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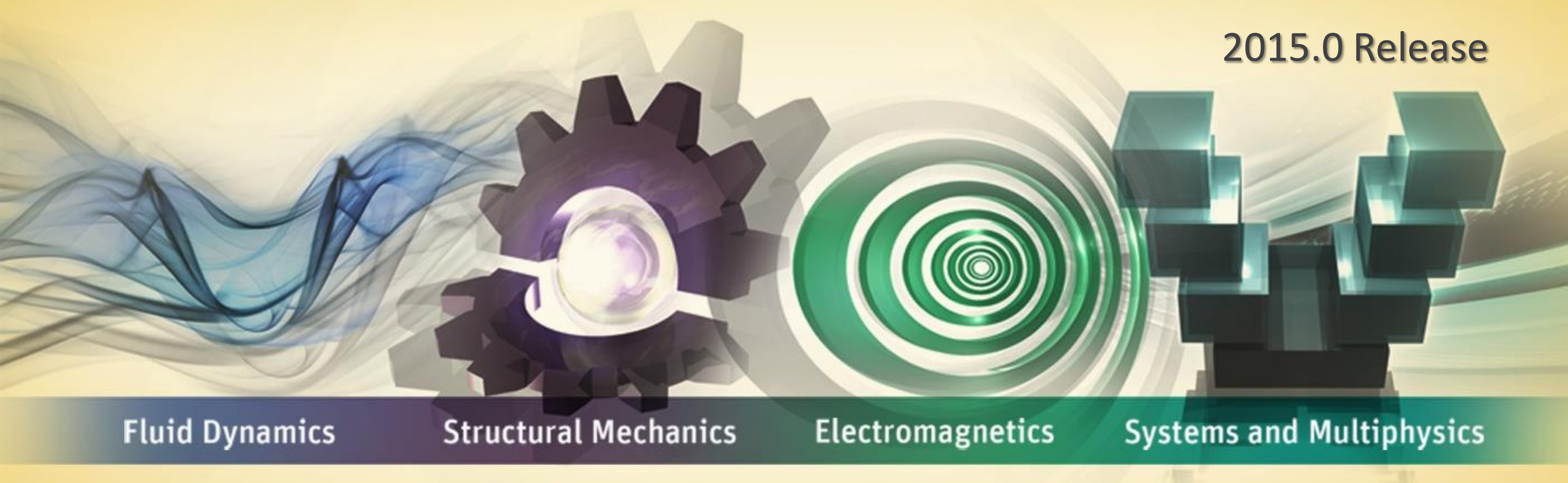
# Workshop 3-1: Antenna Post-Processing

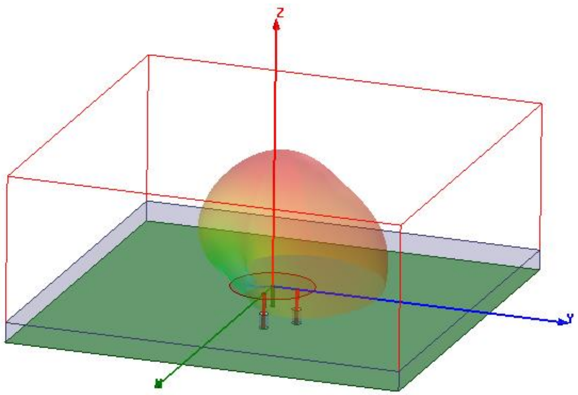
2015.0 Release

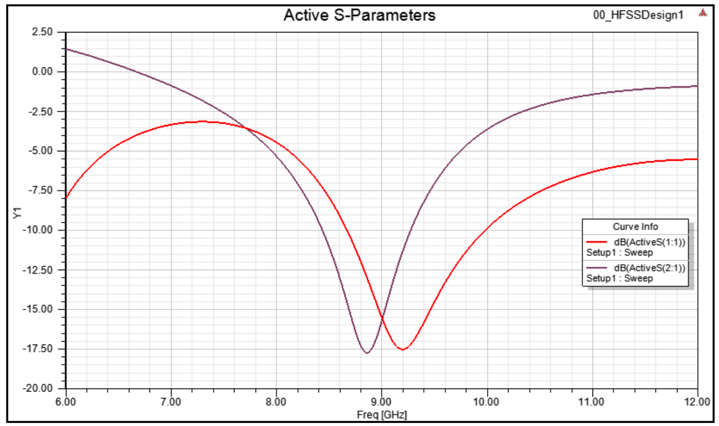


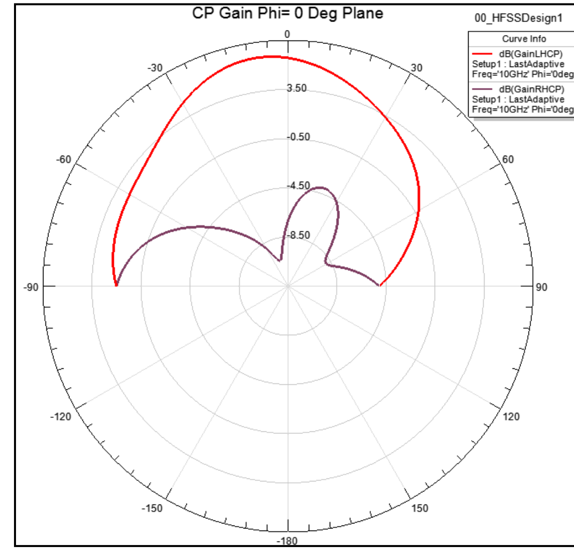

## ANSYS HFSS for Antenna Design

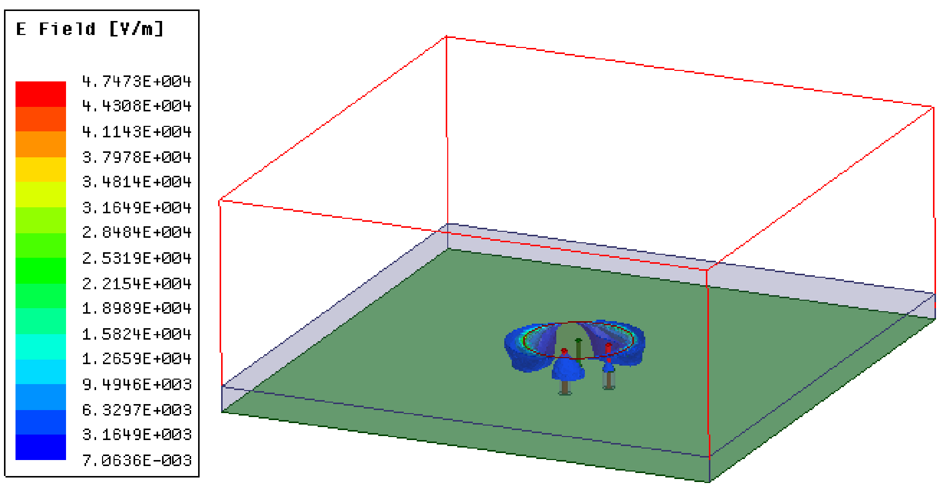
# Example – Antenna Post-Processing

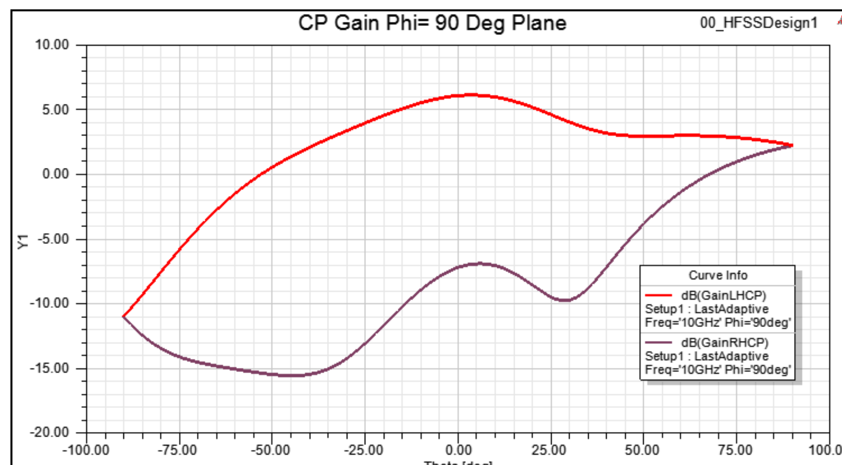
- **Analysis of a Dual Polarized Probe Fed Patch Antenna**
  - This example is intended to show you how antenna post-processing works in HFSS.
  - This workshop includes an optional section, Understanding Far Field Quantities.



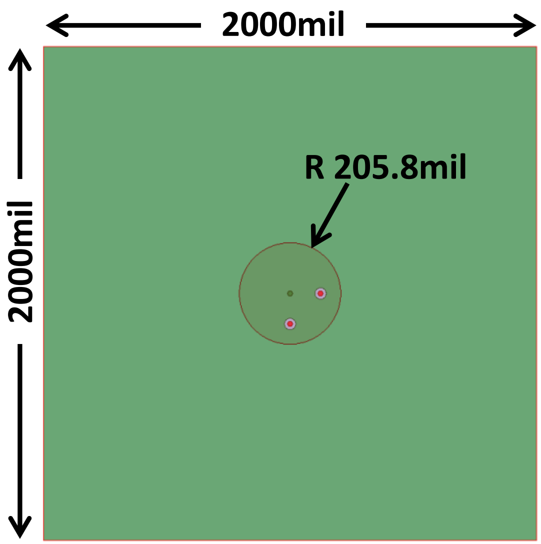



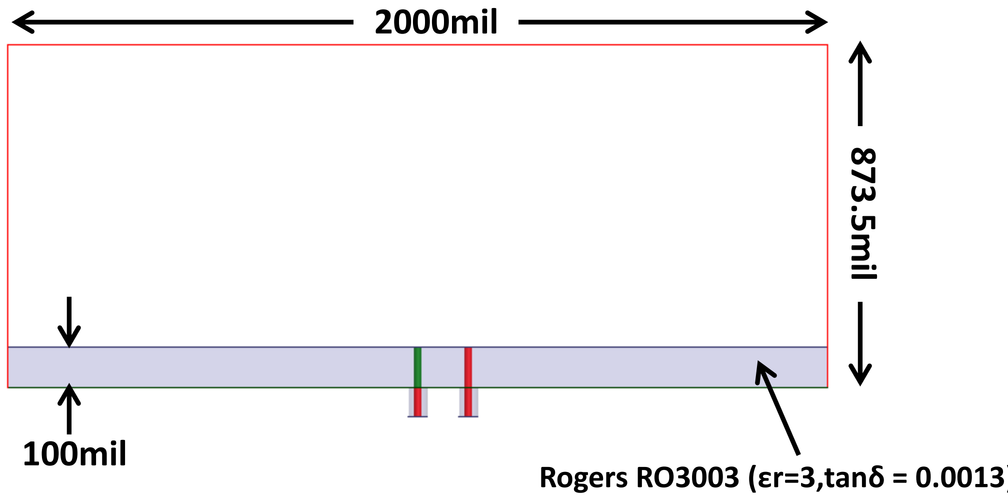
# HFSS: Getting Started

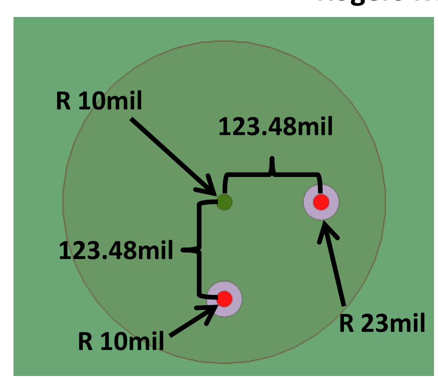
- **Launching ANSYS Electronics Desktop 2015**
  - To access ANSYS Electronics Desktop, click the Microsoft Start button,
    - Select ***Programs > ANSYS Electromagnetics > ANSYS Electromagnetics Suite 16.0***. Select ***ANSYS Electronics Desktop 2015***
- **Setting Tool Options**
  - **Note:** In order 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 > 3D Modeler Options…***.
    - Click the **Operation** tab
      - Select last command on object/submodel select: ☑ **Checked**
    - Click the **Display** tab
      - set default transparency to **0.7**
    - Click the **Drawing** tab
      - Edit properties of new primitives**:** ☑ **Checked**
    - Click the **OK** button

# Open Project

- **Opening the Project**
  - In ANSYS Electronics Desktop, select the menu item ***File > Open***.
  - Browse to the folder containing the file **Post_Proc_WS.aedt** and select **Open**
  - Get familiar with the model. Look over the geometric details, boundary conditions and excitations.
- **If you don't have the project create the patch using the following dimensions and materials**

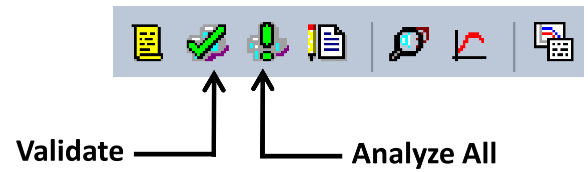


# Analyze

- **Save Project**
  - Select the menu item ***File > Save As***
    - Filename: **CircPatch_Dual_Pol.aedt**
    - 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***

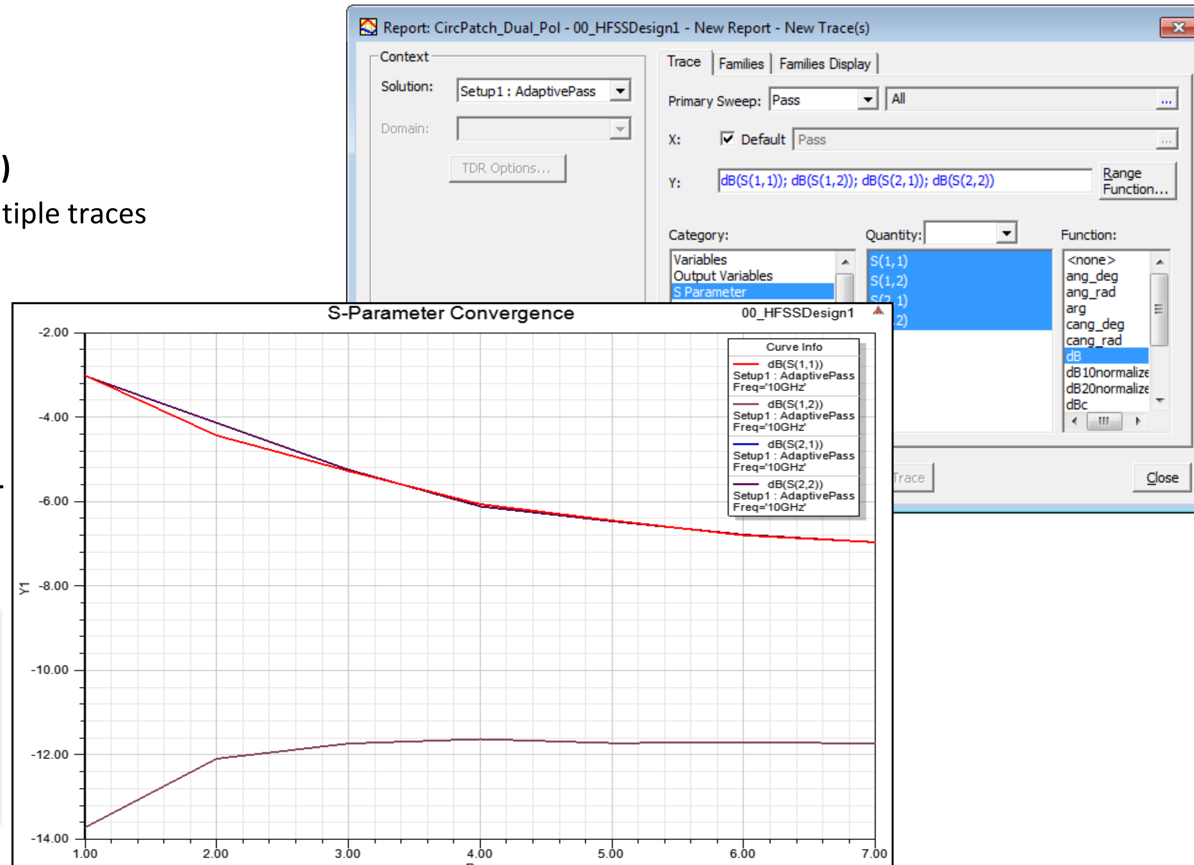
- **Review solution Data**
  - Select the menu item ***HFSS > Results > Solution Data...***
    - Select the **Profile** tab to view solution information
    - Select the **Convergence** tab to show convergence, solved element count, and maximum Delta S
    - Select **Matrix** Data tab to view S-parameters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

# Checking Convergence

- **Is My Project Converged?**
  - We check convergence by plotting the desired S-Parameter vs Adaptive Pass. The plot should show that the S-Parameter flattens out and does not change very much as a function of Adaptive Pass.

- **Create Report : S11 vs Adaptive Pass**
  - Select the menu item ***HFSS > Results > Create Modal Solution Data Report> Rectangular Plot***
    - Solution: **Setup1: AdaptivePass**
    - In the **Trace** Tab
      - Category: **S Parameter**
      - Quantity: **S(1,1), S(1,2), S(2,1), S(2,2)**
        - **Note**: Hold Ctrl key to select multiple traces
      - Function: **dB**
      - Click **New Report** button
    - Click **Close** button

- **Change Report Name**
  - In Project Manager window,select **XY Plot 1**
  - In Properties window:
    - Name: **S-Parameter Convergence**




**Note:** This plot indicates how sensitive the S-parameters are to changes in the mesh. Since the S-parameters stop changing it is safe to say the Adaptive Meshing Process has converged.

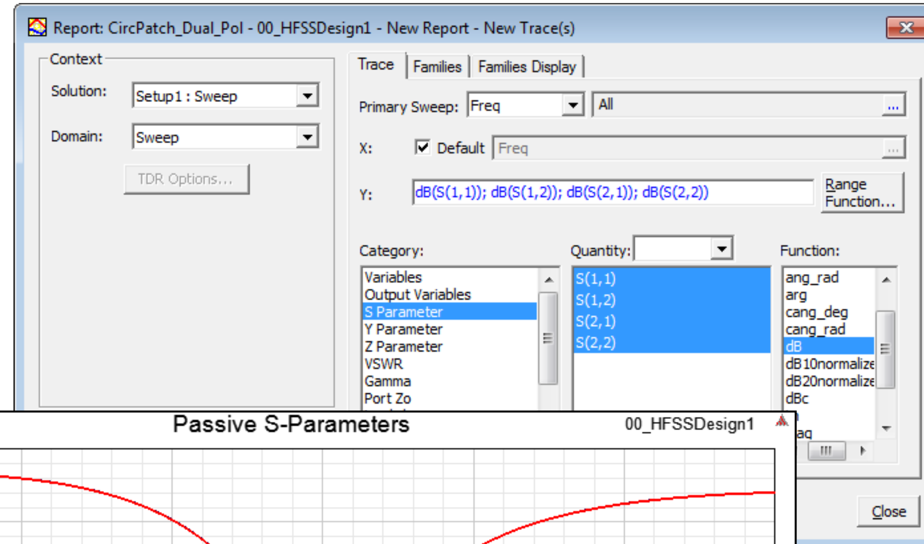
  

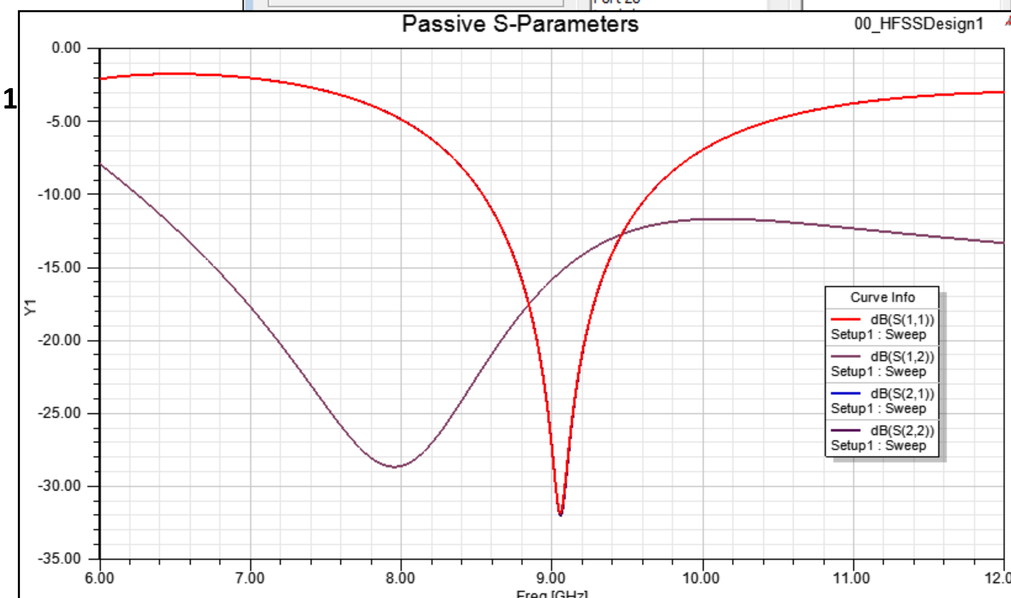
# Evaluating S-Parameter Data

# Create S-Parameter vs Frequency Plot

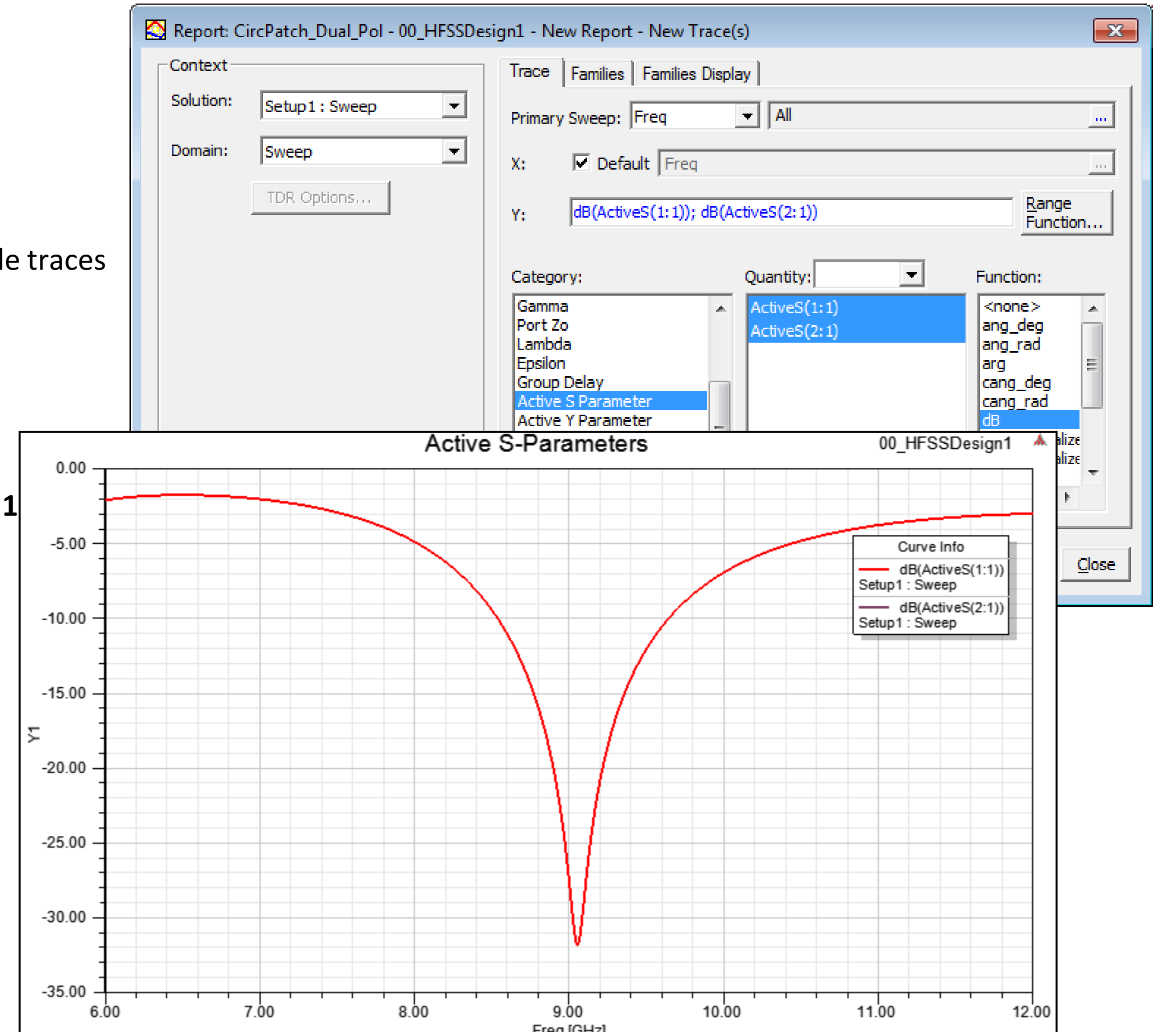
- **Create Reports**
  - Select the menu item ***HFSS > Results > Create Modal Solution Data Report> Rectangular Plot***
    - Solution: **Setup1: Sweep**
    - Domain: **Sweep**
    - In the **Trace** Tab
      - Category: **S Parameter**
      - Quantity: **S(1,1), S(2,1), S(1,2), S(2,2)**
        - **Note**: Hold Ctrl key to select multiple traces
      - Function: **dB**
      - Click **New Report** button
    - Click **Close** button
  - **Change Report Name**
    - In Project Manager window select **XY Plot 1**
    - In Properties window:
      - Name: **Passive S-Parameters**



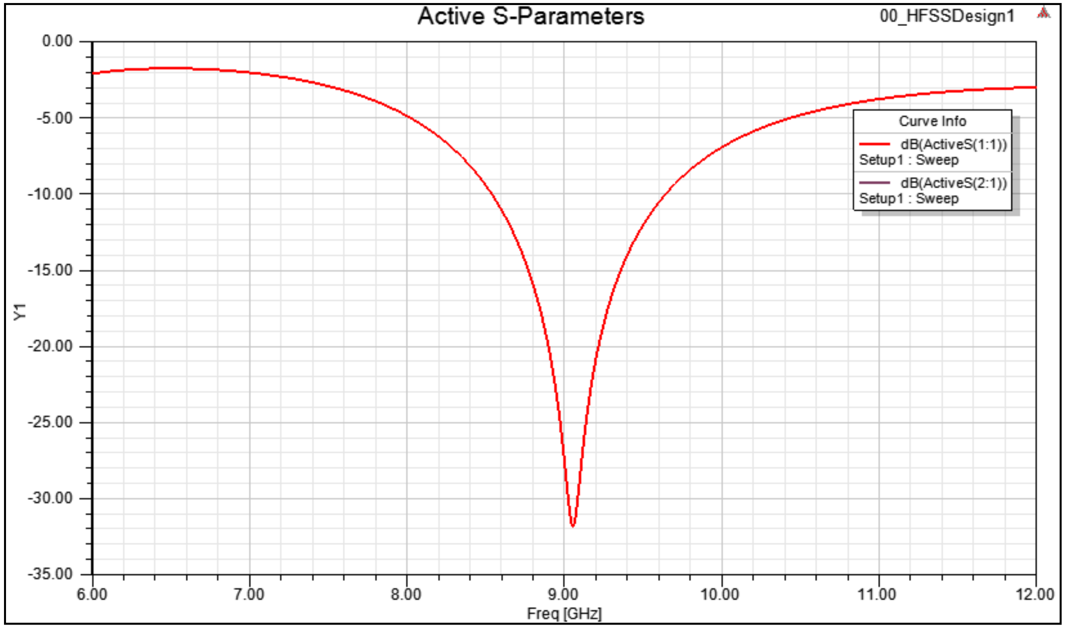
# Create Active S-Parameter vs Frequency Plot

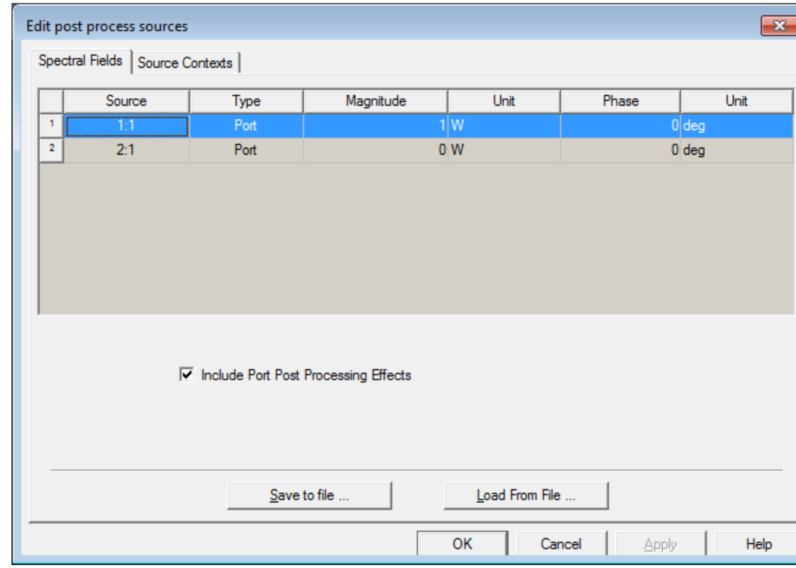
- **Create Reports**
  - Select the menu item ***HFSS > Results > Create Modal Solution Data Report> Rectangular Plot***
    - Solution: **Setup1: Sweep**
    - Domain: **Sweep**
    - In the **Trace** Tab
      - Category: **Active S Parameter**
      - Quantity: **ActiveS(1:1), ActiveS(2:1)**
        - **Note**: Hold Ctrl key to select multiple traces
      - Function: **dB**
      - Click **New Report** button
    - Click **Close** button
- **Change Report Name**
  - In Project Manager window select **XY Plot 1**
  - In Properties window:
    - Name: **Active S-Parameters**



# Active S-Parameters Discussion




**Note:** Active S-Parameters characterize the return loss seen at each port given the device's active excitation. When more than one port is simultaneously excited the signal propagating out of any port consists of the superposition of its own passive self reflection [S(1,1)] and the coupled signals from the other ports.

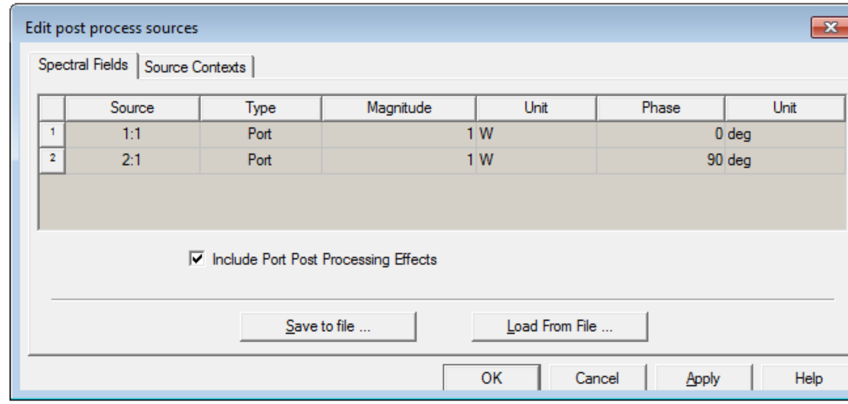
The excitation applied to every port is controlled through the **HFSS > Fields > Edit Sources** dialog window. In this case source 1:1 [Port1 : Mode1] is excited with 1 Watt of power. Source 2:1 [Port2 : Mode1] is effectively turned off because it is excited with 0 Watts of power.

**Note:** Only ActiveS(1:1) is displayed and it looks identical to the passive return loss [S(1,1)] from the Passive S-Parameter plot. Since Port 2 is not excited, it couples no energy to Port 1 which leaves Port 1's self reflection as the only contribution to its Active S-Parameter. ActiveS(2:1) is not plotted because the signal flowing out of it is normalized to it excitation which is 0 watts. This produces a value of infinity.

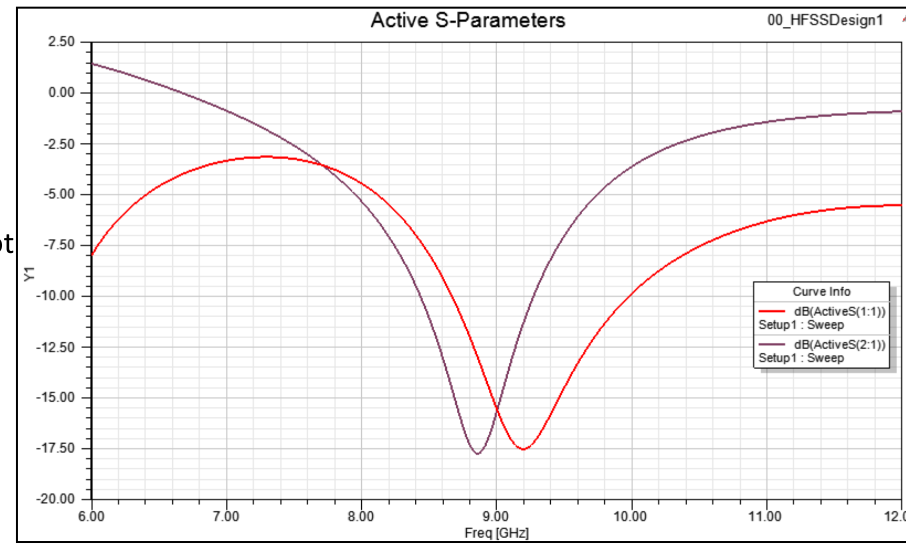
  

# Set the Edit Sources for Circular Polarization

- **Set the Edit Sources Dialog**
  - Select the menu item ***HFSS > Fields > Edit Sources***
  - Change the excitation for  Source 2:1 (Port2 : Mode1):
    - Set **Magnitude** of Source 2:1 to 1 W
    - Set **Phase** of Source 2:1 to 90 deg
    - Click **OK** to apply the change and close the **Edit Sources** Window




- **Observe Impact on Active S-Parameters**
  - In the **Project Manager** window, double-click on **Results > Active S-Parameters** to view the updated plot
  - See how different excitations affect the Active S-Parameters
    - Select the menu item ***HFSS > Fields > Edit Sources***
    - Drag it to the side so you can see the Active S-Parameters Plot
    - Change the values in the Magnitude and Phase fields
    - Click **Apply** to see the updated results in the Active S-Parameters Plot.

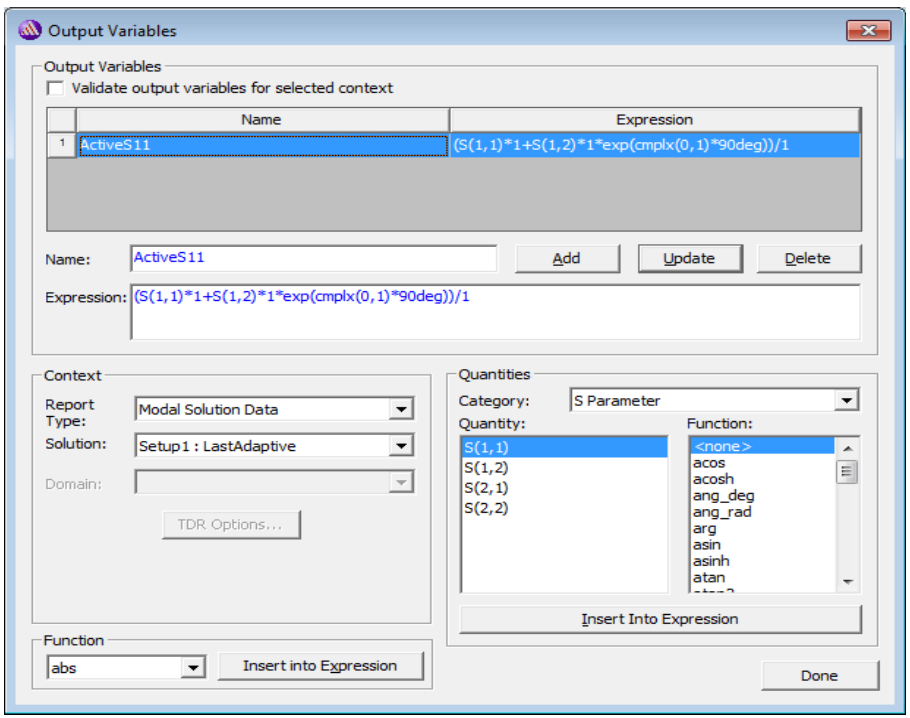



- **Reset the Edit Sources for Circular Polarization**
  - Select the menu item ***HFSS > Fields > Edit Sources***
  - Excite Source 2:1 (Port2 : Mode1) with 1 Watt of Power offset 90deg in phase from port 1's excitation
    - Set **Magnitude** of Source 2:1 to 1 W
    - Set **Phase** of Source 2:1 to 90 deg
    - Click **OK** to apply the change and close the **Edit Sources** Window

**Note:** As long as both Ports 1 and 2 are excited both traces will be visible in the plot. They can also look different from each other depending on weather the superposition is constructive or destructive in nature at the port.

# Deriving Active S-Parameter Solutions

- **Create an Output Variable to Calculate the Active S-Parameters**
  - Select the menu item ***HFSS > Results > Output Variables…***
  - Name: **ActiveS11**
  - Expression: **(S(1,1)*1+S(1,2)*1*exp(cmplx(0,1)*90deg))/1**
  - Context:
    - Report Type: **Modal Solution Data**
    - Solution : **Setup1 : LastAdaptive**
  - Click **Add** to create the Output Variable **ActiveS11**
  - Click **Done** to close the Output Variables dialog.

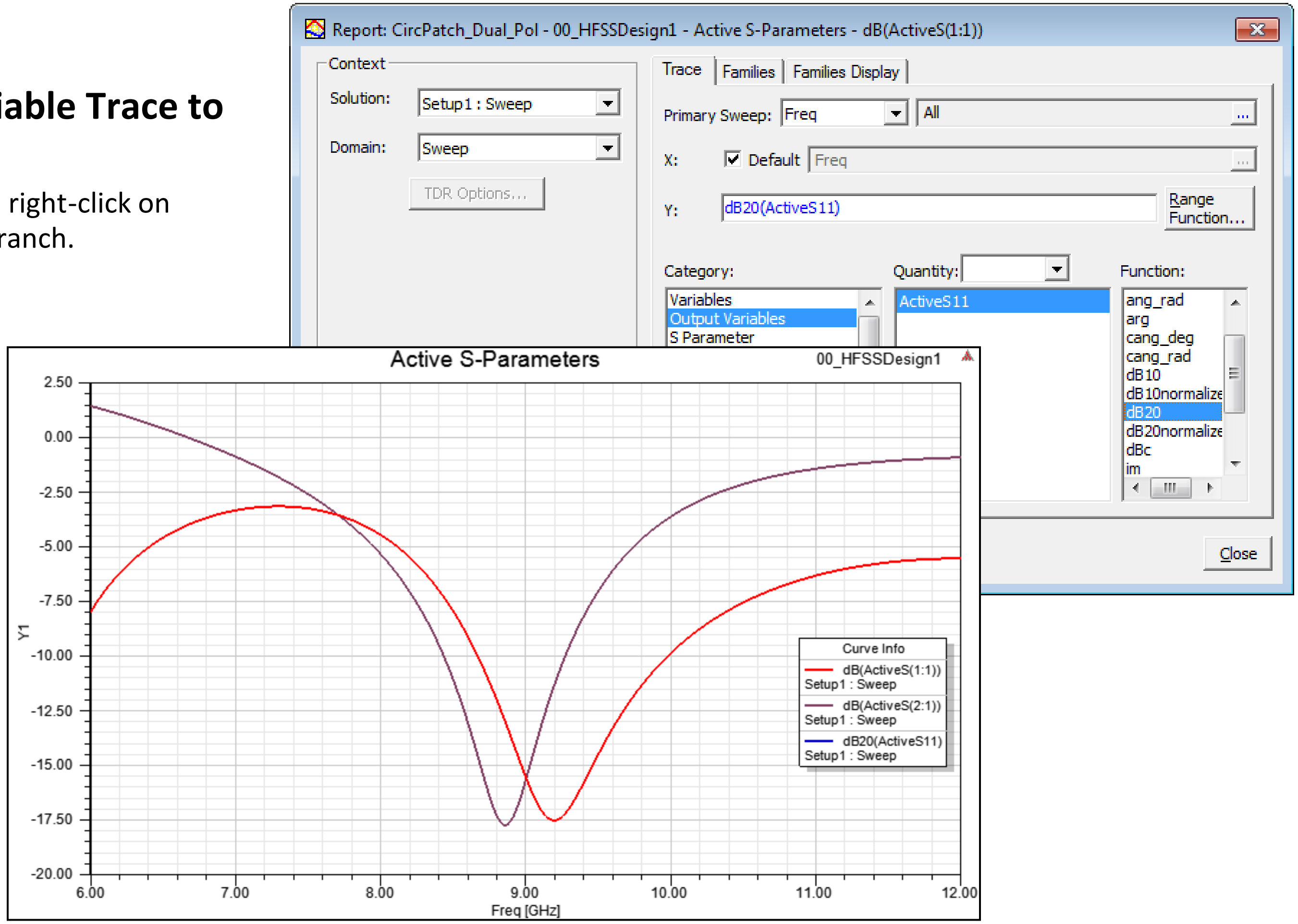



**Note:** The expression used to calculate the Active S-Parameters is (S11*a1 + S12*a2)/a1 where a1 is the complex excitation in volts incident on Port 1 and a2 is the complex excitation in volts incident on Port 2. The 90deg phase offset applied to Port 2 is incorporated through the exponential term $e^{j\phi}$ where $\phi$ is the phase offset. j is expressed as cmplx(0,1).

**Note:** The expression can be typed in manually or the user can use the Category / Quantity selection in conjunction with the Insert Into Expression button to add quantities into the expression. Like wise the exp and cmplx functions can be applied by using the Function selection in conjunction with the Insert into Expression button. If the expression contains an error it will show up in red. Correct expressions show up in blue.

# Deriving Active S-Parameter Solutions

- **Add ActiveS11 Output Variable Trace to Active S-Parameter Plot**
  - In the Project Manager Window, right-click on **Results > Active S-Parameters** branch.
  - Select **Modify Report …**
  - Solution: **Setup1: Sweep**
  - Domain: **Sweep**
  - In the **Trace** Tab
    - Category: **Output Variables**
    - Quantity: **ActiveS11**
    - Function: **dB20**
    - Click **Add Trace** button
  - Click **Close** button




**Note:** dB20 plots 20*log$_{10}$ (ActiveS11). HFSS does not know if the Output Variable is a field quantity or a power quantity so the user needs to specify how the dB should be calculated

**Note:** The ActiveS11 Output Variable overlays perfectly with HFSS built in ActiveS(1:1) solution.

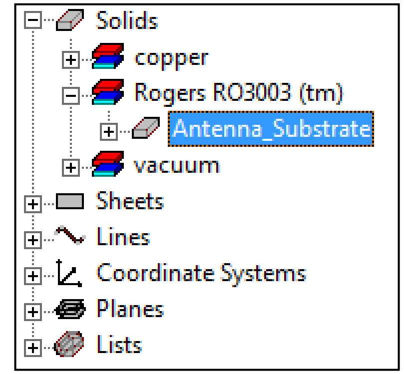
**Note:** Output Variables are one way to create custom outputs HFSS doesn’t calculate automatically. Here it was used to show how Active S-Parameters are calculated, but in general it adds to HFSS’s flexibility by allowing you to look at the results that are most interesting to you.

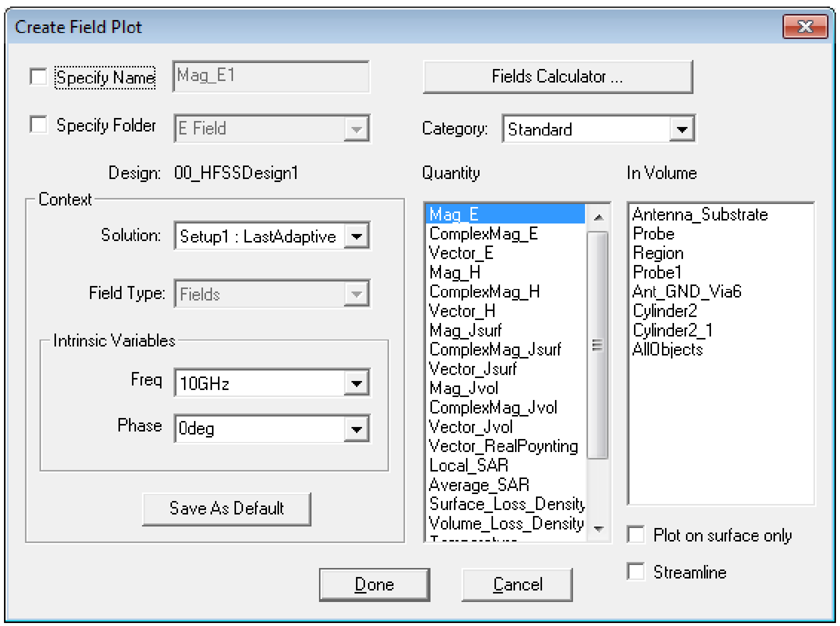
# Evaluating the Solved Fields

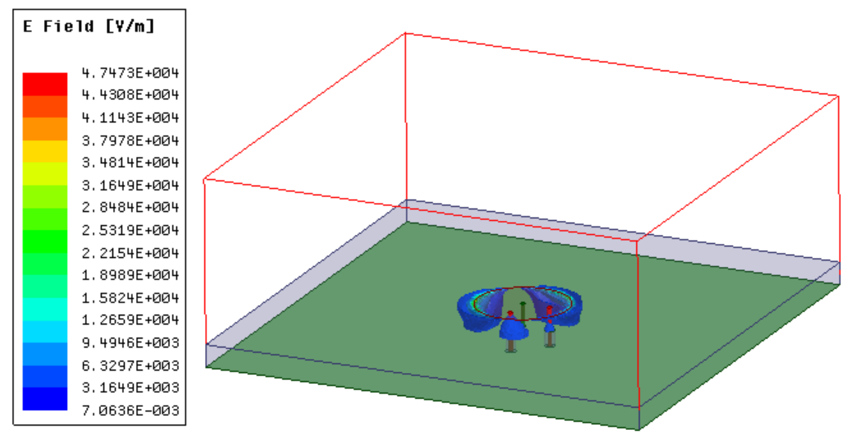
  

# Plotting E-Field in Substrate

- **Select Antenna Substrate**
  - From the **3D Modeler** tree, Click on **Solids > Rogers RO3003 (tm) > Antenna_Substrate**
- **Create Field Overlay Plot**
  - Select the menu item ***HFSS > Fields > Plot Fields > E > Mag_E***
  - Click the **Done** button



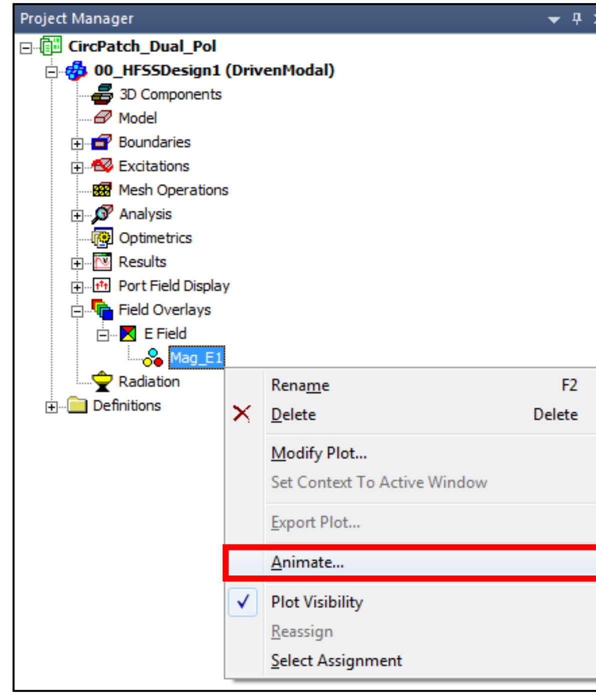



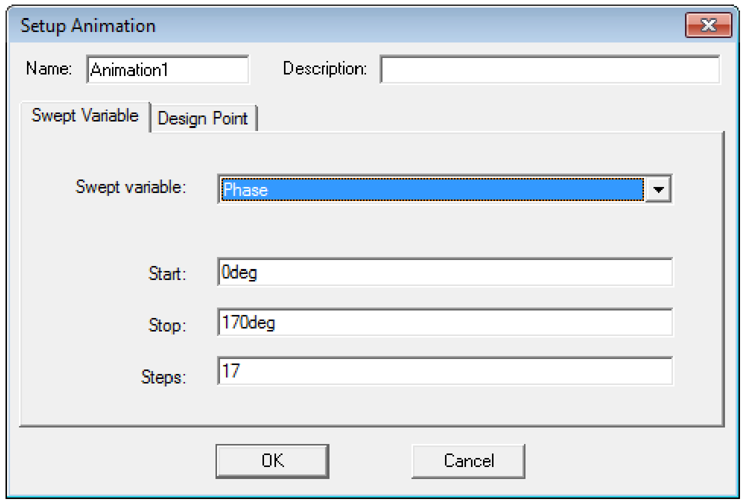

**Note:** This creates a 3D Field overlay contour of the electric field magnitude solved inside the substrate. The plot definition is placed in the Field Overlays > E Field branch of the Project Manager. Right clicking on the Mag_E1 definition and selecting Modify Plot… from the pop-up window will open the Create Field Plot window allowing you to make changes to the definition.
These fields represent the Electric Field produced when Ports 1 and 2 are excited based on the Edit Sources dialog window. Just as with Active S-Parameters, adjusting the Edit Sources will affect the way these contour plots look.

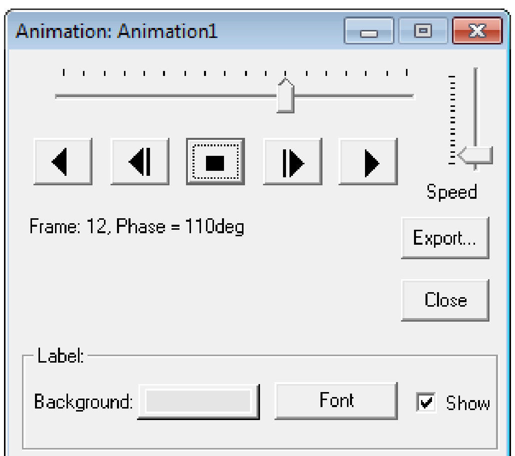
  

# Animate MagE Plot

- **Animate Mag_E1 Plot**
  - From the **Project Manager,** Right-click on **Field Overlays > E Field > Mag_E1**
  - Select **Animate…** from the Pop-Up Window
  - Setup Animation Window
    - Sweep Variable: **Phase**
    - Start: **0deg**
    - Stop: **170deg**
    - Steps: **17**



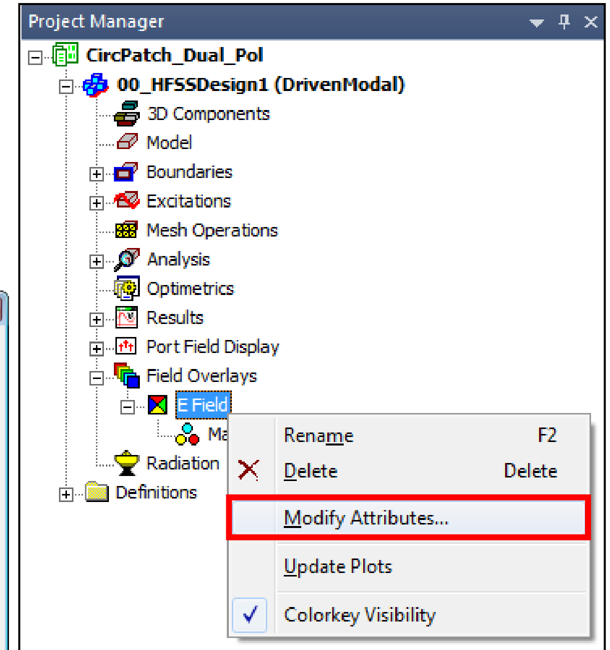

**Note:** This animation depicts the fields as the excitation phase progresses from 0deg to 170deg. This phase should not be confused with the phase delay applied between ports 1 and 2 in the Edit Sources Window. Those ports will still have the same relative phase difference between themselves. Instead, this phase advances both signals simultaneously allowing you to view how the single frequency continuous waves propagate and superimpose throughout the model.

The speed of the animation is controlled through the Animation Window. Likewise, the animation can be exported out of HFSS as an AVI or GIF file

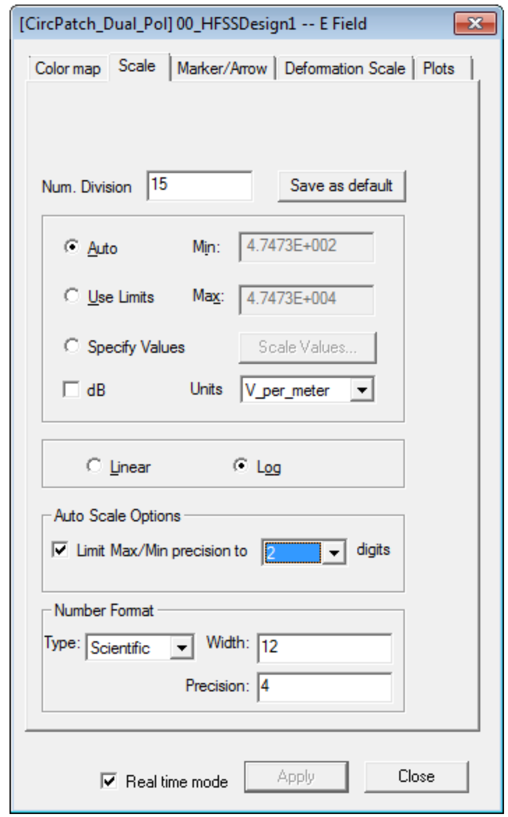
- Click **Close** button when done

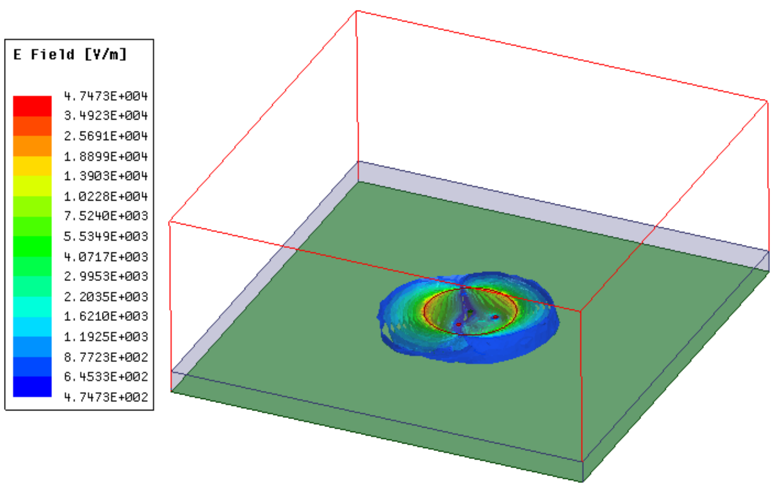
  

# Modifying the Field Overlay Plot




- **Change the Color Key Scale**
  - From the Project Manager, Right-click on the **Field Overlays > E Field**
  - Select Modify **Attributes…**
    - Click on the **Scale** Tab
    - Select the **Log** radio button
    - Check the **Limit Max/Min precision** checkbox
    - Set the number of digits to **2**
    - Click the **Close** button



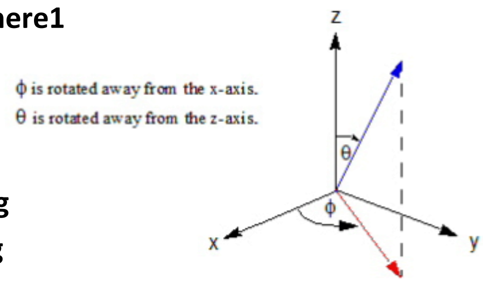

**Note:** Switching to a log scale places more contour lines at the higher end of the color key allowing you to see more detail for the larger field values. Using the Limit Max/Min precision to checkbox sets the minimum value on the color key to be some order of magnitude below the peak value. This allows the user to quickly see how many dB below the peak a particular field is. In this case, we've set darkest blue color to be 40dB below the peak field strength.

# Evaluating Pattern Data

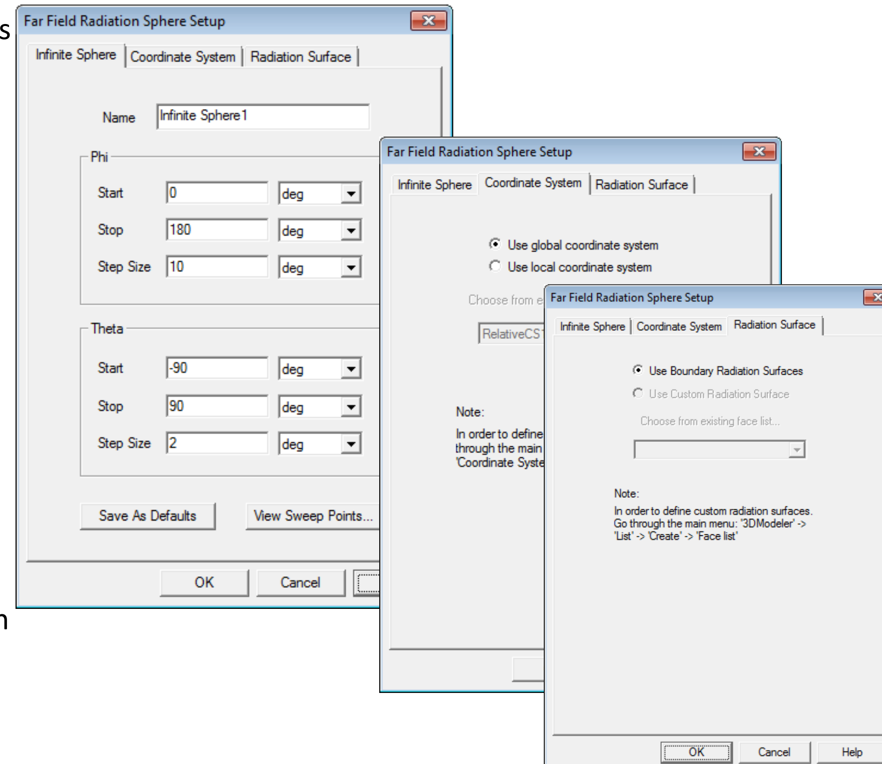
  

# Calculating the Far-Field

- **Create Far Field Radiation Sphere Setup**
  - Select the menu item ***HFSS > Radiation > Insert Far Field Setup > Infinite Sphere…***
  - Define the pattern's observation points using Spherical Coordinates
    - Click the **Infinite Sphere** Tab
      - Name: **Infinite Sphere1**
      - Phi Start: **0 deg**
      - Phi Stop: **180 deg**
      - Phi Step: **10 deg**
      - Theta Start: **-90 deg**
      - Theta Stop: **90 deg**
      - Theta Step Size: **2 deg**




  - Select the Modeler's coordinate system used to define the Far Field Spherical Coordinate System
    - Click the **Coordinate System** Tab
      - Select the **Use global coordinate system** radio button
  - Select the surface HFSS uses for performing the far field integration
    - Click the **Radiation Surface** Tab
      - Select the **Use Boundary Radiation Surfaces** radio button
  - Click the **OK** button to perform the calculation



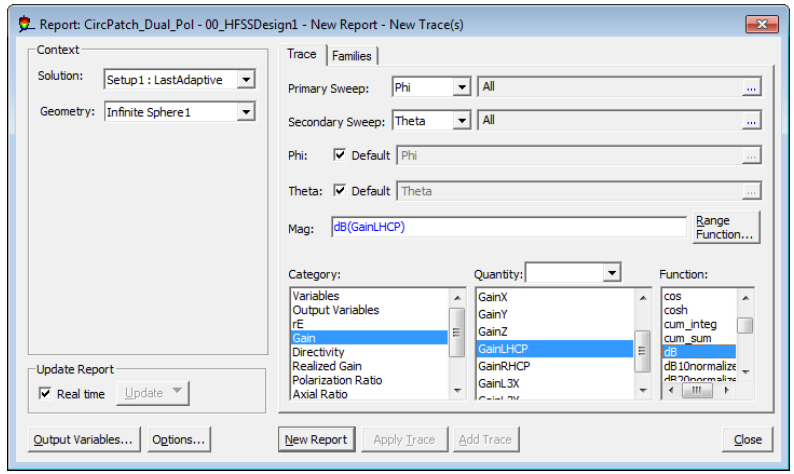

**Note:** The infinite sphere determines what far field points are calculated, what coordinate system is used define the far field spherical coordinate system these points are defined on and what surfaces are uses compute the far field from.

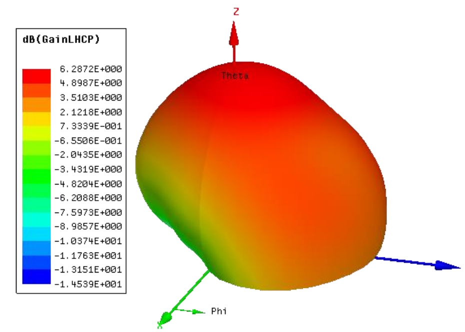
**Note:** The observation points are chosen because antenna points in the +Z direction and contains an infinite ground plane. Therefore all the radiated fields exist in the upper hemisphere of the model. The theta observation points were chosen to range from -90 deg to +90 deg so the plotted patterns will have theta = 0 (the Z direction) in the middle of the plot. Once this choice is made phi must range from 0 deg to 180 deg to cover the entire upper hemisphere.

# Plotting Far Field Pattern

- **Create Far Field Pattern Plot**
  - Select the menu item ***HFSS > Results > Create Far Fields Report > 3D Polar Plot***
  - Define the traces that will be plotted
    - In the **Trace** Tab
      - Solution: **Setup1: LastAdaptive**
      - Geometry: **Infinite Sphere1**
      - Primary Sweep: **Phi**
      - Secondary Sweep: **Theta**
      - Category: **Gain**
      - Quantity: **GainLHCP**
      - Function: **dB**
  - Click **New Report** button
  - Click **Close** button



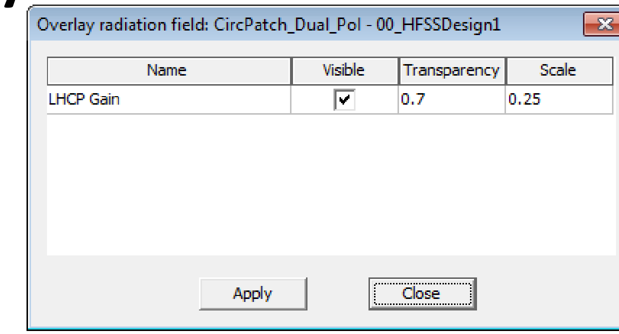




- **Change Report Name**
  - In **Project Manager** window, select **3D Polar Plot 1**
  - In Properties window:
    - Name: **LHCP Gain**
- **Rotate the Plot for Inspection**
  - Hold the **Alt** key and drag the mouse in the 3D Modeler Window with the left mouse button to rotate the plot.

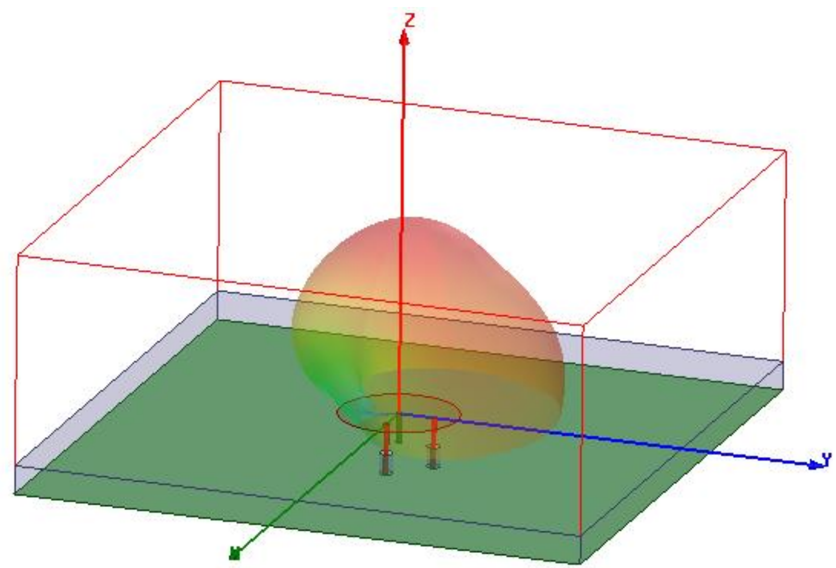
**Note:** This is a 3 dimensional plot with 2 independent variables (theta and phi). Therefore there is a Primary and Secondary sweep that must be defined. The radial position of the contour and it color indicates the intensity of the LHCP Gain.

Often times it is a good idea to plot the gain on a 3D Polar plot first to get a general idea of the pattern's shape before plotting cuts on a Radiation Pattern or Rectangular Plot.

# Overlaying Polar Plot on Geometry




- **Make sure 3D Modeler is Visible**
  - Select the menu item ***HFSS > 3D Model Editor***
- **Insert 3D Polar Plot Overlay**
  - Select the menu item ***HFSS > Fields > Plot Fields > Radiation Field...***
  - In the **Overlay Radiation Field** window check the **Visible** check box for the **LHCP Gain** row
  - Click **Apply**
- **Adjust Radiation Field Size and Transparency**
  - In the **Overlay Radiation Field** window change the **LHCP Gain's Transparency** field to **0.7**
  - Click **Apply**
  - In the **Overlay Radiation Field** window change the **LHCP Gain's Scale** field to **0.25**
  - Click **Apply**



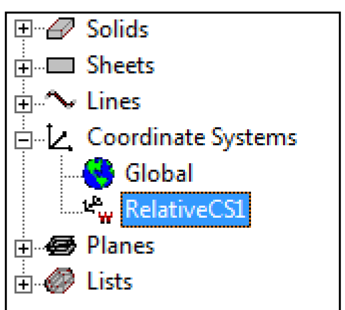

**Note:** Overlaying the 3D Polar Plot of Gain onto the geometry provides a nice functional illustration of the antenna's performance. It also makes it very easy to orient the pattern with respect to the antenna's features.

# Moving Coordinate System

- **Define a New Coordinate System**
  - Select the menu item ***Modeler > Coordinate System > Create > Relative CS > Offset***
  - Set the Coordinate System's Origin to (X=1000mil, Y=1000mil, Z = 0mil)
    - Press the **Tab** key to access the X field for the cursor position
    - **X: 1000**
    - Press the **Tab** key to access the Y field for the cursor position
    - **Y: 1000**
    - Press the **Tab** key to access the Z field for the cursor position
    - **Z: 0**
    - Press the **Enter** key

**Note:** To define the origin of the new coordinate system you must specify a position in 3D space. This can be done in several ways. This example shows you how to control the cursors position using the X, Y and Z fields in the lower right hand corner of HFSS's GUI. This can also be done by snapping to geometric features in the model.

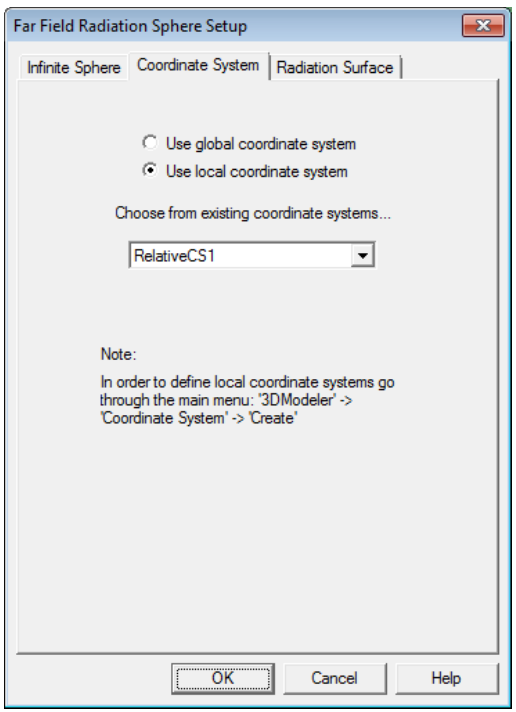

- **Verify New Coordinate System in 3D Modeler Tree**
  - In the **3D Modeler** tree expand **Coordinate Systems** branch
  - Make sure **RelativeCS1** is present

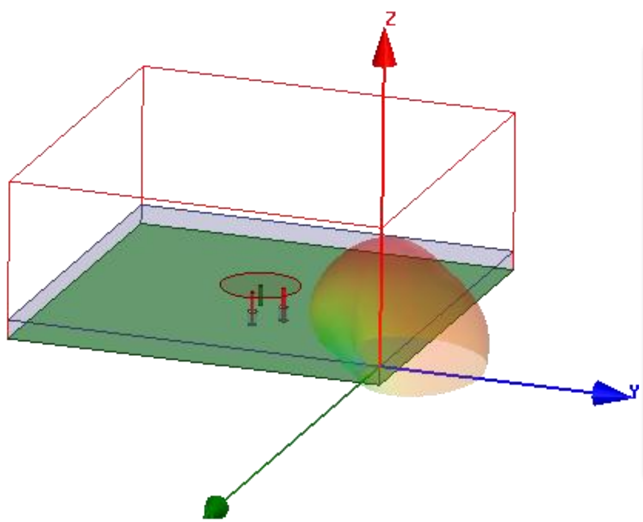



**Note:** A model can have several coordinate systems defined. All of them can be accessed in the Coordinate Systems branch of the 3D Modeler Tree. The Coordinate System with the red W is working coordinate system. It will be used for any executed commands. If you want to change the working coordinate system simply left click on the coordinate system you wish to make use.

# Moving Coordinate System

- **Associate Radiation Infinite Sphere with RelativeCS1**
  - In the **Project Manager** window, expand the **Radiation** branch
  - Right-click on **Infinite Sphere1** and select **Properties**
    - Click the **Coordinate System** Tab
    - Select **Use local coordinate system** radio button
    - Select **RelativeCS1** from the **Choose from existing coordinate systems…** drop down menu
  - Click the **OK** button



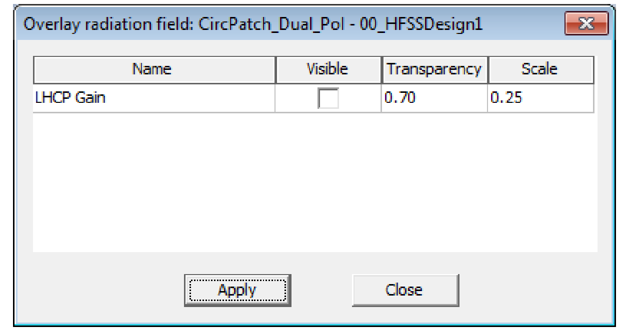




**Note:** The 3D Polar Plot moved with the coordinate system. This pattern exists in the far-field and is not directly associated with a particular geometric feature. Its position and it definition for the theta and phi spherical coordinates are associated with the coordinate system used to compute the far-field from . Therefore its position and orientation adjusts with the coordinate system.

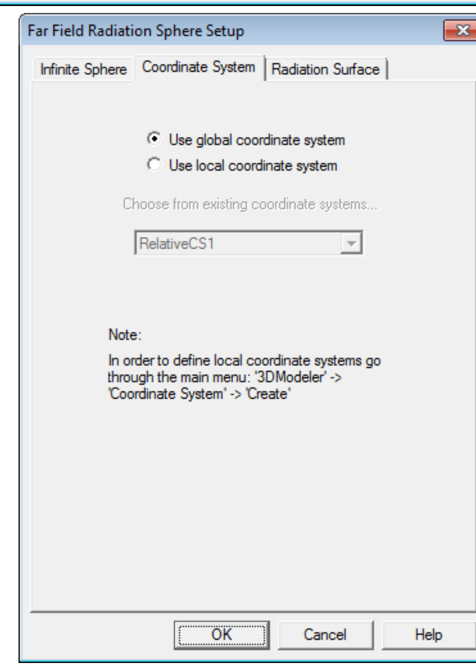
**Note:** You can also use this coordinate system association to tilt the pattern so the theta = 0deg direction points in a different direction. This can be useful when placing an antenna on a platform.

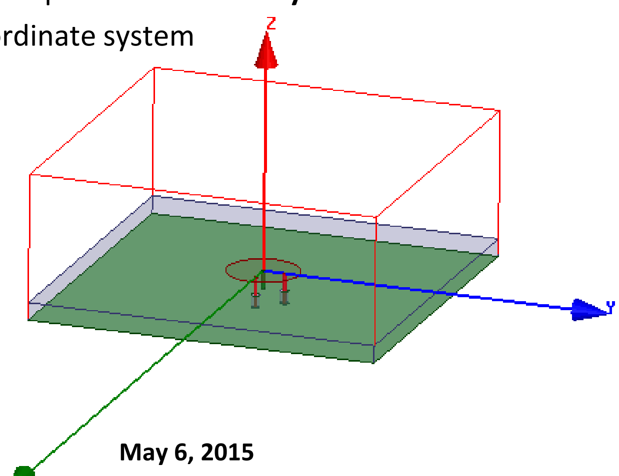
# Resetting the Radiation Pattern

- **Turn Off Radiation Overlay**
  - Select the menu item ***HFSS > Fields > Plot Fields > Radiation Field...***
  - In the **Overlay Radiation Field** window uncheck the **Visible** check box for the **LHCP Gain** row
  - Click the **Apply** button
  - Click the **Close** button



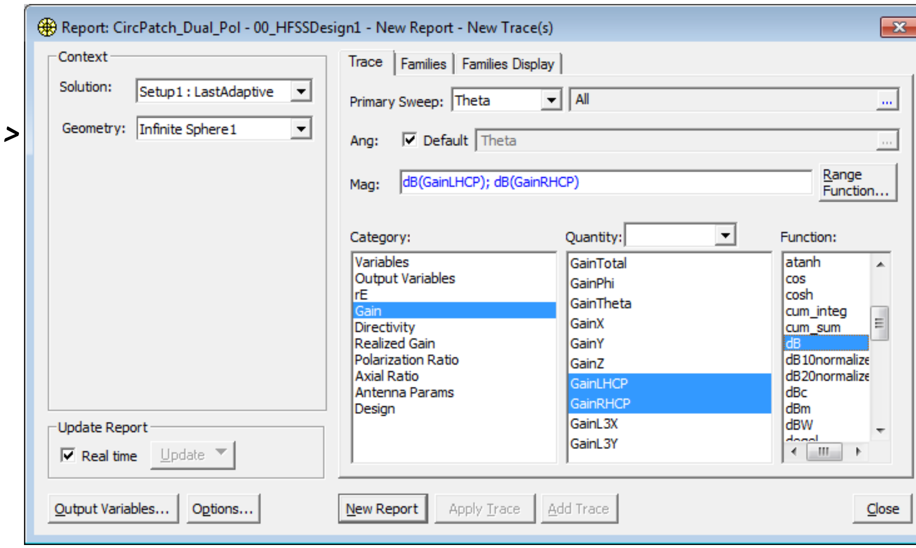

- **Use the Global Coordinate System for Far-Field Calculations**
  - In the **Project Manager** window expand the **Radiation** branch
  - Right-click **Infinite Sphere1** and select **Properties**
    - Click the **Coordinate System** Tab
    - Select **Use global coordinate system** radio button
    - Click the button
  - In the **3D Modeler** tree expand **Coordinate Systems** branch
    - Click on **Global** coordinate system

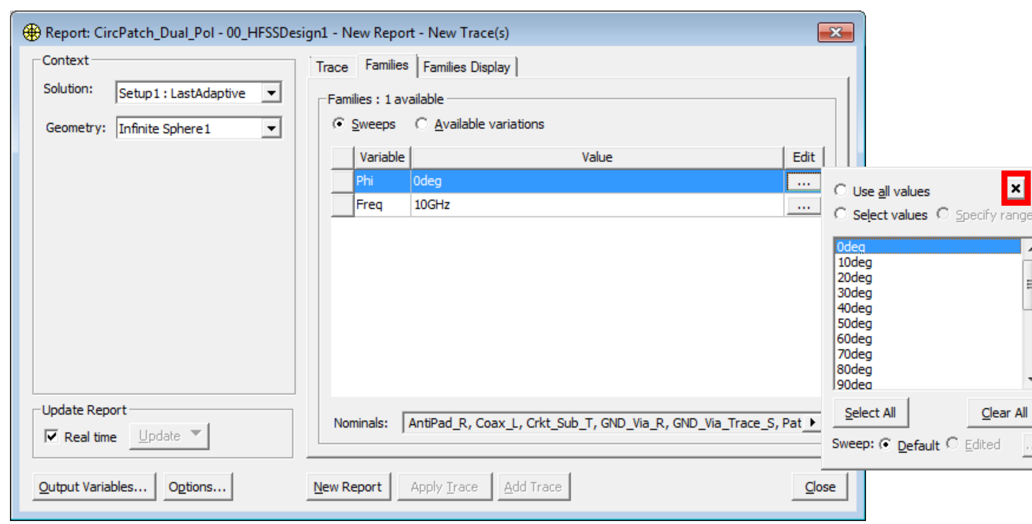


# Plotting Far Field Pattern

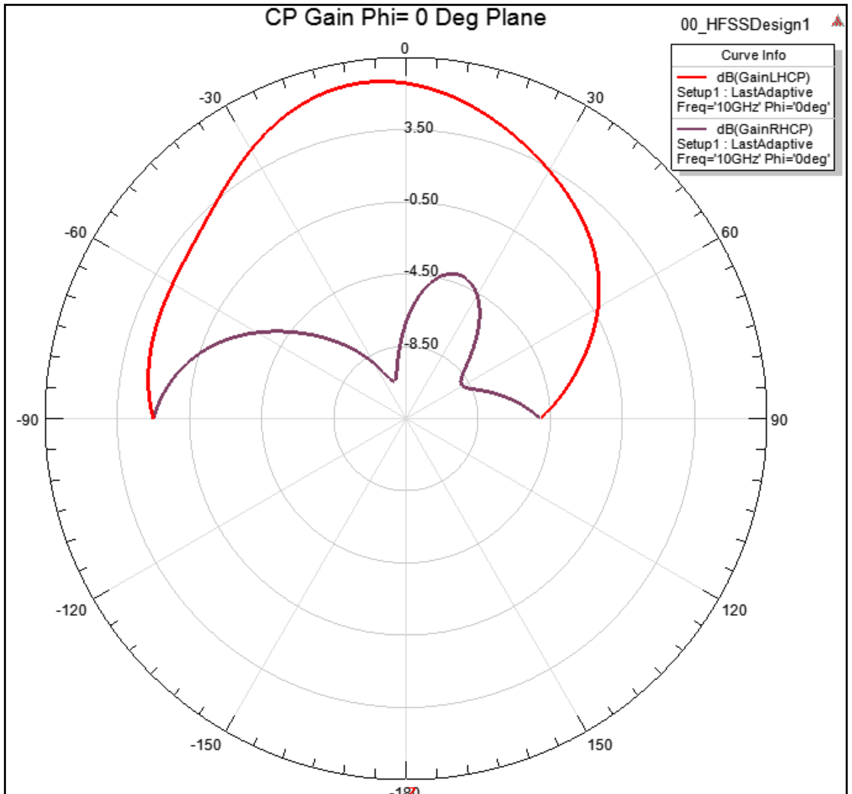
- **Create Far Field Pattern Plot**
  - Select the menu item, ***HFSS > Results > Create Far Fields Report > Radiation Pattern***
  - Define the traces that will be plotted
    - In the **Trace** Tab
      - Solution: **Setup1: LastAdaptive**
      - Geometry: **Infinite Sphere1**
      - Primary Sweep: **Theta**
      - Category: **Gain**
      - Quantity: **GainLHCP, GainRHCP**
        - Note: Hold Ctrl key to select multiple traces
      - Function: **dB**
    - Click the **Families** Tab
      - Click the **Edit** Button associated with the **Phi** variable.
      - Click on **0deg** in pop-up window.
      - Close the pop-up window by clicking the **X** button.
  - Click the **New Report** button
  - Click the **Close** button

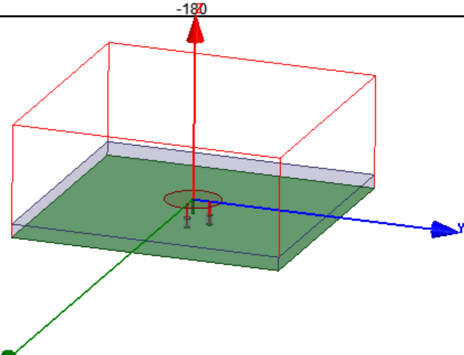



- **Change Report Name**
  - In **Project Manager** window select **Radiation Pattern 1**
  - In Properties window:
    - Name: **CP Gain Phi = 0 Deg Plane**

# Pattern Plot Discussion

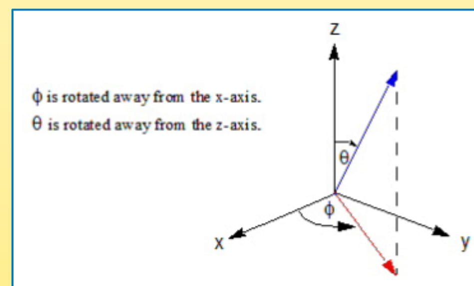



**Note:** This is a plot of the LHCP (Left Hand Circularly Polarized) and RHCP (Right Hand Circularly Polarized) components of the radiated wave in several directions.

The swept variable was chosen as Theta ranging from -90 deg to +90 deg. When Theta is -90 deg the trace corresponds to the gain along some direction in the XY plane (patch's ground plane). Which direction in the XY plane depends on how phi was set in the Families Tab. When Theta is 0 deg the trace corresponds to the gain in the Z direction. When it is 90 deg it corresponds to the gain in the direction opposite of theta = -90 deg .

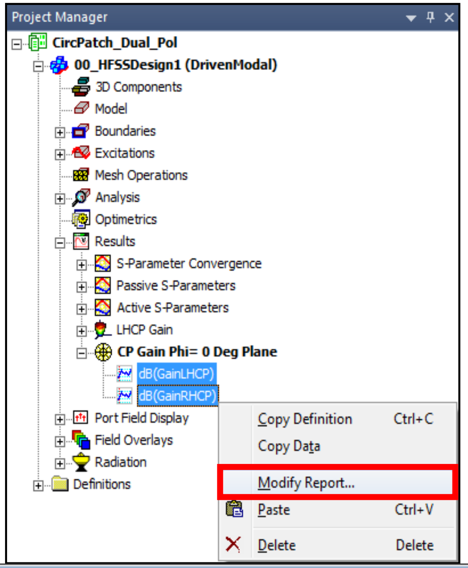
Since Phi was restricted to 0 deg on the Families Tab the cut is in the Phi = 0 deg plane. This corresponds to a cut in the XZ plane.



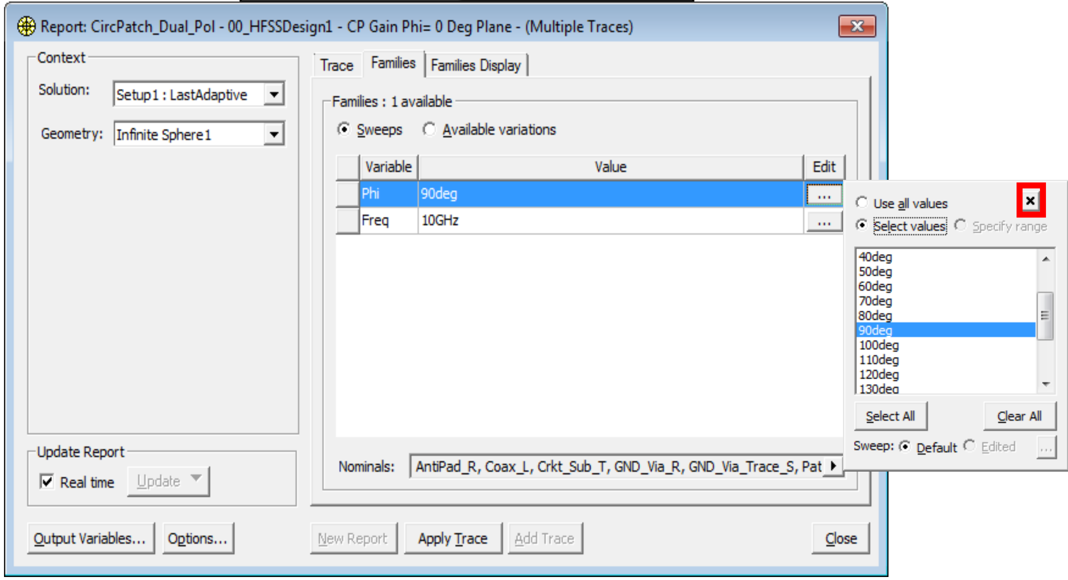

**Note:** This plot indicates that the antenna is predominantly LHCP. It is also asymmetric around the Theta = 0 deg (Z axis) due to the asymmetry of the antenna.

# Change the Cut Plane

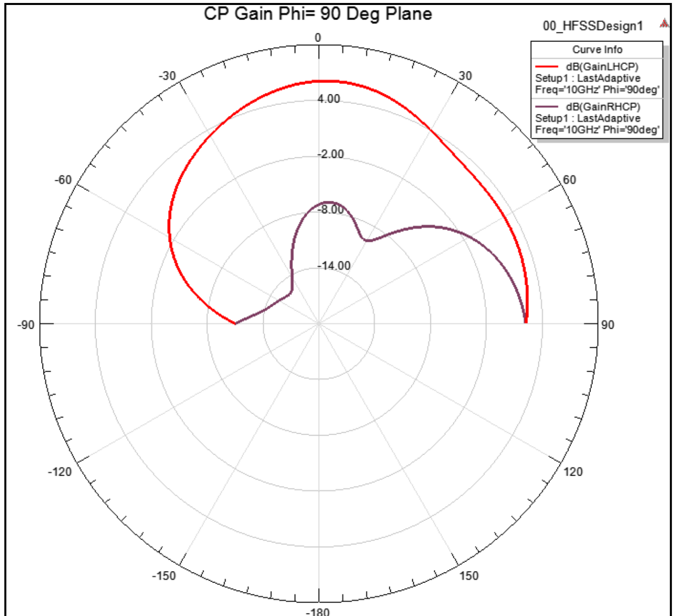



- **Select Gain Trace Definitions**
  - In the **Project Manager** window select
    - **Results > CP Pattern Phi = 0 Deg Plane > dB(GainLHCP)**
    - **Results > CP Pattern Phi = 0 Deg Plane > dB(GainRHCP)**
      - Note: Hold Ctrl key to select multiple trace definitions
- **Modify the Trace Definitions**
  - Right-click on the selected definitions
  - Select **Modify Report …**
    - Alternatively: In the **Properties** window select the **Edit…** button next to the **Families** Property
  - Click the **Families** Tab
  - Click the **Edit…** button on the **Phi** variable row
  - Select **90deg** from the list of phi values
  - Close the window by clicking the **X** button
- **Accept the changes to the plot**
  - Click **Apply Trace** button
  - Click **Close** button to close the Report Editor window



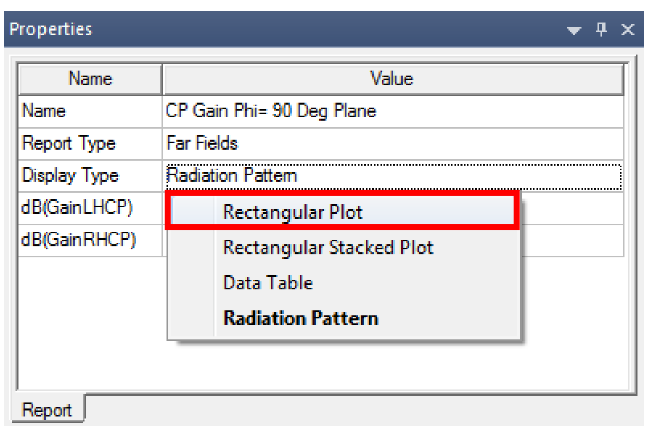

- **Change Report Name**
  - In Project Manager window, select **CP Pattern Phi = 0 Deg Plane**
  - In Properties window:
    - Name: **CP Gain Phi = 90 Deg Plane**

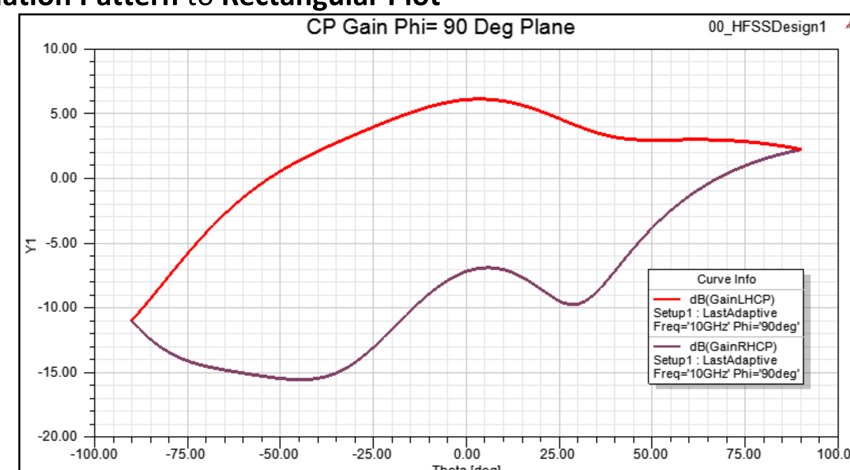
# Change Cut Plane Discussion




**Note:** The radiation plot now shows the LHCP and RHCP gain in the Phi = 90deg cut plane. This corresponds to the YZ plane

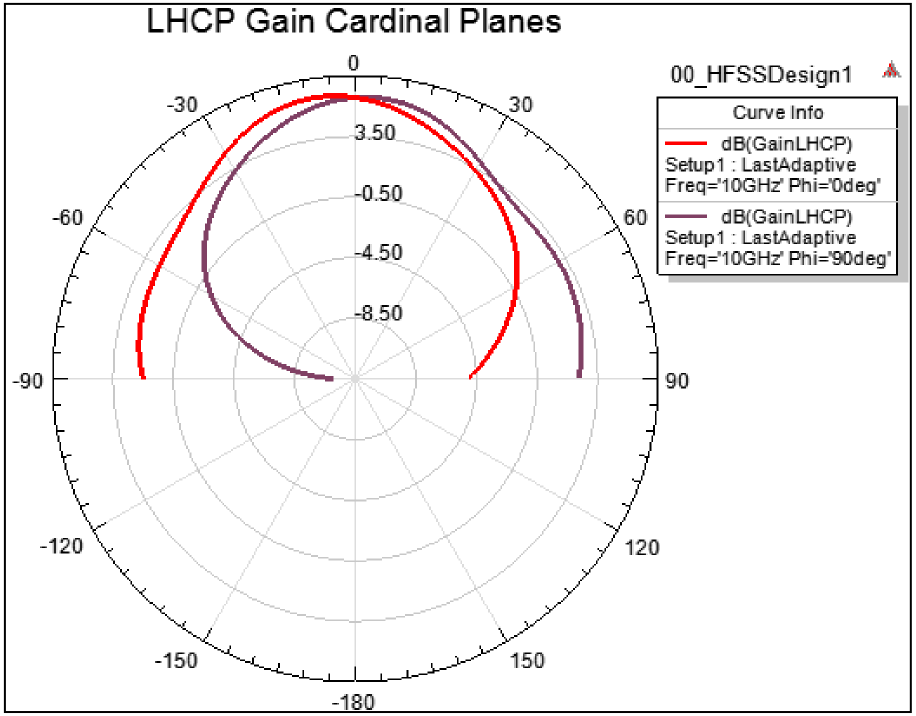
- **Change the plot from Radiation Pattern to Rectangular Display**
  - In the **Project Manager** window, click on **Results** > **CP Pattern Phi = 90 Deg Plane**
  - In the **Properties** window change the Display Type from **Radiation Pattern** to **Rectangular Plot**



# Plot Multiple Cut Planes

- **Create Far Field Pattern Plot**
  - Select the menu item ***HFSS > Results > Create Far Fields Report > Radiation Pattern***
  - Define the traces that will be plotted
    - In the **Trace** Tab
      - Solution: **Setup1: LastAdaptive**
      - Geometry: **Infinite Sphere1**
      - Primary Sweep: **Theta**
      - Category: **Gain**
      - Quantity: **GainLHCP**
      - Function: **dB**
    - Click the **Families** Tab
      - Click the **Edit** button associated with the **Phi** variable.
      - Click on **0deg** and **90deg** in the pop-up window.
        - Note: Hold Ctrl key to select multiple phi angles
      - Close the pop-up window by clicking the **X** button.
  - Click **New Report** button
  - Click **Close** button
- **Change Report Name**
  - In **Project Manager** window, select **Radiation Pattern 1**
  - In **Properties** window:
    - Name: **LHCP Gain Cardinal Planes**

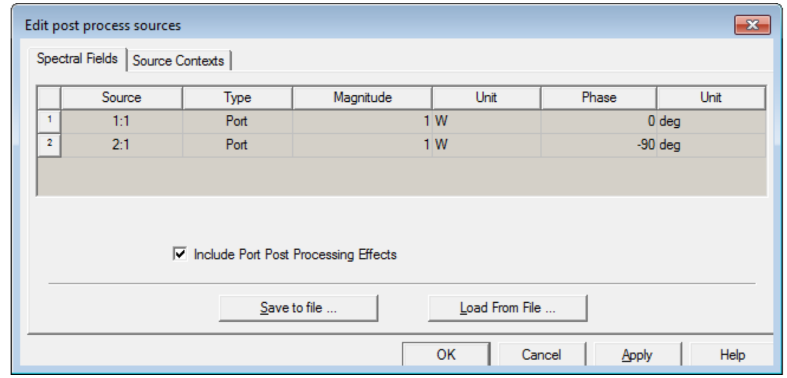



**Note:** Every additional value added to the Families Tab produces an additional curve on the plot. If you want to see more cut planes just specify more values. If you want to plot all cut planes select the **Use all values** when modifying the variables values.

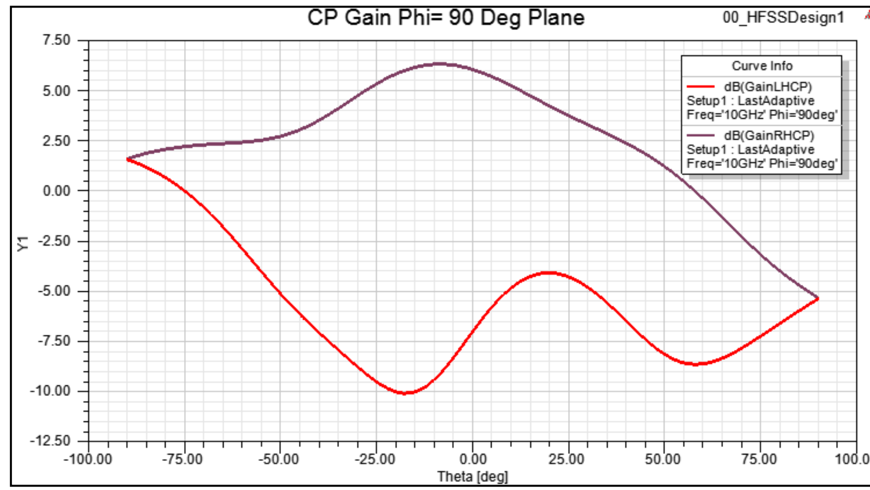
**Note:** Not all variables show up on the Families Tab. If a variable has not been swept, it will show up as the Nominal Value specified in the Project Design Variables or Design Properties. You can change which variables use the Nominal values by adjusting the **Nominals** field at the bottom of the **Families Tab**.

# Change Excitations

- **Set the Edit Sources Dialog**
  - Select the menu item ***HFSS > Fields > Edit Sources...***
  - Excite Source 2:1 (Port2 : Mode1) with 1 Watt of Power offset -90deg in phase from port 1's excitation
    - Set **Phase** of Source 2:1 to **-90 deg**
    - Click **OK** to apply the change and close the **Edit Sources** Window.




- **Observe Impact on CP Gain**
  - In **Project Manager** window double-click on **Results > CP Pattern Phi = 90 Deg Plane** to view the updated plot
  - See how different excitations affect the Active S-Parameters
    - Select the menu item ***HFSS > Fields > Edit Sources...***
    - Drag it to the side so you can see the CP Gain
    - Change the values in the Magnitude and Phase fields
    - Click **Apply** to see the updated results in the Active S-Parameters Plot.




- **Reset the Edit Sources for Circular Polarization**
  - Select the menu item ***HFSS > Fields > Edit Sources...***
  - Excite Source 2:1 (Port2 : Mode1) with 1 Watt of Power offset 90deg in phase from port 1's excitation
    - Set **Phase** of Source 2:1 to 90 deg
    - Click **OK** to apply the change and close the **Edit Sources** Window.

**Note:** Now the RHCP trace has more gain than the LHCP. The affect of switching the phase offset on port 2:1 was to change the antenna's polarization from LHCP to RHCP.

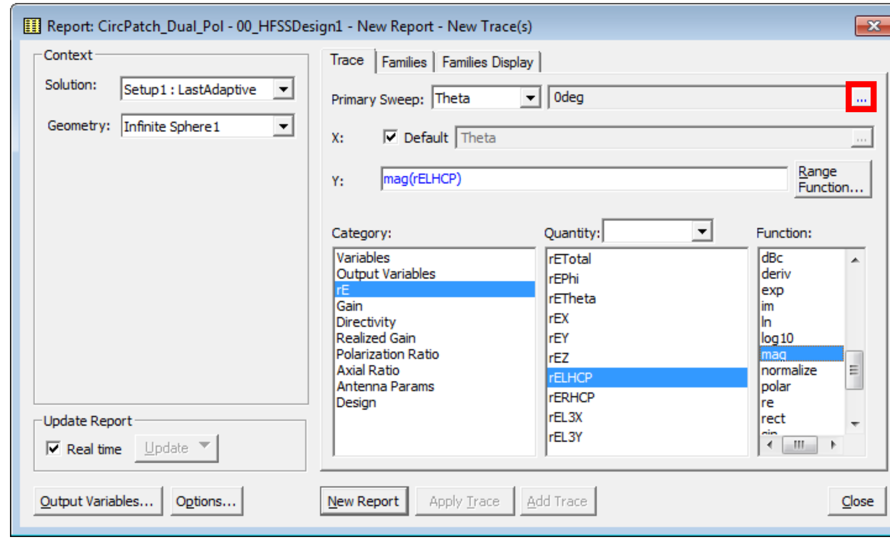
Since the Far-Field pattern is derived from the computed E-fields, pattern plots depend on the excitations applied to each port.

# Optional Advanced Topic: Understanding Far Field Quantities

# Plotting rE: Normalized Far-Field E-Field

- **Create Far Field Pattern Plot**
  - Select the menu item ***HFSS > Results > Create Far Fields Report > Data Table***
  - Define the traces that will be plotted
    - In the **Trace** Tab
      - Solution: **Setup1: LastAdaptive**
      - Geometry: **Infinite Sphere1**
      - Primary Sweep: **Theta**
      - Restrict Primary Sweep to **Theta = 0deg**
        - Click the ... button associated with **Theta** variable
        - Click **Select values** radio button in pop-up window.
        - Click on **0deg**.
        - Close the pop-up window by selecting the **X** button.
      - Category: **rE**
      - Quantity: **rELHCP**
      - Function: **mag**
    - Click the **Families** Tab
      - Click the **Edit** Button associated with the **Phi** variable.
      - Click on **0deg** in pop-up window.
      - Close the pop-up window by selecting the **X** button.
  - Click **New Report** button
  - Click **Close** button




Data Table 1

| | Theta [deg] | mag(rELHCP) [V] Setup1 : LastAdaptive Freq='10GHz' Phi='0deg' |
|---|---|---|
| 1 | 0.000000 | 18.845279 |

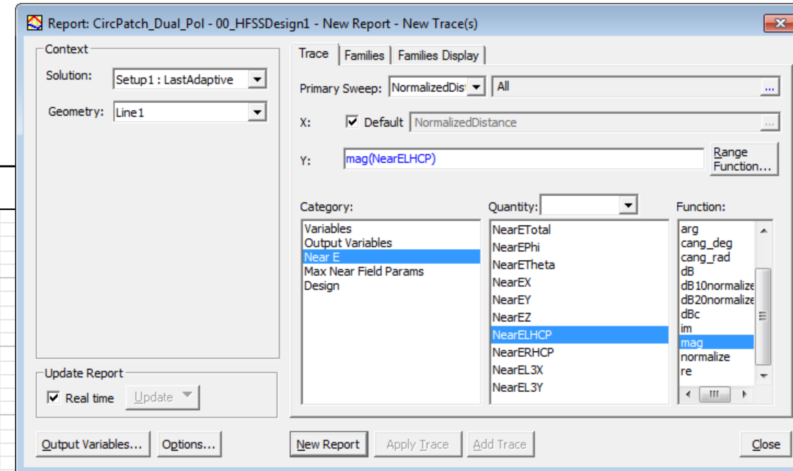
**Note:** rE is HFSS's representation of the E-Field in the Far-Field region. In this region the field strength decays as a function of 1/r (where r is the radial distance away from the antenna) and the phase varies as a function of exp(-jkr). To eliminate this radial dependence the rE quantity normalizes the Far-Field region's E-field according to the following equation.

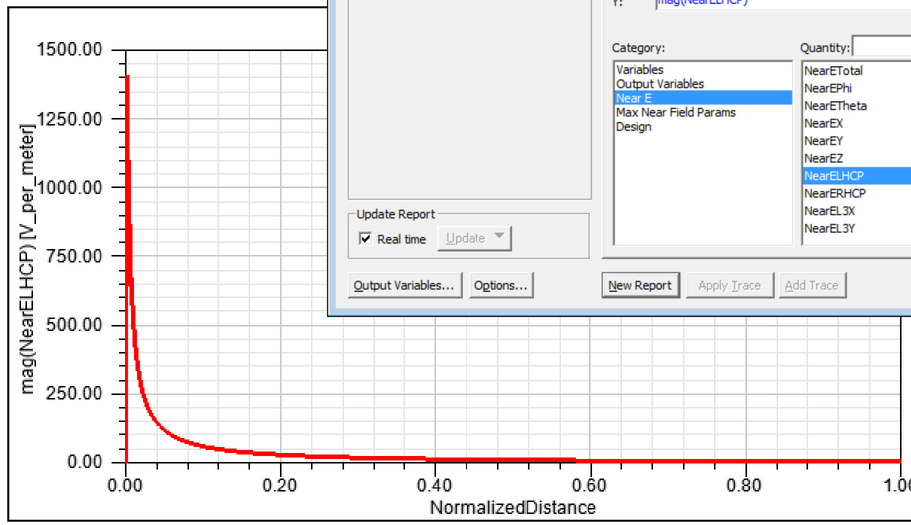
$$\overrightarrow{rE} = re^{jkr}\overrightarrow{E_{FF}}$$

# Show Far-Field Normalization

- **Create Near Field Setup**
  - Select the menu item ***HFSS > Radiation > Insert Near Field Setup > Line…***
  - Near Field Line Setup Tab
    - Name: **Line1**
    - Choose Line: **Polyline3**
    - Number of point: **1000**
  - Click the **OK** button




- **Create Near Field ELHCP Plot**
  - Select the menu item ***HFSS > Results > Create Near Fields Report > Rectangular Plot***
  - Define the traces that will be plotted
    - In the **Trace** Tab
      - Solution: **Setup1: LastAdaptive**
      - Geometry: **Line1**
      - Primary Sweep: **NormalilzedDistance**
      - Category: **Near E**
      - Quantity: **NearELHCP**
      - Function: **mag**
  - Click **New Report** button
  - Click **Close** button

- **Change Report Name**
  - In **Project Manager** window  select **XY Plot 1**
  - In **Properties** window:
    - Name: **NearELHCP**

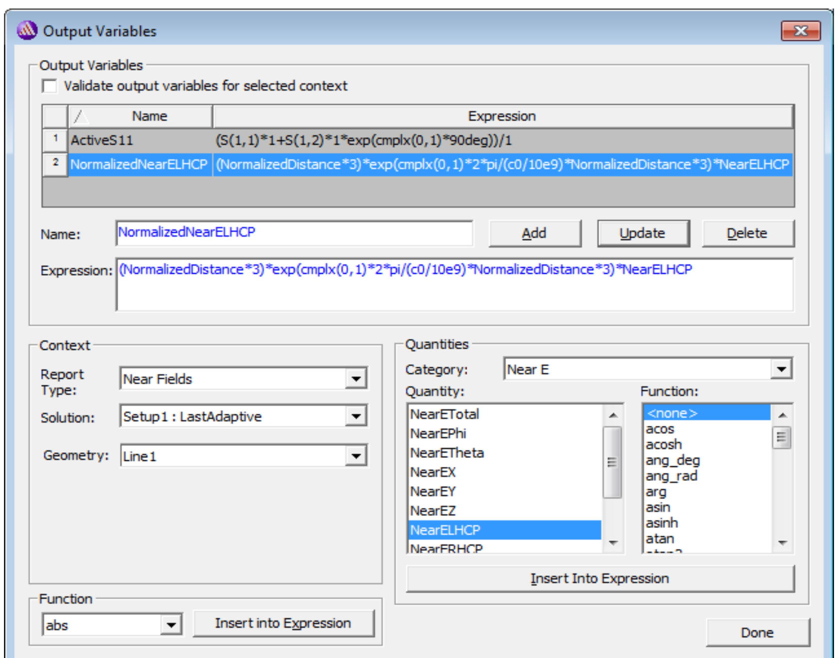
**Note:** The Near Field Setup will compute the value of the E-field along a line (Polyline3)  which is already drawn in the model.  This polyline starts at the origin and extends 3 meters along the z-axis by performing a near field calculation.  This near field calculation does not make any far-field approximations allowing us to predict the field's behavior anywhere outside our solution domain.

**Note:**  The plot shows the field strength in V/m along this line.  The x-axis is a plot of normalized distance where a NormalizedDistance of 1 corresponds to the end of the line; 3 meters out from the coordinate system's origin.

**Note:**  The near field calculation shows very rapid decay near the antenna.  This decay drops to a 1/r dependence near the end of the line.

# Normalizing Near-Field with rE Normalization

- **Create Output Variable for NormalizedNearELHCP**
  - Select the menu item ***HFSS > Results > Output Variables…***
  - Context:
    - Report Type: **Near Fields**
    - Solution : **Setup1 : LastAdaptive**
    - Geometry: **Line1**
  - Name: **NormalizedNearELHCP**
  - Expression: **(NormalizedDistance*3)*exp(cmplx(0,1)*2*pi/(c0/10e9)*NormalizedDistance*3)*NearELHCP**
  - Click **Add** to create the Output Variable **NormalizedNearELHCP**
  - Click **Done** to close the Output Variables dialog.

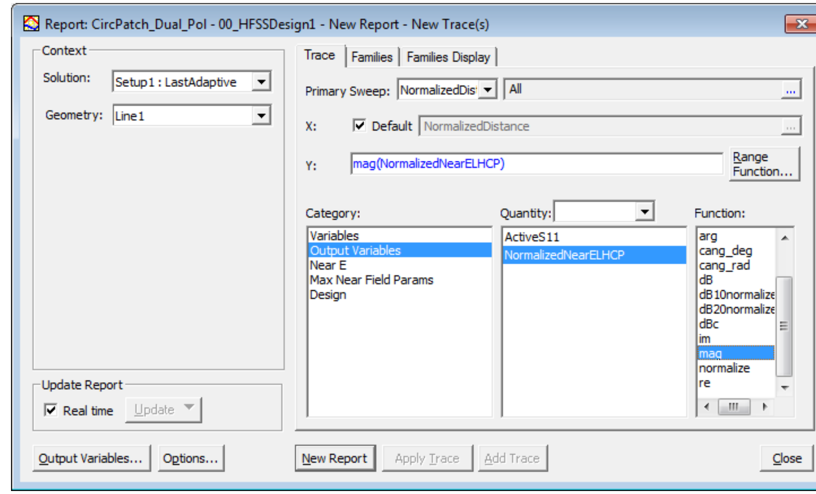


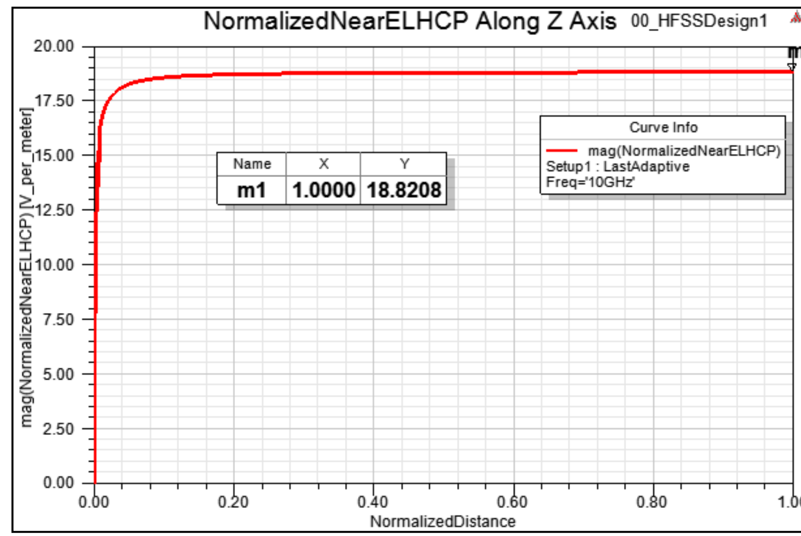

**Note:** The expression used to calculate the Normalized Near Field is r*exp(jkr)*NearELHCP were r is the radial distance from the coordinate system's origin. It shows up in the Output Variable expression as NormalizedDistance*3 since the line is 3 meters long. k is the propagation constant which is represented in the expression as 2*pi/(c0/10e9) where c0 is a constant for the speed of light and 10e9 is the frequency of the field data. j is expressed as cmplx(0,1).

**Note:** The expression can be typed in manually or the user can use the Category / Quantity selection in conjunction with the Insert Into Expression button to add quantities into the expression. Likewise, the exp and cmplx functions can be applied by using the Function selection in conjunction with the Insert into Expression button. If the expression contains an error it will show up in red. Correct expressions show up in blue.

# Normalized Near Field Response in Far Field

- **Create NormalizedNearELHCP Plot**
  - Select the menu item ***HFSS > Results > Create Near Fields Report > Rectangular Plot***
  - Define the traces that will be plotted
    - In the **Trace** Tab
      - Solution: **Setup1: LastAdaptive**
      - Geometry: **Line1**
      - Primary Sweep: **NormalilzedDistance**
      - Category: **Output Variables**
      - Quantity: **NormalizedNearELHCP**
      - Function: **mag**
  - Click **New Report** button
  - Click **Close** button
- **Change Report Name**
  - In Project Manager window  select **XY Plot 1**
  - In Properties window:
    - Name: **NormalizedNearELHCP Along Z Axis**
- **Place a Marker at a NormalizedDistance = 1**
  - Select the menu item ***Report2D > Marker > Add Marker…***
  - Click on the far right side of the trace
  - Press **Esc** key
  - Note the value of **NormalizedNearELHCP Along Z Axis**

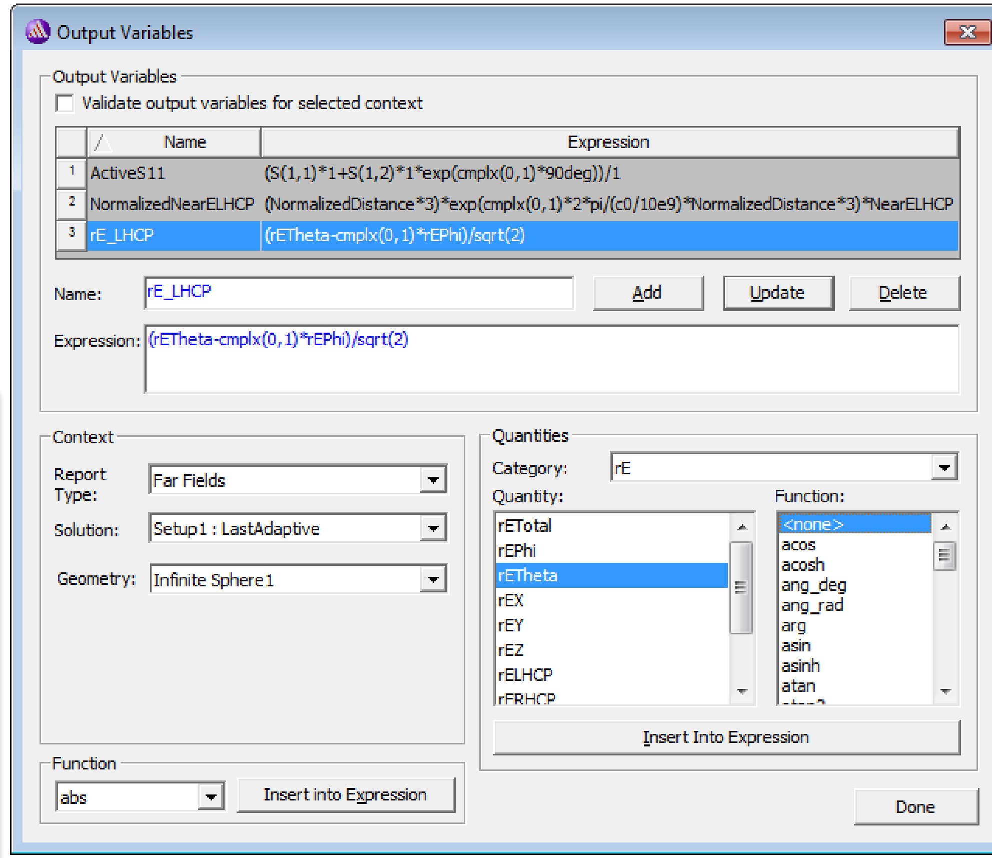



**Note:** Once the far-field radial dependence is removed, the near field magnitude asymptotically approaches the value of rE for large distances.  This confirms that the rE is a far-field quantity with a normalization term to eliminate the 1/r radial dependence.

# rE Polarization

- **Create Output Variable for rELHCP**
  - Select the menu item ***HFSS > Results > Output Variables…***
  - Context:
    - Report Type: **Far Fields**
    - Solution : **Setup1 : LastAdaptive**
    - Geometry: **Infinite Sphere 1**
  - Name: **rE_LHCP**
  - Expression: **(rETheta-cmplx(0,1)*rEPhi)/sqrt(2)**
  - Click **Add** to create the Output Variable **rE_LHCP**



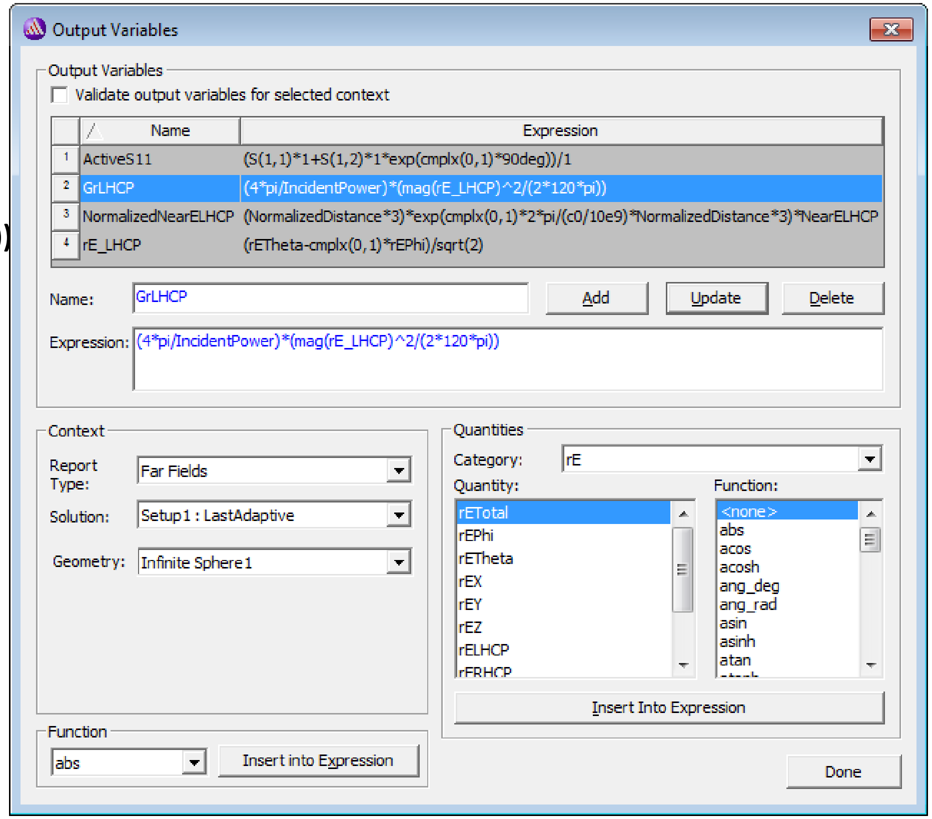

**Note:** Since rE represents the electric field in the far-field radiating zone it is a complex vector quantity. This vector quantity can be decomposed in to any number of components allowing users to analyze specific polarization states. For instance, if you are designing a Left Hand Circularly Polarized (LHCP) antenna a user can look just at the LHCP portion of the far-field. This would allow the user to compare the antenna's co-polarized performance to its cross-polarized performance.

HFSS distinguishes between the different polarizations by applying abbreviations to the end of the quantity's name. So rETheta represents the theta component of the far-field.

Custom polarizations can also be created using combinations of the polarizations HFSS already provide.

# Realized Gain Calculation

- **Create Output Variable for GrELHCP**
  - Context:
    - Report Type: **Far Fields**
    - Solution : **Setup1 : LastAdaptive**
    - Geometry: **Infinite Sphere1**
  - Name: **GrLHCP**
  - Expression: **(4*pi/IncidentPower)*(mag(rE_LHCP)^2/(2*120*pi))**
  - Click **Add** to create the Output Variable **GrLHCP**
  - Click **Done** to close the Output Variables Widow




**Note:** Realized Gain is a measures what portion of the excited power radiates in different directions. It is calculated using a similar equations to the IEEE Definition for Gain

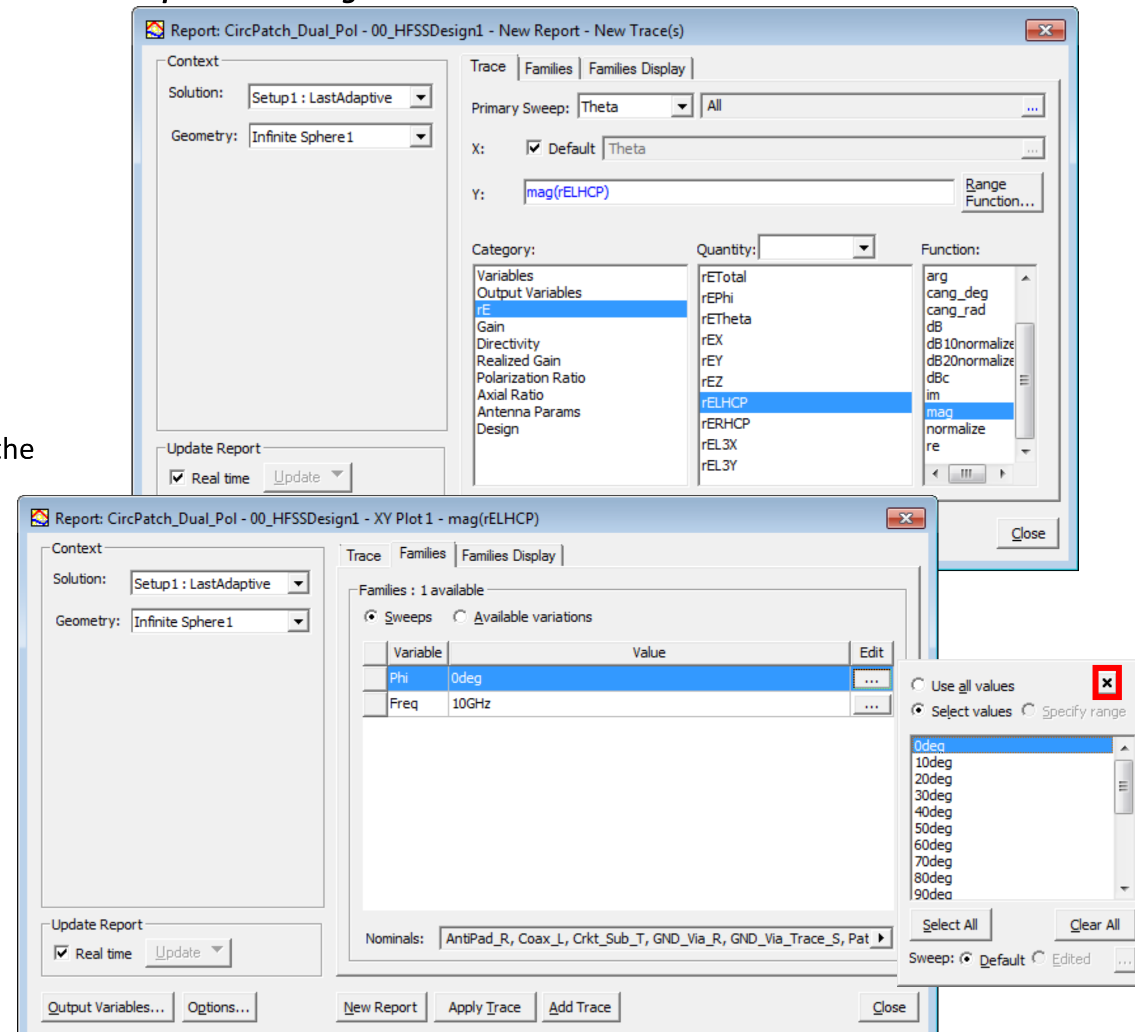
$$RealizedGain_{LHCP} = \frac{4\pi U_{LHCP}\ (\theta,\phi)}{P_{Incident}} = \frac{4\pi |rE_{LHCP}(\theta,\phi)|^2}{2\eta P_{Incident}}$$

where

- **$U_{LHCP}(\theta,\phi)$** is the radiation intensity for the Left Hand Circularly Polarized component of the radiated field in the $(\theta,\phi)$ direction
- **$rE_{LHCP}(\theta,\phi)$** is the normalized Far-Field quantity in the $(\theta,\phi)$ direction
- **$\eta$** is the wave impedance of a plane wave in free space (approx. $120\pi$ ohms)
- **$P_{incident}$** is the power incident toward the ports as defined in Edit Sources

# Comparing rELHCP Calculations

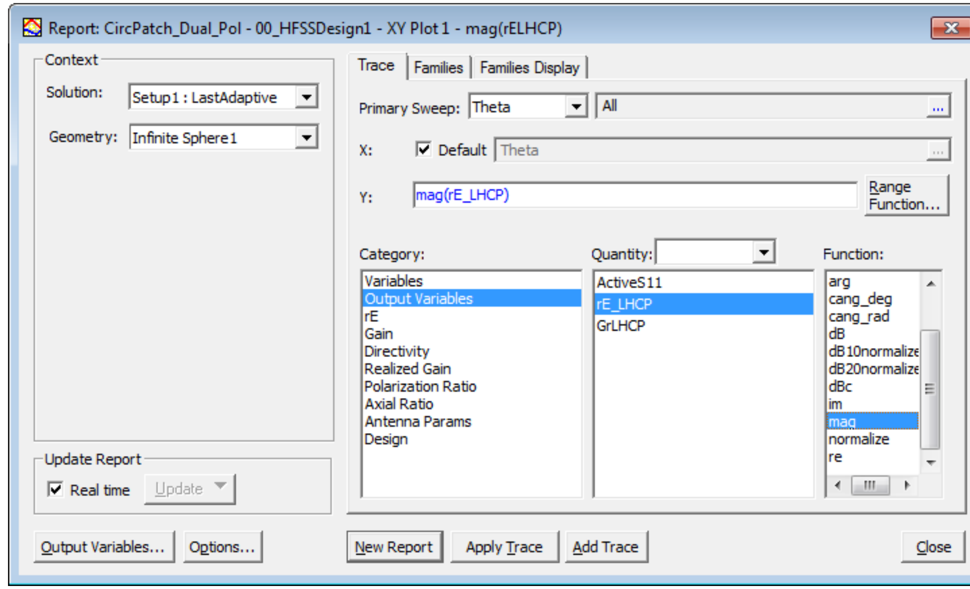
- **Create rELHCP Plot**
  - Select the menu item ***HFSS > Results > Create Far Fields Report > Rectangular Plot***
  - Define the trace that will be plotted
    - In the **Trace** Tab
      - Solution: **Setup1: LastAdaptive**
      - Geometry: **Infinite Sphere1**
      - Primary Sweep: **Theta**
      - Category: **rE**
      - Quantity: **rELHCP**
      - Function: **mag**
    - Click the **Families** Tab
      - Select the **Edit** Button associated with the **Phi** variable.
      - Click on **0deg** in pop-up window.
      - Close the pop-up window by selecting the **X** button.
  - Click the **New Report** button

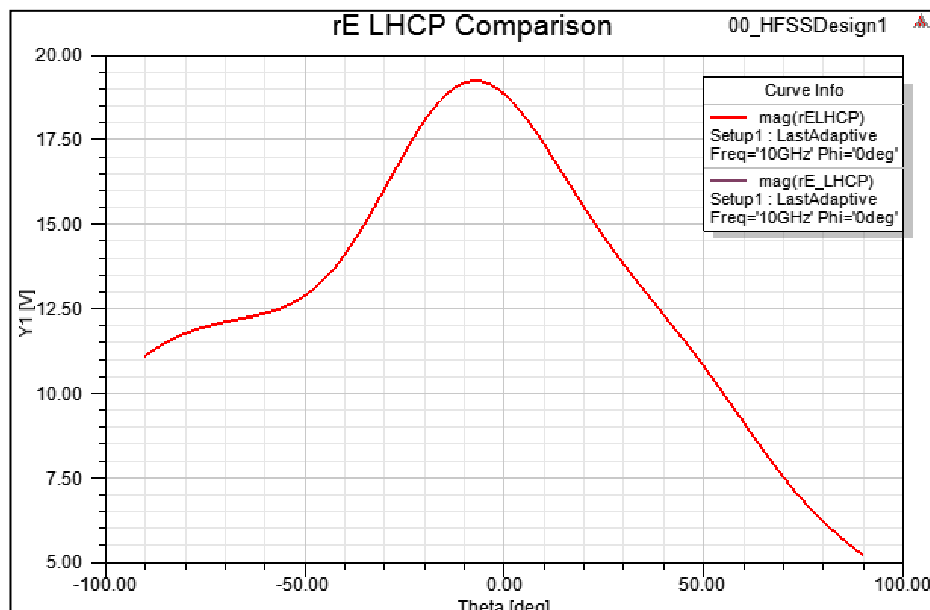


# Comparing rELHCP Calculations

- **Create rE_LHCP Output Variable Plot**
  - Define the trace that will be plotted
    - Click the **Trace** Tab
      - Solution: **Setup1: LastAdaptive**
      - Geometry: **Infinite Sphere1**
      - Primary Sweep: **Theta**
      - Category: **Output Variables**
      - Quantity: **rE_LHCP**
      - Function: **mag**
    - Click the **Families** Tab
      - Make sure **Phi = 0deg** is selected.
  - Click **Add Trace** button
  - Click **Close** Button

- **Change Report Name**
  - In **Project Manager** window  select **XY Plot 1**
  - In Properties window:
    - Name: **rE LHCP Comparison**

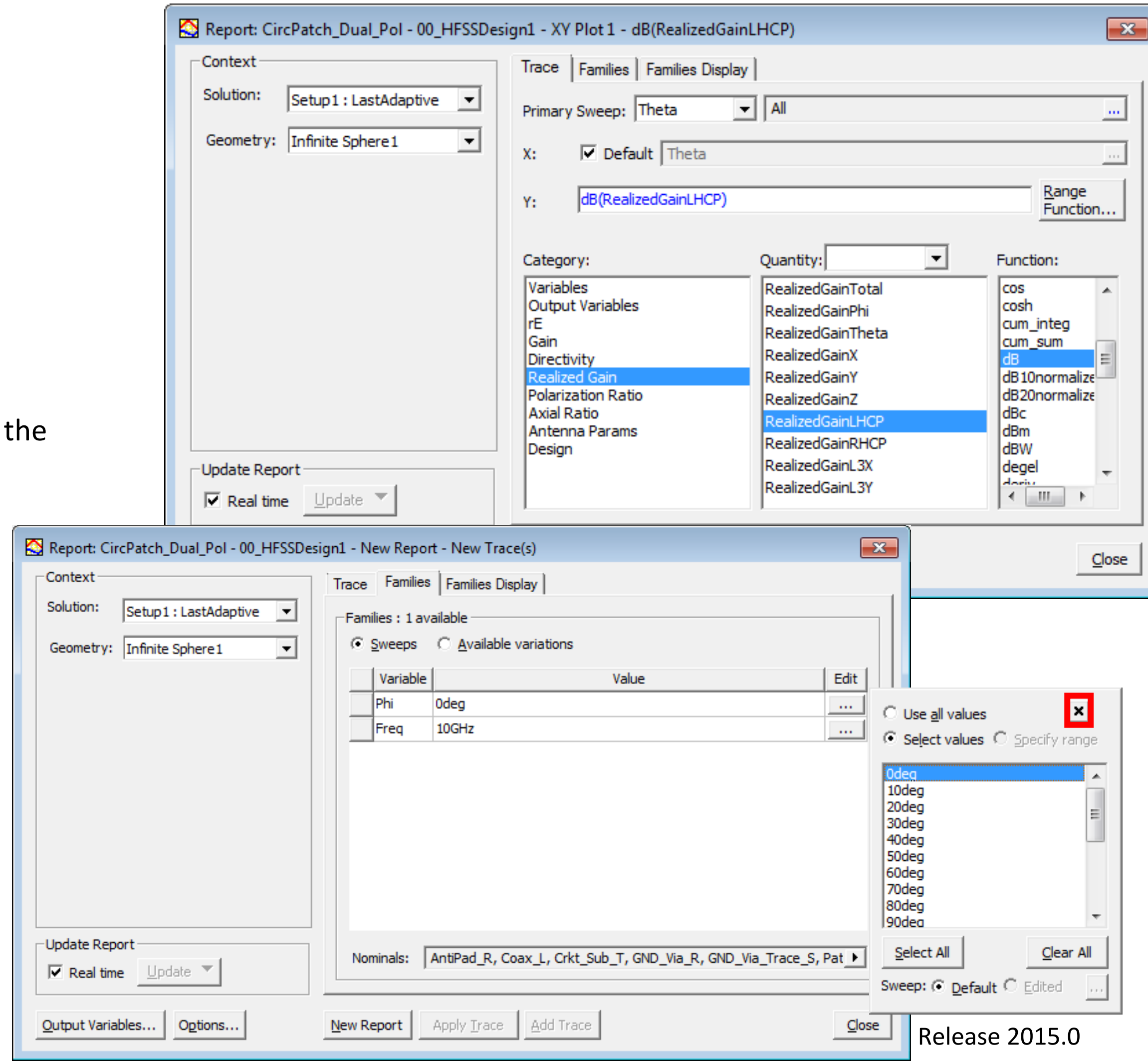



**Note:** The quantity rELHCP HFSS calculates agrees with the Output Variable rE_LHCP verifying how this quantity is derived.

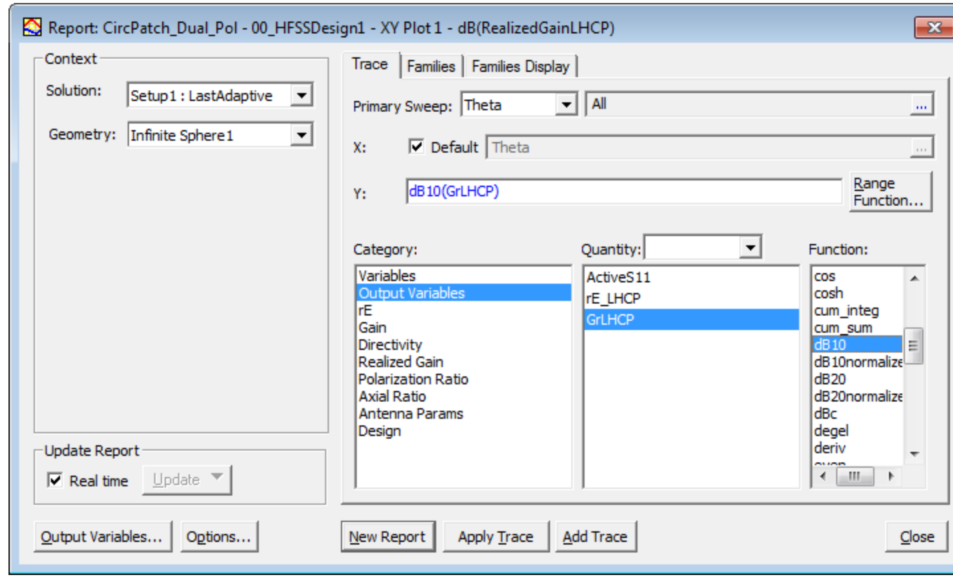
# Comparing rELHCP Calculations

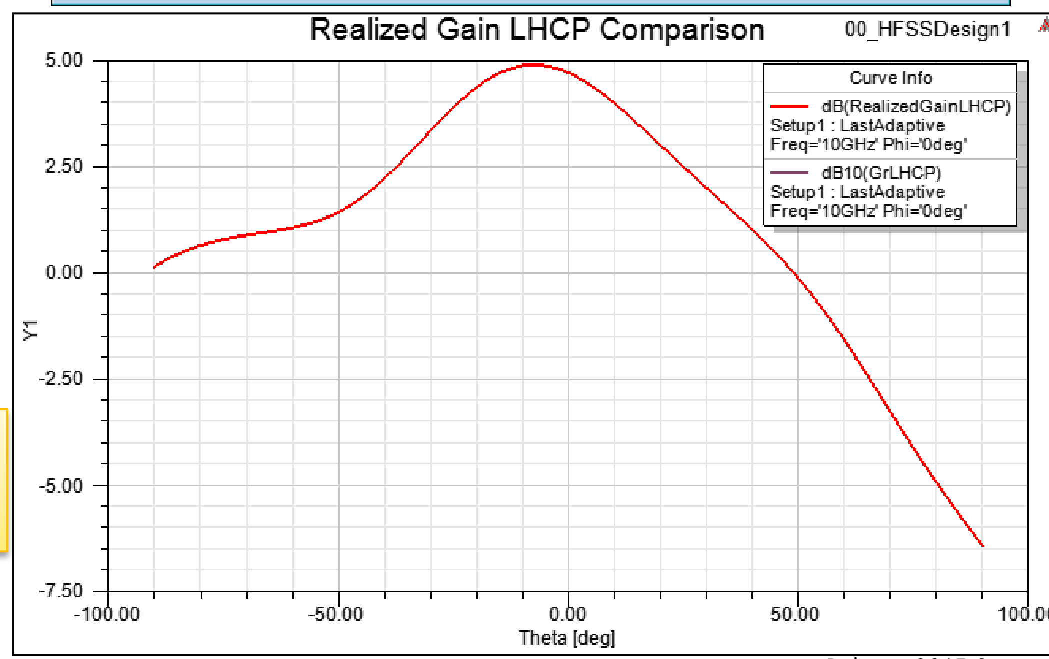
- **Create RealizedGainLHCP Plot**
  - Select the menu item ***HFSS > Results > Create Far Fields Report > Rectangular Plot***
  - Define the trace that will be plotted
    - In the **Trace** Tab
      - Solution: **Setup1: LastAdaptive**
      - Geometry: **Infinite Sphere1**
      - Primary Sweep: **Theta**
      - Category: **Realized Gain**
      - Quantity: **RealizedGainLHCP**
      - Function: **dB**
    - Click the **Families** Tab
      - Select the **Edit** Button associated with the **Phi** variable.
      - Click on **0deg** in pop-up window.
      - Close the pop-up window by selecting the **X** button.
  - Click **New Report** button



# Comparing rELHCP Calculations

- **Create GrLHCP Output Variable Plot**
  - Define the trace that will be plotted
    - Click the **Trace** Tab
      - Solution: **Setup1: LastAdaptive**
      - Geometry: **Infinite Sphere1**
      - Primary Sweep: **Theta**
      - Category: **Output Variables**
      - Quantity: **GrLHCP**
      - Function: **dB10**
    - Click the **Families** Tab
      - Make sure that **Phi = 0deg** is selected.
  - Click **Add Trace** button
  - Click **Close** Button
- **Change Report Name**
  - In Project Manager window select **XY Plot 1**
  - In Properties window:
    - Name: **Realized Gain LHCP Comparison**

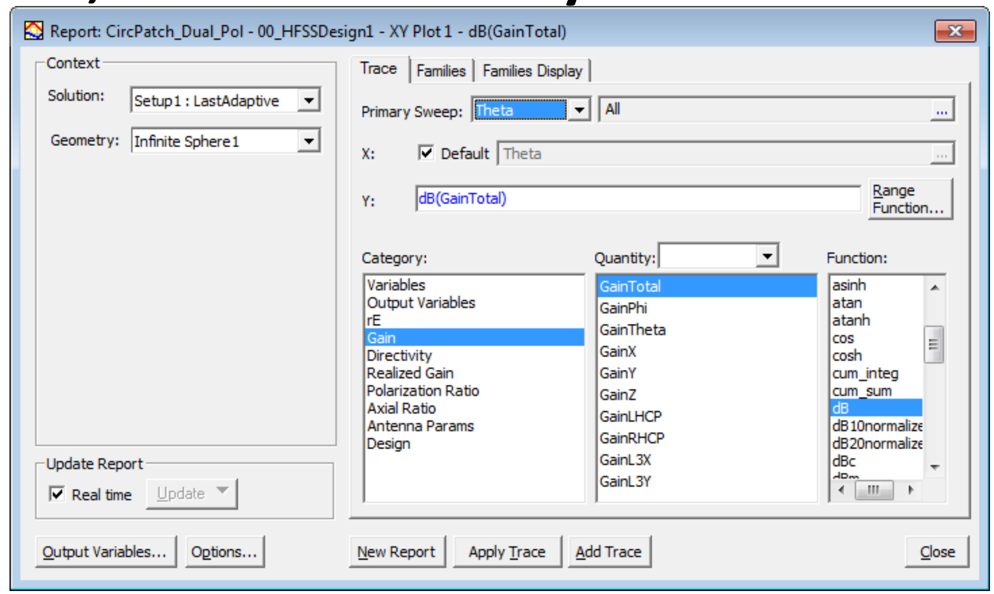


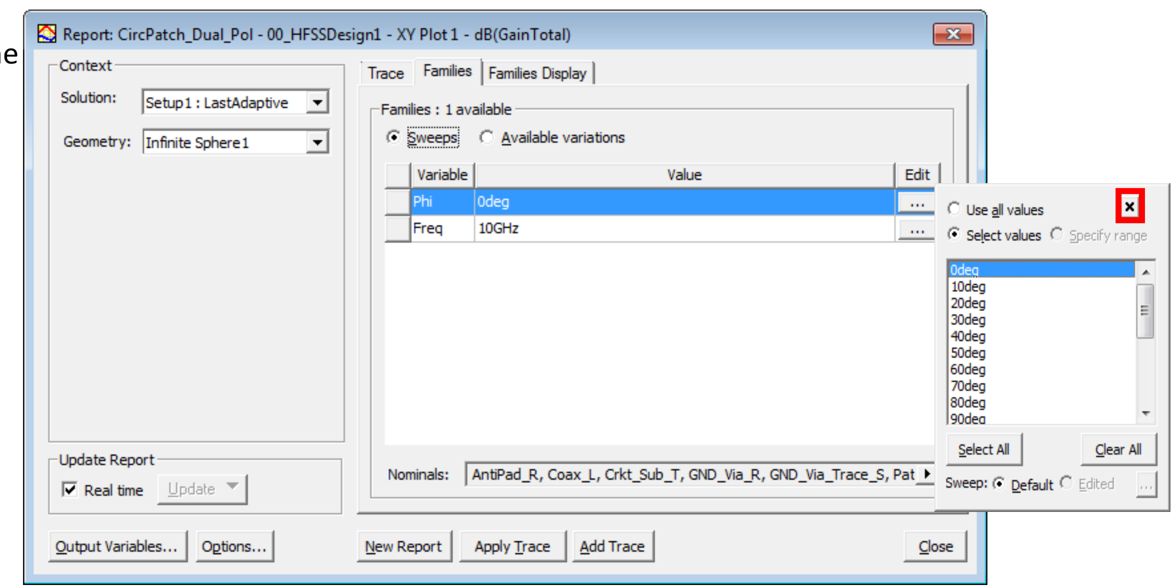




**Note:** The quantity RealizedGainLHCP HFSS calculates agrees with the Output Variable GrLHCP verifying how this quantity is derived.

# Comparing Realized Gain, Gain & Directivity

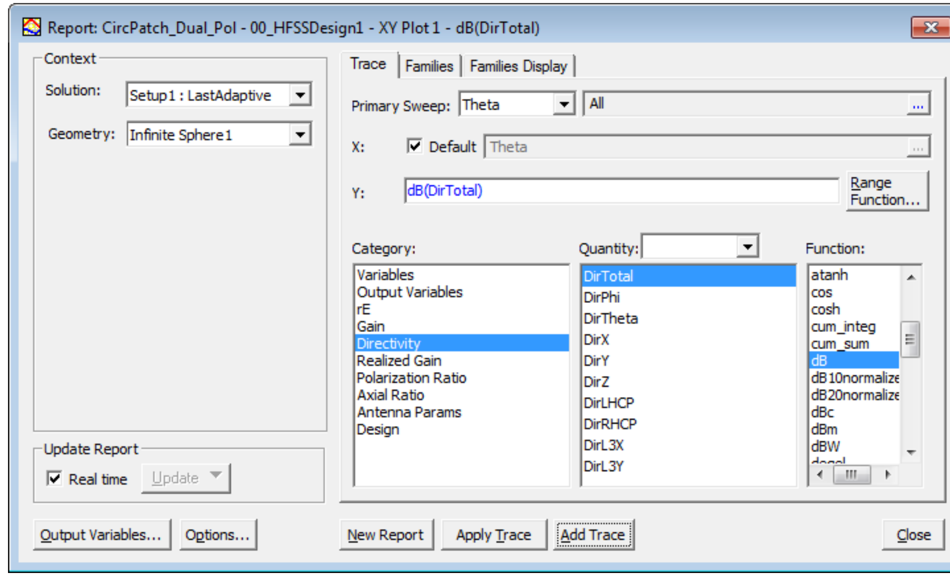
- **Create Gain Pattern Plot**
  - Select the menu item ***HFSS > Results > Create Far Fields Report > Rectangular Plot***
  - Define the traces that will be plotted
    - In the **Trace** Tab
      - Solution: **Setup1: LastAdaptive**
      - Geometry: **Infinite Sphere1**
      - Primary Sweep: **Theta**
      - Category: **Gain**
      - Quantity: **GainTotal**
      - Function: **dB**
    - Click the **Families** Tab
      - Click the **Edit** Button associated with the **Phi** variable.
      - Click on **0deg** in pop-up window.
      - Close the pop-up window by selecting the **X** button.
  - Click **New Report** button

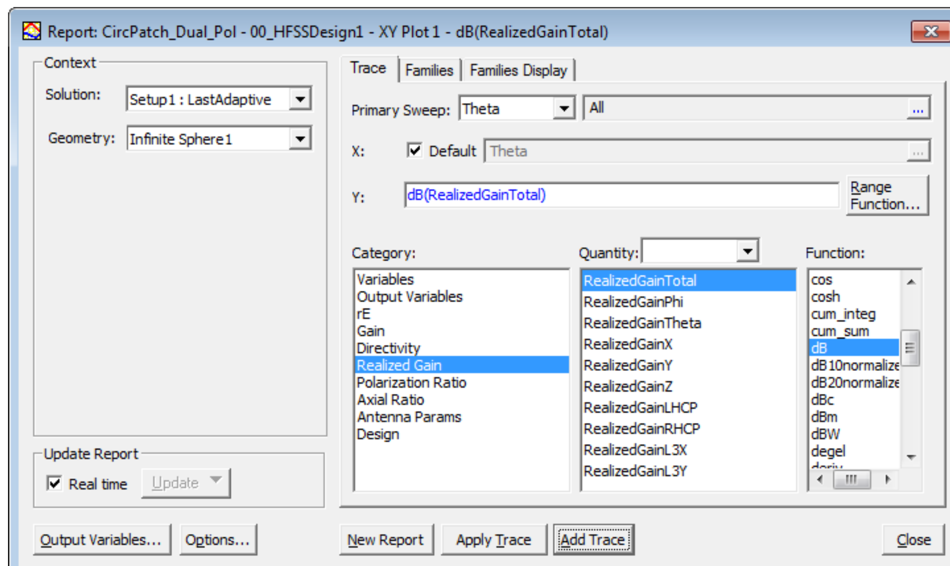


# Comparing Realized Gain, Gain & Directivity

- **Add Directivity Pattern to the Plot**
  - Define the traces that will be plotted
    - Click the **Trace** Tab
      - Category: **Directivity**
      - Quantity: **DirTotal**
      - Function: **dB**
  - Click **Add Trace** button
- **Add Realized Gain Pattern to the Plot**
  - Define the traces that will be plotted
    - In the **Trace** Tab
      - Category: **Realized Gain**
      - Quantity: **RealizedGainTotal**
      - Function: **dB**
  - Click **Add Trace** button
  - Click **Close** button
- **Change Report Name**
  - In **Project Manager** window select **XY Plot 1**
  - In **Properties** window:
    - Name: **Pattern Comparison**



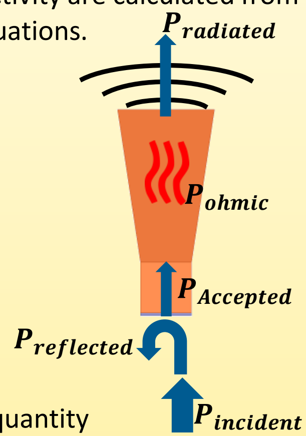
# Comparing Pattern Quantities

**Note:** Gain, Realized Gain and Directivity are calculated from the Far-Field solution using the following equations.

$$RealizedGain = \frac{2\pi\left|\overrightarrow{rE}\right|^2}{\eta P_{incident}}$$

$$Gain = \frac{2\pi\left|\overrightarrow{rE}\right|^2}{\eta P_{accepted}}$$

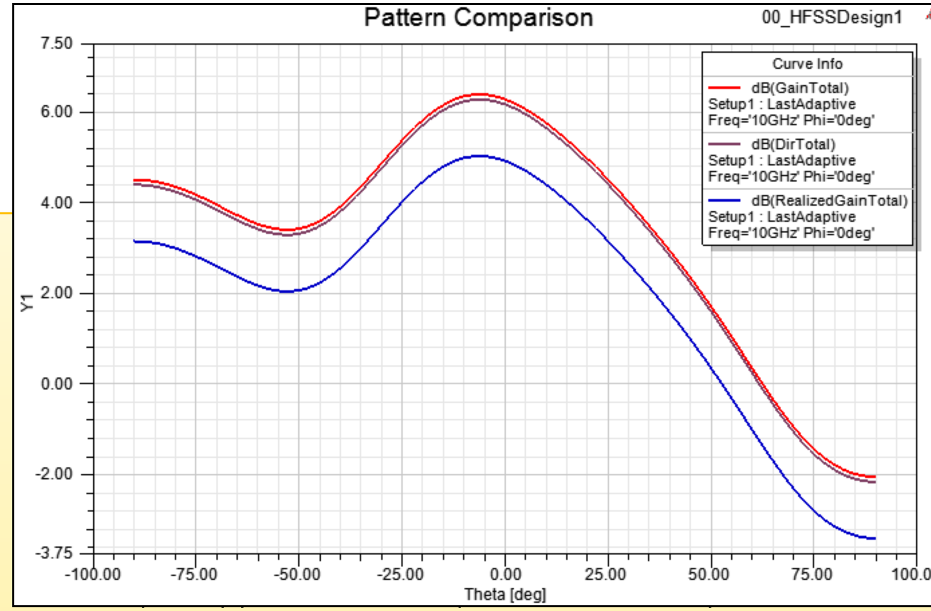
$$\text{Directivity} = \frac{2\pi\left|\overrightarrow{rE}\right|^2}{\eta P_{radiated}}$$




In the above equations:

- **rE** is the normalized Far-Field quantity
- **η** is the wave impedance of a plane wave in free space (approx. 377ohms)
- $P_{incident}$ is the power incident toward the ports as defined in Edit Sources
- $P_{accepted}$ is the power accepted by the antenna
- $P_{radiated}$ is the power radiated out of the antenna.

Since the only difference between these equations is the power rE is normalized by, each of these plots will have the same shape (in dB). They only differ in what losses are considered when calculating their strength. Realized Gain will lose strength if the antenna is poorly matched to its feed where gain and directivity will look the same regardless of the feed's match. Realized Gain and Gain will lose strength if the antenna has more internal losses ($P_{ohmic}$) where directivity will not be affected.




included in the pattern and which losses you carry separately.

**Note:** The plot indicates Gain is stronger than Directivity. This implies that the radiated power is stronger than the accepted power which doesn't make sense. This occurs because the antenna is pretty close to being lossless to begin with.

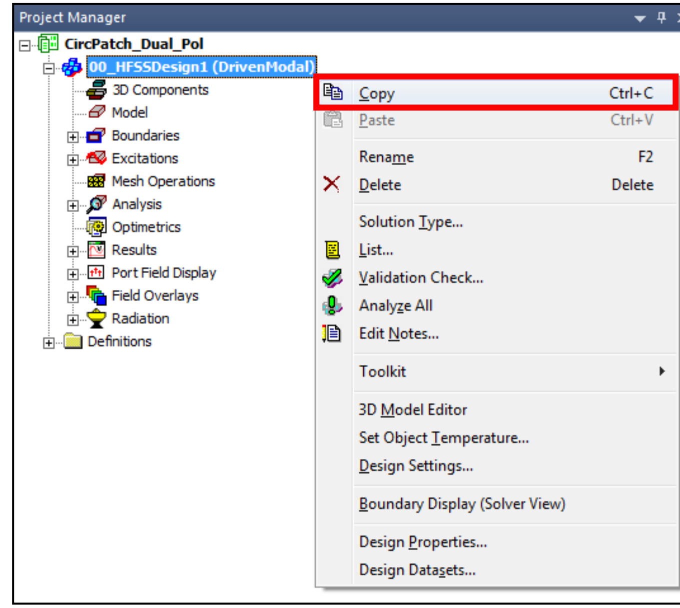
$$\boldsymbol{G - D = -0.0877dB}$$

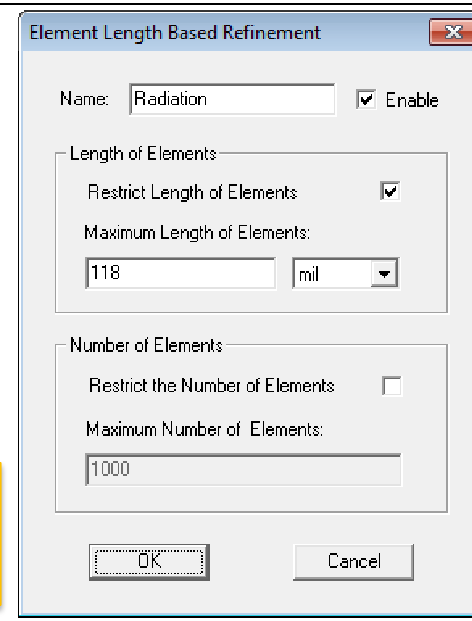
So even a slight error in the radiated power calculation is enough to push the antenna efficiency above 100%. If this slight error is of concern the surface used to perform the far-field integration can be seeded to produce a more accurate field representation and produce the expected result. However, keep in mind, that if the antenna had a little more loss this wouldn't have even of been an issue or even noticed.

# Seed the Far-Field Integration Surface

- **Create a Copy of the Design to Work with**
  - In the **Project Manager** window, Right-click on the **00_HFSSDesign1 (DrivenModal)** Design icon and Select **Copy**
  - In the **Project Manger window,** Right-click on the **CircPatch_Dual_Pol** Project icon and Select **Paste**
  - Double-click on the new design **00_HFSSDesign2**
  - In the **3D Modeler Tree** expand the **Lines** Branch
  - Right-click on **Polyline3** and select ***View > Hide in Active View***
  - Select the menu item ***View > Fit All > Active View*** to zoom onto the antenna geometry
- **Select the Integration Surface**
  - In the **00_HFSSDesign2 (DrivenModal)** project expand the **Boundaries** branch
  - Right-click on **Rad1** and choose **Select Assignment**
- **Apply a Length Based Seed**
  - Select the menu item ***HFSS > Mesh Operations > Assign > On Selection > Length Based…***
  - Define the Mesh Operation
    - Name: **Radiation**
    - Maximum Length of Elements: **118mil**
    - Click the **OK** button

**Note:** 118mils is equivalent to Lambda/10 at 10GHz. This will force the tetrahedral edges on this surface to be at most one tenth of a wavelength long produces a more refined far-field calculation.



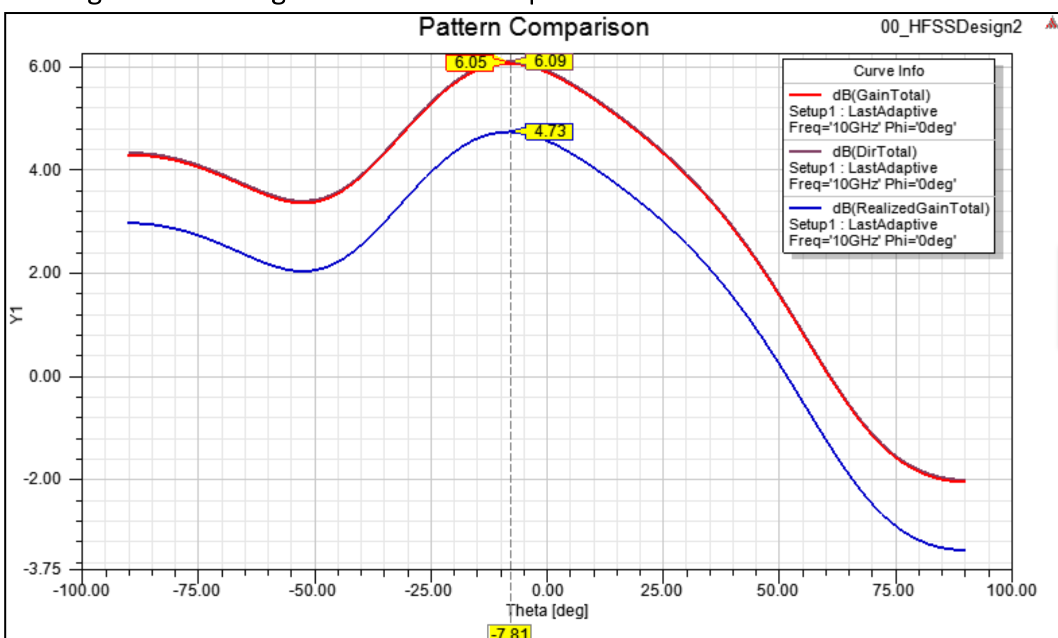

  

# Updated Radiation Patterns

- **Run the Analysis**
  - From the **00_HFSSDesign2 (DrivenModal)** Project Manager, expand the **Analysis > Setup1 > Sweep** branch.
  - Right-click on **Sweep** and select **Disable Sweep** from the pop-up window
  - Select the menu item ***HFSS > Analyze All***
  - After analysis is complete save the project
    - Select the menu item ***File > Save***

**Note:** We are only going to look at the radiation pattern for a single frequency so there is not need to run the Frequency Sweep. It is disabled to save time during the analysis.

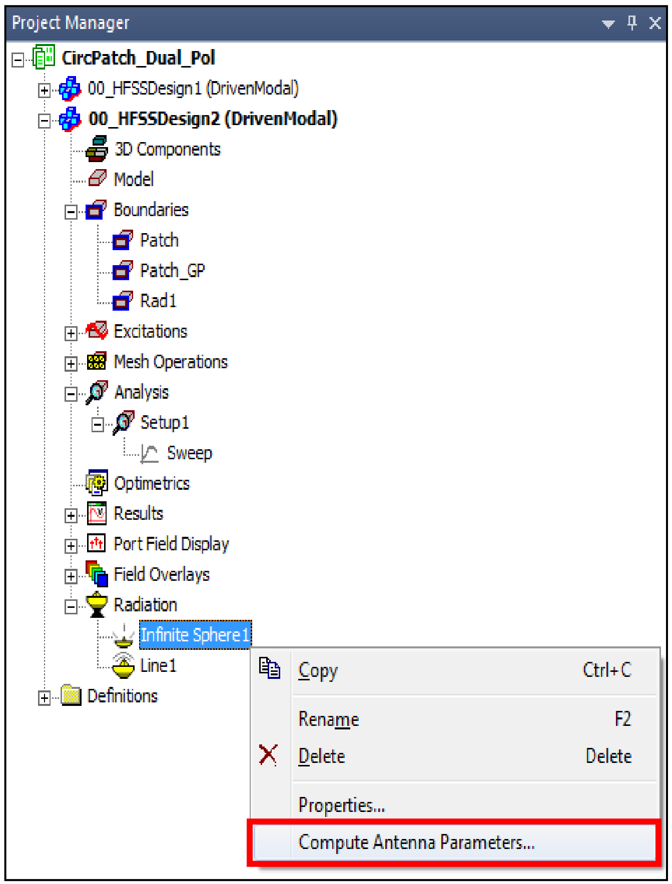
- **Review the Results**
  - From the **00_HFSSDesign2 (DrivenModal)** Project Manager, double-click on the **Results > Pattern Comparison**
  - Select the menu item ***Report2D > Marker > Add X Marker***
  - Drag the line along the X-axis for comparison

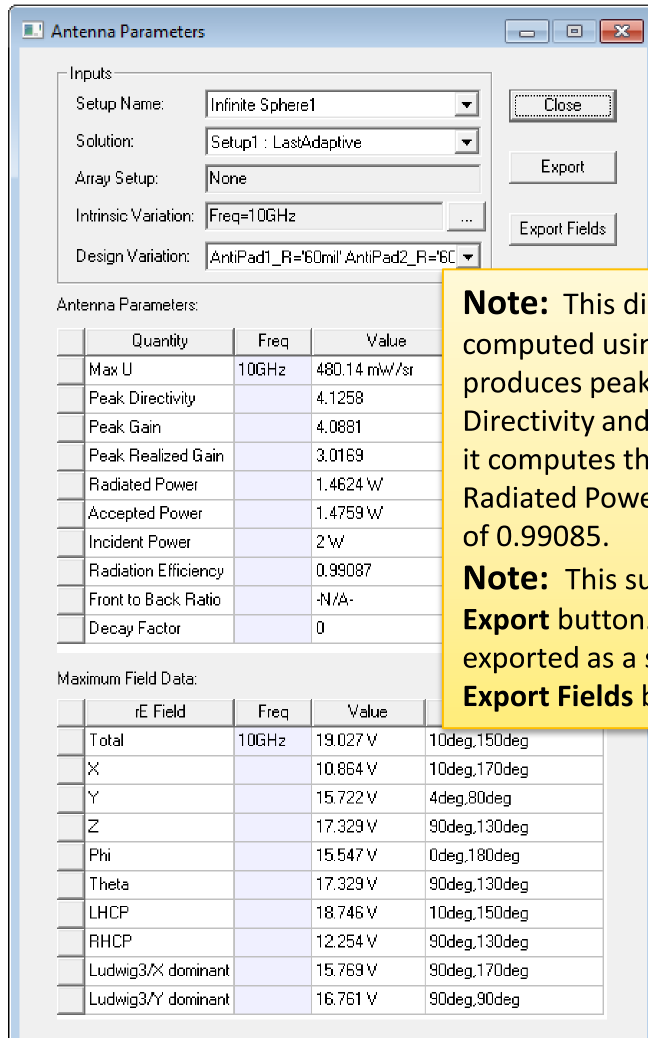



**Note:** The Directivity is now 0.04dB larger than the Gain making the comparison more intuitive.

# Compute Antenna Parameters Dialog

- **Compute Summary of Far-Field Solutions**
  - From the Project Manager, Right-click on **00_HFSSDesign2 (DrivenModal) > Radiation > Infinite Sphere1**
  - Select **Compute Antenna Parameters...**




**Note:** This dialog summarizes the far-field data computed using the Infinite Sphere1 setup. It produces peak values for Realized Gain, Gain, Directivity and Radiation Intensity $|rE|^2$. In addition, it computes the Incident Power, Accepted Power, Radiated Power and efficiency. Notice the efficiency of 0.99085.

**Note:** This summary can be exported using the **Export** button. The Far-Field pattern can be exported as a space delimited text file using the **Export Fields** button.

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