Antenna and Radio Propagation

Theory Class Instructor: Prof. Qingsha S. Cheng
Lab Instructor: Dr. Rusan Kumar Barik
Office: 1110, A7, Nanshan *i*Park

Experiment: 1

Introduction to HFSS and Design & Analysis of a Dipole Antenna

Southern University of Science and Technology, Shenzhen, P.R. China

1. Introduction to HFSS

- The name HFSS stands for High Frequency Structure Simulator.
- 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, Dielect
- Ansoft 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.

Starting Ansoft HFSS

- Click the Microsoft Start button, select Programs, and select the Ansoft, HFSS 14 program group. Click HFSS 14.
- Or Double click on the HFSS 10 icon on the Windows Desktop

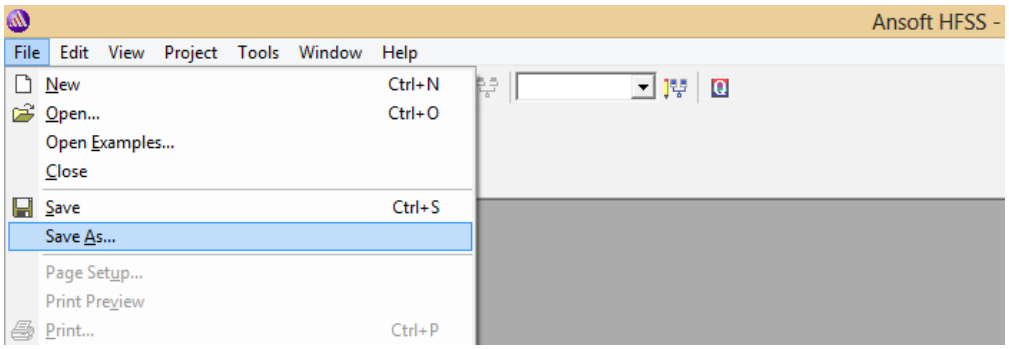
Creating/Opening New HFSS Project

1. Step 1: How to Create/Open

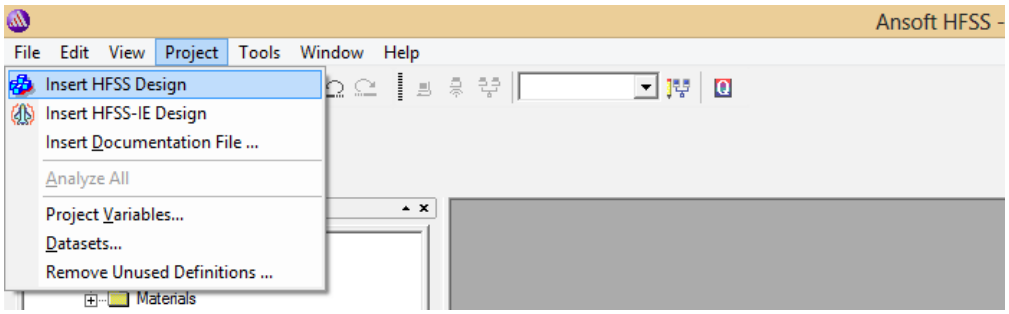
This section describes how to open a new or existing project.

Opening a New Project:

- To open a new project;
  1. In a Ansoft HFSS window, select the menu item ***File → New***

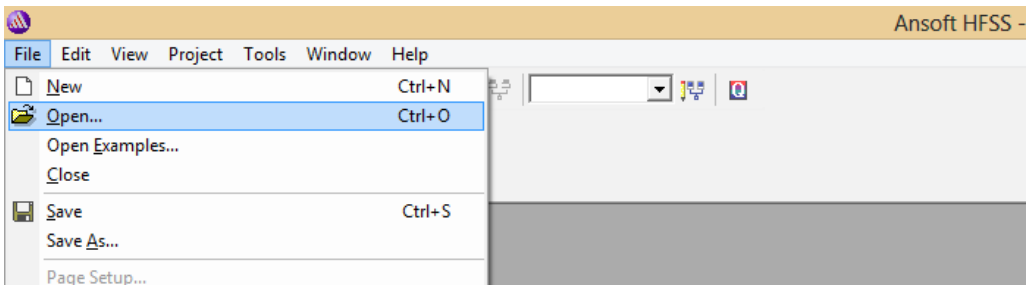


  2. Select the menu ***Project → Insert HFSS Design***



Opening an Existing HFSS Project:

- To open an existing project;
  1. In an Ansoft HFSS window, select the menu ***File → Open***. Use the Open dialog to select the project.
  2. Click **Open** to open the project



Opening an Existing HFSS Project from Explorer:

- You can open a project directly from the Microsoft Windows Explorer.
- To open a project from Windows Explorer, do one of the following:
  1. Double-click on the name of the project in Windows Explorer.
  2. Right-click the name of the project in Windows Explorer and select Open from the shortcut menu.

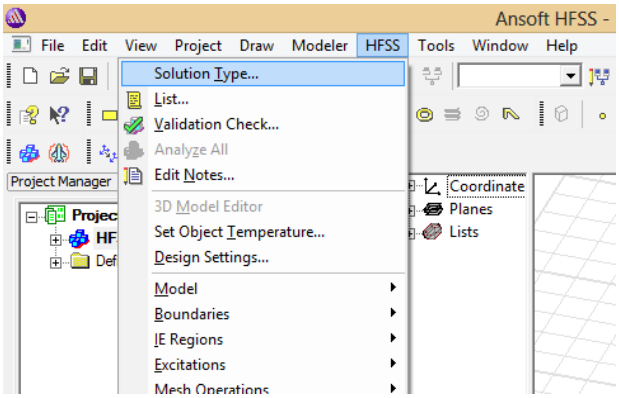
2. Step 2: Set Solution Type

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

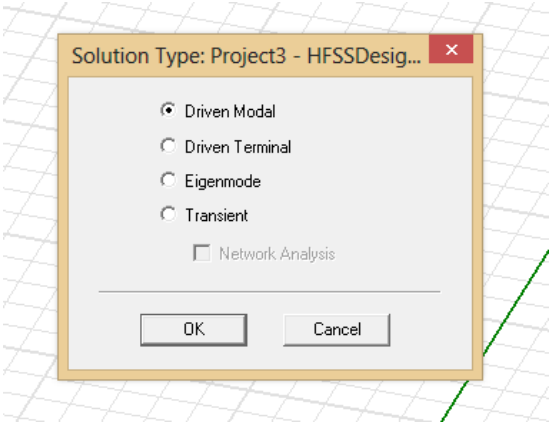
- **Driven Modal** - calculates the modal-based S-parameters. The S-matrix solutions will be expressed in terms of the incident and reflected powers of waveguide modes.
- **Driven Terminal** - calculates the terminal-based S-parameters of multiconductor transmission line ports. The S-matrix solutions will be expressed in terms of terminal voltages and currents.
- **Eignemode** – calculate the eigenmodes, or resonances, of a structure. The Eigenmode solver finds the resonant frequencies of the structure and the fields at those resonant frequencies.

How to set solution type:

1. Select the menu item **HFSS → Solution Type**



2. Solution Type Window:
    a. Choose one of the following:
        i. Driven Modal
        ii. Drive Terminal
        iii. Eigenmode
    b. Click the OK button

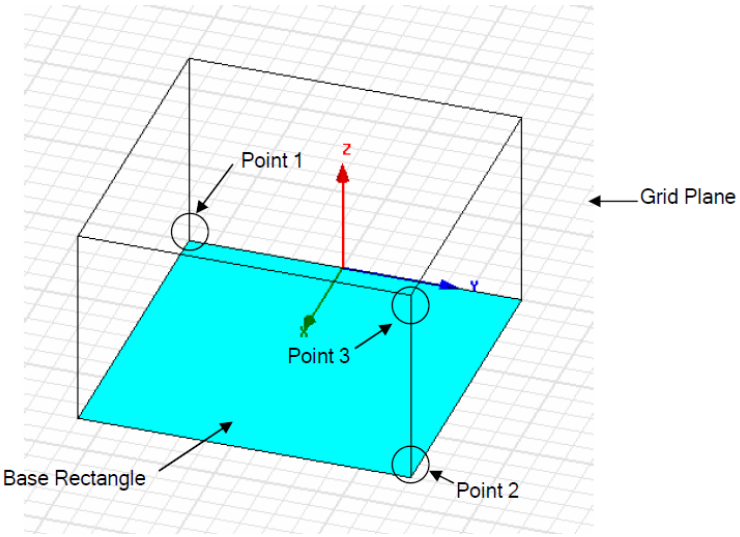


3. Step 2: Create Structures

Example 1: Create a Box

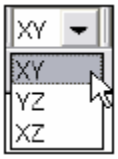
We will investigate creating a box to demonstrate these steps. These steps assume that project and a HFSS design have already been created. Three points are required to create the box. The first two form the base rectangle and the third sets the height.

- Point 1: Defines the start point of the base rectangle
- Point 2: Defines the size of the base rectangle
- Point 3: Defines the height of the Box

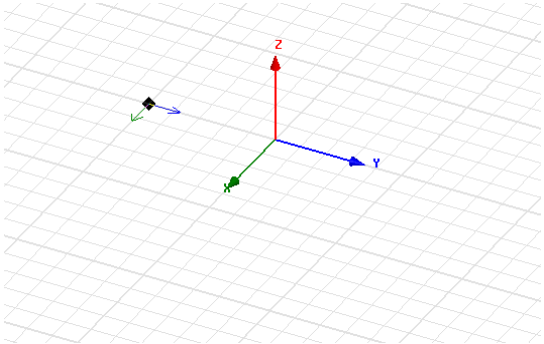


How to draw?

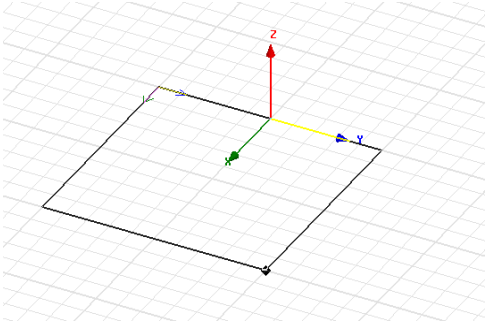
1. Select the menu item 3D Modeler → Grid Plane → XY



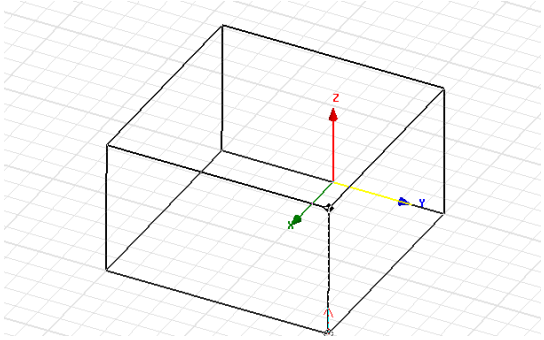
2. Use the mouse to create the base shape
    a. Set the start point by positioning the active cursor and click the left mouse button.



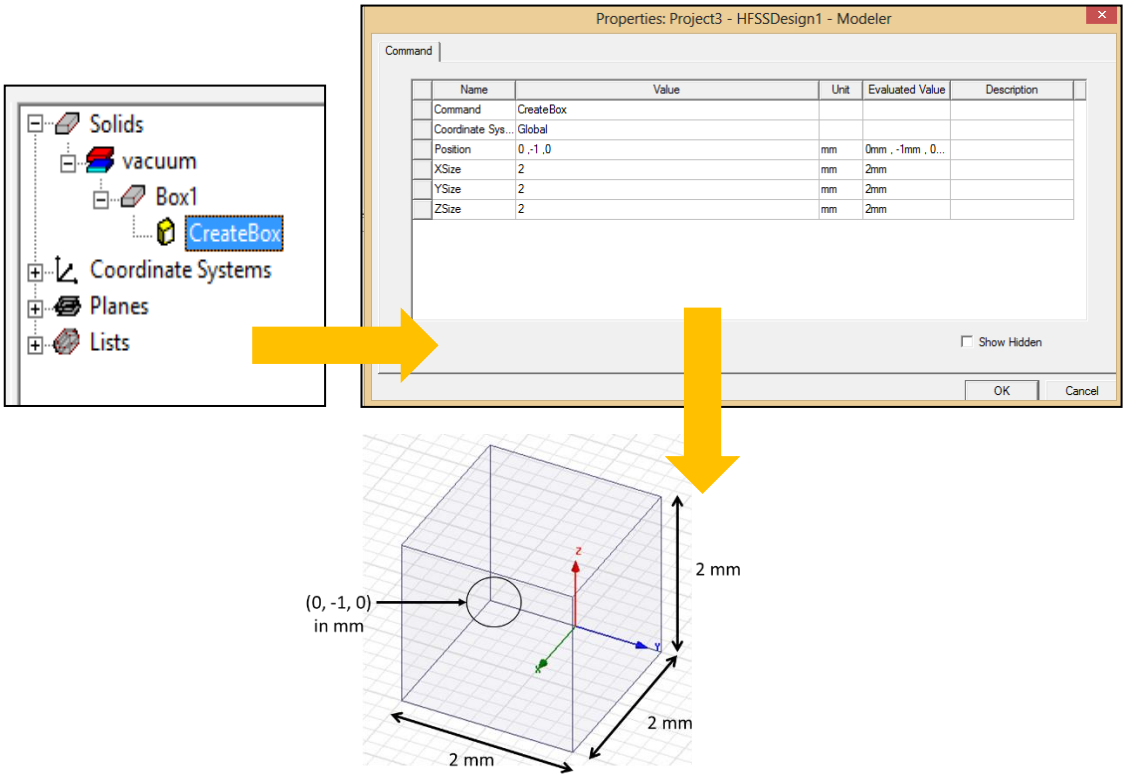
b. Position the active cursor and click the left mouse button to set the second point that forms the base rectangle.



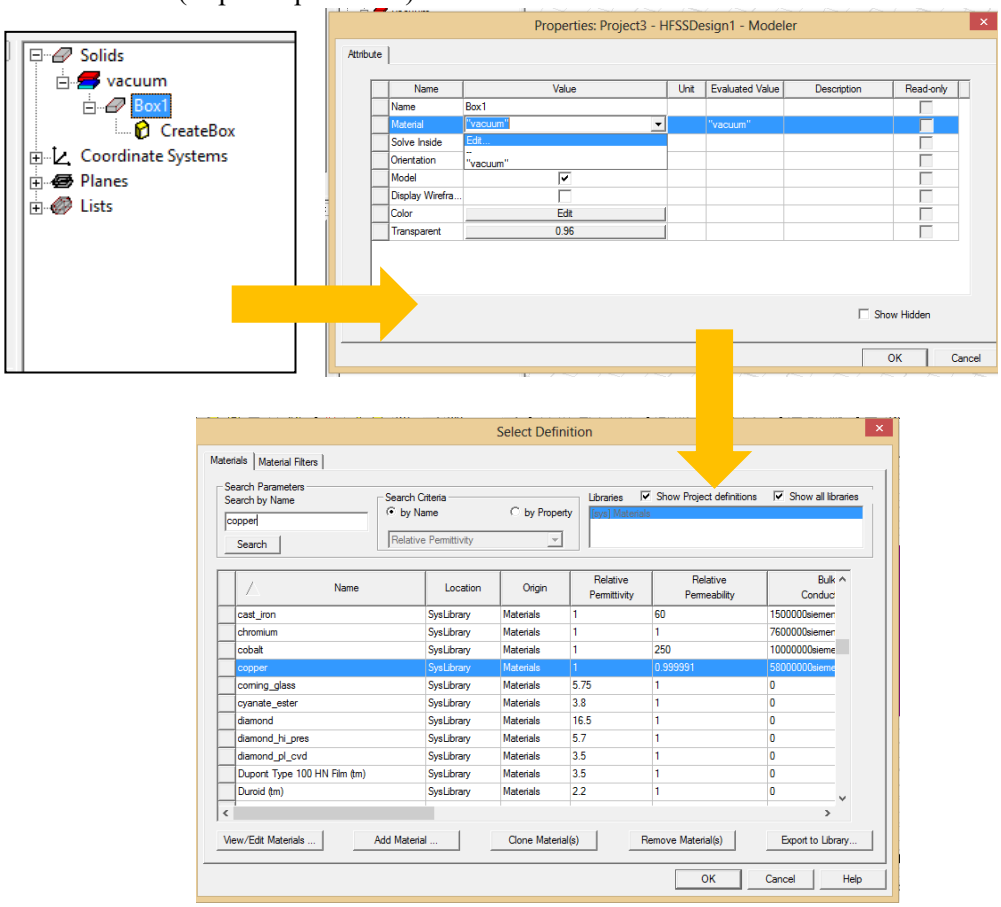
c. Set the Height by positioning the active cursor and clicking left mouse button.



3. Check/Edit the properties of the box:
   Select Box → click on '+' → CreateBox → Poperies window



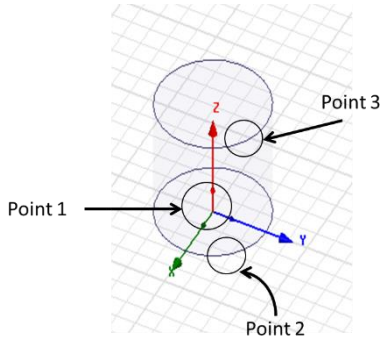
4. Assign/Change material to/of the box:
   Select Box and Double click → Poperies window → Material → Edit (from droop down) → Select material (as per requirement) → Ok



Example 2: Create a Cylinder

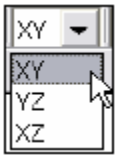
We will investigate creating a cylinder to demonstrate these steps. These steps assume that project and a HFSS design have already been created. Three points are required to create the cylinder. The first two form the base circle and the third sets the height.

- Point 1: Defines the start point of the base cylinder
- Point 2: Defines the radius of the base cylinder
- Point 3: Defines the height of the cylinder

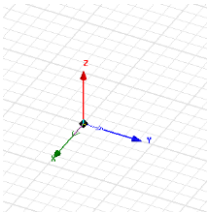


How to draw?

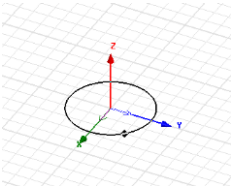
1. Select the menu item 3D Modeler → Grid Plane → XY



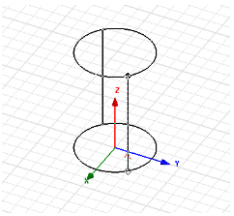
2. Use the mouse to create the base shape
    a. Set the start point by positioning the active cursor and click the left mouse button.



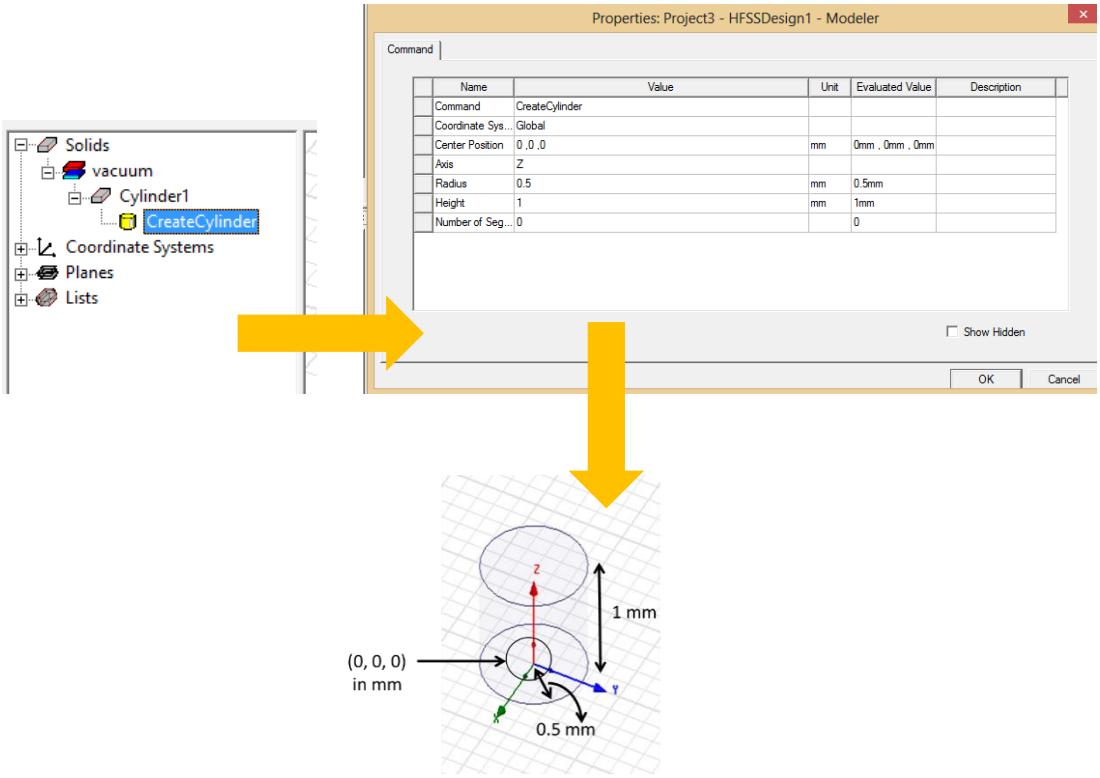
    b. Position the active cursor and click the left mouse button to set the second point that forms the base circle.



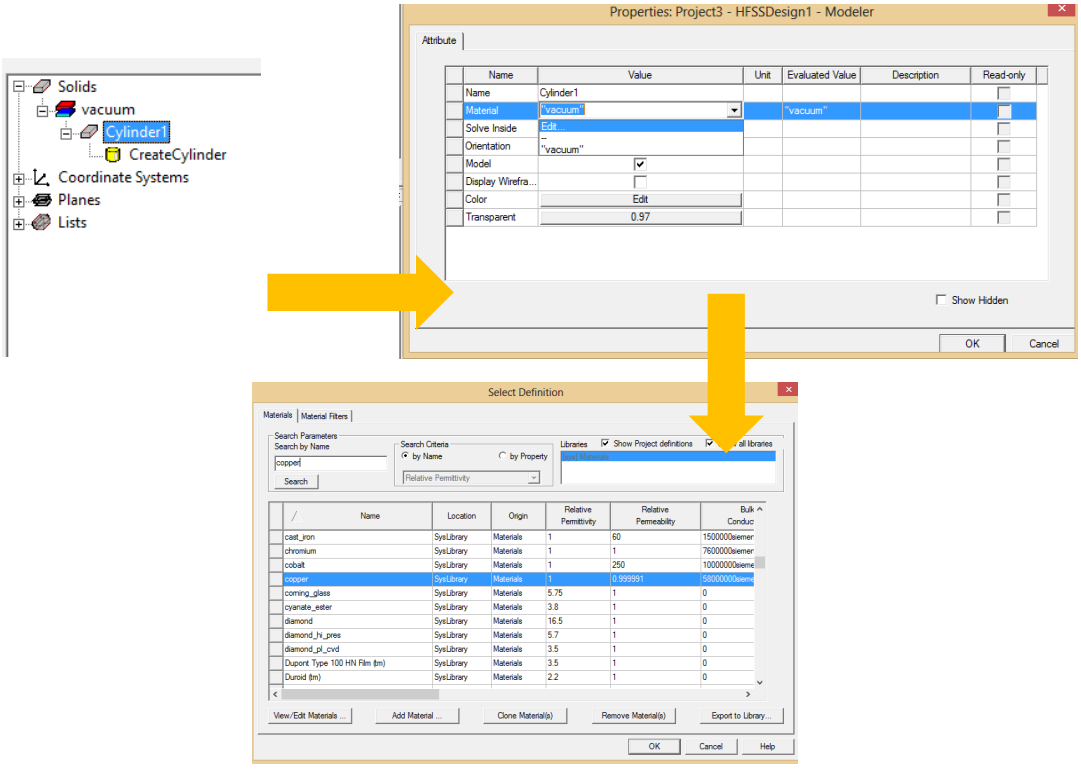
    c. Set the Height by positioning the active cursor and clicking left mouse button.



3. Check/Edit the properties of the box:
   Select Cylinder1 → click on '+' → CreateCylinder → Poperies window



4. Assign/Change material to/of the cylinder:
   Select Cylinder1 and Double click → Poperies window → Material → Edit (from droop down) → Select material (as per requirement) → Ok



2 (a) Design and Analysis of Dipole Antenna

This guide leads you step-by-step through creating, solving, and analysing the results of a microstrip patch antenna.

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

- Draw a geometric model.
- Modify a model's design parameters.
- Assign variables to a model's design parameters.
- Specify solution settings for a design.
- Validate a design's setup.
- Run an HFSS simulation.
- Create a 2D x-y plot of S-parameter results.
- Create a 2D x-y plot of gain, efficiency results.
- Create a 2D Polar/Rectangular plot of radiation pattern.
- Create a 3D plot of radiation pattern.
- Create a field overlay plot of results.

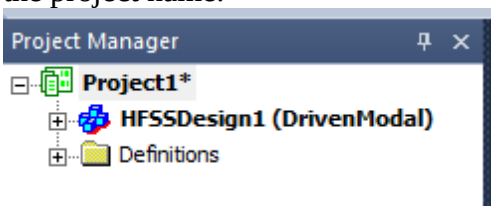
2 (b) Set up the Design

In this section you will complete the following tasks:

- Save a new project.
- Rename the HFSS design in the project.
- Select a solution type for the project.
- Set the drawing units for the design.

Open HFSS and Save a New Project

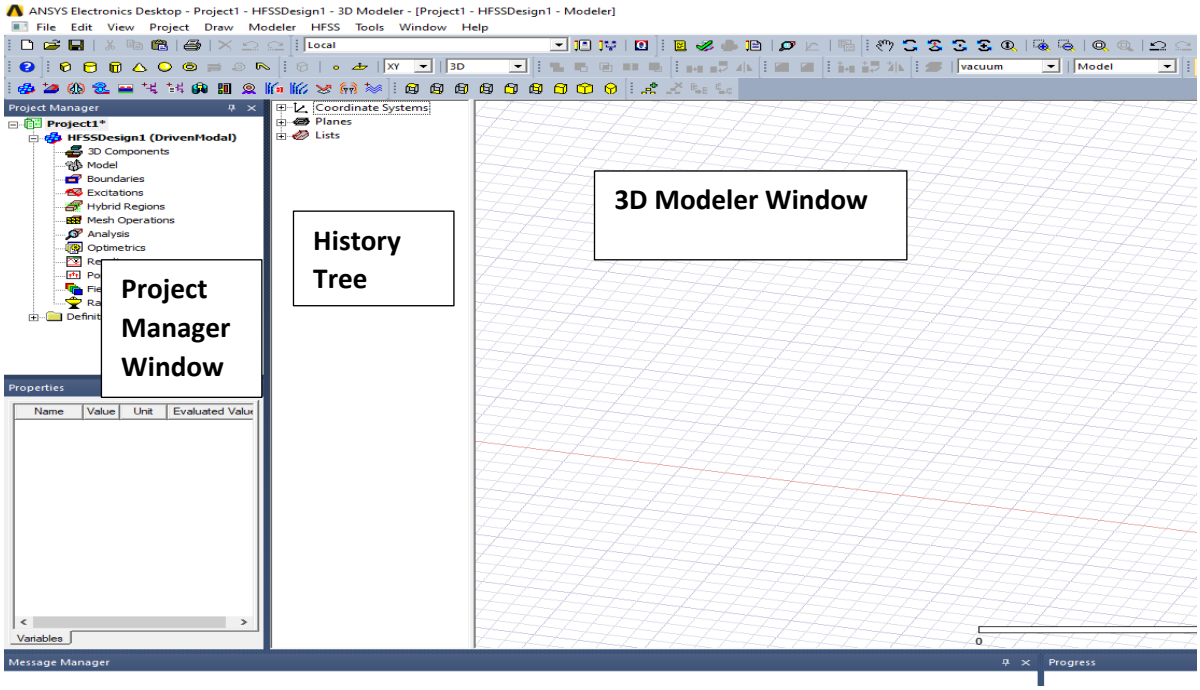
1. Double-click the **HFSS 14/19** icon on your desktop to launch HFSS.
   A new project is listed in the project tree in the **Project Manager** window and is named Project by default. Project definitions, such as material assignments, are stored under the project name.



2. Click **File>Save As**. The **Save As** dialog appears.
3. Use the file browser to locate the folder in which you want to save the project, (such as C:\Program Files\Ansoft\HFSS14/19.0\Projects), and then double-click the folder's name. Type DiA in the **File name** text box, and then click **Save**. The project is saved in the folder you selected to the file name **DiA.hfss**.

Rename the Design

You will now rename the default HFSS design in the project. The design is already listed in the project tree when HFSS opens. It is named HFSSDesignn by default. The **3D Modeler** window appears to the right of the Project Manager.



1. To rename the design: Right-click **HFSSDesignn** in the project tree, and then click Rename on the shortcut menu.
2. Type **DiAModel**, and then press **Enter**.

Select a Solution Type

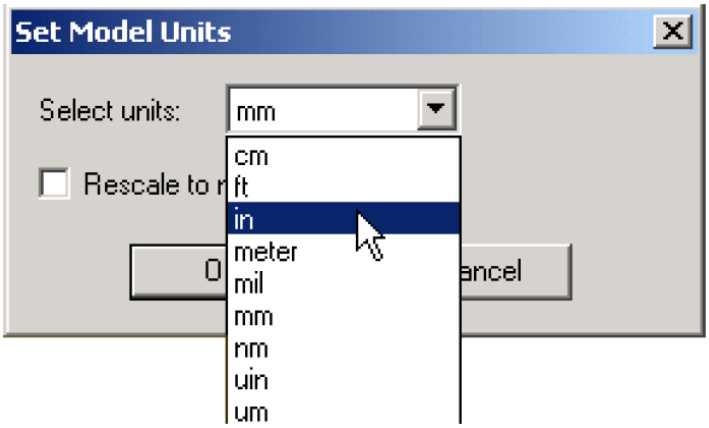
As you set up the design for analysis, available settings depend on the solution type. For this design, you will choose Driven Modal as the solution type, which is appropriate when designing microstrip patch antenna that is being "driven" by a source.

1. To specify the design solution type, click **HFSS>Solution Type**. The Solution Type dialog appears.
2. In the **Solution Type** dialog box, select **Driven Modal**, and then click **OK**.

Set the Drawing Units

To set the units of measurement for drawing the geometric model.

1. Click **Modeler>Units**. The **Set Model Units** dialog appears
2. Select **mm** from the **Select units** pull-down list, and then click **OK**.

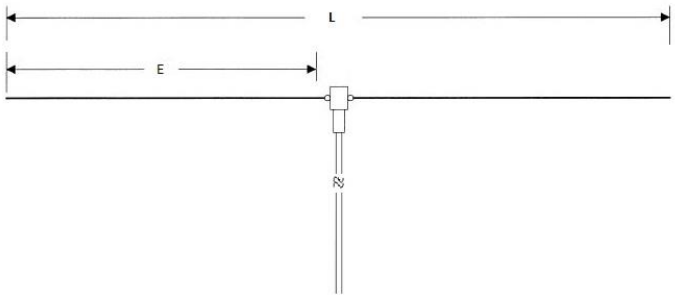


2 (c) Create the Model

In this section you will complete the following tasks:

a. Draw the one side dipole of the dipole antenna and assign material
b. Draw the other side dipole of the dipole antenna and assign material
c. Draw a rectangle sheet between the dipoles connecting their edges and assign excitation.
d. Draw the radiation box/cylinder and assign material

NOTE:



Requirement: Antenna should operate ~ 0.7 GHz. The length of each dipole width can be calculated as follows.

Length of total dipole (L) = 468 / f_o (Where f_o = Centre frequency)

Length of each dipole (E): L / 2

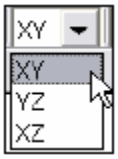
You may check this online at: https://www.everythingrf.com/rf-calculators/dipole-antenna-length-calculator

a. Create Dipole:

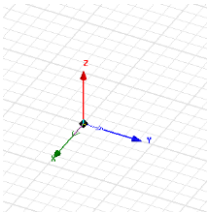
The dipole is made up of conducting material (consider PEC). First you will draw one dipole based on the above formula. You will assign a name, confirm its material assignments. Then duplicate this to design another part of the dipole.

How to draw?

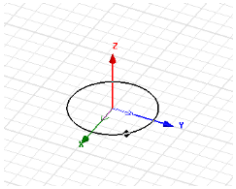
1. Select the menu item 3D Modeler → Grid Plane → XY



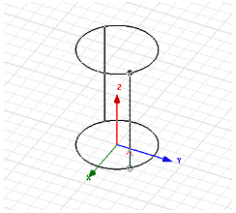
2. Use the mouse to create the base shape (for one part of the Dipole)
    a. Set the start point by positioning the active cursor and click the left mouse button.



b. Position the active cursor and click the left mouse button to set the second point that forms the base circle.

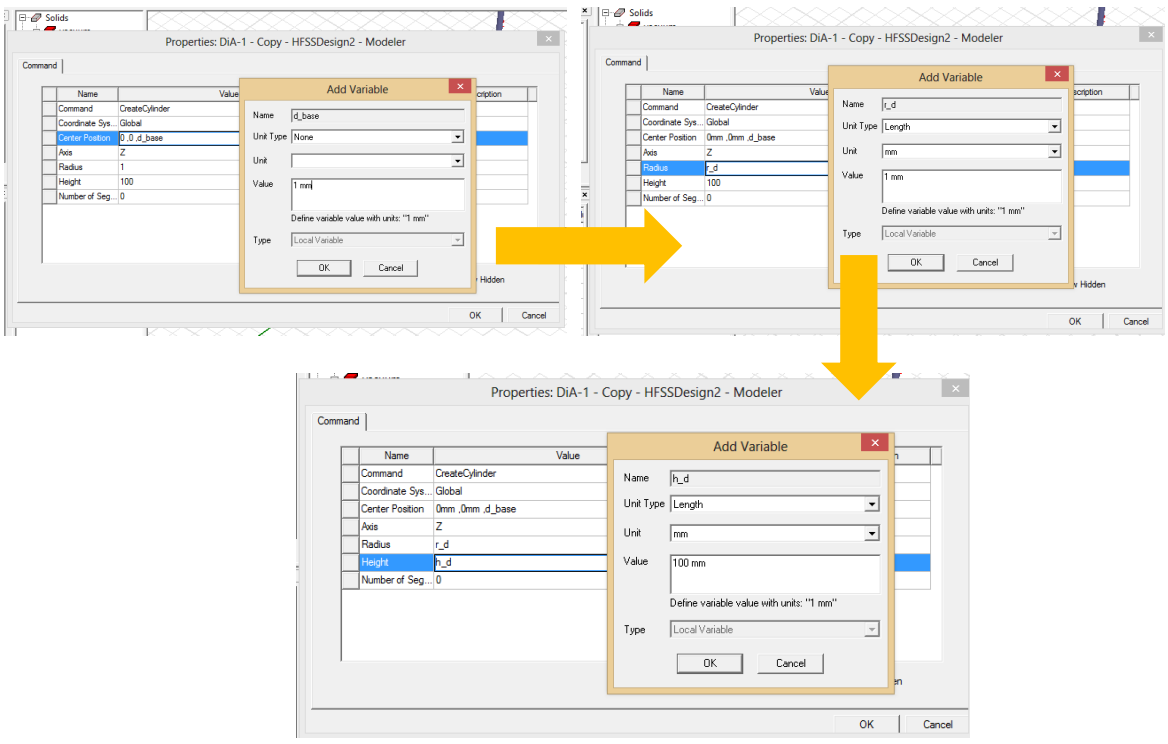


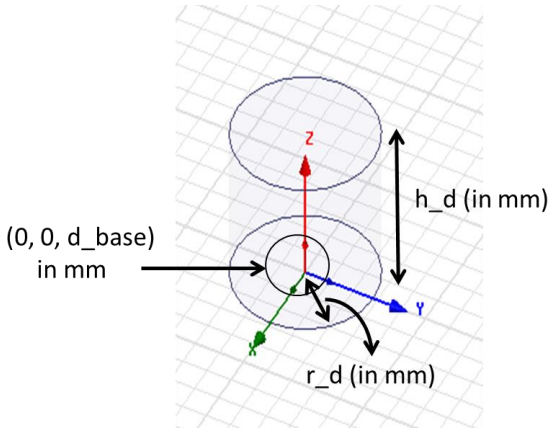
c. Set the Height by positioning the active cursor and clicking left mouse button.



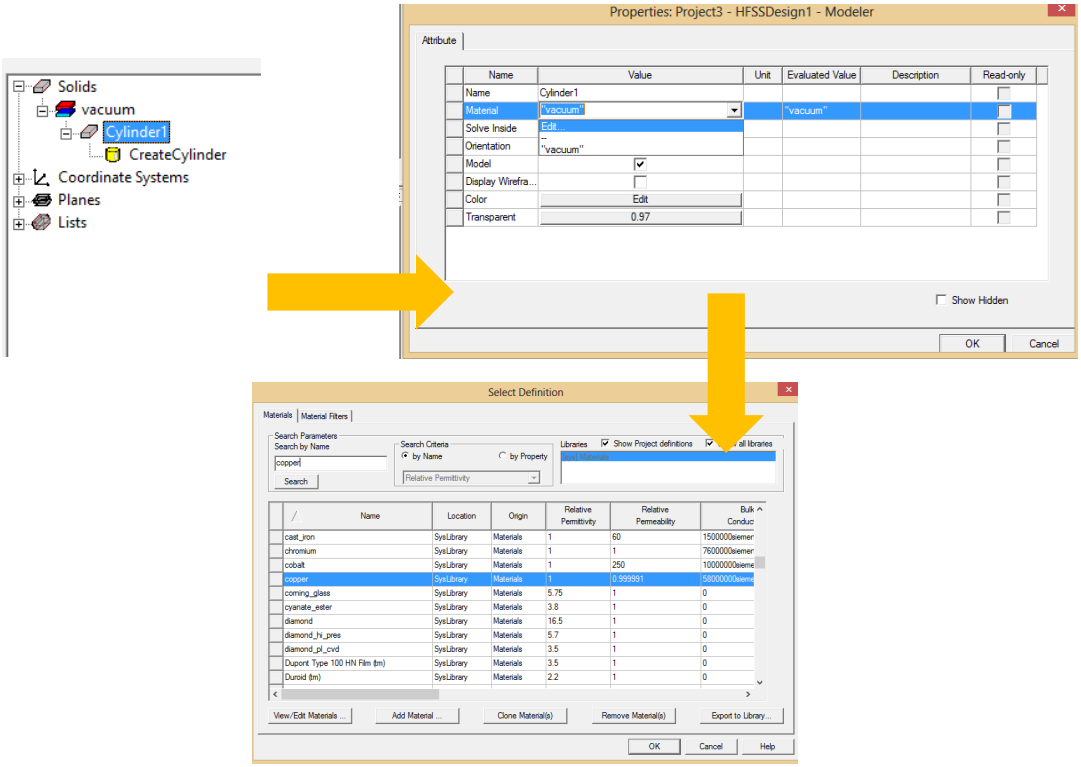
3. Check/Edit the properties of the cylinder:
   Select Cylinder1 → click on '+' → CreateCylinder → Poperies window

   Use parameters for different dimensions of the dipole:
   d_base → base of the dipole (use 1 mm) → Ok
   r_d → radius of the dipole (use 1 mm) → Ok
   h_d → height of the dipole (use 100 mm) → Ok

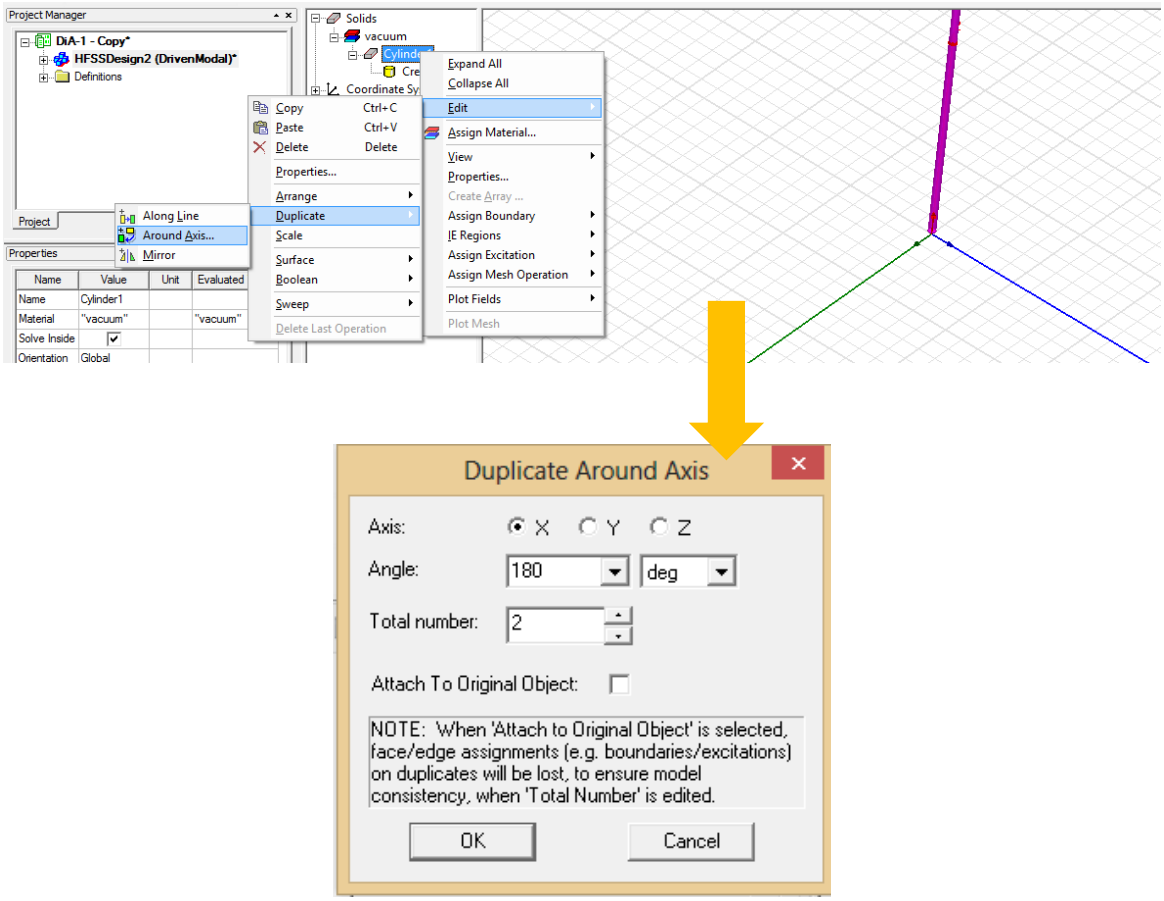




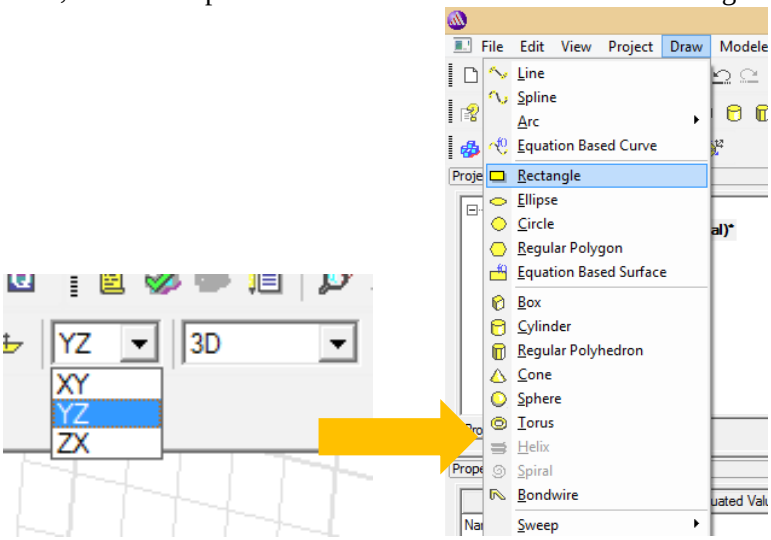
4. Assign/Change material to/of the cylinder:
   Select Cylinder1 and Double click → Poperies window → Material → Edit (from droop down) → Select material (as per requirement) → Ok



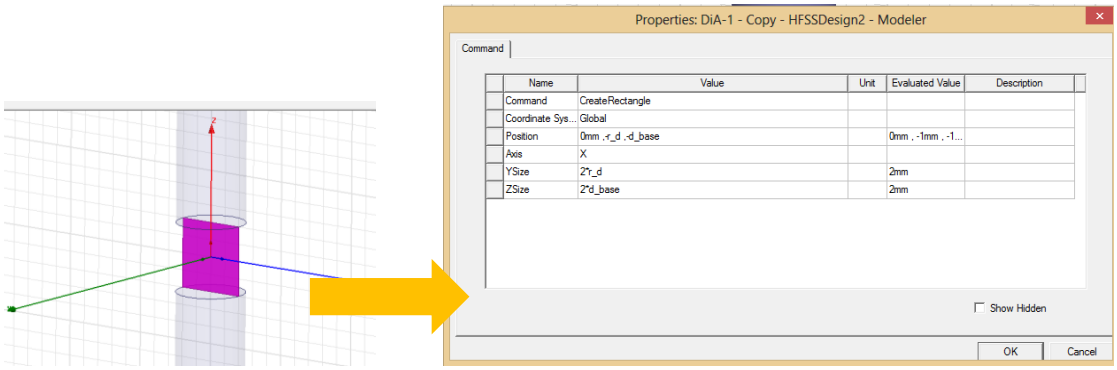
5. Design the other part of the Dipole:
   a. Select Cylinder1 and Right click → Edit → Duplicate → Around axis
   b. Next, one small window will open: Select X axis → Angle 180 Deg →Total Number 2 → Ok
   c. Now the other part of the dipole will be created.



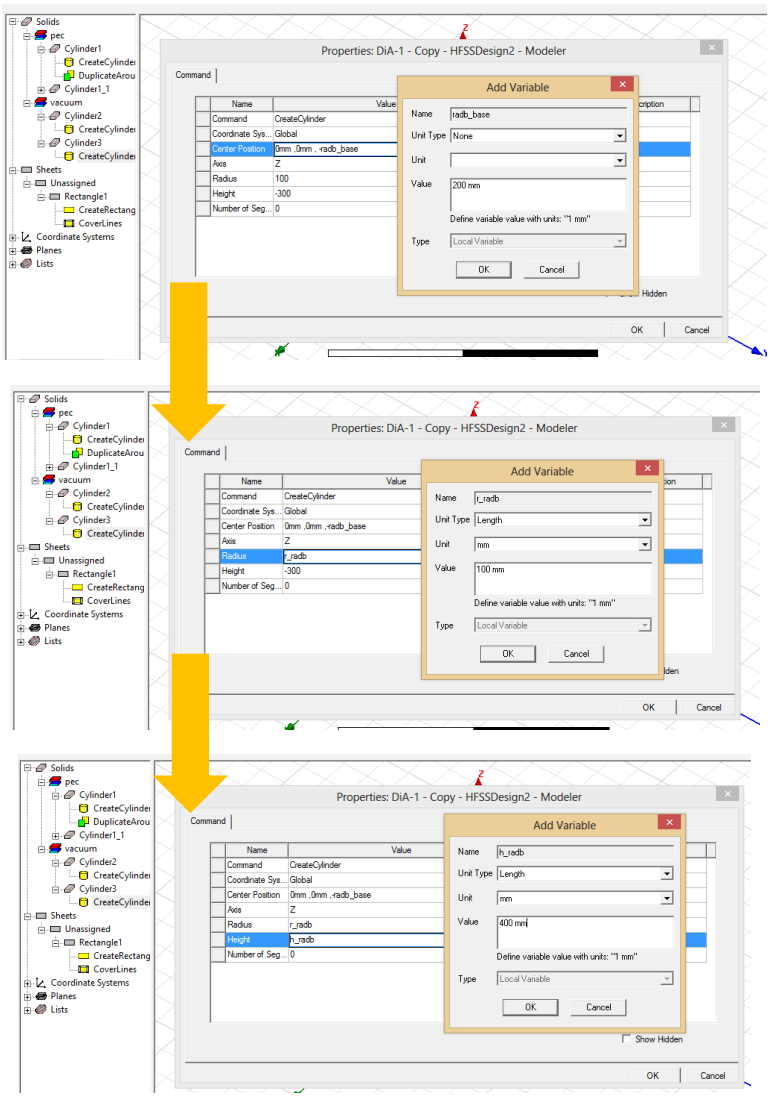
6. Now add rectangular sheet between the dipole that connects the edges of each dipole.
    a. First set the view axis as ‘YZ’
    b. Next, from the top menu bar Click on Draw → Select Rectangle



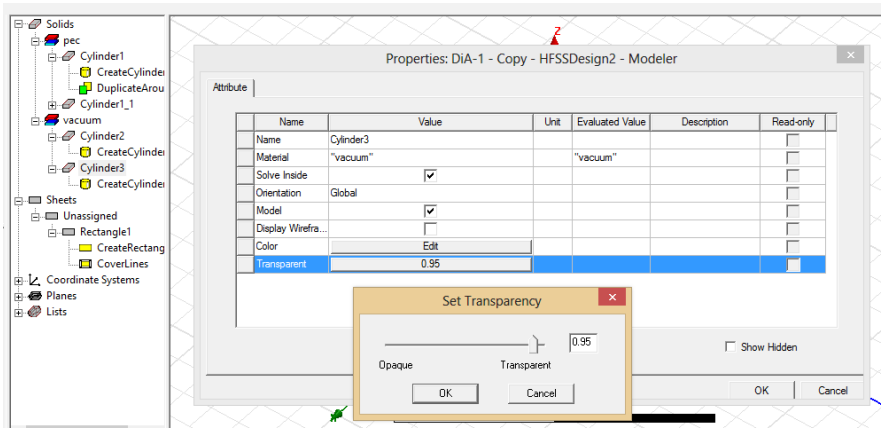
7. Now draw the rectanagle between the dipole. Set the dimensions of the rectangle as shown in the figure below. (Double Click on Rectangle → Create rectangle → Edit on the properties window)



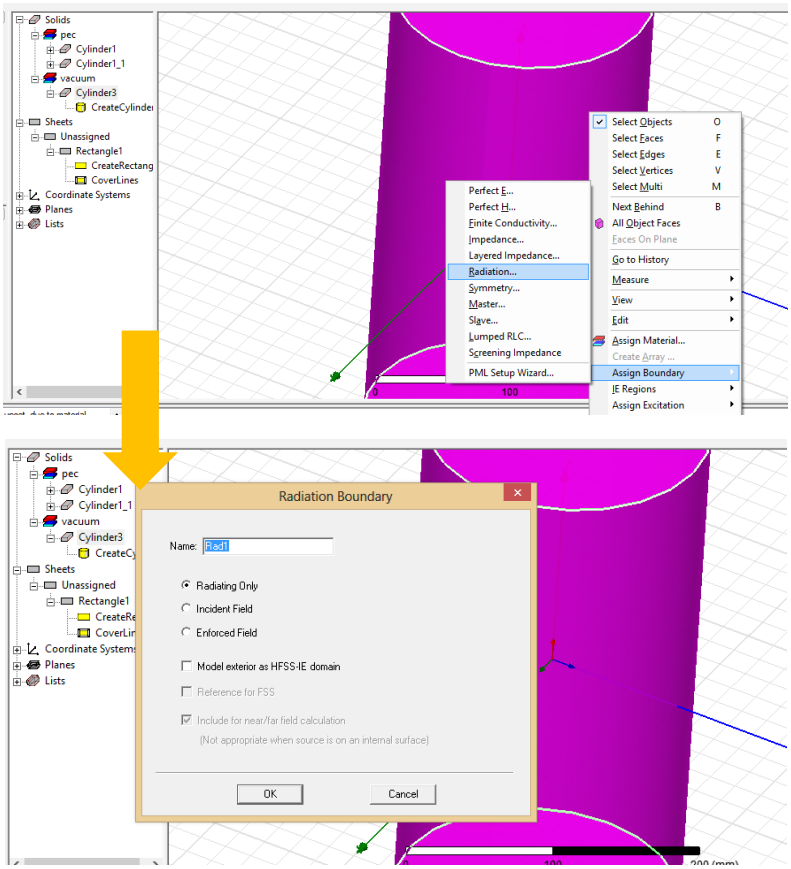
8. Now design the radiation cylinder/box.
Click on create cylinder2 → set the properties (base, radius, and height) one by one as follows.



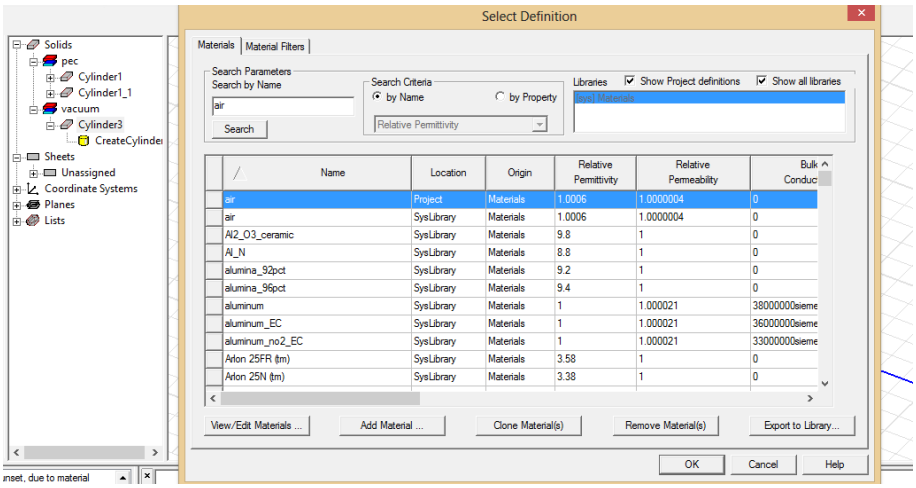
9. Set the transparency of the radiation cylinder. Now design the radiation cylinder/box. Double click on cylinder2 → Set transparency to 90% → Ok.



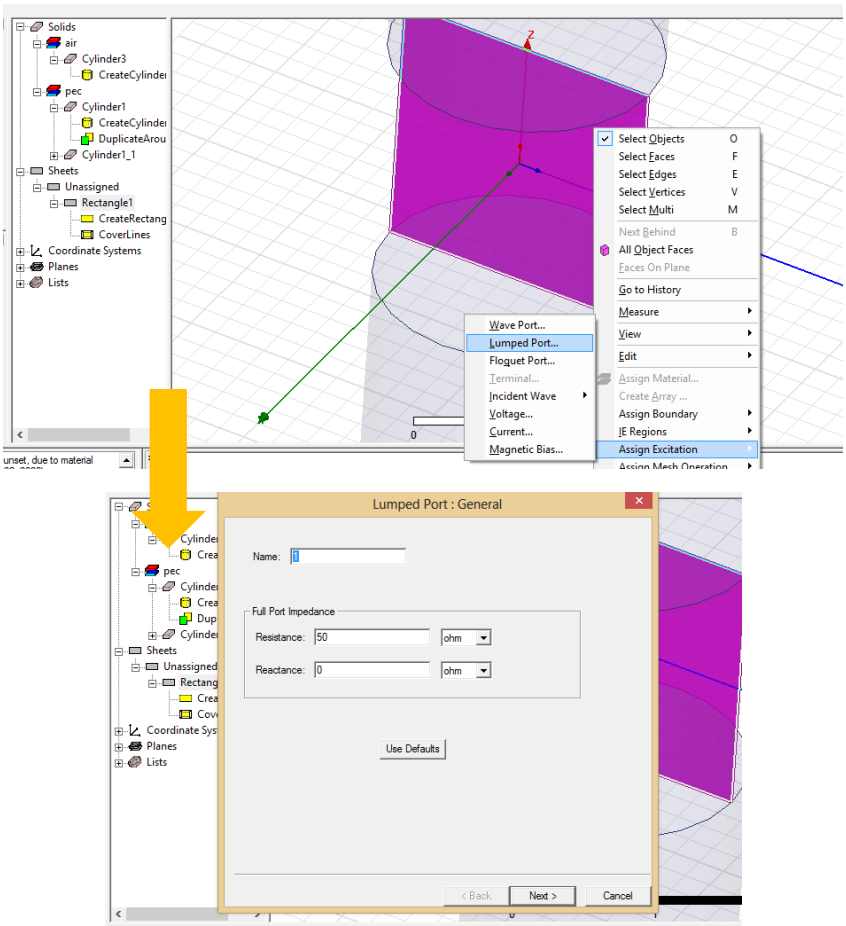
10. Assign radiation boundary to radiation cylinder.
Right click on cylinder 2 → Radiation → Assign bound → Radiation only → Ok.

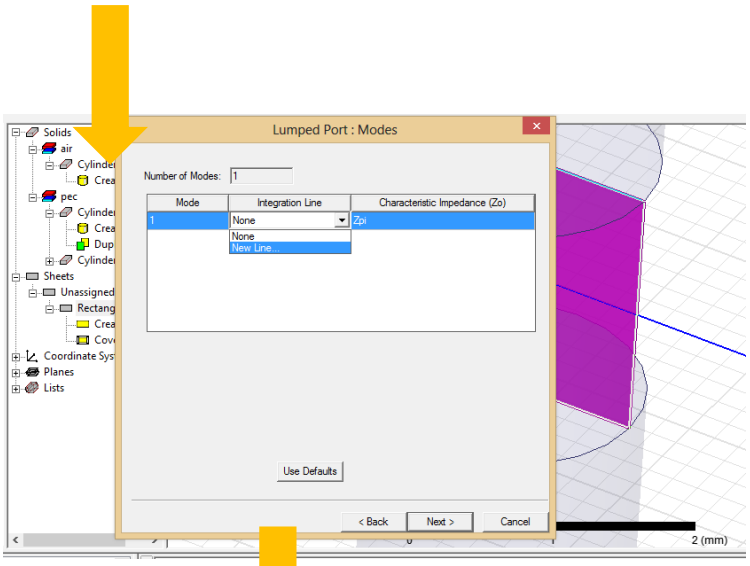


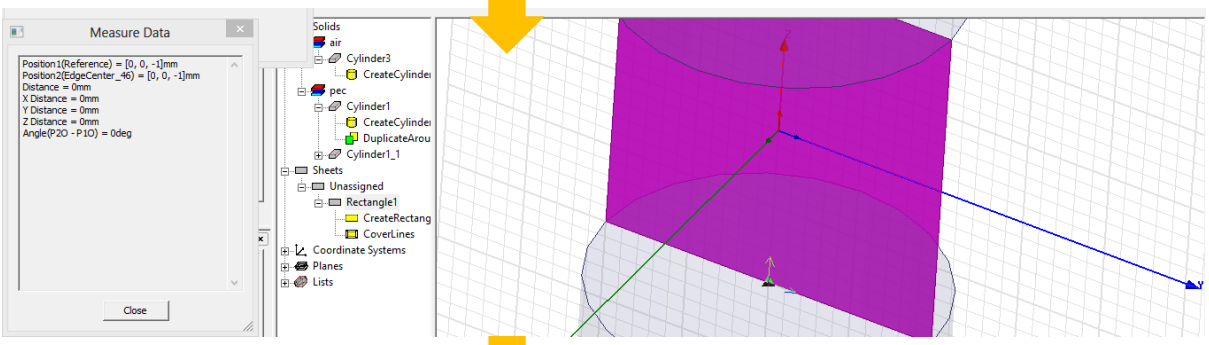
11. Assign material to the radiation cylinder.
    Double click on cylinder2 → click edit on drop down box → select air → Ok

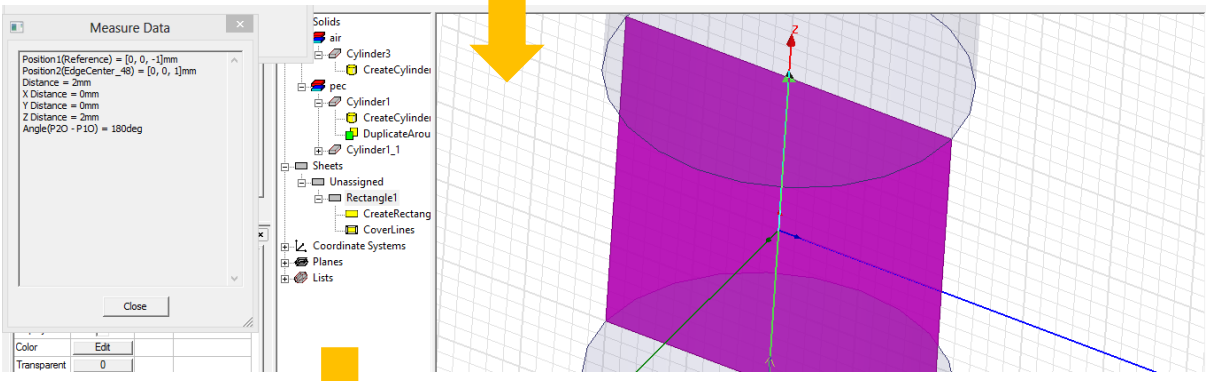


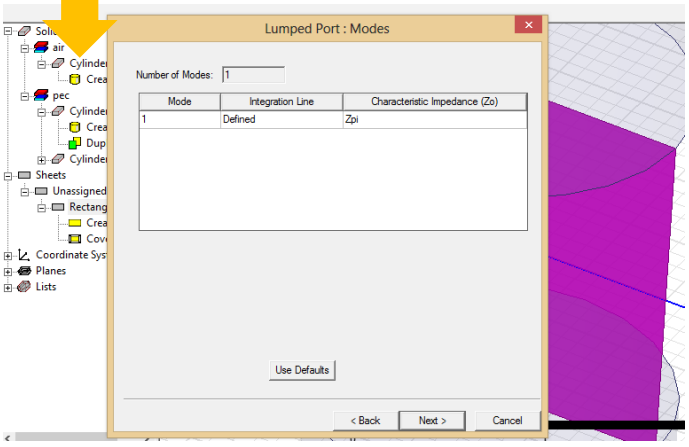
12. Assign excitation.
    Select the rectangle → Assign excitation → Lumped port → 50 Ohm (Next) → New line → Click at the centre of the rectangle → draw up to top of the rectangle and click → Next → Finish.

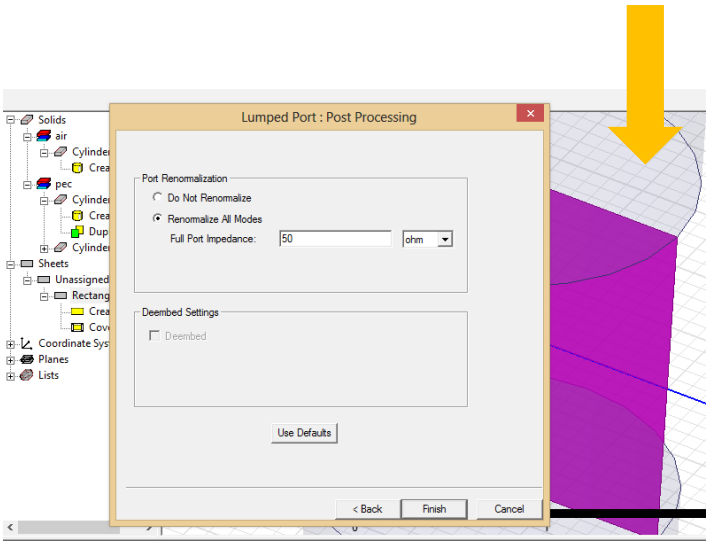



Lumped Port : Modes
Number of Modes: 1
Mode
Integration Line
Characteristic Impedance (Zo)
1
None
Zpi
None
New Line...
Use Defaults
< Back
Next >
Cancel
2 (mm)

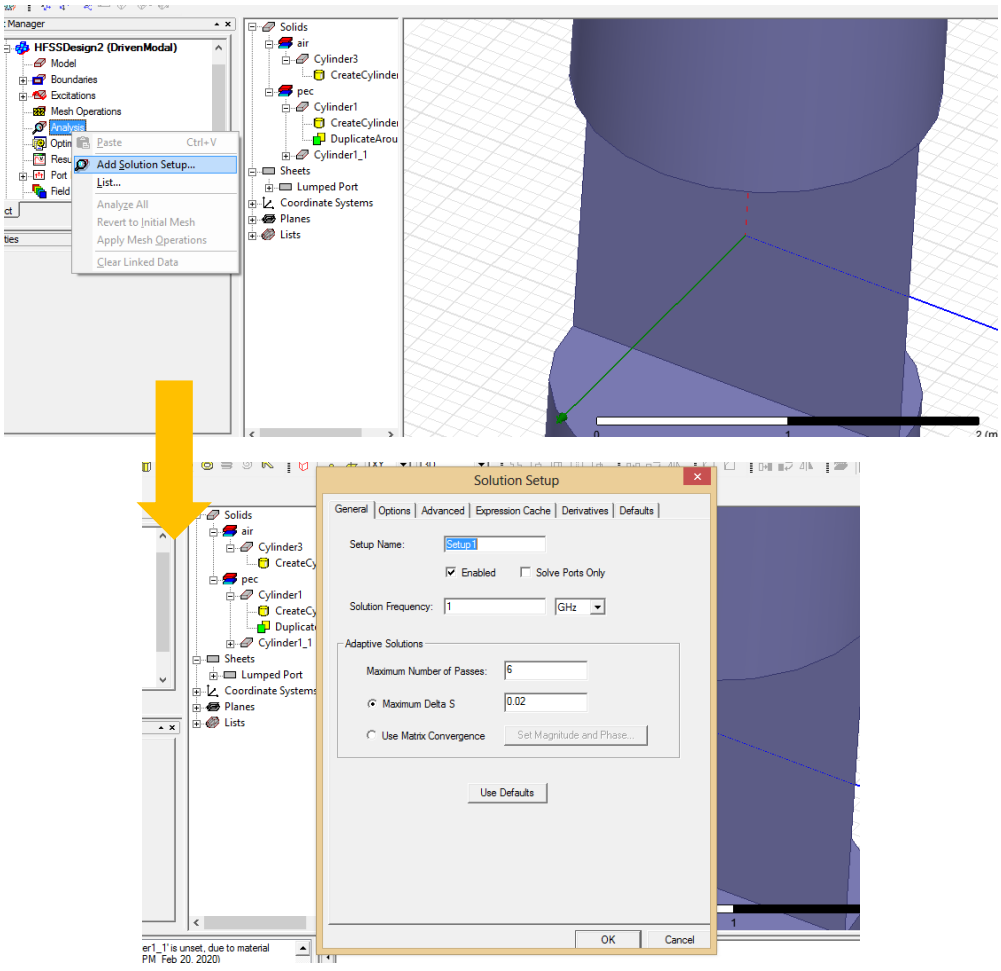

Measure Data
Position1(Reference) = [0, 0, -1]mm
Position2(EdgeCenter_46) = [0, 0, -1]mm
Distance = 0mm
X Distance = 0mm
Y Distance = 0mm
Z Distance = 0mm
Angle(P2O - P1O) = 0deg
Close
Solids
air
Cylinder3
CreateCylinder
pec
Cylinder1
CreateCylinder
DuplicateArou
Cylinder1_1
Sheets
Unassigned
Rectangle1
CreateRectang
CoverLines
Coordinate Systems
Planes
Lists


Measure Data
Position1(Reference) = [0, 0, -1]mm
Position2(EdgeCenter_48) = [0, 0, 1]mm
Distance = 2mm
X Distance = 0mm
Y Distance = 0mm
Z Distance = 2mm
Angle(P2O - P1O) = 180deg
Close
Color
Edit
Transparent
0
Solids
air
Cylinder3
CreateCylinder
pec
Cylinder1
CreateCylinder
DuplicateArou
Cylinder1_1
Sheets
Unassigned
Rectangle1
CreateRectang
CoverLines
Coordinate Systems
Planes
Lists
Z

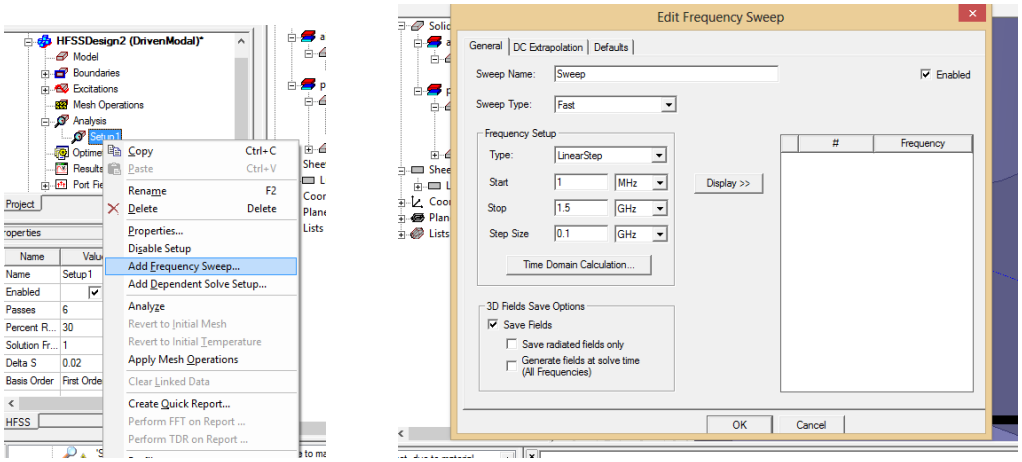

Lumped Port : Modes
Number of Modes: 1
Mode
Integration Line
Characteristic Impedance (Zo)
1
Defined
Zpi
Use Defaults
< Back
Next >
Cancel



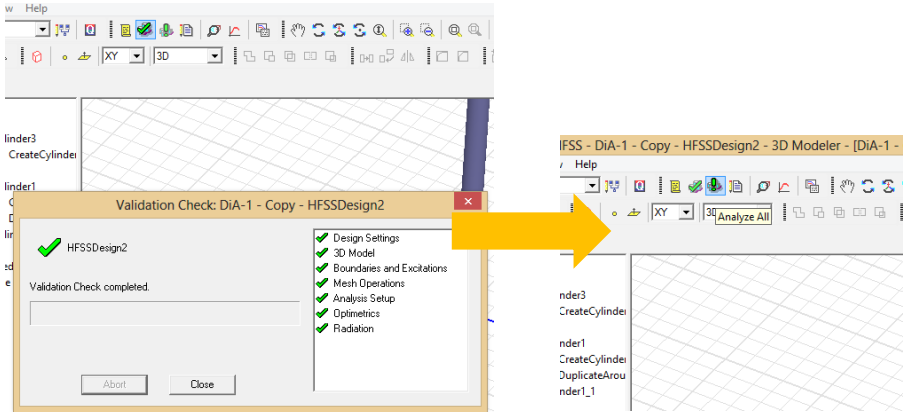
13. Right click on analysis → Add solution setup → Ok



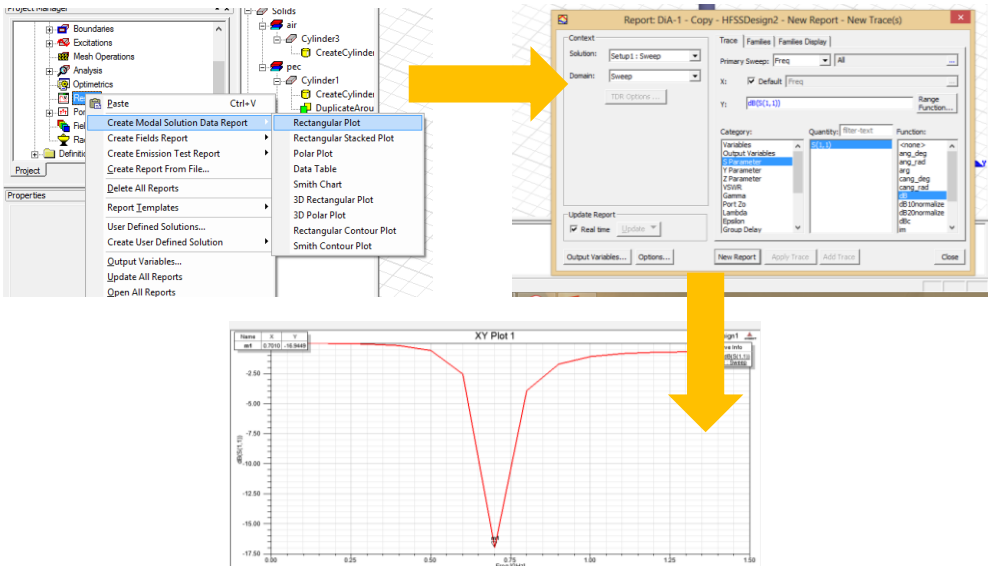
14. Click ‘+’ of the analysis → Click on setup → Add frequency sweep → Edit frequency sweep (Sweep type Fast, Frequency range 1 MHz to 1.5 GHz, Step size 0.1 GHz) → Ok



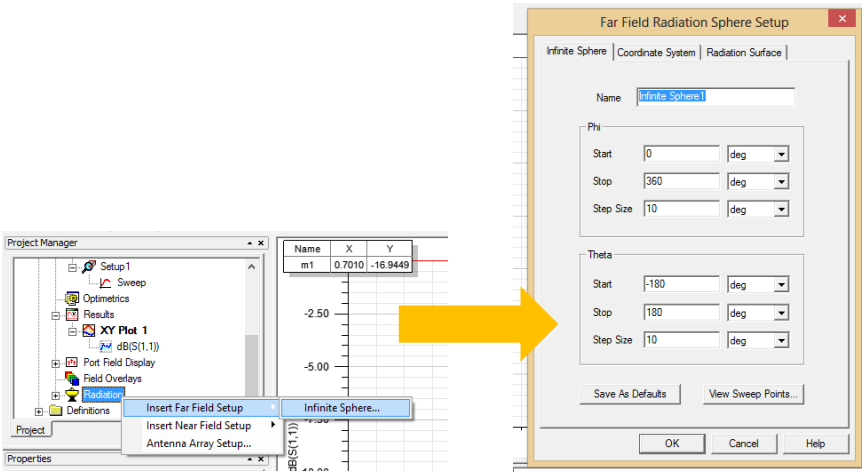
15. Do validation check and go for Analyze all.



16. Now check results (S-parameter).
Right click on results → Create modal solution data report → Rectangular plot select s parameter, S11, dB → New report.



17. Now check results (Radiation pattern).
    Right click on radiation → Insert far field setup → Infinite Sphere → Do the far field radiation sphere setup as shown below → Ok



18. Next, Right click on results → Create far field report → Radiation pattern
    From the new window, select rE → rE Total → dB → New Report.