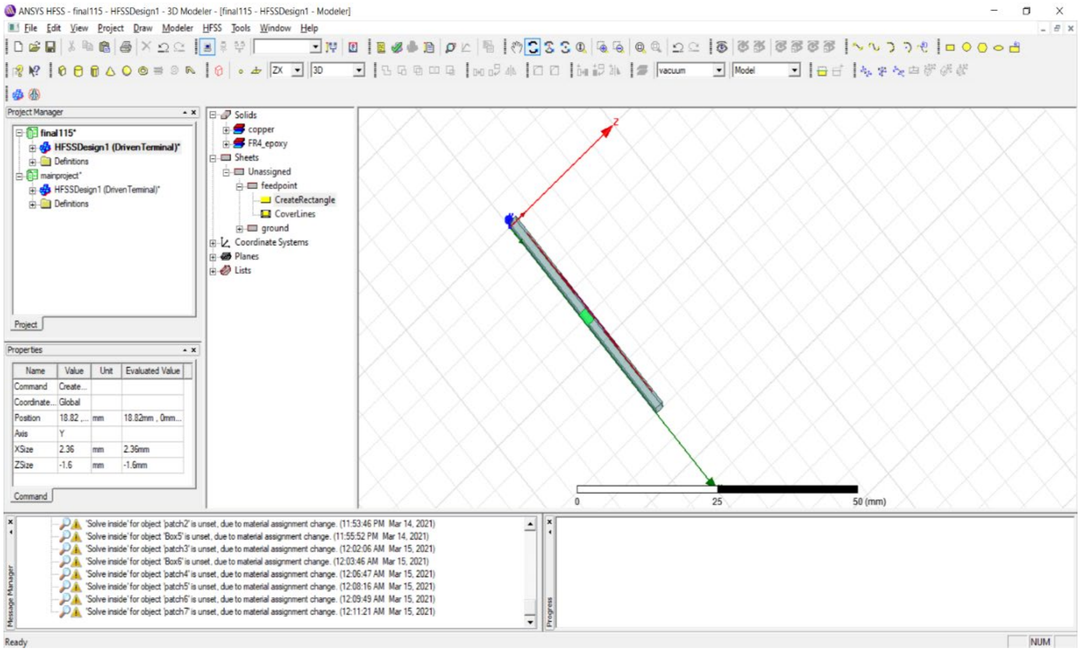


Fig 4.5: After assigning Excitation

Step11: Assign boundary to ground as finite conductivity and use material as copper.

Step12: Add lumped port for excitation with reference to ground.

Step13: Assign boundary to patches as finite conductivity and use material as copper and assign material FR4_epoxy for substrate.

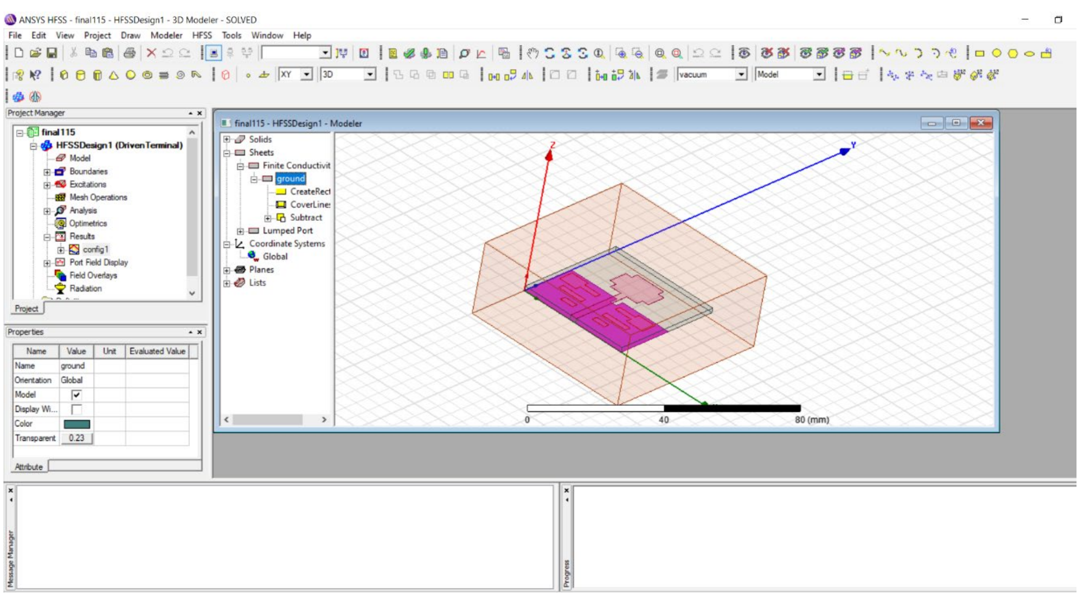


Fig 4.6: After assigning boundaries

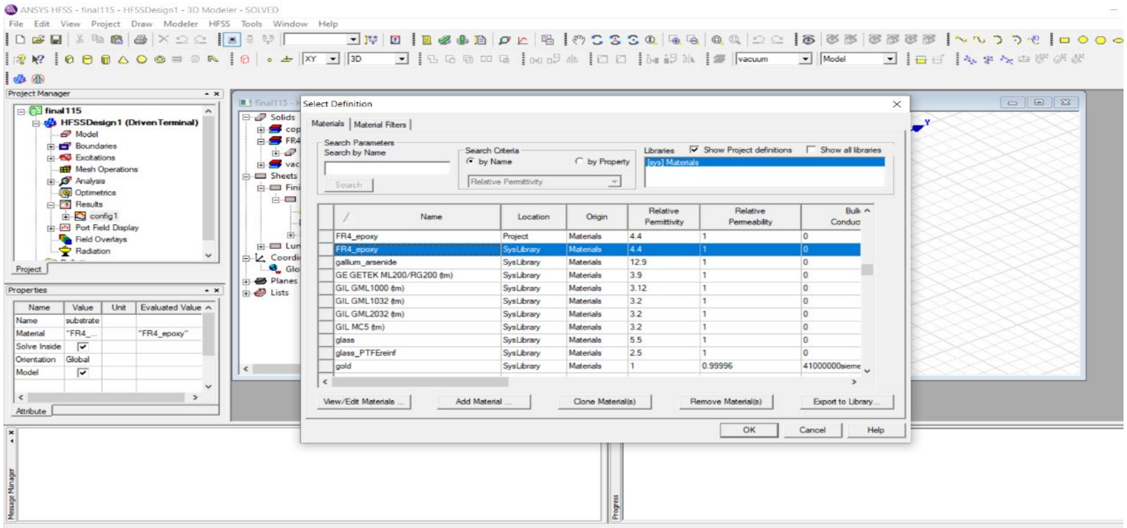


Fig 4.7: Assigning material for substrate

Step14: Now assign the radiation box for the proposed design antenna.

Select HFSS > Excitations > Assign > Radiation.

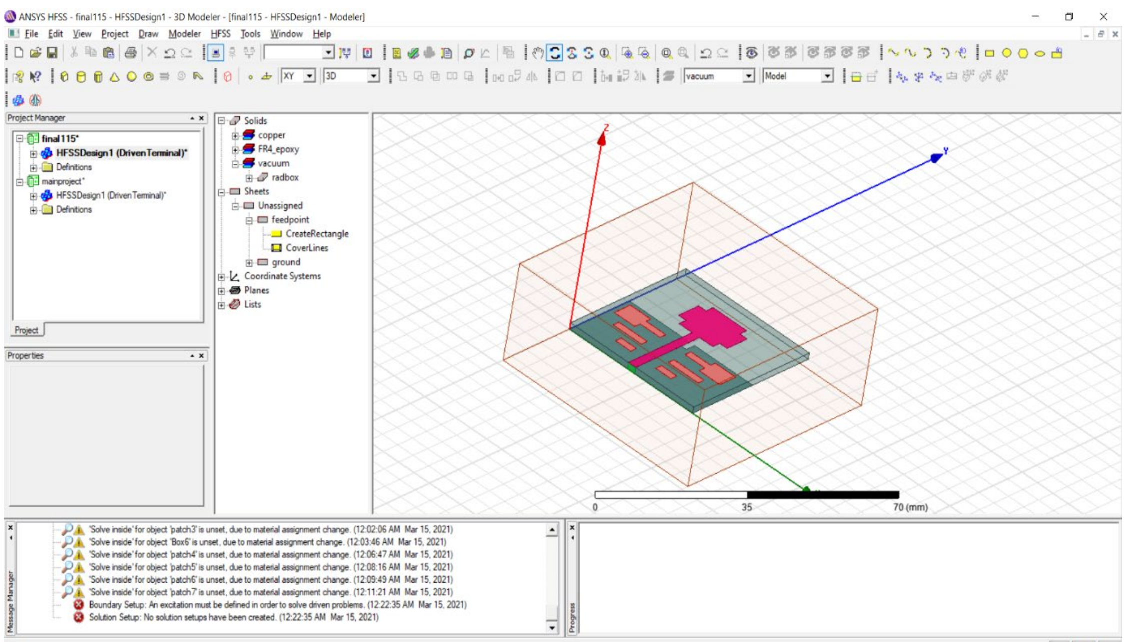


Fig 4.8: Assigning radiation box for designed antenna

Step15: Assign boundary as finite conductivity with copper material for ground.

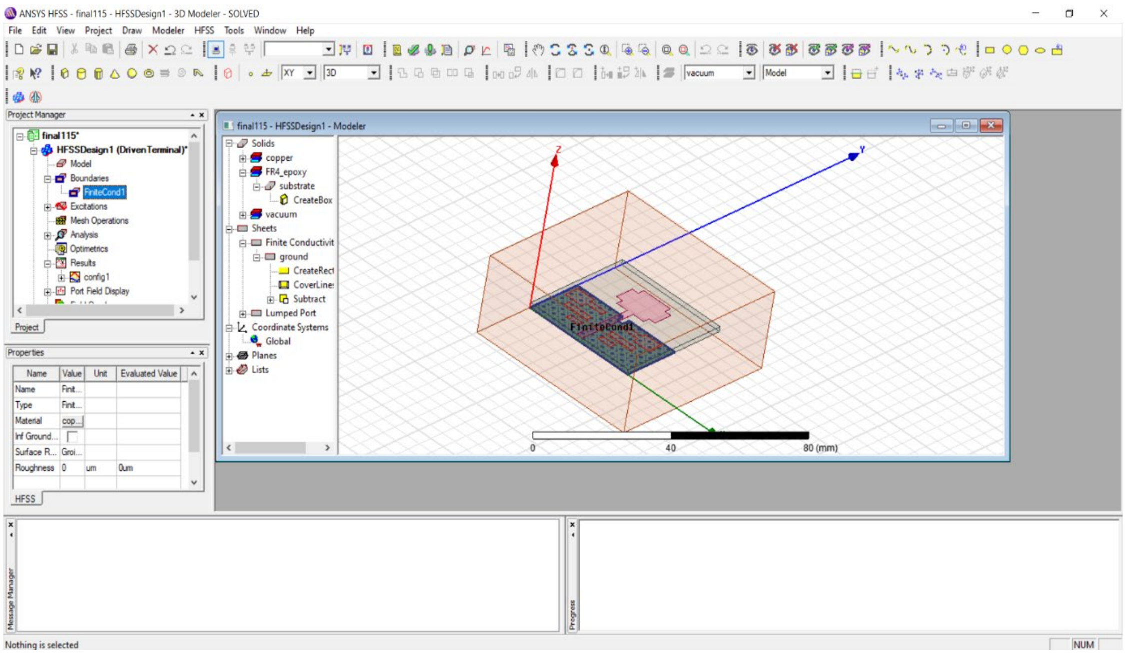


Fig 4.9.1: Assign boundary for ground

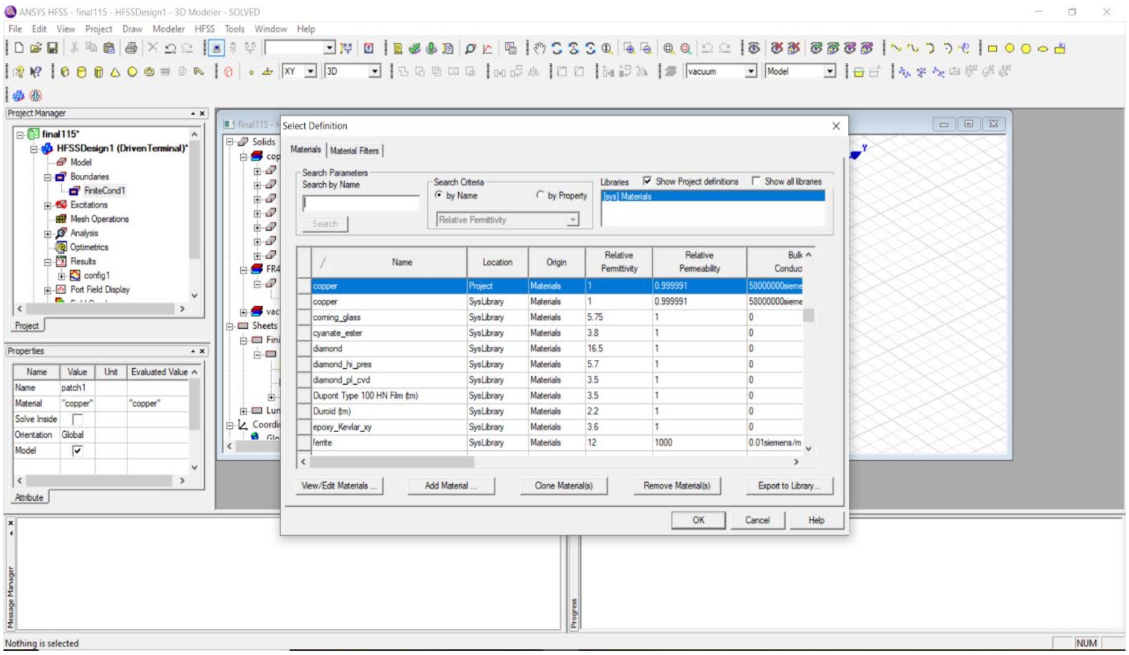


Fig 4.9.2: Assigning material to ground

Step16: To simulate the design antenna, select HFSS> Analysis set up > Add solution set up. A window pops up, in that window define the operating frequency. To specify the start and stop frequency of the plot select HFSS> Analysis set up > Add Frequency Sweep.

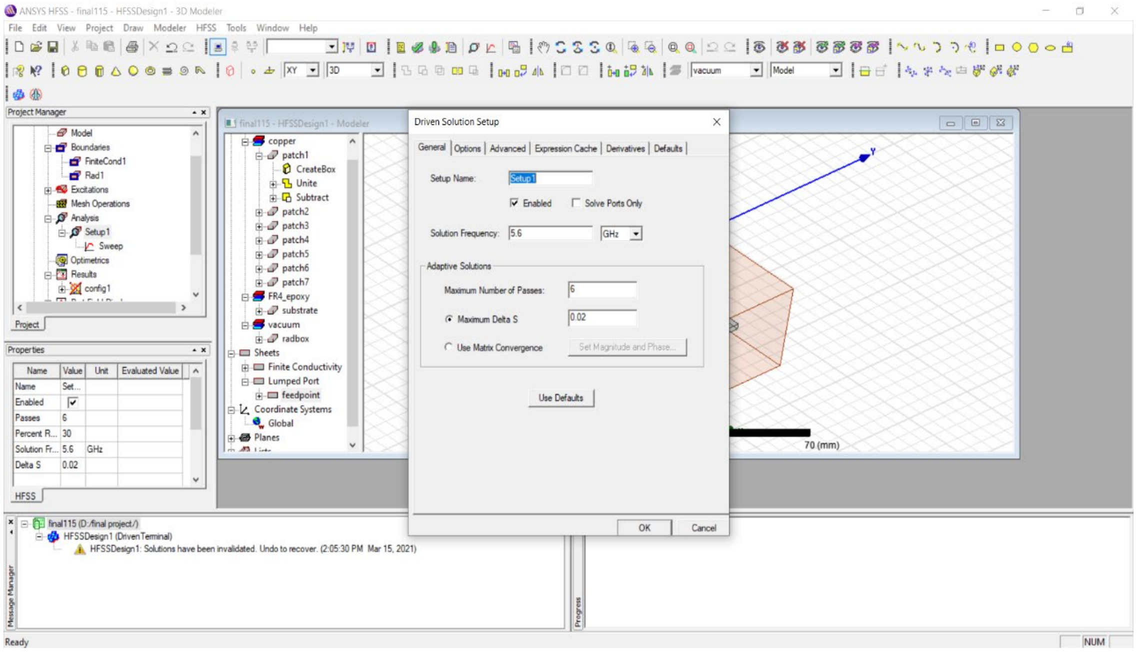


Fig 4.10: After adding solution frequency

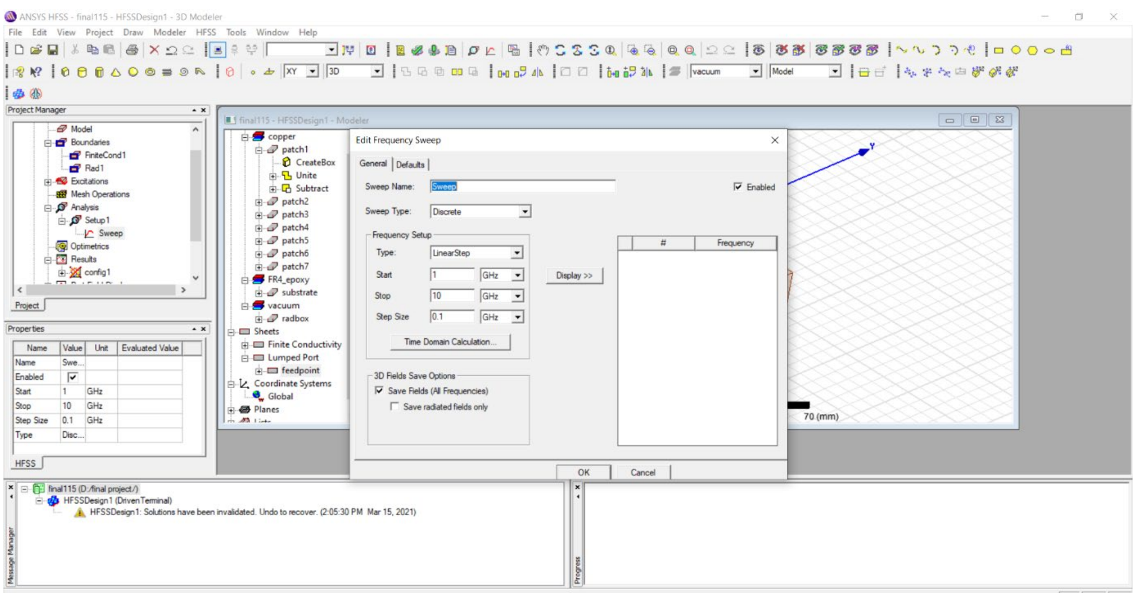


Fig 4.11: Assigning Sweep setup

Step16: To view any errors in the design, click on HFSS > Validation Check and then to analyze the design click on HFSS > Analyze all.

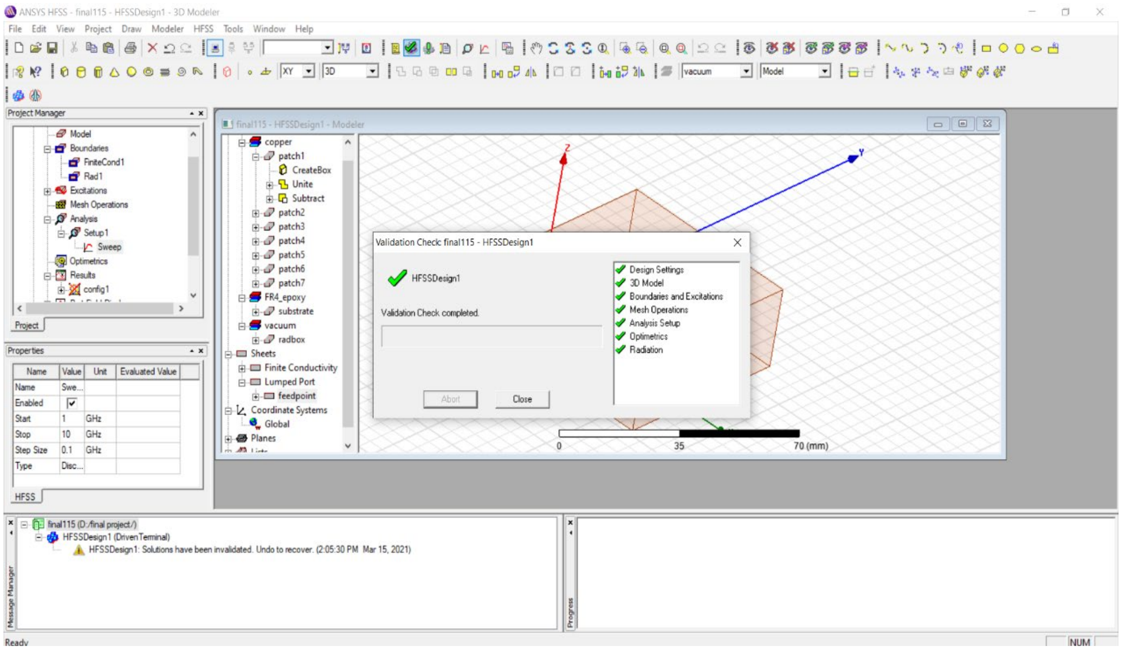


Fig 4.12: Validation check and Simulation

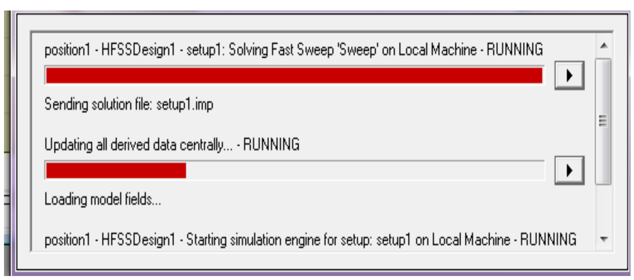


Fig 4.13: Analysis setup

Step17: After completion of the simulation process, the results are observed through select HFSS > Results. These are the results for configuration1 when all switches in OFF condition

Step18: To observe the results for remaining four configurations follow the same above steps and additionally connect the MEMS in between the extended transmission and main feed line as per the configuration ON conditions.

Step19: After optimization, the final design of Switchable microstrip patch antenna is shown in Fig. 5.14 and the dimensions of the antenna is shown in table 5.16.

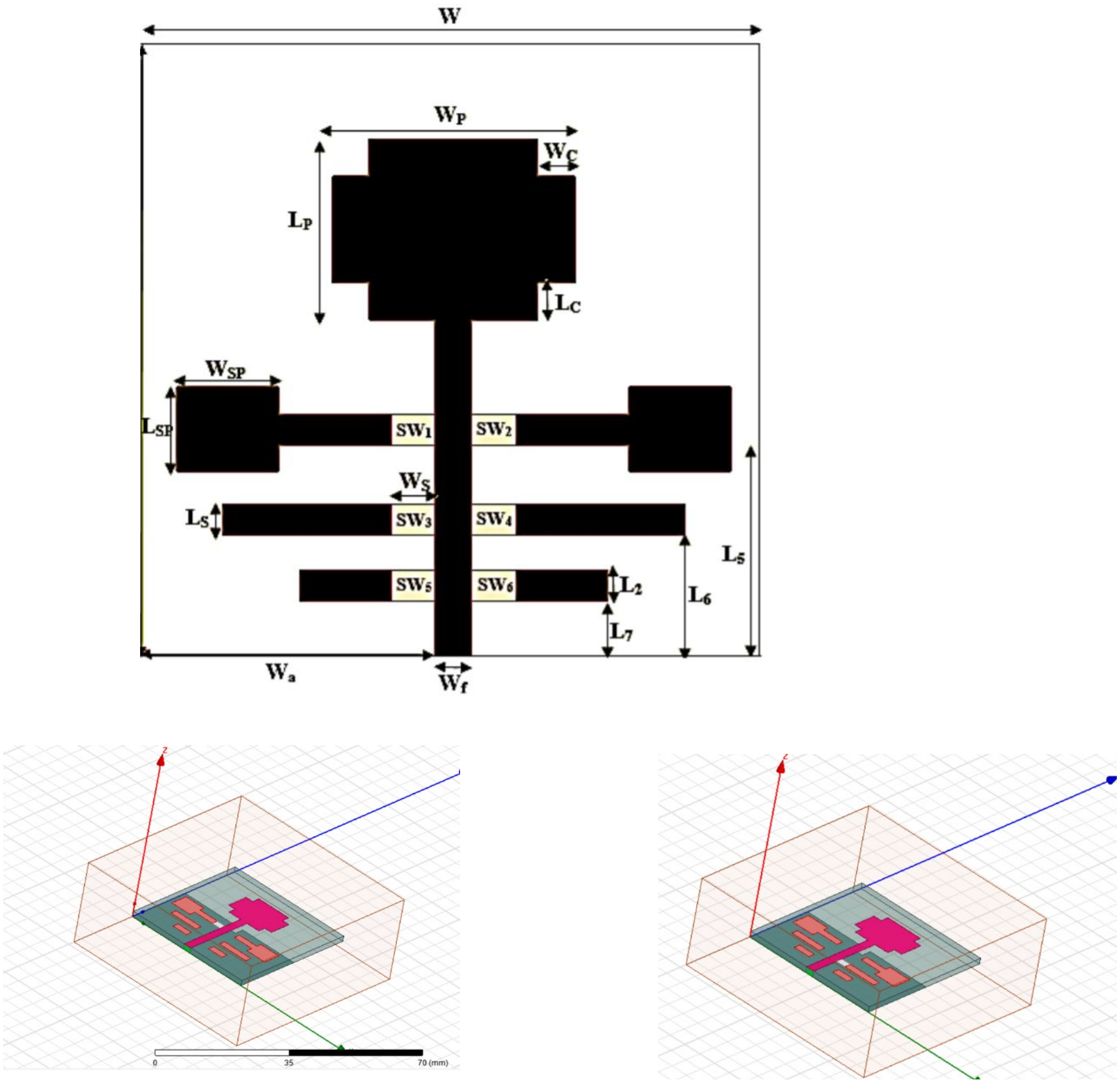


Fig 4.14: Switchable microstrip patch antenna

Fig 4.15.1 config 2 Fig 4.15.2 config 3

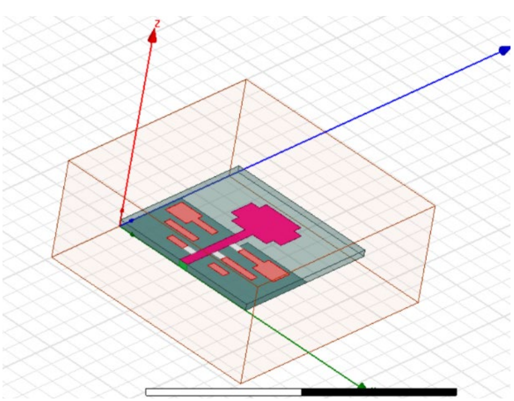
Fig 4.15.3 config 4 Fig 4.15.4 config 5

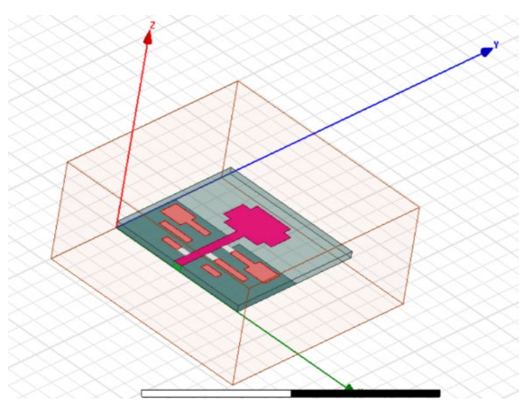
Table 4.1: Switching Configurations

C	SW1	SW2	SW3	SW4	SW5	SW6
C-I	OFF	OFF	OFF	OFF	OFF	OFF
C-II	ON	OFF	OFF	OFF	OFF	OFF
C-III	OFF	OFF	OFF	ON	OFF	OFF
C-IV	OFF	ON	OFF	ON	ON	OFF
C-V	OFF	OFF	OFF	OFF	ON	OFF

Table 4.2: Dimensions of switchable microstrip patch antenna using MEMS.

S. NO	PARAMETER	DESCRIPTION	DIMENSIONS
1	L	Length of the substrate	40.00mm
2	L1	Length of main feed line	22.07mm
3	L2	Length of transmission line 5,6	2.00mm
4	L3	Length of slot cut in ground	2.90mm
5	L4	Length of the ground	20.75mm
6	L5	Length to transmission line 1,2	14.00mm
7	L6	Length to transmission line 3,4	8.16mm
8	L7	Length to transmission line 5,6	3.86mm
9	Ls	Length of transmission lines 3,4	2.00mm
10	Lp	Length of patch 1	11.75mm
11	W	Width of the ground and substrate	40.00mm





12	Wf	Width of main feed line	2.36mm
13	Wc	Width of corner slot	2.40mm
14	Ts	Thickness of substrate	1.6mm
15	Ws	Width of switch	2.90mm
16	Wp	Width of patch 1	15.74mm
17	Wsp	Width of patch 2	6.61mm
18	Lsp	Length of patch 2	5.53mm
19	Lc	Length of corner slot	2.40mm

4.4 RESULTS:

Switchable microstrip patch antenna resonates at a frequency of 3.2-8.6GHz with a return loss of -33.02dB and gain of 1.54dB for configuration1. The design resonates 3.7-6.5GHz with a return loss of -20.1dB and gain of 2.4dB for configuration2, 5.2-8.2GHz frequency, return loss of -19.81dB and gain of 1.4dB for configuration3.For configuration4, this design achieves resonating frequency of 6.8-7.2Ghz, return loss of -23.8dB and gain of 2.505dB and for the last configuration it achieves frequency of 7.8-10GHz, return loss of -22.1dB and gain of 2.4dB.

Return loss (S_{11}) is a measure of how much power is reflected back at the antenna port due to mismatch from the transmission line.

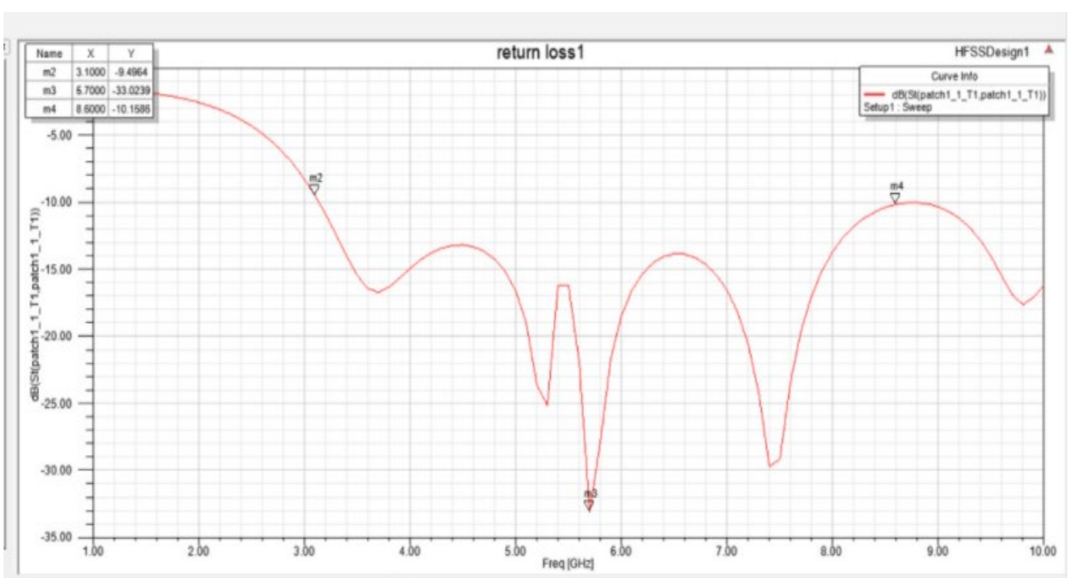


Fig 4.16.1: Return loss of configuration1 (-33.02dB)

Antenna gain is the ability of the antenna to radiate more or less in any direction compared to a theoretical antenna.

Fig 4.16.2: Gain of configuration 1 (1.54dB)

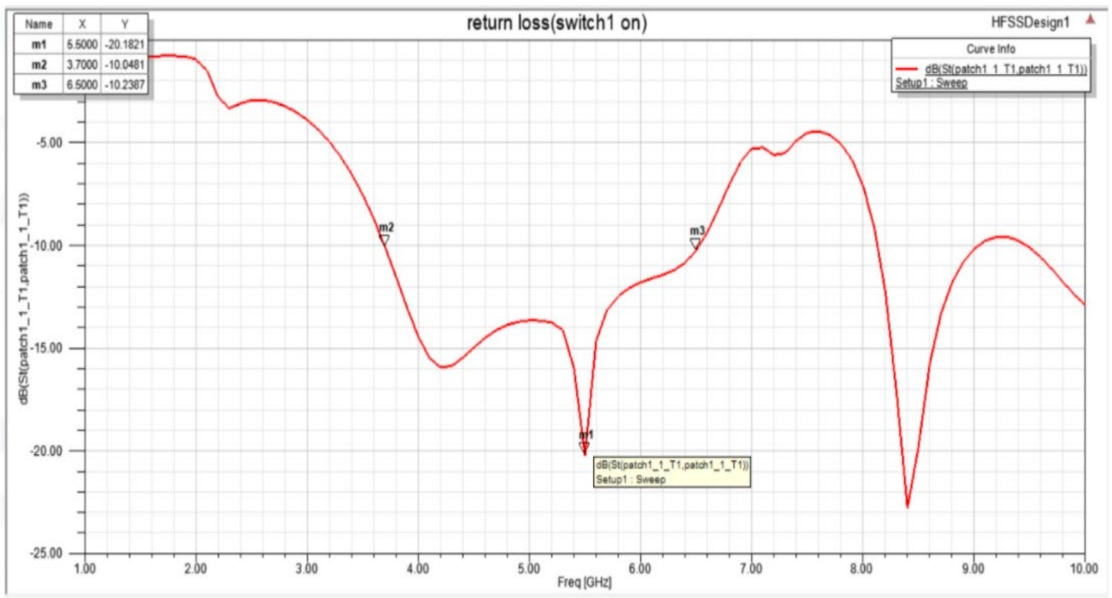
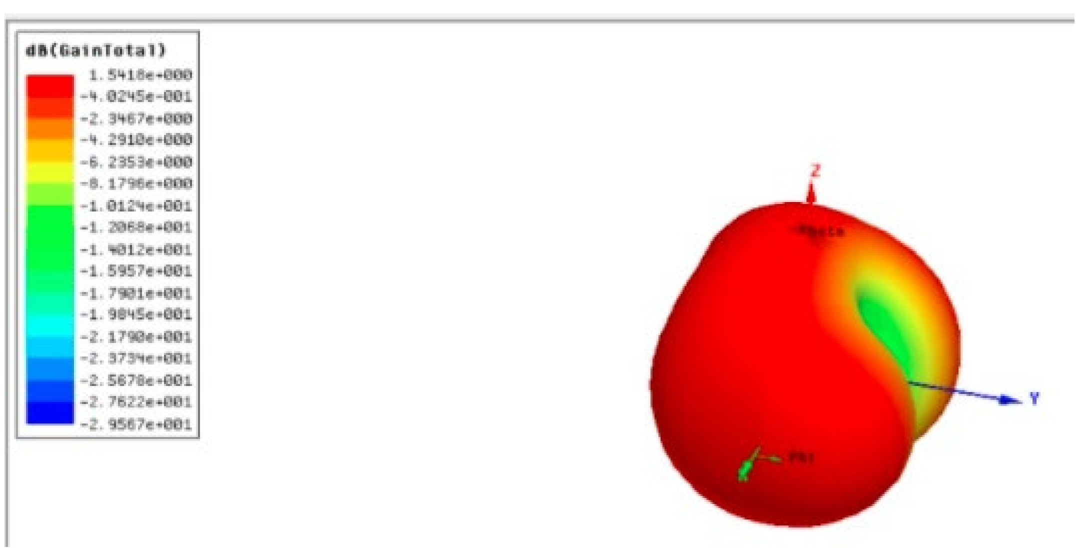


Fig 4.17.1: Return loss of configuration 2 (-20.1dB)



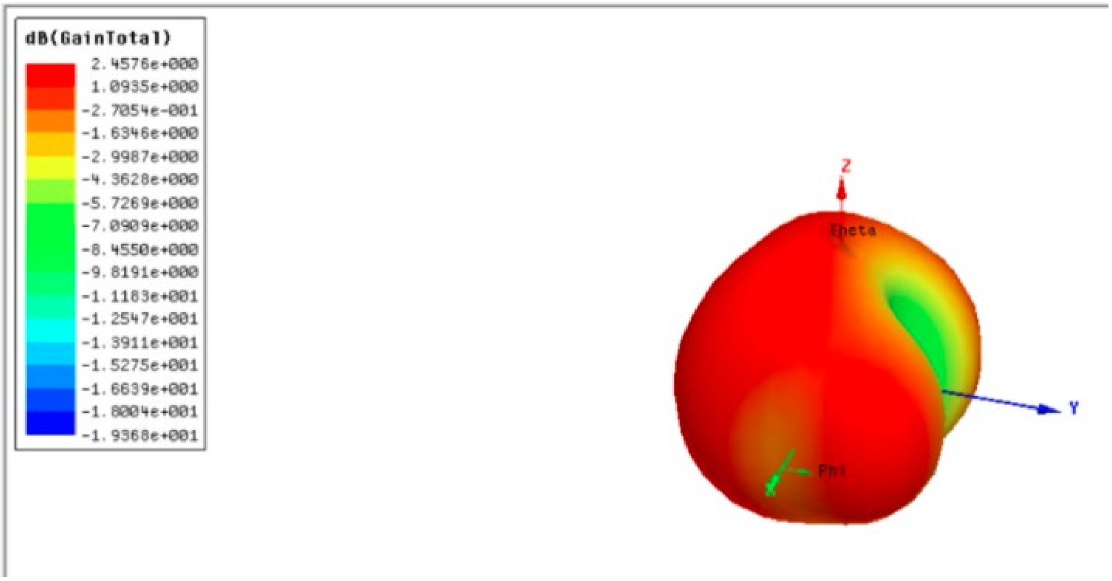


Fig 4.17.2: Gain of configuration2(1.54dB)

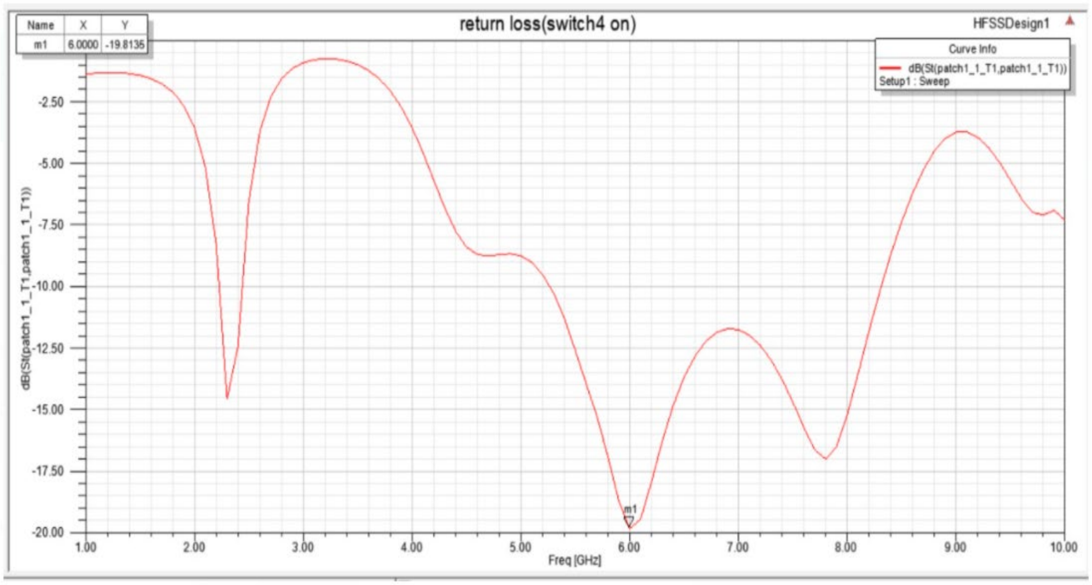


Fig 4.18.1: Return loss of configuration 3 (-19.81dB)

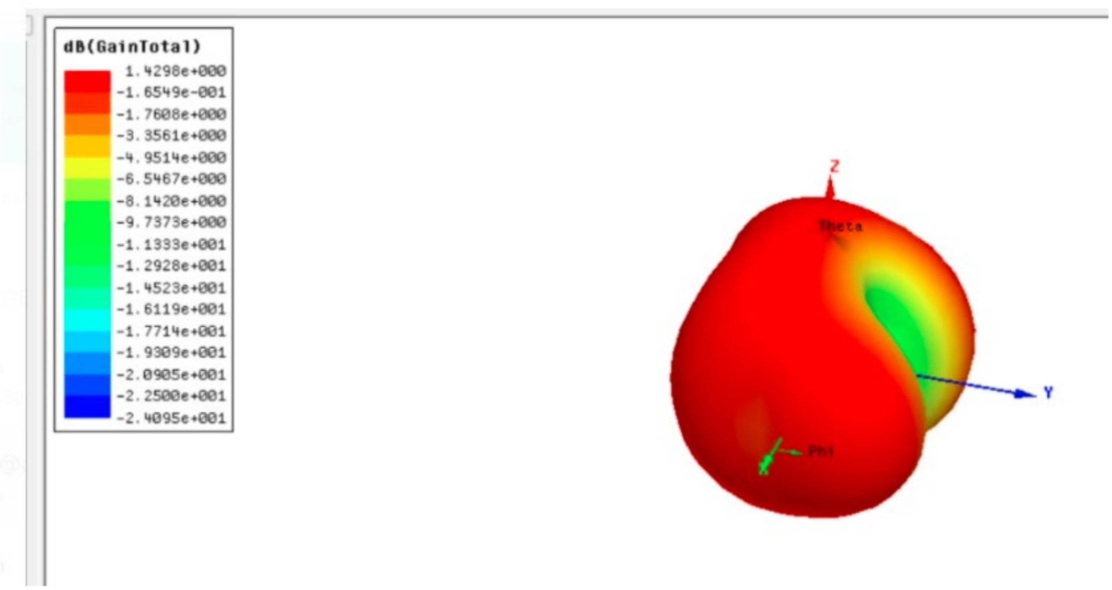


Fig 4.18.2: Gain of configuration 3 (1.4dB)

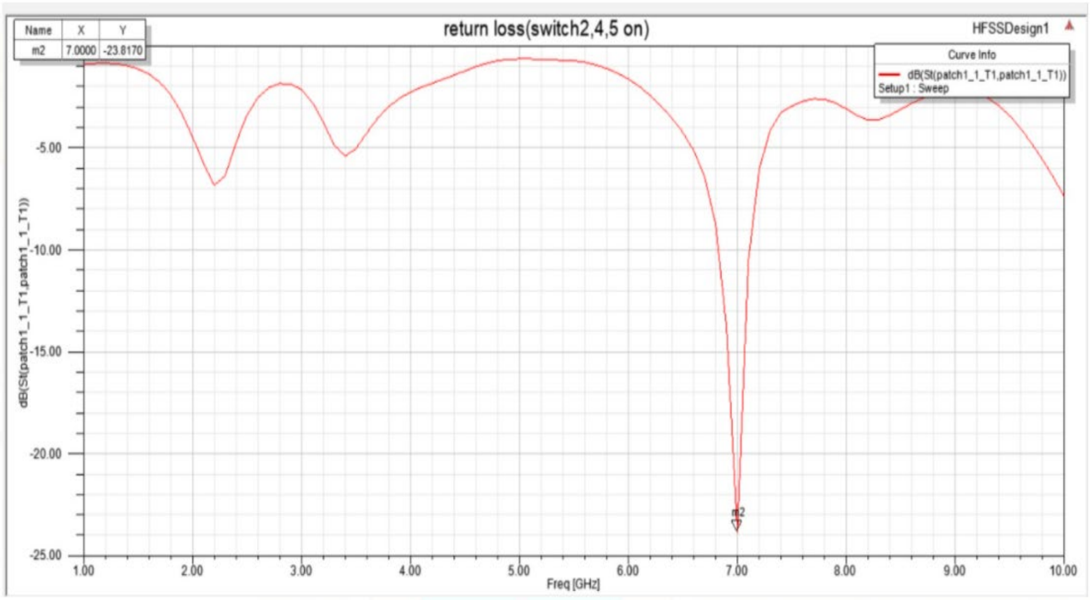


Fig 4.19.1: Return loss of configuration 4(-23.8dB)

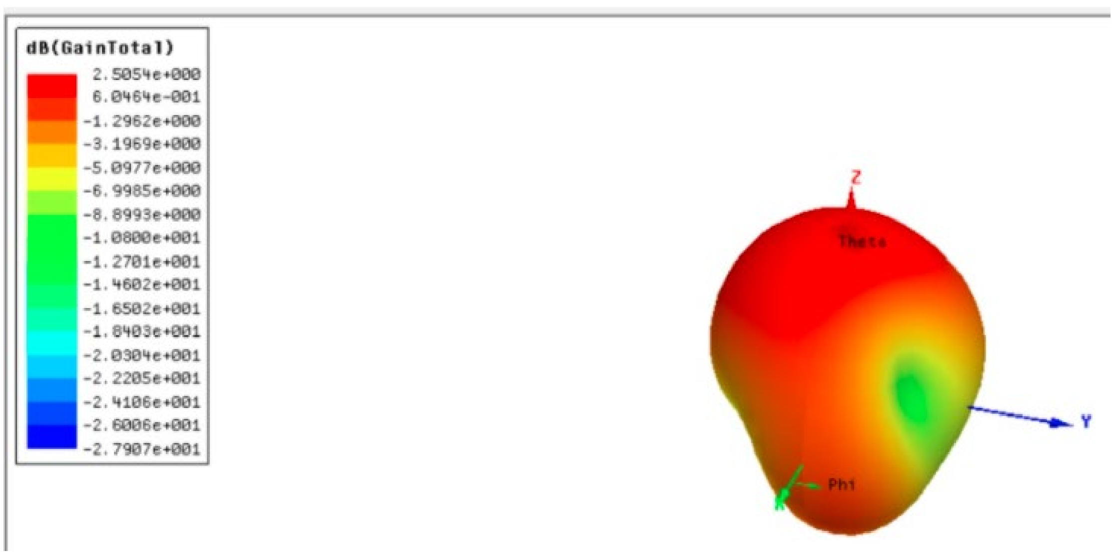


Fig 4.19.2: Gain of configuration 4 (2.505dB)

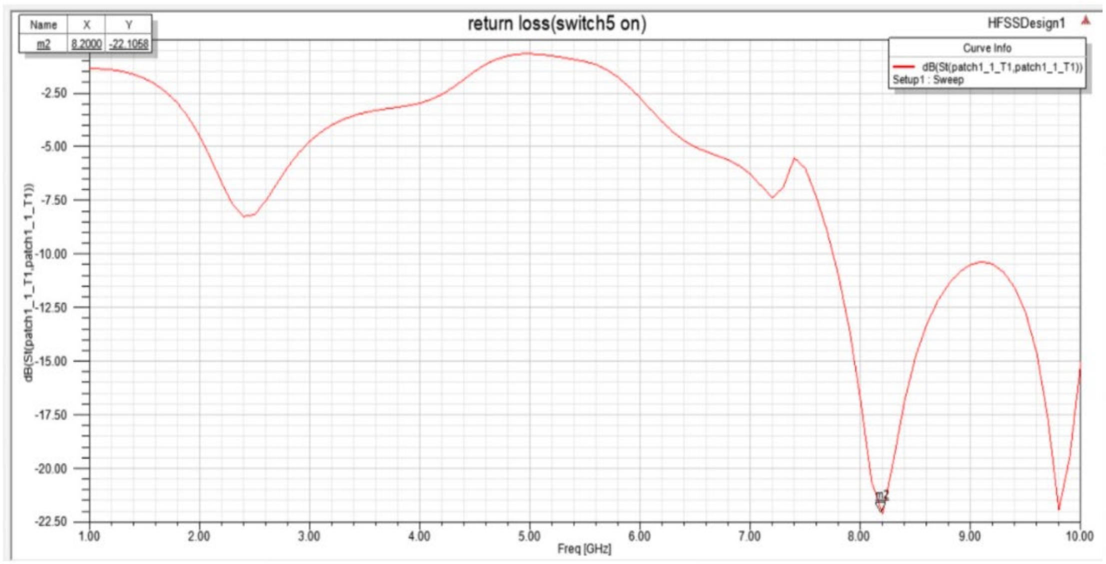


Fig 4.20.1: Return loss of configuration 5 (-22.1dB)

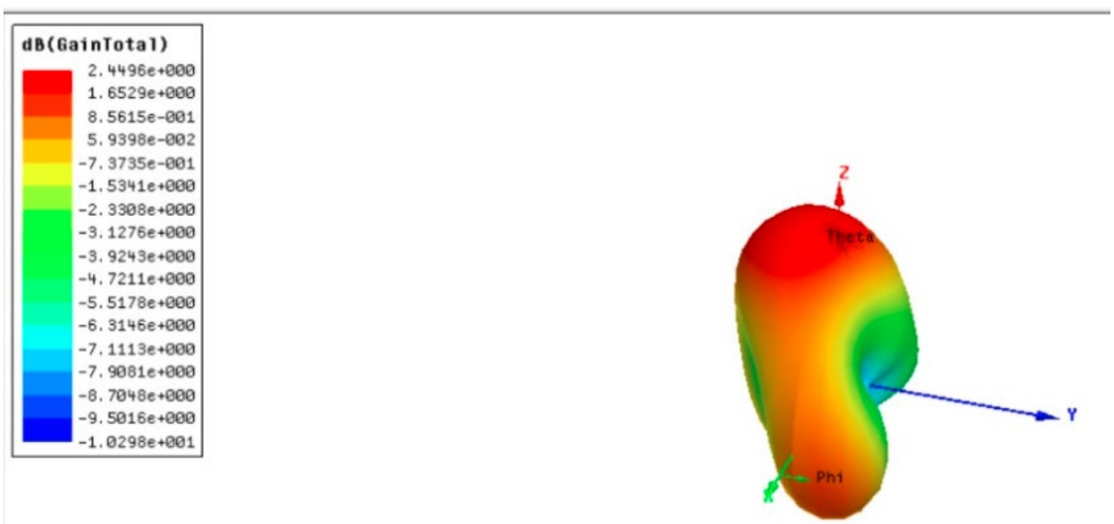


Fig 4.20.2: Gain of configuration 5 (2.4dB)

The results are summarized in the following table.

Table 4.3: Summary of results obtained for the proposed design.

Configurations	Return loss	Gain(dB)	Frequency (GHz)
Configuration-I	-33.02	1.54	3.2-8.6
Configuration-II	-20.1	2.4	3.7-6.5
Configuration-III	-19.81	1.4	5.2-8.2
Configuration-IV	-23.8	2.505	6.8-7.2
Configuration-V	-22.1	2.4	7.8-10

4.5 CONCLUSIONS:

This proposed design reports a reconfigurable antenna that can be reconfigured as a UWB antenna and narrow band antenna. This is achieved by inserting MEMS into the design such that they built the connection and disconnection between the extended transmission line and main feed line. Configuration-I makes the antenna approach for spectrum sensing part of Cognitive Radio, and Configurations II to V allow the antenna to be used for communicating within the UWB spectrum. As configuration I allows the antenna to operate in UWB range (3.2-8.6 GHz) and the remaining four configurations collectively allow the antenna to operate in 3.7-10GHz range. Hence the proposed design can be the good norm to achieve Cognitive radio applications.

5. REFERENCES:

1. Ros Marie C. Cleetus and Gnanadhas Josemin Bala, “Wide-Narrow Switchable Bands Microstrip Antenna for Cognitive Radios,” Progress In Electromagnetics Research C, Vol. 98, 225–238, 2020.

2. Balanis, C.A.(1997). “Antenna theory, analysis and design”. New York:Wiley.

3. Liang, X. L., “Chapter 7: Ultra wideband current status and future trends,” UltraWideband Antenna and Design, 127–152, 2012.

4. Fontana, R., “Recent system applications of short-pulse ultra-wideband (UWB) technology,” IEEE Trans. Microw. Theory Techn., Vol. 52, No. 9, 2087–2104, 2004.

5. Ibrahim, A. A., A. Batmanov, and E. P. Burte, “Design of reconfigurable antenna using RF MEMS switch for cognitive radio applications,” 2017 Progress In Electromagnetics Research Symposium — Spring (PIERS), 369–376, St Petersburg, Russia, May 22–25, 2017.

6. Wu, T., R. L. Li, S. Y. Eom, S. S. Myoung, K. Lim, J. Laskar, and M. M. Tentzeris, “Switchable quad-band antennas for cognitive radio base station applications,” IEEE Trans. Antennas Propag., Vol. 58, No. 5, 1468–1476, 2010