RF & PHOTONICS LABORATORY MANUAL

Subject code: ECC584

Subject name: RF & Photonics Lab

Course: M.Tech

DEPARTMENT OF ELECTRONICS ENGINEERING

General Instructions

Do’s

1. Take observations carefully.

Don’ts

1. While leaving the lab don’t forget to shuntdown the computers.

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PHOTONICS

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RF

Experiment No.- 1

➢ Introduction to HFSS software

HFSS is a high-performance full-wave electromagnetic (EM) field simulator for arbitrary 3D volumetric passive device modeling that takes advantage of the familiar Microsoft Windows graphical user interface. It integrates simulation, visualization, solid modeling, and automation in an easy-to-learn environment where solutions to your 3D EM problems are quickly and accurately obtained. Ansoft HFSS employs the Finite Element Method (FEM), adaptive meshing, and brilliant graphics to give you unparalleled performance and insight to all of your 3D EM problems. Ansoft HFSS can be used to calculate parameters such as S-Parameters, Resonant Frequency, and Fields. Typical uses include:

Package Modeling – BGA, QFP, Flip-Chip
PCB Board Modeling – Power/Ground planes, Mesh Grid Grounds, Backplanes
Silicon/GaAs - Spiral Inductors, Transformers
EMC/EMI – Shield Enclosures, Coupling, Near- or Far-Field Radiation
Antennas/Mobile Communications – Patches, Dipoles, Horns, Conformal Cell Phone Antennas, Quadrafilar Helix, Specific Absorption Rate(SAR), Infinite Arrays, Radar Cross Section(RCS), Frequency Selective Surfaces(FSS)
Connectors – Coax, SFP/XFP, Backplane, Transitions
Waveguide – Filters, Resonators, Transitions, Couplers
Filters – Cavity Filters, Microstrip, Dielectric
HFSS is an interactive simulation system whose basic mesh element is a tetrahedron. This allows you to solve any arbitrary 3D geometry, especially those with complex curves and shapes, in a fraction of the time it would take using other techniques.

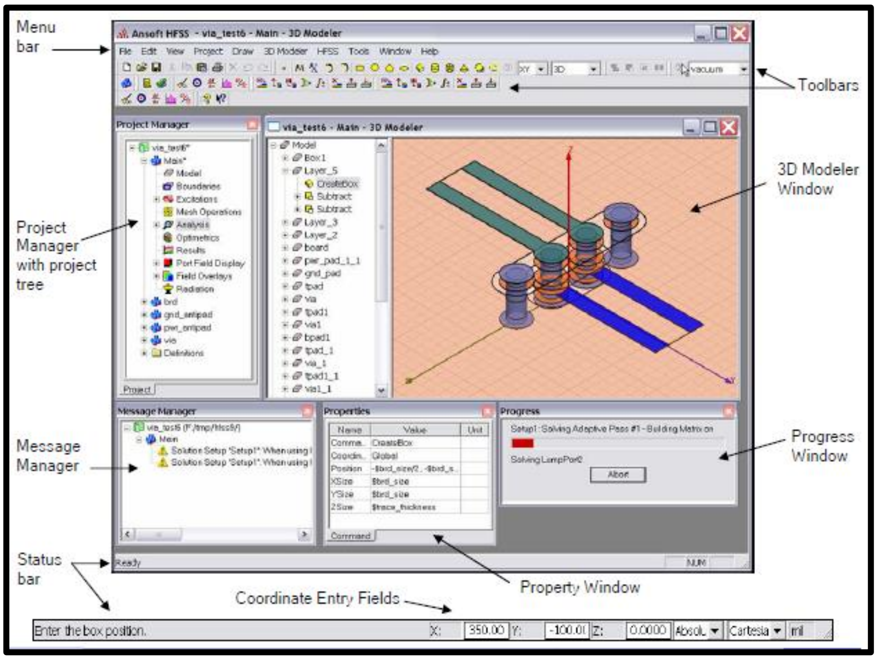
- ✓ The name HFSS stands for High Frequency Structure Simulator. Ansoft pioneered the use of the Finite Element Method (FEM) for EM simulation by developing/implementing technologies such as tangential vector finite elements, adaptive meshing, and Adaptive Lanczos-Pade Sweep(ALPS). Today, HFSS continues to lead the industry with innovations such as Modes-to-Nodes and Full-Wave Spice™.

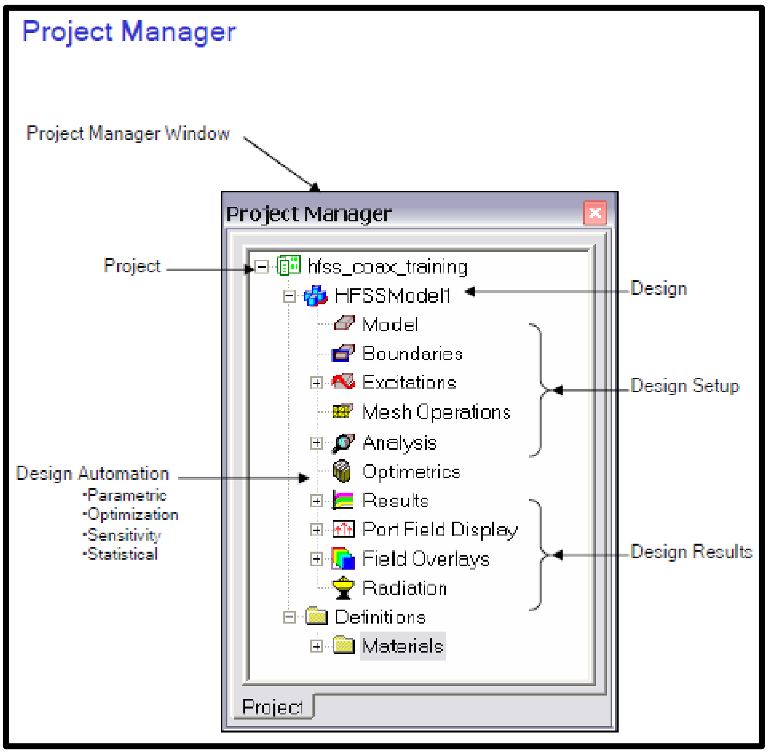
- ✓ Ansoft HFSS has evolved over a period of years with input from many users and industries. In industry, Ansoft HFSS is the tool of choice for high-productivity research, development, and virtual prototyping.

The Ansoft HFSS window has several optional panels:

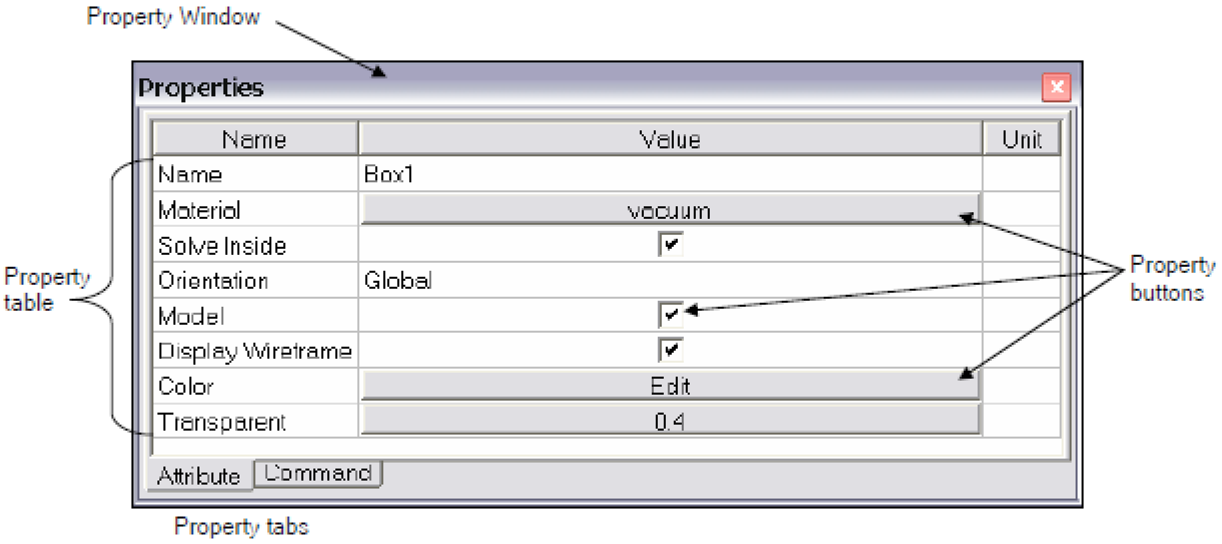
- ✓ A **Project Manager** which contains a design tree which lists the structure of the project.
- ✓ A **Message Manager** that allows you to view any errors or warnings that occur before you begin a simulation.
- ✓ A **Property Window** that displays and allows you to change model parameters or attributes.
- ✓ A **Progress Window** that displays solution progress.
- ✓ A **3D Modeler Window** which contains the model and model tree for the active design.

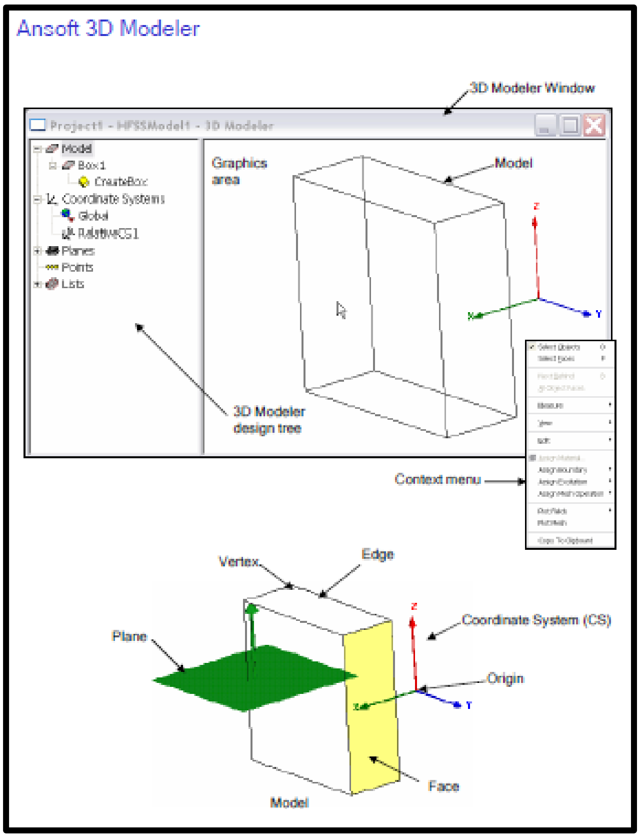
Different windows are shown below:

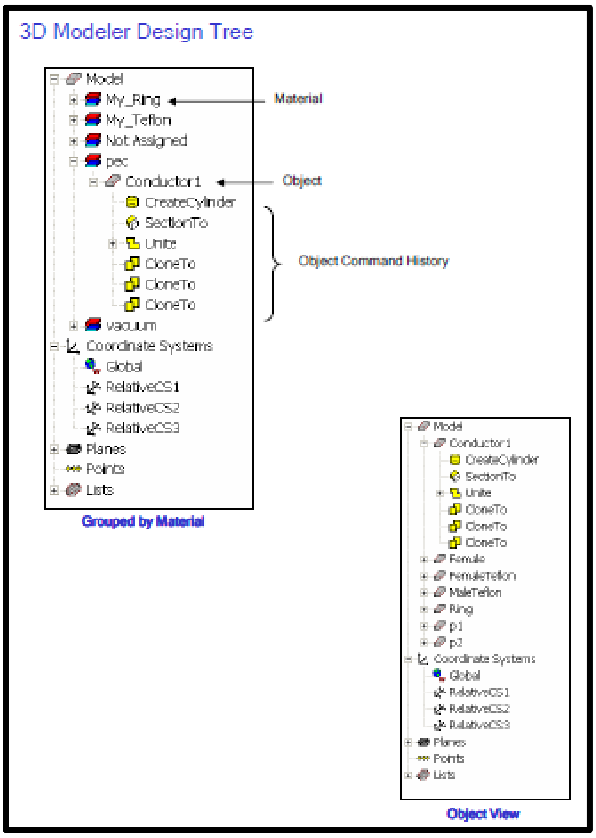




Property Window

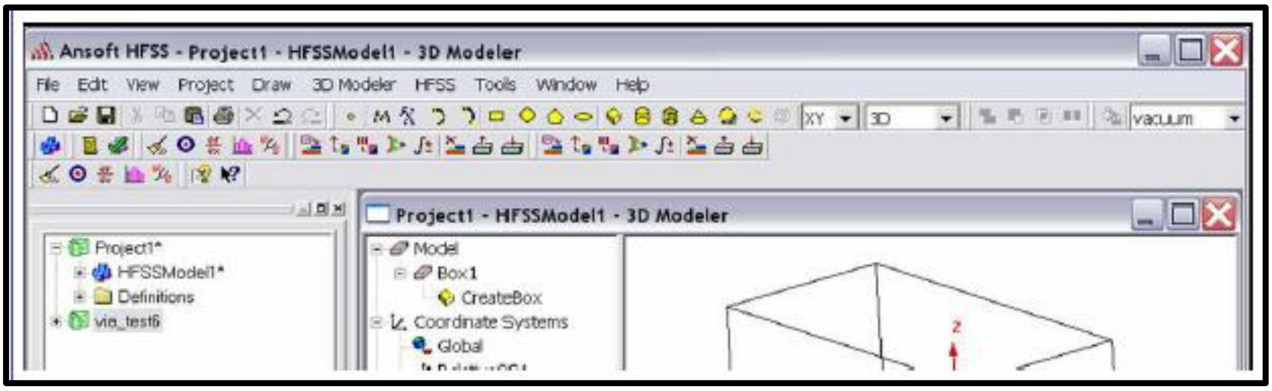






- ✓ The toolbar buttons are shortcuts for frequently used commands. Most of the available toolbars are displayed in this illustration of the Ansoft HFSS initial screen, but your Ansoft HFSS window probably will not be arranged this way. You can customize your toolbar display in a way that is convenient for you.

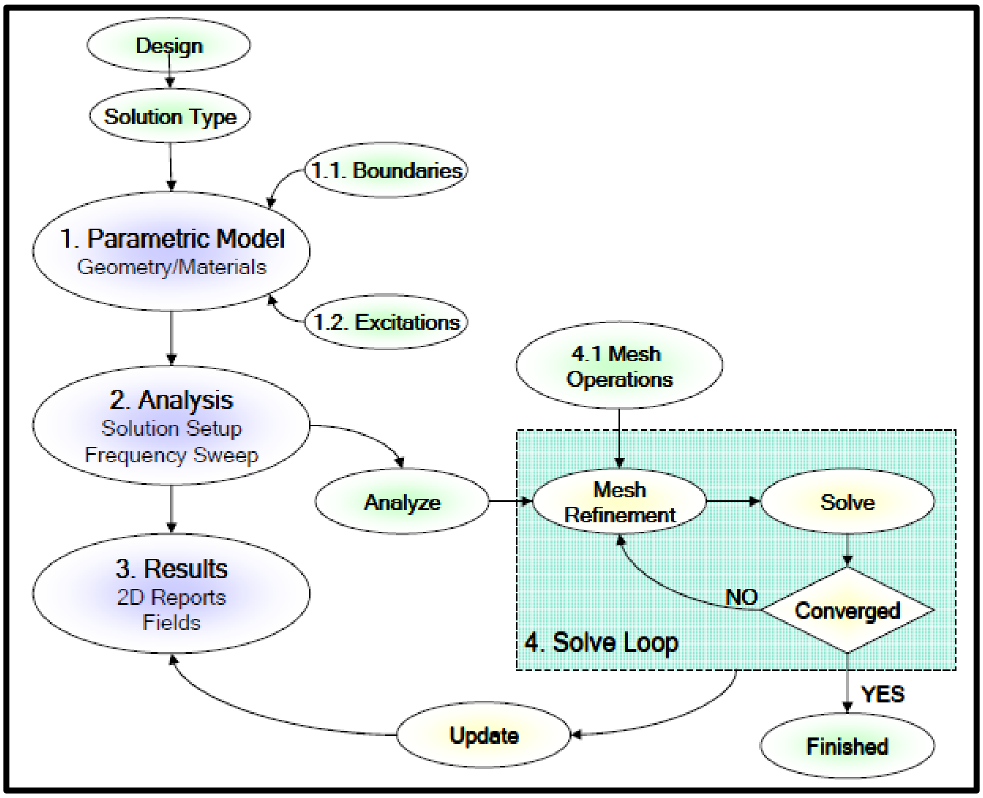
- ✓ Some toolbars are always displayed; other toolbars display automatically when you select a document of the related type. For example, when you select a 2D report from the project tree, the 2D report toolbar displays.



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

1. Parametric Model Generation – creating the geometry, boundaries and excitations
2. Analysis Setup – defining solution setup and frequency sweeps
3. Results – creating 2D reports and field plots
4. Solve Loop - the solution process is fully automated

To understand how these processes co-exist, examine the illustration shown below.



Experiment No. 2

Objective: Design and analysis of microstrip based antenna like patch antenna, fractal antenna, and log periodic antennas.

Software used: HFSS or CST Microwave studio

Theory:

Microstrip antennas are highly demanded antennas in aircraft, satellite and in MMIC designing. They are becoming increasingly useful because they can be printed directly onto a circuit board. It is becoming very widespread within the mobile phone market.

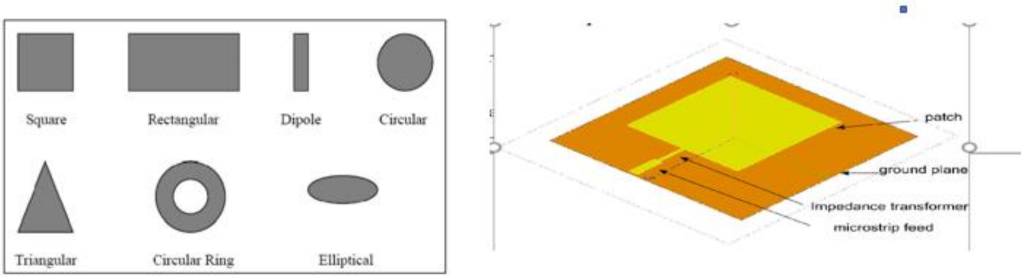
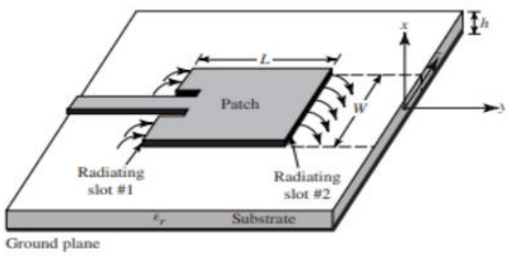


Fig. 1 Different shapes of patch antenna and rectangular microstrip patch antenna

Rectangular Patch Antenna:

It was Invented by Bob Munson in 1972 (but earlier work by Dechamps goes back to1953) and became popular starting in the 1970s. The patch comes in different shapes like rectangular, square, circular, elliptical. But rectangular and circular are the most common. Rectangular Microstrip antenna has a patch which is on one side of the dielectric substrate and ground plane on the other side of the dielectric substrate. So, these microstrip antennas are quite small in size. The ground conductor should also be of good conducting material. The rectangular micro strip antennas can have several physical parameters than an ordinary conventional antenna. The parameters for rectangular micro strip patch antenna like resonant frequency, dielectric material and height of the dielectric material should be chosen properly for an effective radiation. Micro strip antennas are basically separated from the ground plane with dielectric substrate of suitable thickness and printed on a very thin film. Rectangular microstrip has two degrees of freedom, i.e., patch length and width.



(a) Microstrip antenna

Fig. 1

Radiation mechanism of Rectangular Microstrip Patch Antenna:

The rectangular patch acts approximately as a resonant cavity (with short-circuit walls on top and bottom, open-circuit (PMC) walls on the edges). In cavity, after excitation strong field is set up. The fringing fields around the antenna is responsible for radiation. Also known as voltage radiator. To increase fringing effect or radiation:

- Low Er
- H should be high
- W should be high

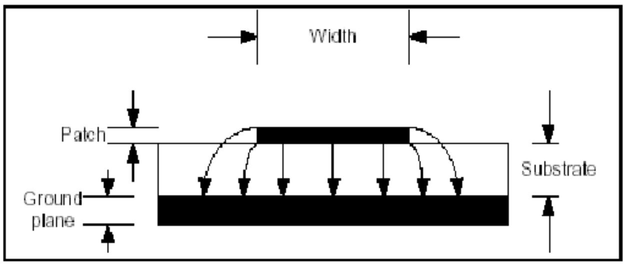


Fig. 2 Fringing fields of patch antenna

Advantages of microstrip patch antenna:

- Light weight and low volume.
- Low profile configuration.
- Easy for fabrication.
- Can be easily integrated with microwave integrated circuits.
- Supports both linear as well as circular polarization.
- Capable of dual and triple frequency operations.
- Mechanically robust when mounted on rigid surfaces.

Disadvantages:

- Narrow Bandwidth.
- Low efficiency.
- Low gain.
- Unwanted radiations from feeds and junctions.
- Low power handling capacity.
- Surface wave excitation.
- Poor end fire radiator.

Feeding Techniques:

1. Micro strip feed lines: It is a conducting strip having much smaller width as compared to patch. They are easy to fabricate but has a limitation to bandwidth due to surface waves.
2. Coaxial linefeed: Inner conductor of coaxial in connected to patch while outer conductor is connected to ground plane. It is also easy to fabricate. However, it is difficult to model for thick substrate.

3. Aperture coupled feed: Aperture coupling consists of two substrates separated by a ground plane. Upper dielectric has low dielectric constant while lower one has very high dielectric constant. There is also a slot on the patch which is used for matching.
4. Proximity coupling: It has the largest bandwidth and low spurious radiation but the designing is most difficult.

Applications:

- Satellite communications.
- Microwave communications.
- Cell phone antennas.
- GPS antennas.
- Integrated phased array system.
- Remote sensing.
- Non-satellite-based applications: such as medical hyperthermia.

Log Periodic Antenna:

It is a multi-element, directional antenna designed to operate over a wide band of frequencies. Impedance and radiation characteristics are repetitive as a logarithmic function of excitation frequency. The lengths and spacings of the elements of a log-periodic antenna increase logarithmically from one end to other. It has higher bandwidth and moderate directivity.

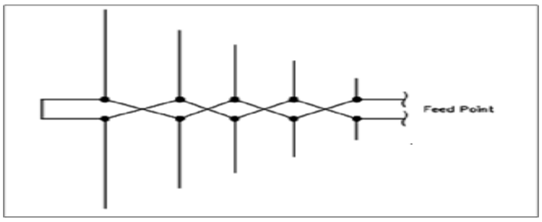


Fig. 3 Log periodic antenna

The lengths and separations are related by the formula:

$$\frac{1}{\tau} = \frac{\iota_{n+1}}{\iota_n} = \frac{\mathcal{R}_{n+1}}{\mathcal{R}_n} = \frac{d_{n+1}}{d_n} = \frac{\mathcal{S}_{n+1}}{\mathcal{S}_n}$$

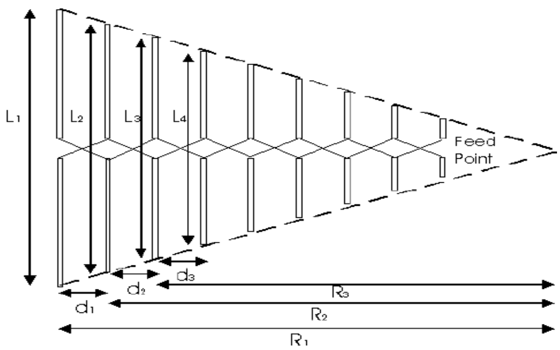


Fig. 4 Logarithmic distribution

Advantages:

- The antenna design is compact.
- Gain and radiation pattern are varied according to the requirements.

Disadvantages:

- External mount.
- Installation cost is high.

Fractal Antenna:

The word fractal means broken or irregular fragments and never-ending pattern. They are formed by repetition of single pattern over and over in ongoing feedback loop. In fractal geometry, the original object is sub-divided into several individual parts where each part is very similar to the original one. This property is called as self-similar property which is occurring at various stages of magnification. Fractal geometries are considered as the complex geometric shapes with self-similarity, self-scaling properties make them a suitable candidate in miniaturized antenna designs.

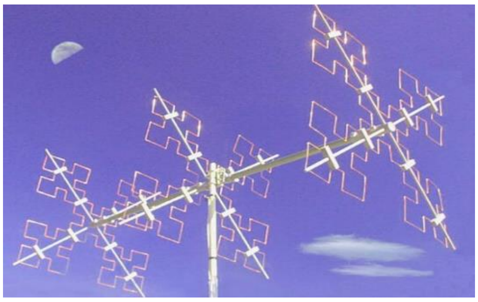


Fig. 5 Fractal Antenna

Applications:

- Fractal Antenna Multiband/ Miniaturization.
- Fractal Encoding in Communication.
- Impedance Transformer.
- Artificial Life (Computer Graphics).
- Fractal Radio and Fractal Radar Concept.
- In design of frequency selective surfaces (FSS).
- Biological Sciences i.e., to analyse biomedical phenomenon like bacteria growth pattern, pattern of nerve dendrites etc.

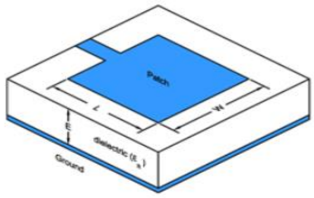
Design Problem:

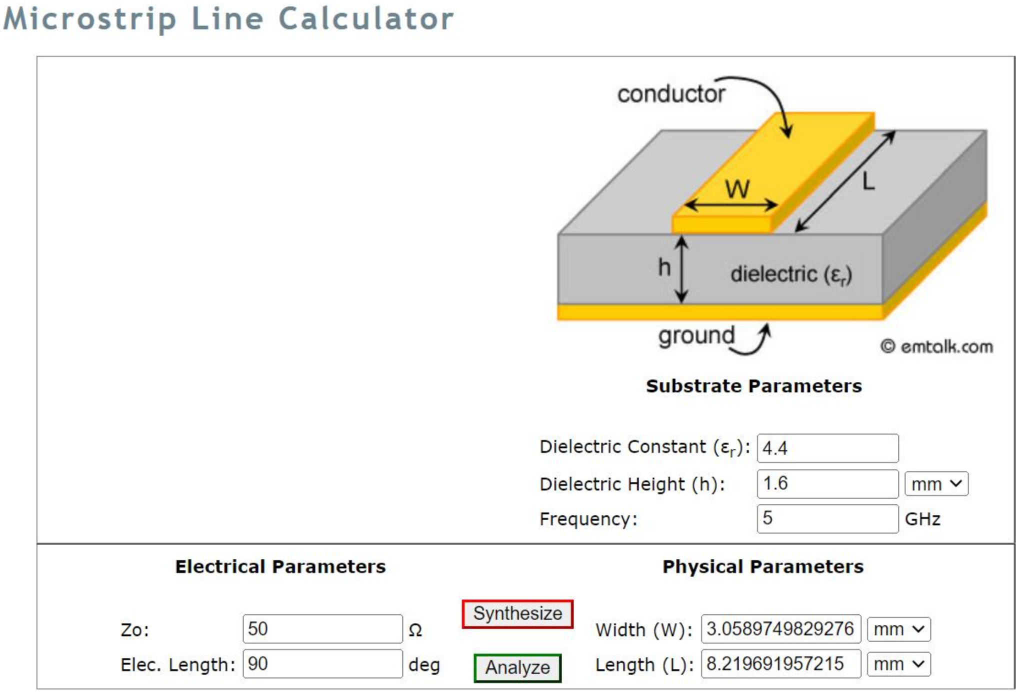
- To design and analyse a rectangular microstrip patch antenna for 5GHz centre frequency using HFSS software.

Calculation:

$$Width = \frac{c}{2f_o\sqrt{\frac{\varepsilon_R+1}{2}}}; \quad \varepsilon_{eff} = \frac{\varepsilon_R+1}{2} + \frac{\varepsilon_R-1}{2}\left[\frac{1}{\sqrt{1+12\left(\frac{h}{W}\right)}}\right]$$

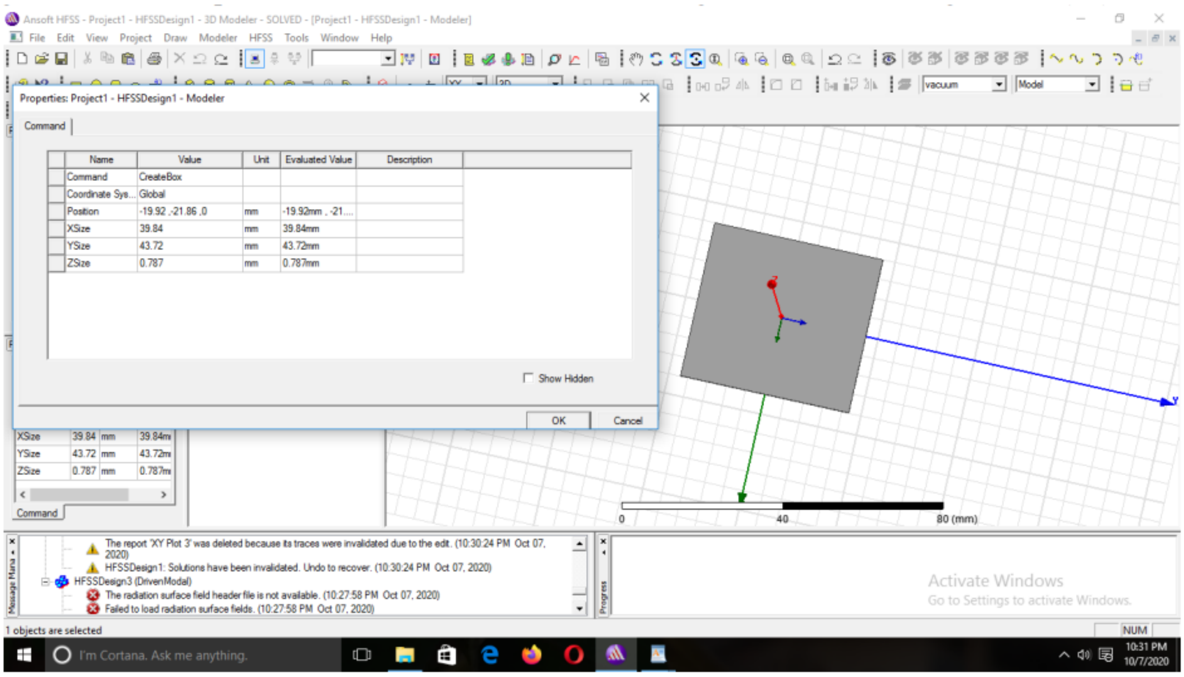
$$Length = \frac{c}{2f_o\sqrt{\varepsilon_{eff}}} - 0.824h\left(\frac{(\varepsilon_{eff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{eff}-0.258)\left(\frac{W}{h}+0.8\right)}\right)$$



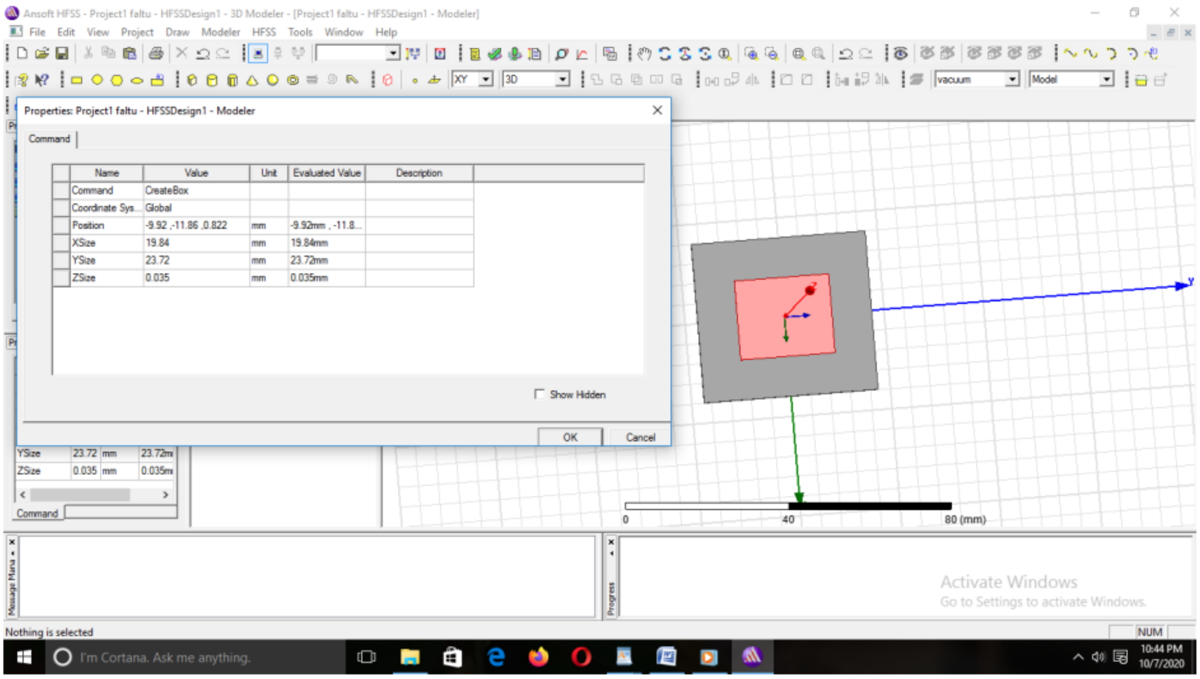


Procedure for Simulation:

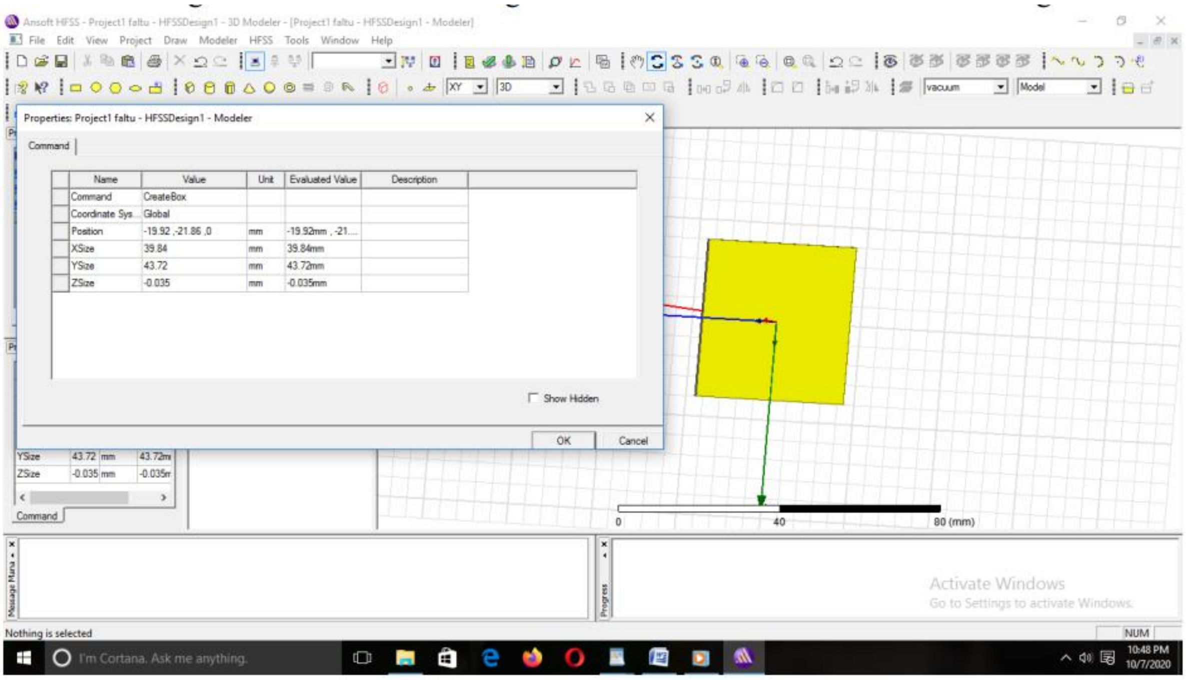
1. Open the HFSS software and click new option from the menu. A white 3-dimensional space is opened where we can design the structure.
2. Draw the 3D substrate (on which antenna is fabricated) using draw box with dimension given in the clip. Then select the substrate to assign material i.e., roger 5880(tm).



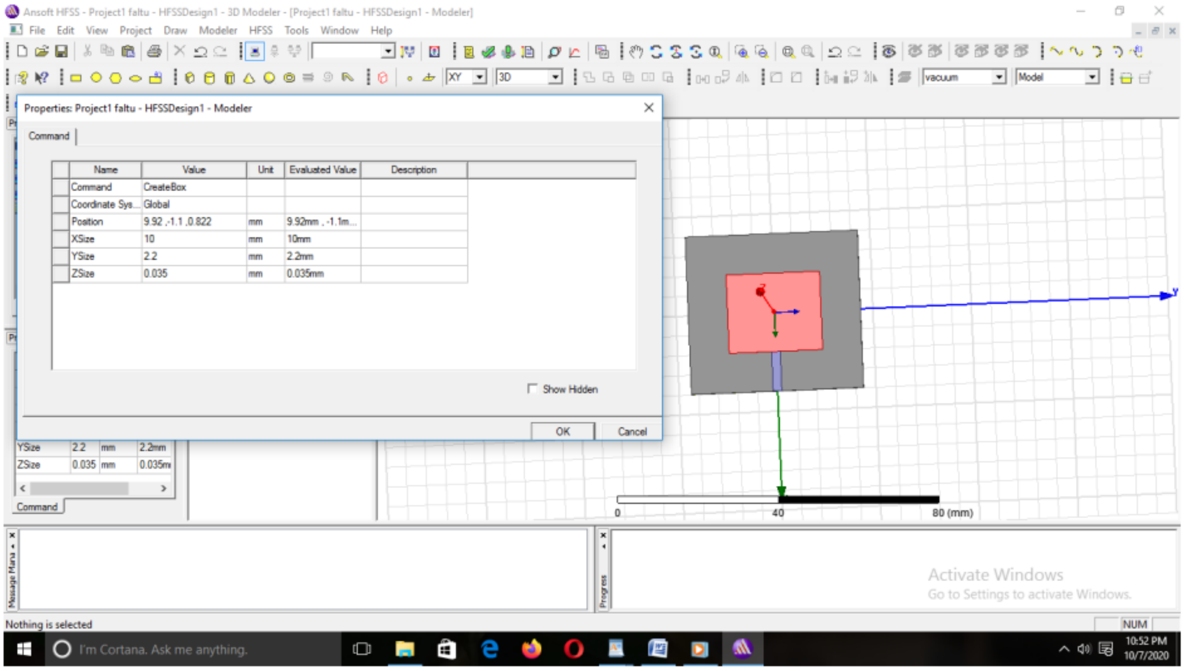
3. Draw a patch by choosing 3D box icon above of the following dimension. Then by selecting Patch assign the material PEC.



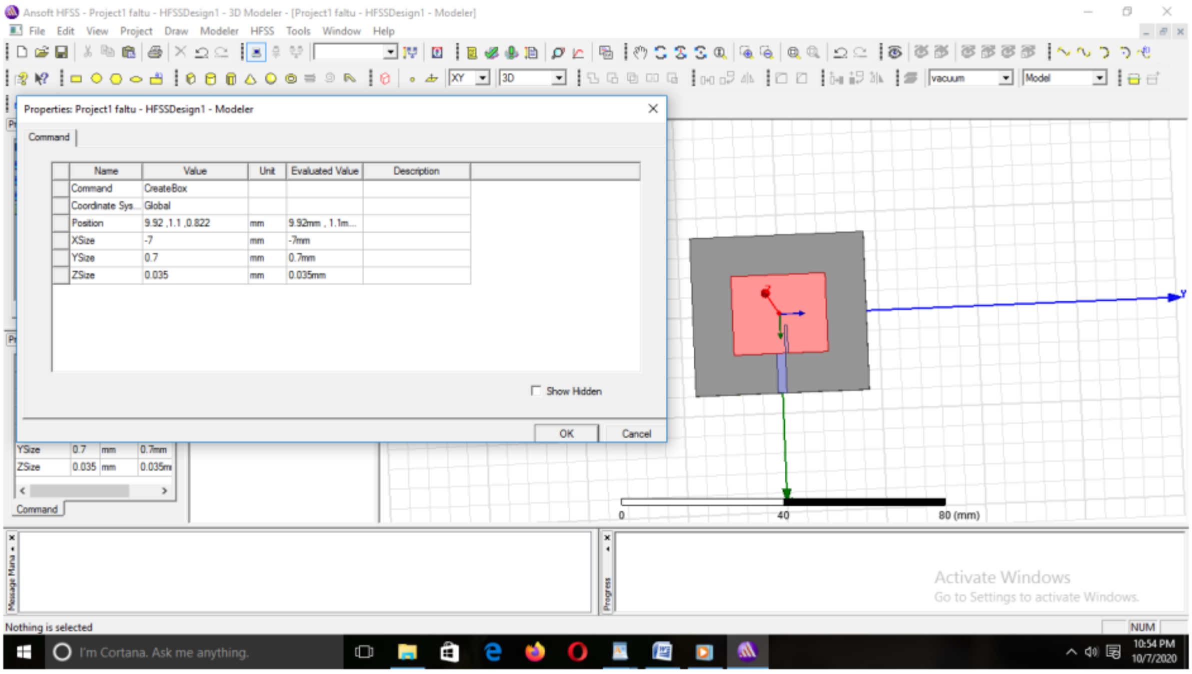
4. Draw a ground surface by making a 3D box over substrate of the same dimension as of substrate. The ground surface is also assigned PEC material and is traced as following.



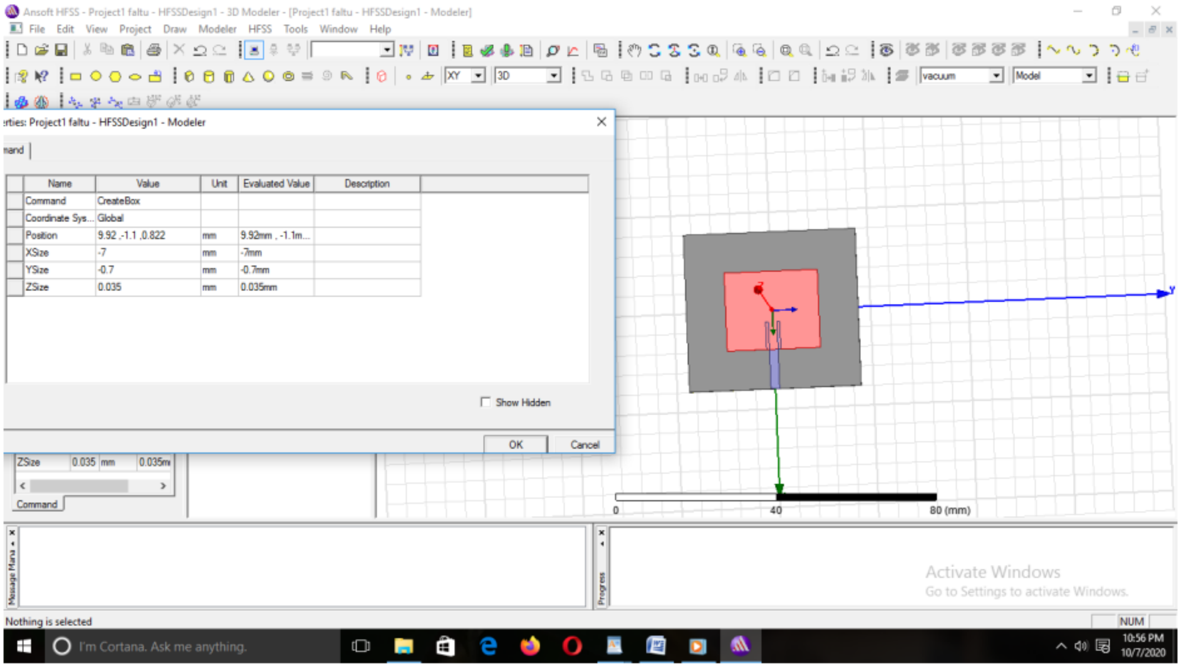
5. Draw a microstrip feed line by selecting 3 D box tool from menu of the following dimension and by selecting it assign PEC material.



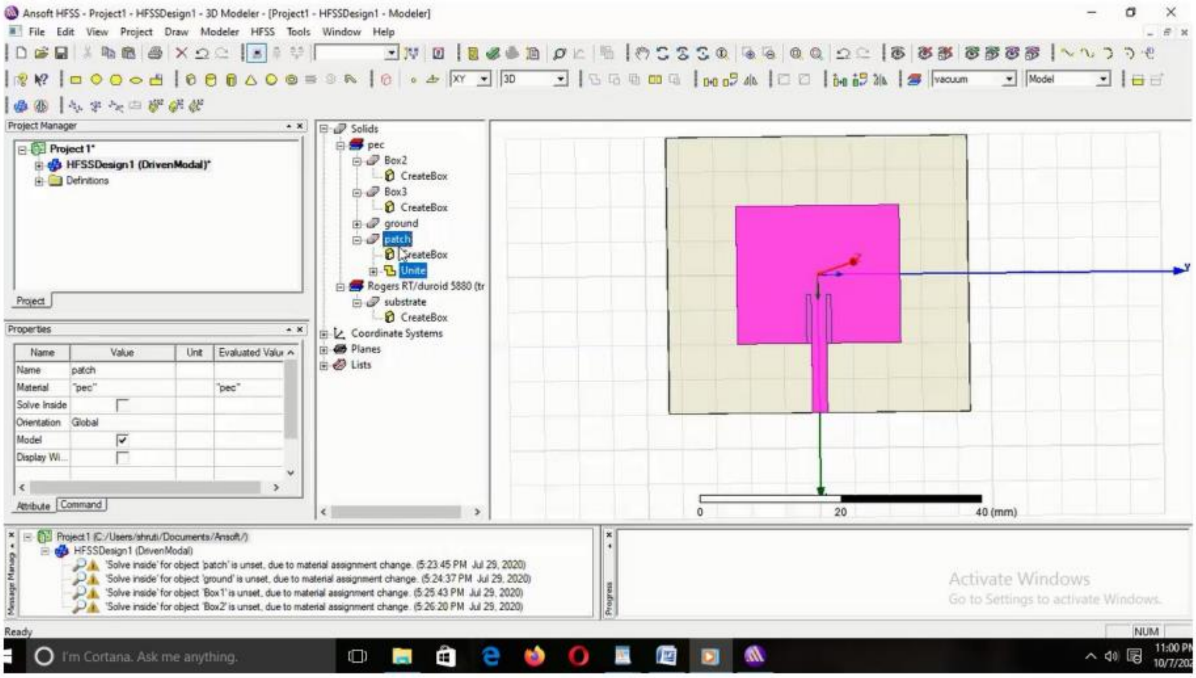
6. Draw slot 1 by choosing 3 D box option of the following dimension and assigning the material PEC.



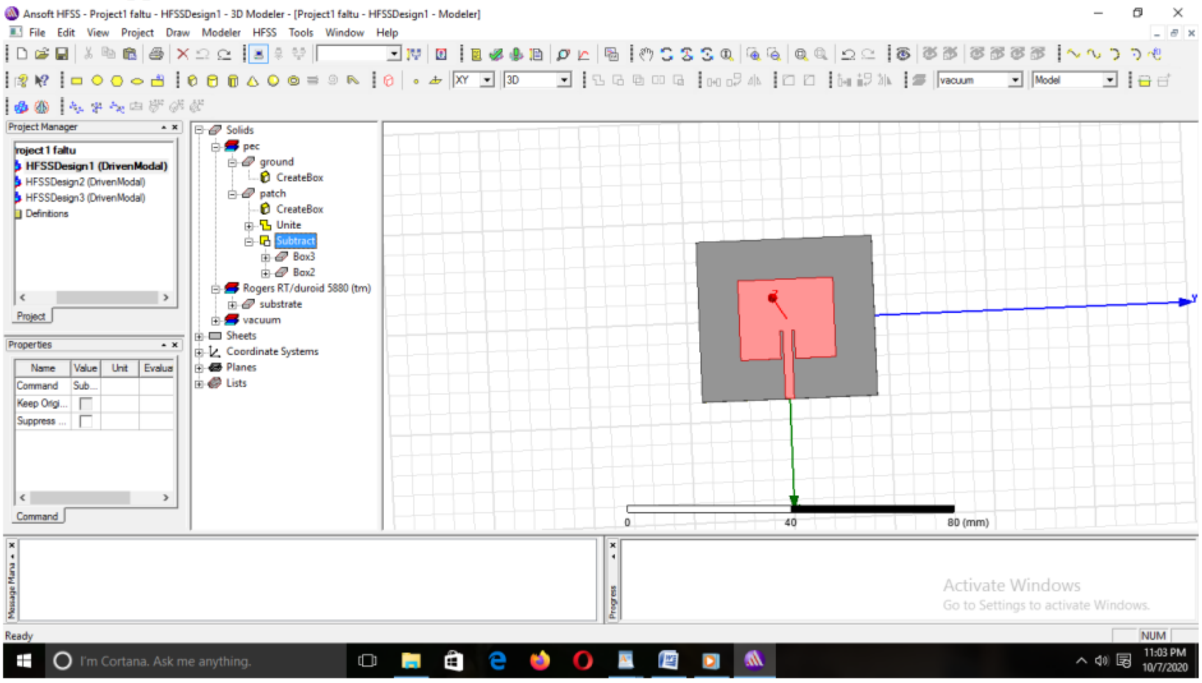
7. Draw slot 2 by choosing 3D box option of following dimension aligned as same as that of slot1. It is also assigned the material of PEC.



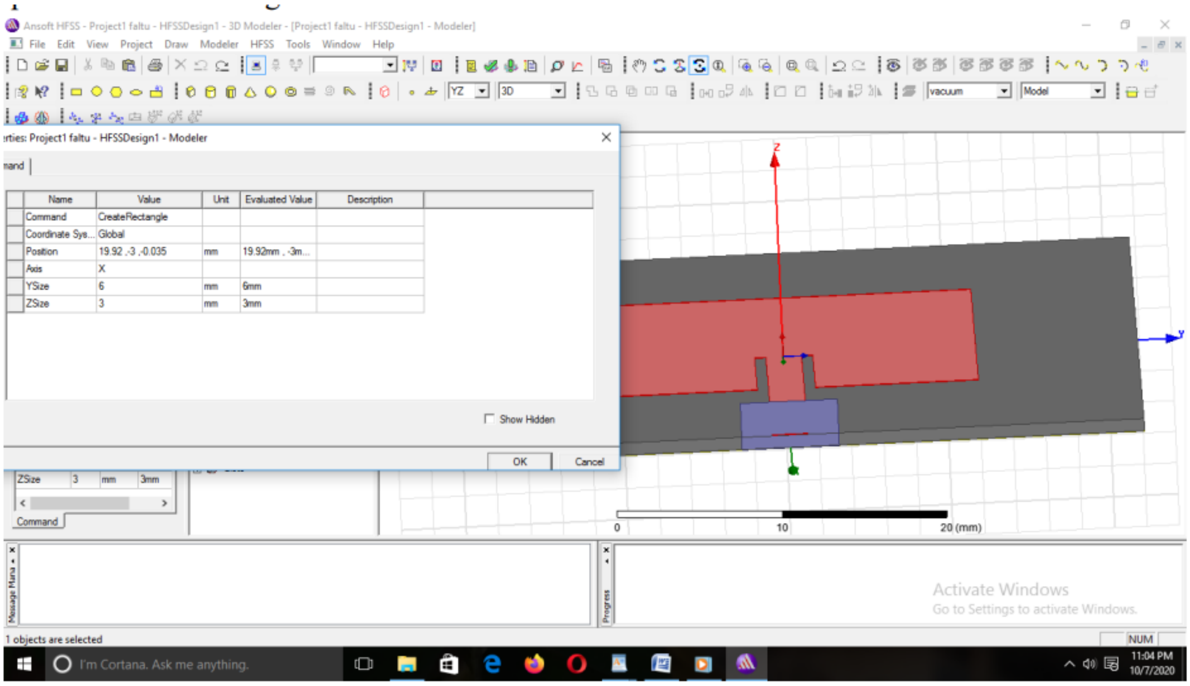
8. Unite feedline and patch by selecting unite icon from toolbox having same material specification.



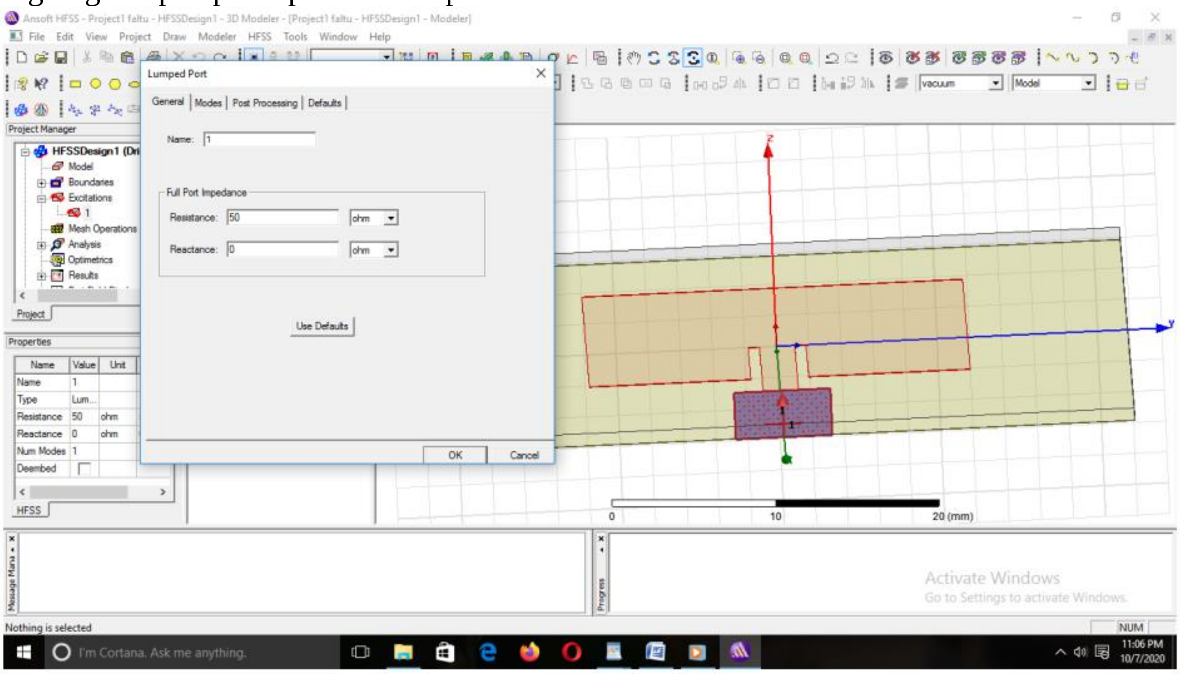
9. Subtract slot 1 and slot 2 from patch to create slot from subtract icon from toolbox and the antenna appears as below.



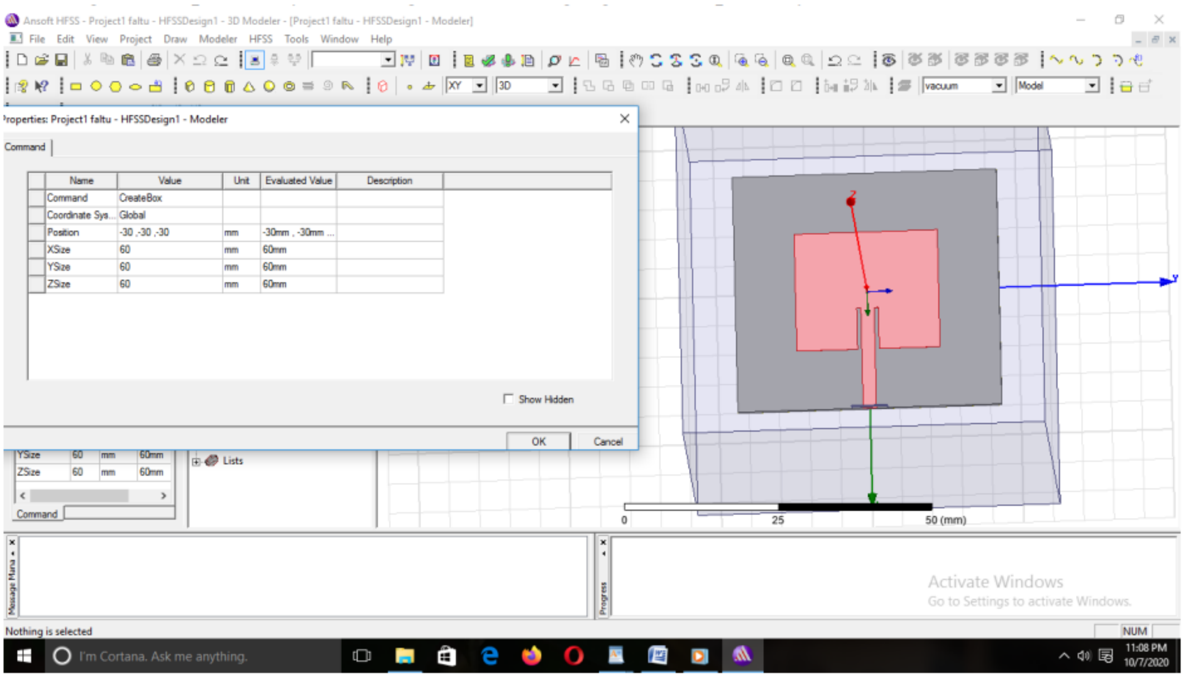
10. Draw a rectangular sheet by selecting rectangle icon from toolbox at the end of feed in YZ plane of the following dimension.



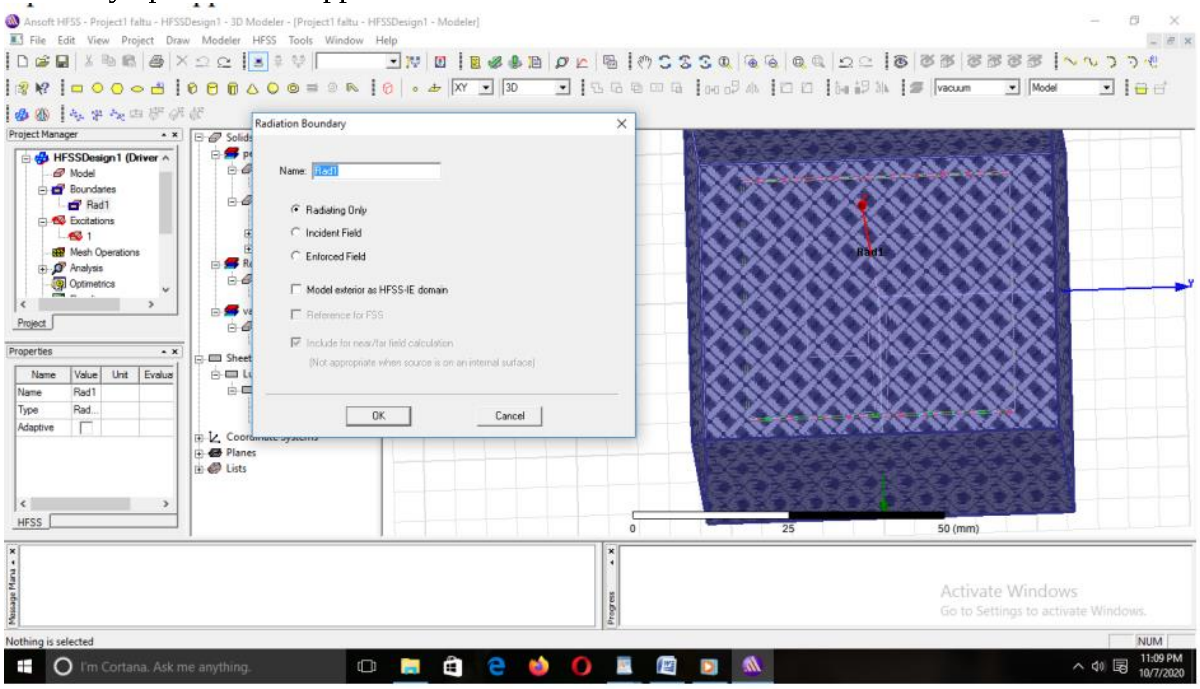
11. Assign lumped port for excitation at the rectangular sheet by selecting the sheet and assigning lumped port option in YZ plane.



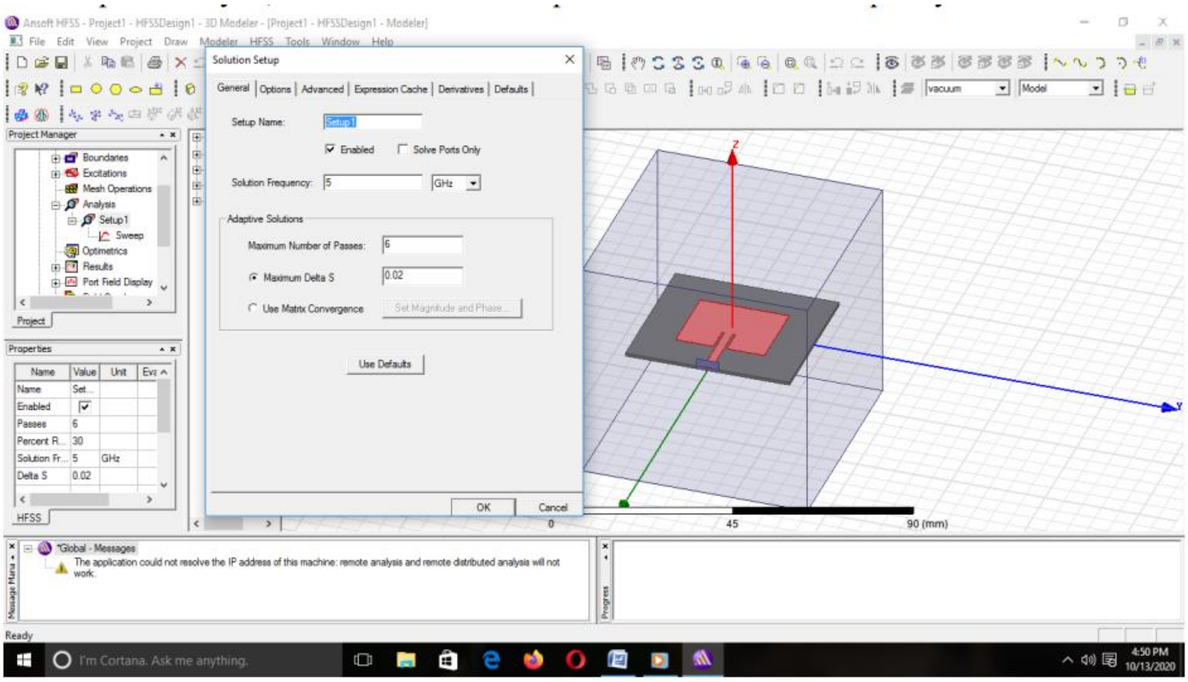
12. Draw a 3D vacuum radiation box surrounding patch antenna of the following dimension and making it transparent by selecting it and changing its transparency.



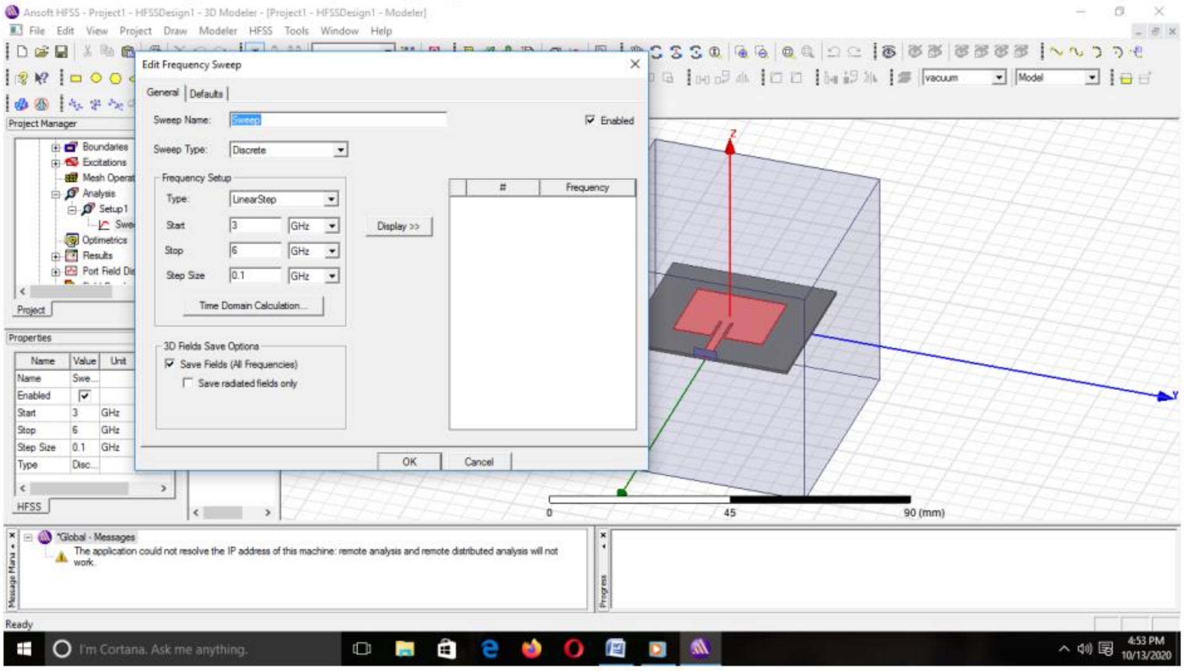
13. Assign a radiation boundary to the radiation box by selecting it followed by assign boundary option which appears as below.



14. From option analysis, click add solution setup and add the solution frequency of 5 GHz.



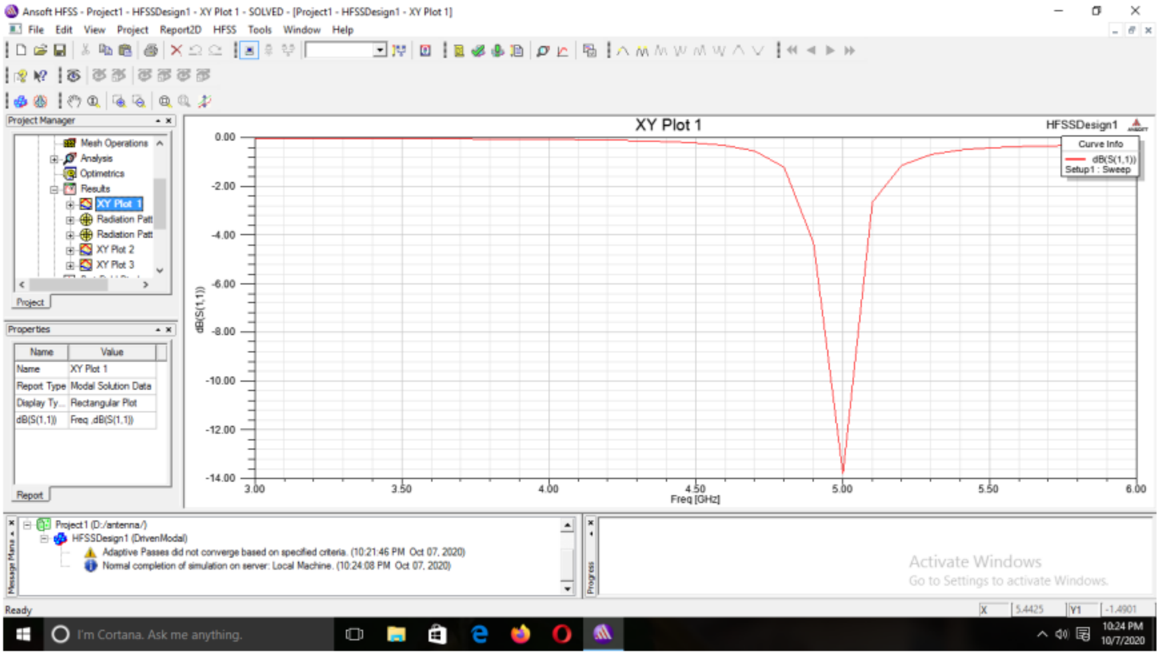
15. Select add frequency sweep from setup 1 and select start and stop frequencies in linear type frequency setup and setting sweep type to be discrete.



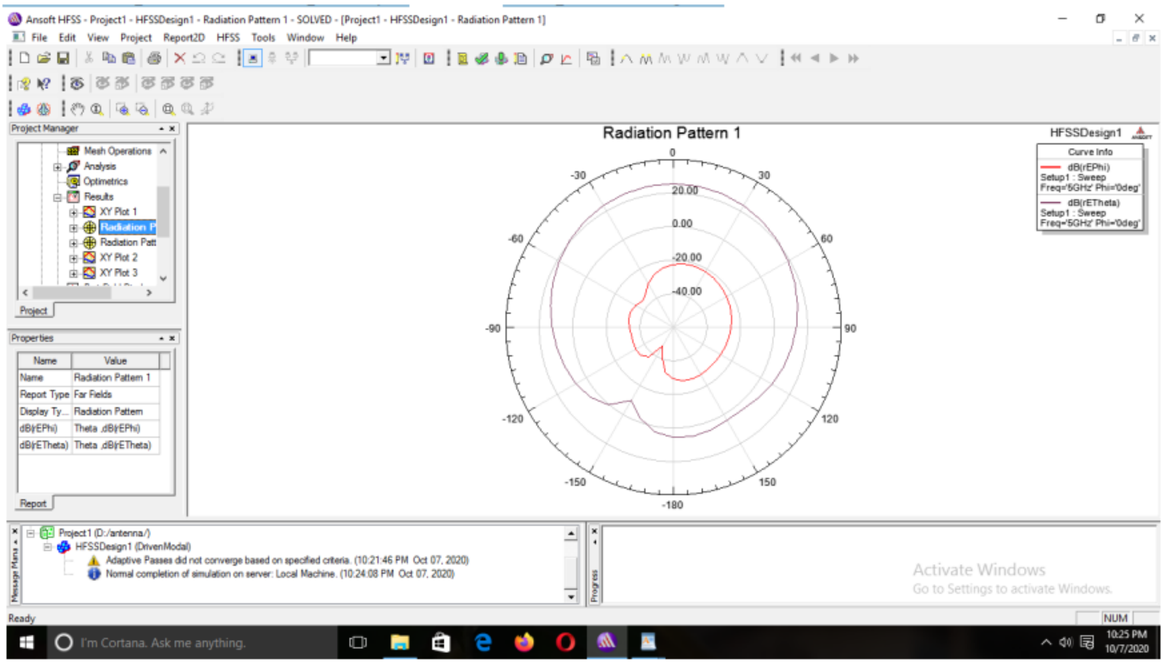
16. Validate all the settings from the tool box and start simulating.
17. After simulation is completed go through graphs in result section and analyze the results.

Results:

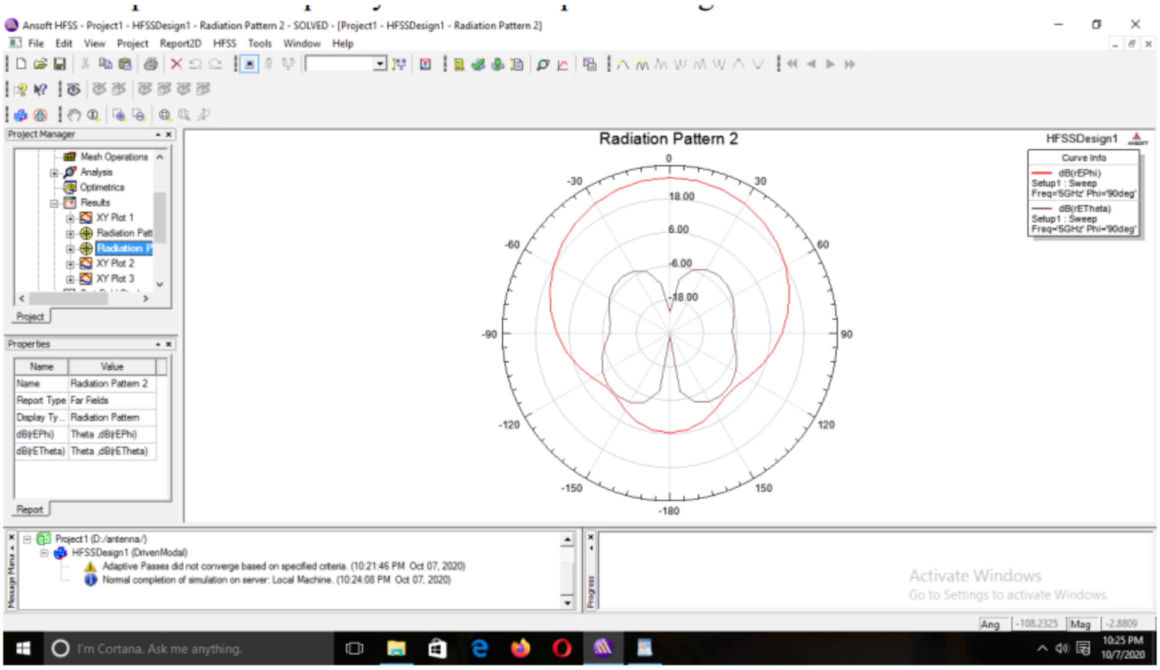
1. S11 plot



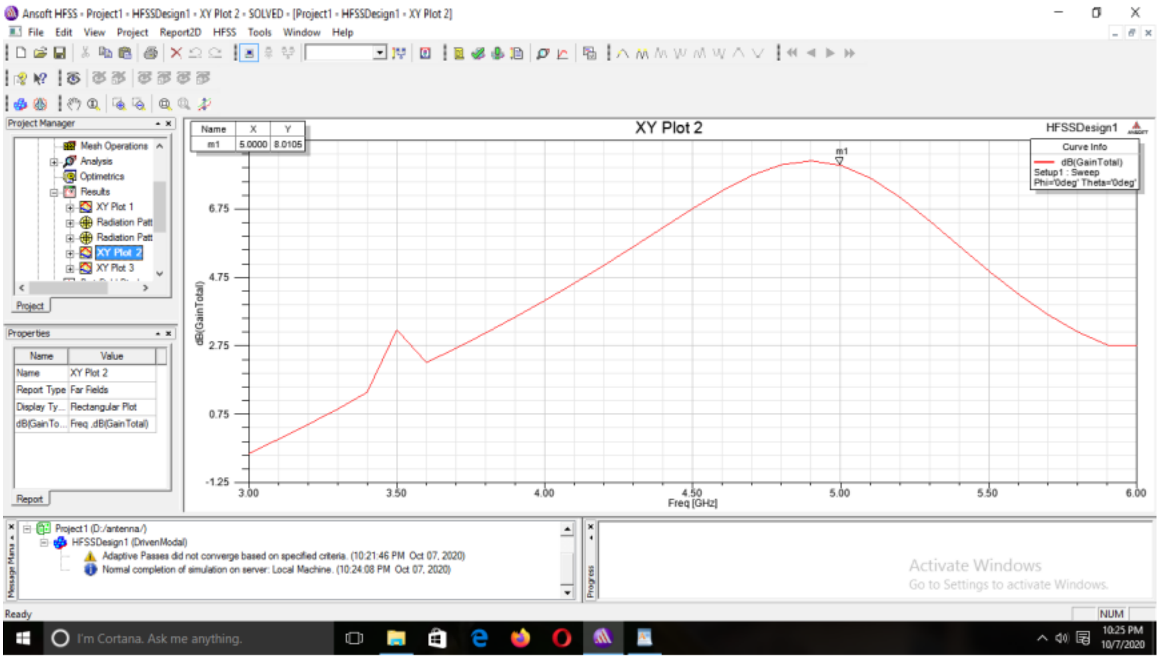
2. Radiation pattern at frequency=5 GHz and phi=0 degree



3. Radiation pattern at frequency =5 GHz and phi= 90 degree



4. Gain plot



Observation Table:

Rectangular patch:

Material Specifications	
Resonating Frequency (GHz)	

-10 dB BW (GHz)	
Peak Gain (dB)	
Radiation efficiency(db)	

Conclusion:

From the simulation results compared, the low dielectric constant substrate Roger

is generally needs to be referred for maximum radiation. This provides better efficiency, narrow bandwidth and better radiation. But the bandwidth is quite small which a major drawback is.

Assignment:

- To design and analyze patch-based log periodic antenna and fractal antenna for resonance frequency of 5GHz.

EXPERIMENT: 03

Objective: Design and analysis of Microstrip filters like low pass, bandpass, high pass and band-reject filters.

Software used: HFSS / CST.

Theory :

Filters are used whenever there is something to be passed and something to get rid of. A microwave filter is a two-port device that plays the important role of controlling the frequency response at certain point at cross section in a microwave system, letting a band of frequencies pass through while rejecting frequencies in another bands. The low frequencies may be rejected with a high-pass filter, the high frequencies may be rejected with a low-pass filter, or all frequencies except a specific band may be rejected with a band-pass filter.

Filters are also commonly used for separating frequencies in duplexers or multiplexers and as a harmonics removal in oscillators or amplifiers. Other tasks that can done by filters are to reduce a noise and reject signals at particular frequencies in bandstop filter applications. The application dictates whether the filter will have lowpass, highpass, bandpass or bandstop characteristics.

Ideal Microwave Filters:

A filter is a two port network used to control the frequency response at a certain point in a system by providing transmission within the pass band of the filter and attenuation in the stop band of the filter. Various type of filter can be design using microstrip line with different construction features are shown in fig.3.1.

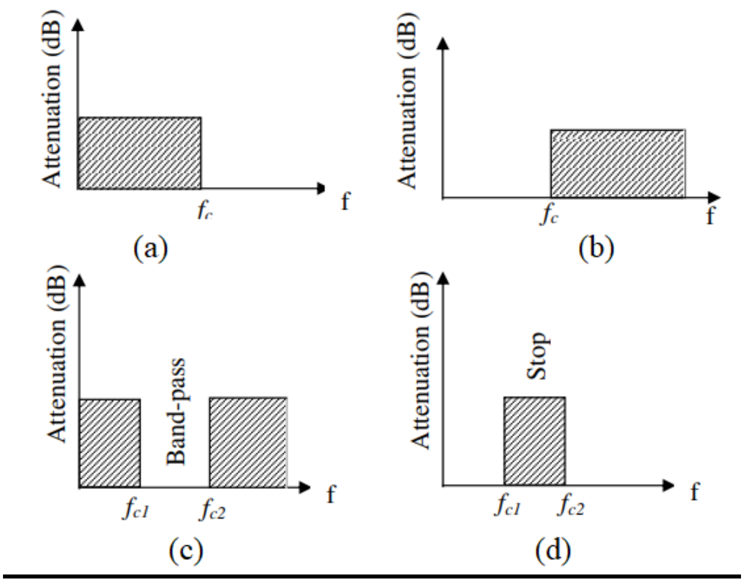


Fig.3.1 Four basic filter types

The low pass filter (LPF) is used to allow low frequency signals, below a cut-off frequency to pass through the filter, while attenuating or stopping higher frequencies.

The high pass filter (HPF) is used to allow high frequency signals above a cut-off frequency to pass through the filter, while attenuating lower frequencies. Often low pas and bandpass filters are combined to form a bandpass filter.

The Bandpass filter (BPF) only allows frequencies in a defined range to pass, above a lower cut-off frequency and below a higher frequency. All lower and higher frequency components are attenuated or stopped.

The Band stop filter (BSF) is used to attenuate or stop signals in a defined range above a lower cut-off frequency and below a higher frequency.

Filter implementation

Filter design at microwave frequencies using lumped elements arise two problems:

1. Lumped elements such as inductors and capacitors are generally available only for a limited range of values and are difficult to implement at microwave frequencies.
2. At microwave frequencies, the distance between filter components is not negligible.

Richards's transformation and Kuroda's identities are used for the microstrip filter realization.

- **Richard's Transformation** is used to convert lumped elements to transmission line sections.

The inductors and capacitors of a lumped elements can be replaced with short and open circuited stubs as shown in fig.3.2, where the length of each stub is $\frac{\lambda}{8}$ at ω_c .

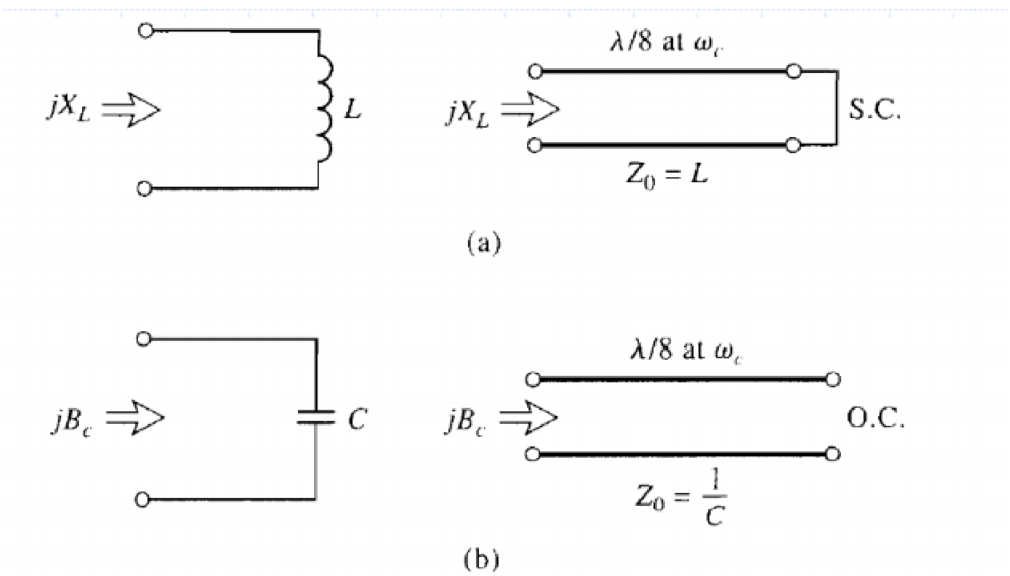


Fig.3.2 Transformation of lumped to transmission line sections.

- **Kurodas identities**: While converting lumped elements into transmission lines, there is need to separate the transmission line elements spatially to achieve practically realizable configurations. This is done by inserting so called unit elements (UEs).Such additional sections do not affect the filter response, this type of filter design is called redundant filter synthesis. z_{UE} is the characteristic impedance of unit elements. It transforms the series stubs into shunt stubs or vice- versa.

Electrical length of unit element is $\theta = \frac{\pi}{4}\left(\frac{f}{f_0}\right)$ (1)

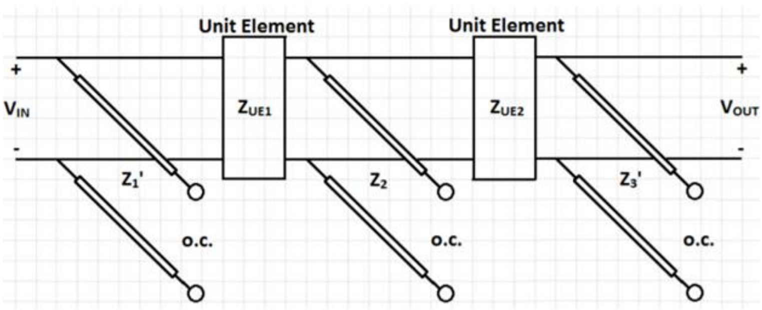
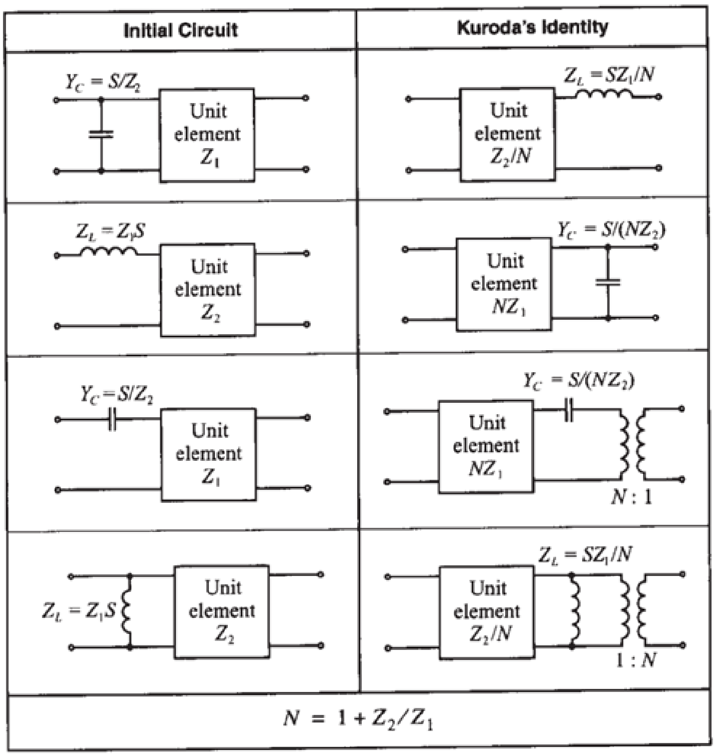


Fig.3.3 Unit elements in filter circuits.

The transformation approach is given in tabular form:



- **Low Pass filter**

Easy way to implement low pass filter prototype in microstrip form is to use alternating sections of a very high and very low characteristics impedances lines. Such filters are referred as stepped impedance filters. These filters takes less space than low pass filter using stubs. Because of the approximate equivalent circuits are involved in this design, their electrical performance is not as good, so having a limited scope.

By using this method the series inductors can be replaced with high impedance line sections (Z_h) and shunt capacitors can be replaced with low impedance line (Z_l). With these approximations the electrical lengths of the inductor and capacitor are given by:

For inductor $\beta l = \frac{LR_0}{Z_h}$; for capacitor $\beta l = \frac{CZ_l}{R_0}$ (2)

The below figure shows the implementation of low pass filter from lumped to micrsotrip.

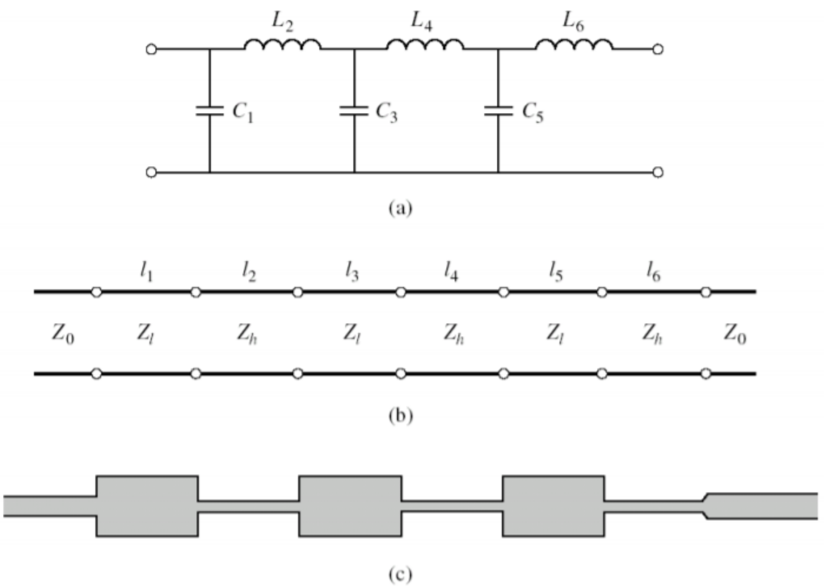


Fig.3.4 Implementation of low pass filter from lumped to microstrip.

Design procedure of low pass filter

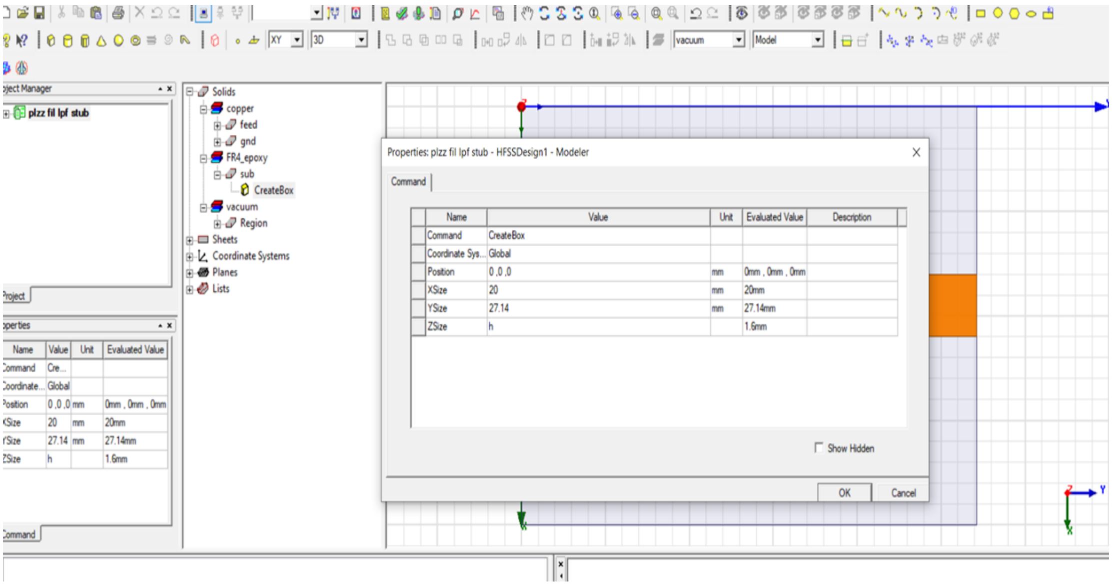
1. Consider the alternate high and low characteristics impedance transmission line sections of Z_h and Z_l respectively as shown in fig.3.4.
2. For the given filter response type (Butterworth/ Chebyshev), find the coefficients of the filter elements.
3. Calculate the electrical length of high impedance, low impedance sections which replaces the series inductance and shunt capacitance from the equation mentioned (2).
4. Calculate the physical parameters of the distributed low pass filter (width and length of the transmission line).
5. Using the obtained values, implement the design in HFSS/CST software and comment on your obtained results.

Design example:

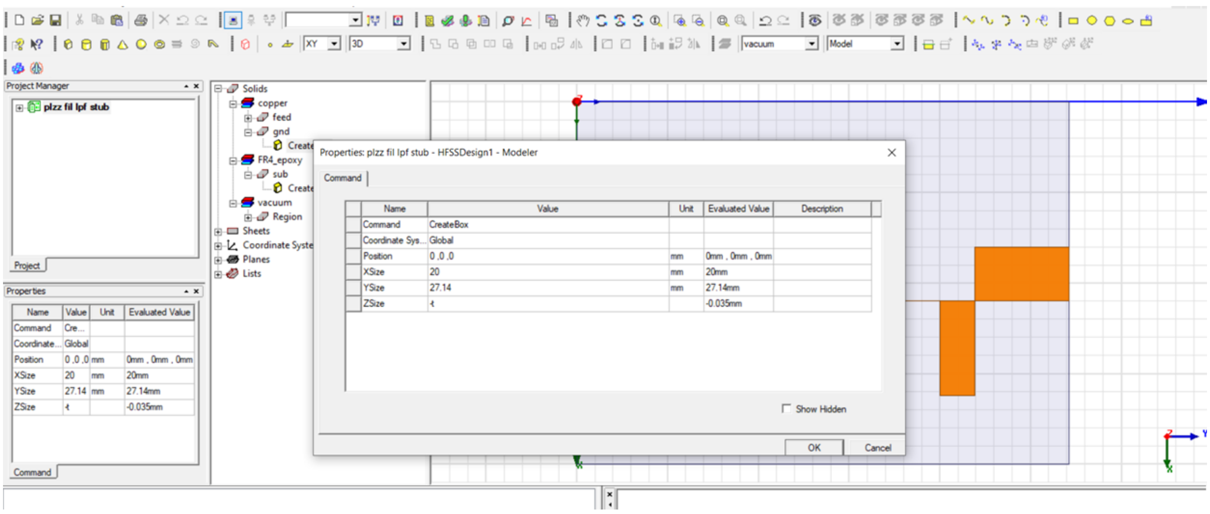
Design a stepped-impedance low pass filter having a maximally flat response and a cut-off frequency of 2.5 GHz having order of 6. The filter impedance is 50 ohm, the highest practical line impedance is 150 ohm and the lowest 10 ohm.

Design Procedure using HFSS software:

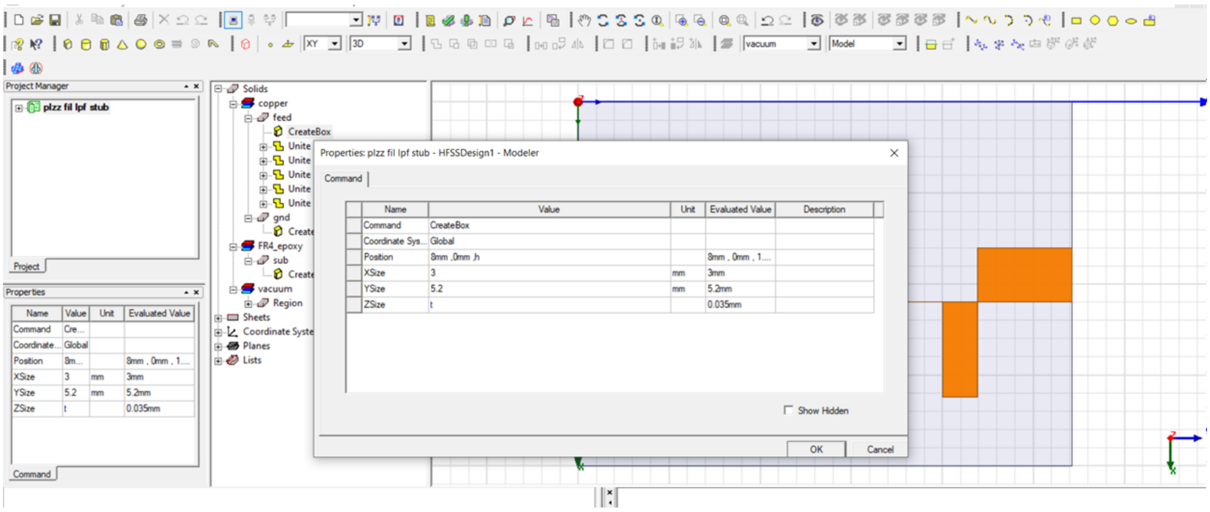
1. Start ANSYS Electronics Desktop. Check (and change if necessary) that the working mode is Driven Modal, HFSS > Solution Type > Modal.
2. Set Modeler length units to mm, Modeler > Units > mm.
3. Calculate all the values of transmission line sections from design procedure of low pass filter.
4. To draw a substrate, and ground select Draw > rectangle and enter calculated values of length, width, and height at corresponding positions.



(a) Substrate

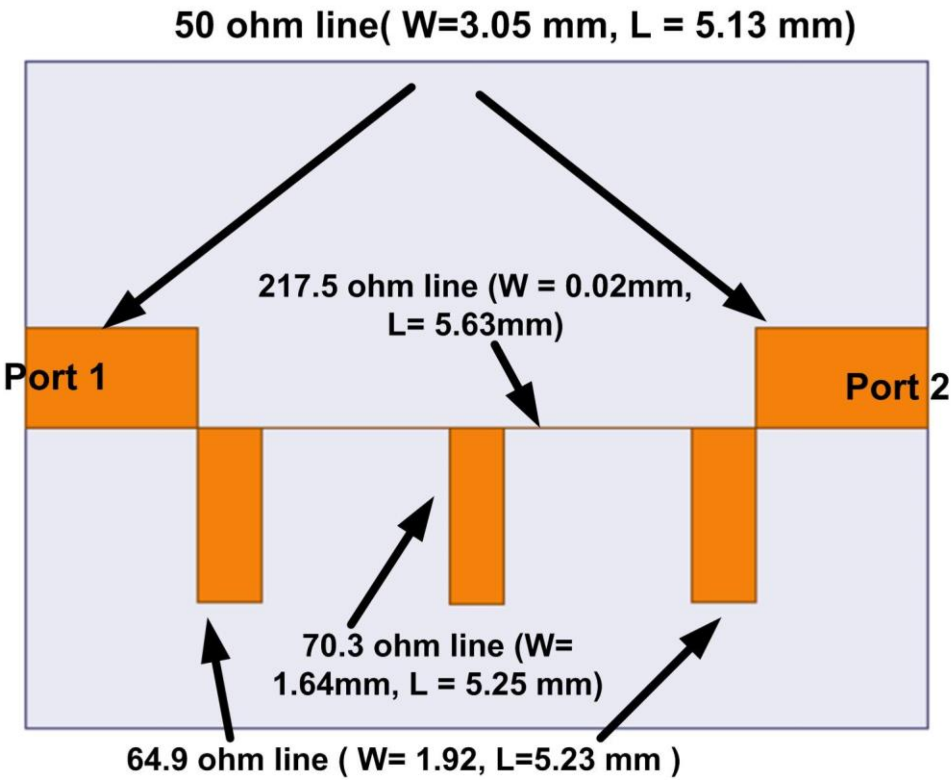


(b) ground



(c) feedline

5. Similarly do the step 4 for all the transmission sections of the line.



6. To provide an input source to perform the simulation. Select Draw > Rectangle and draw a rectangle (! it's a surface model not a volume one) at both the ports.

7. Add a solution. Select HFSS > Analysis Setup > Add Solution Setup

8. After meshing, we define a broadband analysis. Select the previously defined solution (Project Manager > Analysis > Setup1) and add a broadband solution around the frequency corresponding to the single frequency solution HFSS > Analysis Setup > Add Frequency Sweep.

9. Select HFSS > Validation Check to verify that all required steps have been completed.
10. Select HFSS > Analyze All to start the simulation. Click the Show Progress button to view the progress of the solver.
11. Select HFSS > Results > Create Modal Solution Data Report > Rectangular Plot to display the S parameters corresponding to input port P1 (in dB).

Simulated Results:

Add various plots for the designed antenna performances:

1. Plot the attenuation versus frequency response of the filter.

Conclusion:

Please add some comments on this particular experiments related to the difficulties you have faced during simulation and also related to observation from variations of results with respect to different design parameters. Also mentioned some points related to necessary precaution that need to consider during simulation for getting desired results.

Problems:

2. Design a low pass filter for fabrication using microstrip lines. The Specifications are: Cut-off frequency of 4 GHz, third order, impedance of 50 ohm and a 3 dB equal ripple characteristics.
3. Design a three order microstrip band stop filter in Chebyshev prototype with passband ripple of 0.05 dB. The desired band-edge frequencies to equal ripple points are f_1= 1.25 GHz and f_2= 3.75 GHz considering the source / load impedance of the filter is 50 ohm.
4. Design an optimum distributed HPF at cut-off frequency of 1.5 GHz and 0.1 dB ripple passband up to 6.5 GHz using 6 stubs, considering the source / load impedance of the filter is 50 ohm.
5. Design a stub bandpass filter using five-order Chebyshev prototype with a passband ripple of 0.1 dB at 2 GHz with the fractional bandwidth of 0.5 considering the source/ load impedance of the filter is 50 ohm.

Experiment no: 3

Objective: Design and analysis of conventional antennas like Waveguide based horn antenna.

Software used: HFSS or CST MWS software.

Theory:

A horn antenna is an antenna that consists of a flaring metal waveguide shaped like a horn to direct radio waves in a beam. Horns are widely used as antennas at UHF and microwave frequencies, above 300 MHz. They are used as feed antennas (called feed horns) for larger antenna structures such as parabolic antennas, and as directive antennas for devices like radar guns, automatic door openers, and microwave radiometers. Their advantages are moderate directivity, broad bandwidth, and simple construction and adjustment.

The horn antenna is a simple development of the waveguide transmission line. Using some simple theory, it is easy to learn the operation of horn antenna. It is quite possible to leave a waveguide open and let signal radiate from this. However this is not particularly efficient. Signals passing along the waveguide see a sudden transition from the waveguide to free space which has an impedance of around 377Ω. The result of this sudden transition is to cause signals to be reflected back long the waveguide as standing waves as this is exactly the same as for poor matches at the end of coaxial or other forms of wire based transmission lines. To overcome this issue, the waveguide can be tapered out or flared. This has the effect of providing a gradual transition from the impedance of the waveguide to that of free space. In effect it acts like a progressive matching transformer. The flare functions similarly to a tapered transmission line, or an optical medium with a smoothly varying refractive index. In addition, the wide aperture of the horn projects the waves in a narrow beam. The waves of the signal will propagate down the horn antenna towards the aperture. As they travel along the flared opening, the waves travel as spherical wave fronts. As the phase front progressing along the horn antenna is spherical, the phase increases smoothly from the edges of the aperture plane to the centre. The difference in phase between the centre point and the edges is called the phase error. This increases with the flare angle reducing the gain, but increasing the beam width. As a result horn antennas have wider beam widths when compared to similar-sized plane-wave antennas like parabolic reflectors. In order to provide a narrow beam width a longer horn is required, i.e. having a smaller angle of flare. This enables the phase angle to be kept more constant.

As the frequency used by a horn antenna increases, so does the gain and directivity (beam width decreases). The reason for this is that the aperture of the horn remains constant in terms of physical dimensions (obviously), but increases in terms of the number of wavelengths, i.e. it is electrically larger. As the flare angle is increased, the reflection at the mouth decreases rapidly and as a result the gain of the horn antenna increases. The horn antenna can operate very effectively. The flare of the horn antenna provides a smooth match between the waveguide and free space and its angle affects many properties including the gain and directivity.

An advantage of horn antennas is that since they have no resonant elements, they can operate over a wide range of frequencies, a wide bandwidth. The uses of horn antenna are given below:

1. The horn is widely used as a feed element for large radio astronomy, satellite tracking, and communication dishes found installed throughout the world.
2. In addition to its utility as a feed for reflectors and lenses, it is a common element of phased arrays.

3. It serves as a universal standard for calibration and gain measurements of other high-gain antennas.

4. Its widespread applicability stems from its simplicity in construction, ease of excitation, versatility, large gain, and preferred overall performance.

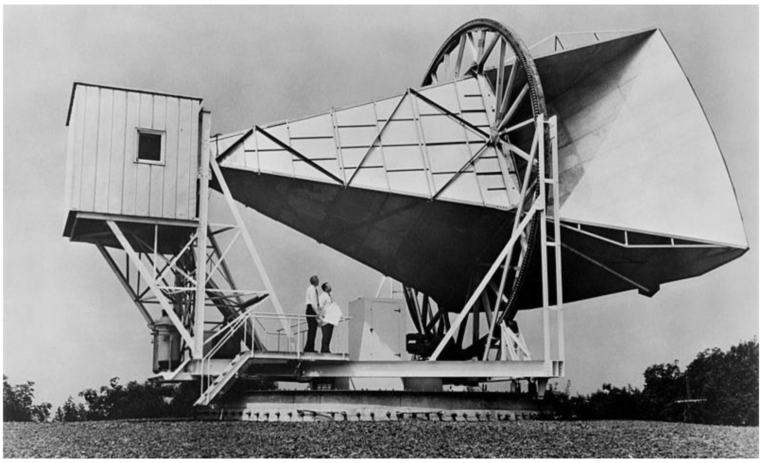
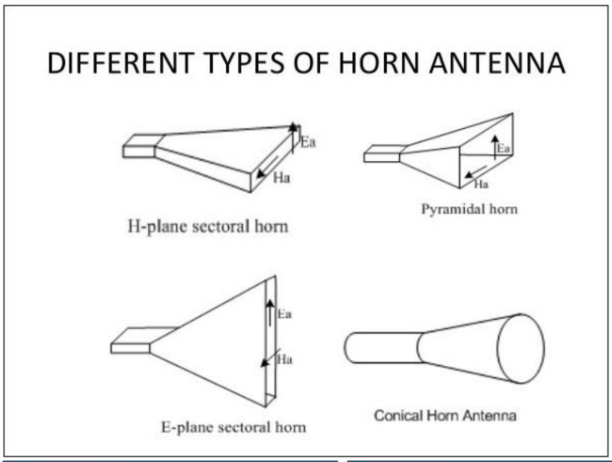
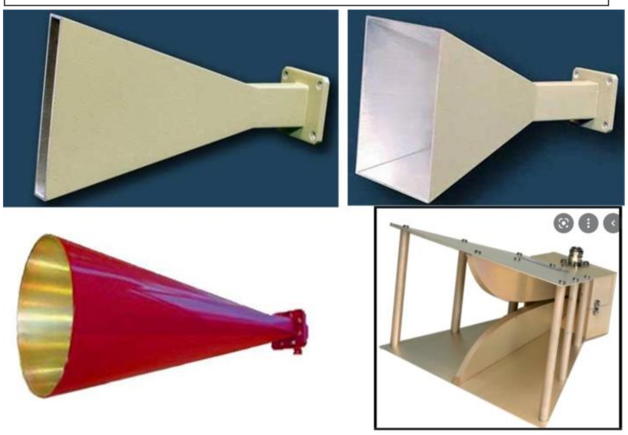


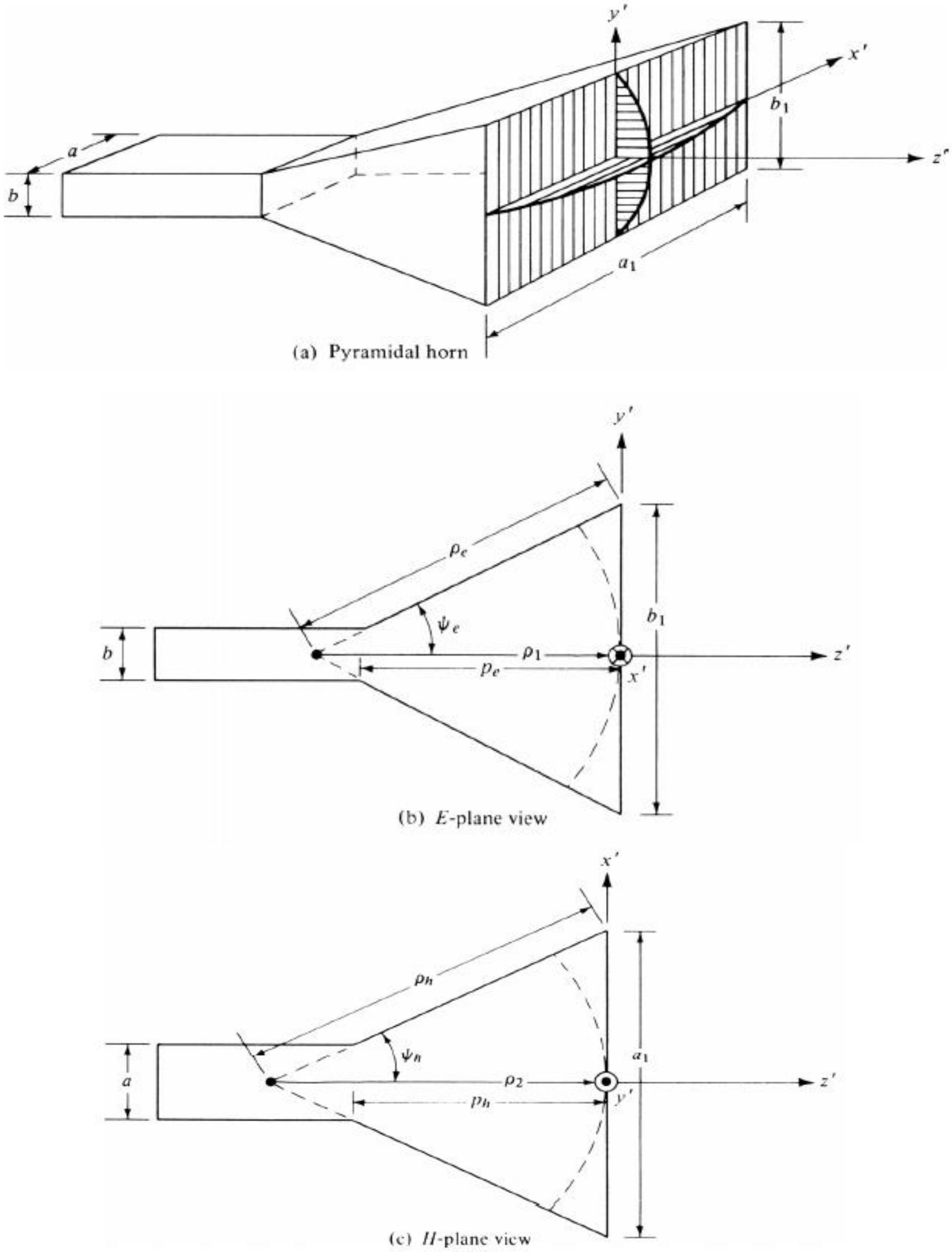
Figure: 1. Probably the most photographed and well-known example is the 15 meter (50 foot) long Holmdel Horn Antenna at Bell Labs in Holmdel, New Jersey, with which Arno Penzias and Robert Wilson discovered cosmic microwave background radiation in 1965, for which they won the 1978 Nobel Prize in Physics.

Different types of horn antennas are shown in below figure.





The cross-sectional view (E-plane and H-plane) of a pyramidal horn antenna is shown below.



(a) Pyramidal horn

(b) E-plane view

(c) H-plane view

Design Procedure of Pyramidal horn antenna:

To design a pyramidal horn, one usually knows the desired gain G0 and the dimensions a, b of the rectangular feed waveguide.

The objective of the design is to determine the remaining dimensions (a1, b1, ρe , ρh , Pe , and Ph) that will lead to an optimum gain.

The design equations are derived by firsts electing values of a1 and b1that lead to optimum directivities for the E and H plane sectoral horns.

$$a_1 \simeq \sqrt{3\lambda\rho_2} \qquad b_1 \simeq \sqrt{2\lambda\rho_1}$$

Since the overall efficiency (including both the antenna and aperture efficiencies) of a horn antenna is about 50%. The gain of the antenna can be related to its physical area. Thus it can be written by

$$G_0 = \frac{1}{2}\frac{4\pi}{\lambda^2}(a_1 b_1) = \frac{2\pi}{\lambda^2}\sqrt{3\lambda\rho_2}\sqrt{2\lambda\rho_1} \simeq \frac{2\pi}{\lambda^2}\sqrt{3\lambda\rho_h}\sqrt{2\lambda\rho_e}$$

Since for long horns ρ2 ≈ ρh and ρ1 ≈ ρe. For a pyramidal horn to be physically realizable, Pe and Ph must be equal. Using this equality, it can be shown that gain reduces to

$$\left(\sqrt{2\chi} - \frac{b}{\lambda}\right)^2 (2\chi - 1) = \left(\frac{G_0}{2\pi}\sqrt{\frac{3}{2\pi}}\frac{1}{\sqrt{\chi}} - \frac{a}{\lambda}\right)^2 \left(\frac{G_0^2}{6\pi^3}\frac{1}{\chi} - 1\right)$$

Where,

$$\frac{\rho_e}{\lambda} = \chi$$

$$\frac{\rho_h}{\lambda} = \frac{G_0^2}{8\pi^3}\left(\frac{1}{\chi}\right)$$

…………………..(1)

This Equation is the horn design equation.

1. As a first step of the design, find the value of χ which satisfies eq.(1) for a desired gain G_0 (dimensionless). Use an iterative technique and begin with a trial value of

$$\chi\,(\text{trial}) = \chi_1 = \frac{G_0}{2\pi\sqrt{2\pi}}$$

2. Once the correct χ has been found, determine ρe and ρh using eq.(1).
3. Find the corresponding values of a1 and b1.

$$a_1 = \sqrt{3\lambda\rho_2} \simeq \sqrt{3\lambda\rho_h} = \frac{G_0}{2\pi}\sqrt{\frac{3}{2\pi\chi}}\lambda$$

$$b_1 = \sqrt{2\lambda\rho_1} \simeq \sqrt{2\lambda\rho_e} = \sqrt{2\chi\lambda}$$

4. Then find the value of pe and ph using following equations.

$$p_e = (b_1 - b)\sqrt{\left(\frac{p_e}{b_1}\right)^2 - \frac{1}{4}}$$

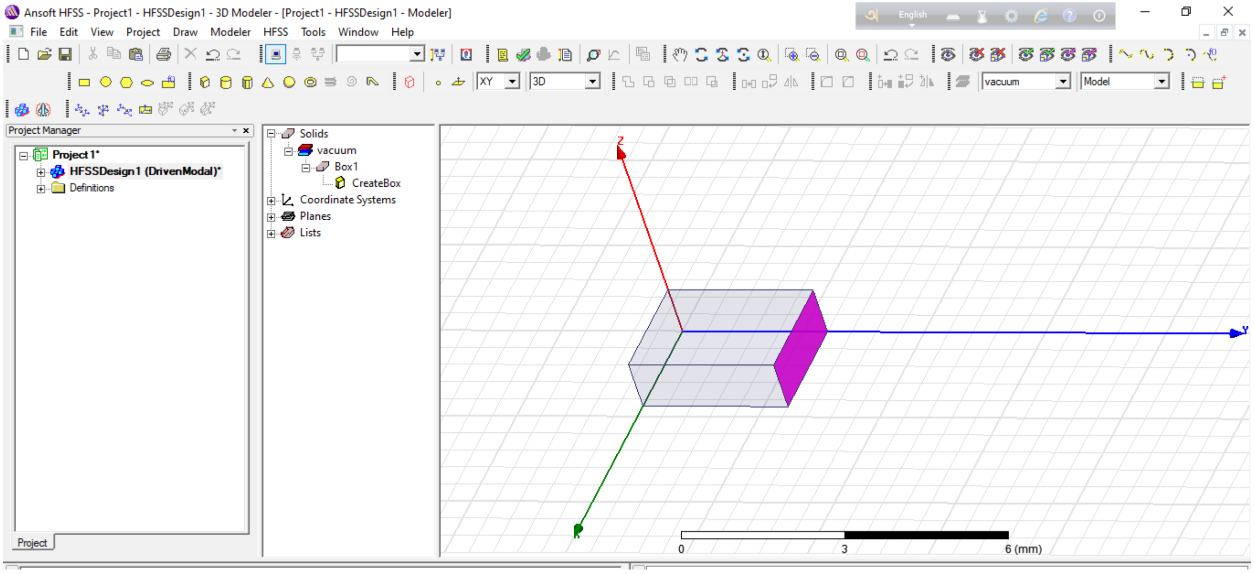
$$p_h = (a_1 - a)\sqrt{\left(\frac{p_h}{a_1}\right)^2 - \frac{1}{4}}$$

Design Problem:

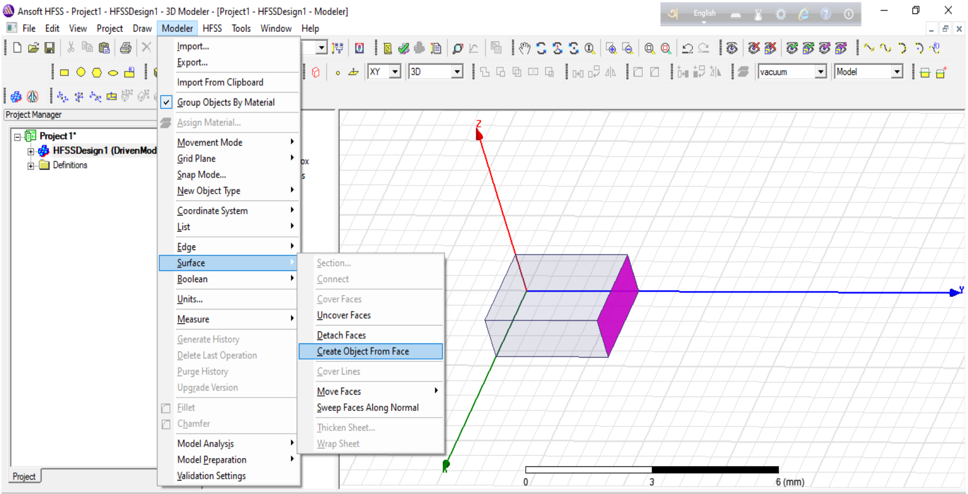
Design an X-band Horn antenna with the specifications as given below:
Given: X-band (8.2 – 12.4 GHz), f = 11 GHz Horn and Gain = 22.6 dB.
Here, a = 0.9 inch, b = 0.4 inch.
Find the dimensions of Pyramidal Horn antenna and then simulate that structure using HFSS or CST software.

Design procedure using HFSS software:

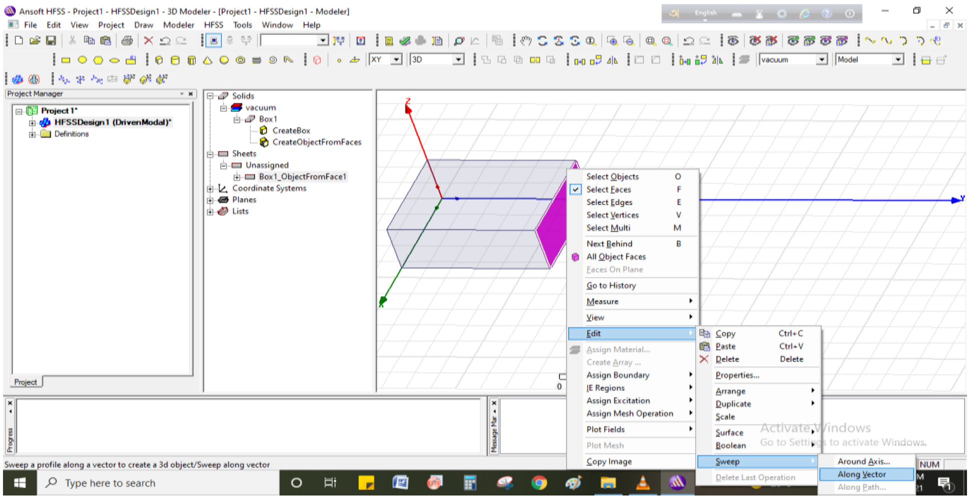
1. After opening of the HFSS software, design the wave guide feeding section as shown below.



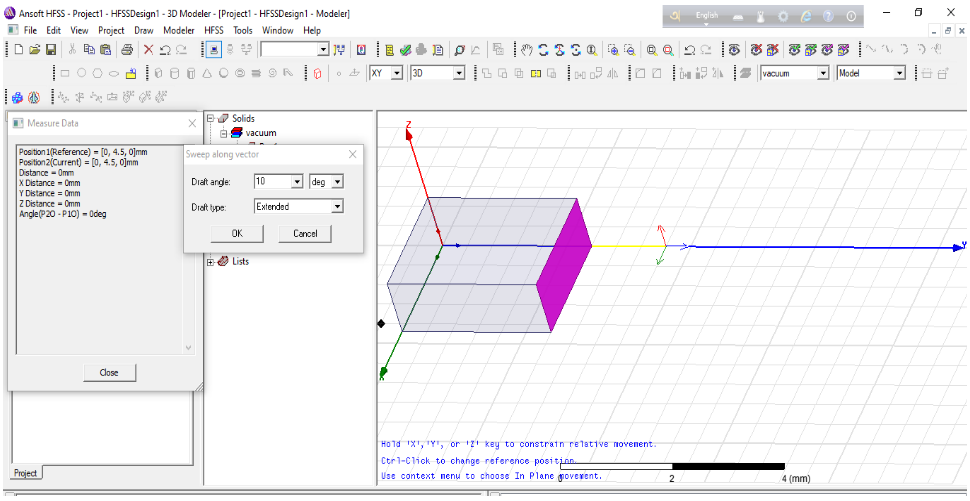
2. Then, select the face and then “Modeler” – “Surface” – “Create object from face”.



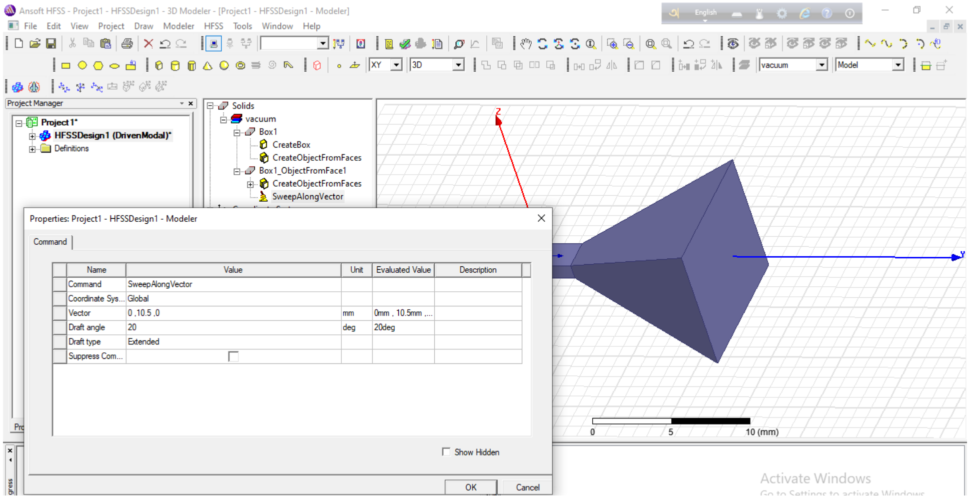
3. Then right click on the surface and "Edit" – "Sweep" – "Along Vector".



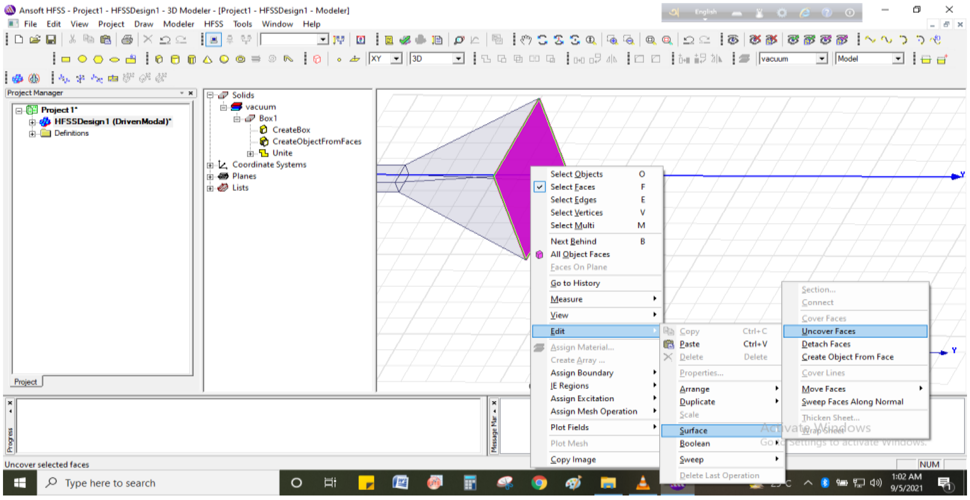
4. Choose "Draft angle" and "Draft type".



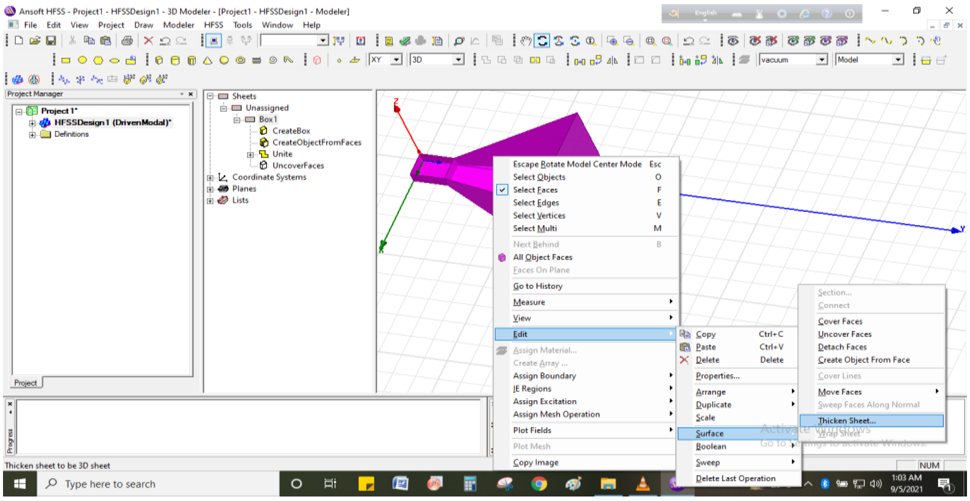
5. Choose the length and angle from "Sweep Along Vector".



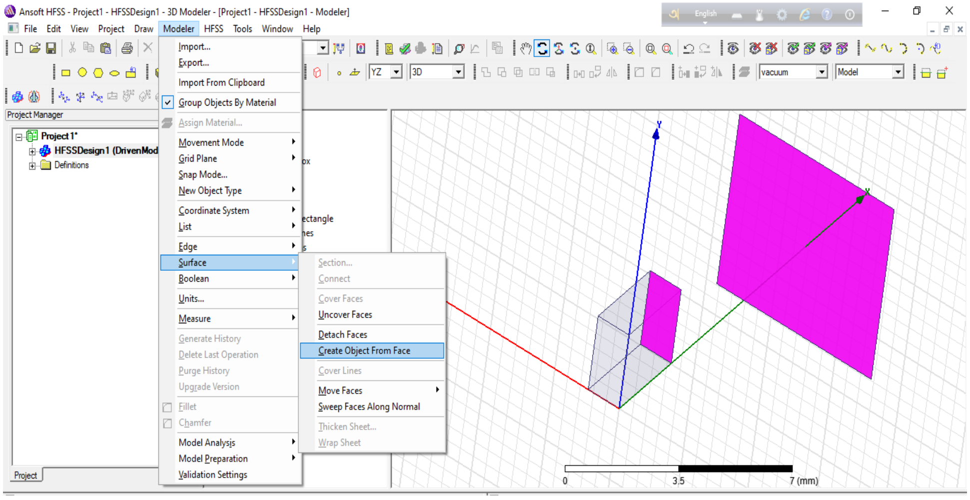
6. Then select the surface and “Edit” – “Surface” – “Uncover Faces”.



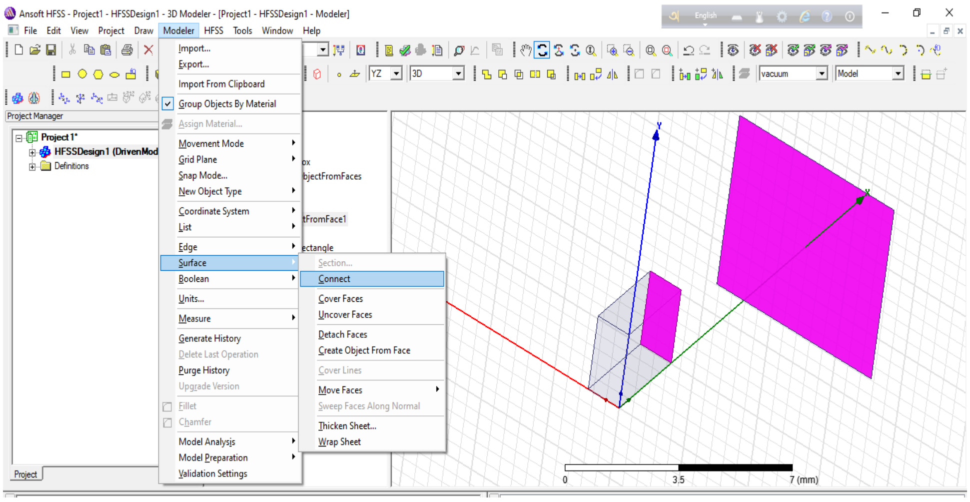
7. Then unite the structure and select it. After that “Edit” – “Surface” – “Thicken Sheet”.



8. An alternate approach to design:



9. Go to “Modeler” – “Surface” – “Connect” to create the horn antenna geometry and then follow the same steps as shown before.



Simulated results:

Add various plots for the proposed antenna performance:

1. -10 dB impedance bandwidth (BW in GHz)
2. Gain variations over whole operating BW (in dB)
3. 2-D radiation patterns at different resonating frequencies
4. VSWR plot
5. 3-D radiation patterns at different resonating frequencies
6. Efficiency over the operating band

Observation Table:

Frequency range of the Horn antenna (-10dB BW)	Gain variations over the band	VSWR	Cross- polarization suppression at different frequencies	Efficiency

Conclusions:

Please add some comments on this particular experiments related to the difficulties you have faced during simulation and also related to observation from variations of results with respect to different design parameters. Also mentioned some points related to necessary precaution that need to consider during simulation for getting desired results.

Experiment -5

Aim: Design and analysis of microstrip couplers and power dividers.

Software: ANSYS HFSS

Theory:

Coupler is a four-port device, which couples the power from input ports, while the fourth port is isolated. It is a passive device that divides and distributes power. Couplers have an additional "coupled" port which taps the main signal at a small fraction of the power of the through line. It takes one signal as the input and provides two outputs, one being the regular output and the other being the coupled output. Due to the inherent narrow-band nature of the conventional branch line coupler that is based on single section quarter-wavelength transmission lines, it suffers from narrow bandwidth and large size. In modern communication system, need for dual band operation and compactness possess new requirements. The Characteristics of a coupler are defined as follows:

Transmission factor (T) = 10log(P2/P1) (1)

Coupling factor (C) = 10log(P1/P3) dB (2)

Isolation (I) = 10log(P1/P4) dB (3)

Directivity (D) = 10log(P4/P3) dB (4)

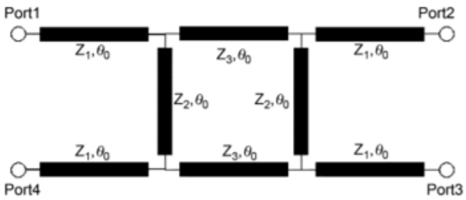


Fig. 1 Microstrip Branch line coupler

Design and observations:

- Design Specifications-: Substrate thickness:1mm, Dielectric Constant: 2.65
- The Geometric parameters of the branch line coupler needs to be calculated by going through the revised formulas: for centre frequency 2.4GHz and 3.5GHz.

Table-I Observation Table

	Impedance(Ω)	Length(mm)	Width(mm)
Z_O			
Z_1			
Z_2			
Z_3			

For $W/h \leq 2$, $\frac{W}{h} = \frac{8\exp(A)}{\exp(2A) - 2}$,

with

$$A = \frac{Z_c}{60}\left\{\frac{\varepsilon_r + 1}{2}\right\}^{0.5} + \frac{\varepsilon_r - 1}{\varepsilon_r + 1}\left\{0.23 + \frac{0.11}{\varepsilon_r}\right\} \tag{5}$$

And for

$$W/h \geq 2, \frac{W}{h} = \frac{2}{\pi}\left\{(B-1) - \ln(2B-1) + \frac{\varepsilon_r - 1}{2\varepsilon_r}\left[\ln(B-1) + 0.39 - \frac{0.61}{\varepsilon_r}\right]\right\},$$

with

$$B = \frac{60\pi^2}{Z_c\sqrt{\varepsilon_r}} \tag{6}$$

$$\varepsilon_{re} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + \frac{10}{u}\right)^{-ab} \tag{7}$$

where $u = W/h$, and

$$a = 1 + \frac{1}{49}\ln\left(\frac{u^4 + \left(\frac{u}{52}\right)^2}{u^4 + 0.432}\right) + \frac{1}{18.7}\ln\left[1 + \left(\frac{u}{18.1}\right)^3\right] \tag{8}$$

$$b = 0.564\left(\frac{\varepsilon_r - 0.9}{\varepsilon_r + 3}\right)^{0.053} \tag{9}$$

$$\lambda_g - \frac{300}{f(\text{GHz})\sqrt{\varepsilon_{re}}}\ \text{mm.} \tag{10}$$

Interpretation of microstrip based branch line coupler:

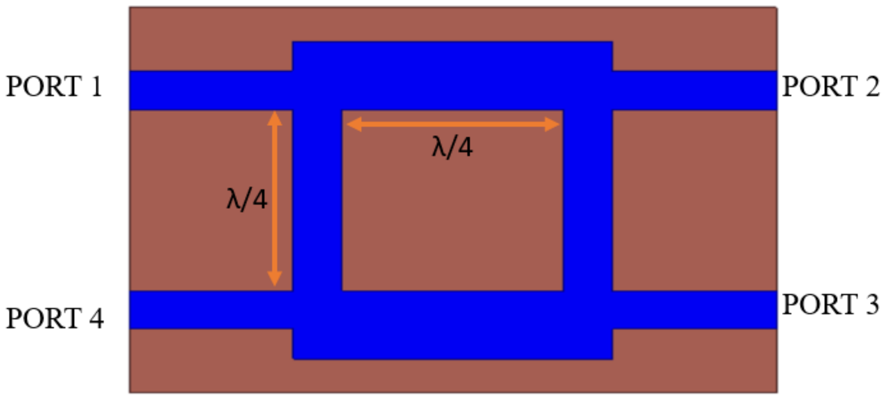


Fig.1. Branch line Coupler

S-matrix of 3dB branch line coupler

$$[S] = \frac{1}{\sqrt{2}}\begin{bmatrix} 0 & 1 & j & 0 \\ 1 & 0 & 0 & j \\ j & 0 & 0 & 1 \\ 0 & j & 1 & 0 \end{bmatrix}$$

The branch line coupler consists of four transmission lines, each a quarter-wavelength long at the target frequency. Two have the characteristic impedance of the terminations (Ports P1-P4) and two have one that is reduced by 1/√2 or is 35.35 Ohms.

Applications

1. Branch-line couplers are mostly used in microwave and millimeter wave circuits.

2. Branch line couplers find various applications in wireless communication systems, such as the phase shifters, balanced amplifiers and mixers, and antenna/array feeding networks.

The disadvantages of branch line couplers are:

1. Inconvenient line impedance

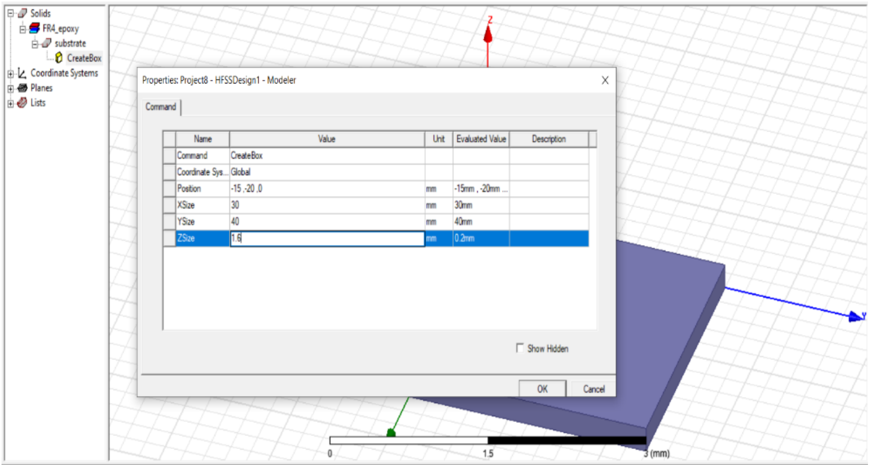
2. Narrow operating bandwidth

Design Specifications:

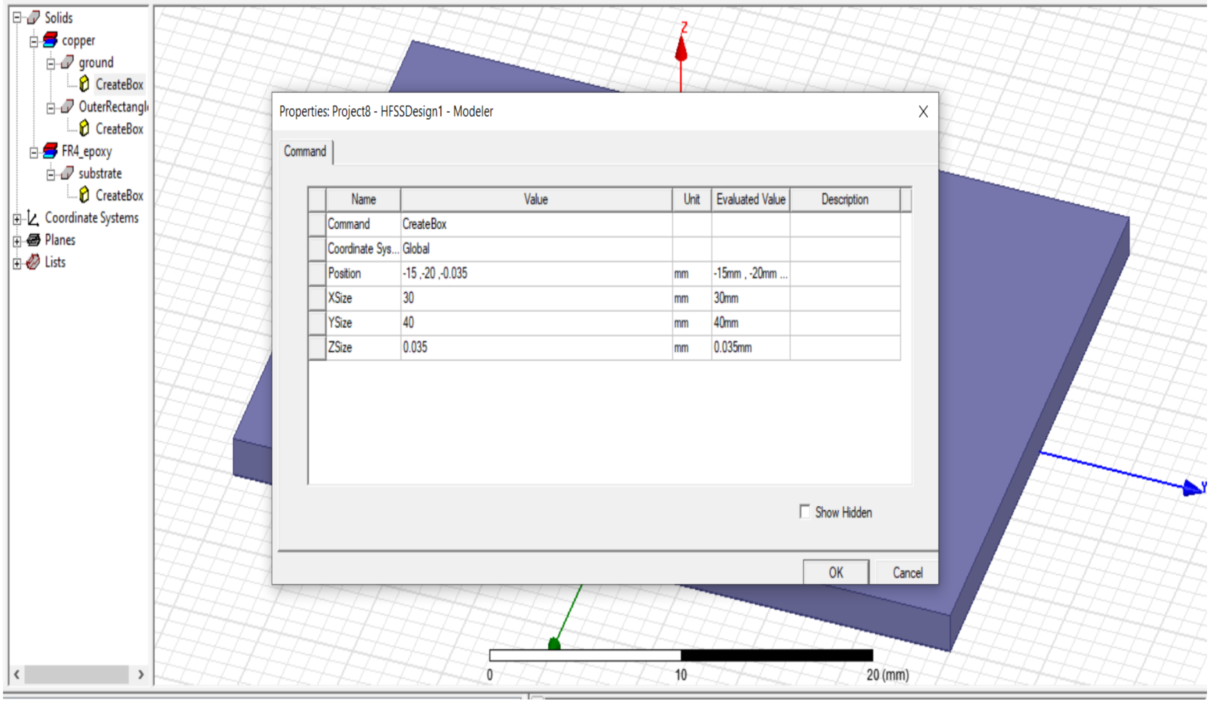
Substrate (FR4)	**Design frequency = 2.4 GHz**
H = 1.6 mm	**Z0 = 50 Ohm**
ϵ_r = 4.4	**Z0/√2 = 35 Ohm**
W50 = 3.05 mm	
L50 = 17.1 mm	
W35 = 5.3 mm	
L35 = 16.7 mm	

Modelling of branch line coupler in HFSS software

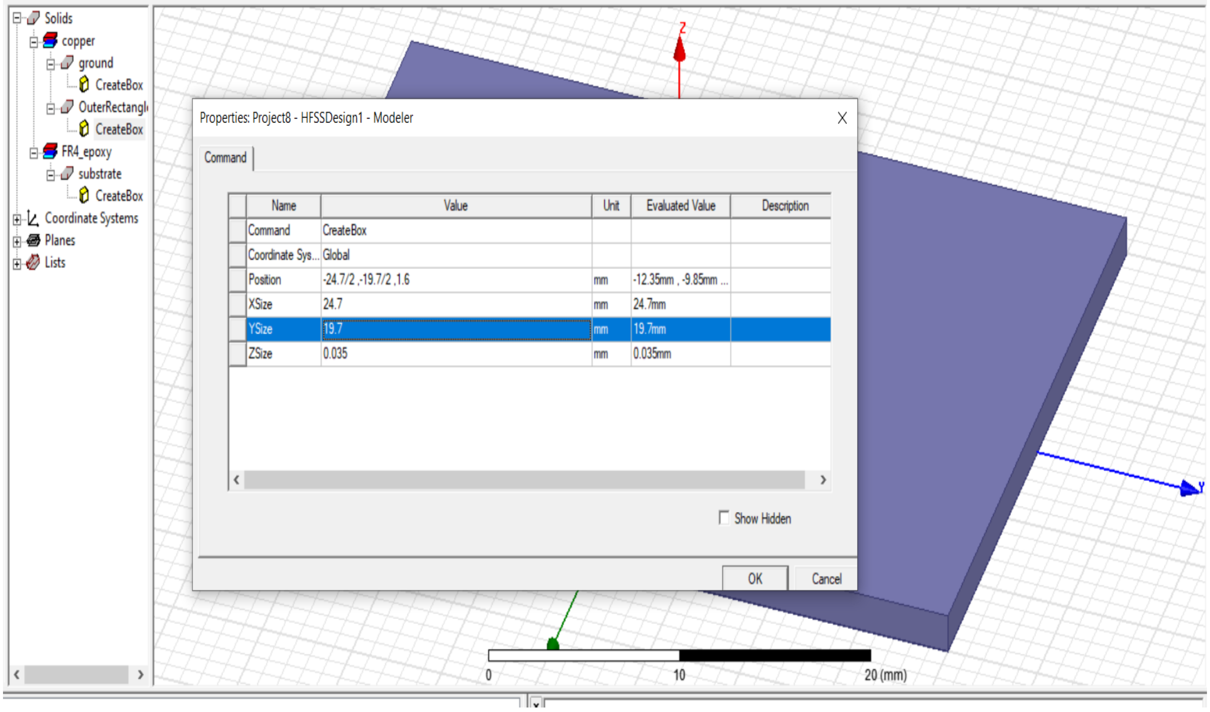
Step-1: Create a substrate by selecting a Box from upper palate of 30x40x1.6 mm^3 , material is FR4 epoxy.



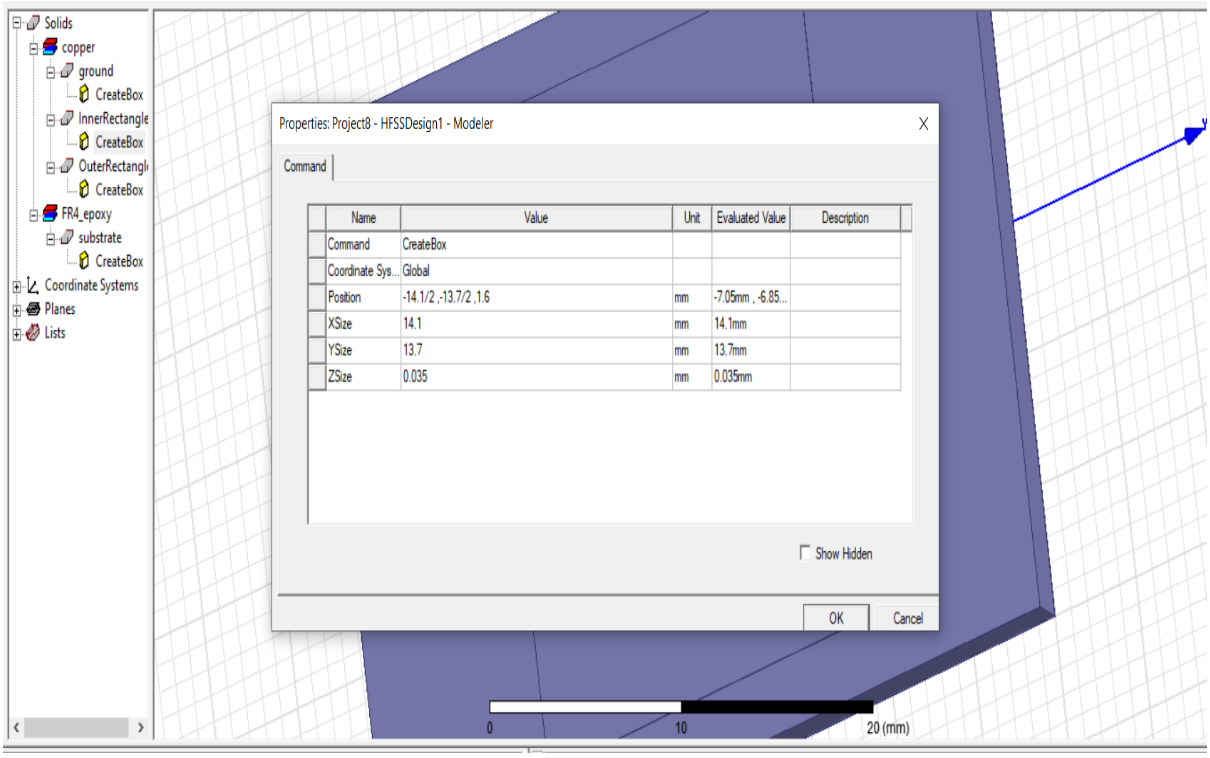
Step-2: Create a ground by selecting a Box from upper palate of 30x40x0.035 mm^3, material is copper.



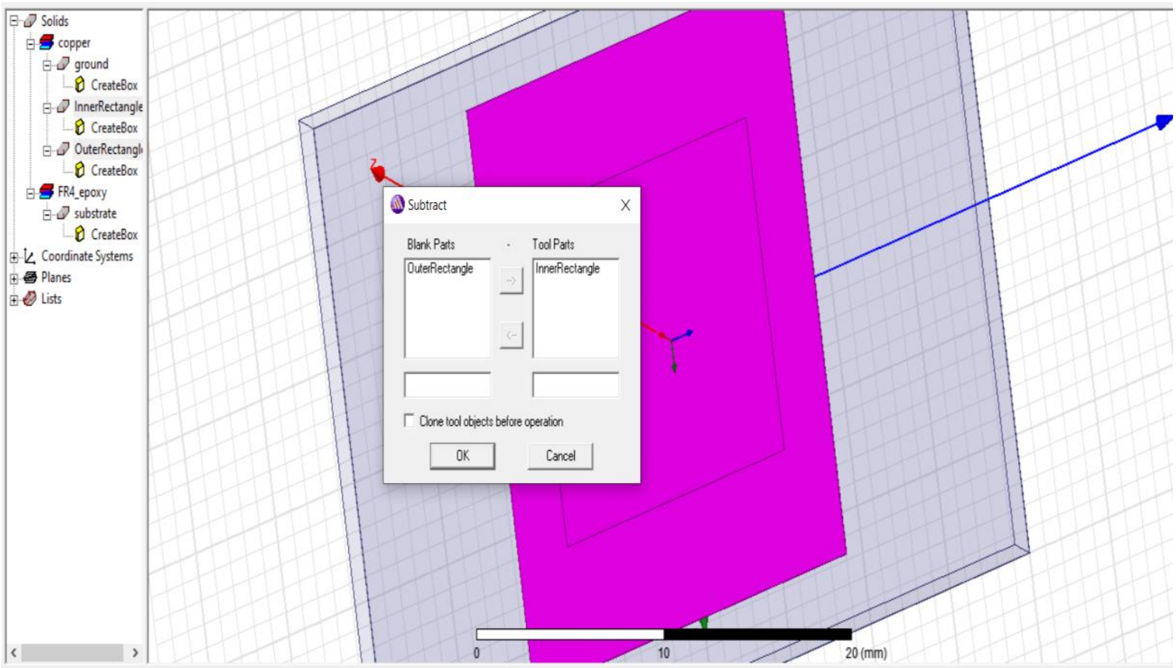
Step-3: For modelling of main line, create an Outer Rectangle by selecting a Box from upper palate of 24.7x19.7x0.035 mm^3, material is copper.



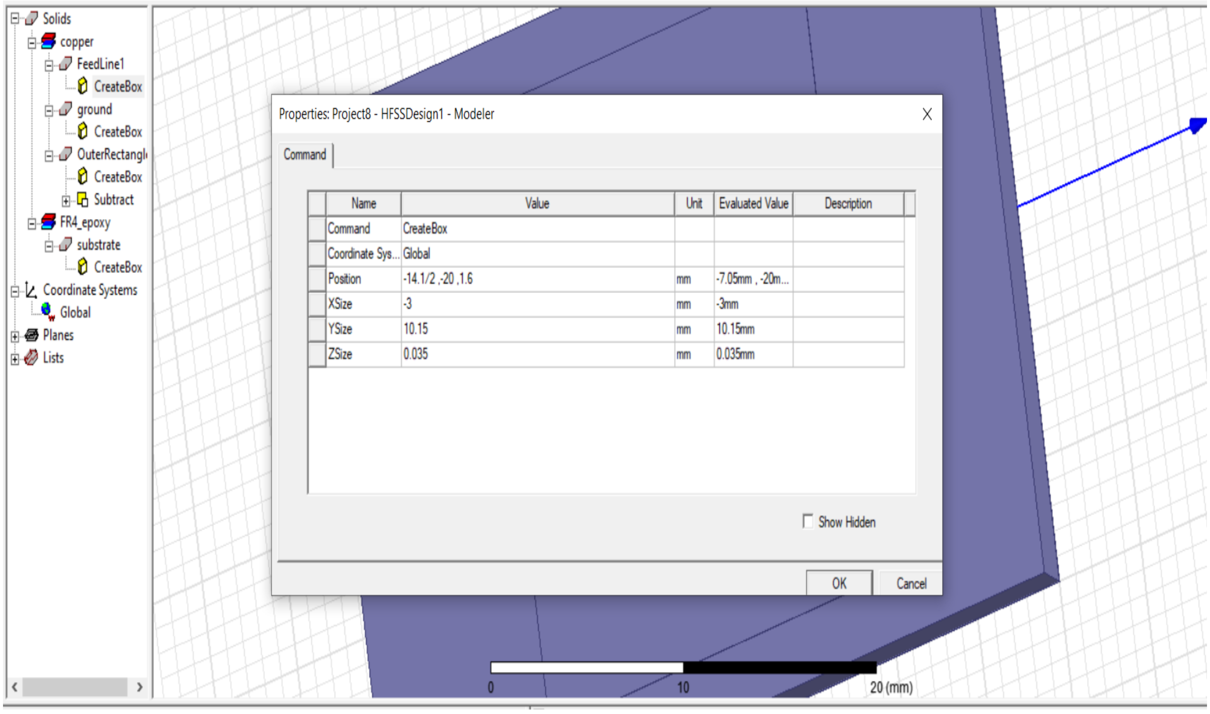
Step-4: For branch line, Create a Inner Rectangle by selecting a Box from upper palate of 24.7x19.7x0.035 mm^3 of same material.



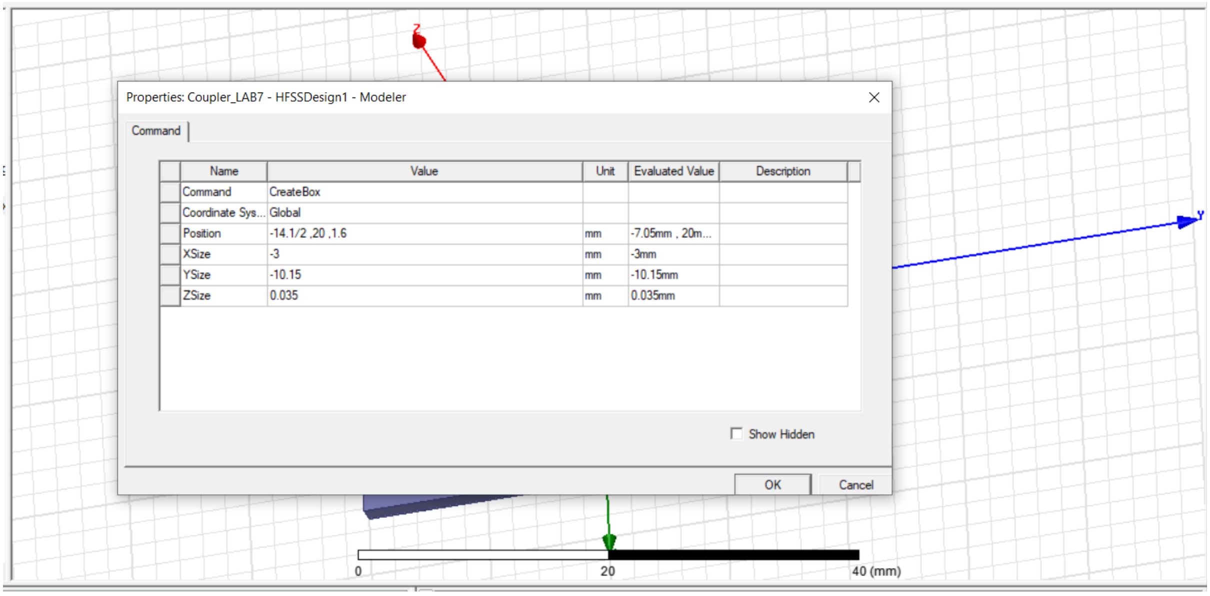
Step-5: At last, Subtract Inner Rectangle from Outer Rectangle by selecting both the box.



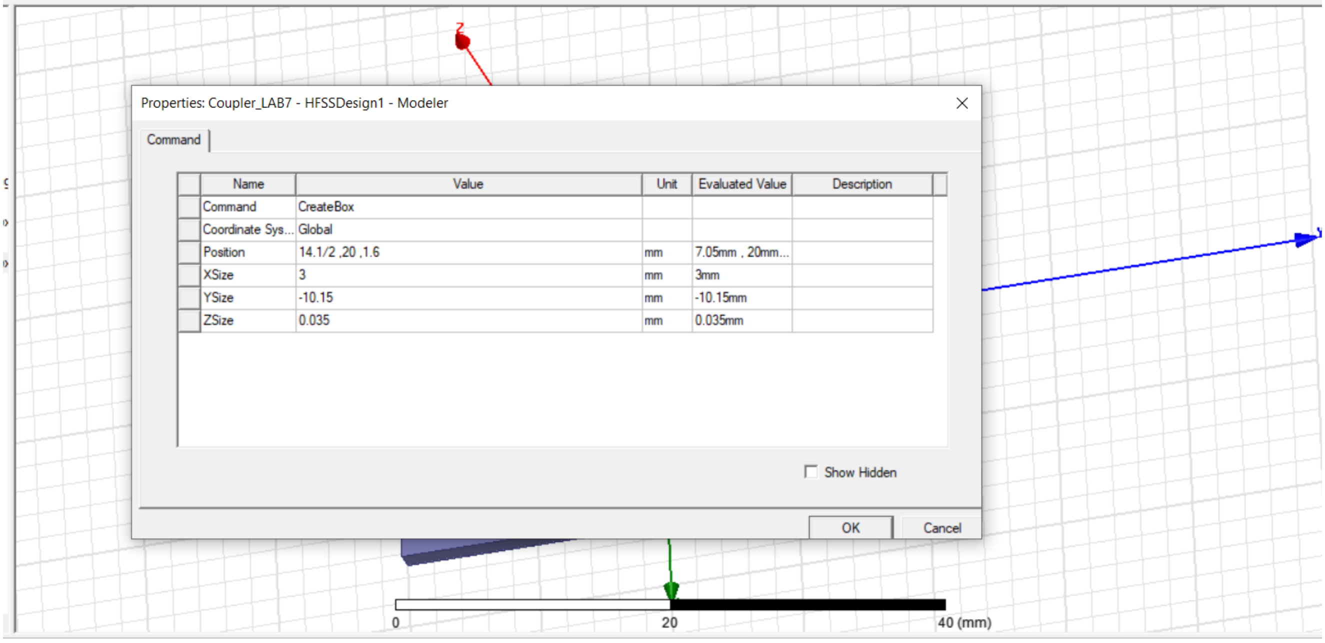
Step-6: For giving feed to branch line we have to create a feedline by selecting a Box of 3x10.15x0.035 mm^3 at port-1, of copper material.



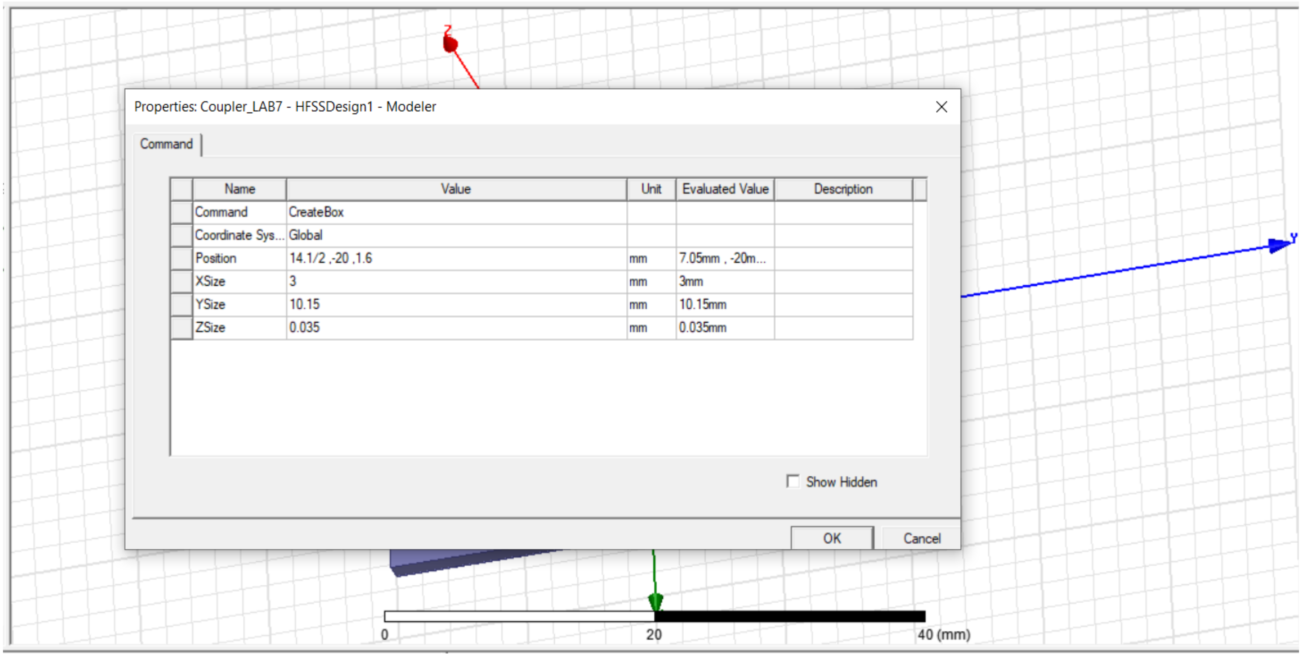
Step-7: Similarly, Create a FeedLine2 by selecting a Box of 3x10.15x0.035 mm^3 at port-2.



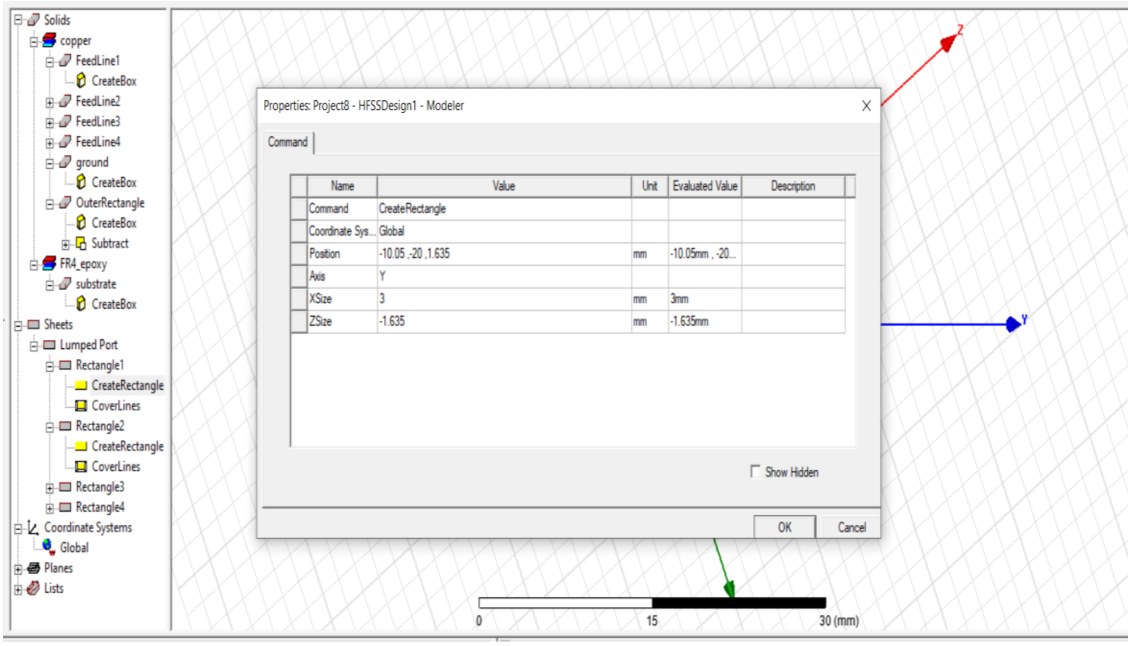
Step-8: Create a FeedLine3 at port-3 by selecting a Box of 3x10.15x0.035 mm^3 .



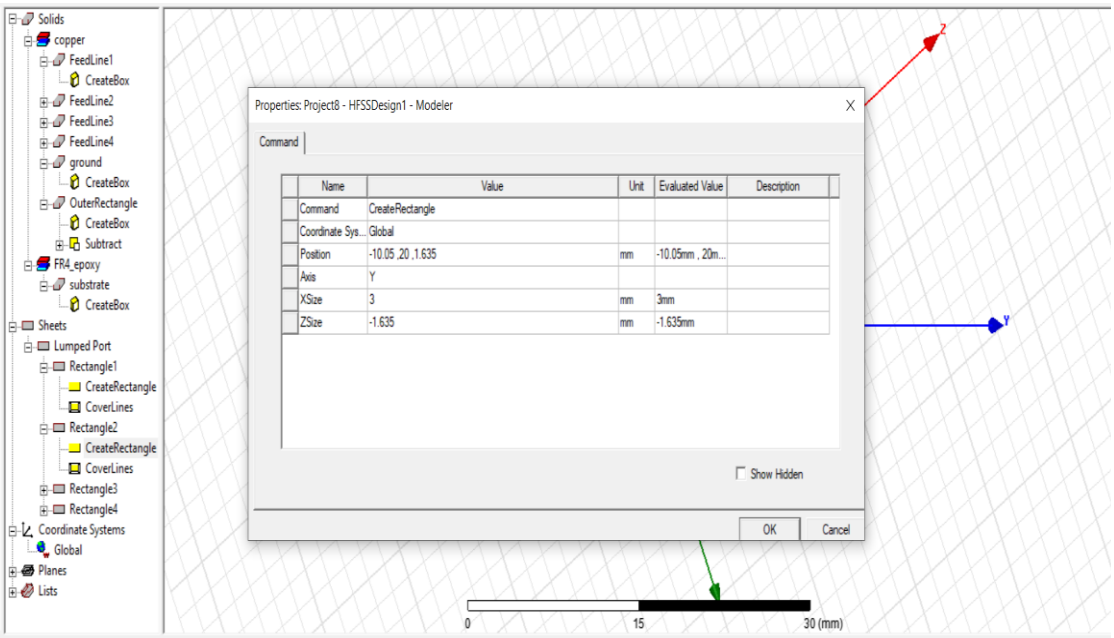
Step-9: Create a FeedLine4 by selecting a Box of 3x10.15x0.035 mm^3 of copper material at port-4.



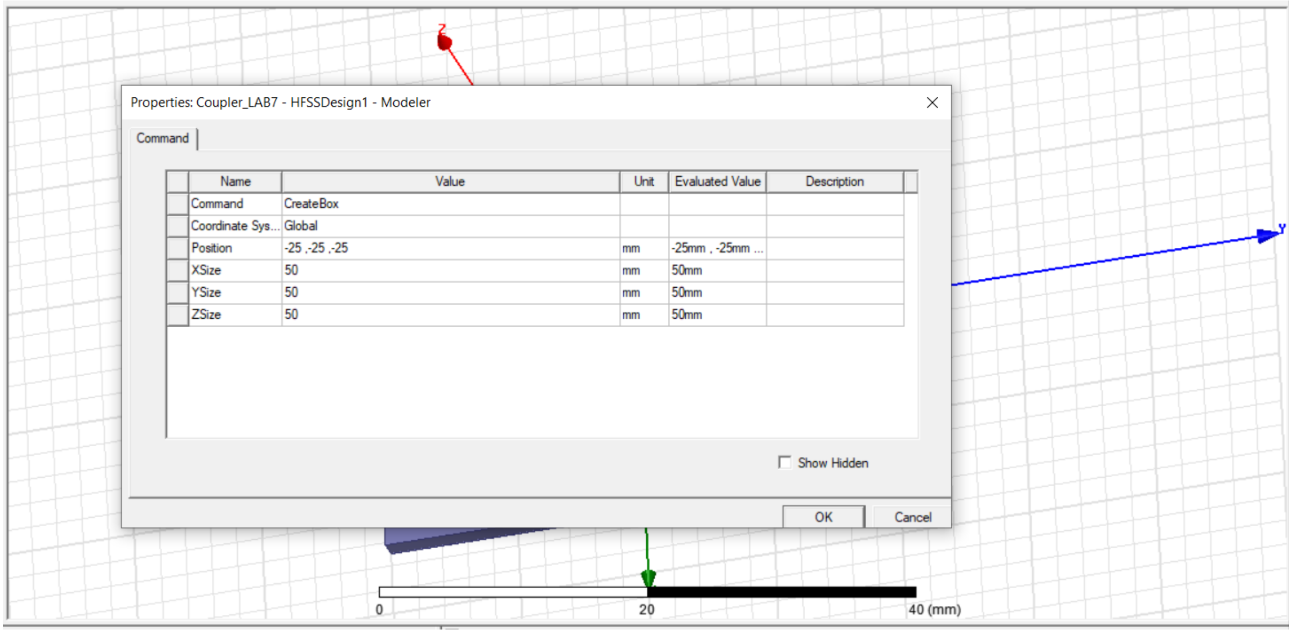
Step-10: For exciting the feedline, Create a Feed to give lumped port by selecting a rectangle of 3x1.635 mm^2. Drawing plane should be changed to ZX, rename it as Rectangle1.



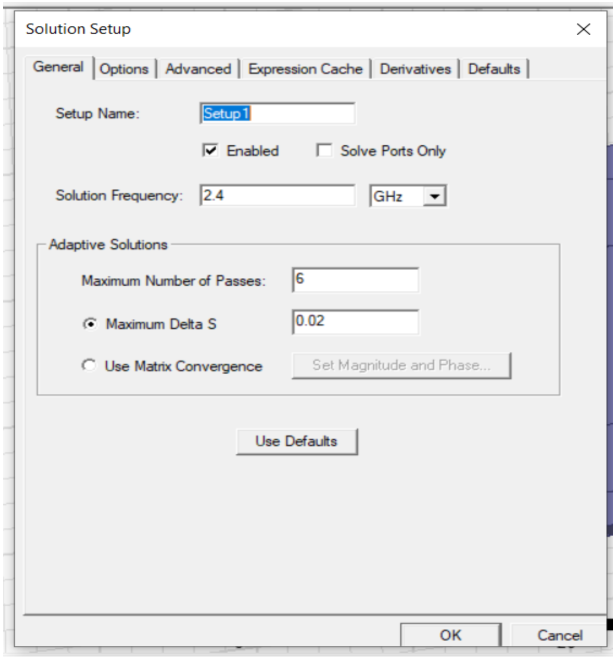
Step-11: Similarly, create lumped port at port-2 by selecting a rectangle of 3x1.635 mm^2. Repeat this step for all the consecutive ports.



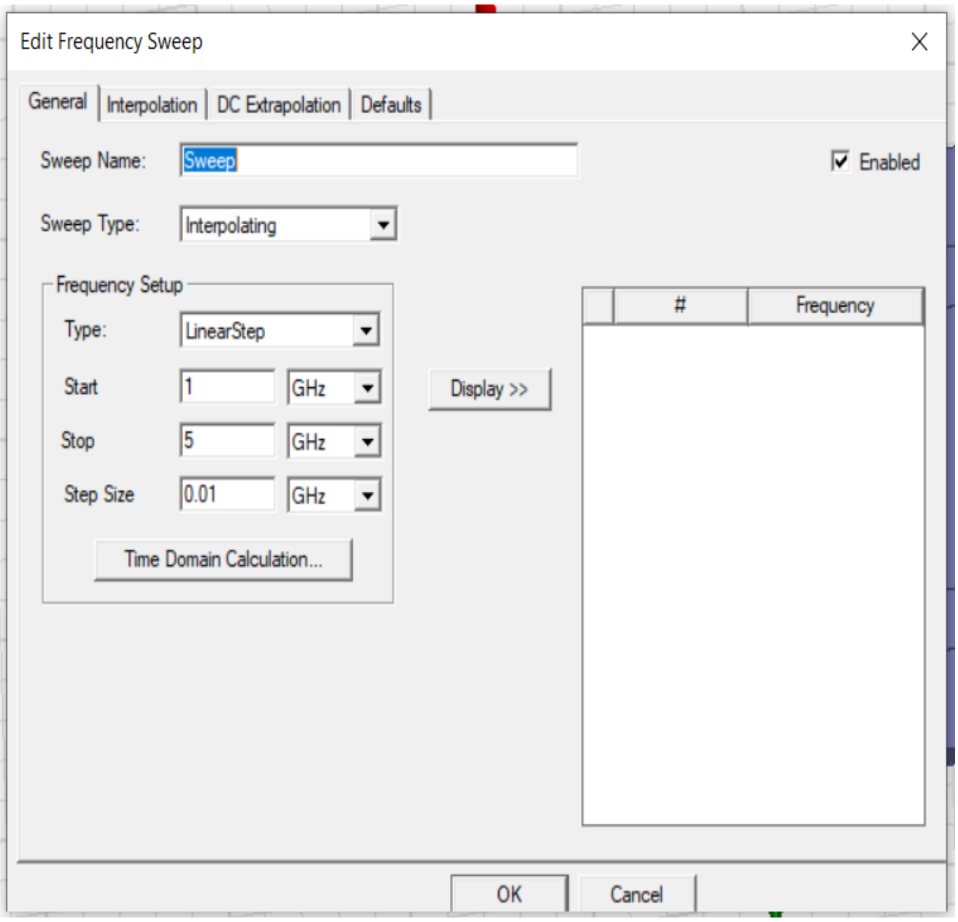
Step-12: For assigning the radiation baundary. Change the drawing plane to XY, Create a Rad_box by selecting a box of 50x50x50 mm^3 ,



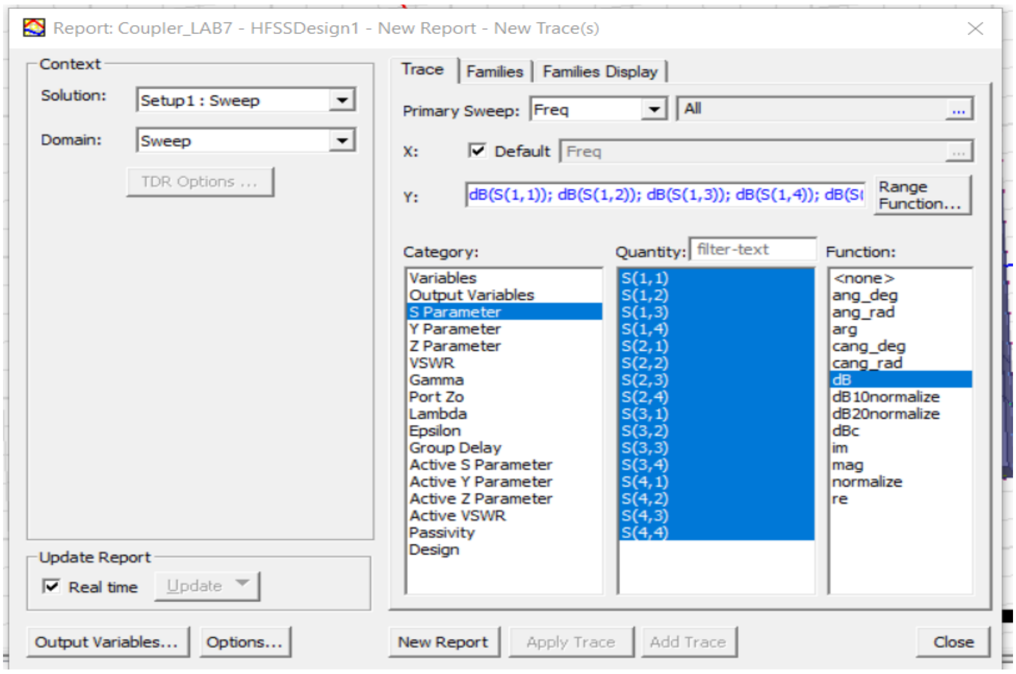
Step-13: Complete the solution setup by assigning solution setup, and solution frequency as 2.4 GHz.



Step-14: Add frequency sweep.

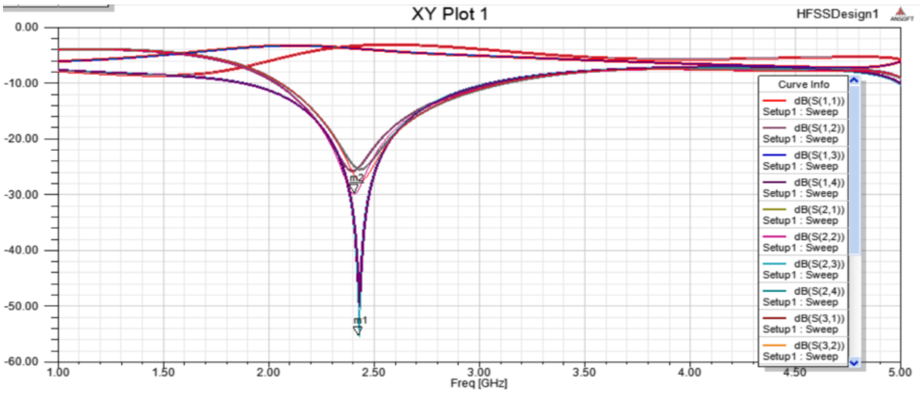


Step-15: Validate the structure and analyse all. For results, go to results section and choose rectangular plot.



❑ Results & Discussion

S- Parameter



➢ Similarly, design a 2-way power divider for microwave applications

❑ Design of a simple T- Junction Power Divider at 3.5 GHz:

1. Selected an appropriate substrate of thickness (h) and dielectric constant (ε_r) for the design of the power divider.

2. Calculate the wavelength λ_g from the given frequency specifications as follows: $\lambda_g = \frac{c}{\sqrt{\varepsilon_r} * f}$

Where, c is the velocity of light in air.

f is the frequency of operation of the coupler.

ε_r is the dielectric constant of the substrate.

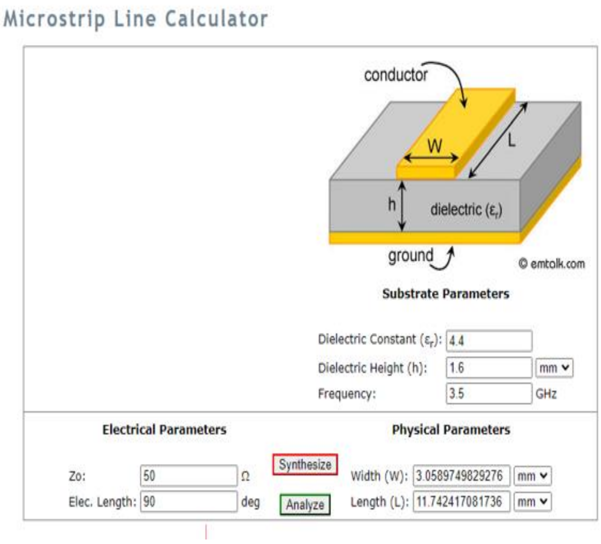
3. Synthesize the physical parameters (length & width) for the λ/4 lines with impedances of Z_0 and √2 Z_0 (Z_0 is the characteristic impedance of microstrip line which is = 50 Ω).

4. Calculate the physical parameters of the T-Junction power divider from the electrical parameters like Z_0 and electrical length using the above given design procedure.

○ SIMULATION (ANSYS HFSS):

➢ Power Divider Simulation at 3.5 GHz

First of all, we have to calculate the dimensions of the 50 Ohm and 70.7 Ohm microstrip line width lengths. Use online microstrip line calculator for the calculation.



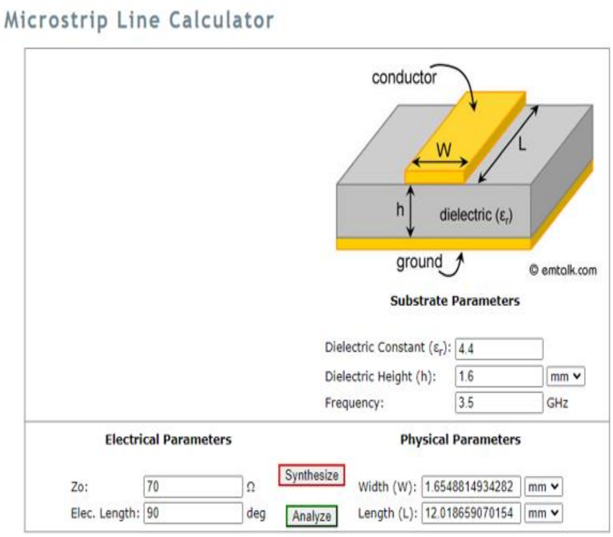


Fig. Microstrip Line calculator

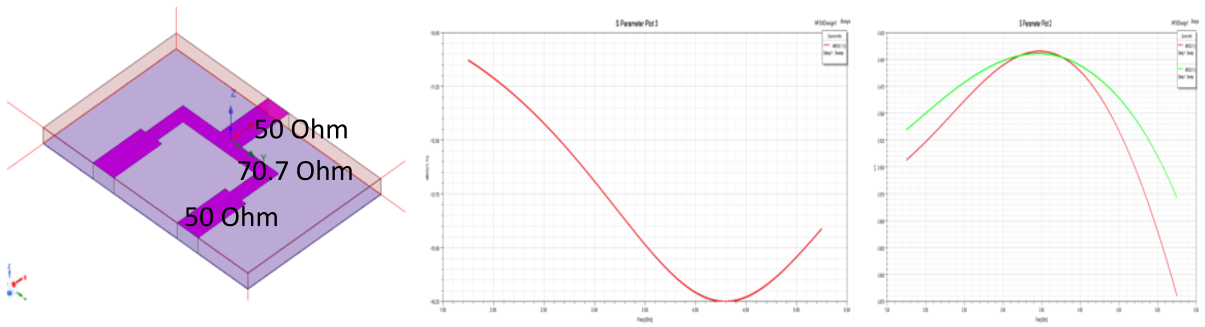


Fig. 2-way Power divider HFSS structure, reflection coefficient and transmission parameter in a 2-way PD

Simulated results:

Add various plots for the proposed antenna performance:

1. -10 dB impedance bandwidth (BW in GHz)
2. Isolation observation
3. coupling and directivity observation
4. S-parameter plot

Observation Table:

Frequency range of the microstrip coupler (-10dB BW)	**Isolation**	**Coupling**	**Directivity**

Frequency range of the Power divider (-10dB BW)	**|S11|**	**|S12|**	**|S13|**

Conclusions:

Please add some comments on these particular experiments related to the difficulties you have faced during simulation and also related to observation from variations of results with respect to different design parameters. Also mention some points related to necessary precaution that need to consider during simulation for getting desired results.

PHOTONICS

Experiment No.-1

OBJECTIVE: - Plot the Refractive index profile and Numerical aperture profile for α=1, 2, 3, 4, and 1000.

(a) Plot the refractive index profile for the values of α=1, 2, 3,...∞.

$$n^2(r) = n_1^2[1 - 2\Delta(r/a)^\alpha] \; ; \; 0<r<a \text{ (core)}$$

$$= n_1^2[1 - 2\Delta] \; ; \; r>a \text{ (cladding)}$$

(b) The local NA is defined for any shape of refractive index profile fiber by

$$NA(r) = [n^2(r)-n_2^2]^{1/2} \approx NA(0)[1-(r/a)^\alpha]^{1/2} \quad \text{for } r\leq a$$

$$=0 \quad \text{for } r\geq a$$

Where the axial numerical aperture is defined by $NA(0) = n_1(2\Delta)^{1/2}$. It is given n_1=1.5, n_2=1.48. Hence, plot the NA(r) versus (r/a) for α=1, 2, 3,... ∞ and comment on the results. Identify the various names of the refractive index profile.

SOFTWARE REQUIRED: - Matlab R2019a

THEORY: -

- In optics, the **refractive index** or **index of refraction** of a material is a dimensionless number that describes how fast light propagates through the material.
- It is expressed as a ratio of the speed of light in a vacuum relative to that in the considered medium. It is defined as

$$n = \frac{c}{v}$$

  where c is the speed of light in vacuum and v is the phase velocity of light in the medium. For example, the refractive index of water is 1.333, meaning that light travels 1.333 times as fast in a vacuum as in water.

Why Refractive index is important?

- The refractive index of a material medium is an important optical parameter since it exhibits the **optical properties** of the material.
- The refractive index coefficients are important parameters in the design of optical fiber and waveguide.
- It is used to calculate the focusing power of lenses.

- In optics, the **numerical aperture (NA)** of an optical system is a dimensionless number that characterizes the range of angles over which the system can accept or emit light.
- The numerical aperture (NA) of a fiber is a number that defines its light gathering capability.
- A larger NA corresponds to a larger acceptance angle, which result in the ability to collect more light.

$$NA(r) = \begin{cases} [n^2(r) - n_2{}^2]^{\frac{1}{2}} = NA(0)\sqrt{1-\left(\frac{r}{a}\right)^{\alpha}}; r < a \\ 0; otherwise \end{cases}$$

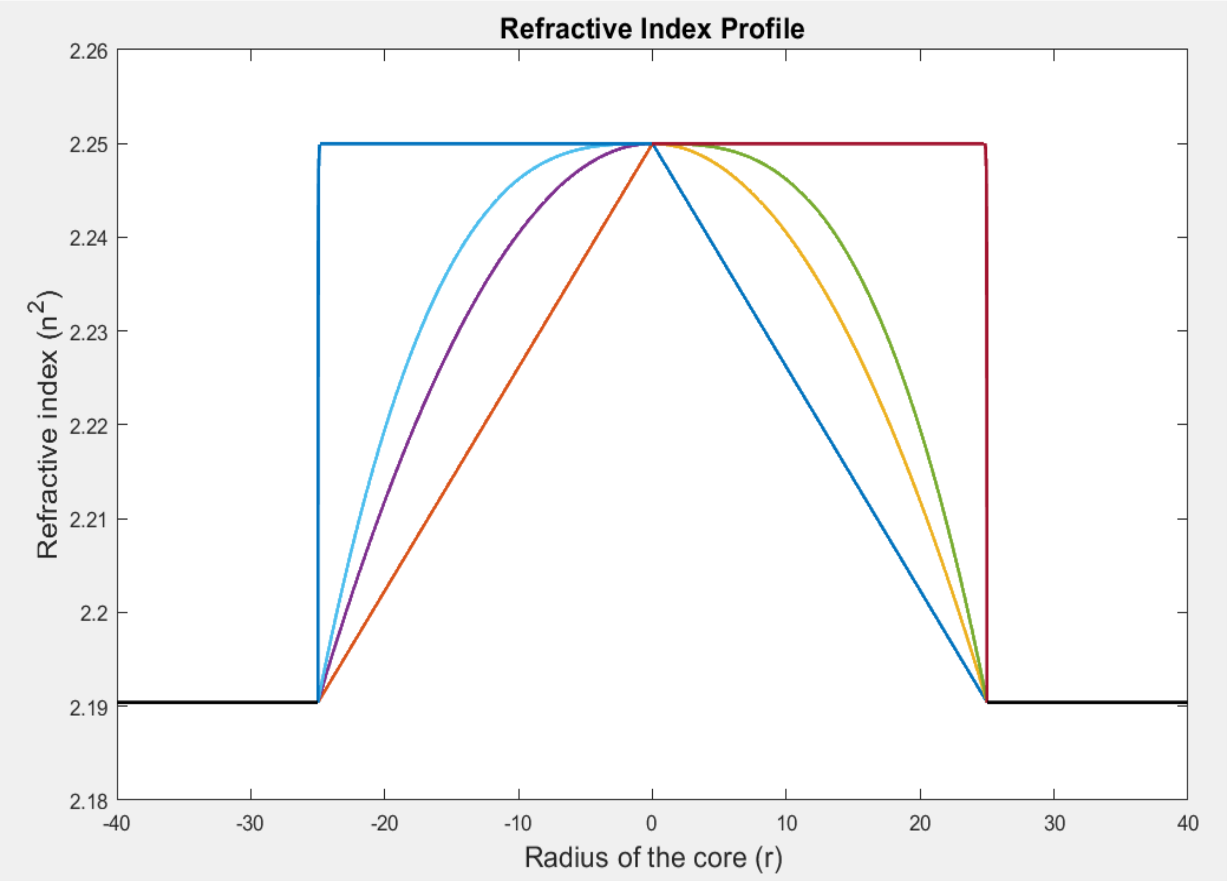
PROCEDURE: -

1) Matlab coding has to be done to plot those equations.

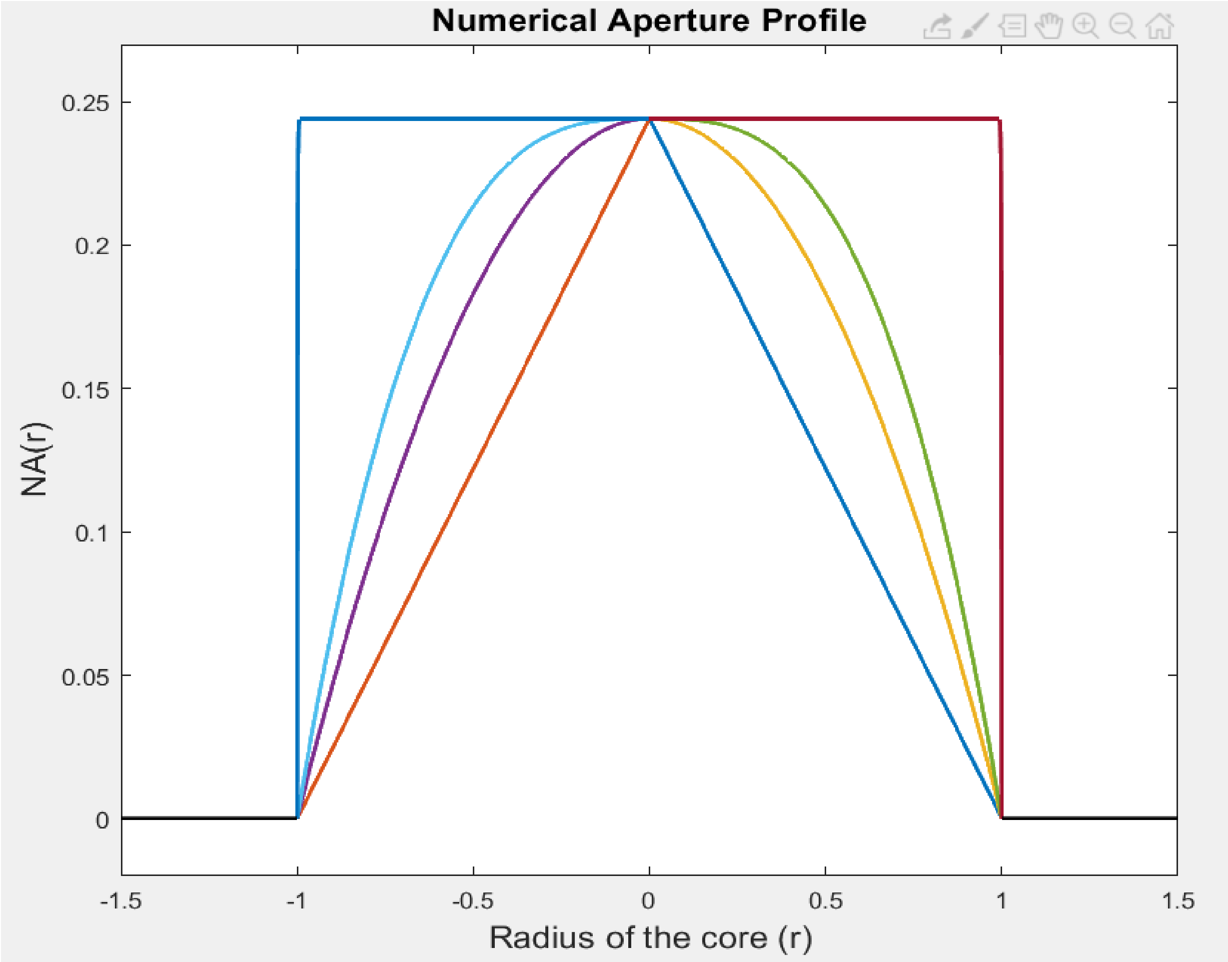
2) Plot all three questions and solve them with the help of the given values.

GRAPH: -

(a).



(b).



RESULT: -

α = 1; Triangular refractive index profile

α = 2; Parabolic refractive index profile

α = 3; Step index profile

(1) The graph becomes more flatter as we are increasing the value of 'α' in both graphs.

(2) The value of refractive index n(r) is constant for r >a.

Experiment No.-2

OBJECTIVE: - To study the material dispersion in silica fiber.

The material dispersion in silica fiber can be defined as:

$$D_m\left(\frac{ps}{km-nm}\right)=\frac{\Delta\tau}{L\Delta\lambda_0}=-\frac{1}{\lambda_0 c}\left(\lambda_0^{\ 2}\frac{d^2n}{d\lambda_0^{\ 2}}\right)\times 10^9$$

Where λ_0 is measured in µm and $c=3x10^8$ m/s.

$$n(\lambda_0)=C_0+C_1\lambda_0^{\ 2}+C_2\lambda_0^{\ 4}+\frac{C_3}{(\lambda_0^{\ 2}-l)}+\frac{C_4}{(\lambda_0^{\ 2}-l)^2}+\frac{C_5}{(\lambda_0^{\ 2}-l)^3}$$

where C_0 = 1.4508554, C_1 = - 0.0031268, C_2 = - 0.0000381, C_3 = 0.0030270,
C_4 = - 0.0000779, C_5 = 0.0000018, l = 0.035

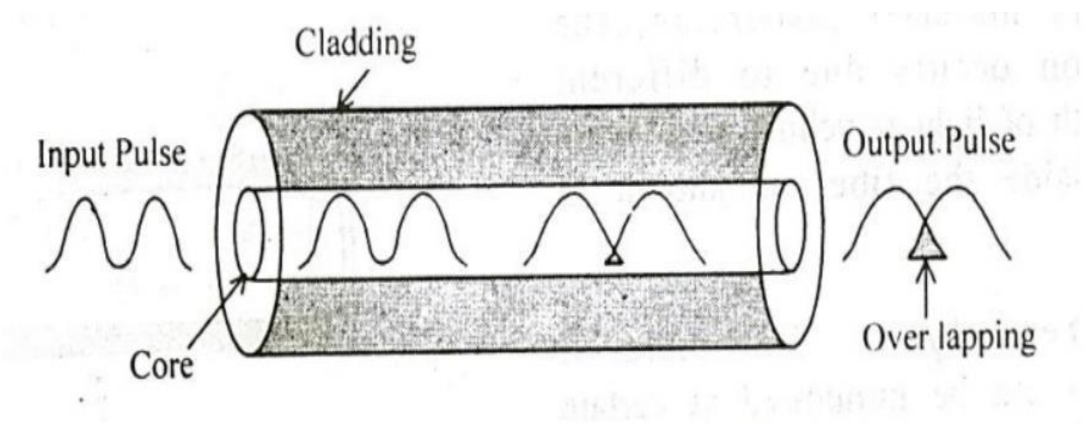
Plot:

1) $n(\lambda_0)$ v/s λ_0
2) $dn(\lambda_0) / d\lambda_0$ v/s λ_0
3) $d^2n(\lambda_0) / d\lambda_0^2$ v/s λ_0
4) D_m v/s λ_0

SOFTWARE REQUIRED: - Matlab R2019a

THEORY: -

When an optical signal or pulse is guided into the fiber the pulse spreads/broadens as it transmits through the fiber. This occurrence is called dispersion.



The spreading of the optical pulse limits the information-carrying capacity of the fiber.

There are two different types of dispersion in optical fibers:

1. Intramodal dispersion
2. Intermodal dispersion

Intramodal or chromatic dispersion occurs in all types of fibers. Intermodal dispersion occurs only in multimode fibers.

Intramodal dispersion primarily depends on fiber materials. There are two types of Intramodal dispersion:

1. Waveguide Dispersion
2. Material Dispersion

Waveguide Dispersion: - It is caused by the difference in the index of refraction between core and cladding.

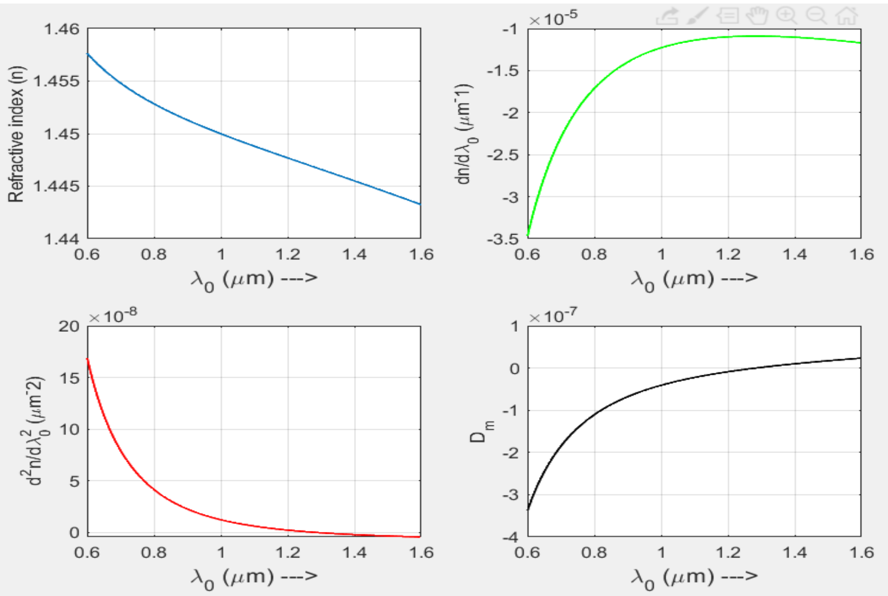
Material Dispersion: - Material dispersion take place due to different wavelength traveling at different speed inside the fibers. From the material dispersion equation, we can say that the material dispersion is proportional to the spectral width (Δλ) and also to the length 'l' traversed in the medium. Material dispersion is usually specified in the units of **ps/km-nm**.

PROCEDURE: -

1) Matlab coding has to be done to plot those equations.

2) Plot all four questions and solve them with the help of the given values.

GRAPH: -



RESULT: -

1. The value of $n(\lambda_0)$, $dn(\lambda_0)/d\lambda_0$, and $d^2n(\lambda_0)/d\lambda_0^2$ for pure silica is obtained from the given equation for the given length.
2. The wavelength where $d^2n(\lambda_0)/d\lambda_0^2 = 0$ is called zero material dispersion wavelength (ZMDW) and a pulse of light centered around the ZMDW and passing through fused silica suffers negligible dispersion.

Experiment No.-3

OBJECTIVE: - Equalization of optical channel strength in a multi-wavelength fiber optic system using attenuators.

Design a multi-wavelength fiber optic system with the given components and equalize the optical channel strength (30 dBm) using optical attenuators so that all the channels have similar power levels.

SOFTWARE REQUIRED: - OptiSystem

Components required for Optisystem:

1. C W Lasers – 4 (P1 = 60 dBm, 1510 nm; P2 = 50 dBm 1530 nm; P3 = 40 dBm, 1550 nm; P4 = 70 dBm, 1570 nm)
2. WDM Mux 4x1 -1 (Channel Wavelength=1510, 1530, 1550, 1570 in nm)
3. WDM Demux 1x4 - 1
4. Optical Attenuator - 4
5. Optical power Meter - 4
6. Optical Spectrum Analyzer – 5

THEORY: -

An optical attenuator, or fiber optic attenuator, is a device used to reduce the power level of an optical signal, either in free space or in an optical fiber. Optical attenuators are commonly used in fiber-optic communications, either to test power level margins by temporarily adding a calibrated amount of signal loss, or installed permanently to properly match transmitter and receiver levels. Sharp bends stress optic fibers and can cause losses. If a received signal is too strong a temporary fix is to wrap the cable around a pencil until the desired level of attenuation is achieved. However, such arrangements are unreliable, since the stressed fiber tends to break over time.

Fixed Optical Attenuators: Fixed optical attenuators used in fiber optic systems may use a variety of principles for their functioning. Preferred attenuators use either doped fibers, or misaligned splices, or total power since both of these are reliable and inexpensive. Fixed optical attenuators in doped optical fiber usually have 1dB, 5dB, and 10dBetc.

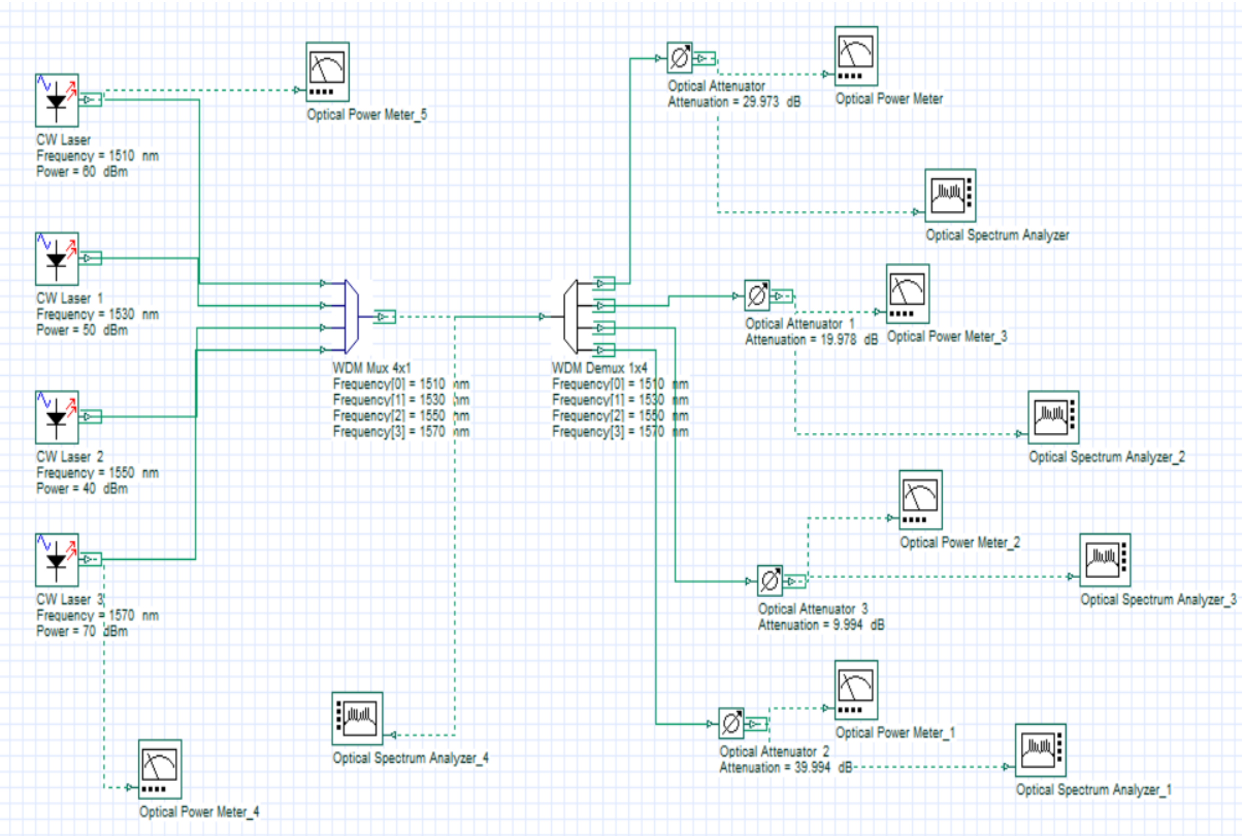
Variable Optical Attenuators: Variable optical test attenuators generally use a variable neutral density filter. Despite its relatively high cost, this arrangement has the advantages of being stable, wavelength insensitive, mode insensitive, and offering a large dynamic range. Other schemes such as LCD, variable air gap, etc. have been tried over the years, but with limited success. They may be either manually or motor control. Variable optical attenuators have an adjustable range from 0.5dB to 20dB, some have very high resolution i.e. 0.01dB or even

Working Principles of Fiber Optic Attenuators: Optical attenuators achieve the desired attenuation in optical fiber links in three different principles, which relatively are the gap-loss principle, absorptive principle, and reflective principle**.**

Optical Attenuator Applications:

- Test power level margin by temporarily adding a calibrated amount of signal loss.
- Installed permanently to properly match transmitter and receiver levels.

CIRCUIT DIAGRAM: -



SIMULATION PROCEDURE: -

Run the simulation and record the data: Output of Optical Power (in dBm), Optical spectrum after Demux, and Attenuation (in dB).

OBSERVATION TABLE: -

Sl. No.	Wavelength (nm)	Input Power (dBm)	Attenuation (dB)	Output Power (dBm)

RESULT: -

Show the output spectrum of all the four attenuators, WDM mux, and de-mux.

Experiment No.-4

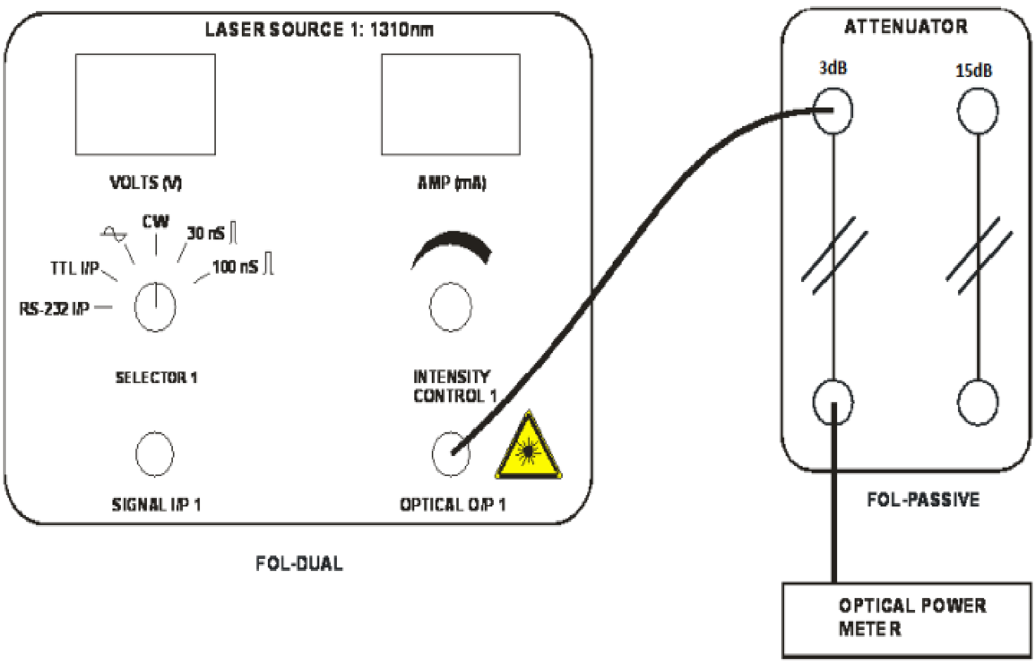
Objective: - To Measure the Attenuation in Fiber Optic Attenuator

Apparatus Required: -

- FOL-DUAL
- FOL-PASSIVE
- 1 meter ST-ST glass Fiber cables
- Optical Power Meter

Theory: - In certain applications we may need to use calibrated attenuators in order to reduce the luminescent intensity of a known quantity. The fiber attenuators are easy to realize. They are made by realizing bad splicing between two fibers. The two cores of the two identical fibers are voluntarily spliced together transversely. Optical attenuators used in fiber optic communications systems may use a variety of principles for their functioning. Those using the gap – loss principle are sensitive to the modal distribution ahead of the attenuator, and should be used at or near the transmitting end, or they may introduce less loss than intended. Optical attenuators using absorptive or reflective techniques avoid this problem. The basic types of optical attenuators are fixed, step-wise variable and continuously variable.

Block Diagram



BLOCK DIAGRAM FOR MEASUREMENT OF ATTENUATION IN FIBER OPTIC ATTENUATOR

Procedure: -

1. Make sure that the intensity control 1 and intensity control 2 ports are turned fully

anticlockwise before switching on the FOL- DUAL module.
2. Keep the selector 1 pot in FOL-DUAL module on CW selection.
3. Connect the optical power meter to the optical O/P 1 port of the laser source 1310 nm on the FOL-DUAL module.
4. Gradually turn the Intensity Control 1 Port clockwise till you get around 1.1mW of optical power reading on the Optical Power meter. Note down this as power P1.
5. Now remove the power meter and connect Optical O/P 1 port to one of the ports of the 3 dB attenuator on the FOL-Passive module.
6. Connect the optical power meter to remaining port of the 3dB attenuator.
7. Note down the reading as power P2 and find out the Attenuation loss,
8. A_{dB} = 10 log (P2 / P1) where, P2 is the Optical power after attenuator and P1 is the laser source power input to attenuator.
9. Repeat the measurement after altering the ports of the Attenuator. Thus deduce the attenuation A_{dB} in both the directions
10. Repeat the experiment for 15dB attenuator and 1550nm Laser source and calculate the attenuation, Loss A_{dB}.

Measurements

Example:

P1 (1310nm Laser source power input to 3dB Attenuator) = 1.1mW
P2 (Optical power after 3dB attenuator) = 491.35uW
Attenuation loss for 3dB attenuator,
A_{dB} = 10 log (P2 / P1)
= -3.5dB

Example:

P_1 (1310nm Laser source power input to 15dB Attenuator) = 1.1mW
P_2 (Optical power after 15dB attenuator) = 31.00uW
Attenuation loss for 15dB attenuator,
A_{dB} = 10 log (P_2 / P_1)
= -15.5dB

Conclusion; -

The Attenuation for 3 dB and 15 dB attenuators is verified with 1310nm and 1550nm Laser source.

Experiment No.-5

Objective: **-** To Measure the Insertion Losses & Isolation Rate in Fiber Optic Isolator.

Apparatus Required: -

- FOL-DUAL
- FOL-PASSIVE
- 1 meter ST-ST glass Fiber cables
- Optical Power Meter

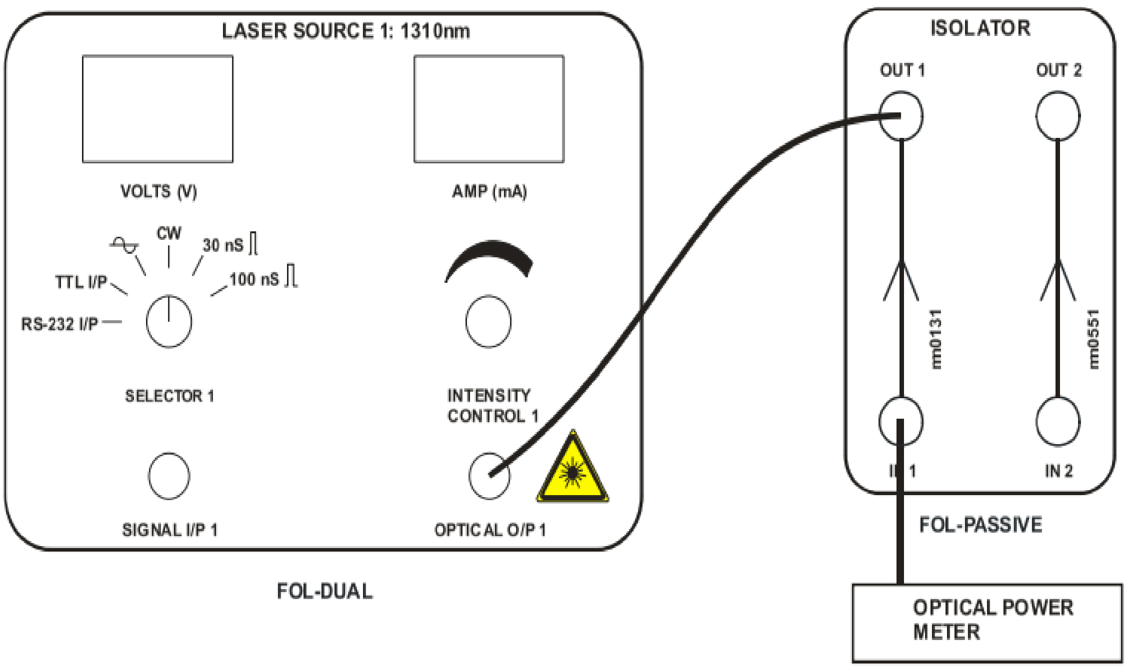
Theory: - An optical isolator, or optical diode, is an optical component which allows the transmission of light in only one direction. They are typically used to prevent unwanted feedback into an optical oscillator, such as a laser cavity. The operation of the device depends on the Faraday effect (which in turn is produced by magneto-optic effect), which is used in the main component, the Faraday rotator.

The main component of the optical isolator is the Faraday rotator. The magnetic field, ***B***, applied to the Faraday rotator causes a rotation in the polarization of the light due to the Faraday Effect. The angle of rotation, β, is given by,

$$\beta = \nu \, B \, d$$

Where, ν is the Verdict constant of the material (amorphous or crystalline; solid, liquid, or gaseous) of which the rotator is made, and *d* is the length of the rotator. Specifically for an optical isolator, the values are chosen to give a rotation of 45 degrees.

Block Diagram



BLOCK DIAGRAM FOR MEASUREMENT OF ISOLATION RATE IN FIBER OPTIC ISOLATOR

Procedure

1. Make sure that the intensity control 1 and intensity control 2 ports are turned fully anticlockwise before switching on the FOL- DUAL module.
2. Keep the Selector 1 pot in FOL-DUAL module on CW selection.
3. Connect the optical power meter to the Optical O/P 1 port of the Laser Source: 1310nm on the FOL-DUAL module.
4. Gradually turn the Intensity Control 1 Port clockwise till you get around 1.3mW of optical power reading on the Optical Power meter. Note down this as power P_1.
5.Now remove the power meter and connect Optical O/P 1 port to input port of the isolator in FOL-PASSIVE module.
6. Connect the optical power meter to output port of the Isolator.
7. Note down the reading as power P_2 and find out the Insertion Losses,
$a_{dB} = 10 \log (P_2 / P_1)$. Where, P_2 is the Optical output power after Isolator and P_1 is the Laser source power input to Isolator.
8. Connect the optical power meter to the Optical O/P 1 port of the Laser Source: 1310nm on the FOL-DUAL module.
9. Gradually turn the Intensity Control 1 Port clockwise till you get around 1.7mW of optical power reading on the Optical Power meter. Note down this as power P_3.
10 Now connect the Optical O/P 1 port to output post of the isolator in FOL-PASSIVE module. Connect the optical power meter to Input port of the Isolator.
11. Connect the optical power meter to Input port of the Isolator.
12. Note down the reading as power P_4.
13.Calculate the Isolation rate, $I_{dB} = 10 \log (P_3 / P_4)$.
14. Repeat the measurements for 1550nm Laser source

Measurement

Example

P_1 (1310nm Laser source power input to Isolator input) = 1.3mW
P_2 (Optical power at Isolator output) = 1.1mW
Insertion losses are,
$\alpha_{dB} = 10 \log (P_2 / P_1)$
$= -0.72dB$

P_3 (1310nm Laser source power input to Isolator output) = 1.7mW
P_4 (Optical power at Isolator input) = 150ηW
Isolation Rate is,
$I_{dB} = 10 \log (P_4 / P_3)$

$= -40dB$

Conclusion:

We note that the Isolators are very efficient on the operating wavelength as they have low insertion losses (0.72dB for example) and an isolation rate that is higher than 40dB.