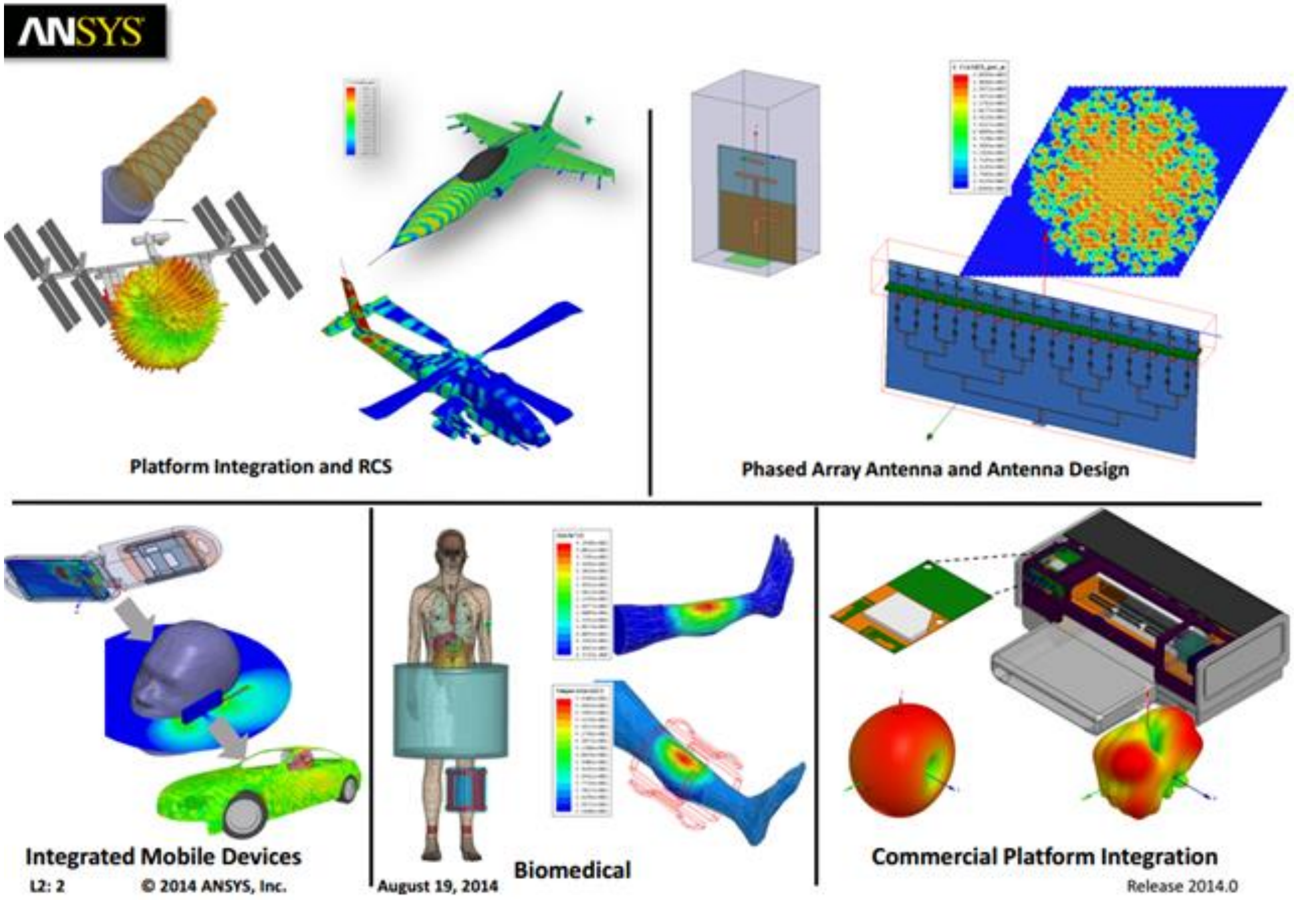
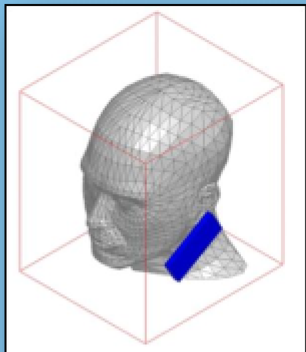
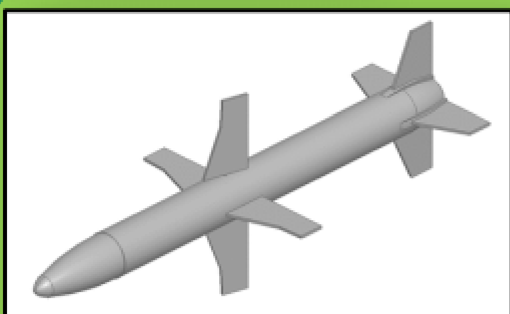
HFSS TUTORIAL



HFSS: Simulation Technologies

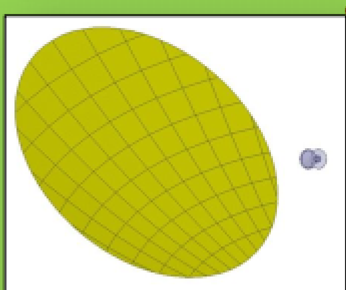


- **Finite Element Method**
  - Enabled with HFSS
  - Efficiently handles complex material and geometries
  - Volume based mesh and field solutions
  - Fields are explicitly solved throughout entire volume
  - Frequency and Transient solutions

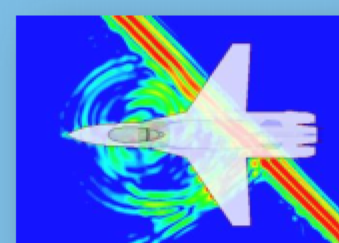


- **Integral Equations**
  - Enabled with HFSS-IE
  - Efficient solution technique for open radiation and scattering
  - Currents solved only on surface mesh
  - Efficiency is achieved when structure is primarily metal

Hybrid Solutions

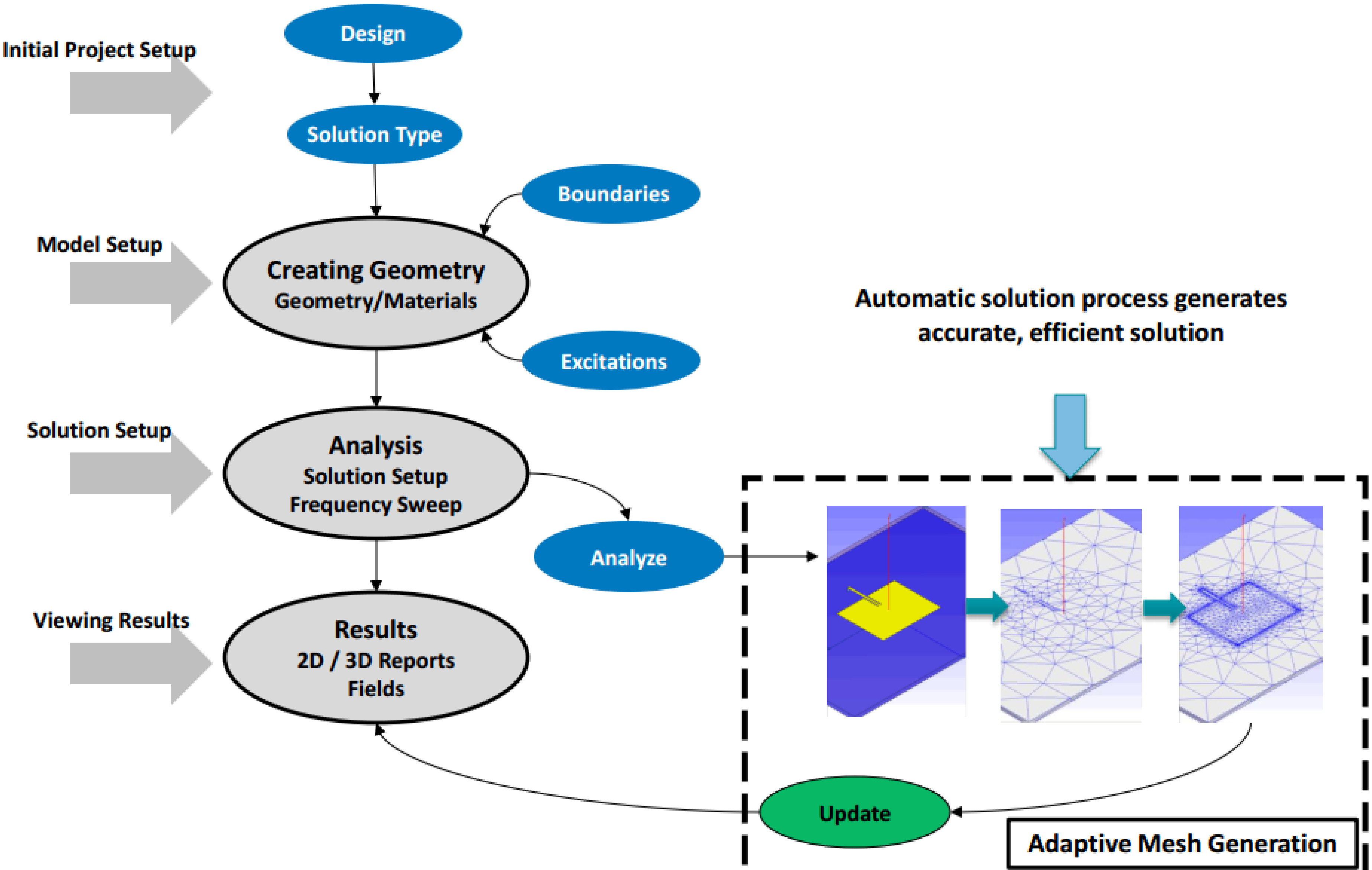


- **Physical Optics**
  - **Enabled with HFSS-IE**
  - **High frequency approximation**
  - **Ideal for electrically large, smooth objects**
  - **1st order interactions**



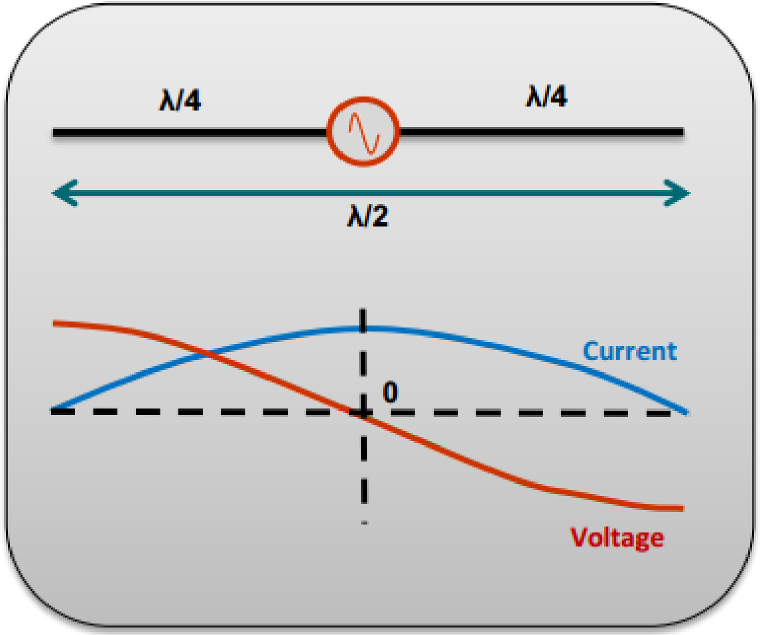
- **FEM Transient**
  - **Enabled with HFSS**
  - **Ideal for fields that change versus space and time; scattering locations**

HFSS – Overview of Solution Process



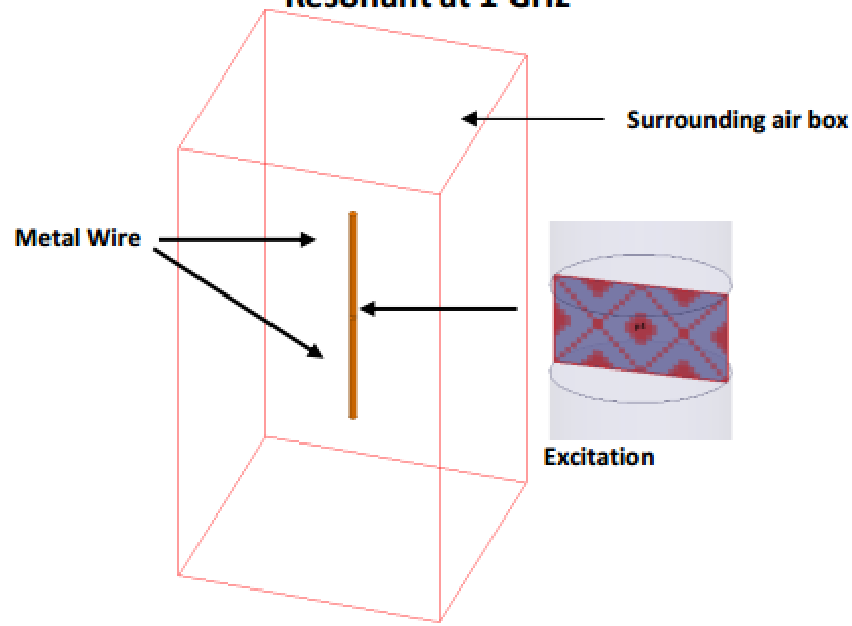
Half Wave Dipole Example

Ideal Half Wave Dipole

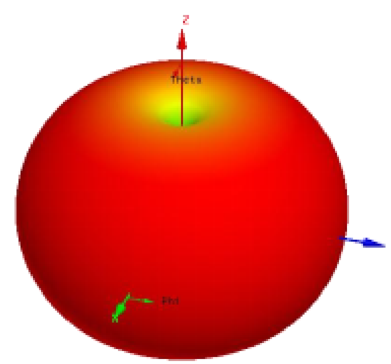


Finite element analysis of real half wave dipole antenna using HFSS

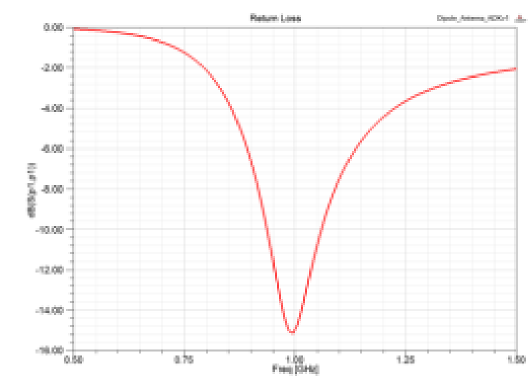
HFSS Model of Half Wave Dipole Antenna Resonant at 1 GHz



Excitation

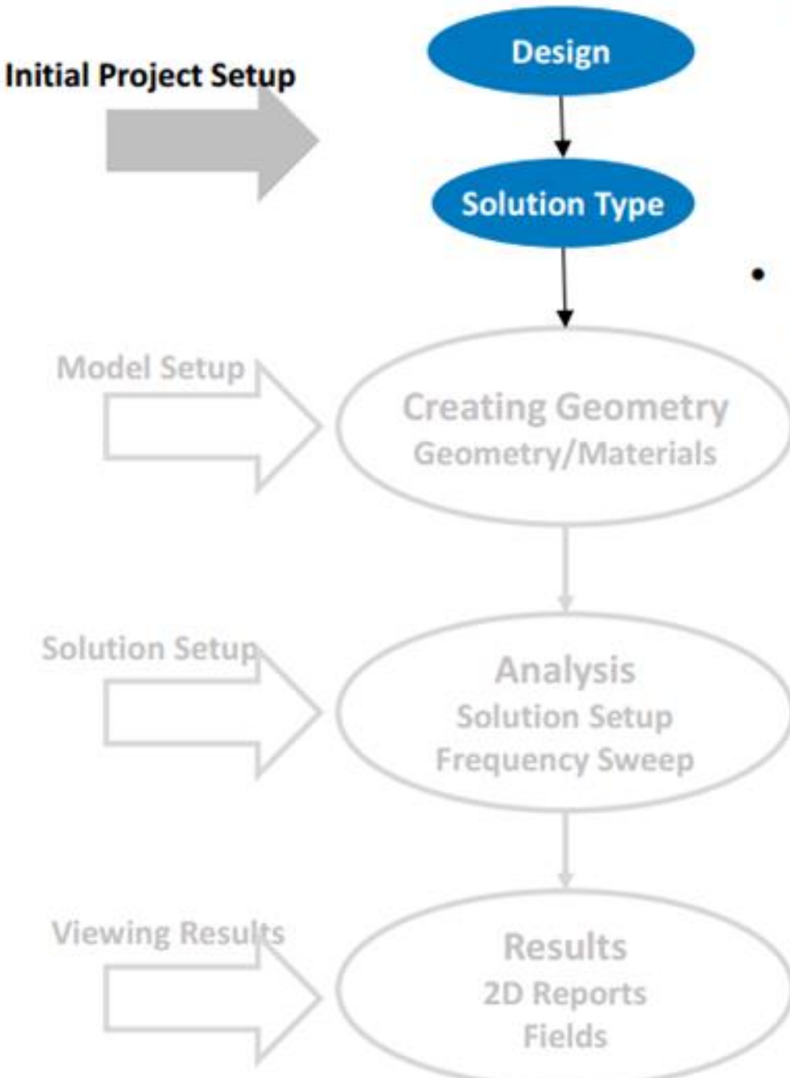


Far Field Radiation Pattern

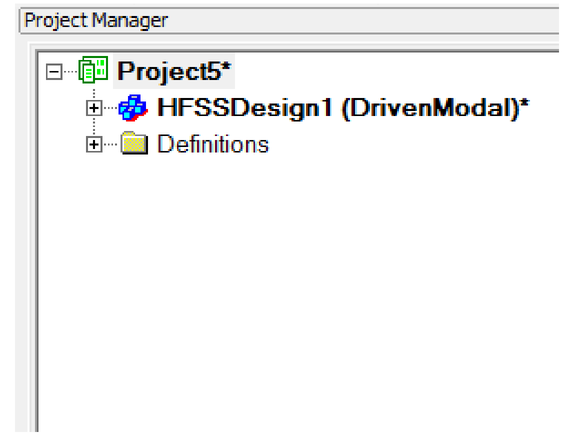


Return Loss

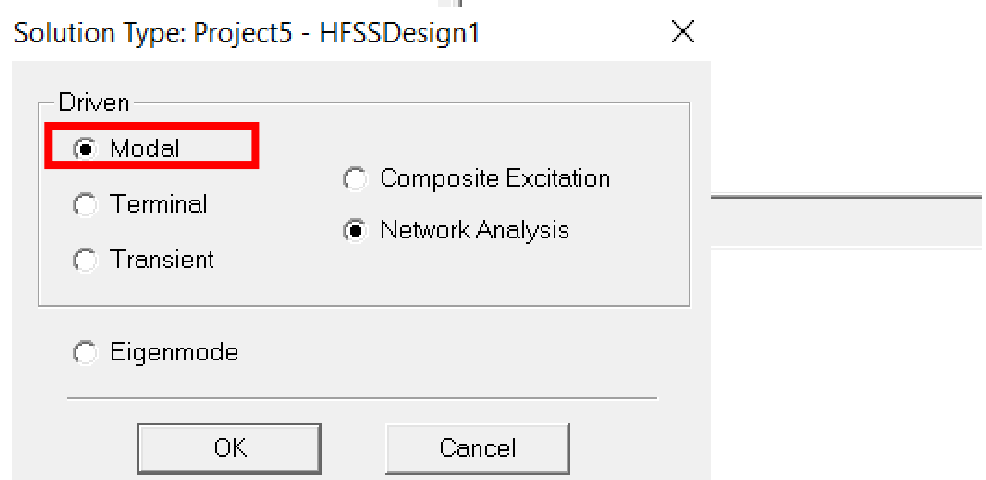
HFSS – Initial Project Setup



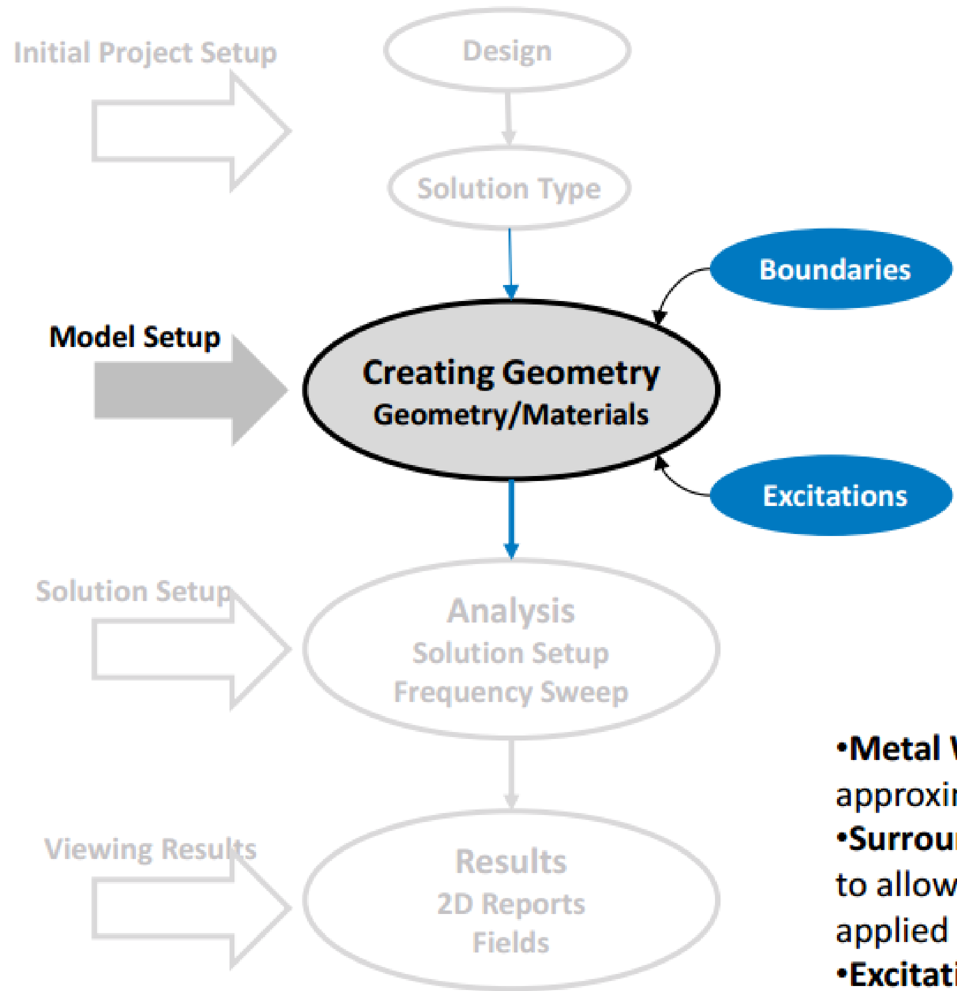
- **Opening a New Project**
  - If a new project and new design are not already opened, then:
    - In HFSS Desktop, click the 🗋 On the Standard toolbar, or select the menu item ***File > New***.
    - From the Project menu, select **Insert HFSS Design**.

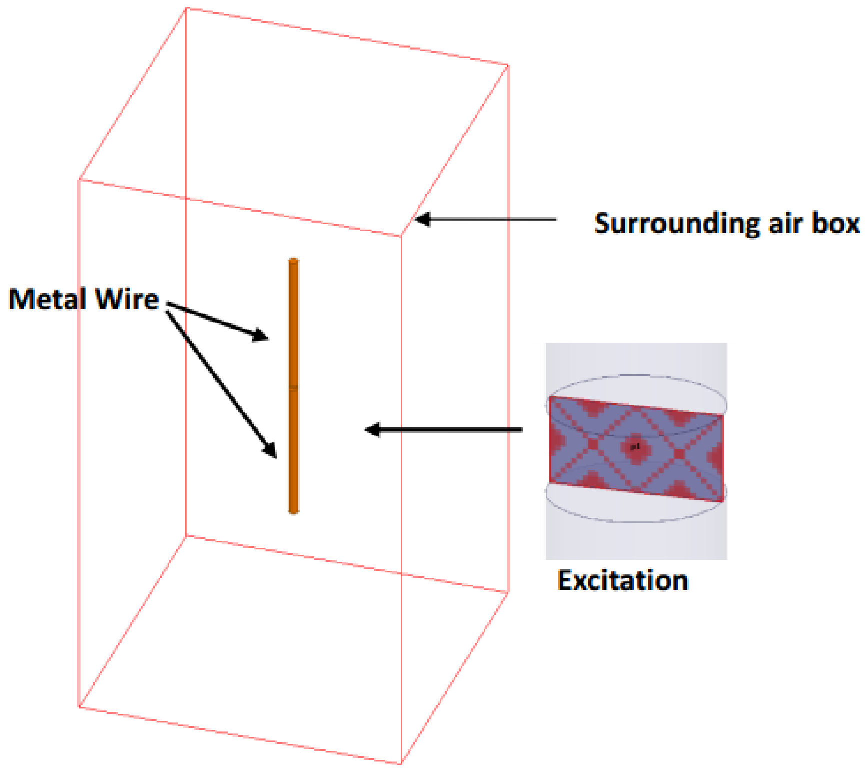


- **Set Solution Type**
  - Select the menu item ***HFSS > Solution Type***
    - Choose **Driven Modal**
    - Click the **OK** button



HFSS – Model Setup

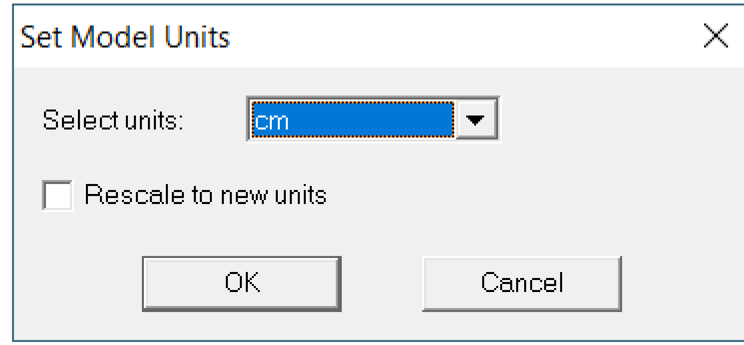




- **Metal Wire –** 2 perfectly conducting cylinders with a length of approximately $\lambda/2$
- **Surrounding Air Box –** Air volume surrounding antenna element to allow radiation of fields, radiating boundary condition will be applied to outer surface to act as infinite free space
- **Excitation –** Lumped port excitation applied to a rectangle drawn between each arm of dipole to provide an RF excitation to antenna element

HFSS- Creating Geometry

- Select the menu item ***Tools > Options > Modeler Options….***
  - Click the **Display** tab
  - Set default transparency to **0.7**
- Select the menu item ***Modeler > Units…***
  - Set Model Units: **cm**



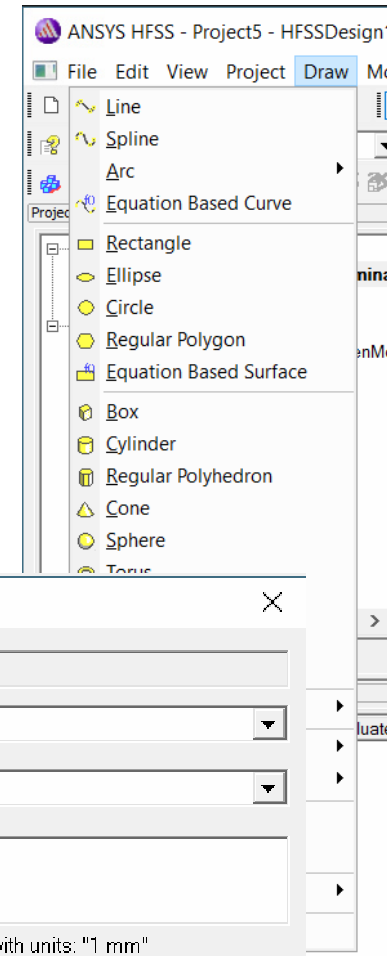
Operating Frequency= 1 GHz Wavelength= 30 cm

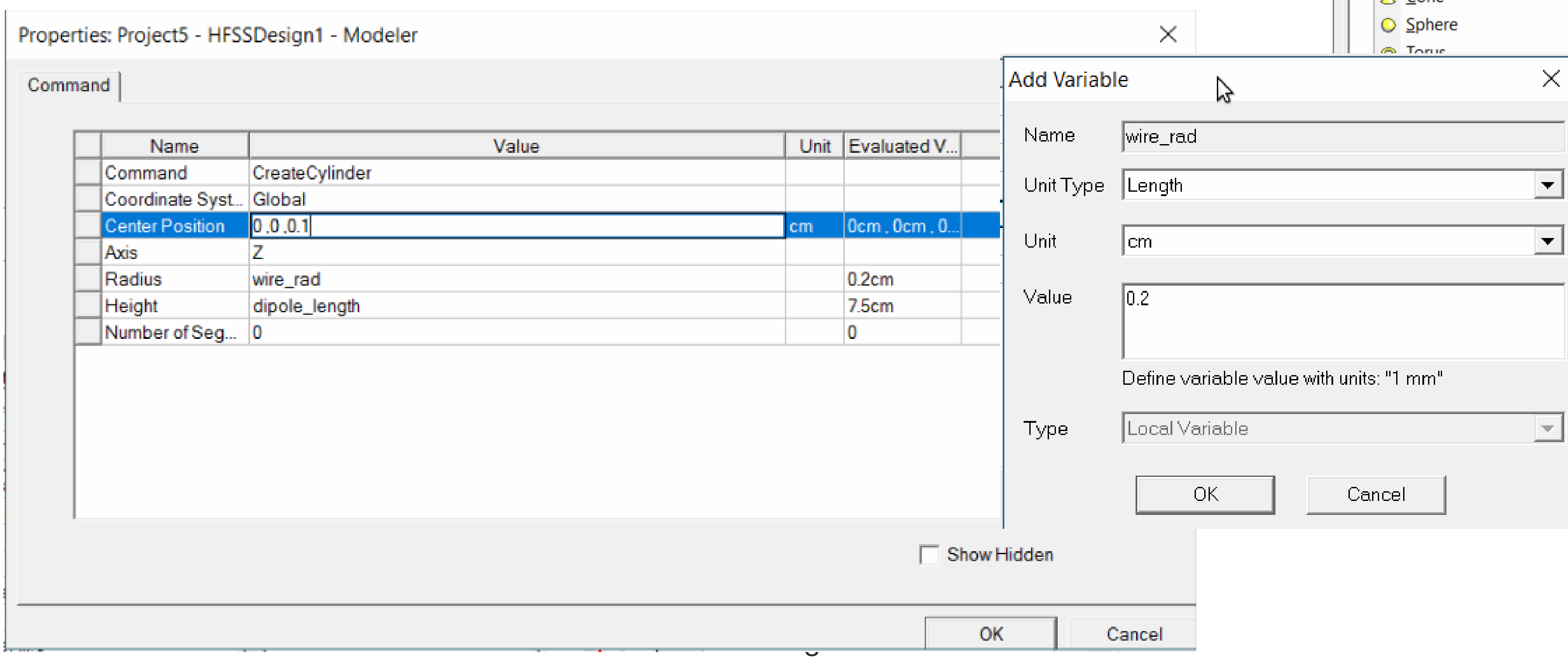
Dimensions of the Dipole Antenna	
Dipole total length (λ/2)	15 cm
Dipole one arm length	7.5 cm
Wire Radius	0.2 cm
Port Gap	0.2 cm

NOTE: For parametric simulations, we will assign variables to the each dimension.

HFSS- Creating Geometry

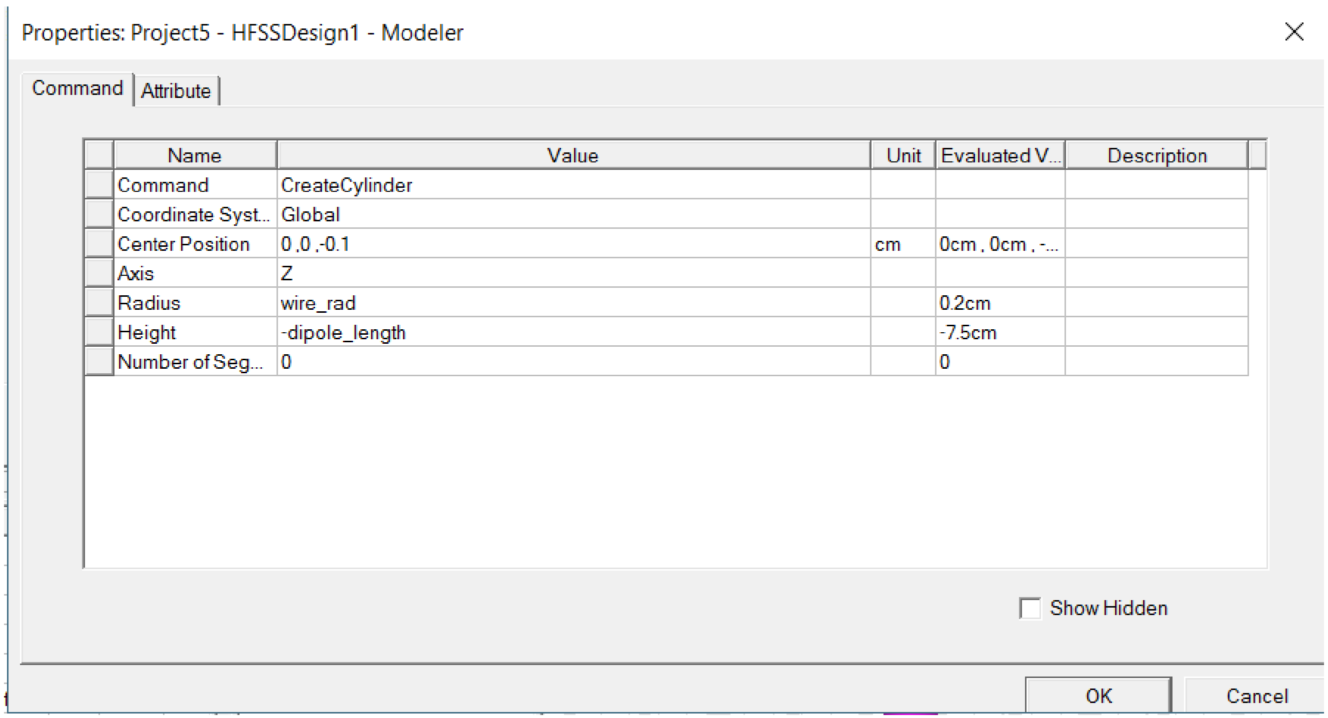
- Select the menu item ***Draw > Cylinder***
- Choose the origin as the center of the cylinder and draw the cylinder
  - Properties menu appears automatically
  - Set Radius to the **wire_rad. Add Variable** window opens automatically. Set value to **0.2** then press OK.
- In the Properties menu, Set **Height** to **dipole_length. Add Variable** window opens automatically. Set value to **7.5** then press OK.
- Set Center Position to **0,0,0.1**
- Use **Ctrl+D** to see the workspace clearly.



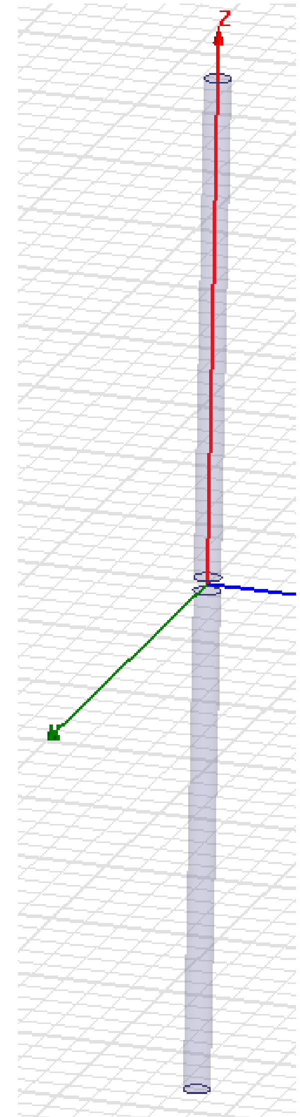


Select the menu item ***Draw > Cylinder***

- Choose the origin as the center of the cylinder and draw the cylinder
  Properties menu appears automatically
  - Set Radius to the **wire_rad.**
  - Set Height to **-dipole_length**.
  - Set Center Position to **0,0,-0.1**
  - Then Click **OK.** Now we have two dipole arms.

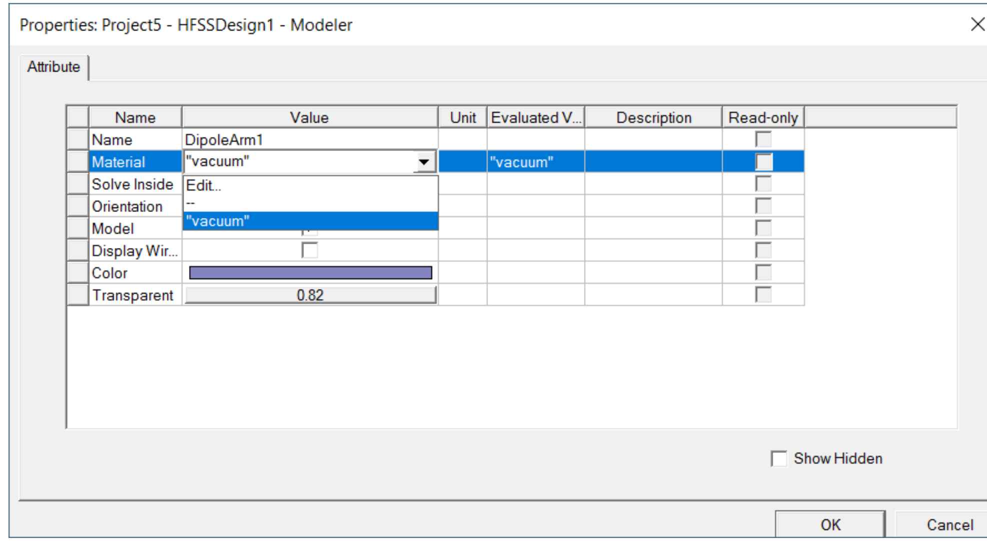


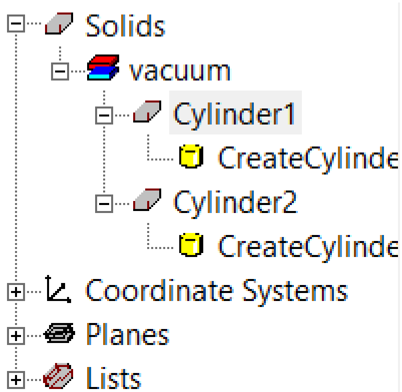
Name	Value	Unit	Evaluated V...	Description
Command	CreateCylinder			
Coordinate Syst...	Global			
Center Position	0 ,0 ,-0.1	cm	0cm , 0cm , -...	
Axis	Z			
Radius	wire_rad		0.2cm	
Height	-dipole_length		-7.5cm	
Number of Seg...	0		0	



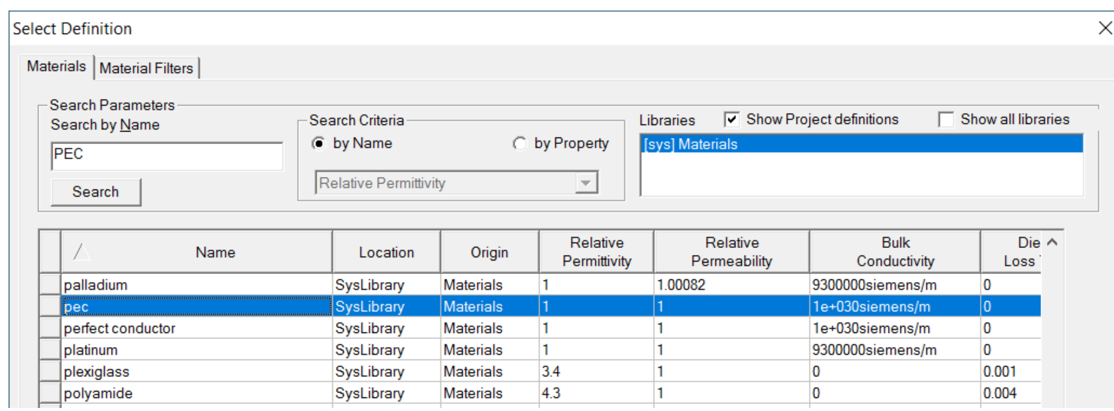
HFSS- Assigning Materials

- Double click to the **Cylinder1,** Properties window will be opened. Under the **Attribute** tab
  - Change the **Name** as DipoleArm1.
  - Click the small arrow near the «**vacuum**» in the **Material** section. Click on **Edit.**



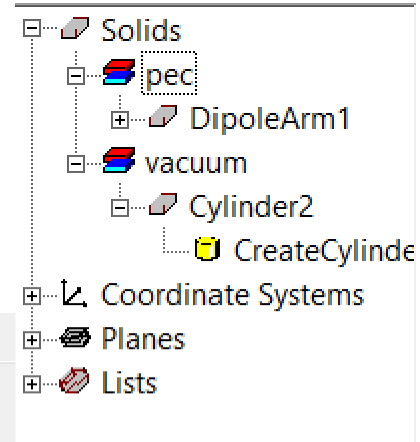


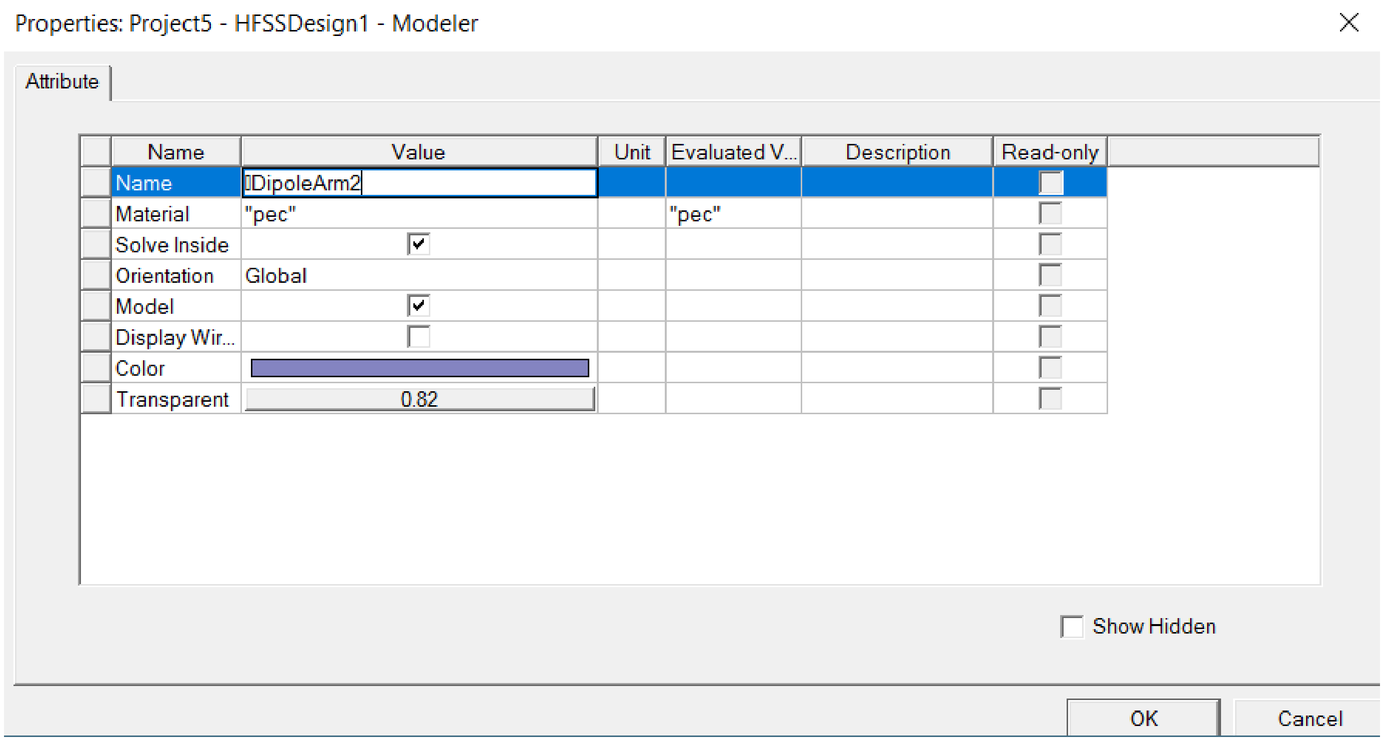
- Select Definition window will be opened.Under the Materials tab , there is a seach part.
  - Write **PEC** to the **Search by Name** section. Select PEC by double clicking on it. Then Click **OK.**
  - Then again Click **OK** in the properties window.
  - Now we have assigned dipole arm as PEC.



HFSS- Assigning Materials

- Notice that DipoleArm1 is under the pec section now.
- Do the same procedure for the **Cylinder2.** Name it as **DipoleArm2** and assgin **PEC** as the Material. Pec appears the material section automatically since it is used before.

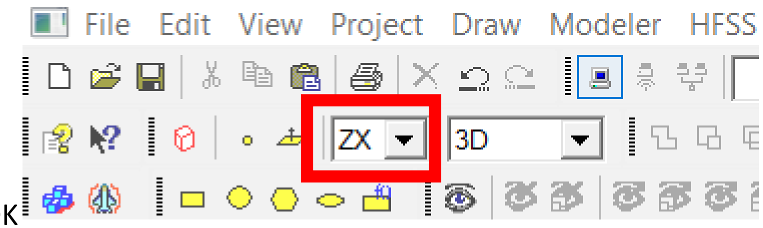




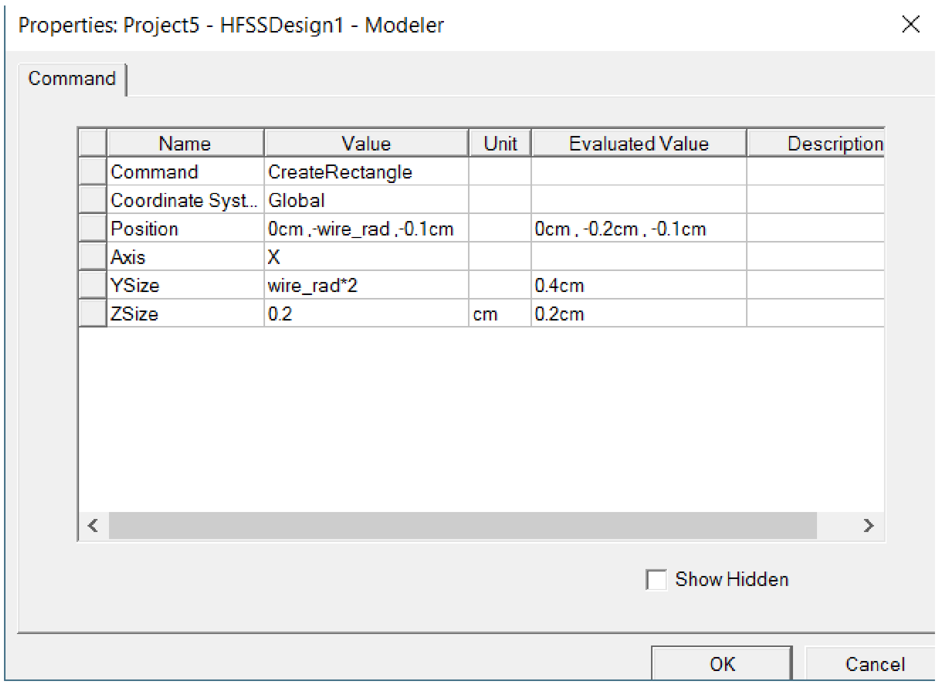
HFSS-Excitation Assignment

Now we need to assign the excitation

- Zoom to the space between two dipole arms.
- Select the menu item ***Draw > Rectangle***
- *Change alignment from XY to ZX and draw the rectangle between dipole arms*



- Double click on Create Rectangle
- Make the settings as given as the properties window given below and click on OK

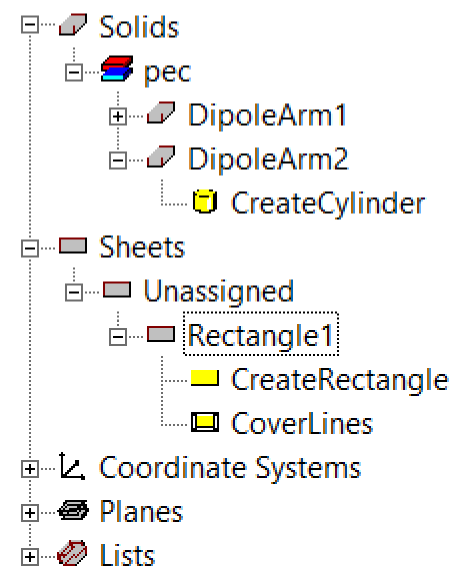

Properties: Project5 - HFSSDesign1 - Modeler

Command

Name	Value	Unit	Evaluated Value	Description
Command	CreateRectangle			
Coordinate Syst...	Global			
Position	0cm ,-wire_rad ,-0.1cm		0cm , -0.2cm , -0.1cm	
Axis	X			
YSize	wire_rad*2		0.4cm	
ZSize	0.2	cm	0.2cm	

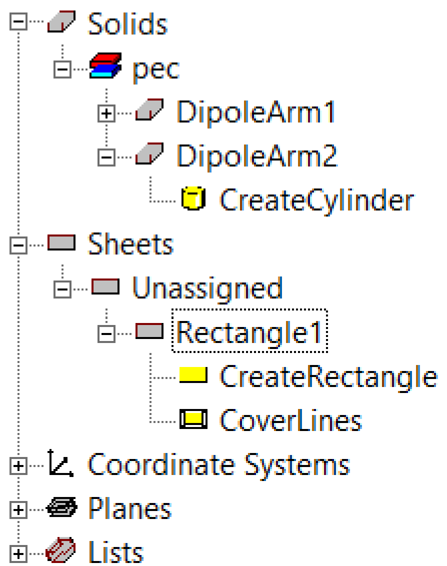
Show Hidden

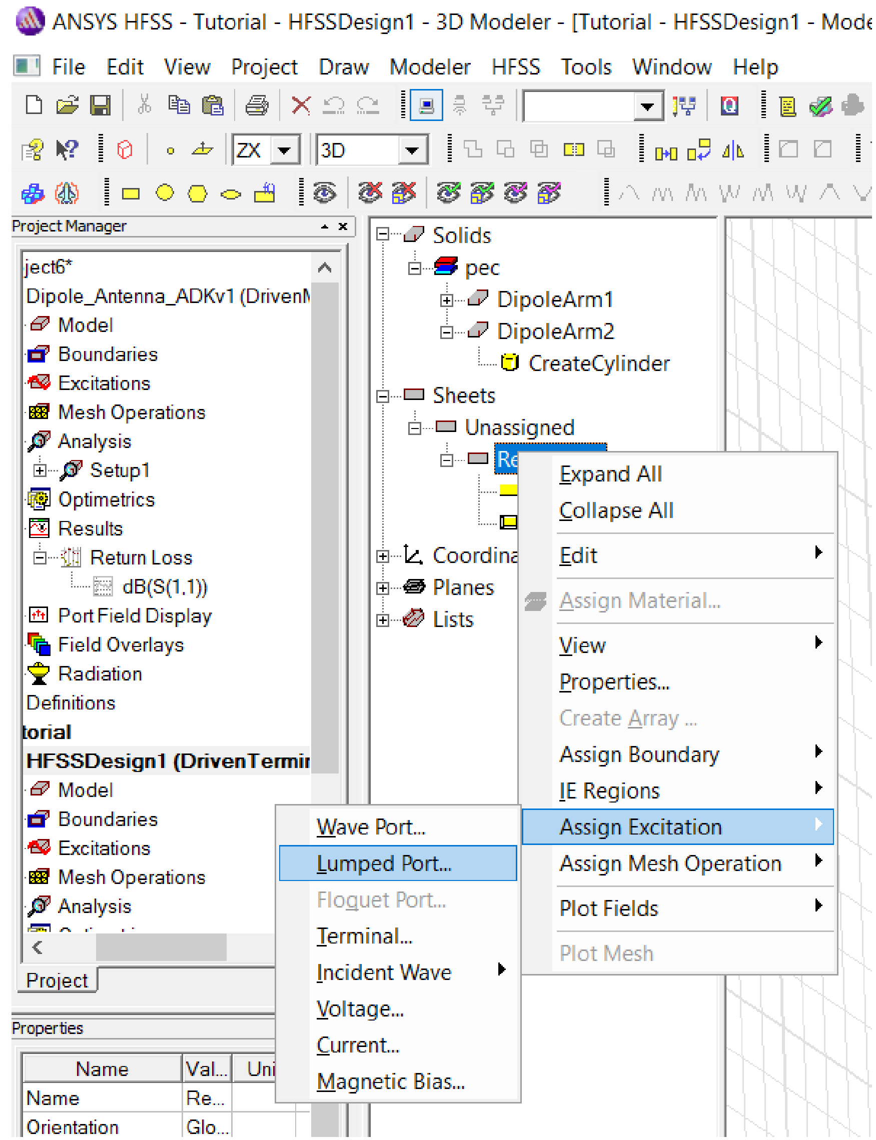
OK Cancel



HFSS-Excitation Assignment

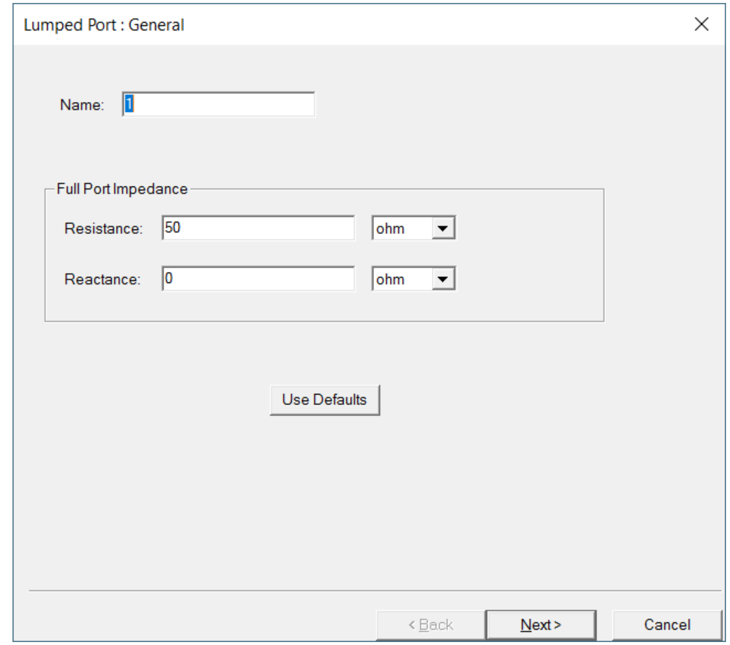
- Right click on **Rectangle 1 > Select Assign Excitation > Lumped Port**



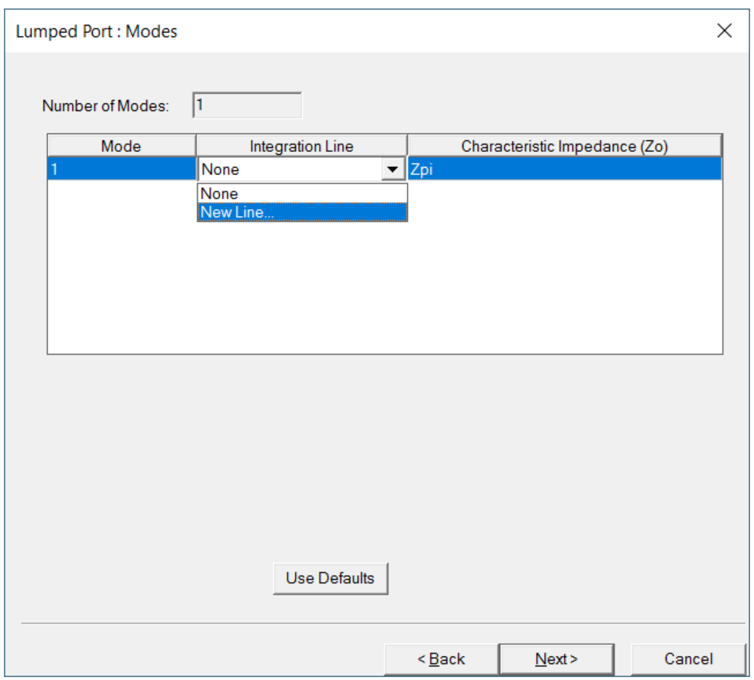


HFSS-Excitation Assignment

- Make the settings as given in the figure on the right and click on Next.
- Since you will design anttenas for 50 ohm impedance, we defined input resistance as 50 ohm.

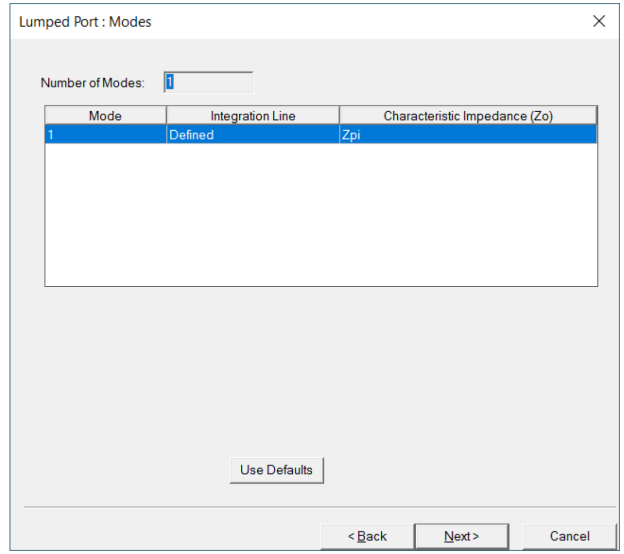


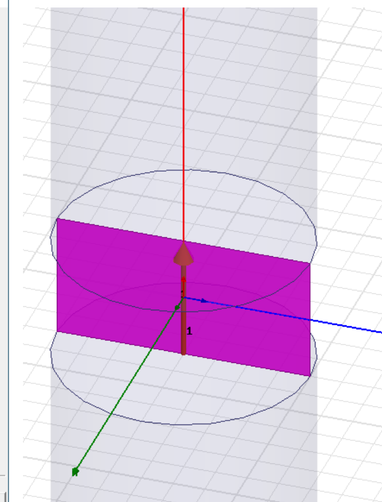
- Click the small arrow in the Integration line and select **New line...**
- Now we need to draw the port line.
- An integration line is a vector that can represent the direction of the excitation field pattern at a port.



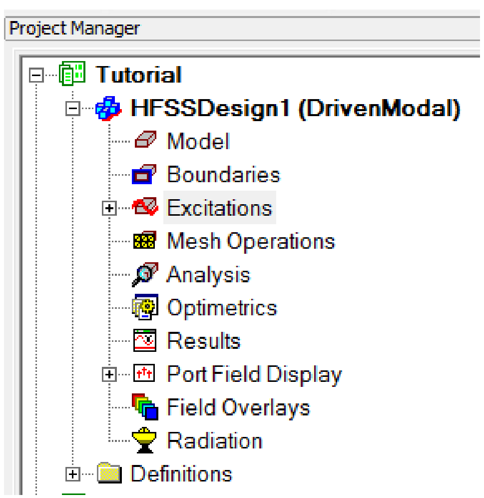
HFSS-Excitation Assignment

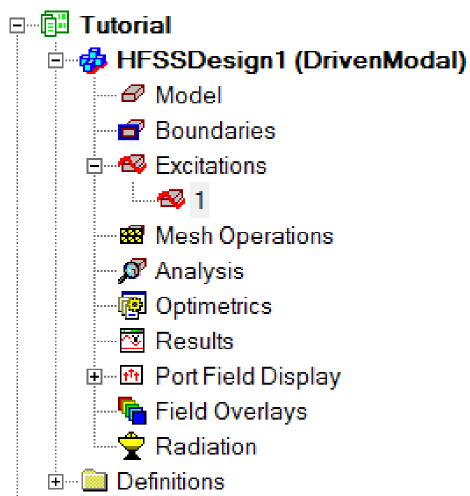
- An integration line will appear. In addition, Integration line section becomes Defined.
- Click on Next and then Finish.

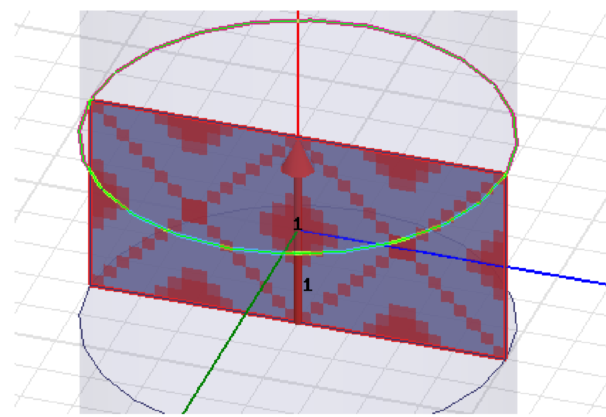




- To check the excitation, click on the plus sign of Excitations in the Project Manager Window.
- Then click on 1.
- You can see the excitation between dipole arms.







HFSS-Radiation Boundary

- Now, we will assign a radiation boundary. It is called as Air box.

A radiation boundary is used to simulate an open problem that allows waves to radiate infinitely far into space, such as antenna designs. HFSS absorbs the wave at the radiation boundary.

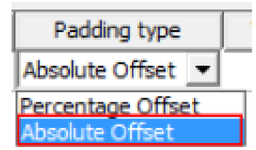
- Note that airbox must be located **at least a quarter wavelength** from the radiating source.

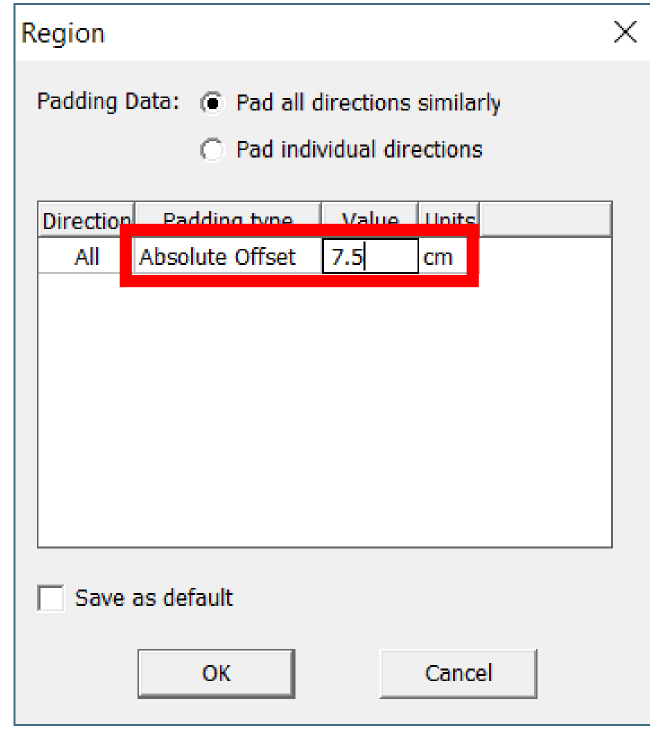
- Lets calculate the quarter wavelength for our operating frequency.

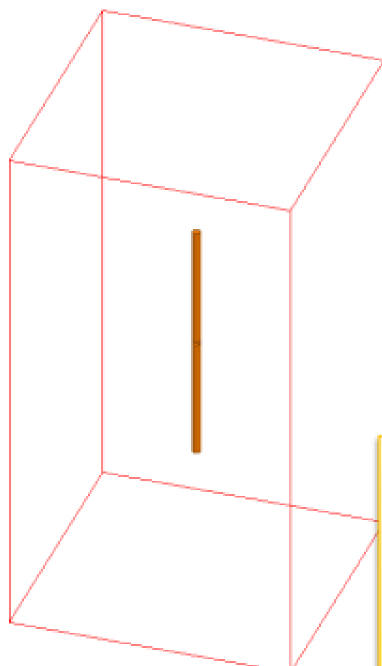
Operating Frequency= 1 GHz, λ= 30 cm, **$\lambda/4$=7.5 cm**

Create Air Box

- **Create Air box**
  - Select the menu item ***Draw > Region***
    - Padding Type: **Absolute Offset**
    - Value: **75 mm**
    - Click the **OK** button
  - Select th**7.5 cm** item ***View > Fit All > Active View***. Or press the **CTRL+D** key



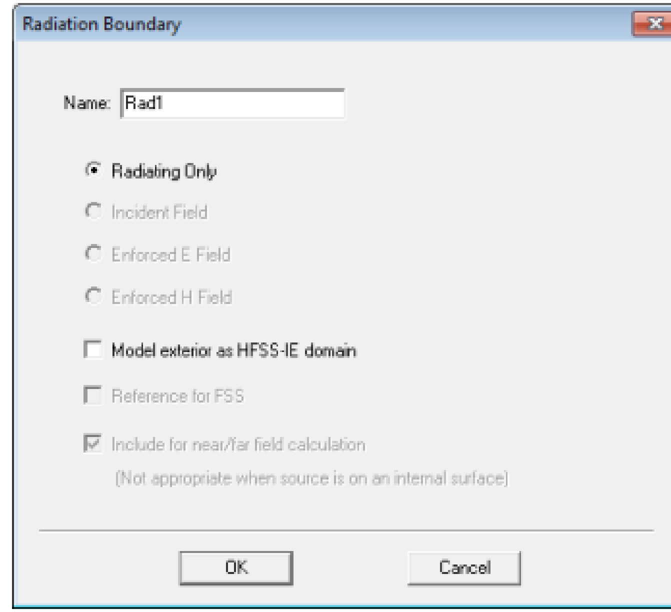




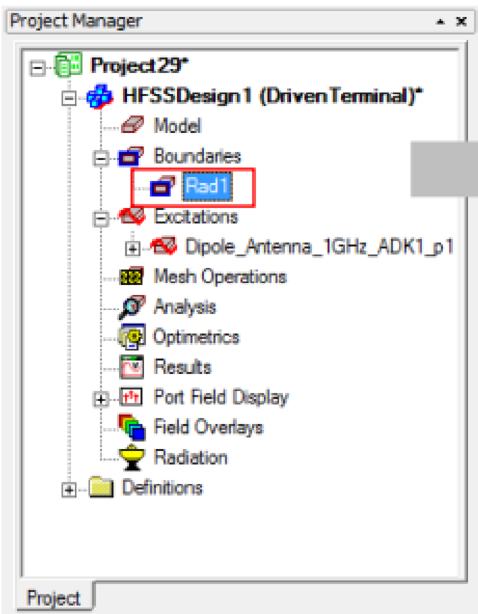
Note: Air box sizing is chosen to approximately λ/4 away from radiating element. This is the suggested distance when using an Absorbing Boundary Condition (ABC).

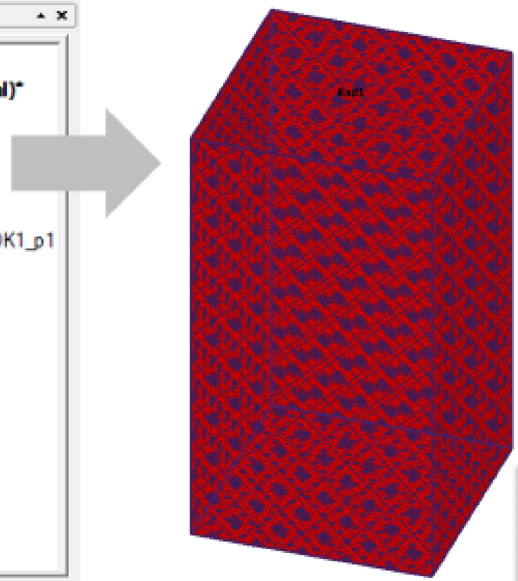
The finite element method only solves what is drawn in the model, if we want an air volume around the antenna element, we need to include this geometry in the simulation.

Add Radiation Boundary



- **Add a Radiation Boundary to Air box**
  - Select the menu item ***Edit > Select > By Name***
    - Select the object named: **Region**
    - Click the **OK** button
  - Select the menu item ***HFSS > Boundaries > Assign > Radiation…***
    - Click the **OK** button

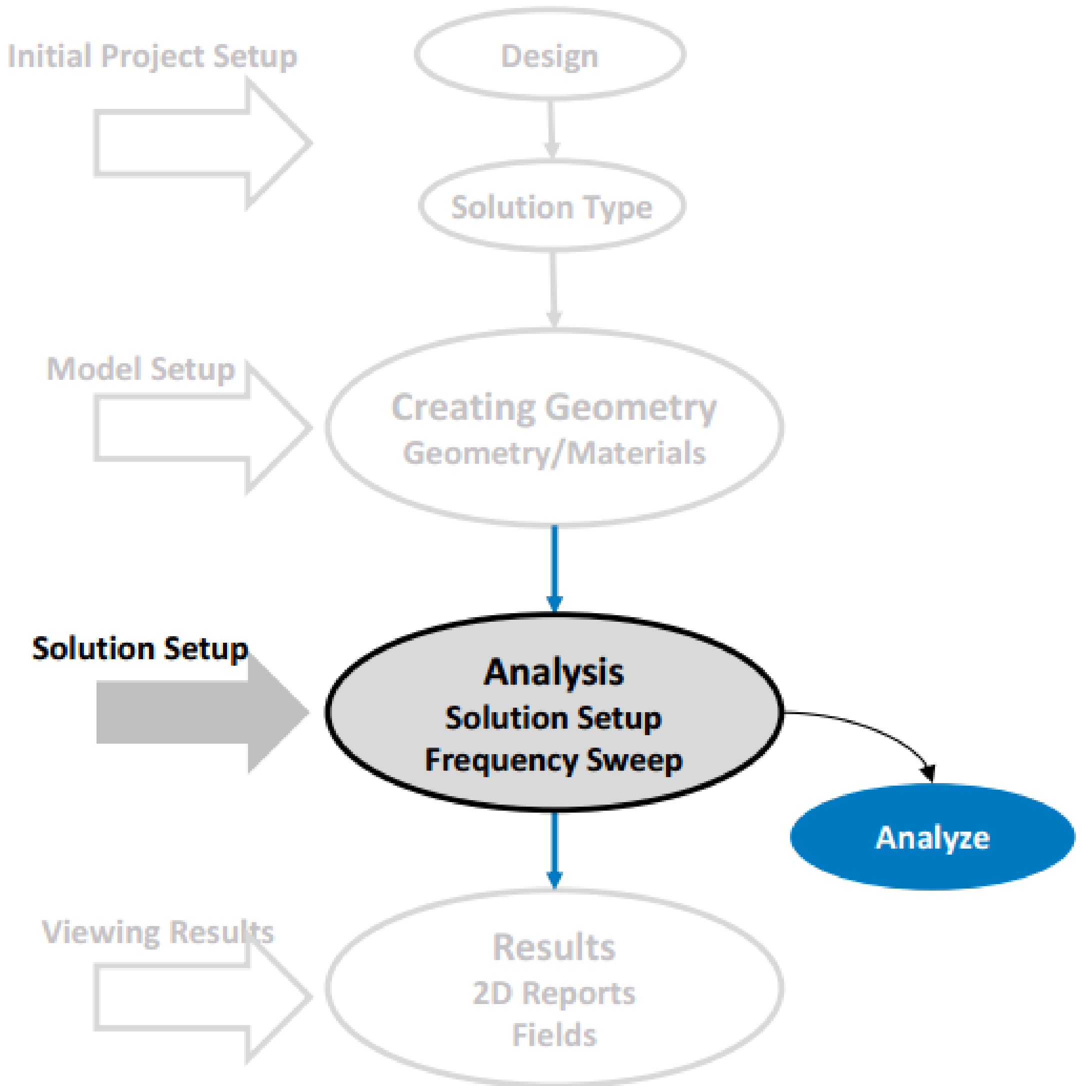




Note: Radiation boundary assignment can be visualized by selecting the boundary condition in the Project Manager window.

The radiation boundary acts as a way to extend and make the model look like it is surrounded by infinite free space.

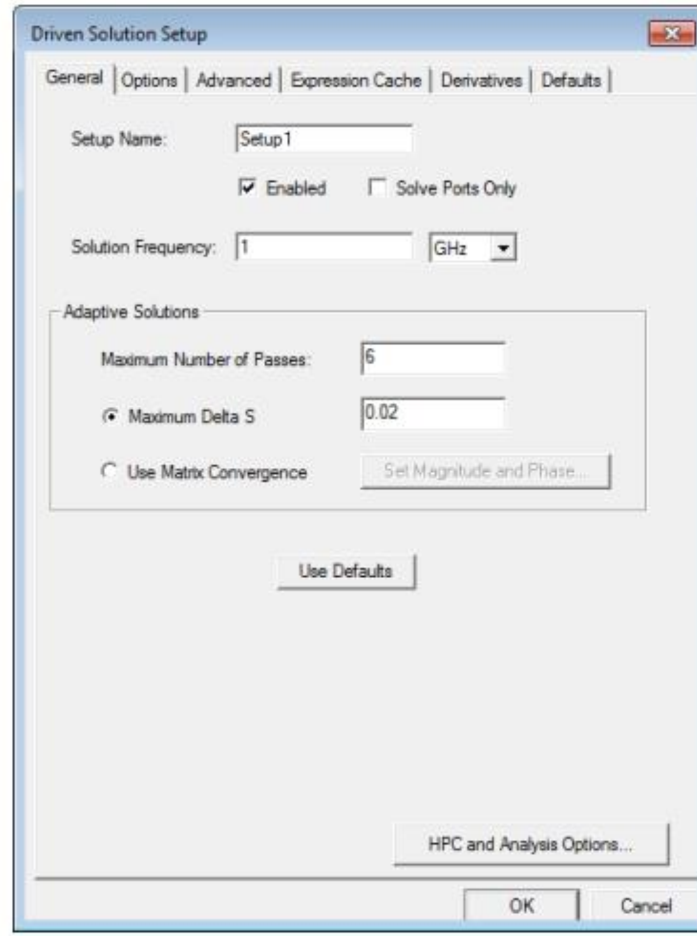
HFSS – Solution Process



Analysis Setup

Add Solution Setup

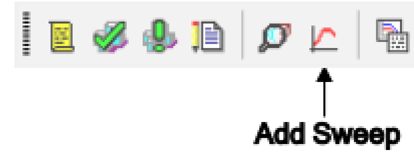
- **Creating an Analysis Setup**
  - Select the menu item ***HFSS > Analysis Setup > Add Solution Setup…***
    - Click the General tab:
      - Solution Frequency: **1 GHz**
      - Maximum Number of Passes: **6**
      - Maximum Delta S: **0.02**
    - Click the Options tab:
      - Select order of basis functions: **First Order**
    - Click the **OK** button



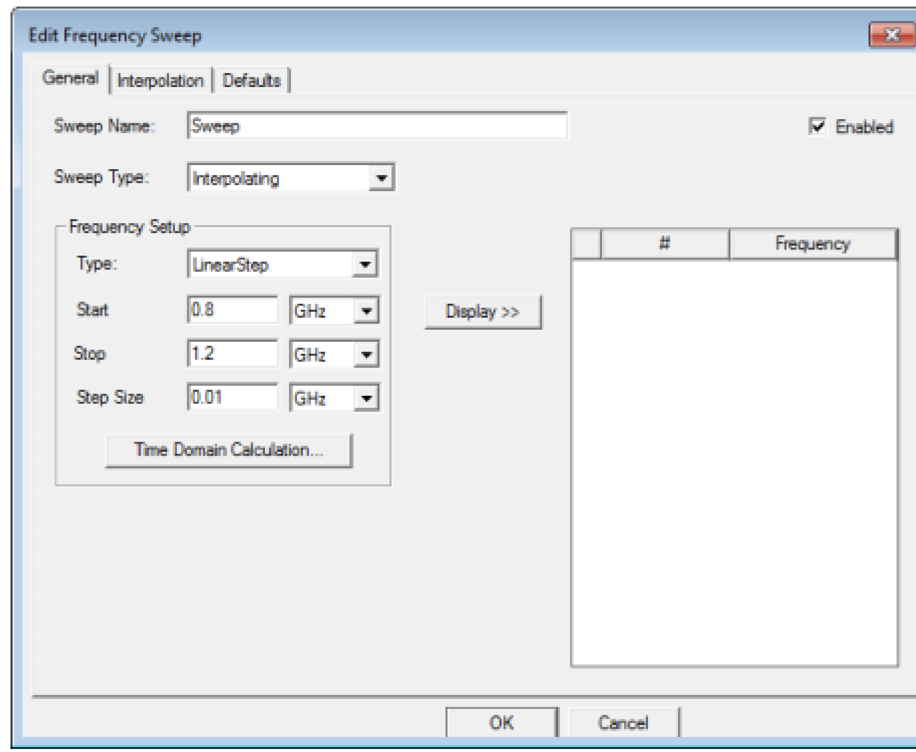
Note: The solution setup controls how the Adaptive Analysis is performed.

- The **Solution Frequency** indicates what frequency the solutions are evaluated and impacts the size of the initial mesh.
- **Maximum Delta S** controls accuracy of the process by indicating the allowable variation between consecutive meshes. It determines when the meshing process stops
- The **Maximum Number of Passes** indicates the maximum times through the adaptive meshing process before proceeding to the frequency sweep analysis. HFSS will proceed to the frequency sweep regardless of it meeting the Delta S convergence criteria.

Analysis Setup

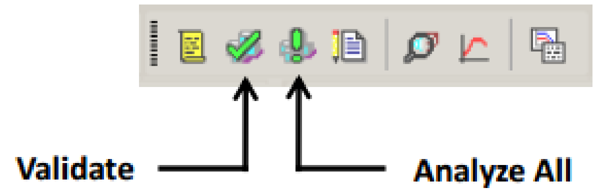


- **Adding a Frequency Sweep**
  - Select the menu item ***HFSS > Analysis Setup > Add Frequency Sweep…***
    - Select Solution Setup: **Setup1**
    - Click the **OK** button
  - Edit Sweep Window:
    - Sweep Type: **Interpolating**
    - Frequency Setup Type: **Linear Step**
      - Start: **0.8 GHz**
      - Stop: **1.2 GHz**
      - Step Size: **0.01 GHz**
    - Click the **OK** button



Analyze

- **Save Project**
  - Select the menu item ***File > Save As***
    - Filename: **dipole.hfss**
    - Click the **Save** button



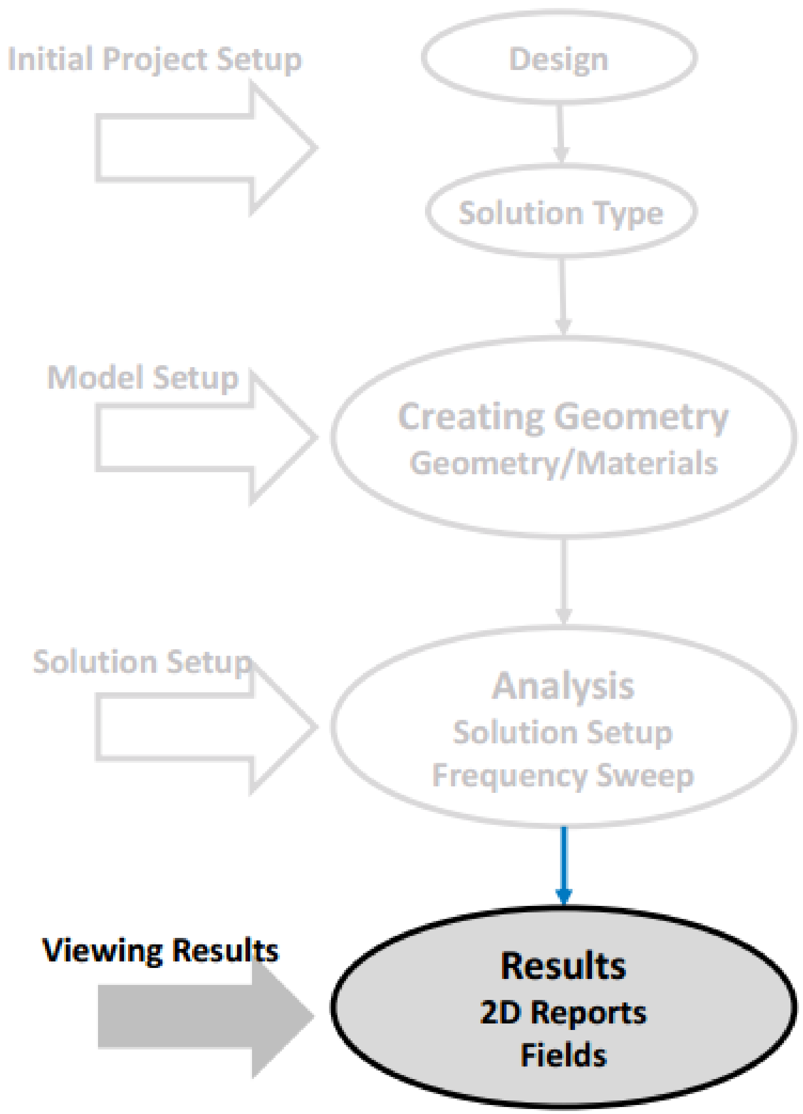
- **Model Validation**
  - Select the menu item ***HFSS > Validation Check***
    - Click the **Close** button

      Note: To view any errors or warning messages, look at the Message Manager window.

- **Analyze**
  - Select the menu item ***HFSS > Analyze All***
  - After analysis is complete save the project
    - Select the menu item ***File > Save***

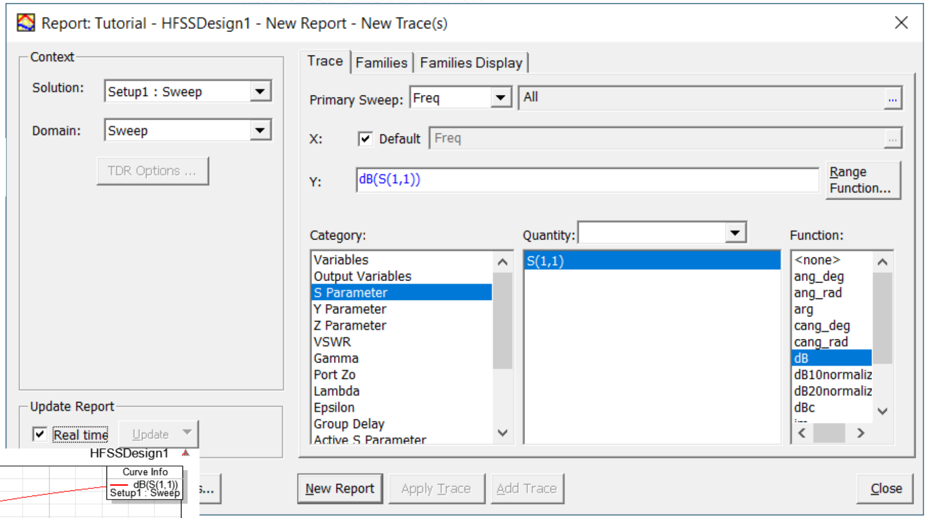
- **Review solution Data**
  - Select the menu item ***HFSS > Results > Solution Data***
    - Select the Profile tab to view solution information
    - Select the Convergence tab to show convergence, solved element count, and maximum Delta S
    - Select Matrix Data tab to view S-parameters and Port impedance
  - Click the **Close** button

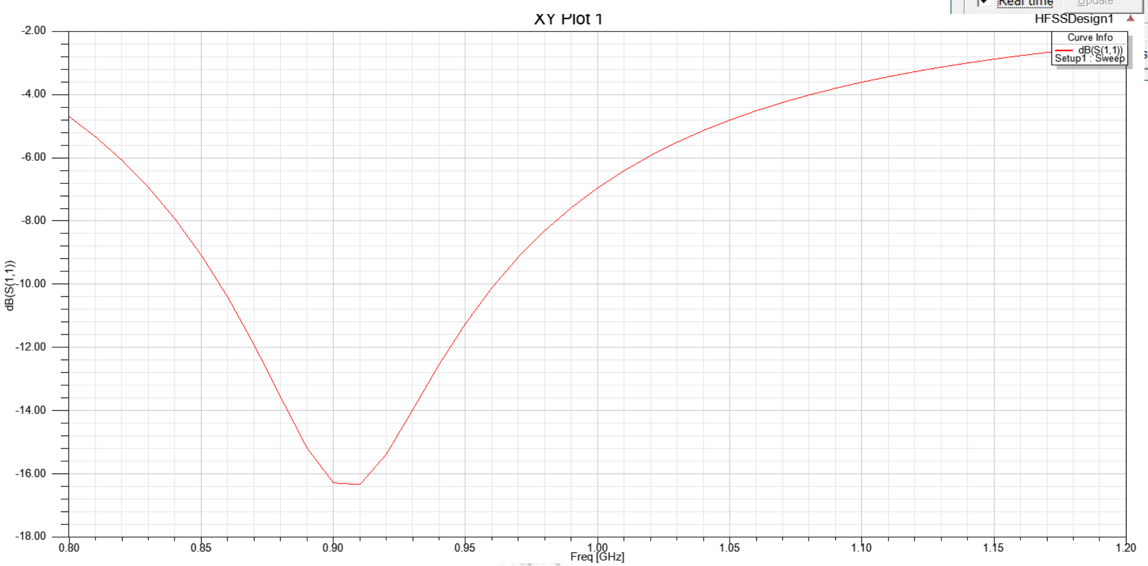
HFSS – Post Processing



Post Processing – Create S-Parameter Report

- **Create Reports**
  - Select the menu item ***HFSS > Results >*** **Create Modal Solution Data Report*****> Rectangular Plot***
    - Solution: **Setup1: Sweep**
    - Domain: **Sweep**
      - Category: **S Parameter**
      - Quantity: **S(1,1)**
      - Function: **dB**
      - Click **New Report** button
    - Click **Close** button

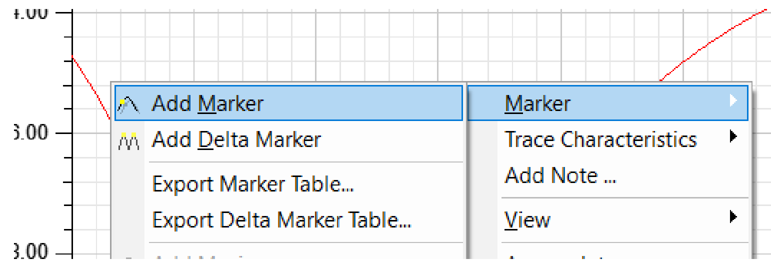


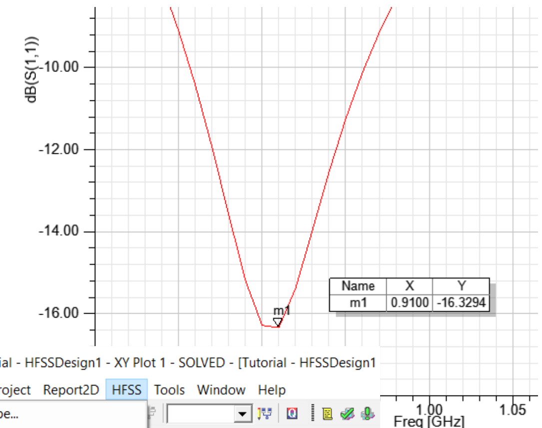


Parametric Simulation

- We can insert a marker to see the resonance frequency.
  - Right Click to the plot > Marker > Add Marker
  - Insert marker to the minimum S11.
- You can see Marker and also the value of the frequency and the S11.

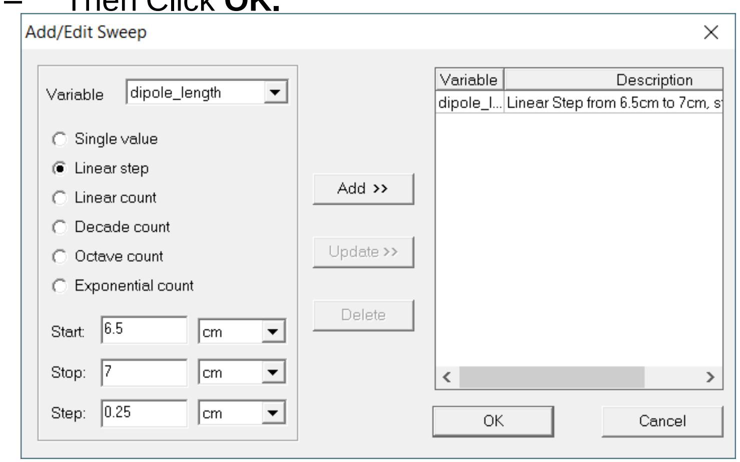
Freq (GHz)	S11 (dB)
0.91	-16.33

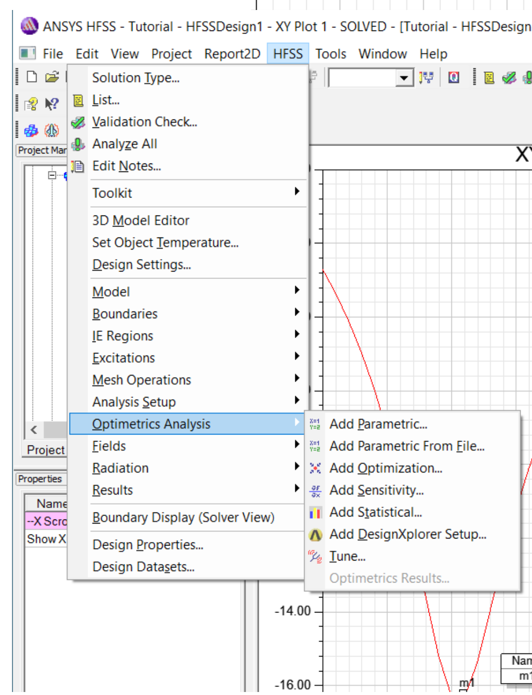




- Our desired operating frequency is 1 GHz. Therefore, we need to change the length of the dipole arms to increase the best matching frequency from 0.91 GHz to 1 GHz.

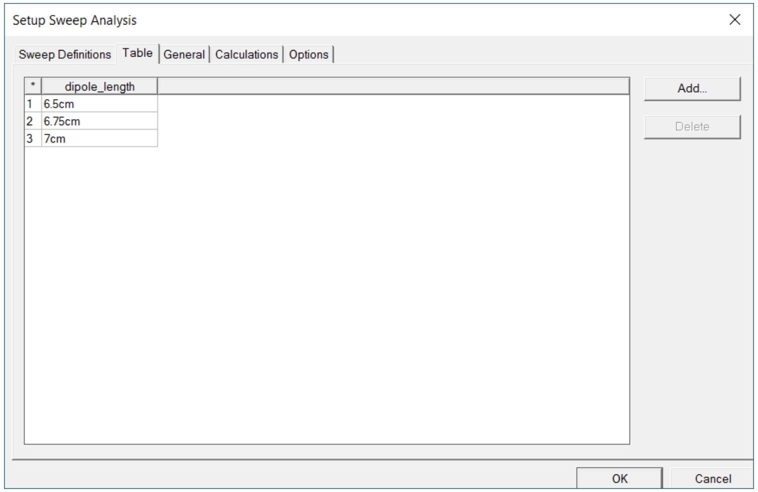
- We will make parametric simulation.
  - Select the menu item **HFSS> Optimetrics Analysis > Add Parametric**
  - Click Add...
  - Add/Edit Sweep window will be opened.
  - Choose **dipole_length** as variable.
  - Mark Linear step.
  - Adjust **Start**, **Stop** and **Step** points as given in the Figure below.
  - Click **Add.**
  - Then Click **OK.**

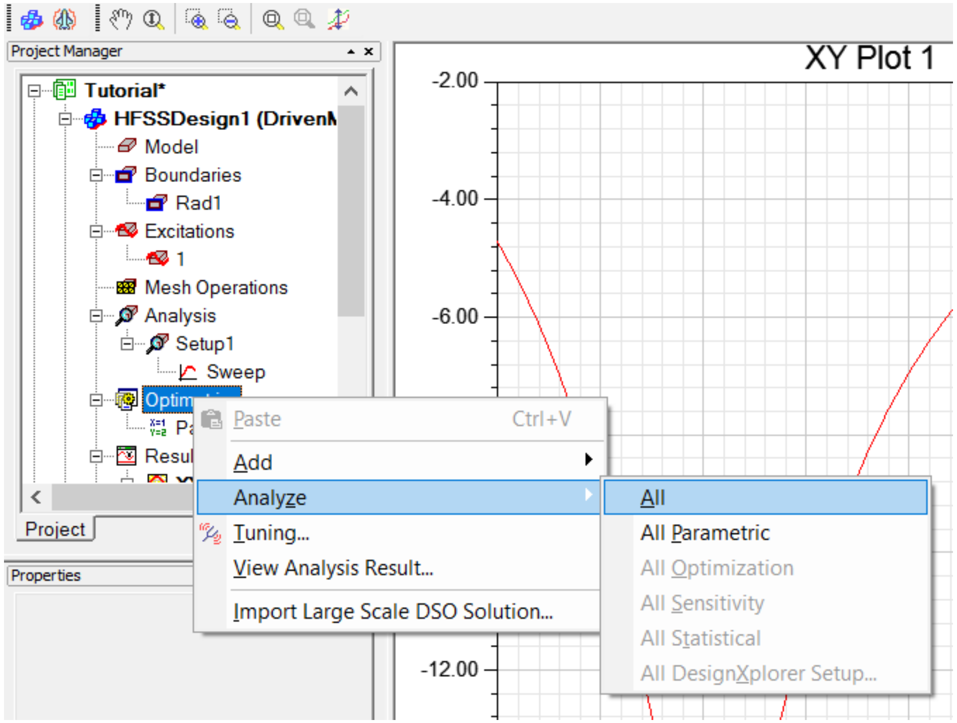


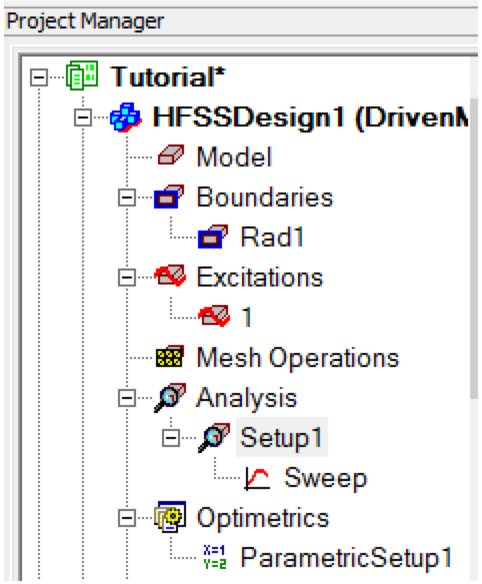


Parametric Simulation

- In the Setup Sweep Analysis window,
  - Select Table tab and observe the selected values.
  - Then Click OK
- To make sure you add an parametric setup, find Optimetrics in 3D Modeler Window. Then Click the + sign and expand it.
- Right click to the Optimetrics.
  - Analyze > All
  - The simulation begins.
- Simulation is conducted for the selected parameters.

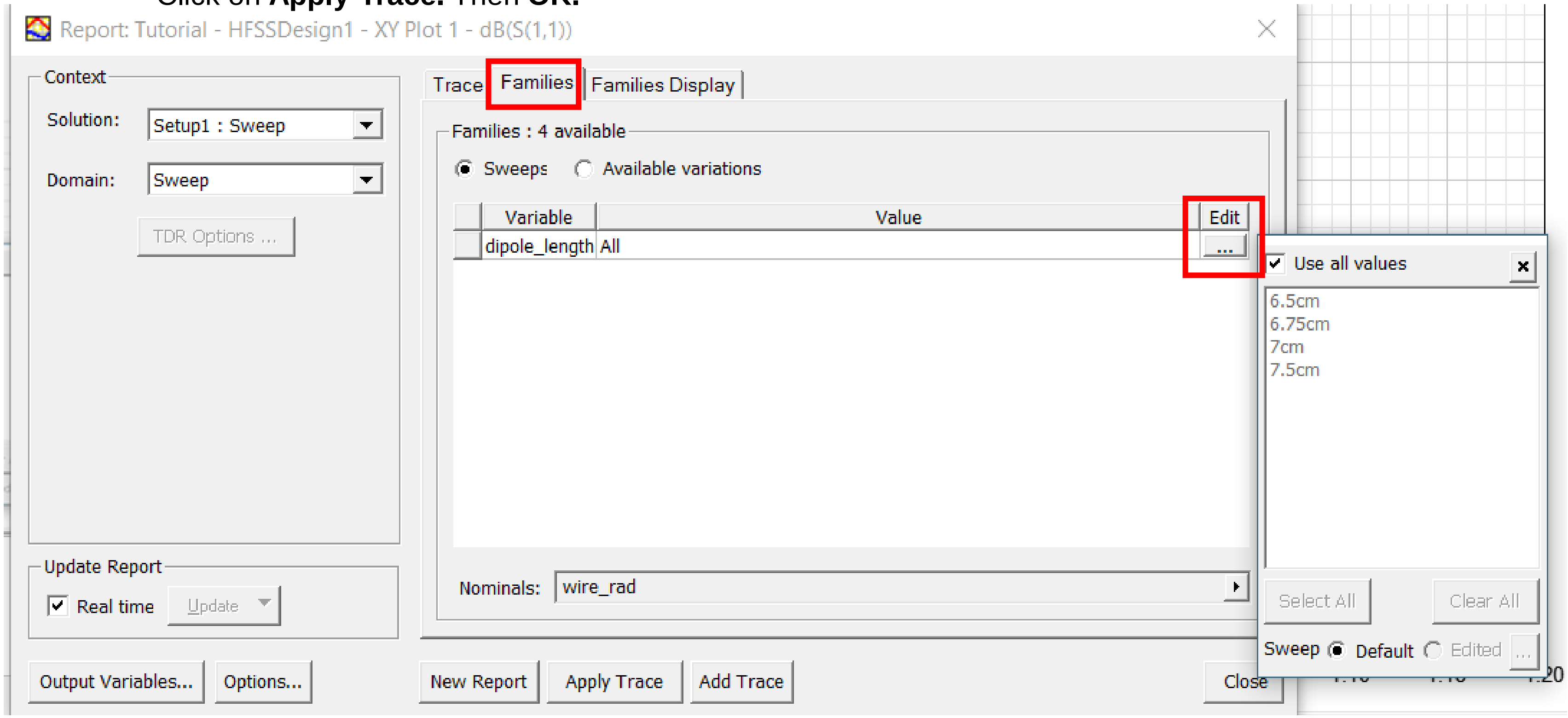






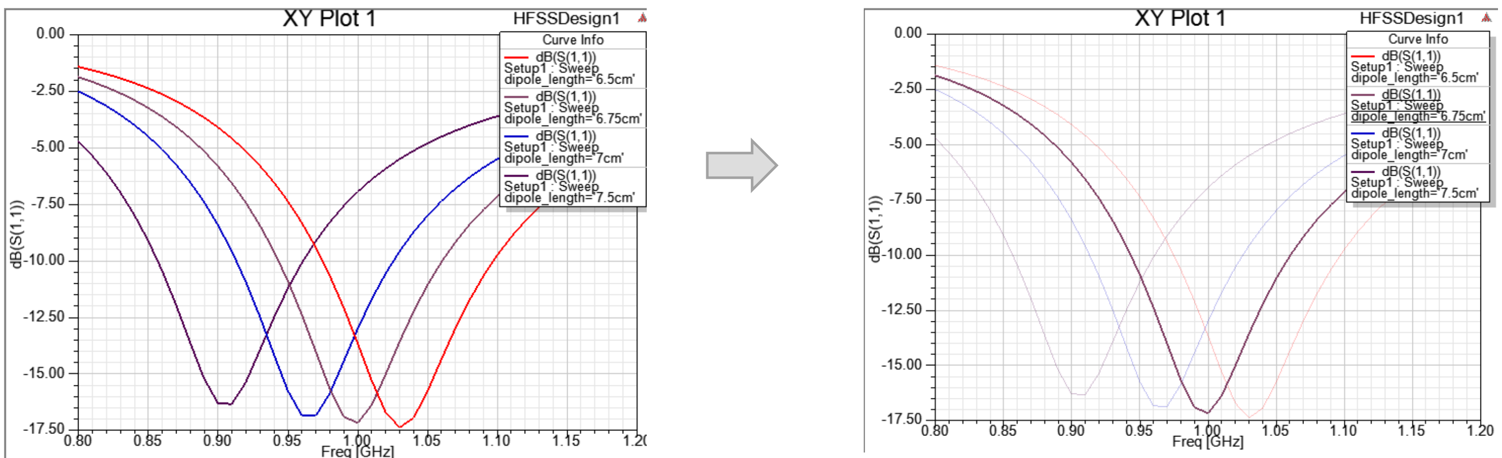
Parametric Simulation-Create S Parameter Plot

- We will create S paramater Plot for the different lengths of the dipole.
  - From 3D Modeler Window find **Results** section.
  - Double Click on **dB (S(1,1))**
  - In the opened menu, select **Families** Tab.
  - Click to the «**...**» under the **Edit**.
  - Then, Check the box **Use all values**
  - Click on **Apply Trace.** Then **OK.**

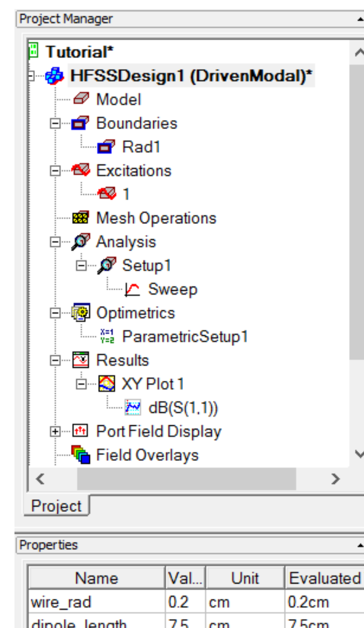


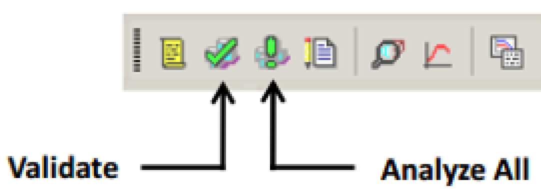
Parametric Simulation-Create S Parameter Plot

- Now, we can see S11 vs Freq Plot for different dipole lengths.
  - Select the length, which gives the closest value to the operating frequency by clicking on it.
  - The slected plot becomes underlined.
- For dipole_length=6.75 cm, the resonance frequency is 1 GHz. Therefore, we can adjust Dipole Length as 6.75 cm

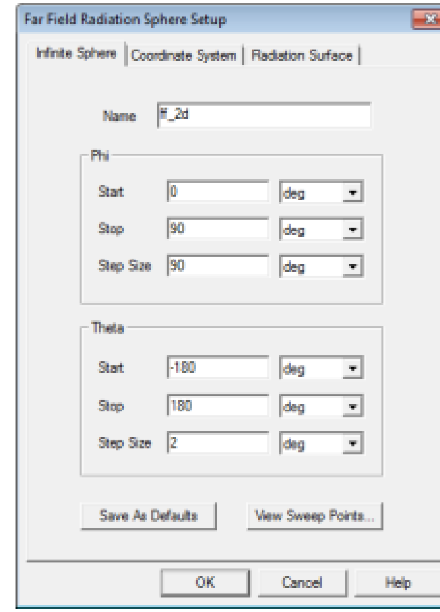


- From 3D Modeler Window, Click to the **HFSSDesign1 (DrivenModal)**
- In the **Properties** menu, you can see our variables, i.e; **wire_rad** and **dipole_length**
- Zoom to the workspace so that you can see that the length of the dipole will change when the value of the dipole_length parameter is changed.
- In the Properties window
  - Change value of the dipole_length from 7.5 cm to 6.75 cm
  - Then Click **Validate** and then **Analyze All**



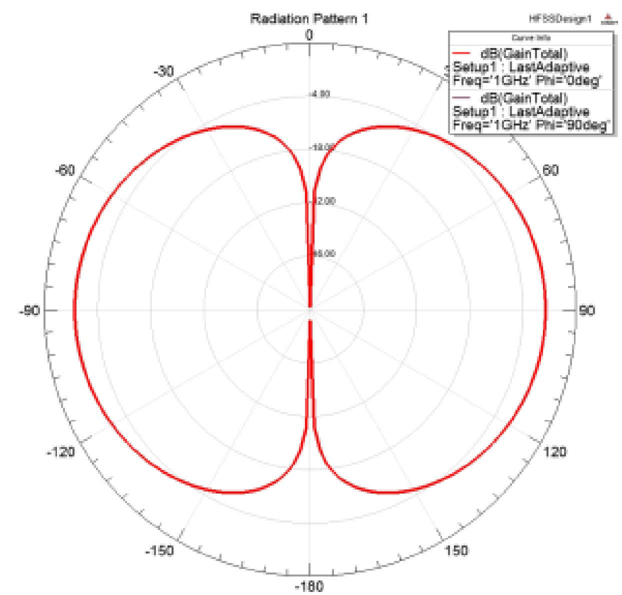


Post Processing – 2D Radiation Plot



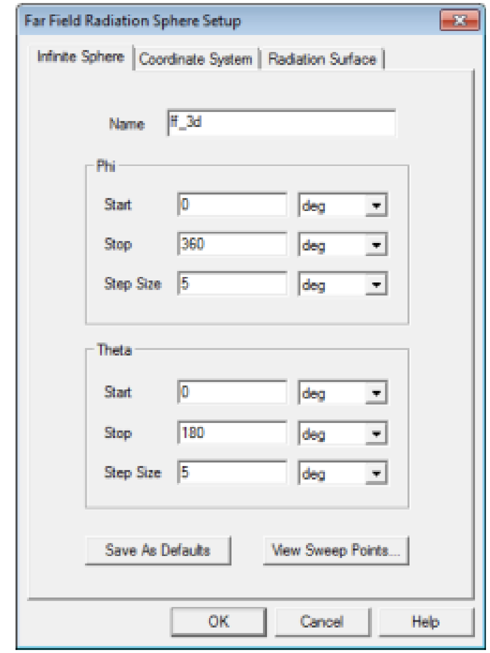
- **Create a Radiation Setup**
  - Select the menu item ***HFSS > Radiation > Insert Far Field Setup > Infinite Sphere***
    - Name: **ff_2d**
    - Phi: Start: **0,** Stop: **90,** Step Size: **90**
    - Theta: Start: **-180,** Stop: **180,** Step Size: **2**
  - Click the **OK** button
  - Note: A radiation setup is required in order to create far-field reports, this can be done before or after the simulation has been run. The choice of Phi and Theta angles here will result in only cuts in the principal planes.

- **Create 2D Radiation Plot**
  - Select the menu item ***HFSS > Results > Create Far Fields Report> Radiation Patter***
  - New Report Window:
    - Solution: **Setup1: Last Adaptive**
    - Geometry: **ff_2d**
      - Category: **Gain**
      - Quantity: **GainTotal**
      - Function: **dB**
      - Click **Families** Tab. For dipole_length, click «**...**» under **Edit** and select 6.75 cm .
      - Click **New Report** button.
      - Click **Close** button

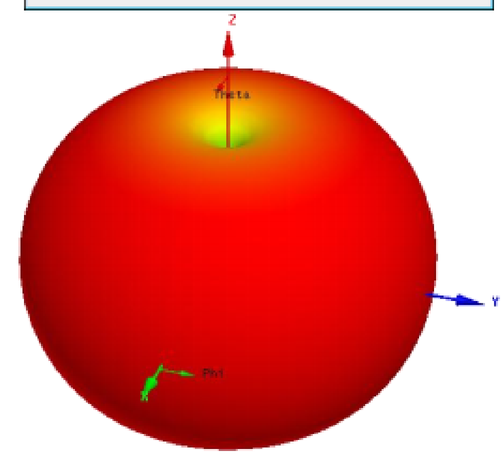


Post Processing – 2D Radiation Plot

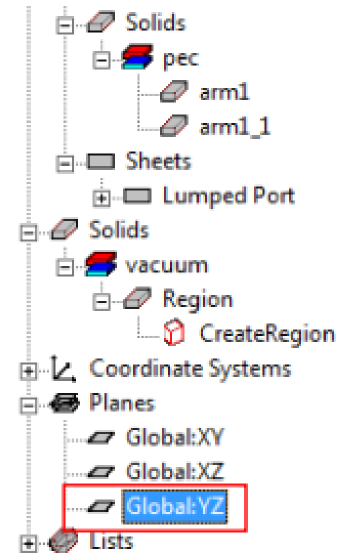
- **Create a Radiation Setup**
  - Select the menu item ***HFSS > Radiation > Insert Far Field Setup > Infinite Sphere***
    - Name: **ff_3d**
    - Phi: (Start: 0, Stop: 360, Step Size: 5)
    - Theta: (Start: 0, Stop: 180, Step Size: 5)
  - – Click the **OK** button
  - Note: We didn't need to create 2 separate radiation setups, instead we could have used a single 3D pattern setup and create 2D and 3D plots from the same setup by selecting the correct phi and theta angles to be swept in the report creation window.



- **Create 3D Polar Plot**
  - Select the menu item ***HFSS > Results > Create Far Fields Report> 3D Polar Plot***
  - New Report Window:
    - – Solution: **Setup1: Last Adaptive**
    - – Geometry: **ff_3d** ← **Note:** <u>Make sure to select the correct radiation setup</u>
      - Category: **Gain**
      - Quantity: **GainTotal**
      - Function: **dB**
      - Click **Families** Tab. For dipole_length, click «**...**»
    - – under **Edit** and select 6.75 cm .
      - Click **New Report** button.
      - Click **Close** button

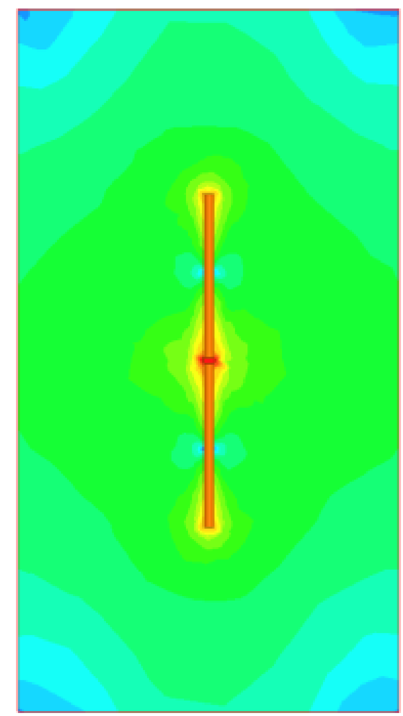


Post Processing – Field Overlay



- **Return to 3D modeler**
  - To return to the 3D modeler window, go to the menu **HFSS > 3D Model Editor** or double click on the design name

- **Create Field Overlay**
  - From the 3D Model tree, expand the Planes
  - From the tree, select the **Global YZ**
  - Select the menu item ***HFSS > Fields > Plot Fields > E > Mag_E***
    - Solution: **Setup1 : LastAdaptive**
    - Quantity: **Mag_E**
    - Click the **Done** button
  - Select the menu item ***HFSS > Fields > Modify Plot Attributes***
    - Select E Field in Plot Folder Window, Click the **OK** button
    - E-Field Window:
      - Click the Scale tab
        - Scale: **Log**
      - If real time mode is not checked, click the **Apply** button.
    - Click the **Close** button
  - To Animate the field plot:
    - Select the menu item ***HFSS > Fields> Animate***
      - Click the **OK** button



Post Processing – Radiation Pattern Overlay

- **Turn off previous field overlay**
  - Select the menu item: **View > Visibility > Active View Visibility**
  - Select tab: **FieldsReporter** uncheck visibility of all plots

- **Create Radiation Pattern Overlay**
  - Right click on the 3D modeler window to display context menu
  - From the context menu select: **Plot Fields >*Radiation Field…***
    - Select Visible for the 3D Polar Plot that was created in a previous slide
    - Set the **Scale: 0.2** and select **Apply**
    - Select: **Close**