ANTENNA DESIGN GUIDE

(A TUTORIAL HANDBOOK)

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SECTION 1: DUAL BAND MIMO PIFA ANTENNA

Prepared by: Kobina Ackon Annan & Sean Donkor (Telecom Eng. 2021)

INTRODUCTION

ANSYS HFSS is a 3D electromagnetic (EM) simulation software for designing and simulating high frequency electronic products such as antennas, antenna arrays, RF or microwave components, high speed interconnects, filters, connectors, IC packages a printed circuit board. Engineers worldwide use ANSYS HFSS software to design high frequency, high speed electronics found in communication systems, satellites and IoT products.

This book introduces the structure and design of a dual band MIMO PIFA antenna for Bluetooth and WIFI application in laptops operating at 2400/5000 for Wi-Fi and 2450 for Bluetooth. This guide will typically walk you through the steps to build the geometry, setup the solution, run the analysis, and evaluate the results by generating plots using ANSYS HFSS 2020.

By following the steps in this guide you will learn how to perform the following tasks in HFSS:

1. Draw the geometric models.
2. Add the boundaries and excitation.
3. Specify solution setting for the design.
4. Run HFSS transient simulation.
5. Create plots for the results.

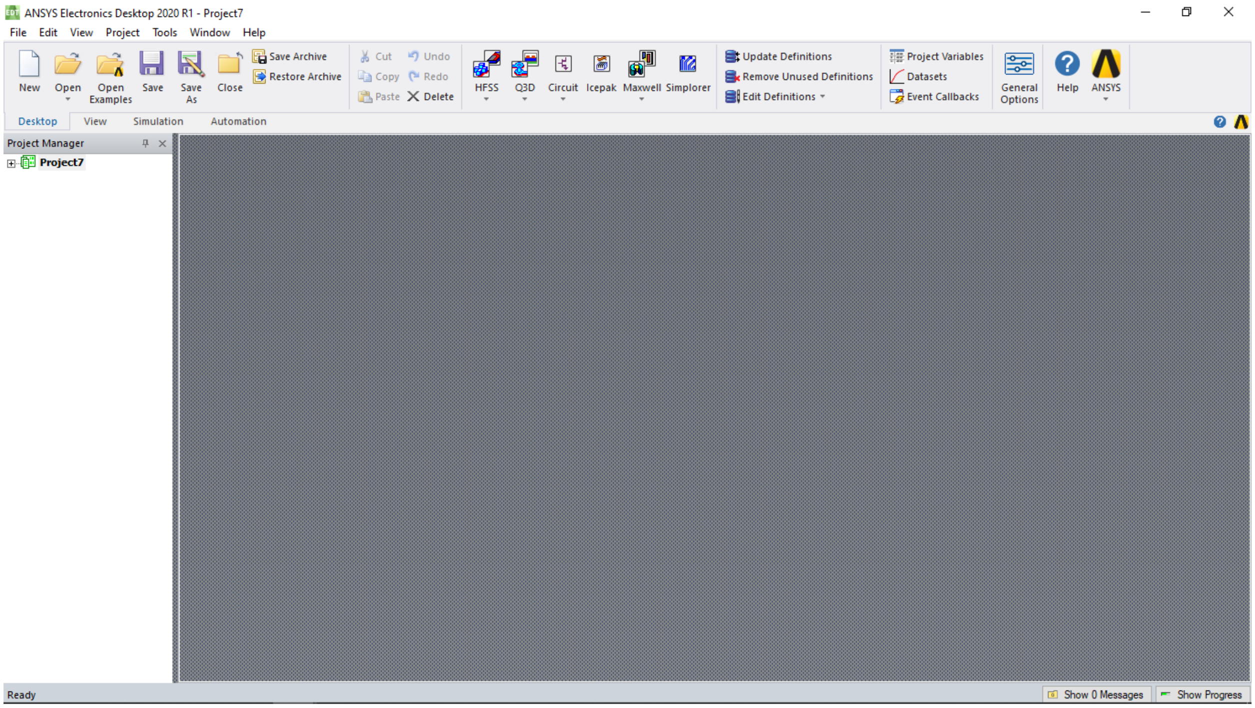
For basic design tutorials using HFSS:

https://www.youtube.com/playlist?list=PLdIVd39LNkpSaTzAFCS_jh3sV3Gc21mNg

1. <u>STARTING HFSS</u>

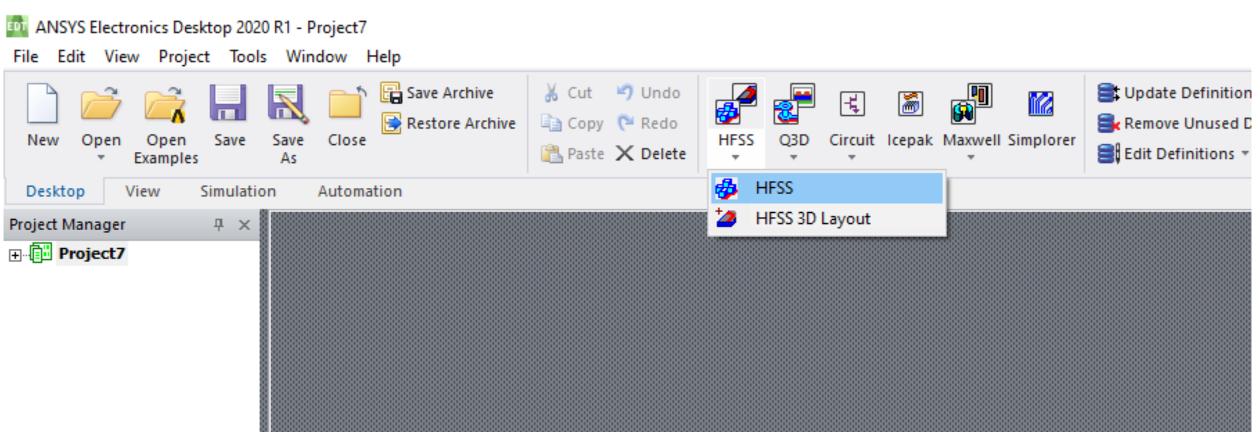
To be able to start the project you would have to first start or launch the software.

- **Launching ANSYS Electronics Desktop 2015**
  a. Select **Programs** > **ANSYS Electromagnetics** > **ANSYS EM Suite 2020 R1**
  b. Select **ANSYS Electronics Desktop 2020 R1**



2. <u>CREATING THE PROJECT</u>

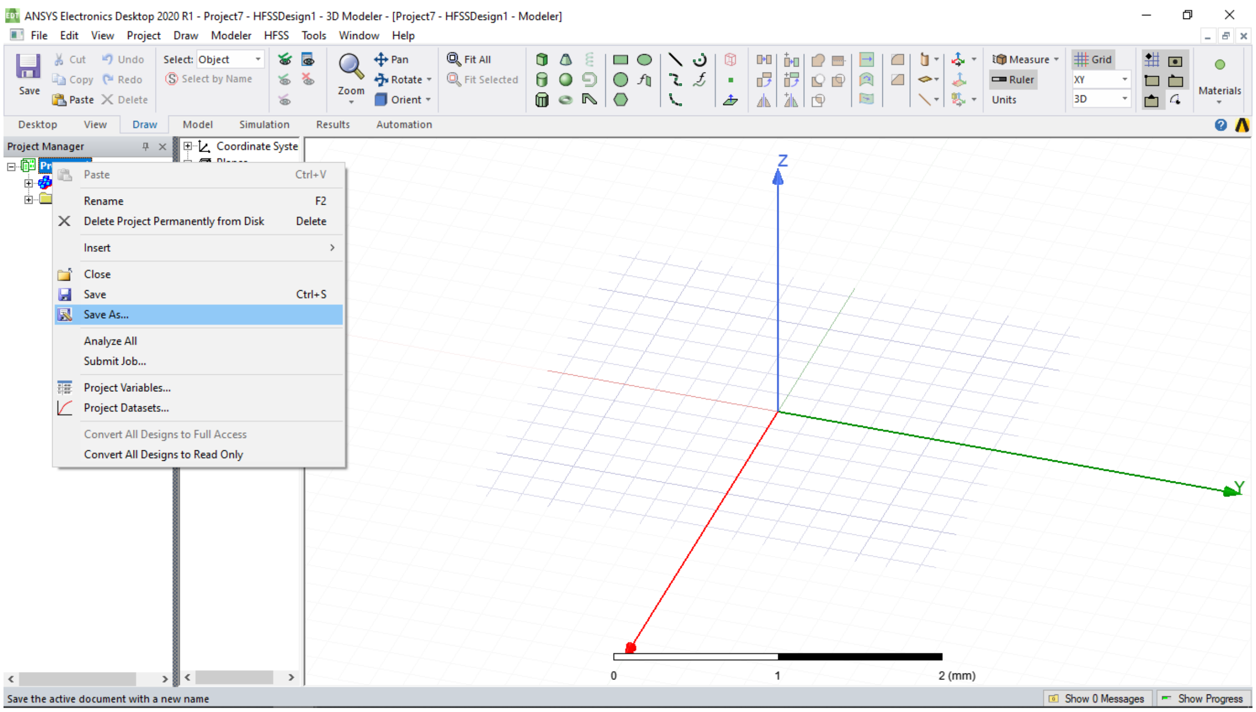
- To begin working with geometrics you need to insert an HFSS design.
  a. From the toolbar, double click on the HFSS icon to open an HFSS project.



3. WORKING WITH THE GEOMETRICS

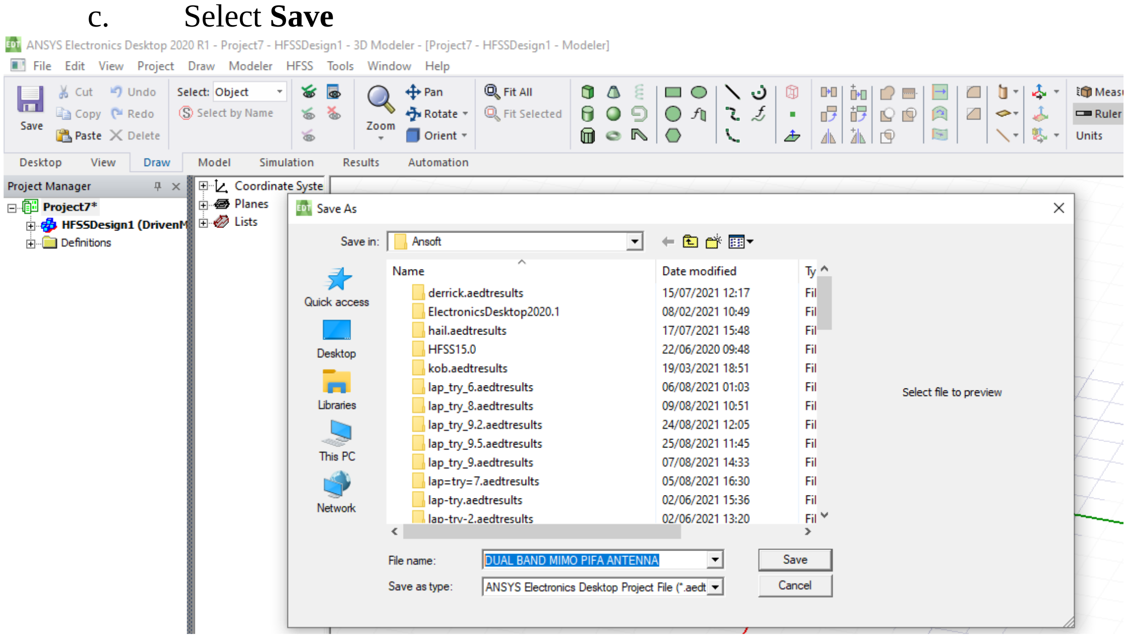
- On the left side of the HFSS window, right click on **Project** from the Project Manager pane.

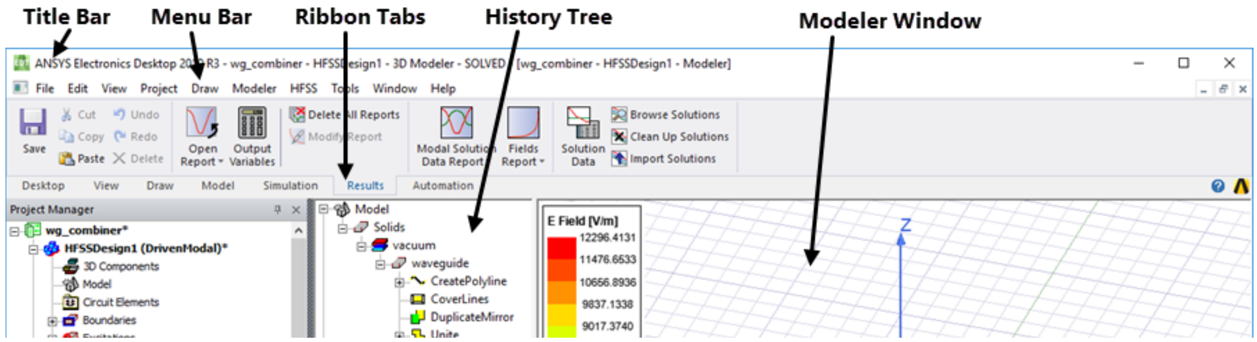
  a. Select **Save As** from the pop up.



  b. Enter the File name as **DUAL BAND MIMO PIFA ANTENNA**

  c. Select **Save**

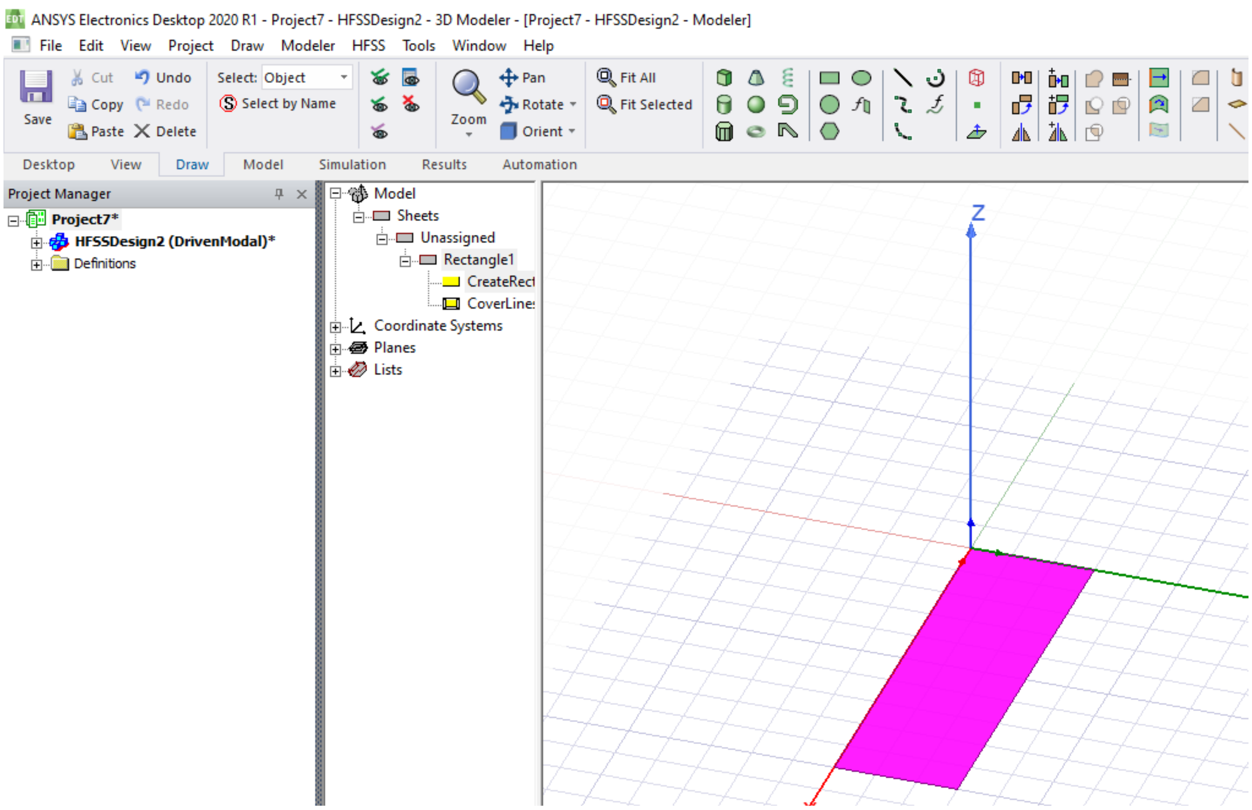




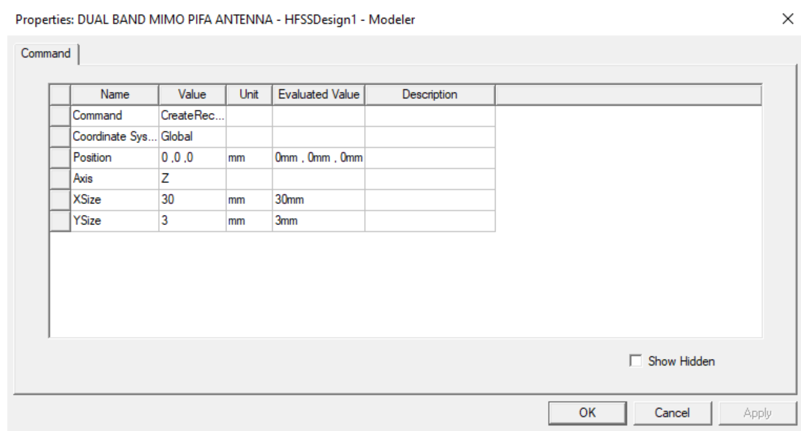
4. DRAW THE GEOMETRIC MODELS

❖ Creating the Radiating Patch.

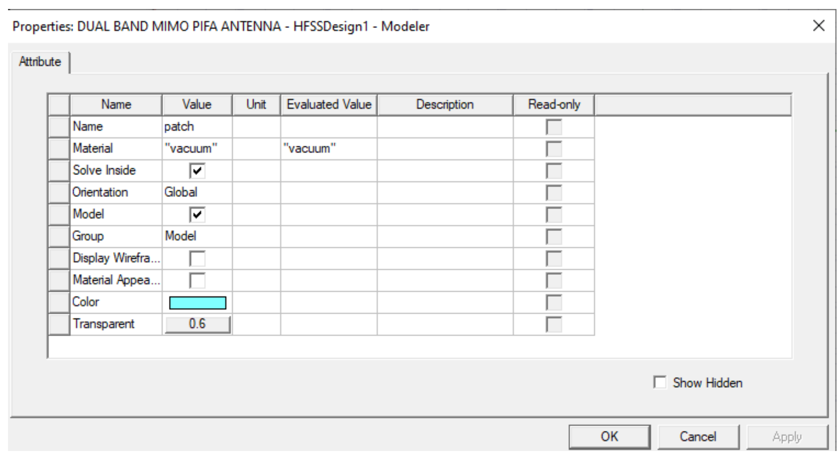
- ➢ From the *Draw* Ribbon Tab, select the rectangle tool
- ➢ In the *Modeler Window*, click and drag from the origin to draw the rectangle.



- From the *History Tree*, right click on the **CreateRectangle** to change the dimensions and position of the rectangle.
    - Position: **0, 0, 0 mm**
    - Axis: **Z**
    - Xsize: **36 mm**
    - Ysize: **3 mm**
- Select **Apply**
- Select **OK**



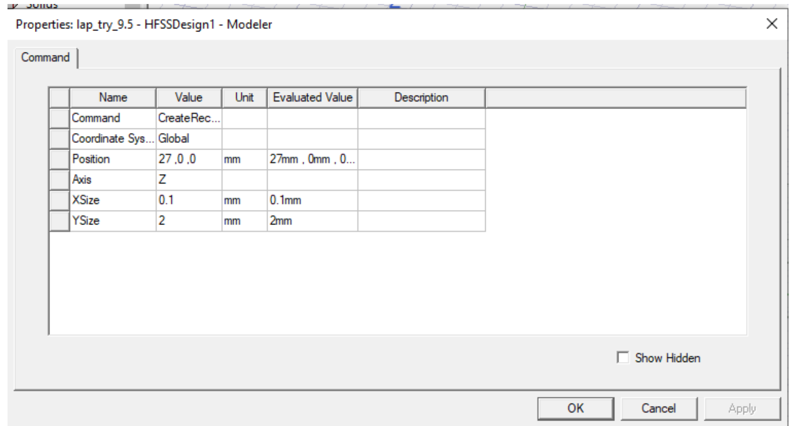
- From the *History Tree*, right click on the **Rectangle1** to change its properties.
    - Name: **Patch**
    - Material: **Copper**
    - Colour: **Blue**
    - Transparency: **0.6**
- Select **Apply**
- Select **OK**



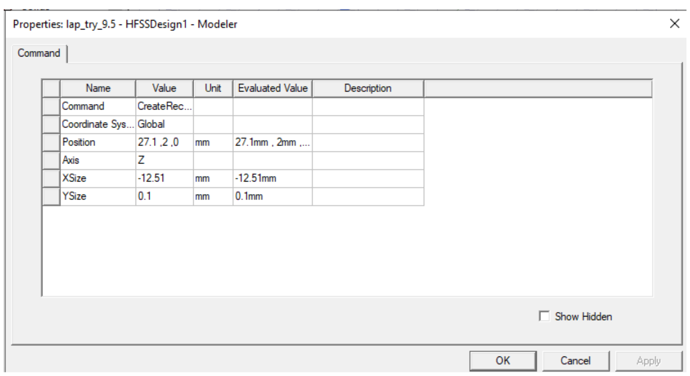
5. <u>CREATING THE SLOTS.</u>

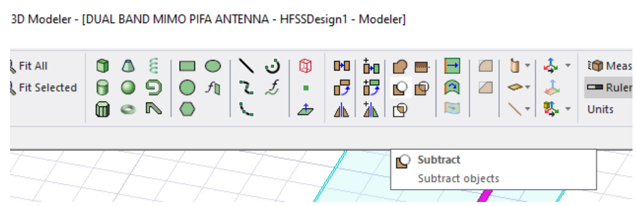
- From the *Draw* Ribbon Tab, select the **Rectangle** tool.
- In the *Modeler Window*, click and drag to draw the rectangle.
- From the *History Tree*, right click on the **CreateRectangle** to change the dimensions and position of the rectangle.
    - Position: **27.1 ,2 ,0 mm**
    - Axis: Z
    - Xsize: -12.51 mm
    - Ysize: 0.1 mm

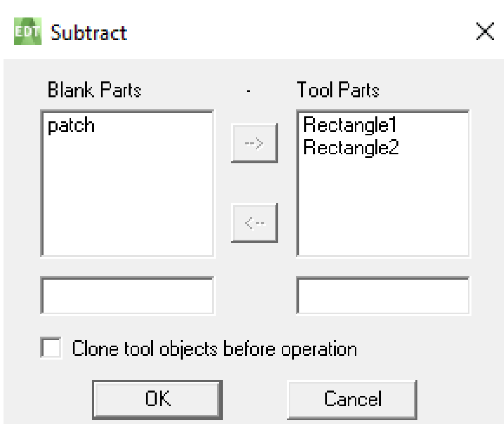
- ➢ Select **Apply** Select OK
- ➢ Draw another rectangle
- ➢ From the *History Tree*, right click on the **CreateRectangle** to change the dimensions and position of the rectangle.
    - ▪ Position: **27 ,0 ,0 mm**
    - ▪ Axis: **Z**
    - ▪ Xsize: **0.1 mm**
    - ▪ Ysize: **2 mm**

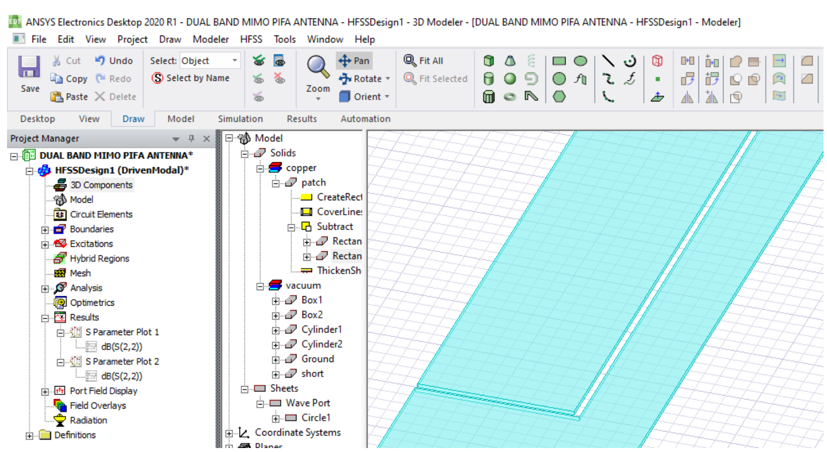


- ➢ Select **Apply**
- ➢ Select **OK**
- ➢ Select the **patch** and **two rectangles** together
- ➢ Select **Subtract** from the Ribbon Tab.
- ➢ Move **Patch** under *Blank Parts*
- ➢ Move **Rectangle1** and **Rectangle2** under *Tool Parts*.
- ➢ Select **OK.**
- ➢ Select **Rectangle1** > Select **Thicken Sheet** > Set the value to **0.05 mm.**



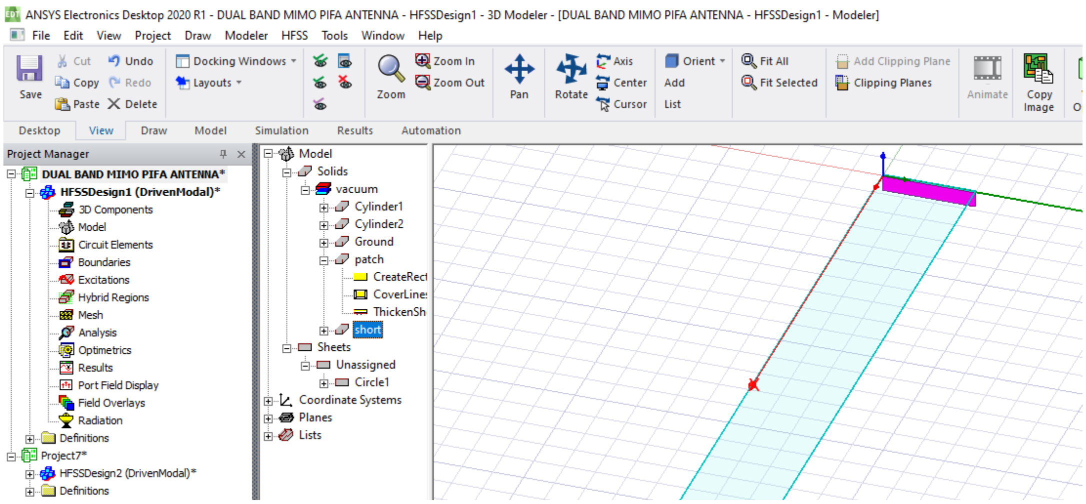




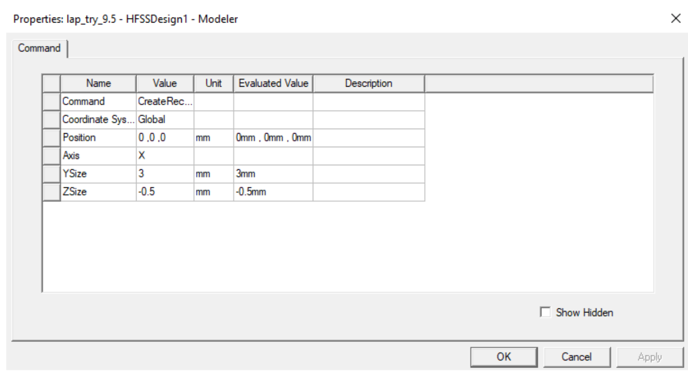


6. CREATING THE SHORTING PLATE.

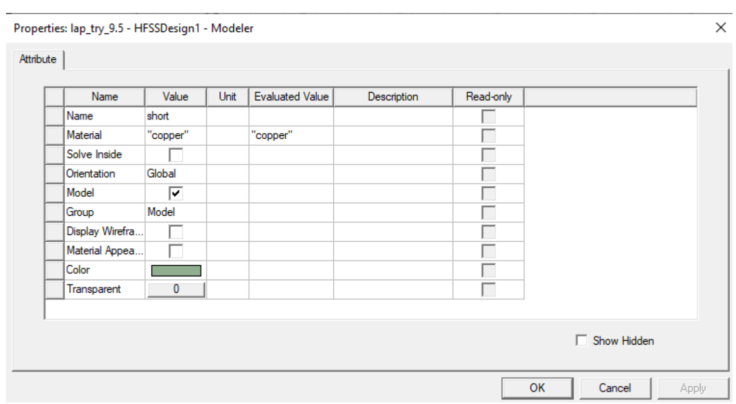
- From the *Draw* Ribbon Tab, select the rectangle tool
- In the *Modeler Window*, click and drag from the origin to draw the rectangle.



- From the *History Tree*, right click on **CreateRectangle** under Rectangle2 to change the dimensions and position of the rectangle.
    - Position: **0, 0, -0.5 mm**
    - Axis: X
    - Ysize: **3 mm**
    - Zsize: **0.5 mm**
- Select **Apply**
- Select **OK**
- Select **Rectangle2** > Select **Thicken Sheet** > Set the value to **0.05 mm**

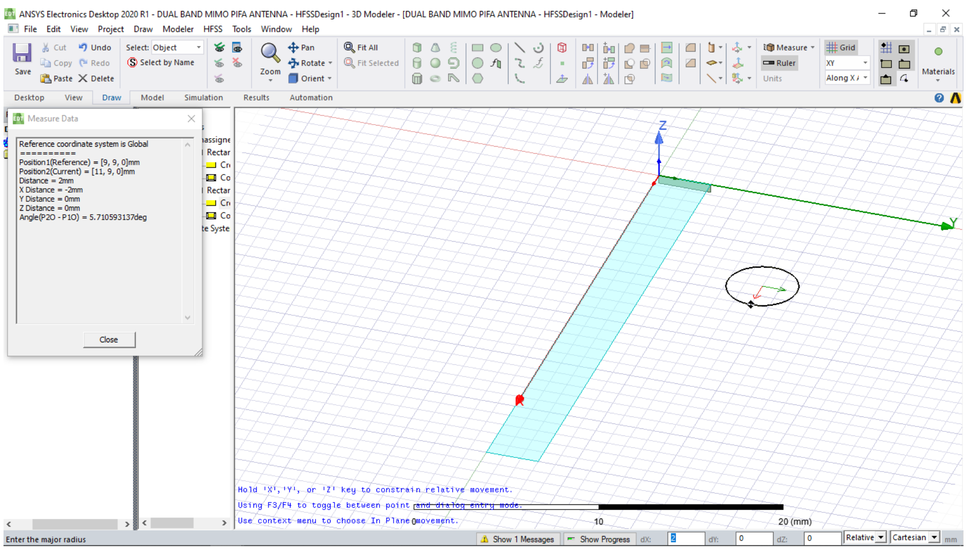


- From the *History Tree*, right click on the **Rectangle2** to change its properties.
    - Name: **Short**
    - Material: **Copper**
    - Colour: **default**
    - Transparency: **0**
- Select **Apply**
- Select OK

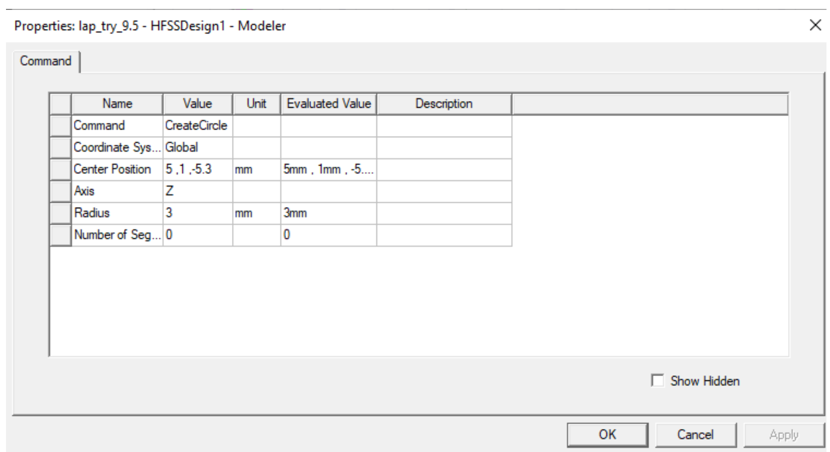


7. CREATING THE FEEDING PORT.

- From the *Draw* Ribbon Tab, select the circle tool.
- In the *Modeler Window*, click and drag to draw the circle.

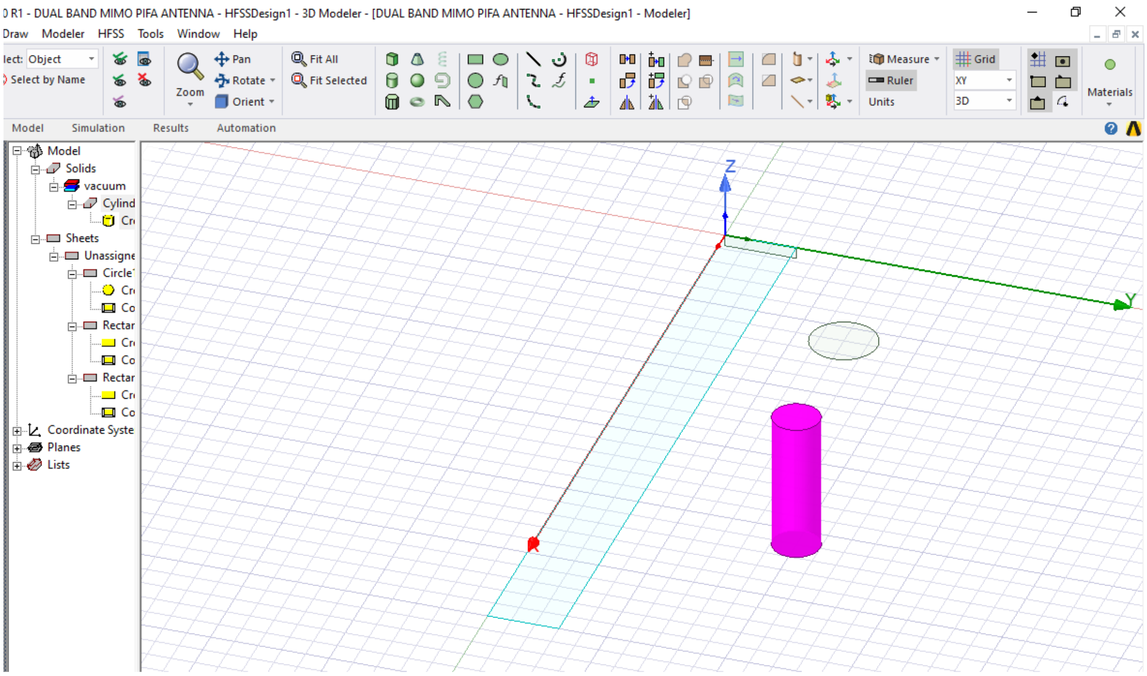


- From the *History Tree*, right click on **CreateCircle** under Circle1 to change the dimensions and position of the circle.
  - Position: **5 ,1 ,-5.3 mm**
  - Axis: **Z**
  - Radius: **3 mm**
  - Number of Seg: **0**
- Select **Apply**
- Select **OK**

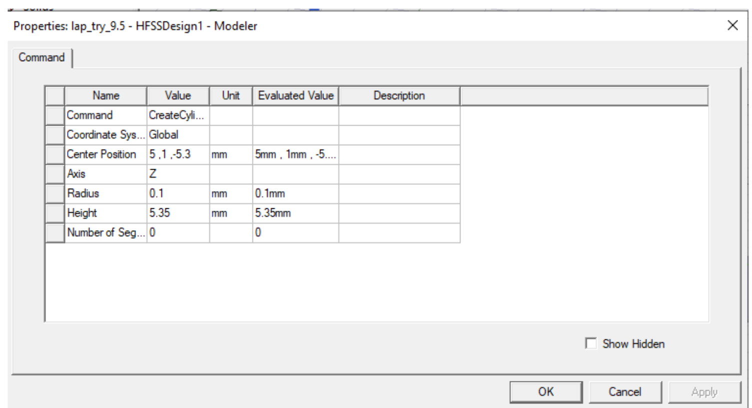


8. CREATING THE FEED LINE.

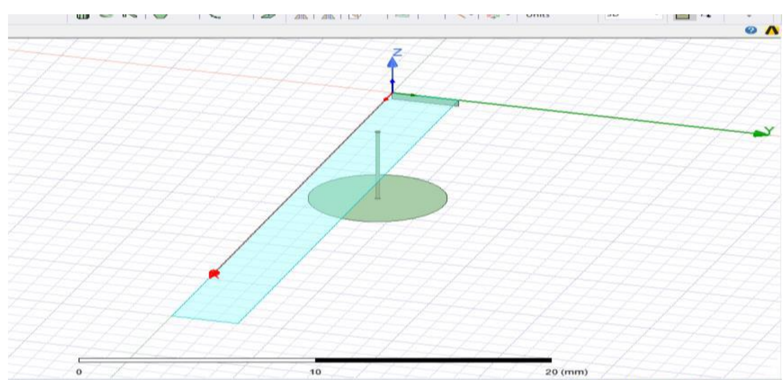
- From the *Draw* Ribbon Tab, select the cylinder tool.
- In the *Modeler Window*, click and drag to draw the cylinder.



- ➢ From the *History Tree*, right click on **CreateCylinder** under Cylinder1 to change the dimensions and position of the cylinder.
  - ▪ Center Position: **5, 1, -5.3 mm**
  - ▪ Axis: **Z**
  - ▪ Radius: **0.1 mm**
  - ▪ Height: **5.35 mm**
  - ▪ Number of Seg: **0**
- ➢ Select **Apply**
- ➢ Select **OK**

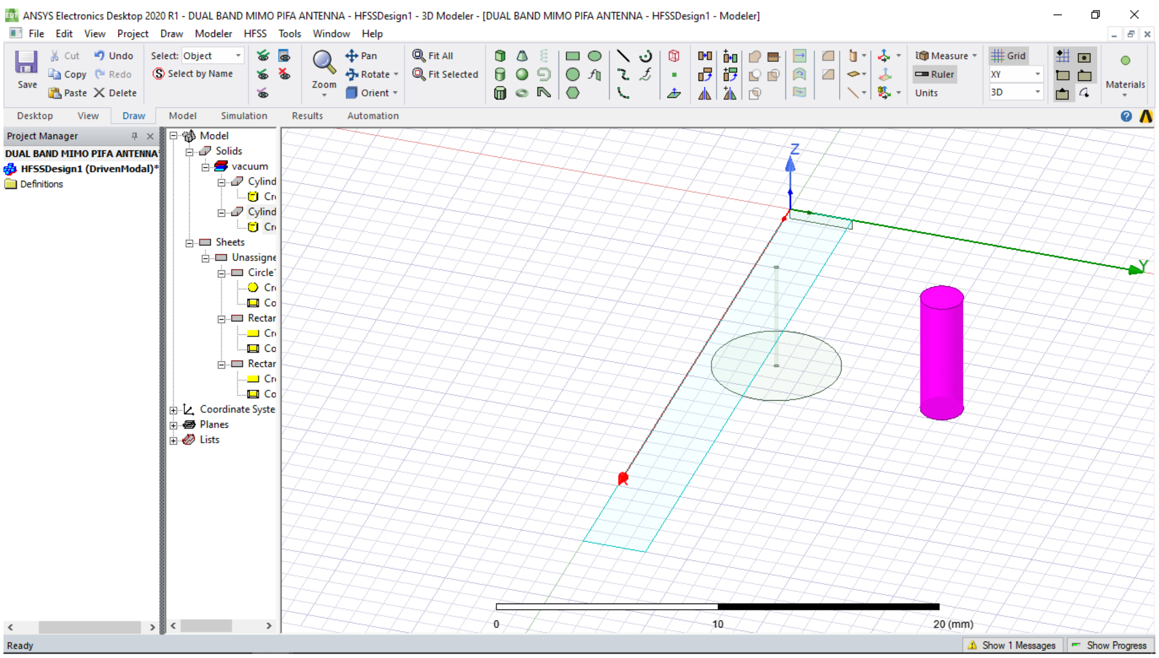


- ➢ From the *History Tree*, right click on the **Cylinder1** to change its properties.
  - ▪ Name: **feed**
  - ▪ Material: **Copper**
  - ▪ Colour: **brown**
  - ▪ Transparency: **0**
- ➢ Select **Apply**
- ➢ Select **OK**

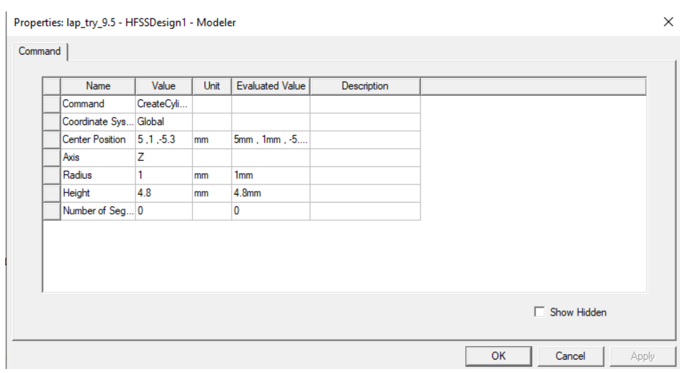


9. <u>CREATING THE FEED LINE COVER.</u>

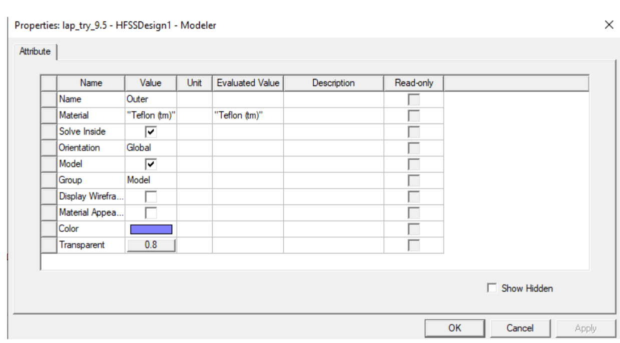
- From the *Draw* Ribbon Tab select the Cylinder tool.
- In the *Modeler Window*, click and drag to draw the circle.



- From the *History Tree*, right click on **CreateCylinder** under Cylinder2 to change the dimensions and position of the cylinder.
  - Center Position: **5, 1, -5.3 mm**
  - Axis: **Z**
  - Radius: **1 mm**
  - Height: **4.8 mm**
  - Number of Seg: **0**
- Select **Apply**
- Select **OK**

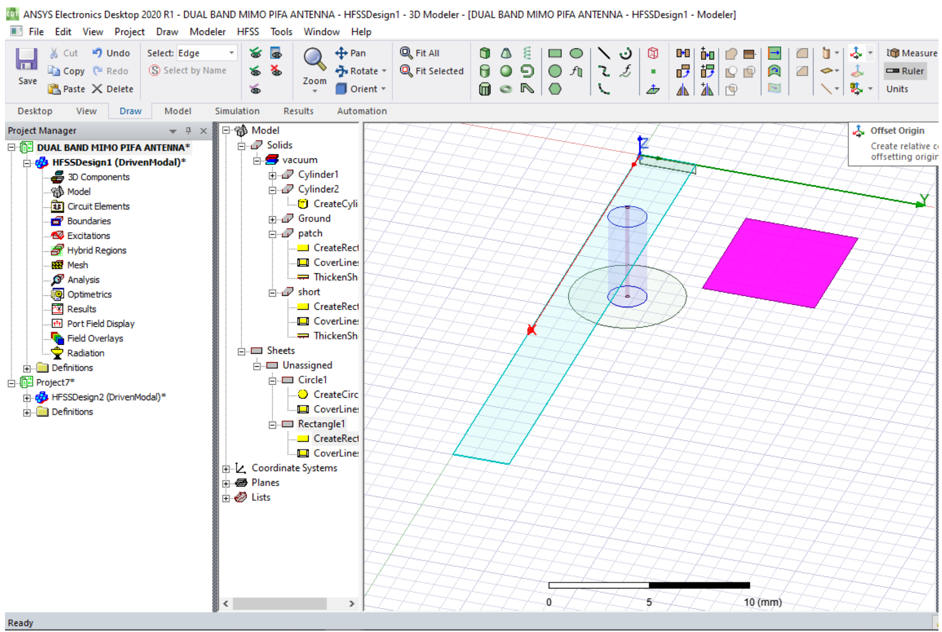


- From the *History Tree*, right click on the **Cylinder2** to change its properties.
  - Name: **Outer**
  - Material: **Teflon**
  - Colour: **blue**
  - Transparency: **0.8**
- Select **Apply**
- Select **OK**

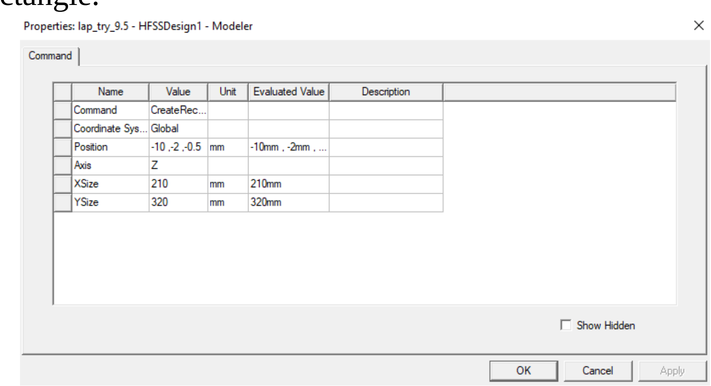


10. CREATING THE GROUND PLANE.

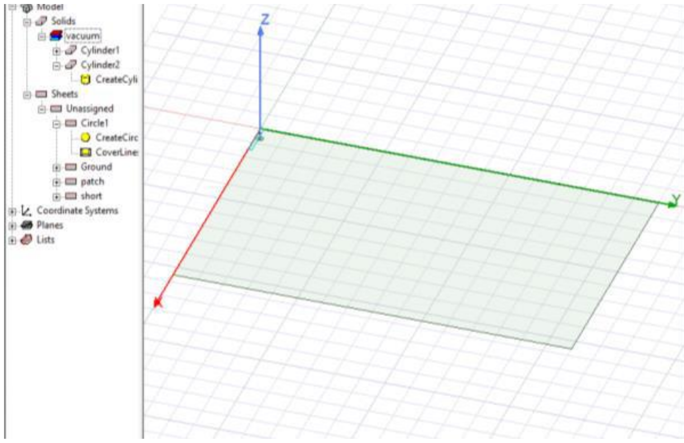
- From the *Draw* Ribbon Tab, select the rectangle tool.
- In the *Modeler Window*, click and drag to draw the rectangle.



- From the *History Tree*, right click on **Create Rectangle** under Rectangle3 to change the dimensions and position of the rectangle.
  - Position: **-10 ,-2 ,-0.5 mm**
  - Axis: **Z**
  - Xsize: **210 mm**
  - Ysize: **320 mm**
- Select **Apply**
- Select OK

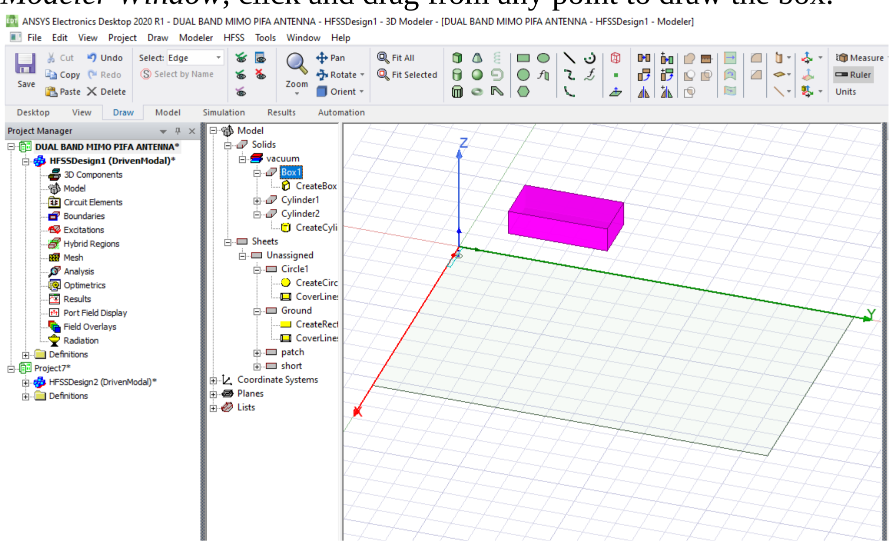


- Select **Rectangle3** > Select **Thicken Sheet** > Set the value to **0.05 mm**
- From the *History Tree*, right click on the **Rectangle3** to change its properties.
  - Name: **Ground**
  - Material: **FR4 epoxy**
  - Transparency: **0.6**
  - Select **Apply**
  - Select **OK**

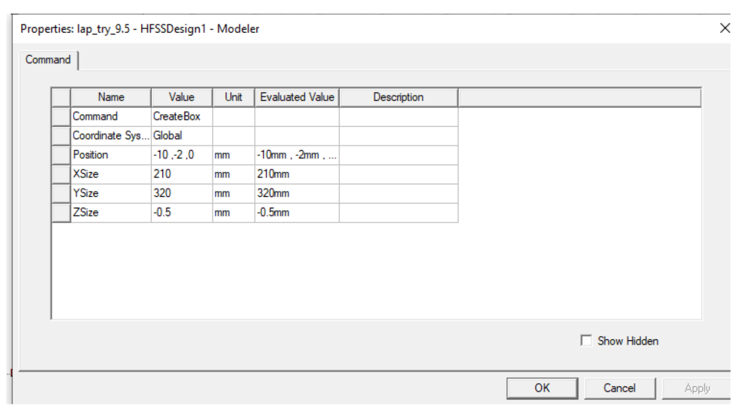


11. <u>CREATING THE SUBSTRATE</u>

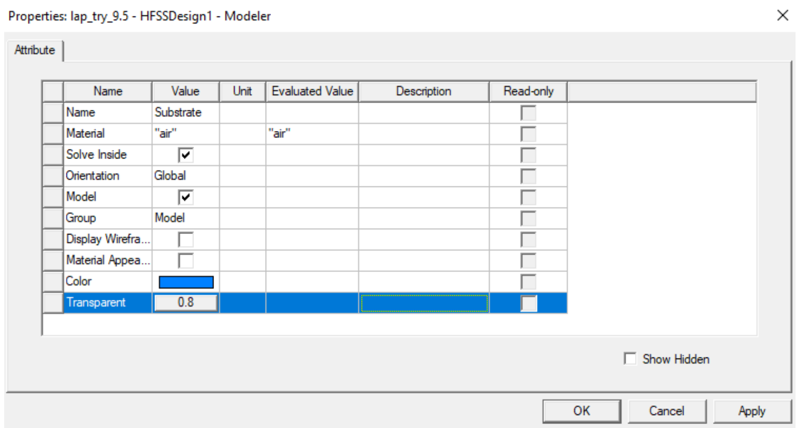
- From the *Draw* Ribbon Tab, select the Box tool
- In the *Modeler Window*, click and drag from any point to draw the box.



- From the *History Tree*, right click on **CreateBox** under Box1 to change the dimensions and position of the box.
  - Position: **-10 ,-2 ,0 mm**
  - Xsize: **210 mm**
  - Ysize: **320 mm**
  - **Zsize: -0.5 mm**
- Select **Apply**
- Select **OK**



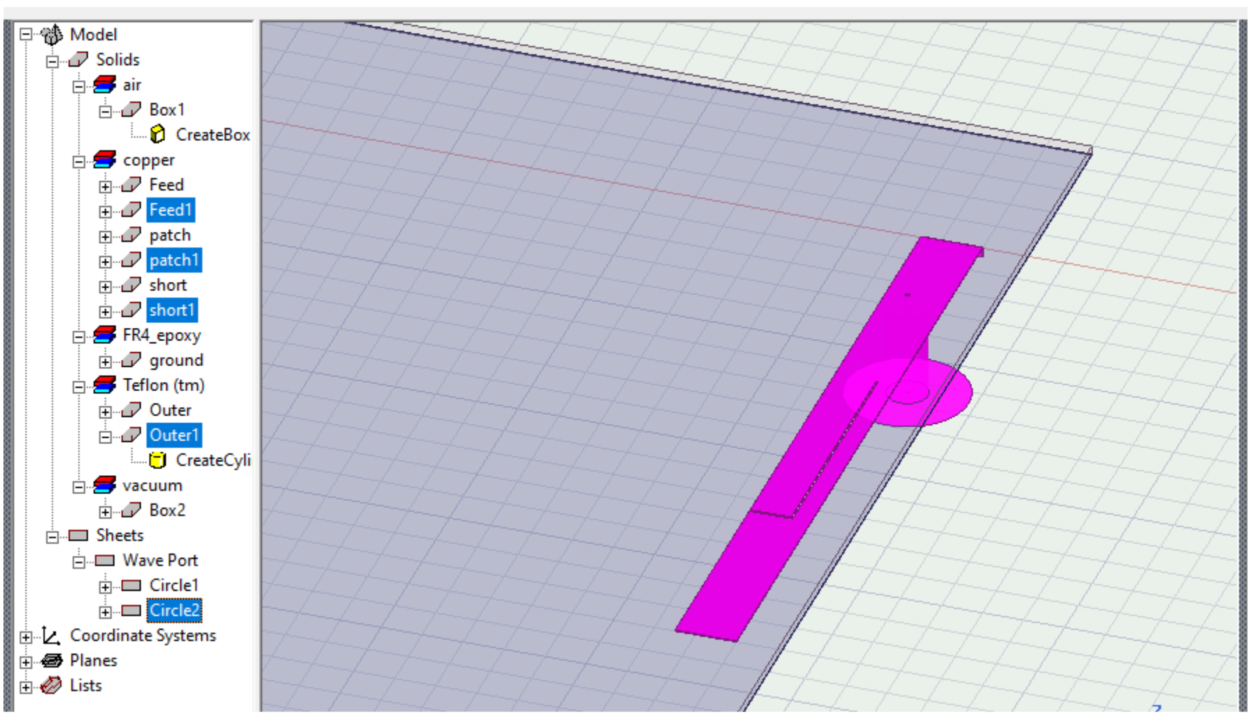
- From the *History Tree*, right click on the **Box1** to change its properties.
  - Name: **Substrate**
  - Material: Air
  - Colour: **blue**
  - Transparency: **0.8**
- Select **Apply**
- Select OK



12. <u>MODELLING ANTENNA-2</u>

In modelling antenna 2, there are two options;

1. Repeat the steps for creating the individual components but with different coordinates for their positions.
2. Copy and paste the individual components, thereafter, change the coordinates for their positions.



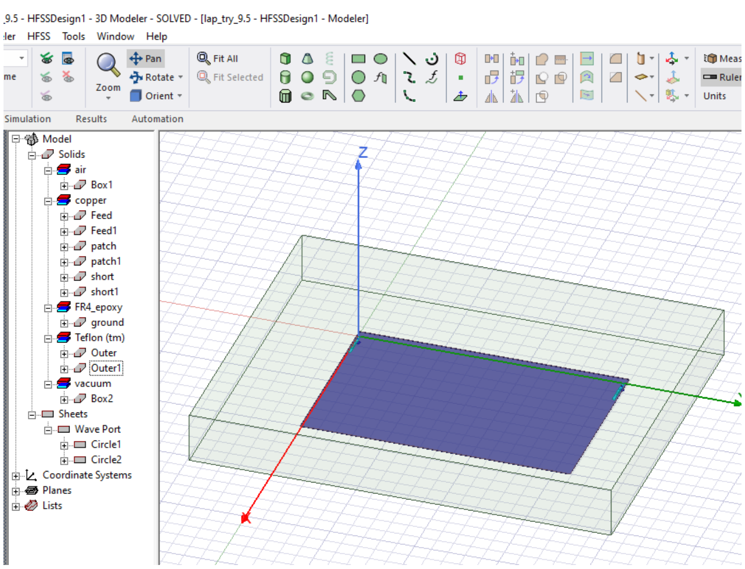
Using Option 2

- **Copy and Paste the components.**
  - In the *History Tree*, **select Patch, Short, Feed, Outer, Circle**
  - Press **Ctrl + C** to copy the selected components
  - **Single click** inside the *Modeller Window*
  - Press **Ctrl + V** to paste the components

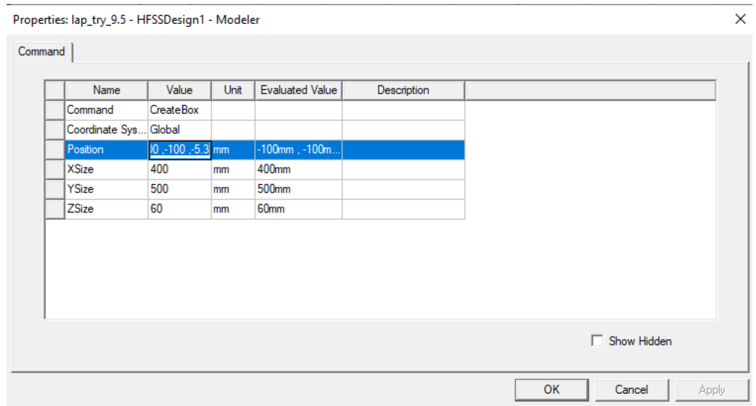
- **Change the coordinates of the components.**
  - Select the **Create Rectangle** under Patch1
  - Type the new coordinates for the *Position* as shown in the table below.
  - Repeat this step for the other pasted components using their new coordinates.

Component	**Coordinates**
Patch1	0 , 313 , 0 mm
Short1	0 , 313 , 0 mm
Feed1	5 , 314 , -5.3 mm
Outer1	5 , 314 , -5.3 mm
Circle1	5 , 314 , -5.3 mm

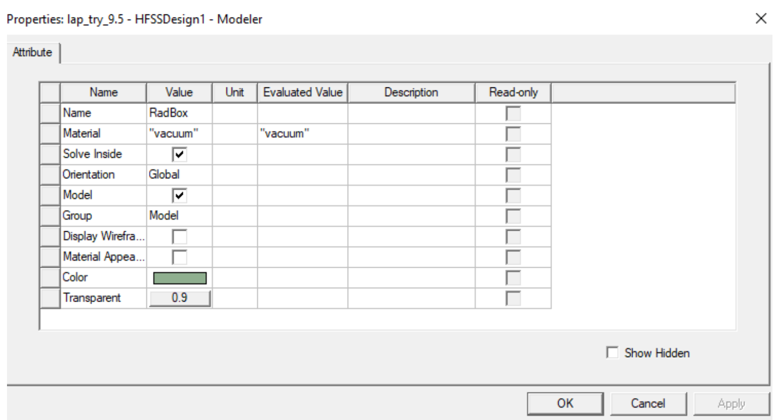
- **Creating Radiation Box**
  - From the *Draw* Ribbon Tab, select the Box tool
  - In the *Modeler Window*, click and drag from any point to draw the box.



- From the *History Tree*, right click on **CreateBox** under Box1 to change the dimensions and position of the box.
  - Position:**-100 ,-100 ,-5.3 mm**
  - Xsize: **400 mm**
  - Ysize: **500 mm**
  - Zsize: **60 mm**
- Select **Apply**
- Select OK



- From the *History Tree*, right click on the **Box1** to change its properties.
  - Name: **RadBox**
  - Material: **Vacuum**
  - Colour: **green**
  - Transparency: **0.9**
- Select **Apply**
- Select OK

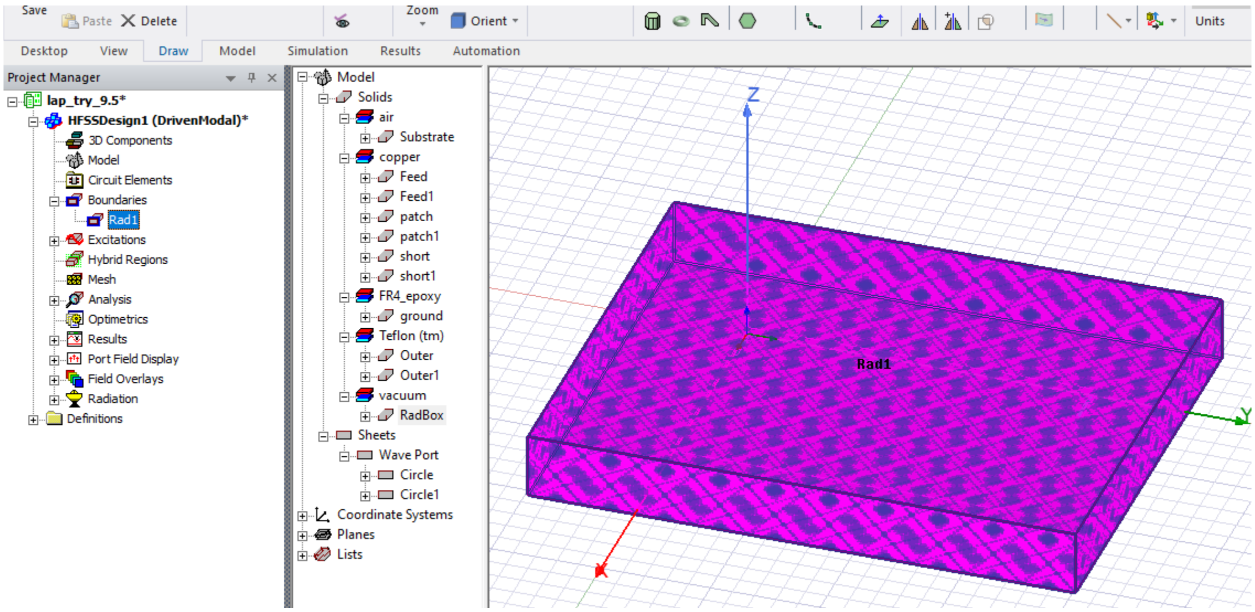


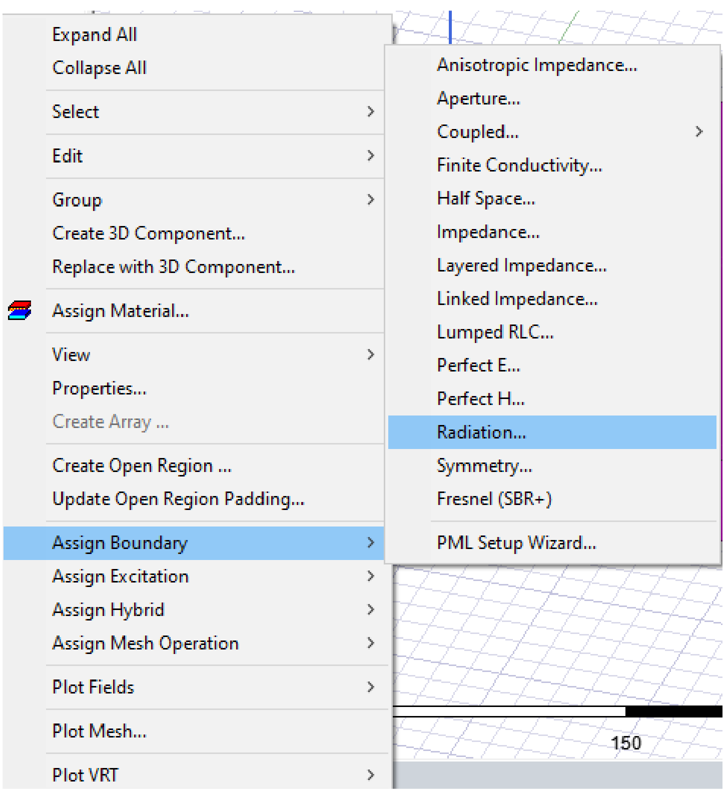
13. ASSIGNING BOUNDARIES AND EXCITATIONS

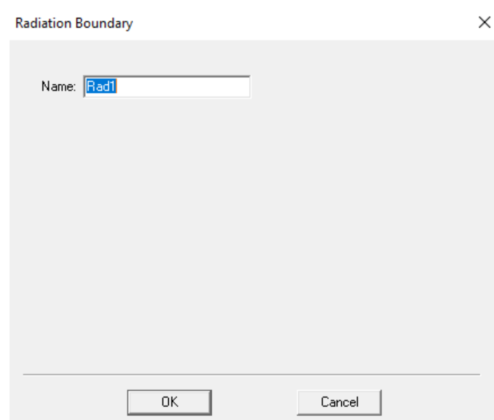
Radiation Boundary

The purpose of using boundary conditions in HFSS is to define the behaviour of the electromagnetic. Field on the object interfaces and at the edges of a problem region. Defining boundary conditions reduces the electromagnetic or geometric complexity of the model.

- Create Boundary
- Right click on **RadBox** inside the *History Tree.*
- Select **Assign Boundary** from the pop-up.
- Select **Radiation.**
- Select **Ok** from the pop-up.

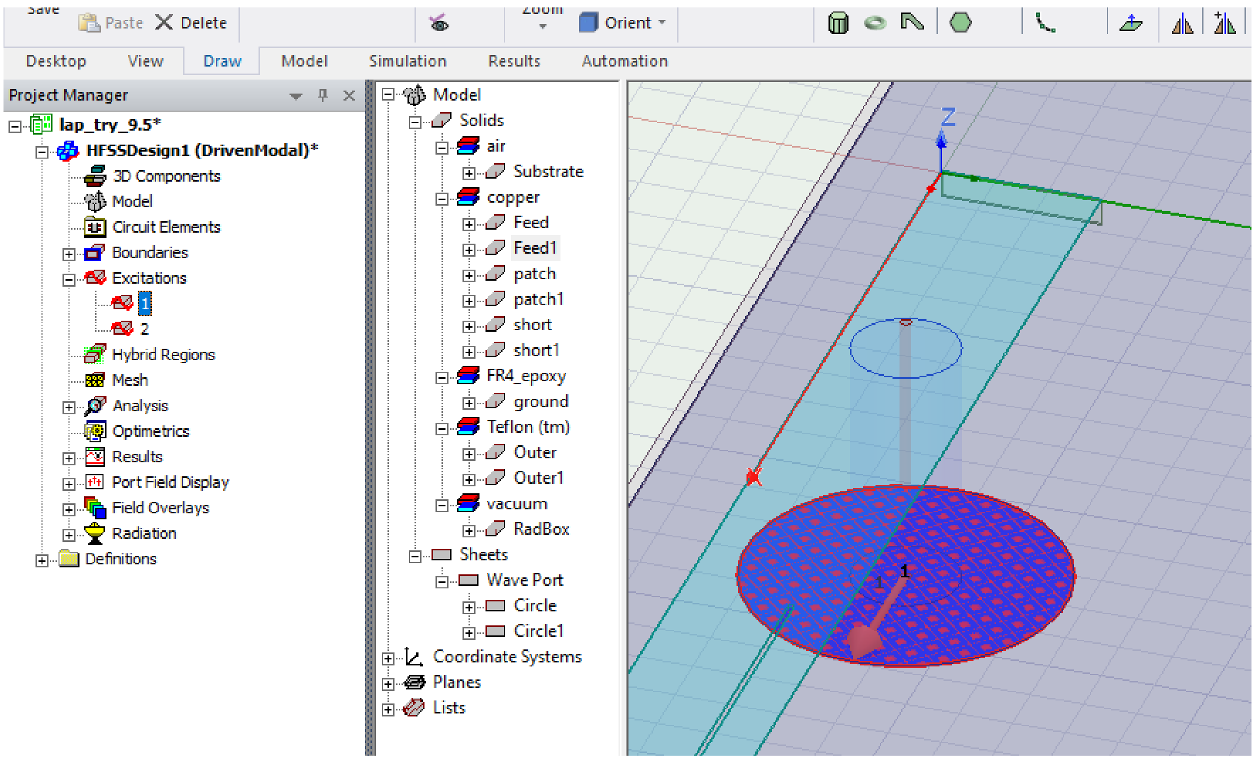

Save
Paste
Delete
Zoom
Orient
Units
Desktop
View
Draw
Model
Simulation
Results
Automation
Project Manager
lap_try_9.5*
HFSSDesign1 (DrivenModal)*
3D Components
Model
Circuit Elements
Boundaries
Rad1
Excitations
Hybrid Regions
Mesh
Analysis
Optimetrics
Results
Port Field Display
Field Overlays
Radiation
Definitions
Model
Solids
air
Substrate
copper
Feed
Feed1
patch
patch1
short
short1
FR4_epoxy
ground
Teflon (tm)
Outer
Outer1
vacuum
RadBox
Sheets
Wave Port
Circle
Circle1
Coordinate Systems
Planes
Lists
Z
Y
Rad1


Expand All
Collapse All
Select
Edit
Group
Create 3D Component...
Replace with 3D Component...
Assign Material...
View
Properties...
Create Array ...
Create Open Region ...
Update Open Region Padding...
Assign Boundary
Assign Excitation
Assign Hybrid
Assign Mesh Operation
Plot Fields
Plot Mesh...
Plot VRT
Anisotropic Impedance...
Aperture...
Coupled...
Finite Conductivity...
Half Space...
Impedance...
Layered Impedance...
Linked Impedance...
Lumped RLC...
Perfect E...
Perfect H...
Radiation...
Symmetry...
Fresnel (SBR+)
PML Setup Wizard...
150


Radiation Boundary
Name:
Rad1
OK
Cancel

Wave Ports

Wave ports are used to excite transmission lines like microstrip, and hollow waveguides. A wave port represents the region through which electromagnetic energy enters or exits the solution space. In HFSS a wave port is treated as if it were a semi-infinitely long wave guide or transmission line of the exact same cross-section attached to them where it's excited. Wave ports yield S, Y, Z parameters, characteristic wave impedance and the propagation constant gamma. The S-parameters generated by a wave port are normalized to the matched loads and can also be normalized to any constant complex impedance.



❖ **Create Excitation**

➢ Right click **Circle** inside the *History Tree*

➢ Select **Assign Excitation** from the pop-up

➢ Select **Wave port**

➢ Right click **None** from the pop-up

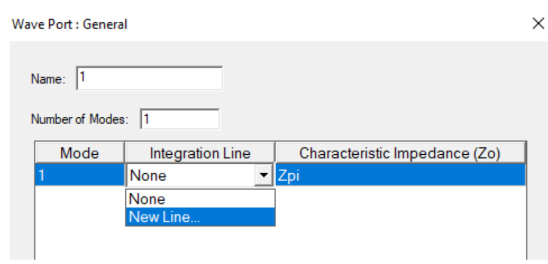
➢ Select **New Line**.

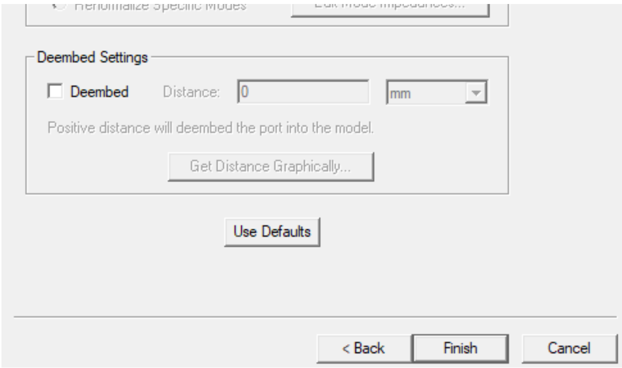
➢ In the *Modeller Window* draw a line from the **centre of the circle to its circumference.**

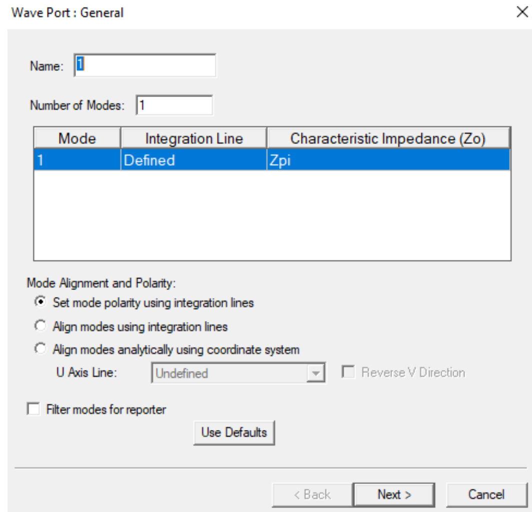
➢ Ensure that the None has changed to **Defined**

➢ Click **Next** at the bottom of the pop-up.

➢ Select **Finish.**





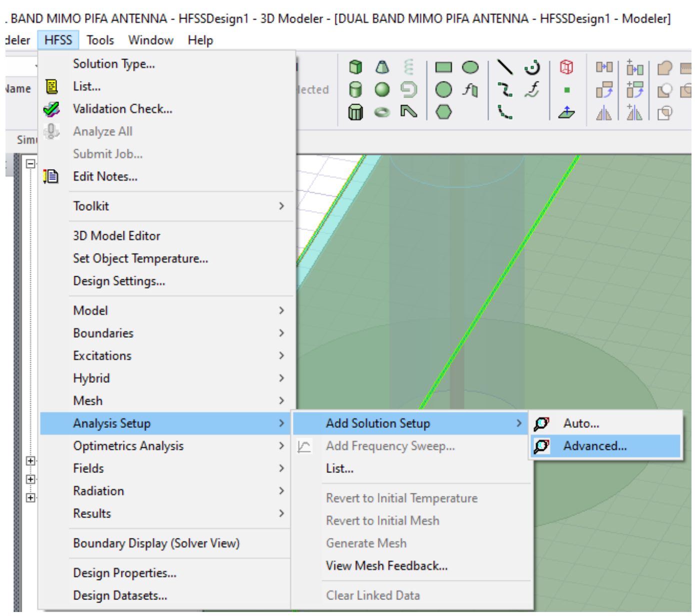


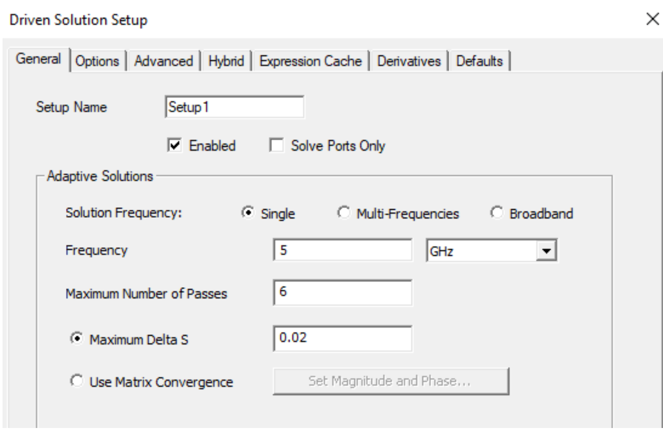
- ➢ Repeat the above steps for **Circle1** to create the wave port for *Antenna-2*.

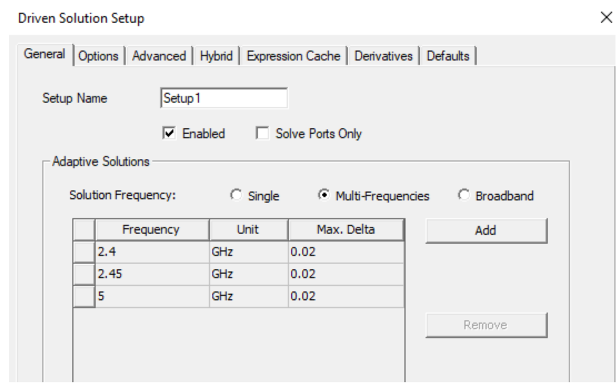
14. SPECIFYING SOLUTION SETTINGS

❖ Performing Analysis Setup

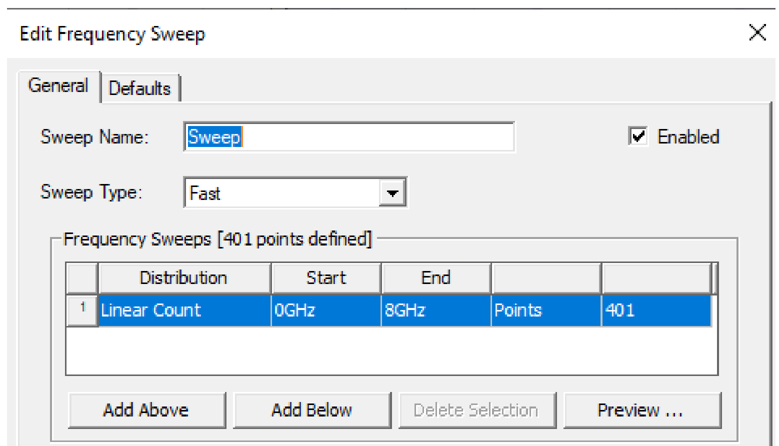
- ➢ Right click on **HFSS** on the *Menu Bar.*
- ➢ Select **Analysis Setup** from the drop down menu.
- ➢ Select **Add Solution Setup.**
- ➢ Select **Advanced**.
- ➢ Select **Multi-Frequencies** under *Adaptive Solutions*
- ➢ Fill out the details as shown in the second image below





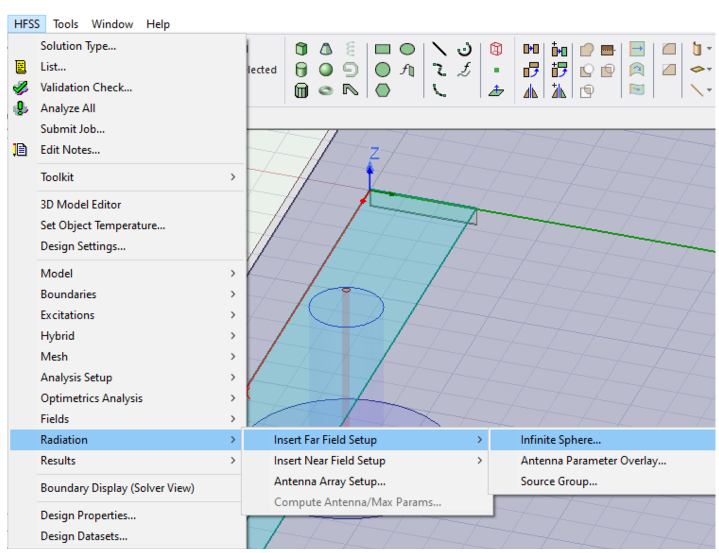


- ➢ Select OK.
- ➢ In the next pop-up window, select **Fast** under *Sweep Type.*
- ➢ Under *Frequency Sweeps* change the following parameters:
  - Start: **0 GHz**
  - End: **8 GHz**
- ➢ Select OK.



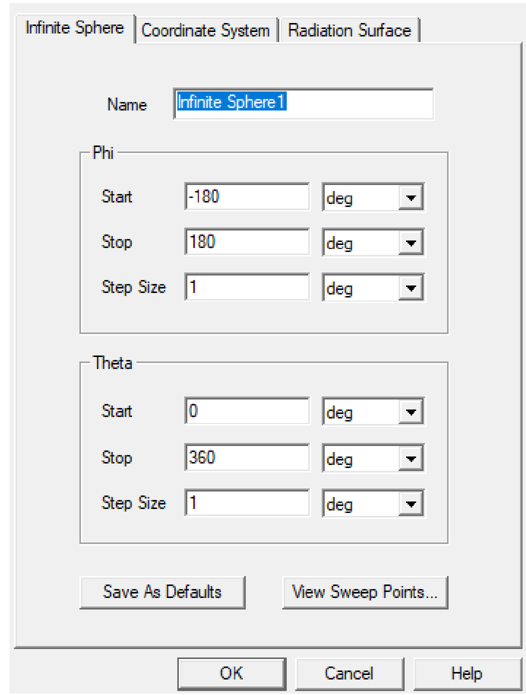
❖ Inserting Far Fields

- ➢ Right click on **HFSS** on the *Menu Bar.*
- ➢ Select **Radiation** from the drop down menu.
- ➢ Select **Insert Far Field Setup.**
- ➢ Select **Infinite Sphere.**

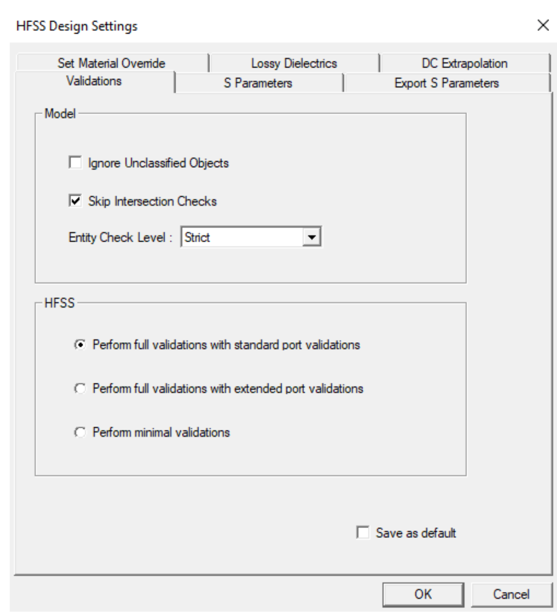


- Fill in the section under Phi with the following parameters.
  - **Start: -180**
  - **Stop: 180**
  - **Step Size: 1**

- Fill in the section under Theta with the following parameters.
  - **Start: 0**
  - **Stop: 360**
  - **Step Size: 1**
- Click **OK.**
- **Apply Design Settings.**

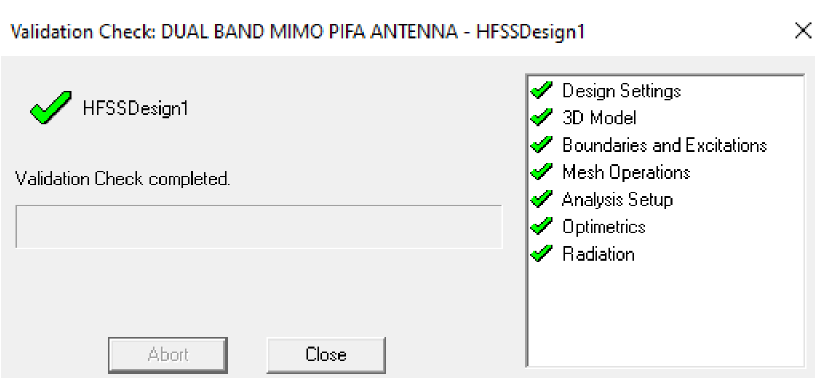


- Right click on **HFSS** on the *Menu Bar*.
- Select **Design Settings** from the drop down menu.
- Select the **Validations** tab.
- Check the box for **Skip Intersection Checks**.
- Click **OK.**



❖ **Perform Validations**

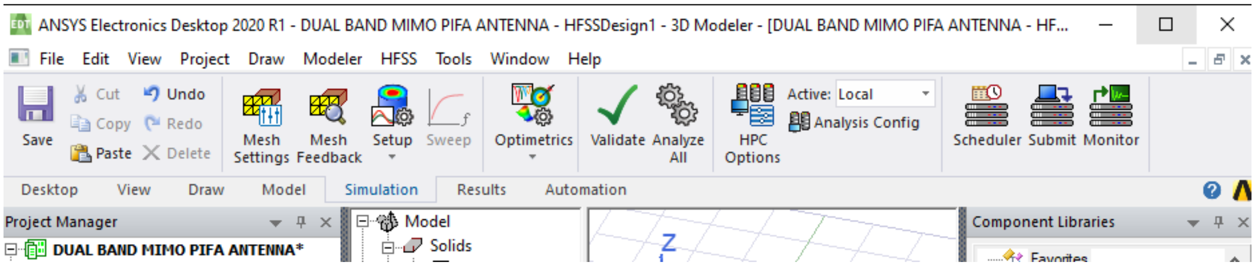
- Right click on **HFSS** on the *Menu Bar*.
- Select **Validation Check** from the drop down
- menu.
- Ensure all *Validation Checks* have been completed.
- Click **Close.**



15. RUN HFSS TRANSIENT SIMULATION

❖ **Run Simulation**

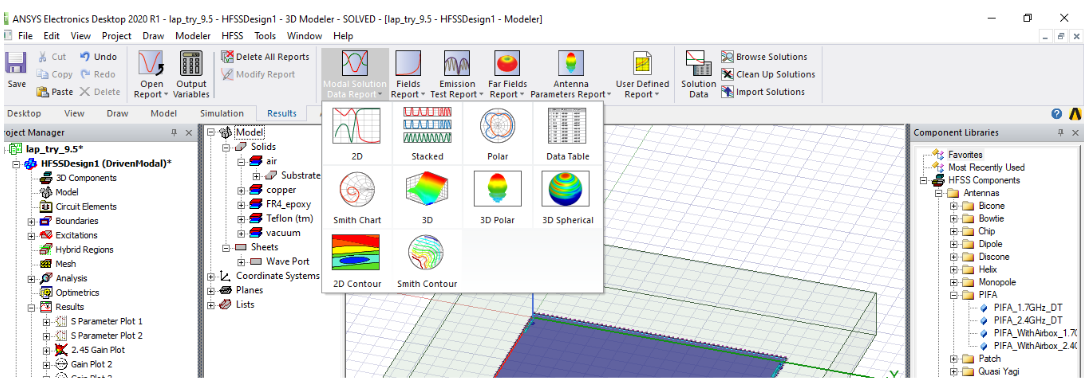
- ➢ Select **Simulation** on the *Ribbon Tab*.
- ➢ Click **Analyze All.**

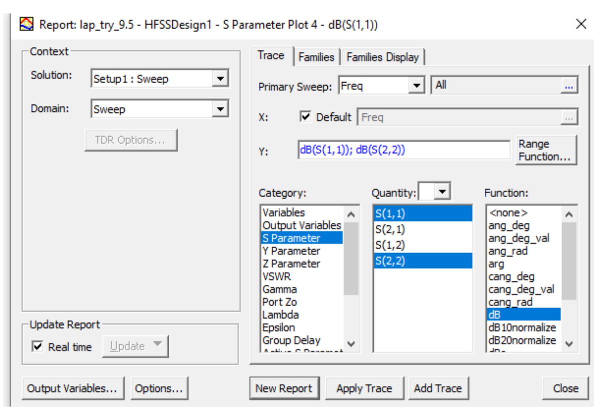


16. PLOTTING THE RESULTS

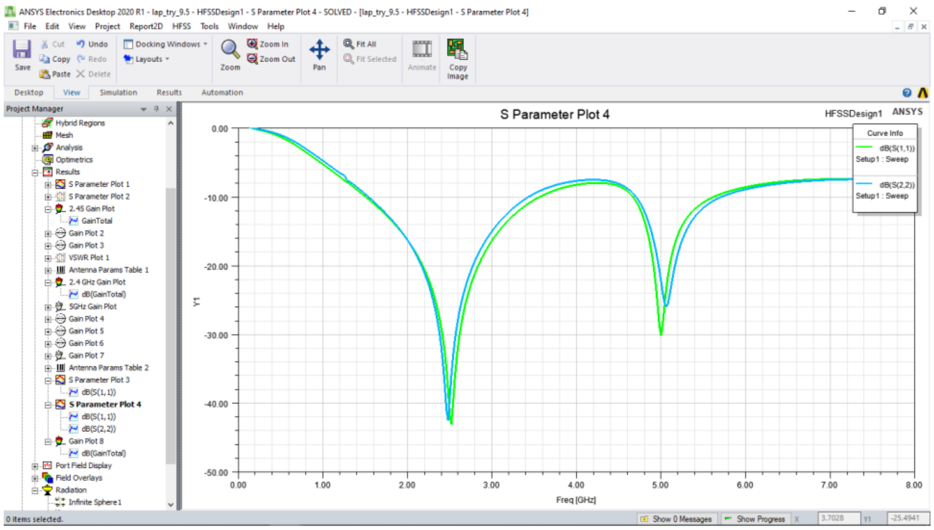
❖ **Plotting the S Parameters.**

- ➢ Click on **Results** on the *Ribbon Tab*.
- ➢ Select **Modal Solution Data Report.**
- ➢ Select the **2D Graph** on the menu.



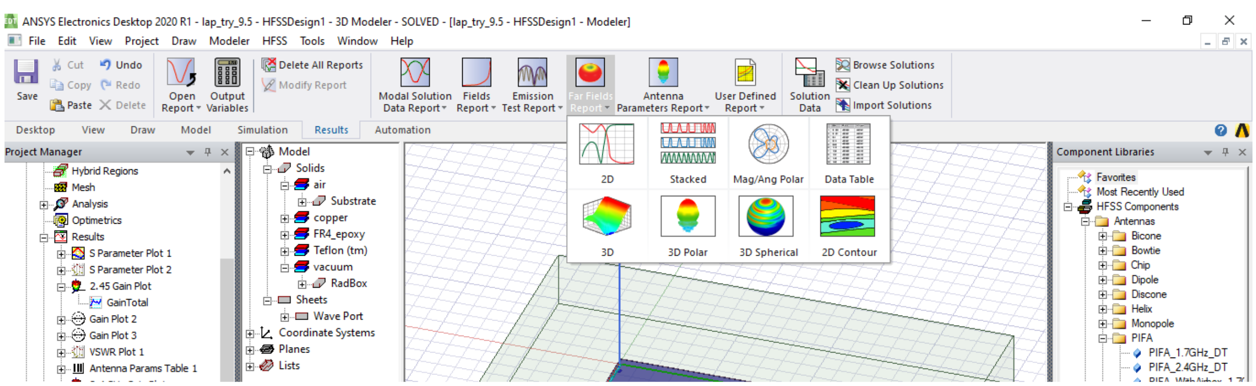


- ➢ Select the following parameters in the pop-up menu
- ➢ Category: **S Parameter**
- ➢ Quantity: **S(1,1)**
- ➢ Function: **dB**
- ➢ Click on **New Report.**

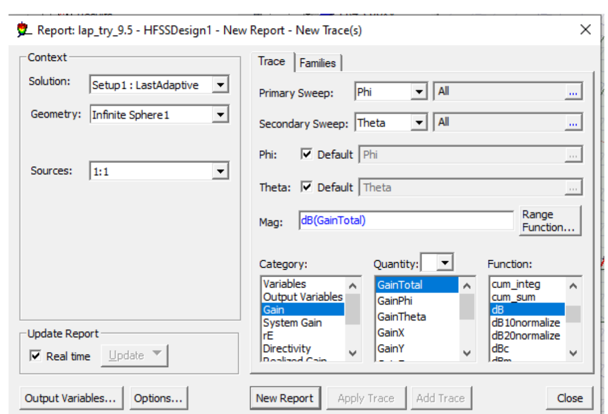


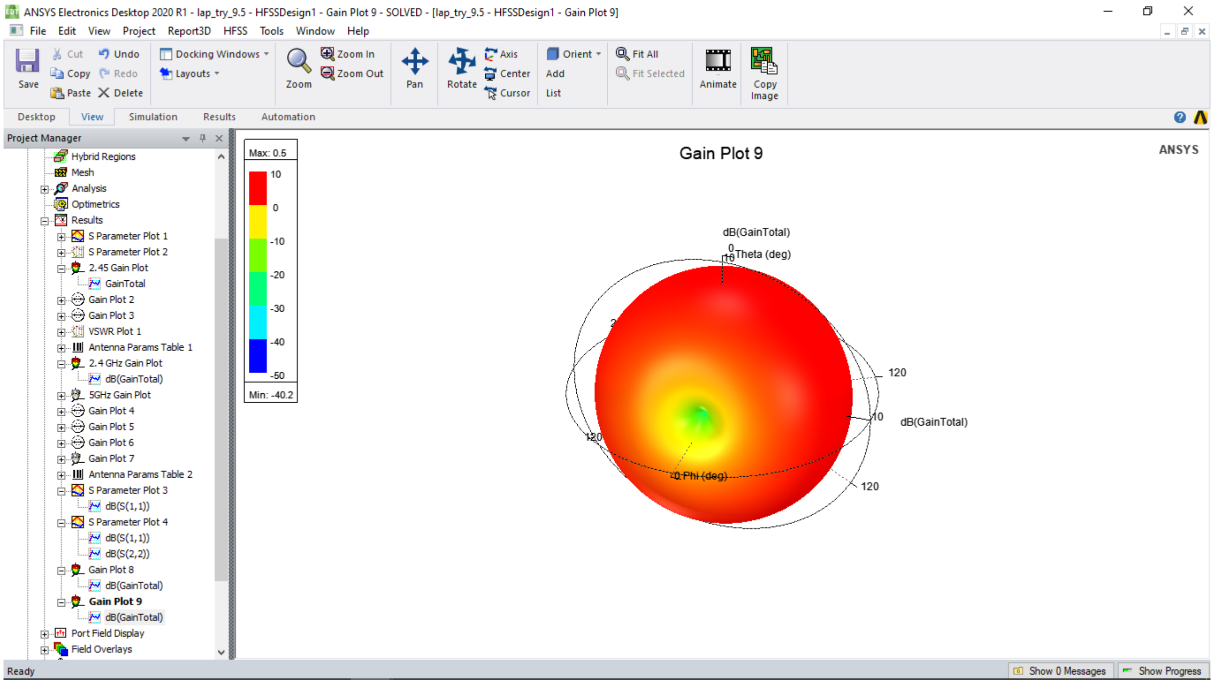
❖ Plotting the Radiation Pattern

- ➢ Click on **Results** from the *Ribbon Tab.*
- ➢ Click on **Far Fields Report**.



- ➢ Select **3D Polar** from the drop down menu.
- ➢ Select the following parameters in the pop-up menu
  - ▪ Sources: **1:1**
  - ▪ Category: **Gain**
  - ▪ Quantity: **GainTotal**
  - ▪ Function: **dB**
- ➢ Click on **New Report.**




ANSYS Electronics Desktop 2020 R1 - lap_try_9.5 - HFSSDesign1 - Gain Plot 9 - SOLVED - [lap_try_9.5 - HFSSDesign1 - Gain Plot 9]
Gain Plot 9
ANSYS
Max: 0.5
Min: -40.2
dB(GainTotal)
Theta (deg)
Phi (deg)
Project Manager
Ready

SECTION 2: HORN-FED REFLECTOR ANTENNA

Prepared by: Kwakye Akosah Jeffrey & Emmanuel Frimpong (Telecom Eng. 2021)

INTRODUCTION

Ansys HFSS is a 3D electromagnetic (EM) simulation software that can be used to design and simulate high-frequency electronic items including antennas, antenna arrays, RF or microwave components, high-speed interconnects, filters, connectors, IC packages, and printed circuit boards. Ansys HFSS software is used by engineers all over the world to develop high-frequency, high-speed electronics that can be found in communications networks, advanced driver assistance systems (ADAS), satellites, and internet-of-things (IoT) devices.

This document is intended to show you how to create, simulate, and analyze horn-fed reflector antenna system efficiently, using the ANSYS Electronics Desktop; HFSS and HFSS-IE Design Environments.

This example is intended to show you how to create, simulate, and analyze horn-fed reflector antenna system efficiently, using the ANSYS Electronics Desktop; HFSS and HFSS-IE Design Environments.

The design process is divided into 4 main parts namely;

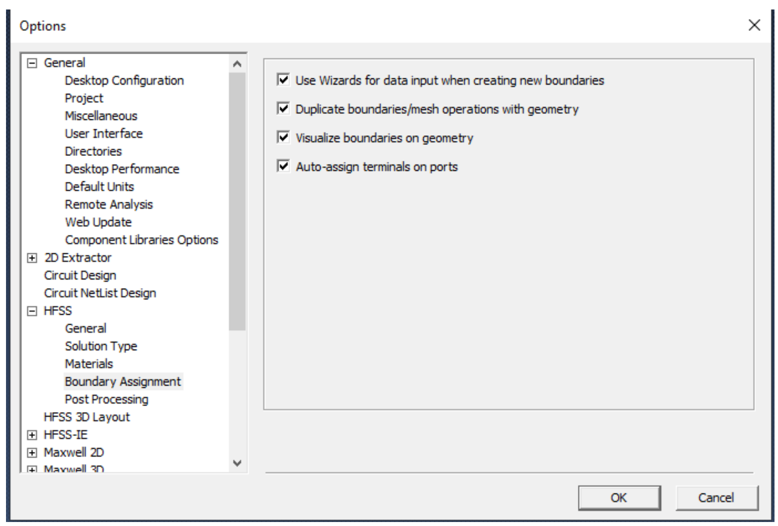
1. **Part 1:** HFSS Design of horn antenna
2. **Part 2:** HFSS-IE design of reflector with excitation linking to HFSS design in part 1. Antenna solution using an Integral Equation and Physical Optics solution methods, both techniques are available within HFSS-IE.
3. **Part 3**: HFSS Hybrid design of a reflector + horn antenna
4. **Part 4:** Design simulations and results

1. LAUNCHING ANSYS ELECTRONICS DESKTOP

- Select Programs > ANSYS Electromagnetics > ANSYS Electromagnetics Suite 16.0
- Select ANSYS Electronics Desktop 2016.

2. SETTING TOOL OPTIONS

- Note: In order to follow the steps outlined in this example, verify that the following tool options are set:
- Select the menu item **Tools > Options > HFSS Options…**
  – Click the General tab
- Use Wizards for data input when creating new boundaries: √ Checked
- Duplicate boundaries/mesh operations with geometry: √ Checked
  – Click the OK button
- Select the menu item **Tools** > **Options** > **Modeler Options**….
  – Click the Operation tab
- Automatically cover closed polylines: √ Checked
- Select last command on object select: √ Checked
  – Click the Drawing tab
- Edit properties of new primitives: √ Checked
  – Click the OK button



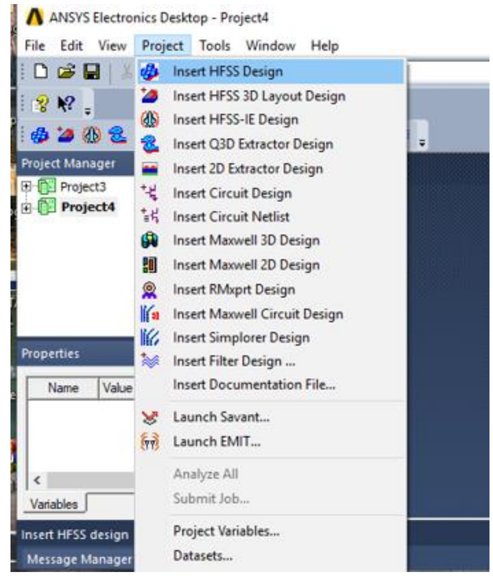
PART 1 – HFSS: CREATING THE HORN ANTENNA

- **Opening a New Project**
  - In HFSS Desktop, click the / On the Standard toolbar, or select the menu item **File** > **New.**

For basic design tutorials using HFSS:

https://www.youtube.com/playlist?list=PLdIVd39LNkpSaTzAFCS_jh3sV3Gc21mNg

➢ From the Project menu, select Insert HFSS Design.



❖ **Set Solution Type**

➢ Select the menu item **HFSS > Solution Type**

– Choose Driven Modal

– Choose Network Analysis

– Click the OK button

❖ **Set Model Units**

➢ Select the menu item **Modeler > Units**

– Select Units: in

– Click the OK button

➢ Select The Menu Item Draw > 3D Component Library > Browse

– Browse 3D Component Dialog

➢ Filename: Horn_10GHz.a3dcomp

➢ Click the Open button

– Insert 3D Component Dialog

➢ FlareA: 2.65in

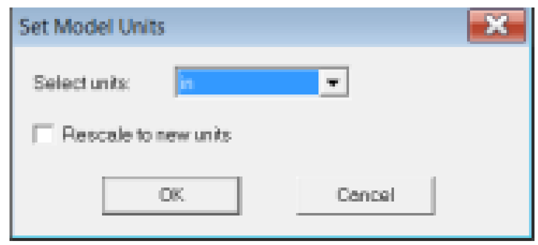
➢ FlareB: 1.95in

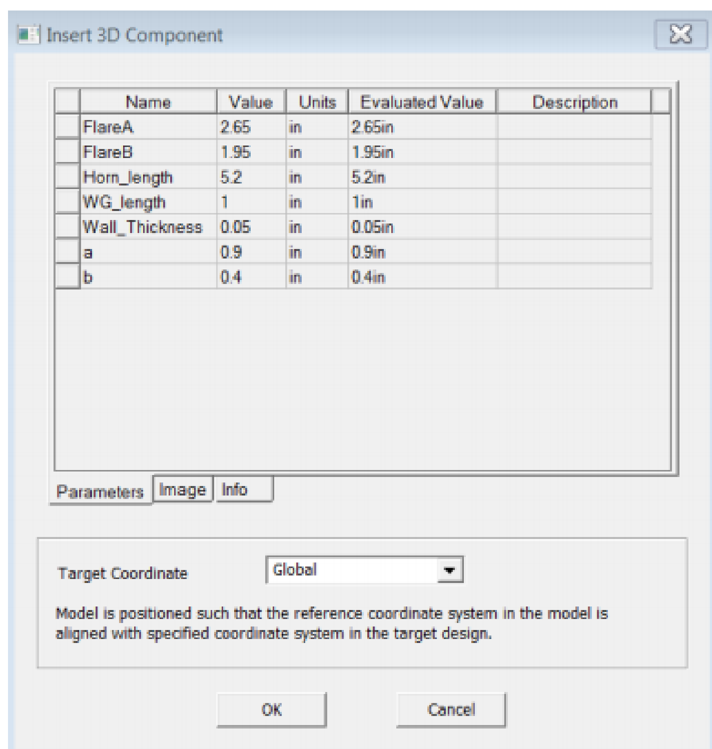
➢ Horn_length: 5.2in

➢ Click the OK button

➢ To fit the view:

– Select the menu item **View > Fit All > Active View** OR press the CTRL+D key





3. <u>CREATING THE AIRBOX</u>

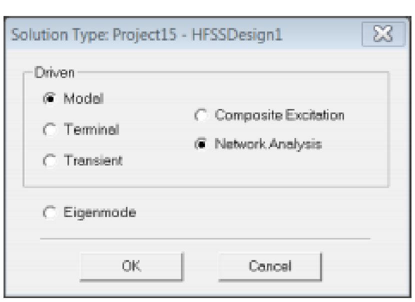
➢ Select the menu item **Draw > Region**

– Padding Data: Pad all directions similarly

– Direction: All

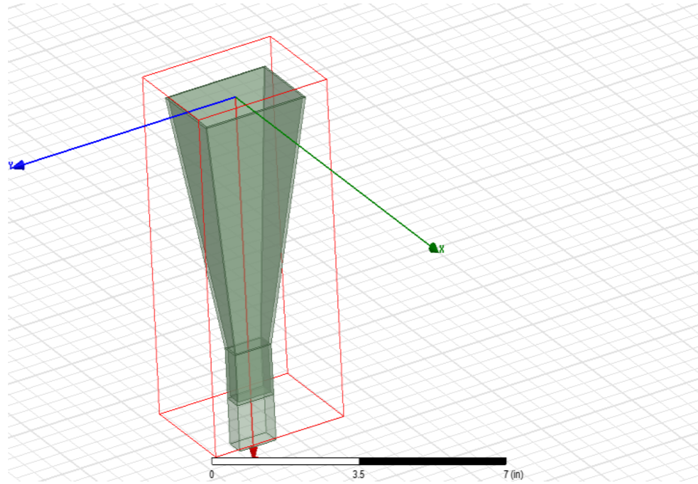
– Padding type: Absolute Offset

– Value: 0.3in



– Click the OK button

4. CREATE RADIATION BOUNDARY



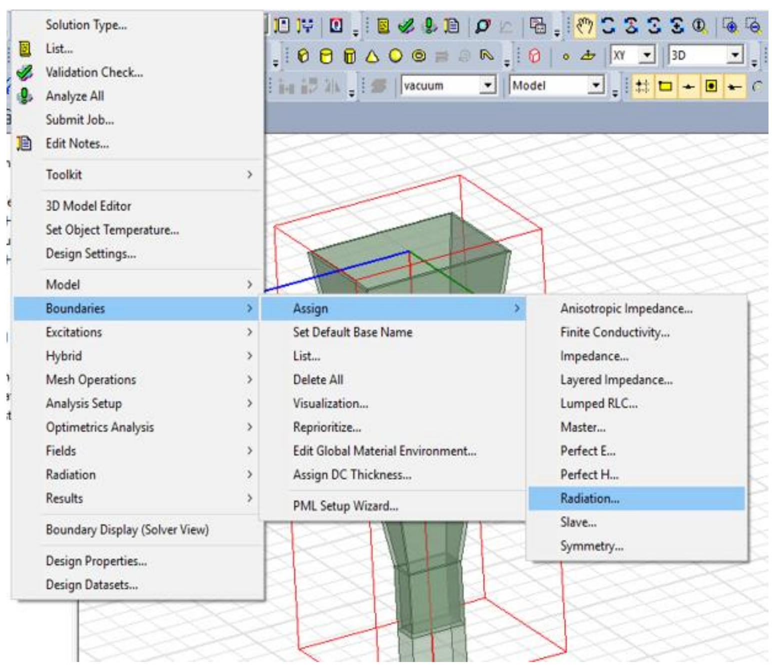
- Select the menu item Edit > Select > By Name
  – Object Name: Region
  – Click the OK button
- Select the menu item **HFSS > Boundaries > Assign > Radiation**…
  – Click the OK button

5. CREATE A RADIATION SETUP

- Select the menu item

HFSS > **Radiation** > **Insert Far Field Setup** > **Infinite Sphere**

– Infinite Sphere Tab



- Name: 2D
- Phi: (Start: 0, Stop: 90, Step Size: 90)
- Theta: (Start: -180, Stop: 180, Step Size: 1)

  – Click the OK button

6. CREATING AN ANALYSIS SETUP

- Select the menu item **HFSS>**

Analysis Setup > Add Solution Setup

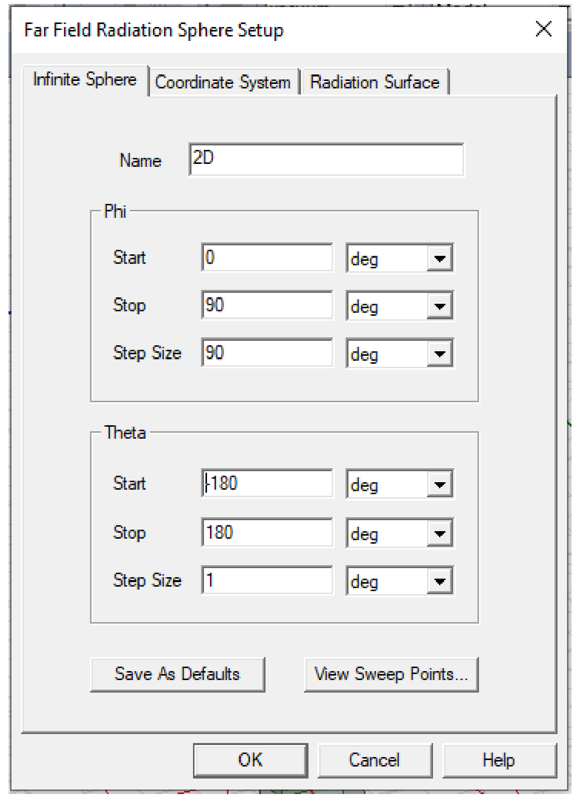
– Click the General tab:

- Solution Frequency: 10 GHz
- Maximum Number of Passes: 6
- Maximum Delta S per Pass: 0.02

– Click the OK button

7. SAVE PROJECT

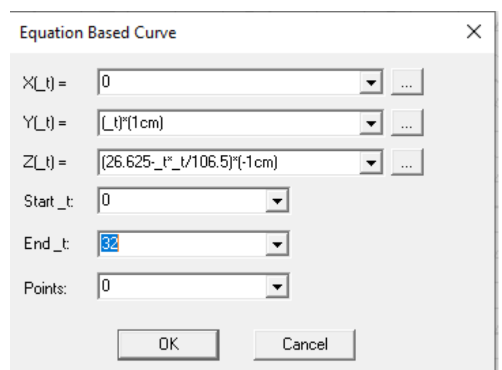
- Select the menu item **File > Save As**
  - – Filename: Reflector
  - – Click the Save button
- Source Design Analyze
- Select the menu item **HFSS > Analyze All**



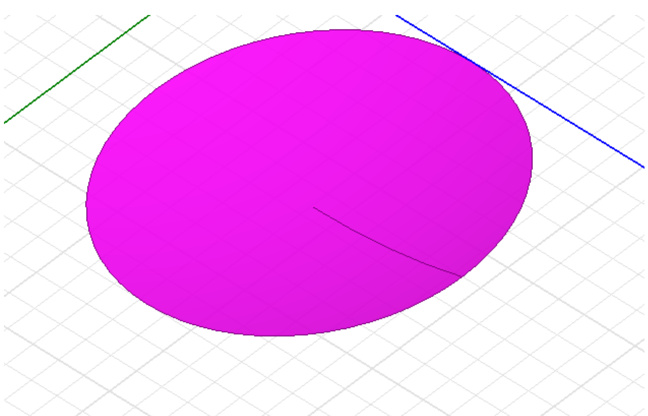
PART 2: CREATING THE 3D MODEL

❖ **Create Reflector**

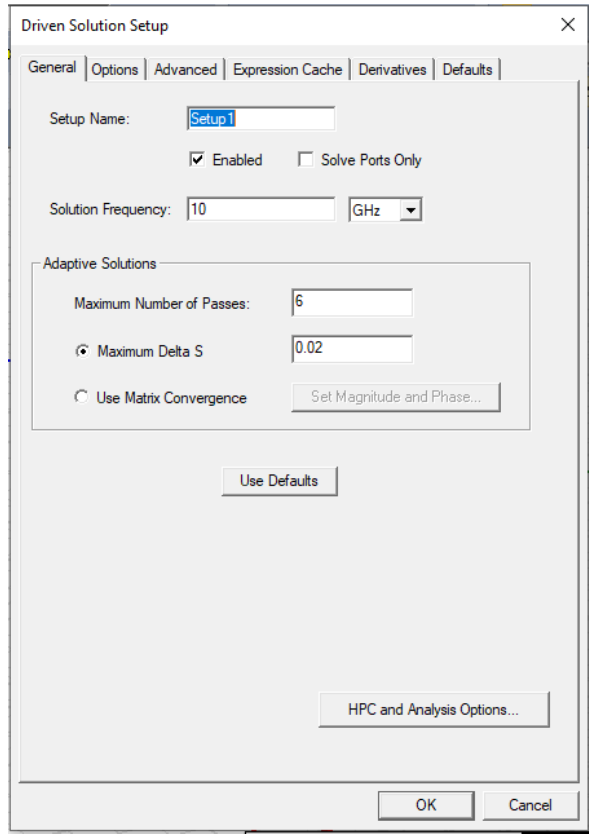
- Select the menu item **Draw > Equation Based Curve**
  - – X(_t): 0
  - – Y(_t): (_t)*(1cm)
  - – Z(_t): (26.625-_t*_t/106.5)*(-1cm)
  - – Start_t: 0
  - – End_t: 32
  - – Number of Points: 0
  - – Click the OK button



- Select the menu item **Edit > Select All**
- Select the menu item Draw > Sweep Around Axis
  - – Sweep axis: Z
  - – Angle of sweep: 360 deg
  - – Draft angle: 0
  - – Draft type: Round
  - – Number of segments: 0
  - – Click the OK button



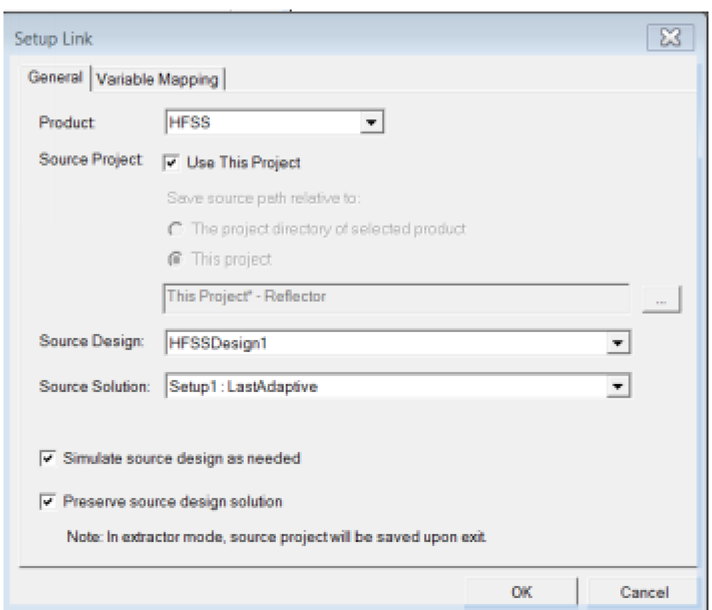
8. ASSIGN PEC



- ➢ Select the menu item Edit > Select All
- ➢ Select the menu item **HFSS-IE > Boundaries > Assign > Perfect E**
  – Click the OK button

9. CREATE LINKED EXCITATION

- ➢ Select the menu **item HFSS-IE > Excitations > Assign > Incident Wave > Near Field Wave**
  – General Data
- ➢ Name: Feed
- ➢ Vector Input Format: Cartesian
- ➢ Click the Next button
  – Near Field Wave options
- ➢ Theta (rotation about the resultant X-axis): 180deg
- ➢ Click the Setup Link button
  – Product: HFSS
  – Source Project: √ Use This Project
  – Source Design: HFSSDesign1
  – Source Solution: Setup1: Last Adaptive – Simulate source design as needed: √
  – Preserve source design solution: √
  – Click the OK button

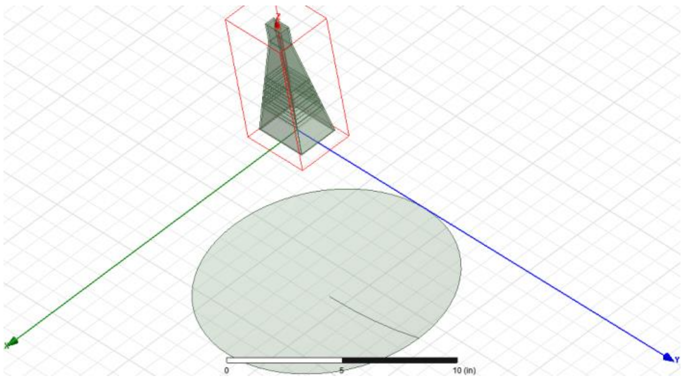


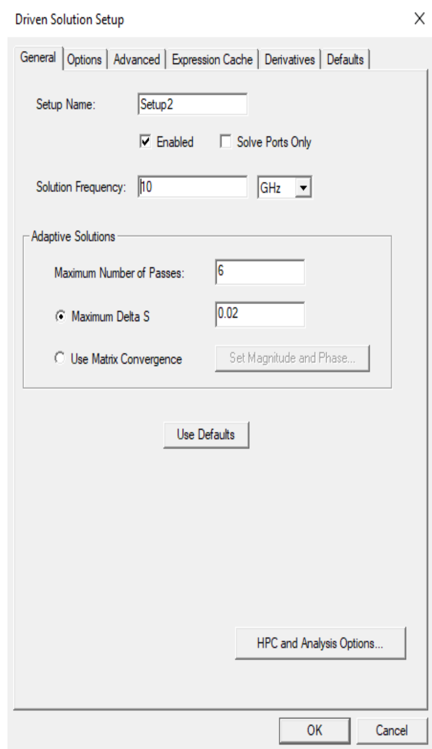
PART 3: HFSS HYBRID DESIGN OF A REFLECTOR + HORN ANTENNA

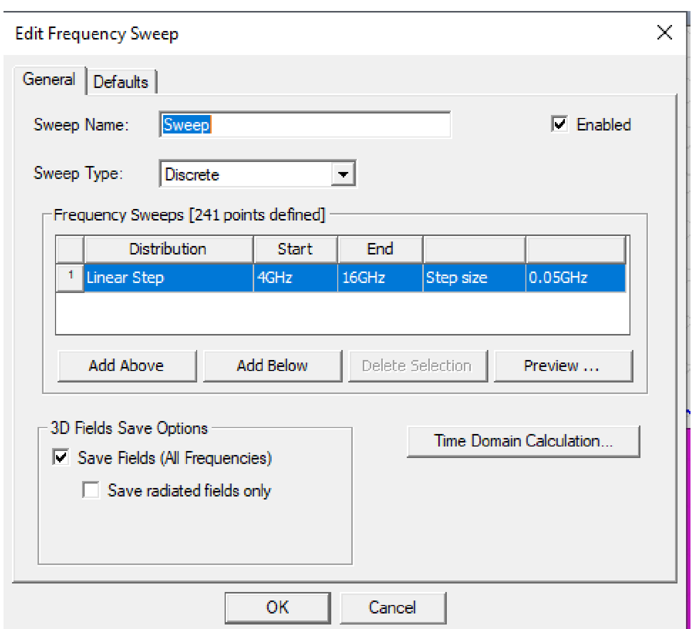
After the creation of the horn, we export it as a 3D component and save it on a desired location on our computer. Next, we design the parabolic reflector and save it as a separate component on any location on the computer. Finally, we include the two components to obtain our parabolic reflector antenna.

The horn is positioned such that its aperture is directly facing the inside surface of the parabolic reflector with the aim of collecting and recycling electromagnetic emissions. The coordinate system employed in this set up is the reflector focus coordinate system.

Next, a solution setup is added to the two components. After adding a solution set up, we do a frequency sweep for our design. This is where we indicate the frequency range in which our design should operate. We set the step size 0.05GHz.

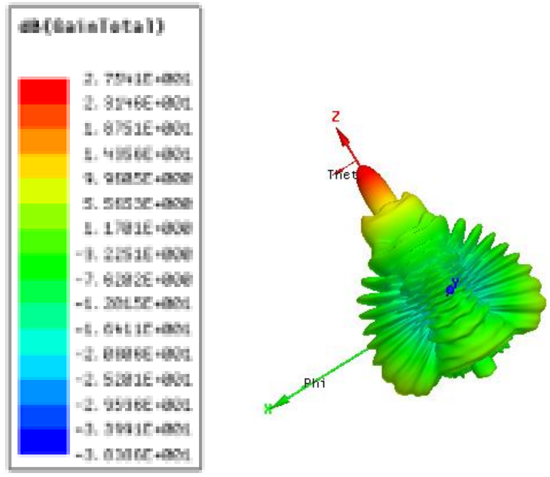






10. <u>PART 4: 3D PATTERN RESULTS</u>

- Create 3D Far Field Pattern for IE Solution
  – Select the menu item **HFSS-IE > Results > Create Far Fields Report > 3D Polar Plot**
- Solution: IE_Setup: LastAdaptive
- Geometry: 3D
- Primary Sweep: Phi
- Secondary Sweep: Theta
- Category: Directivity
- Quantity: DirTotal
- Function: dB
- Click the New Report button



NB: *For results and discussion, refer to chapter 4 of our project report.*

SECTION 3: SPHERICAL PHANTOM DESIGN FOR SPECIFIC ABSORPTION RATE (SAR) SIMULATION

Prepared by: Philip Arthur (MPhil. Telecom Eng. 2021)

INTRODUCTION

With the increasing consumer demand for wireless devices, consumers and the media have become aware of and are concerned with the biological effects of long-term exposure to radio frequency radiation (RFR). To ensure public safety, the Federal Communication Commission (FCC) has developed safety standards that wireless devices are required to meet in order to be sold in the US (Similar guidelines exist in other countries). The quantity used to quantify the amount of energy absorbed is the Specific Absorption Rate or SAR [1]. The specific absorption rate which is defined as the amount of electromagnetic energy absorbed per-unit mass by the human body when using a wireless communication device and can be represented mathematically as:

$$SAR = \frac{\sigma \times E^2}{\rho} \tag{1}$$

Where $\boldsymbol{\sigma}$ is the conductivity of the body tissue (S/m), $\boldsymbol{E}$ expresses the RMS electric field intensity (V/m) and $\boldsymbol{\rho}$ denotes the mass density of the body tissue (Kg/m^3). According to the IEEE C95.1-2005 standard for safety levels with respect to human exposure to RF energy, SAR limit is set to 1.6 W/kg and 2 W/kg over 1g and 10 g of contiguous tissue respectively by the FCC and International Commission on Non-Ionizing Radiation Protection (ICNIRP).

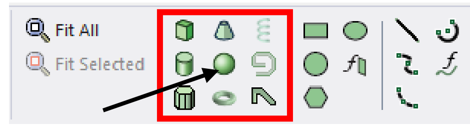
This example is intended to show you how to create, simulate, and analyze a simple phantom, which is commonly used to calibrate Specific Absorption Rate test equipment, using the Ansoft HFSS Design Environment.

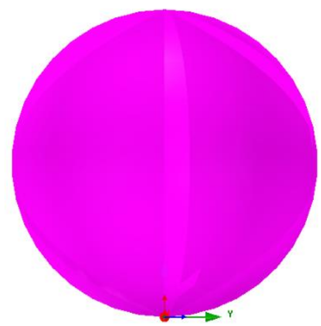
For basic design tutorials using HFSS:

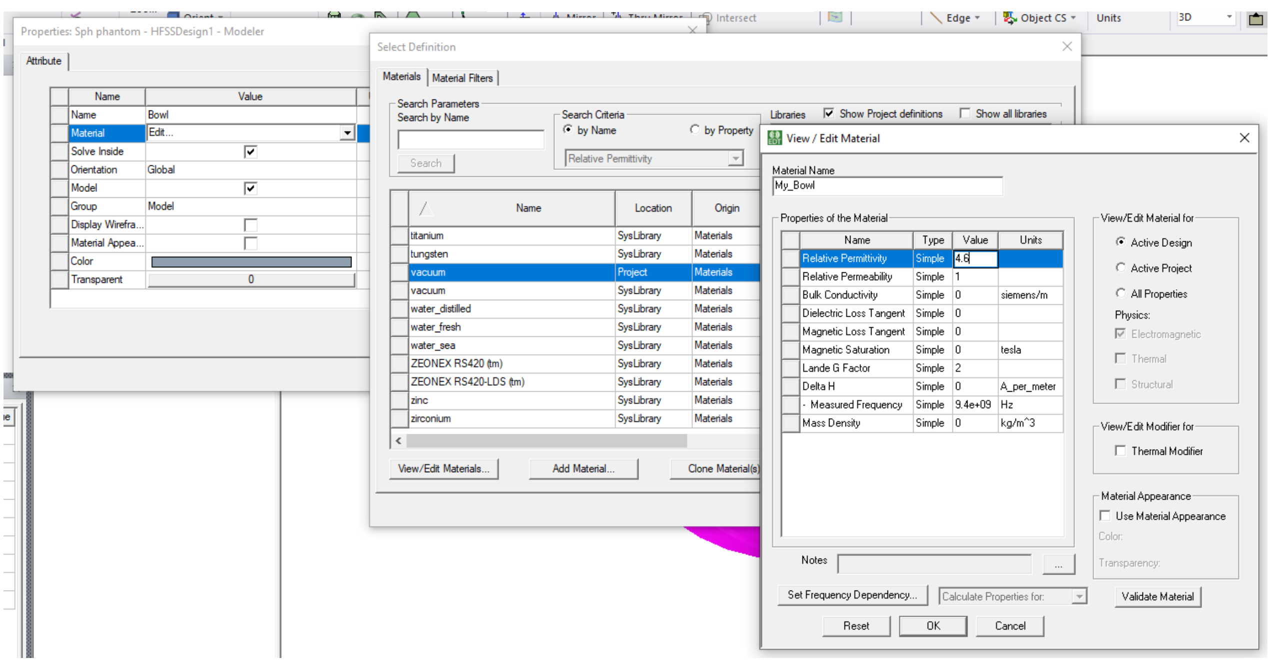
https://www.youtube.com/playlist?list=PLdIVd39LNkpSaTzAFCS_jh3sV3Gc21mNg

1. CREATE BOWL

- Select the menu item **Draw** > **Sphere**
- Using the coordinate entry fields, enter the sphere position
  - X: 0.0, Y: 0.0, **Z: 56.5**, Press the **Enter** key
- Using the coordinate entry fields, enter the radius:
  - **dX: 56.5**, dY: 0.0, dZ: 0.0, Press the Enter key
- Change name of **Sphere1** to **Bow1**





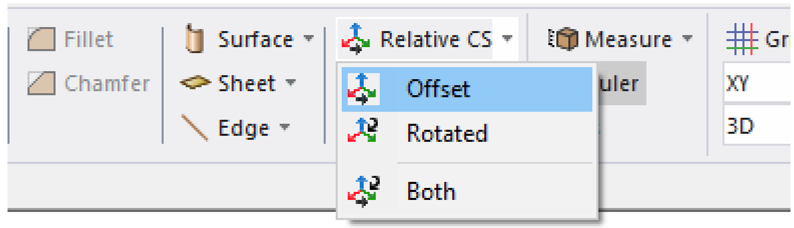


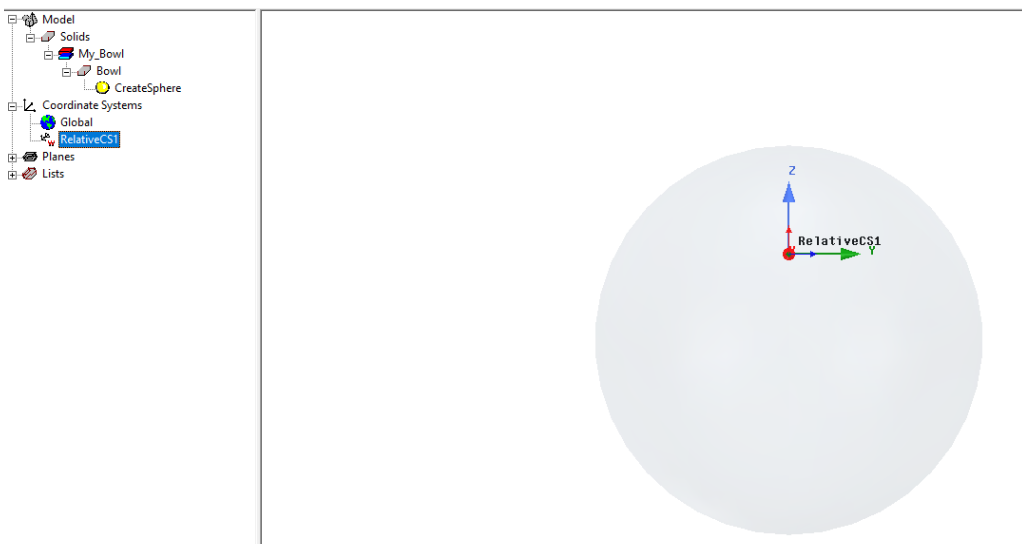
2. SET MATERIAL PROPERTIES (View/Edit Material Window)

- Change material name to **My_Bowl**
- For the Value of Relative Permittivity type: **4.6**
- Click the **OK** button

3. CREATE OFFSET COORDINATE SYSTEM

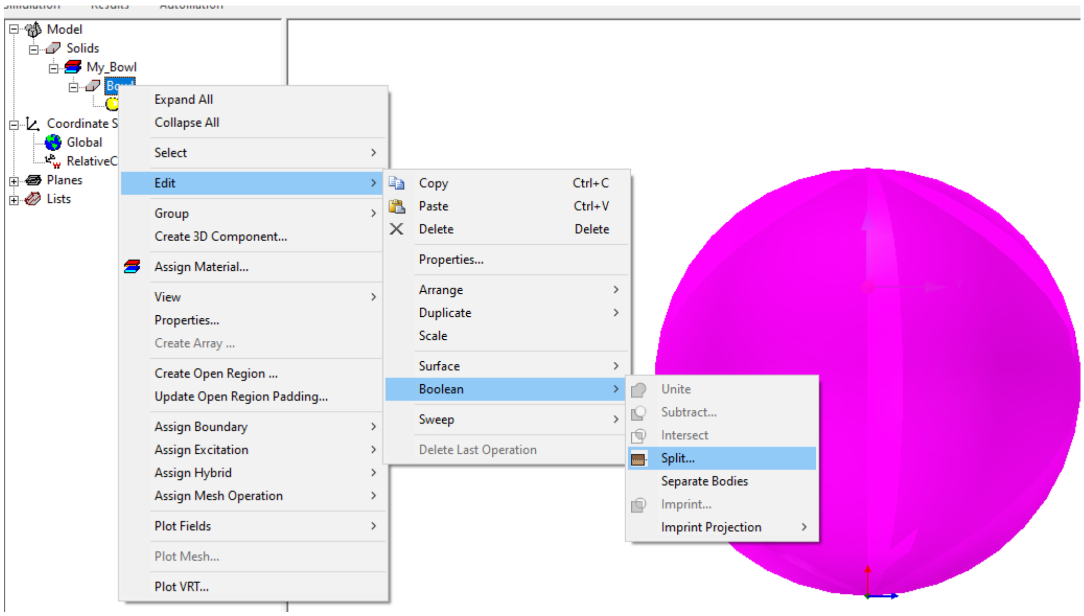
- Select the menu item **3D Modeler** > **Coordinate System** > **Create** > **Relative CS** > **Offset**
- Using the coordinate entry fields, enter the origin
  - X: 0.0, Y: 0.0**, Z: 81.5**, Press the **Enter** key

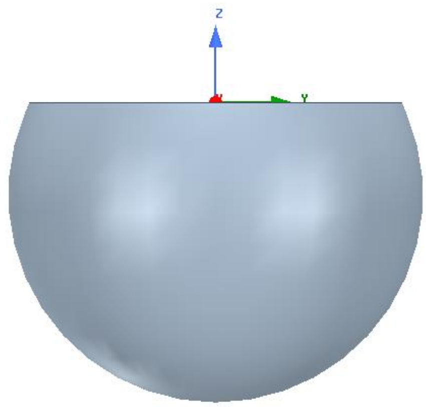




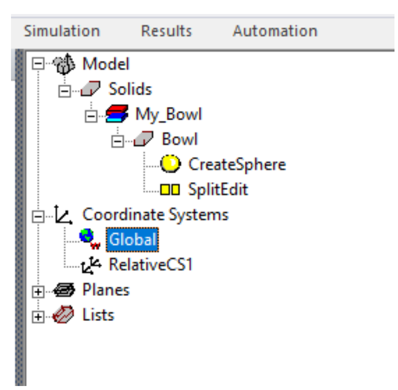
4. CREATE THE OPENING IN THE BOWL

- Right click **Bowl** > **Edit** > **Boolean** > **Split**
- Split Window:
  - Split Plane: **XY**
  - Keep Fragments: **Negative Side**
  - Click the **OK** button

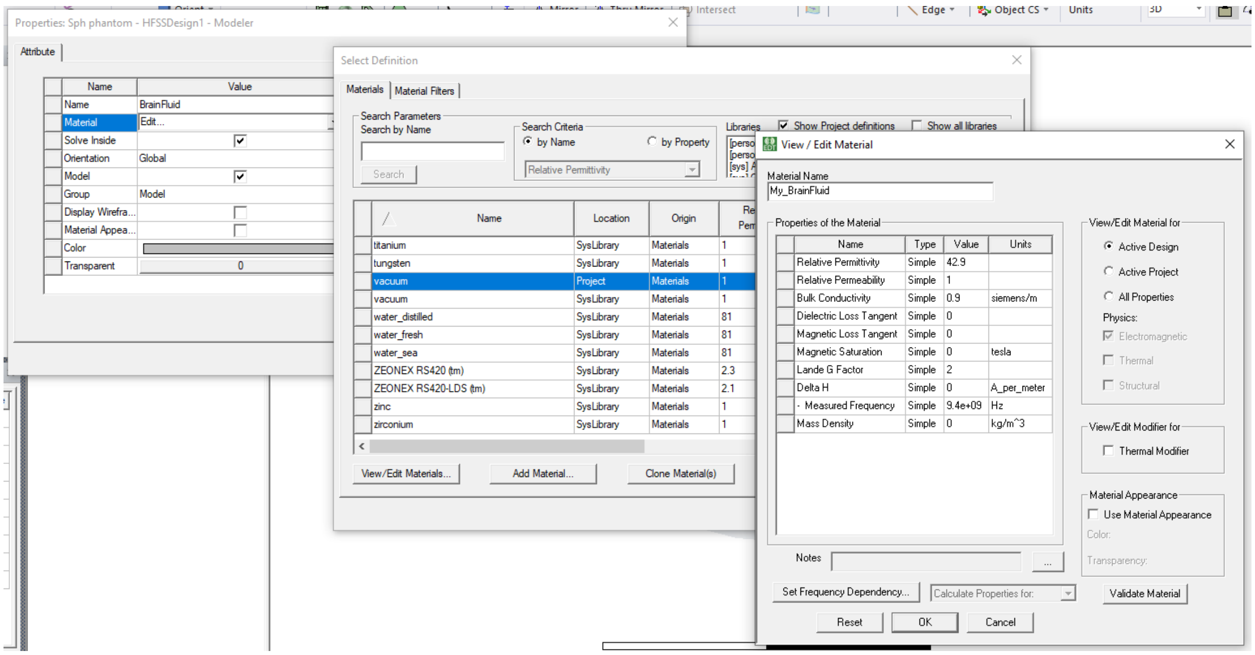




5. CREATE BRAIN FLUID

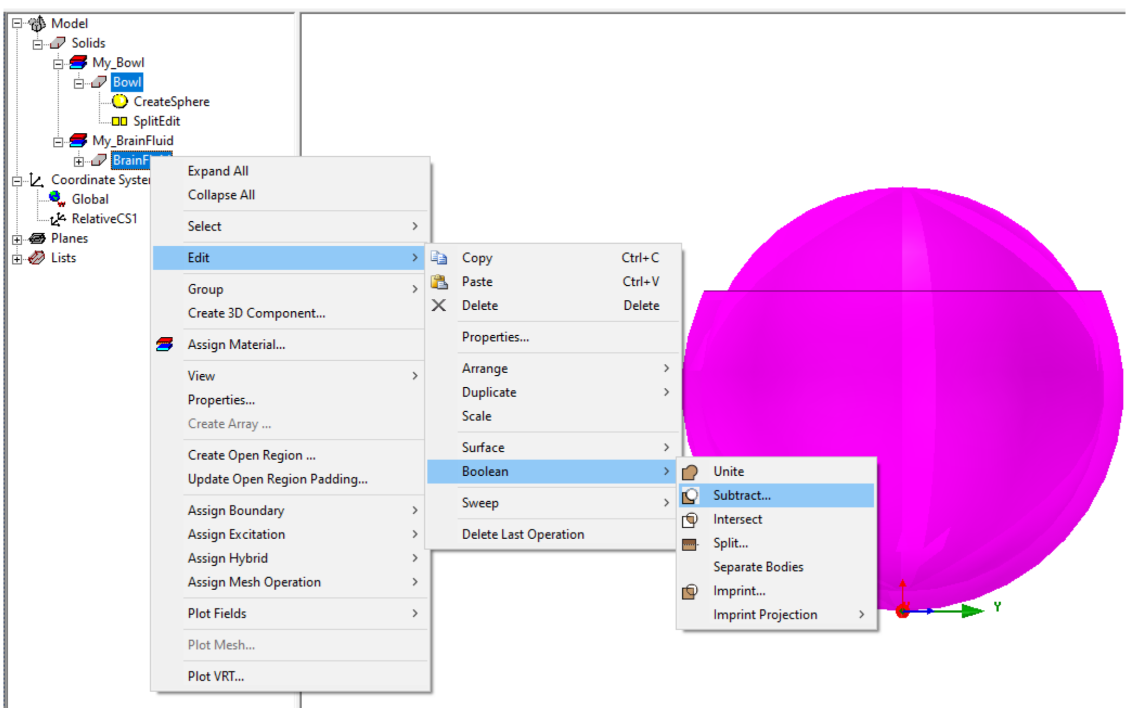


- Set the working coordinate system (CS): **Global** or simply click on the **Global** CS
- Select the menu item **Draw > Sphere**
- Using the coordinate entry fields, enter the sphere position
  - X: 0.0, Y: 0.0, **Z: 56.5**, Press the **Enter** key
- Using the coordinate entry fields, enter the radius:
  - **dX: 51.5**, dY: 0.0, dZ: 0.0, Press the **Enter** key
- Change name **Sphere1** to **BrainFluid**



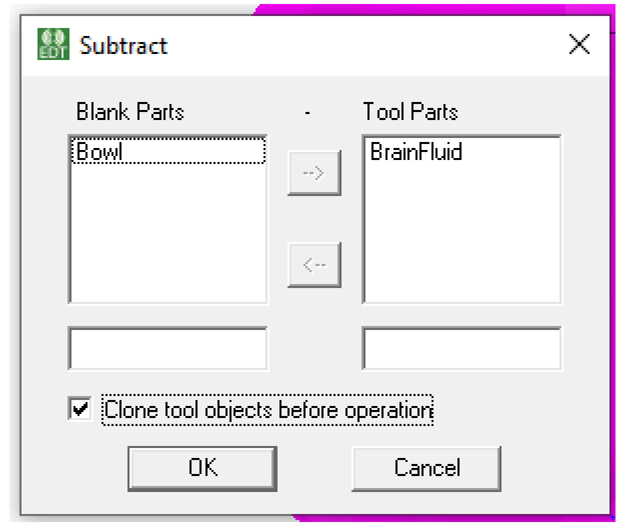
6. SET MATERIAL PROPERTIES (View/Edit Material Window)

- Change material name to **My_BrainFluid**
- For the Value of Relative Permittivity type: **42.9**
- For the Value of Bulk Conductivity type: **0.9**
- Click the **OK** button



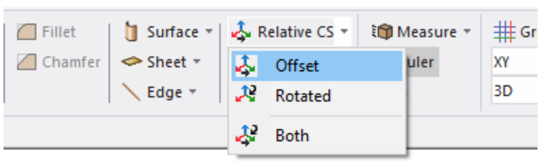
7. CREATE THE SHELL OF THE BOWL

- Select the objects: **Bowl**, **BrainFluid**
- Clone tool objects before subtracting: √ Checked
- Click the **OK** button



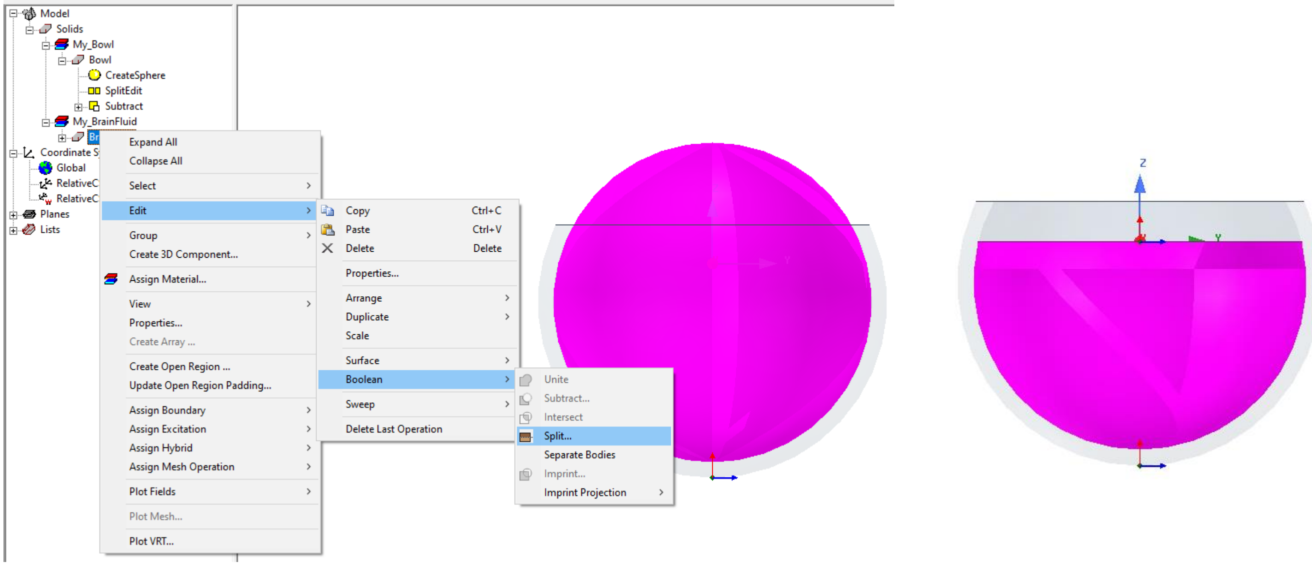
8. CREATE OFFSET COORDINATE SYSTEM

- Select the menu item **3D Modeler** > **Coordinate System** > **Create** > **Relative CS** > **Offset**
- Using the coordinate entry fields, enter the origin
  - X: 0.0, Y: 0.0**, Z: 69**, Press the **Enter** key

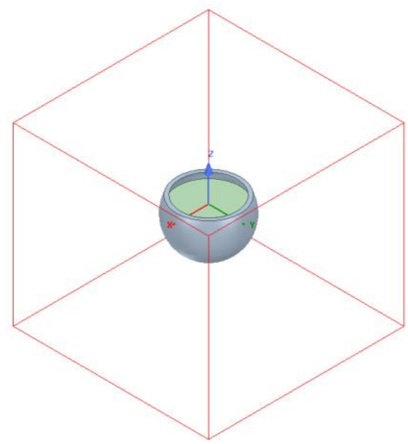


9. SET THE FLUID LEVEL

- Right click **BrainFluid** > **Edit** > **Boolean** > **Split**
- Split Window
  - Split Plane: **XY**
  - Keep Fragments: **Negative Side**
  - Click the **OK** button



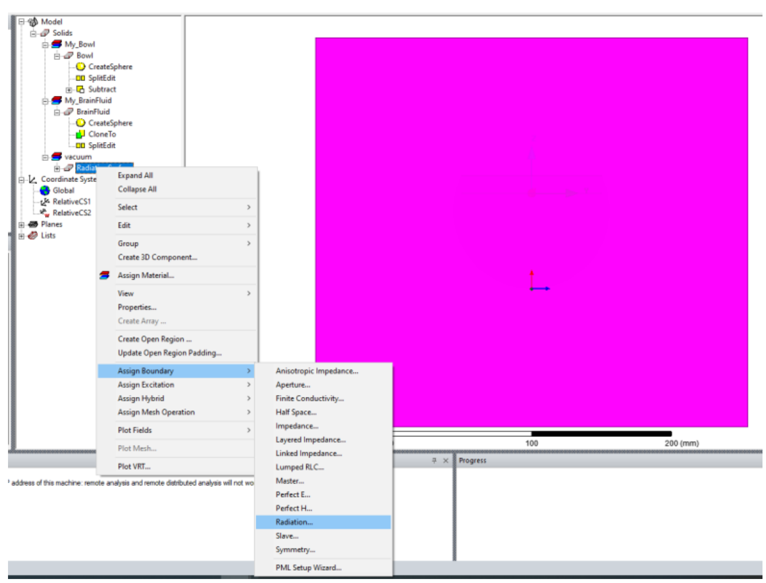
10. CREATE AIR BOX



- Select the menu item **Draw > Box**
- Using the coordinate entry fields, enter the box position
  - **X: -150.0, Y: -150.0, Z: -150.0**, Press the Enter key
- Using the coordinate entry fields, enter the opposite corner of the base rectangle:
  - **dX: 300.0, dY: 300.0, dZ: 300.0**, Press the Enter key
- Change name of **Box1** to **Airbox**

1. CREATE RADIATION BOUNDARY

- Right click **Airbox > Assign Boundary > Radiation**
- Radiation Boundary Window:
  - Name: **Rad1**
  - Click the **OK** button



SECTION 4: PIN DIODE MODELLING FOR ON/OFF SWITCHING IN RECONFIGURABLE ANTENNAS USING HFSS 2018

Prepared by: Philip Arthur (MPhil. Telecom Eng. 2021)

INTRODUCTION

Antenna reconfiguration has become an important feature in modern wireless communications such as MIMO systems, cognitive radio, 5G and satellite communication systems, IoT networks, and smartphones [4]. A reconfigurable antenna is capable of changing its performance characteristics (resonant frequency, radiation pattern, polarization, etc.) by mechanically or electrically modifying its architecture [5]. The basic goal of a reconfigurable antenna is to achieve more functionality with a single antenna element or an array.

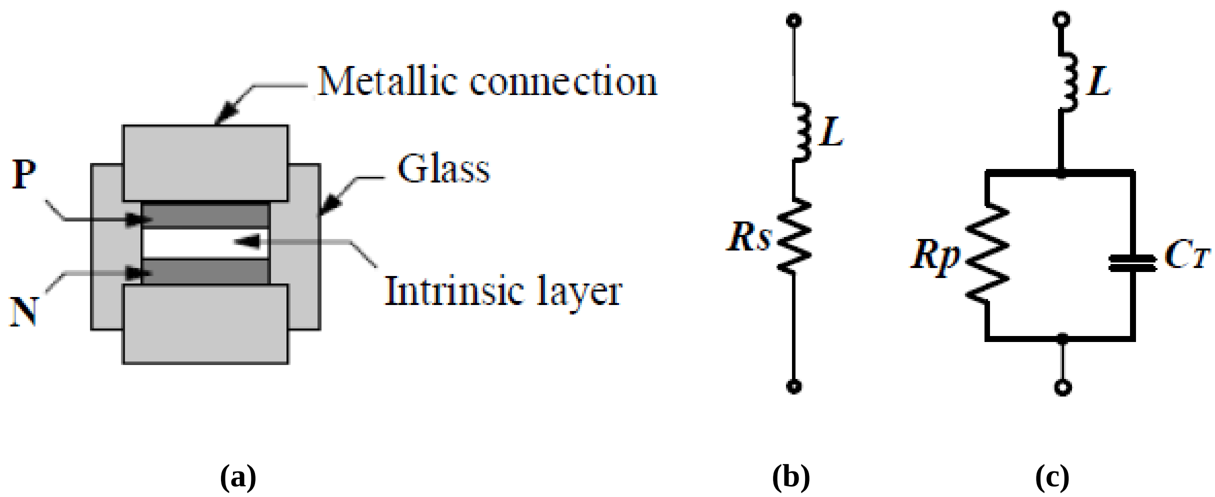


Fig.1 PIN Diode (a) Basic structure [50] (b) Equivalent forward bias circuit (c) Equivalent reverse bias circuit.

The PIN diode is a simple technique of electronically modifying the functional properties of the antenna by the switching states of the diode. The PIN diode conducts current in one direction only and therefore determines the ON and OFF states respectively. When the diode is forward biased (ON state) the equivalent circuit is a combination of parasitic inductance L and a series resistance Rs as shown in Fig.4.0 (b). When a reverse-biased voltage is applied, the diode is known to operate in the OFF state with the equivalent circuit containing a large resistance (Rp) in shunt with a capacitor as shown in Fig.4.0 (c). This effect can be modeled as an RLC boundary in HFSS.

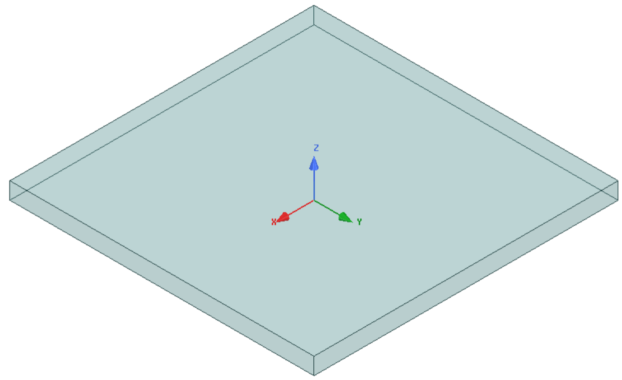
This example is intended to show you how to create, simulate, and analyze a PIN diode in a simple transmission line using the Ansoft HFSS Design Environment.

For basic design tutorials using HFSS:

https://www.youtube.com/playlist?list=PLdIVd39LNkpSaTzAFCS_jh3sV3Gc21mNg

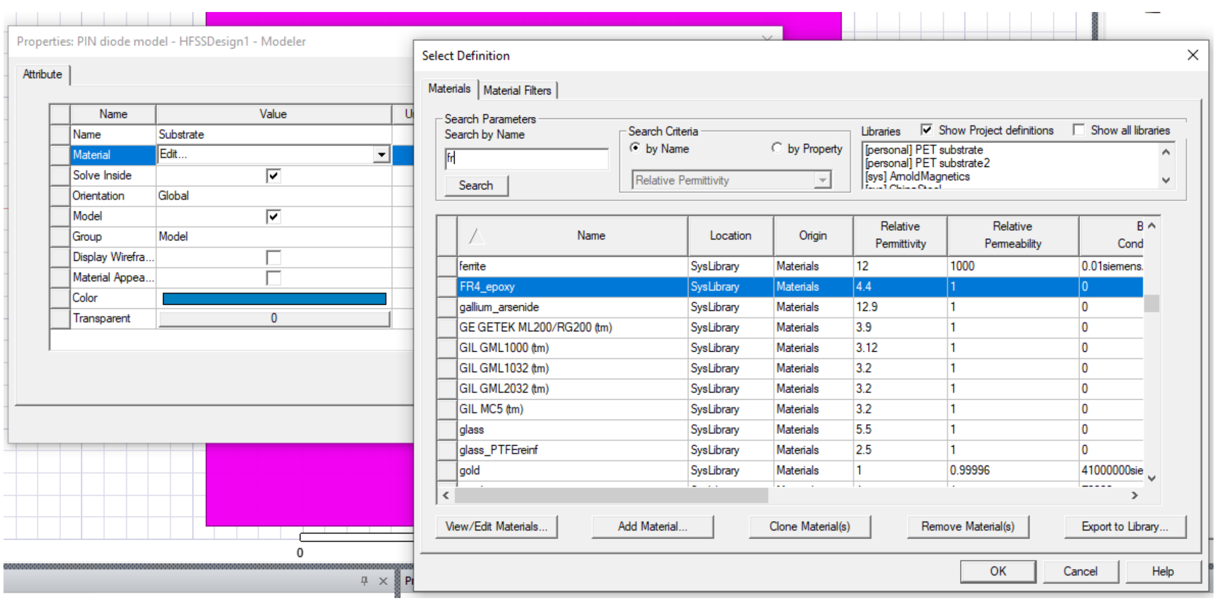
1. CREATE DIELECTRIC SUBSTRATE

- Select the menu item **Draw > Box**
- Using the coordinate entry fields, enter the sphere position
  - **X: -14.4, Y: -14.4**, Z: 0, Press the **Enter** key
- Using the coordinate entry fields, enter the radius:
  - **dX: 28.8, dY: 28.8, dZ: 1.6**, Press the **Enter** key
- Change name of **Box1** to **Substrate**

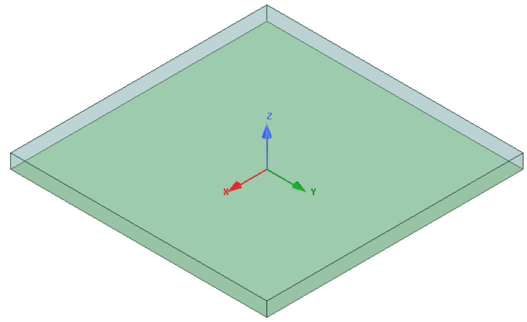


2. SET MATERIAL PROPERTIES (View/Edit Material Window)

- Assign material: **FR-4 epoxy**
- Click the OK button

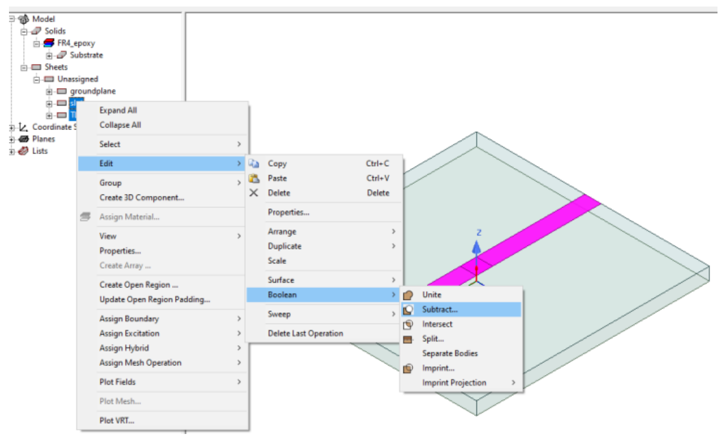


3. CREATE GROUND PLANE

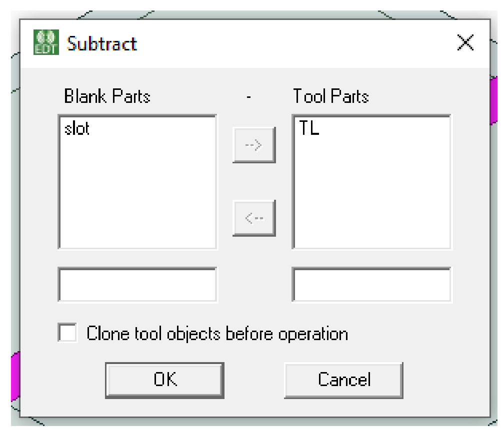


- Select the menu item **Draw** > **Rectangle**
- Using the coordinate entry fields, enter the sphere position
  - **X: -14.4, Y: -14.4**, Z: 0, Press the **Enter** key
- Using the coordinate entry fields, enter the radius:
  - **dX: 28.8, dY: 28.8, dZ: 0**, Press the **Enter** key
- Change name of **Rectangle1** to **groundplane**

4. CREATE TRANSMISSION LINE



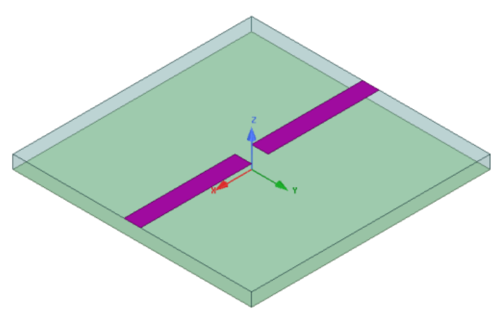
- Select the menu item **Draw** > **Rectangle**
- Using the coordinate entry fields, enter the sphere position
  - **X: -14.4, Y: -1**, Z: 1.6, Press the **Enter** key
- Using the coordinate entry fields, enter the radius:
  - **dX: 28.8, dY: 2, dZ: 1.6**, Press the **Enter** key
- Change name of **Rectangle1** to **TL**



5. CREATE SLOT

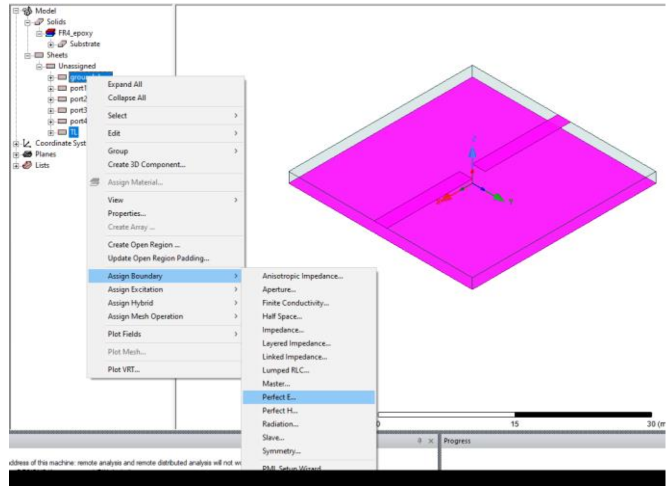
- Select the menu item **Draw** > **Rectangle**
- Using the coordinate entry fields, enter the sphere position
  - **X: -1, Y: -1**, Z: 1.6, Press the **Enter** key
- Using the coordinate entry fields, enter the radius:
  - **dX: 2, dY: 2, dZ: 1.6**, Press the **Enter** key
- Change name of **Rectangle1** to **slot**

6. ASSIGN MATERIAL

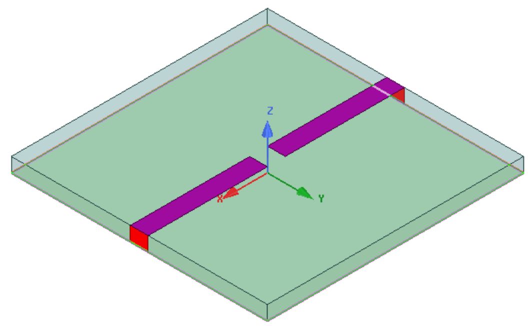


- Select **groundplane** and **TL**
- Right click > **Assign Boundary** > **Perfect E**
- Click **OK** for PerfE1

7. CREATE PORTS

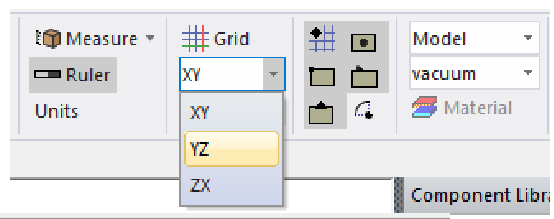


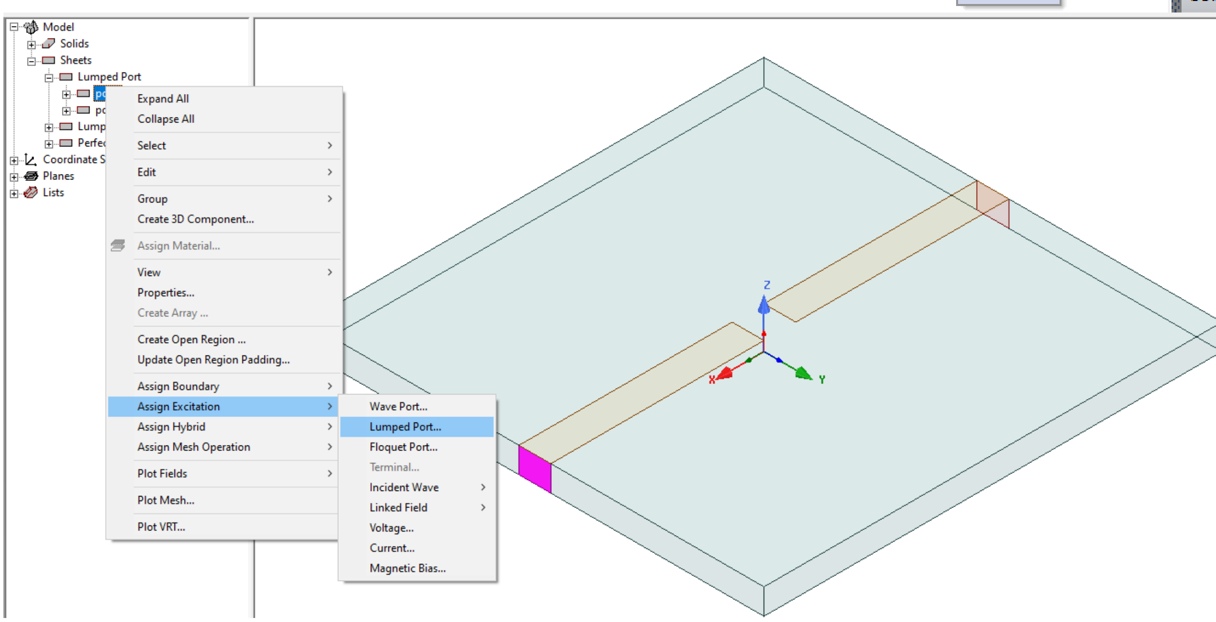
- ➢ Change drawing plan from default **XY** to **YZ**
- ➢ Select the menu item **Draw > Rectangle**
- ➢ Using the coordinate entry fields, enter the sphere position
  - **X: -14.4, Y: -2**, Z: 0, Press the **Enter** key
- ➢ Using the coordinate entry fields, enter the radius:
  - **dX: 0, dY: 2, dZ: 1.6**, Press the **Enter** key
- ➢ Change name of **Rectangle1** to **port1**
- ➢ Duplicate along line to create **port2** (click and drag)

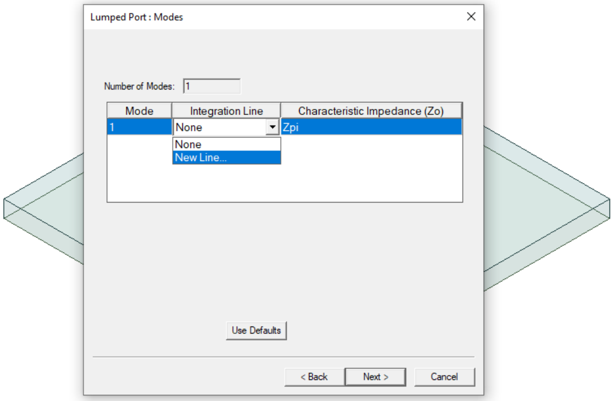


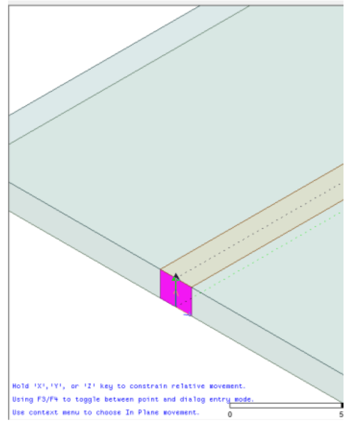
8. ASSIGN EXCITATION

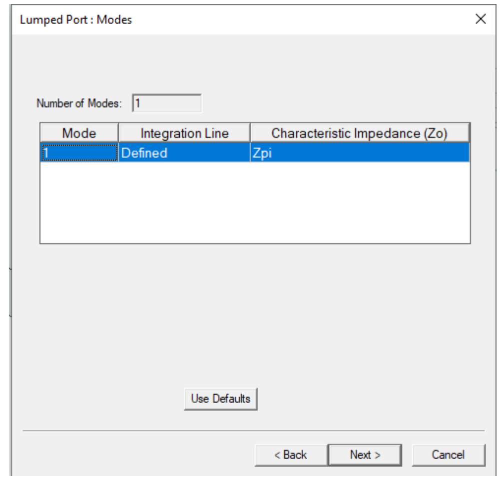
- ➢ Right click **port1 > Assign Excitation > Lumped port**
- ➢ Draw integration line from bottom to top of **port1**
- ➢ Right click **port2 > Assign Excitation > Lumped port**
- ➢ Draw integration line from bottom to top of **port2**





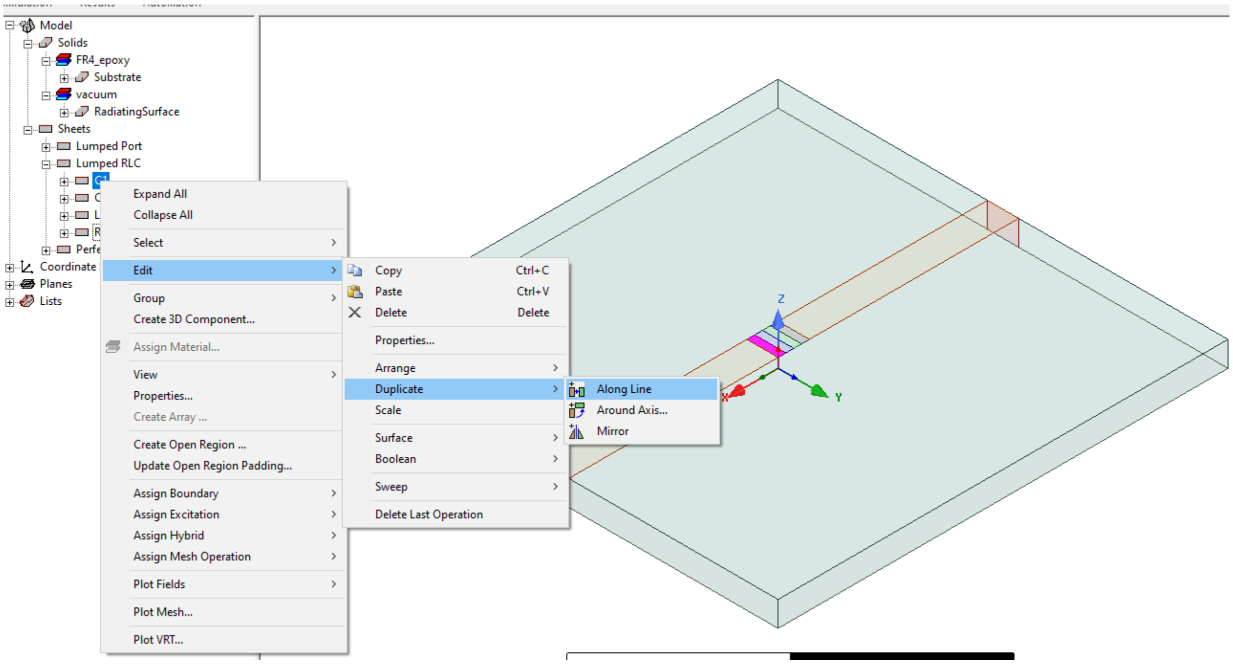






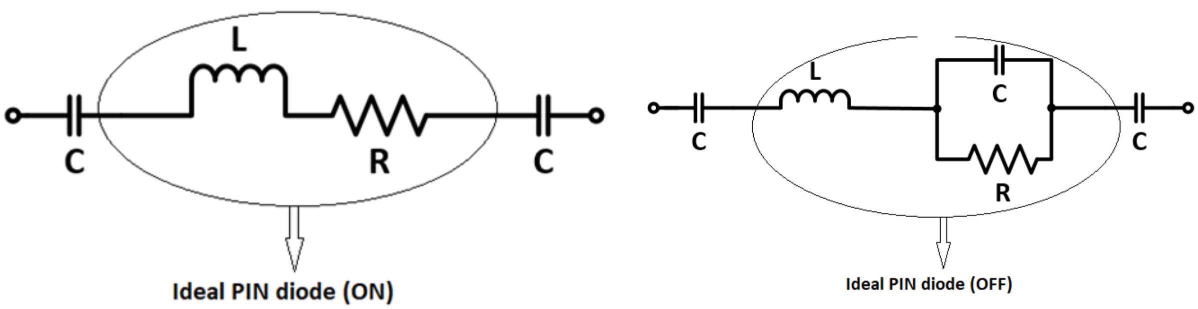
9. CREATE RLC BOUNDARY

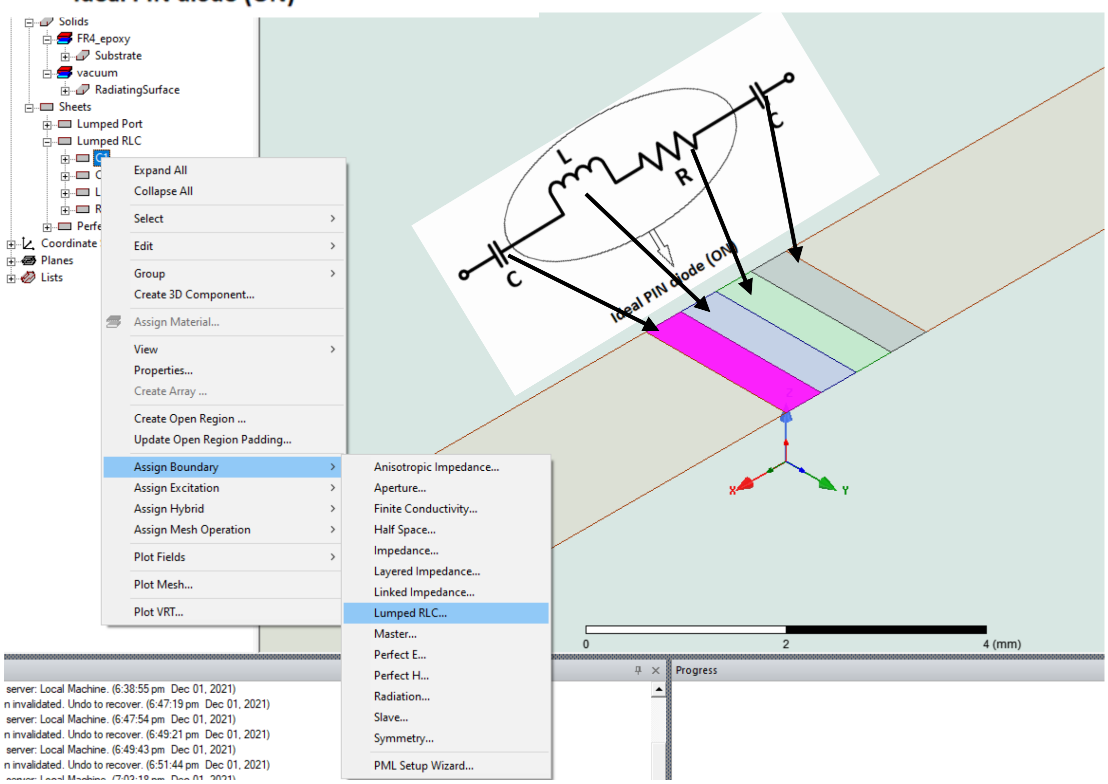
- Change drawing plan from **YZ** to **XY**
- Select the menu item **Draw > Rectangle**
- Using the coordinate entry fields, enter the sphere position
  - **X: -1, Y: -1**, **Z: 1.6**, Press the **Enter** key
- Using the coordinate entry fields, enter the radius:
  - **dX: 0.5, dY: 2, dZ: 1.6**, Press the **Enter** key
- Change name of **Rectangle1** to **C1** (Blocking capacitor 1)
- Duplicate along line to create **3** other rectangles (click and drag) in the same slot.
- Rename other ending rectangle as **C2,** middle 2 rectangles as **L** and **R**

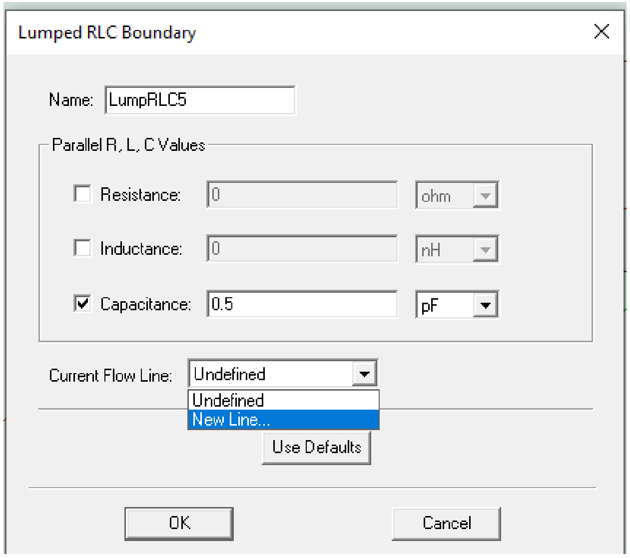


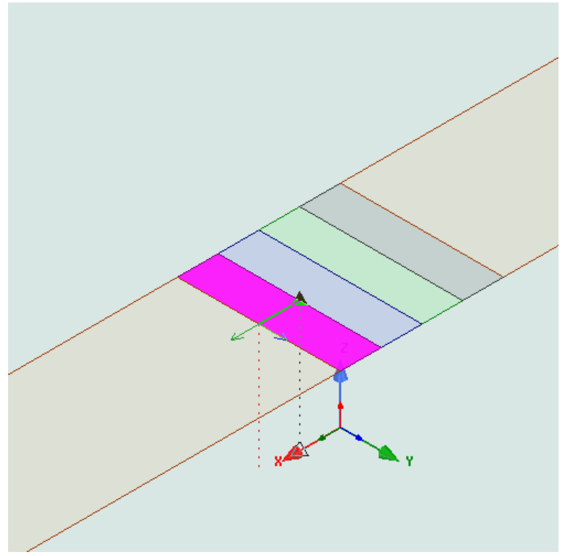
10. ASSIGN RLC BOUNDARY

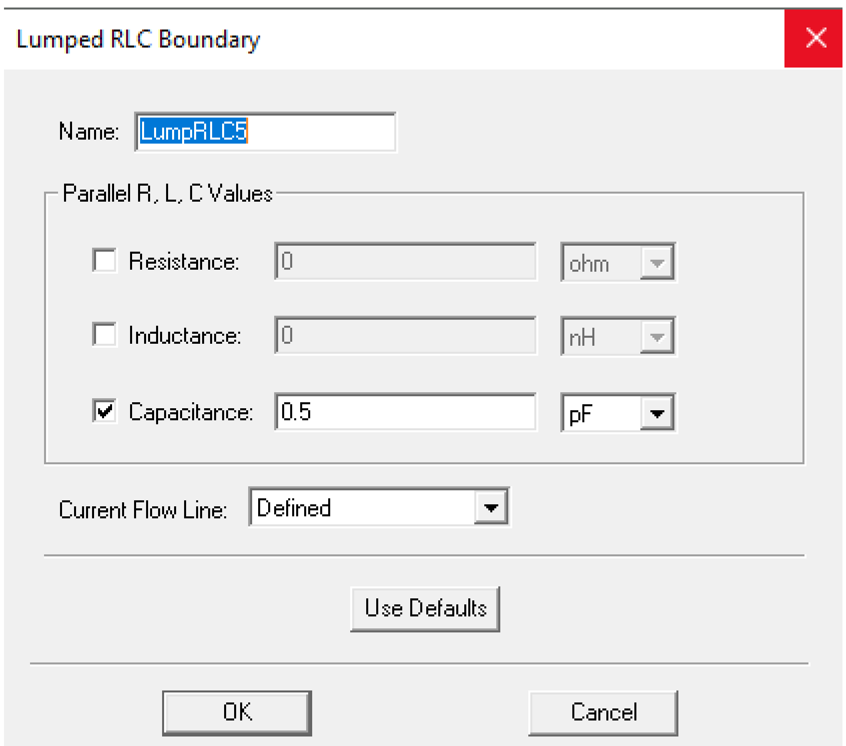
- Right click **C1** > **Assign Boundary** > **Lumped RLC**
- Draw integration line in the chosen direction of the current flow.
- Set C1 and C2 = 0.5uF (**ON** state)
- Right click **L** > **Assign Boundary** > **Lumped RLC**
- Draw integration line in the chosen direction of the current flow (same direction as C1).
- Set L = 0.4nH, R = 2 Ω (**ON** state)
  - For **OFF** state:
  - Set C1 and C2 = 32fF
  - Set L = 0.4nH, in parallel with R = > 15 kΩ (**ON** state)

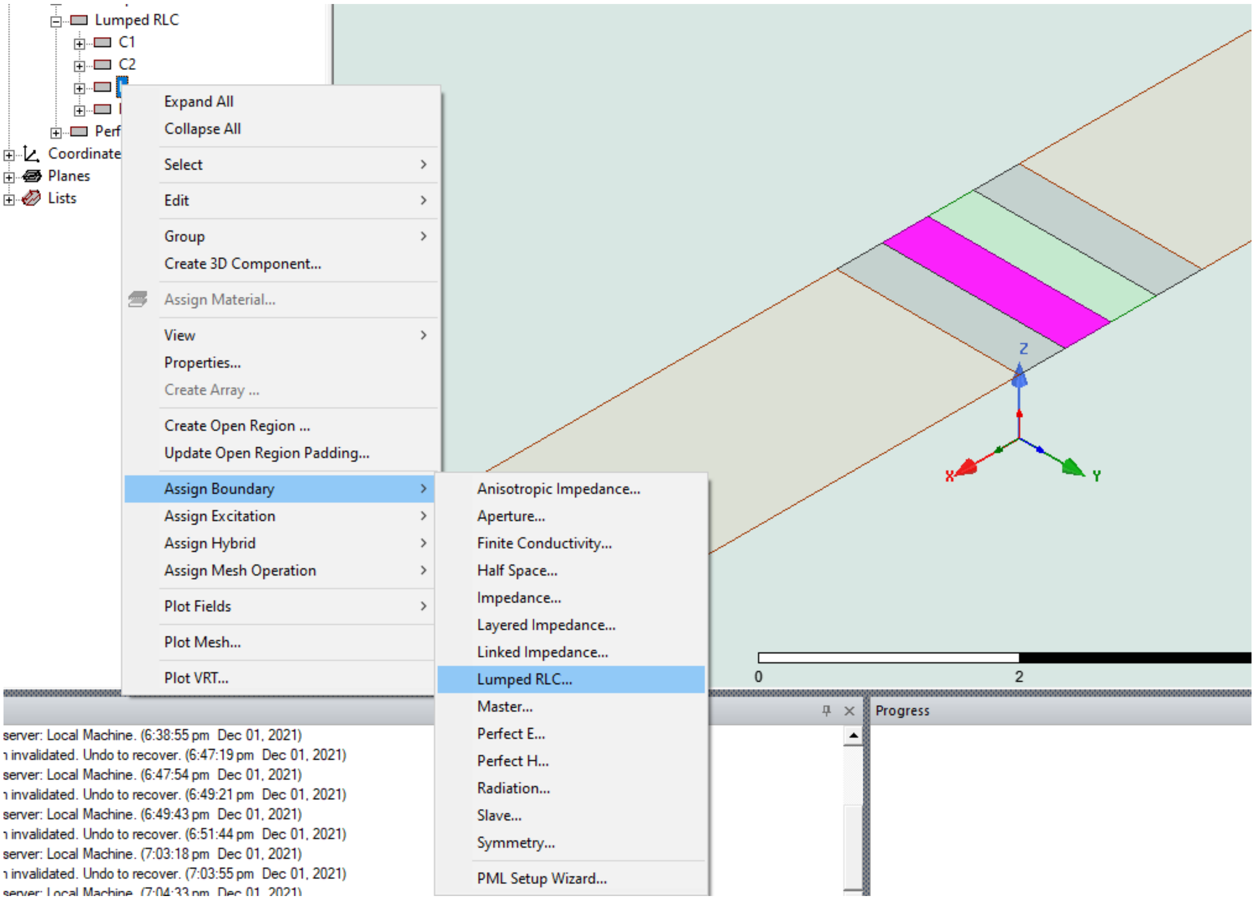




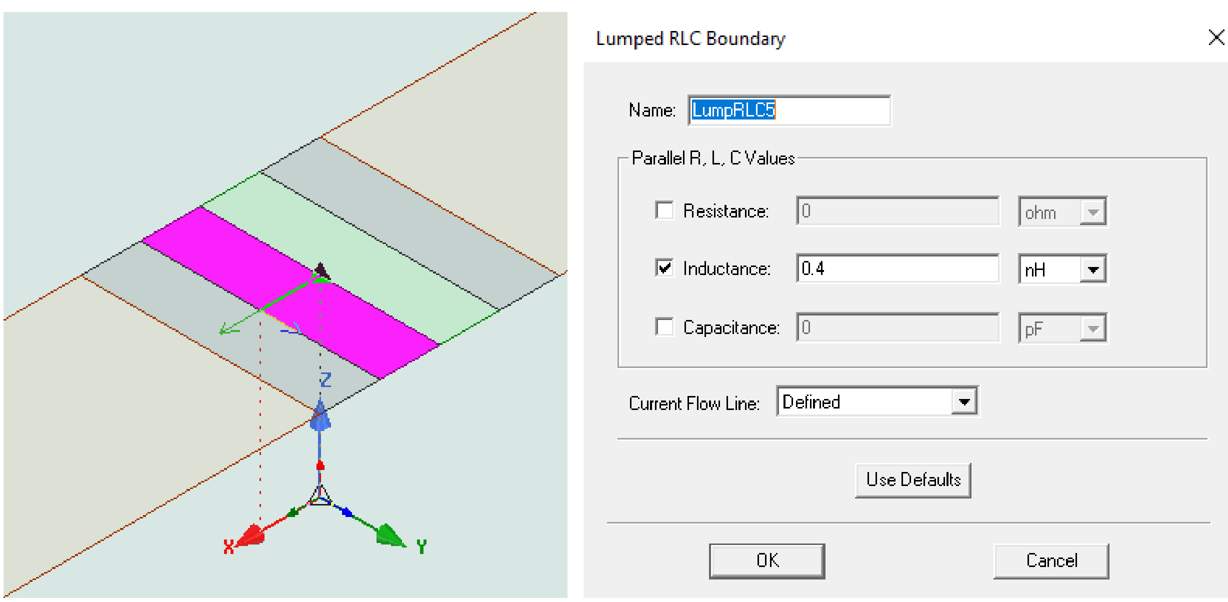

Lumped RLC Boundary
Name: LumpRLC5
Parallel R, L, C Values
Resistance: 0 ohm
Inductance: 0 nH
Capacitance: 0.5 pF
Current Flow Line: Undefined
Undefined
New Line...
Use Defaults
OK
Cancel


X
Y

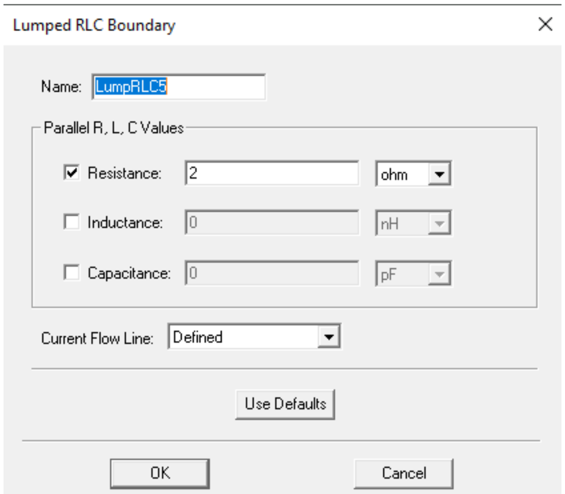

Lumped RLC Boundary
Name: LumpRLC5
Parallel R, L, C Values
Resistance: 0 ohm
Inductance: 0 nH
Capacitance: 0.5 pF
Current Flow Line: Defined
Use Defaults
OK
Cancel

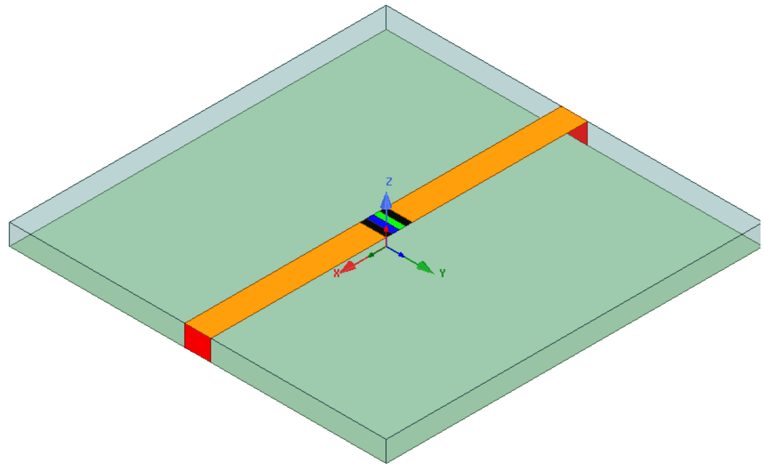


Lumped RLC
C1
C2
Perf
Coordinate
Planes
Lists
Expand All
Collapse All
Select
Edit
Group
Create 3D Component...
Assign Material...
View
Properties...
Create Array ...
Create Open Region ...
Update Open Region Padding...
Assign Boundary
Assign Excitation
Assign Hybrid
Assign Mesh Operation
Plot Fields
Plot Mesh...
Plot VRT...
Anisotropic Impedance...
Aperture...
Finite Conductivity...
Half Space...
Impedance...
Layered Impedance...
Linked Impedance...
Lumped RLC...
Master...
Perfect E...
Perfect H...
Radiation...
Slave...
Symmetry...
PML Setup Wizard...
Progress
server: Local Machine. (6:38:55 pm Dec 01, 2021)
invalidated. Undo to recover. (6:47:19 pm Dec 01, 2021)
server: Local Machine. (6:47:54 pm Dec 01, 2021)
invalidated. Undo to recover. (6:49:21 pm Dec 01, 2021)
server: Local Machine. (6:49:43 pm Dec 01, 2021)
invalidated. Undo to recover. (6:51:44 pm Dec 01, 2021)
server: Local Machine. (7:03:18 pm Dec 01, 2021)
invalidated. Undo to recover. (7:03:55 pm Dec 01, 2021)
0
2
Z
X
Y



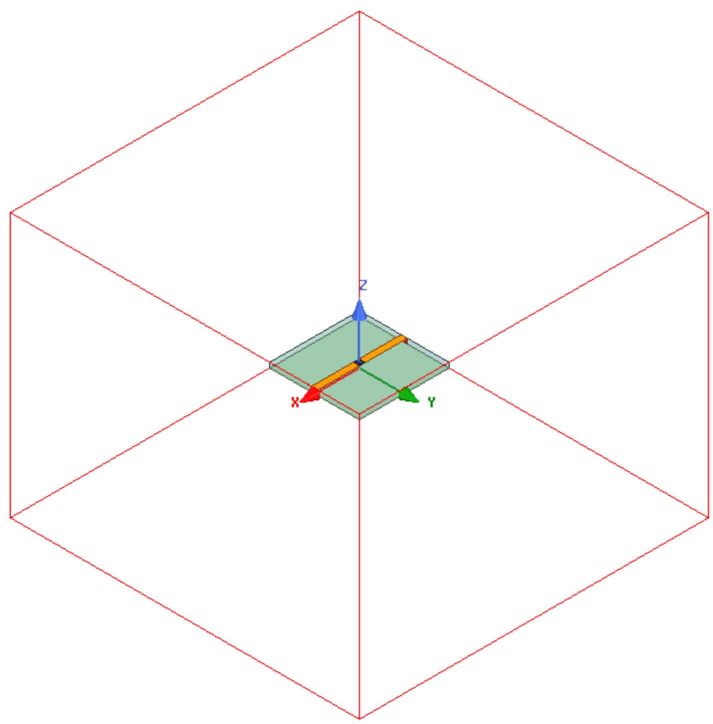
Z
X
Y
Lumped RLC Boundary
Name: LumpRLC5
Parallel R, L, C Values
Resistance: 0 ohm
Inductance: 0.4 nH
Capacitance: 0 pF
Current Flow Line: Defined
Use Defaults
OK
Cancel





11. CREATE AIR BOX

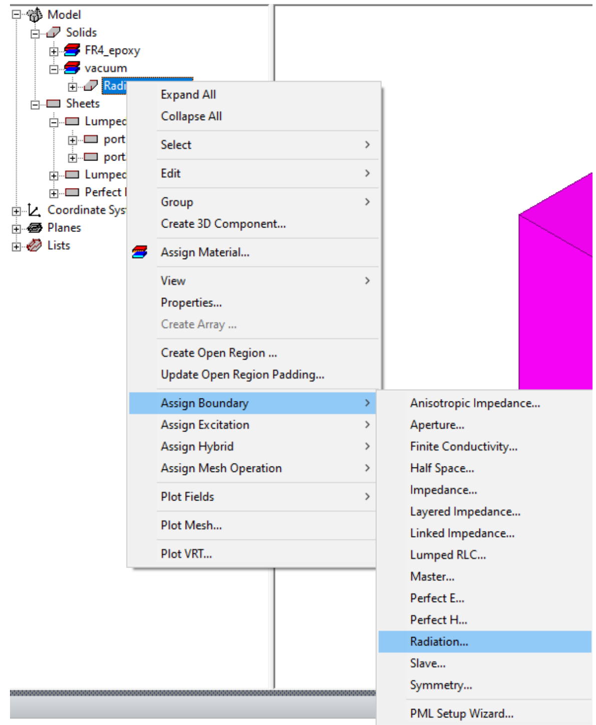
- ➢ Select the menu item **Draw** > **Box**
- ➢ Using the coordinate entry fields, enter the box position
  - **X: -50.0, Y: -50.0, Z: -50.0**, Press the Enter key
- ➢ Using the coordinate entry fields, enter the opposite corner of the base rectangle:
  - **dX: 100.0, dY: 100.0, dZ: 100.0**, Press the Enter key
- ➢ Change name of **Box1** to **Airbox**



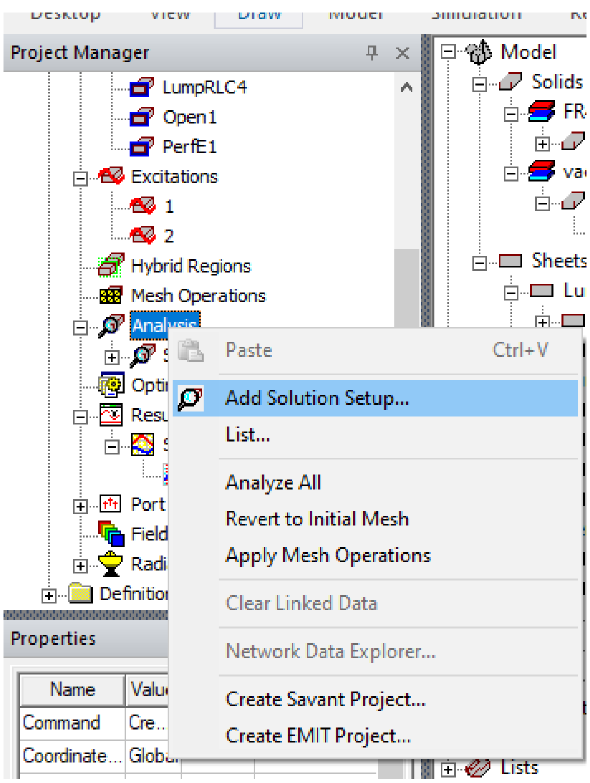
12. CREATE RADIATION BOUNDARY

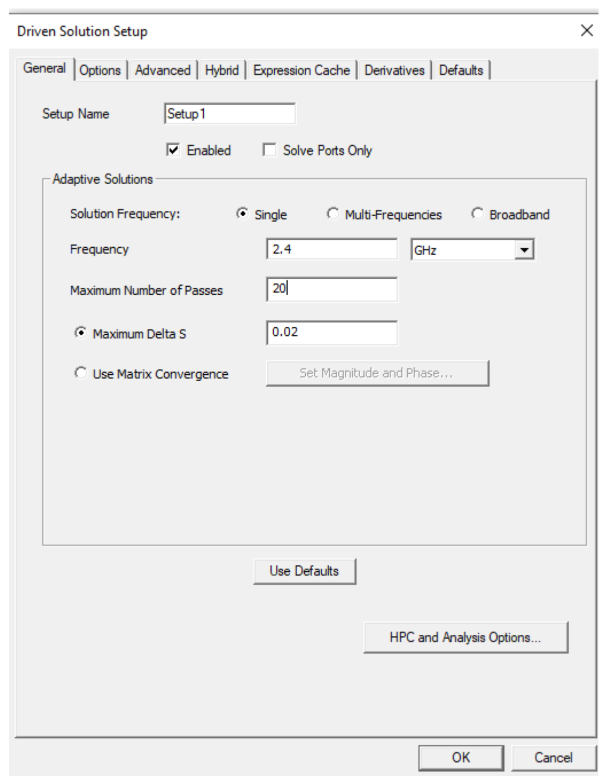
- ➢ Right click **Airbox** > **Assign Boundary** > **Radiation**
- ➢ Radiation Boundary Window:
- ➢ Name: **Rad1**
- ➢ Click the **OK** button

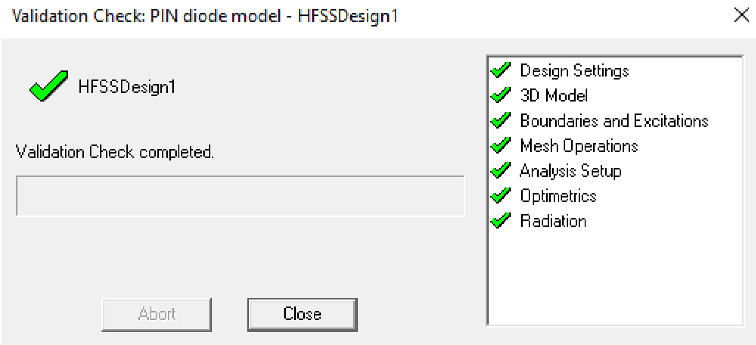
13. SIMULATION (ANALYSIS) SET UP

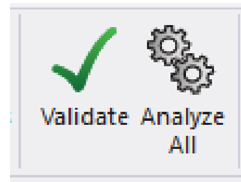


- ➢ Right click **Analysis** > **Add Solution Set up**
- ➢ Driven Solution Set up window:
  - Set frequency = 2.4 GHz
  - Set Maximum Number of passes = 20
  - Maximum Delta S = 0.02
  - Click **OK**
- ➢ Right click on **Setup1** > **Add Frequency Sweep**
- ➢ Edit frequency sweep window:
  - Set frequency sweep from 1GHz – 5GHz
  - Click **OK**
  - Validate
  - Analyze





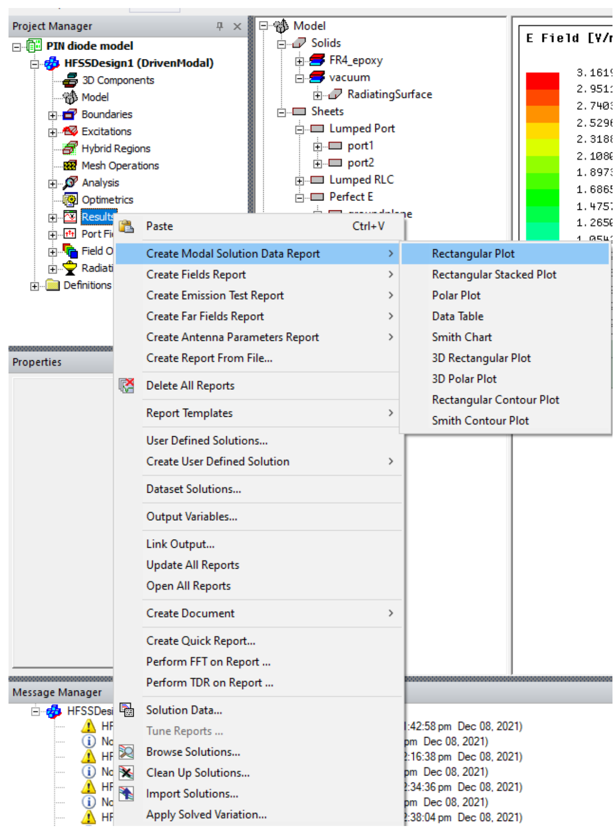


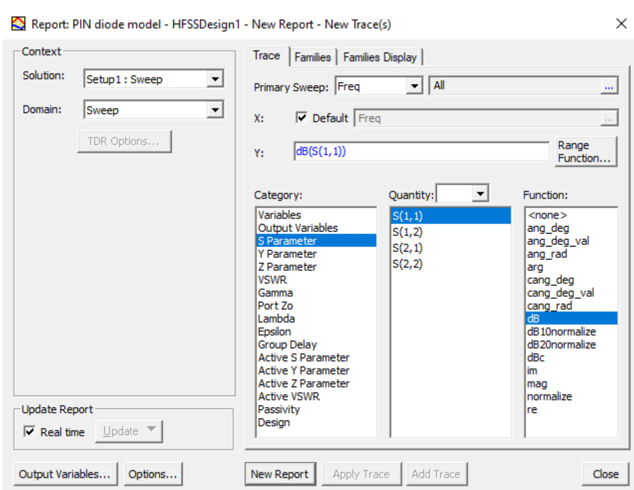


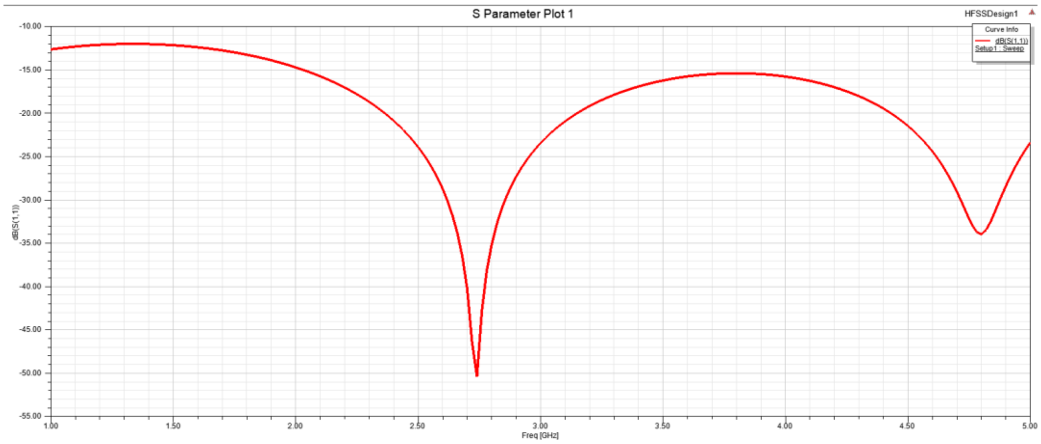
14. PLOTTING RESULTS

❖ (When PIN diode is switched ON)

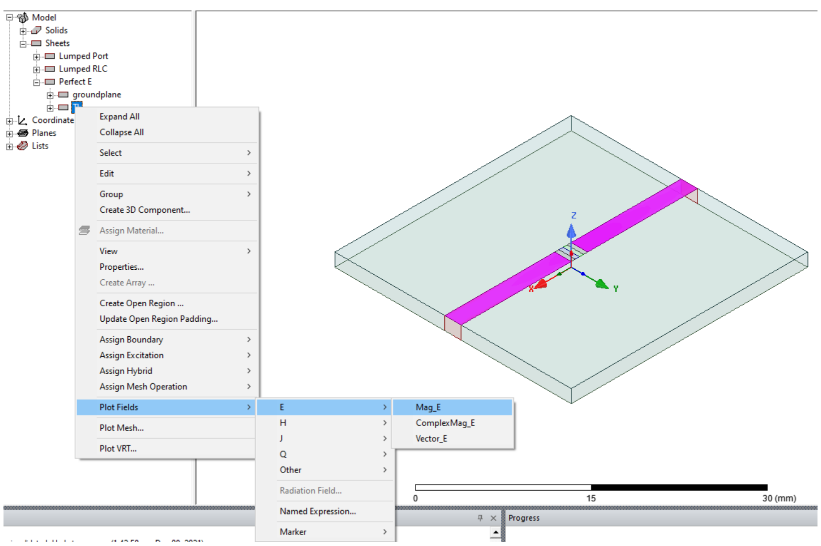
- ➢ Right click on **Results > Create Modal Solution Data Report > Rectangular Plot**
- ➢ In the New Report dialog box
  - Solution setup1: Sweep
  - Domain: **Sweep**
  - Primary Sweep: **Frequency (All)**
  - Category: **S Parameter**
  - Quantity: **S(1,1)**
  - Function: **dB**
  - Click **New Report**

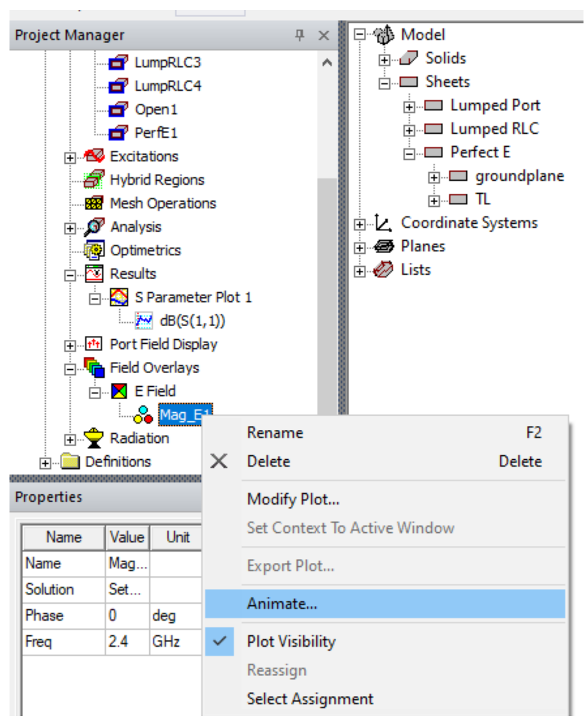


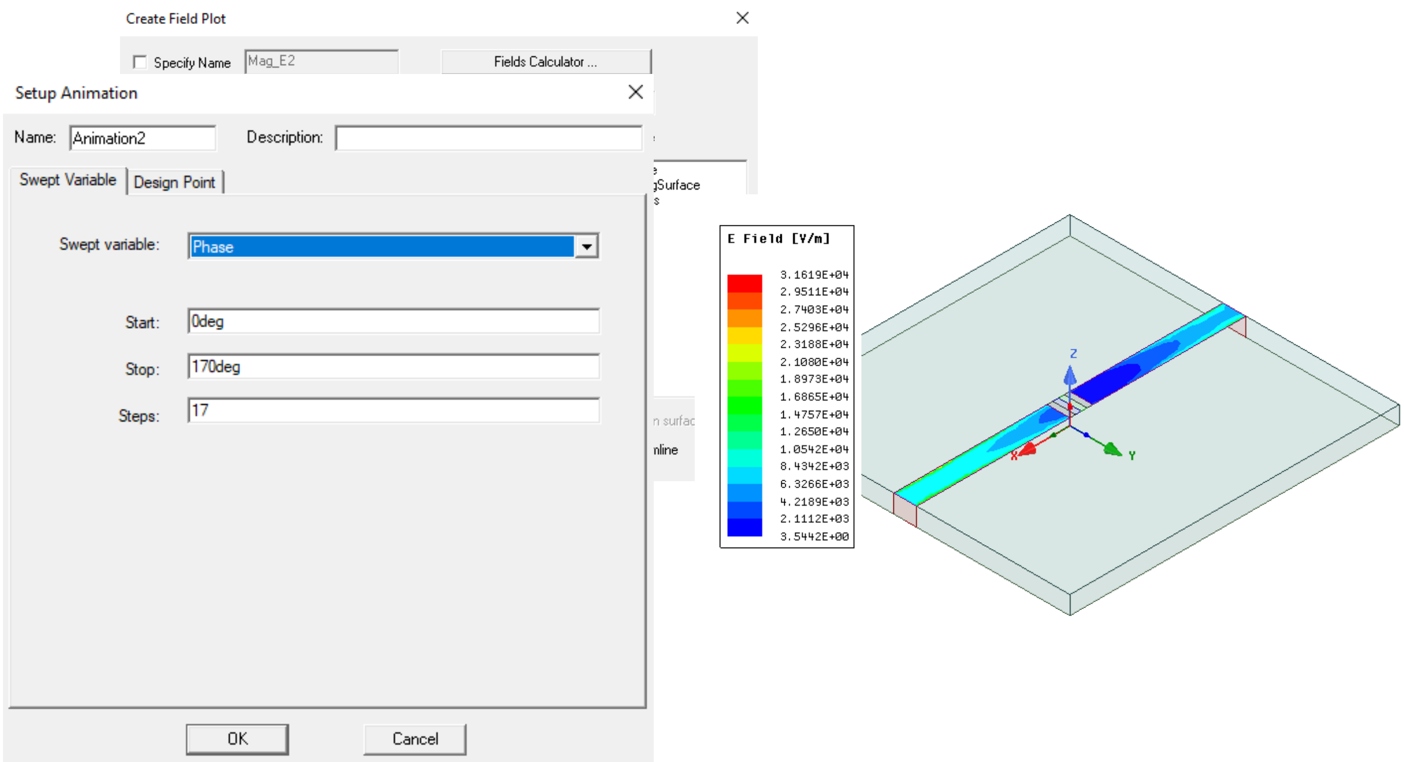




- ➢ Right click on **TL > Plot Fields > E > Mag_E**
- ➢ Create Field Plot window : Click **Done**
- ➢ Right click on **Mag_E1 > Animate**
- ➢ Set up Animation window: click **OK**

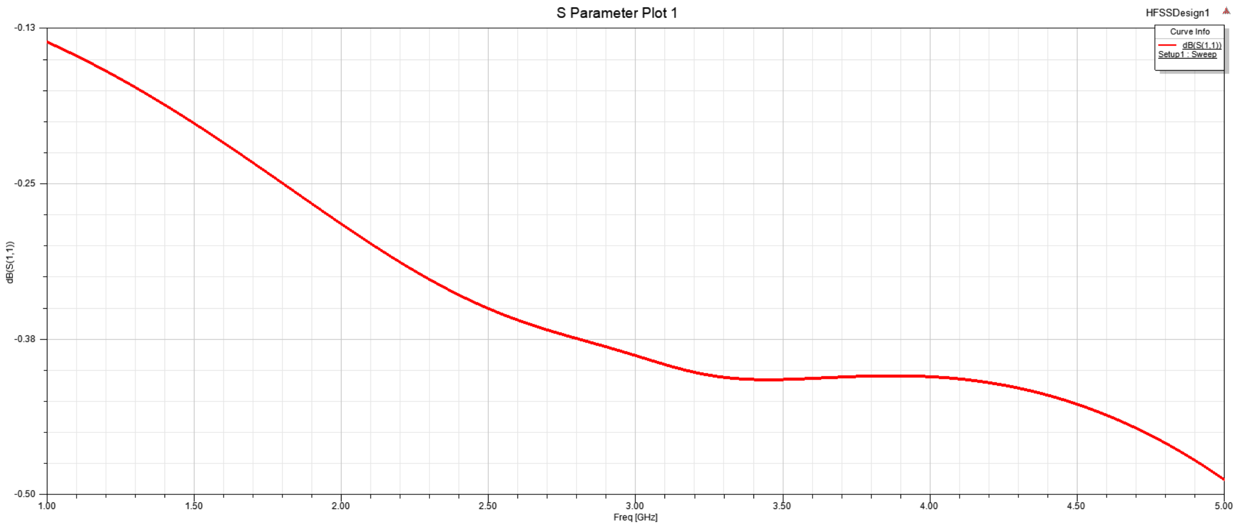


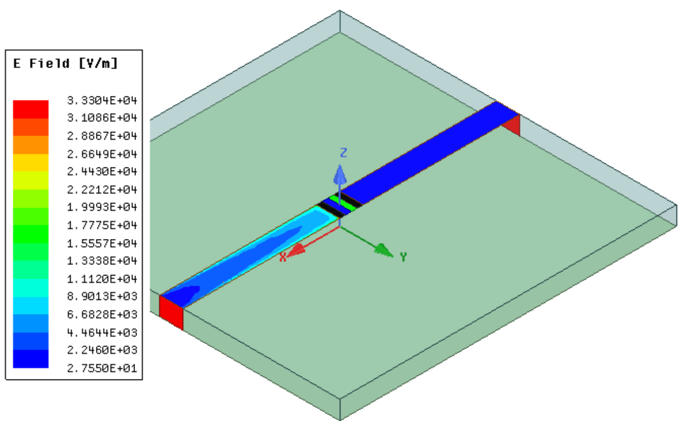




❖ **(When PIN diode is switched OFF)**

- Set parallel combination of R and C from the Boundaries and simulate (analyze all) – Refer to section 10.
- Right click on **Results > Create Modal Solution Data Report > Rectangular Plot**
- In the New Report dialog box
  - Solution setup1: **Sweep**
  - Domain: **Sweep**
  - Primary Sweep: **Frequency (All)**
  - Category: **S Parameter**
  - Quantity: **S(1,1)**
  - Function: **dB**
  - Click **New Report**
- Right click on **TL > Plot Fields > E > Mag_E**
- Create Field Plot window : Click **Done**
- Right click on **Mag_E1 > Animate**
- Set up Animation window: click **OK**


S Parameter Plot 1
HFSSDesign1
Curve Info
dB(S(1,1))
Setup1 : Sweep
dB(S(1,1))
Freq [GHz]
-0.13
-0.25
-0.38
-0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
5.00


E Field [V/m]
3.3304E+04
3.1086E+04
2.8867E+04
2.6649E+04
2.4430E+04
2.2212E+04
1.9993E+04
1.7775E+04
1.5557E+04
1.3338E+04
1.1120E+04
8.9013E+03
6.6828E+03
4.4644E+03
2.2460E+03
2.7550E+01
Z
Y
X

SECTION 5: MODELLING BENDING FEATURES IN FLEXIBLE ANTENNAS USING CST 2019

Prepared by: Philip Arthur (MPhil. Telecom Eng. 2021)

INTRODUCTION

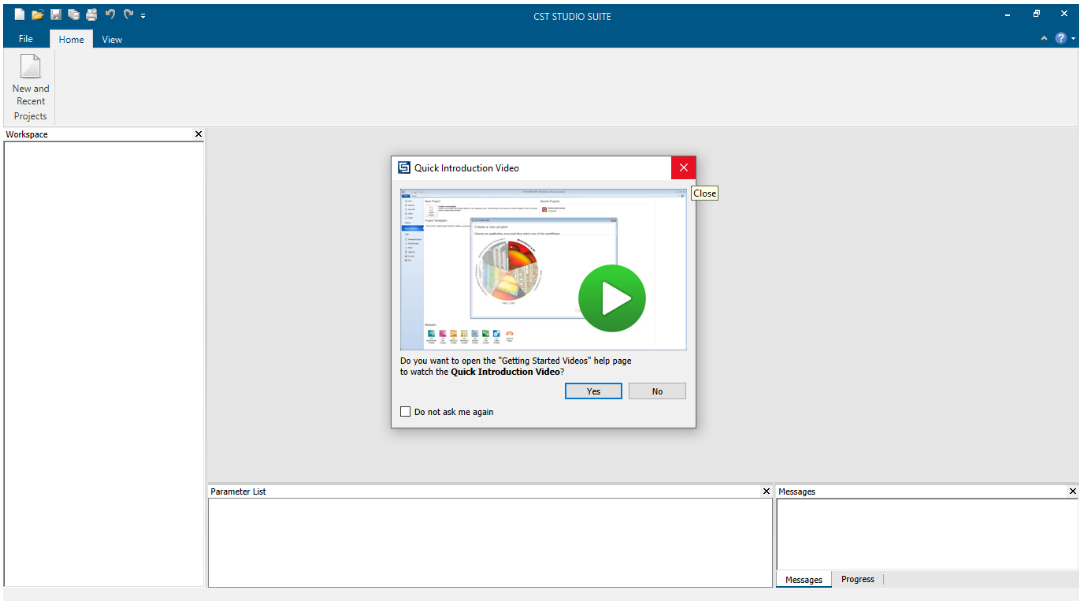
The demand for wearable electronics to establish wireless body area communication has been growing rapidly. This places unique requirements on some electronic devices to possess conformable features. The flexibility feature has some striking advantages over its fixed counterparts in wearable applications. Due to the random postures of the host body, poor performance effects may result from the operation of these devices. Several applications of body-worn sensors in health monitoring, sports and entertainment, emergency services and the military present the demand for flexible antennas. Hence, the simulation and design techniques to address the conformable features and its effects in such systems is equally important.

This guide is intended to show you how to apply bending features to an already designed slotted planar monopole antenna using the Computer Simulation Technology (CST) EM tool. CST Studio Suite is a high-performance 3D EM analysis software package for designing, analyzing and optimizing electromagnetic (EM) components and systems [6].

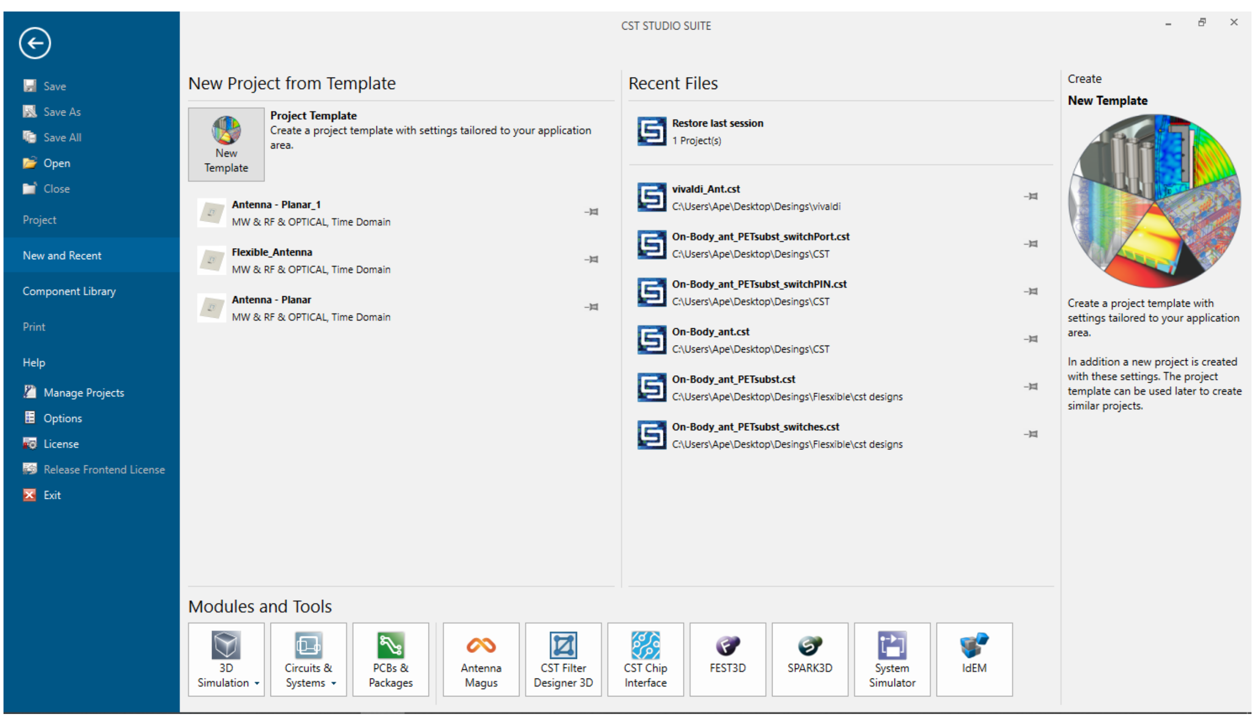
Fig.1 Applications of Flexible antennas [8]-[11]

1. LAUNCHING CST

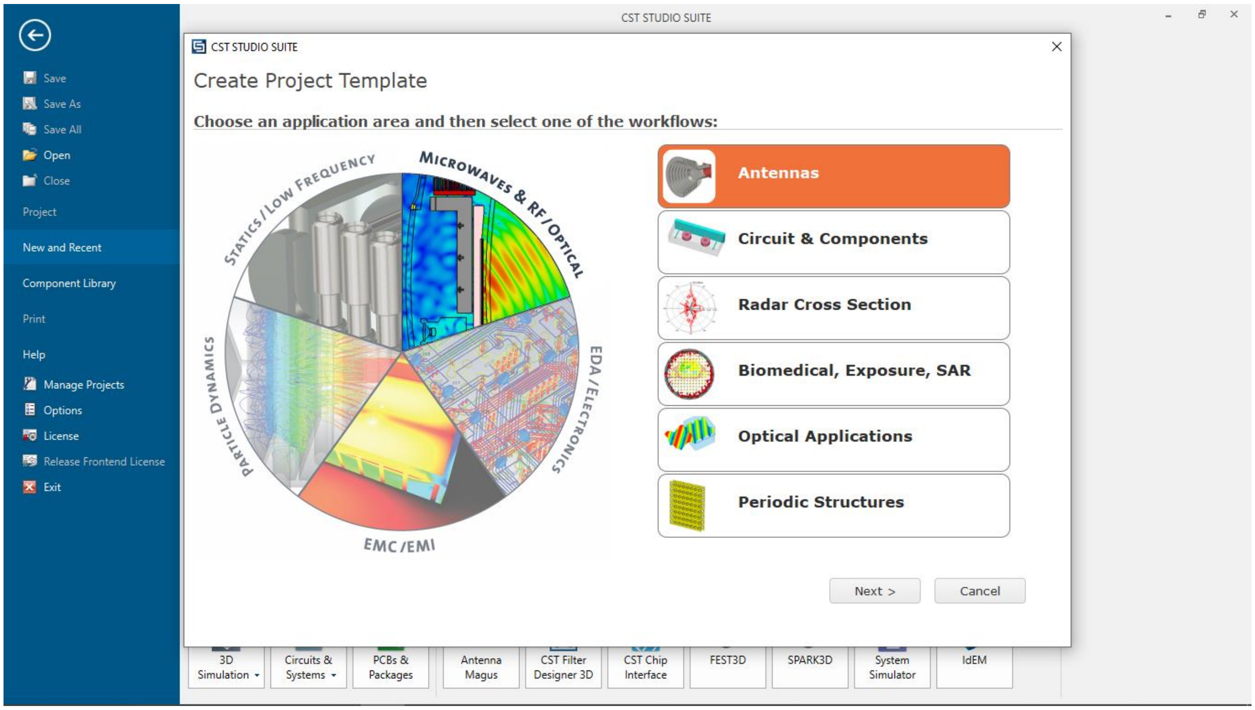
- ➢ Select Programs > **CST Studio Suite 2019**
- ➢ Close **quick introduction video** window.



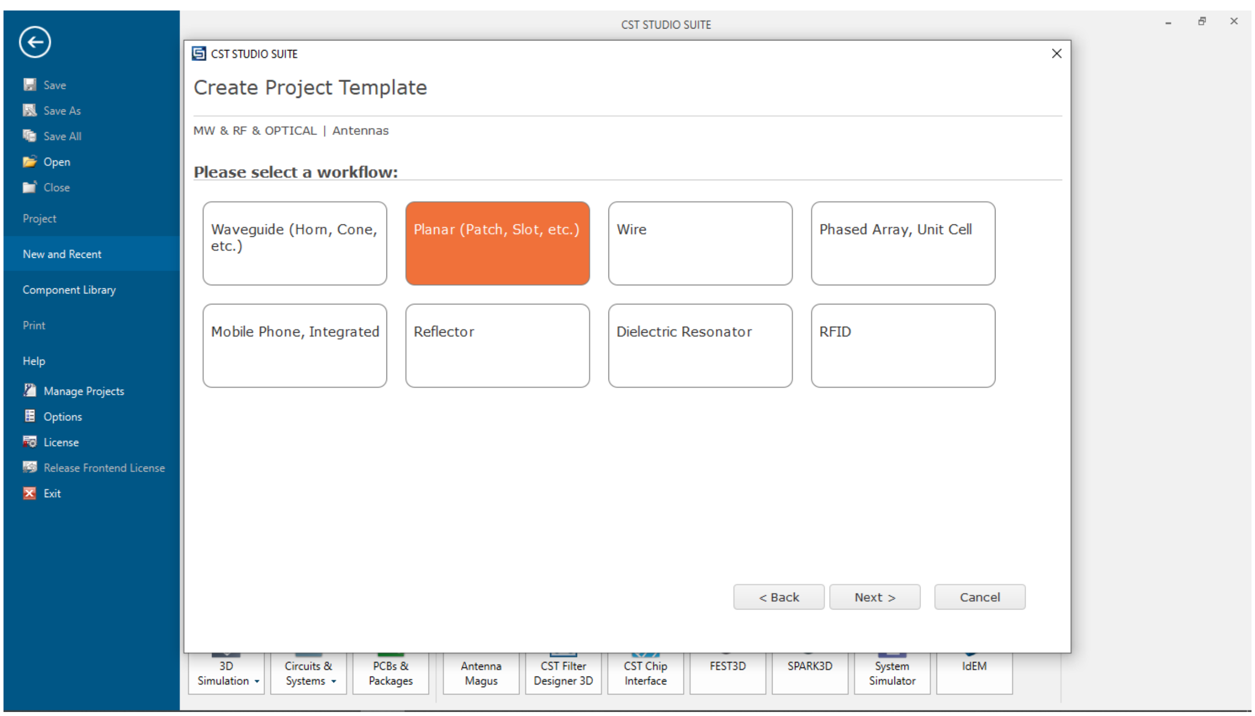
- ➢ Click on > **New Project Template >**



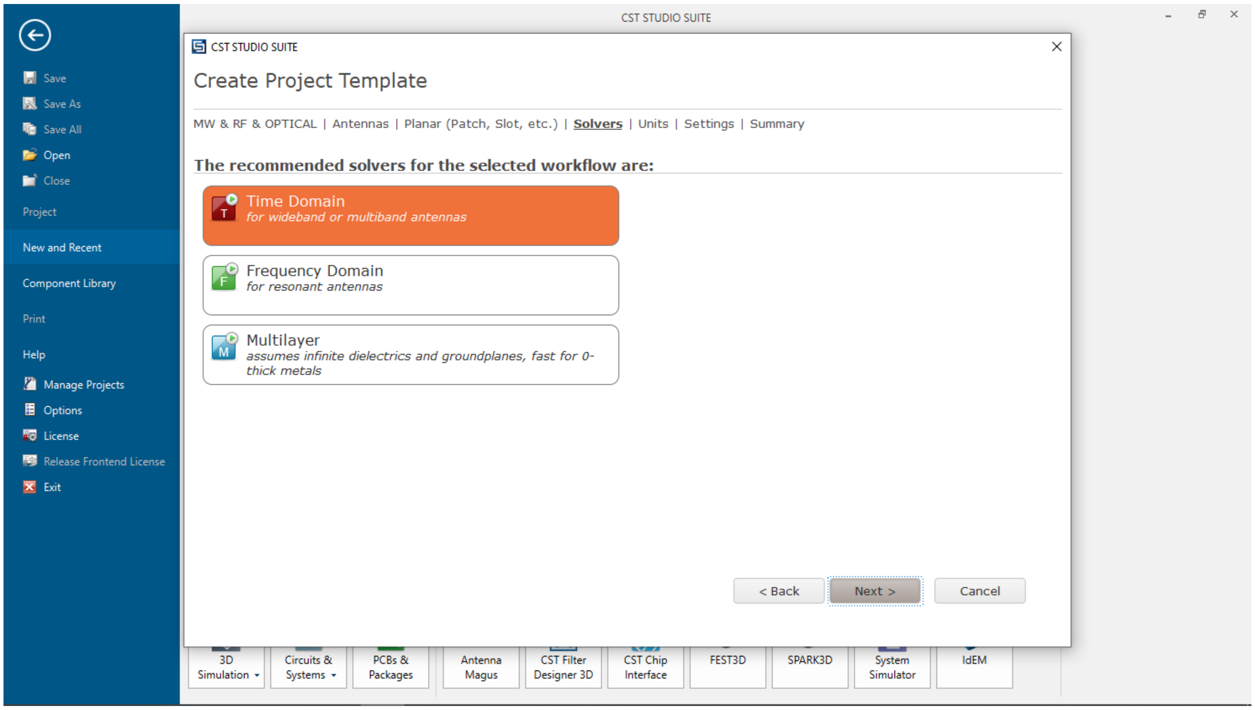
➢ Click on **Microwaves & RF/Optical > Antennas**



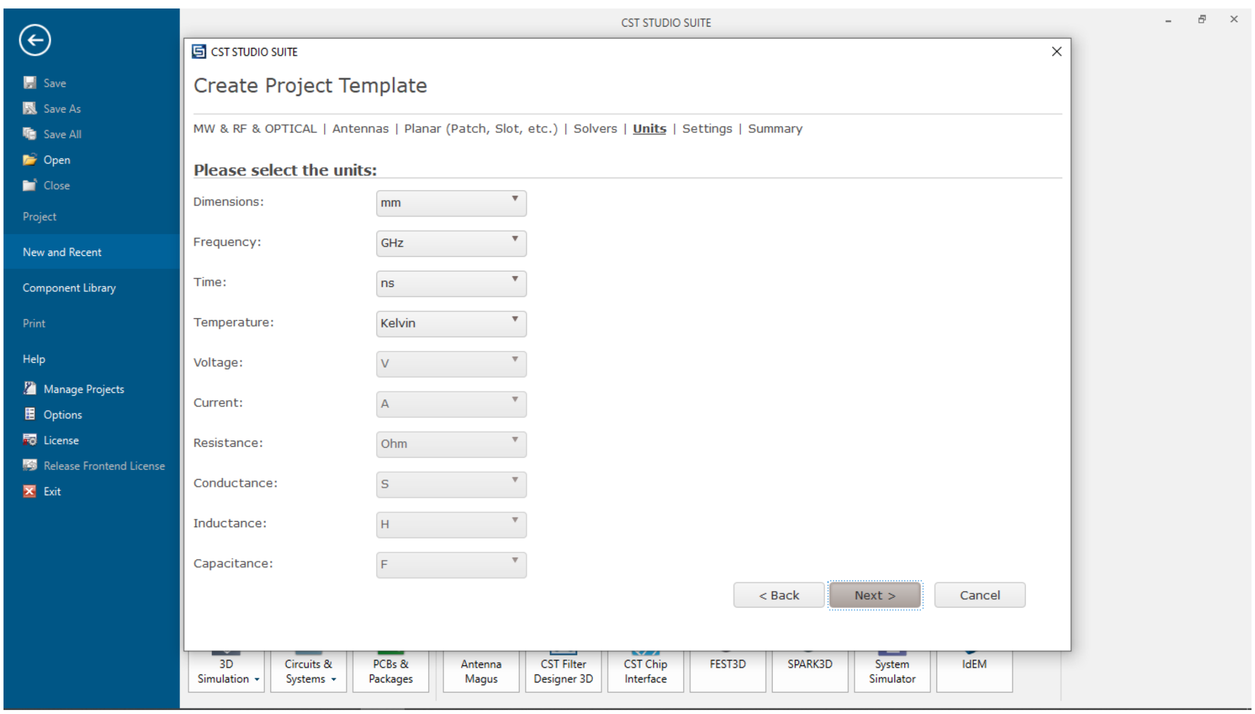
➢ Click on > **Planar (Patch, Slot, etc.) > Next**



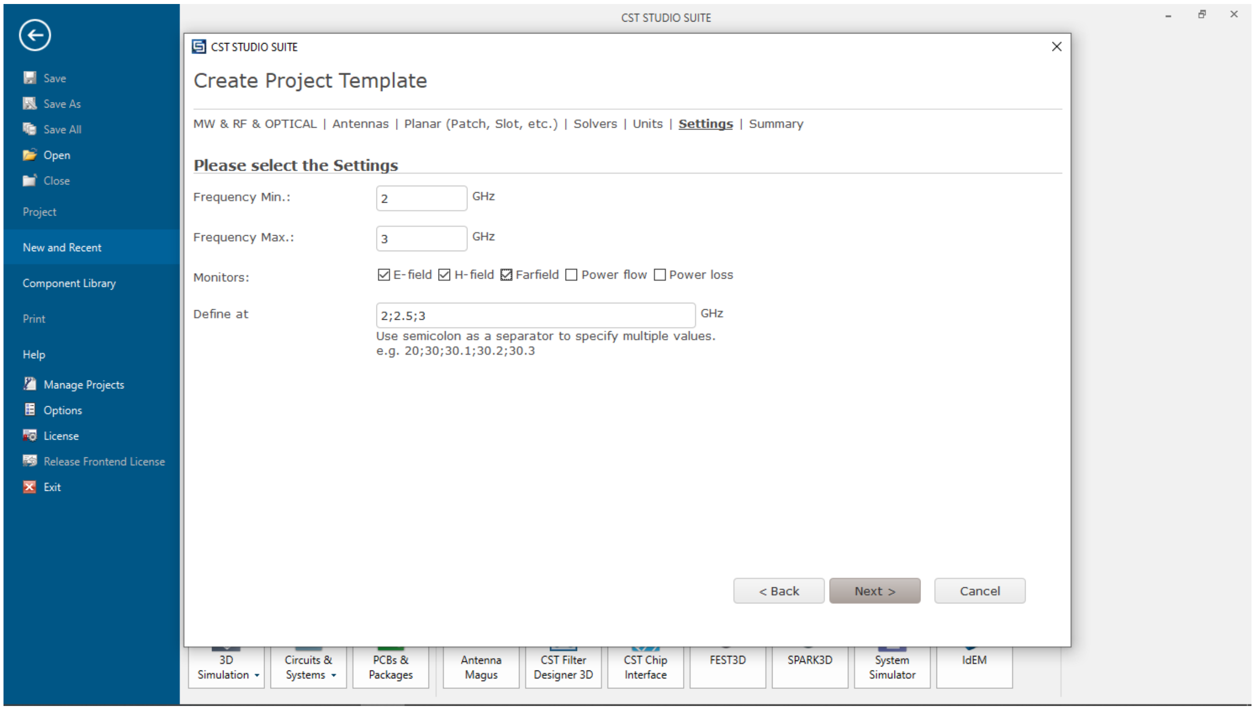
➢ Click on > **Time Domain** > **Next**



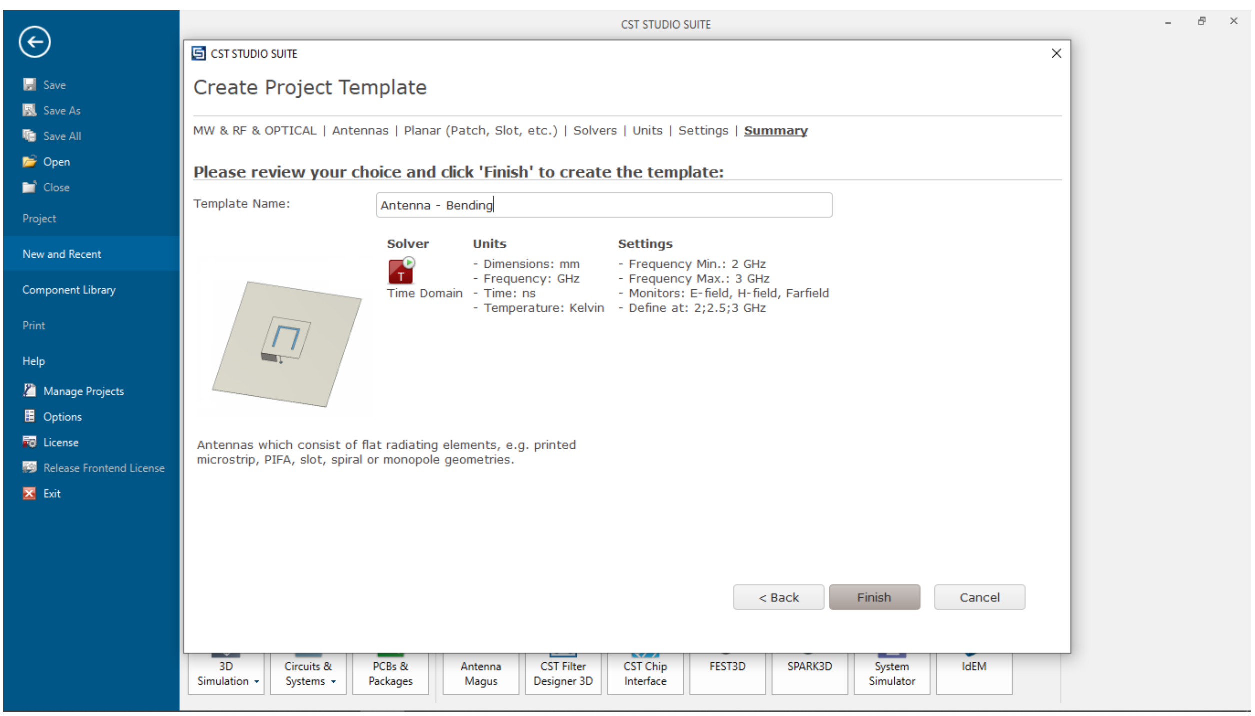
➢ Set the **units**



➢ Set frequency from **2 -3 GHz** > Check **E-filed, H-field and Far field** > **Next**

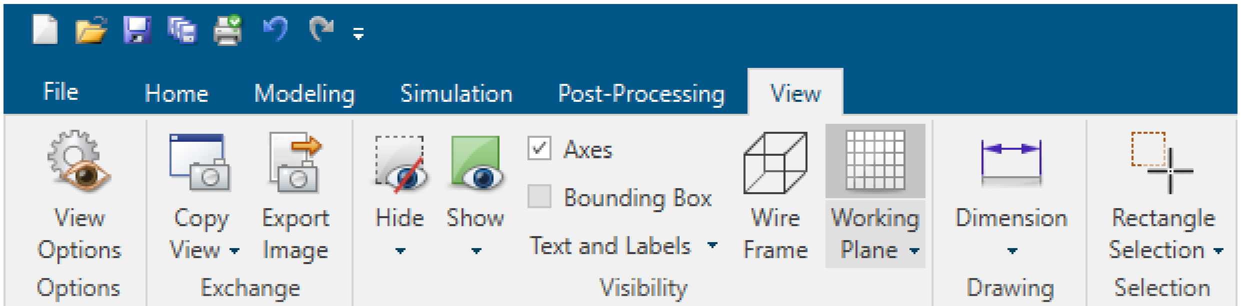


➢ Change name of project



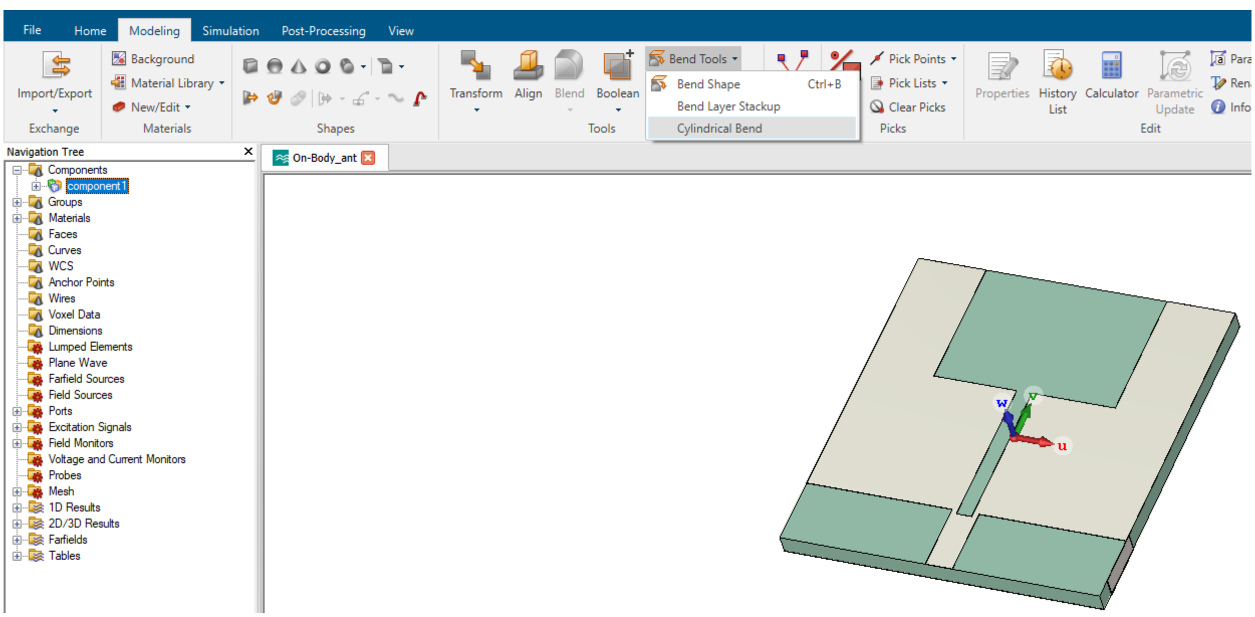
2. HIDING THE BOUNDING BOX

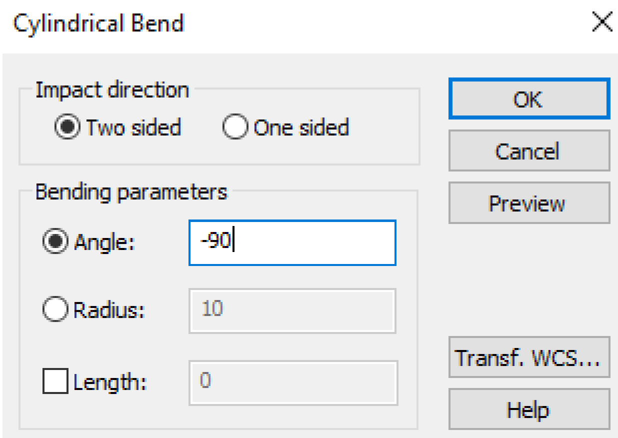
➢ Go to > View > Uncheck Bounding Box

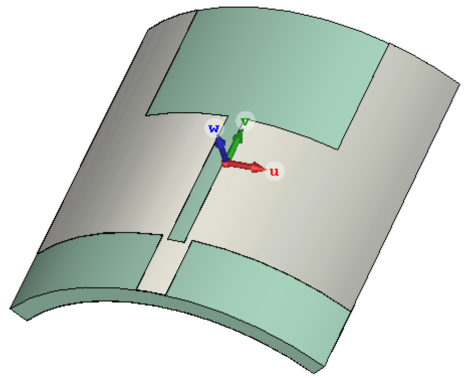


3. ANTENNA BENDING

➢ Perform outward cylindrical bending along the *x*-axis (*u*-axis; local coordinate)
➢ Select **component1 > Go to Bending Tools > Cylindrical Bending**
➢ Cylindrical Bend Window:
- Impact direction: **Two sided**
- Bending Parameters: Select Angle = **-90 or choice of angle**
- Preview; **OK**







For basic bending and antenna modelling tutorials in CST:

https://www.youtube.com/watch?v=nnnr0ccXOmE

https://www.youtube.com/c/tensorbundle/videos

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