HFSS Antenna WS 5.1

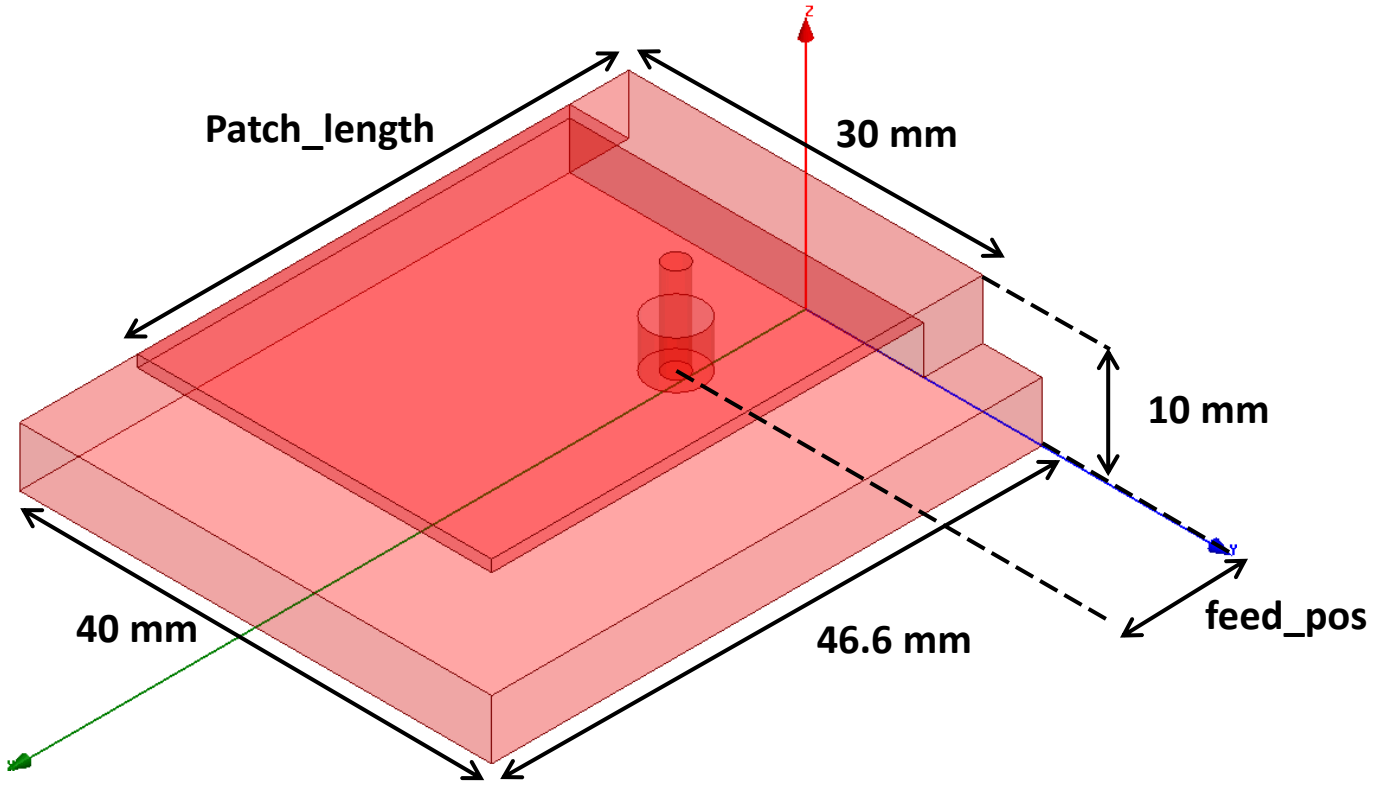
Workshop 5.1: Antenna Optimetrics

Ansys HFSS for Antenna Design

Release 2021R1

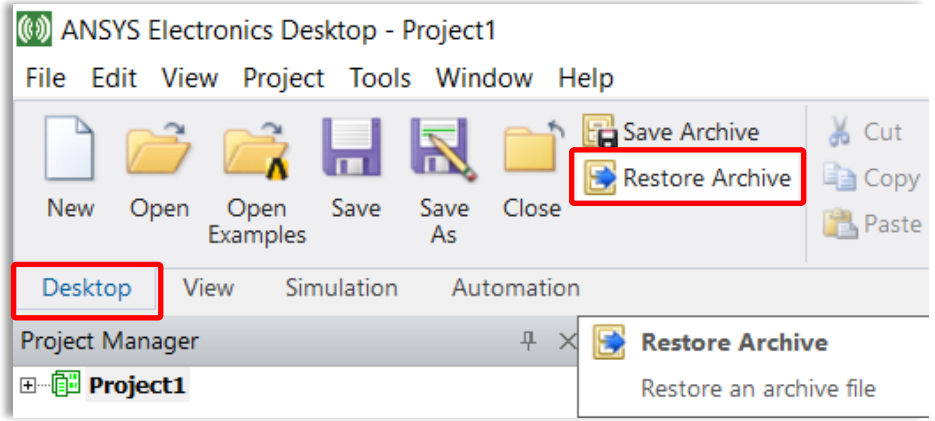
Probe-Fed Patch Antenna with Optimetrics

- This example shows how to set up a parametric study, optimize, and simulate the Analytic Derivatives of a probe-fed patch antenna using Ansys HFSS in the Ansys Electronic Desktop (AEDT).
- A parametric sweep will be used to determine the effect on the input impedance match as a function of the feed pin position.
  - This parametric sweep will be used to seed an optimization analysis to find the optimal position for the feed pin.
  - Analytic Derivatives will also be used to perform real time tuning of the feed position of the probe (feed_pos).



Restore Archive and Save Optimetrics_Patch1.aedt

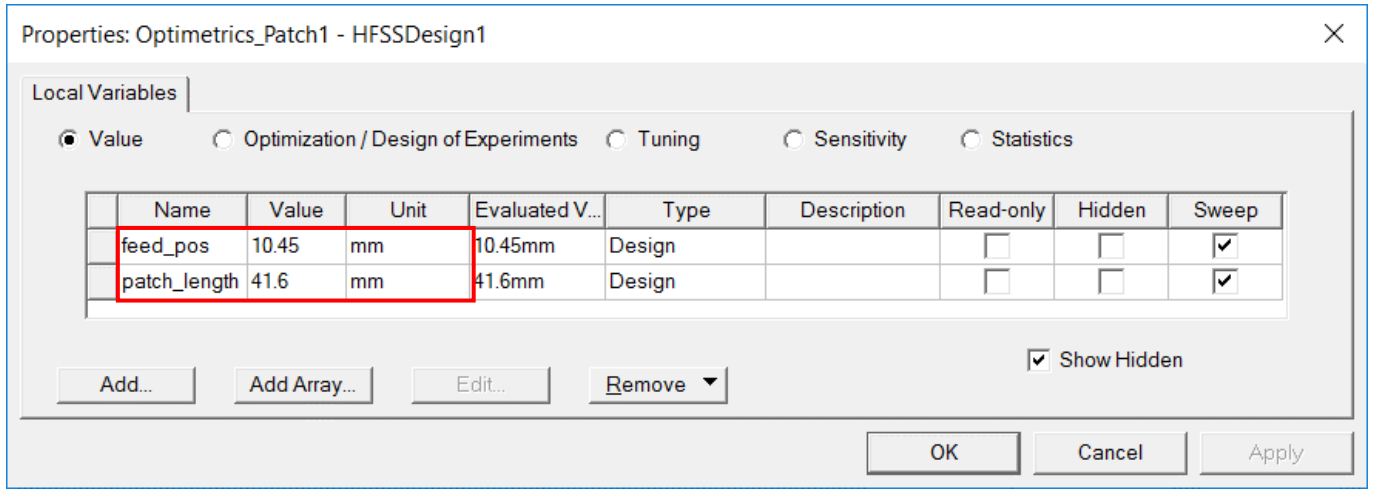
- In the ribbon, in the **Desktop** tab, selected: ***Restore Archive*** to bring up the ***Archive to Restore*** search browser.
- Browse to the training files location and select: **Optimetrics_Patch.aedtz**.
- Click ***Open***
- Save the file as **Optimetrics_Patch1.aedt**.

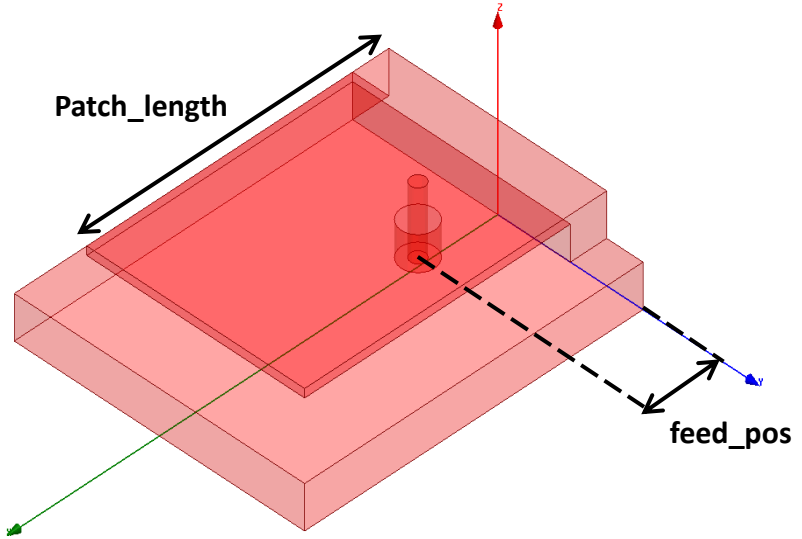


FileName.aedtz indicates an archive, where ***FileName.aedt*** indicates the usual Ansys Electronics Desktop file extension.

Checking *Local Variables* feed_pos and patch_length

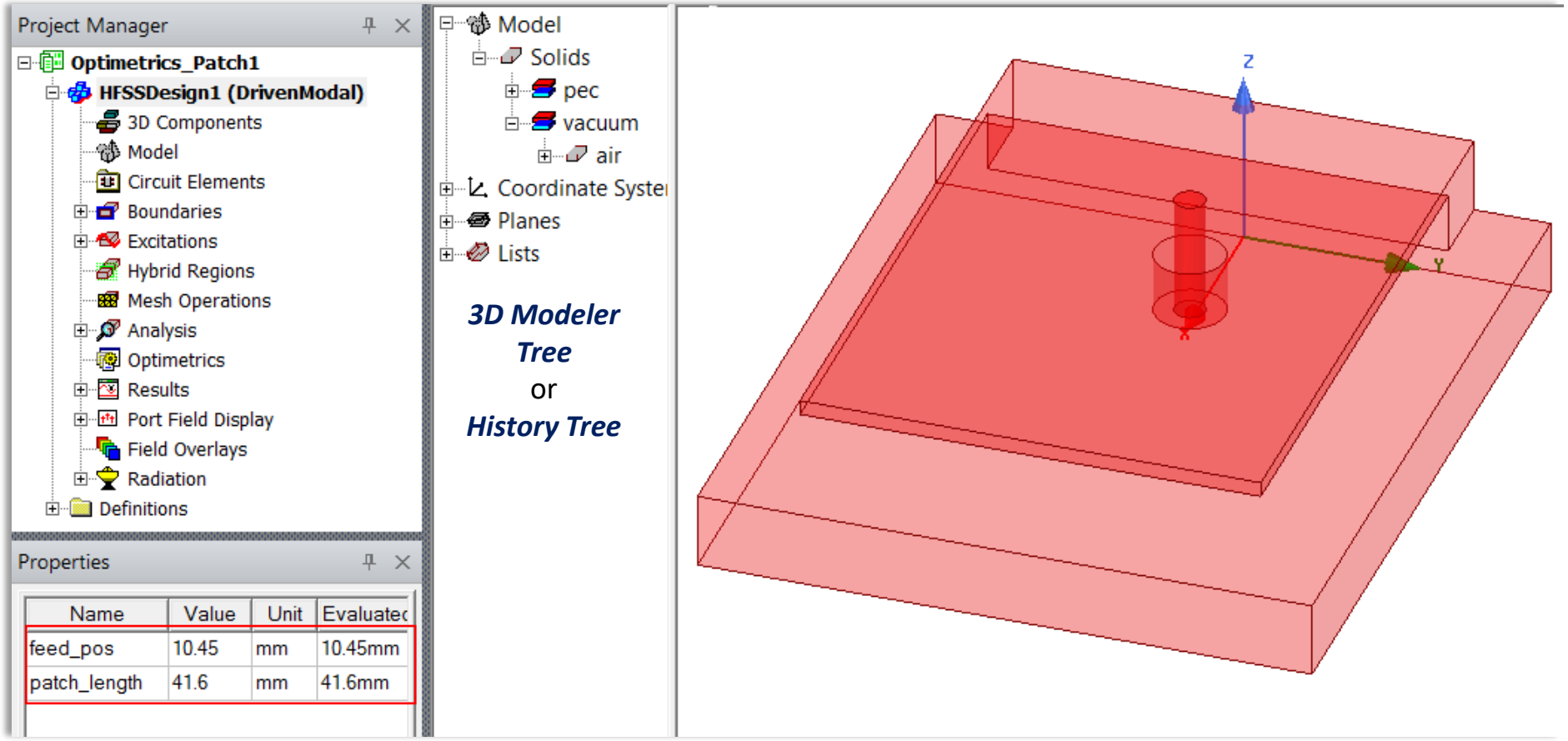
- There are two design variables that have been created. They control the location of the feed of the patch antenna, **feed_pos** in X, and the length of the patch, **patch_length** in X.
- To view a list of any design variables that have been created for this design:
  - Go to the menu item ***HFSS > Design Properties.***
  - Verify that the variable **feed_pos** is assigned the value **10.45 mm.**
  - Verify that the variable **patch_length** is assigned the value **41.6mm.**
  - Press the ***OK*** button.





Design Variables are *Local Variables*

- Alternatively, in the ***Project Manager,*** click on the design name **HFSSDesign1**. The design variables will be displayed in ***Properties***. Think ***local*** to this ***design*** to understand this equivalence in terms.

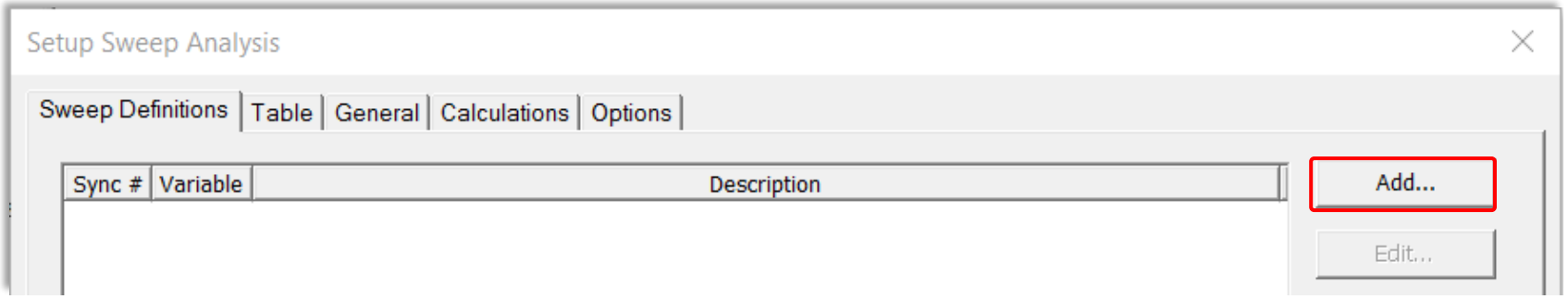


To get this view of the antenna, in the ***3D Modeler Tree,*** right-click on ***air*** and select ***Hide in Active View.***

Start Parametric Analysis Setup

- **Parametric Sweep of Feed Position feed_pos**
  - We will now complete the parametric project simulation setup using the defined variable **feed_pos** to vary the coaxial feed position in order to achieve optimal match between the patch antenna and its coaxial feed line. The ratio of the coaxial feed inner and outer diameters was chosen to achieve a 50 Ohm characteristic impedance. We will change the value of the feed offset location until we find a position which presents a 50 Ohm load impedance to the coaxial feed line.
- **Create Parametric Sweep**
  - In the ***Project Manager***, right-click on ***Optimetrics*** and select ***Add > Parametric...***
    - In in the ***Setup Sweep Analysis*** window, click the ***Add...*** button to open the ***Add/Edit Sweep*** window

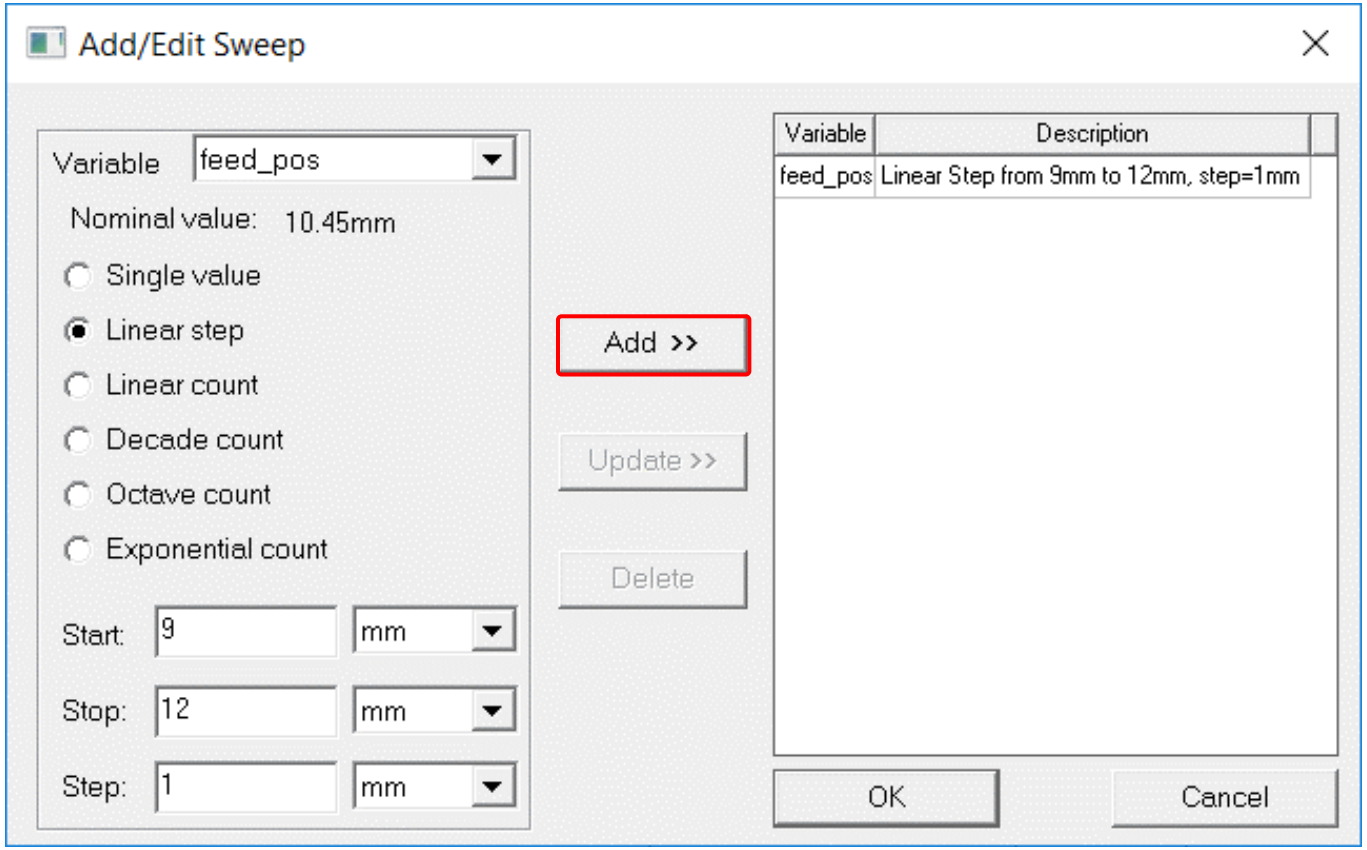
...continued...



Parametric Analysis Setup - *Add/Edit Sweep*

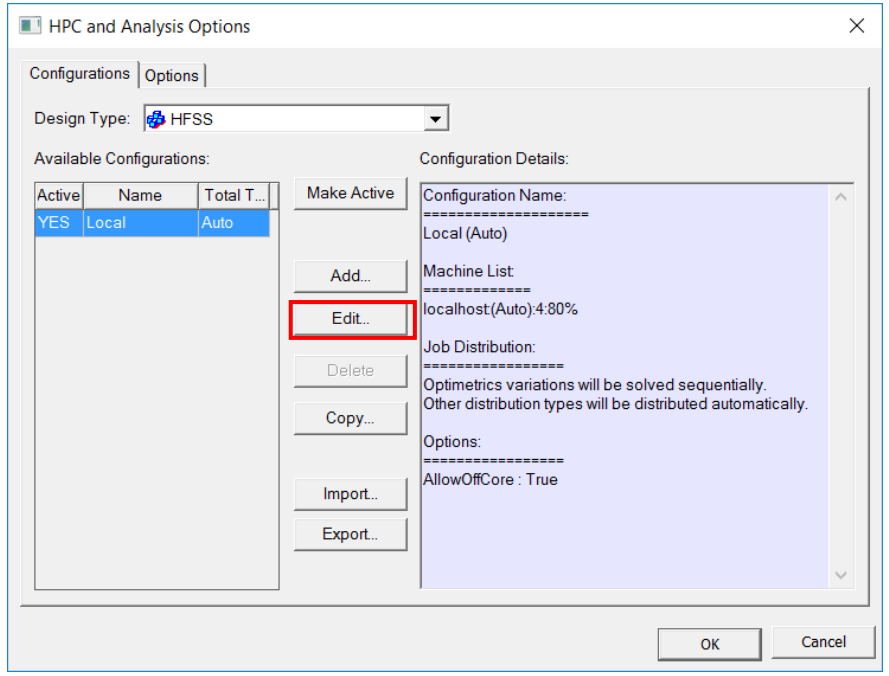
Creating the Parametric Sweep for *feed_pos*

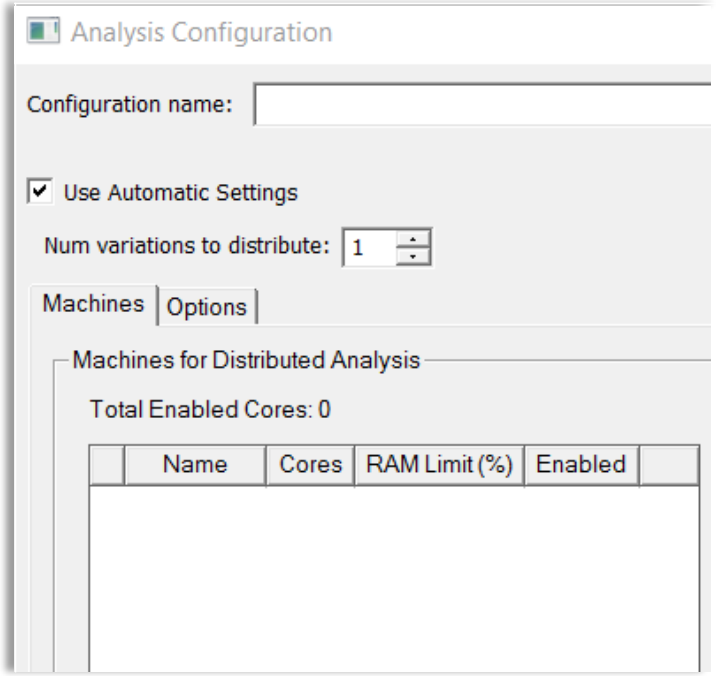
- In the ***Add/Edit Sweep*** window:
  - Select the ***Variable* feed_pos**
  - Select ***Linear Step***
    - ***Start: 9mm***
    - ***Stop: 12mm***
    - ***Step: 1mm***
    - Click the ***Add>>*** button
    - Click the ***OK*** button to close the ***Add/Edit Sweep*** dialog box.
  - Click the ***OK*** button to close the ***Setup Sweep Analysis*** window.



HPC and Analysis Options

- **High Performance Computing Configuration**
  - Parametric sweeps can be accelerated by solving multiple variations of a design in parallel. The HPC ***Analysis Configuration*** allows us to specify the number of cores and the number of tasks we would like to run. The number of tasks will correspond to the number of parametric variations or frequency points to run in parallel.
- **Configuring HPC Settings**
  - Select the menu item ***Tools > Options > HPC and Analysis Options...***
  - In the ***Configurations*** tab, click ***Edit*** button to bring up the ***Analysis Configuration*** dialog box.

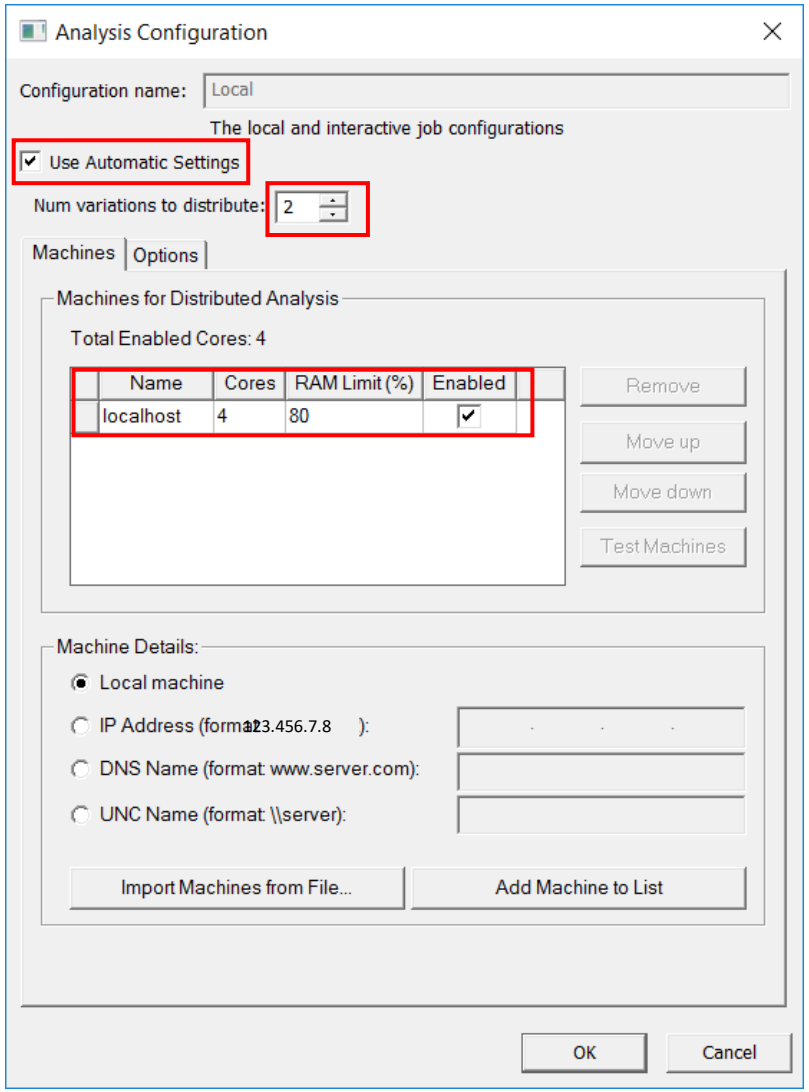




See Also:
High Performance Computing section in ***HFSS Help*** documentation.

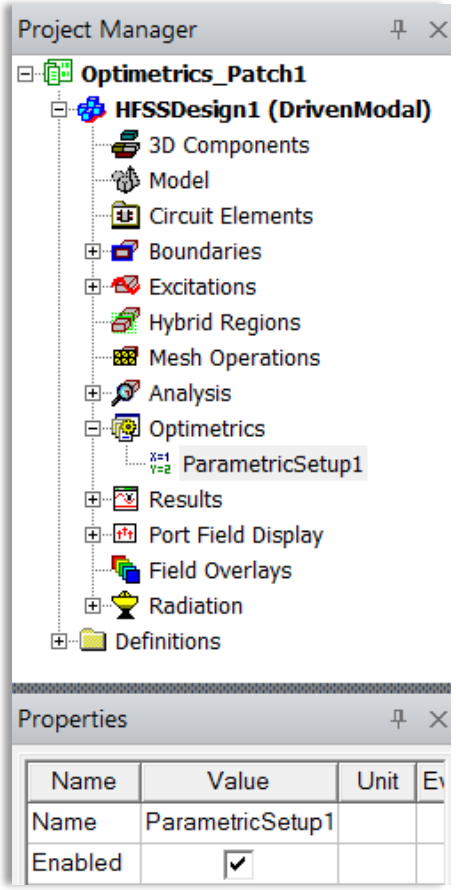
HPC: Analysis Configuration - Analyze Optimetrics_Patch1

- **In the *Analysis Configuration* window**
  - *Use **Automatic Settings***: ☑ ***Checked***
  - ***Num variations to distribute: 2***
  - change or verify the following in the ***Machines*** tab:
    - ***Name: localhost***
    - ***Cores: 4***
    - ***RAM Limit(%): 80***
    - ***Enabled***: ☑ ***Checked***
  - Click the ***OK*** button to finish and close ***Analysis Configuration*** window.
  - Click the ***OK*** button to close ***HPC*** *and* ***Analysis Options*** dialog box.

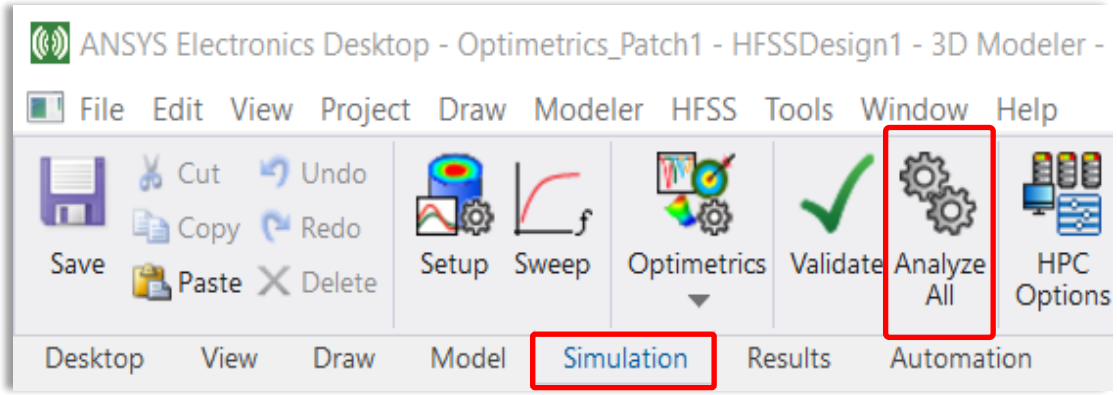


Note: ***Num variations to distribute*** refers to the number of parallel simulations to run for parametric and ***Optimetrics*** variations. With 4 total cores, this means 2 cores run each of those distributed simulations. The number of cores might vary with different computers.

Save, Validate, and Analyze HFSS Design Optimetrics_Patch1



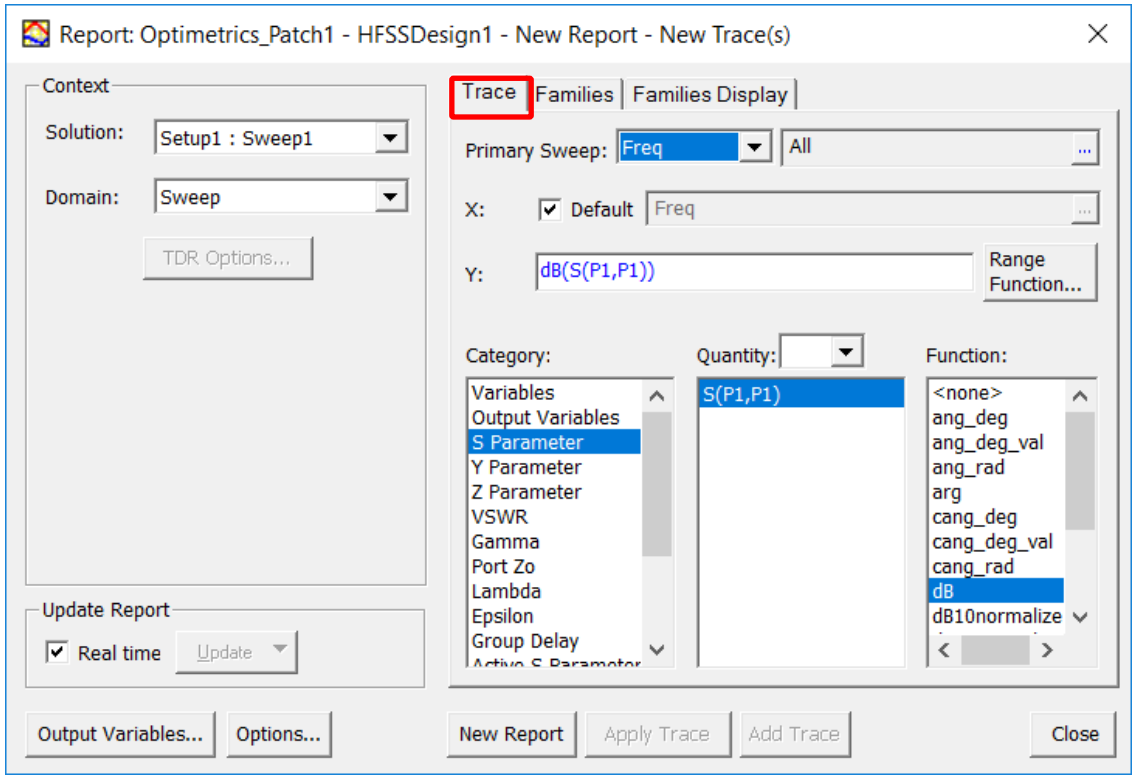
Note the* ParametricSetup1 *under Optimetrics.

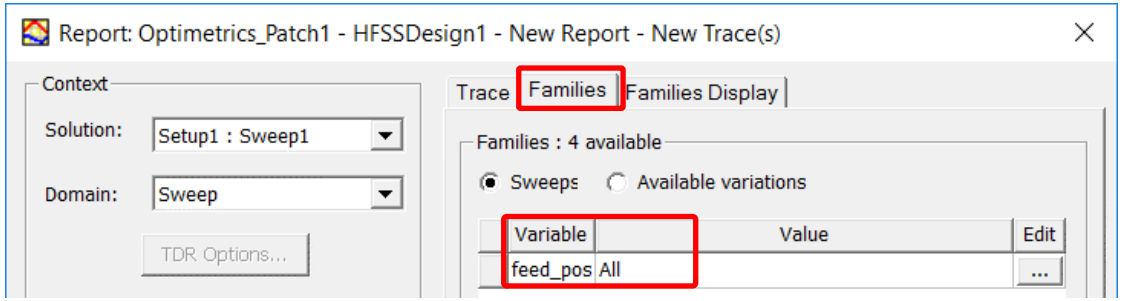


- In the ***Ribbon***, with the Simulation tab chosen, click the ***Validate*** green check mark to validate the project.
- Select ***File > Save***
- In the ***Project Manager***, under ***Optimetrics,*** right click on ***ParametricSetup1*** and select ***Analyze***.
- Select ***File > Save*** when the simulation finishes.

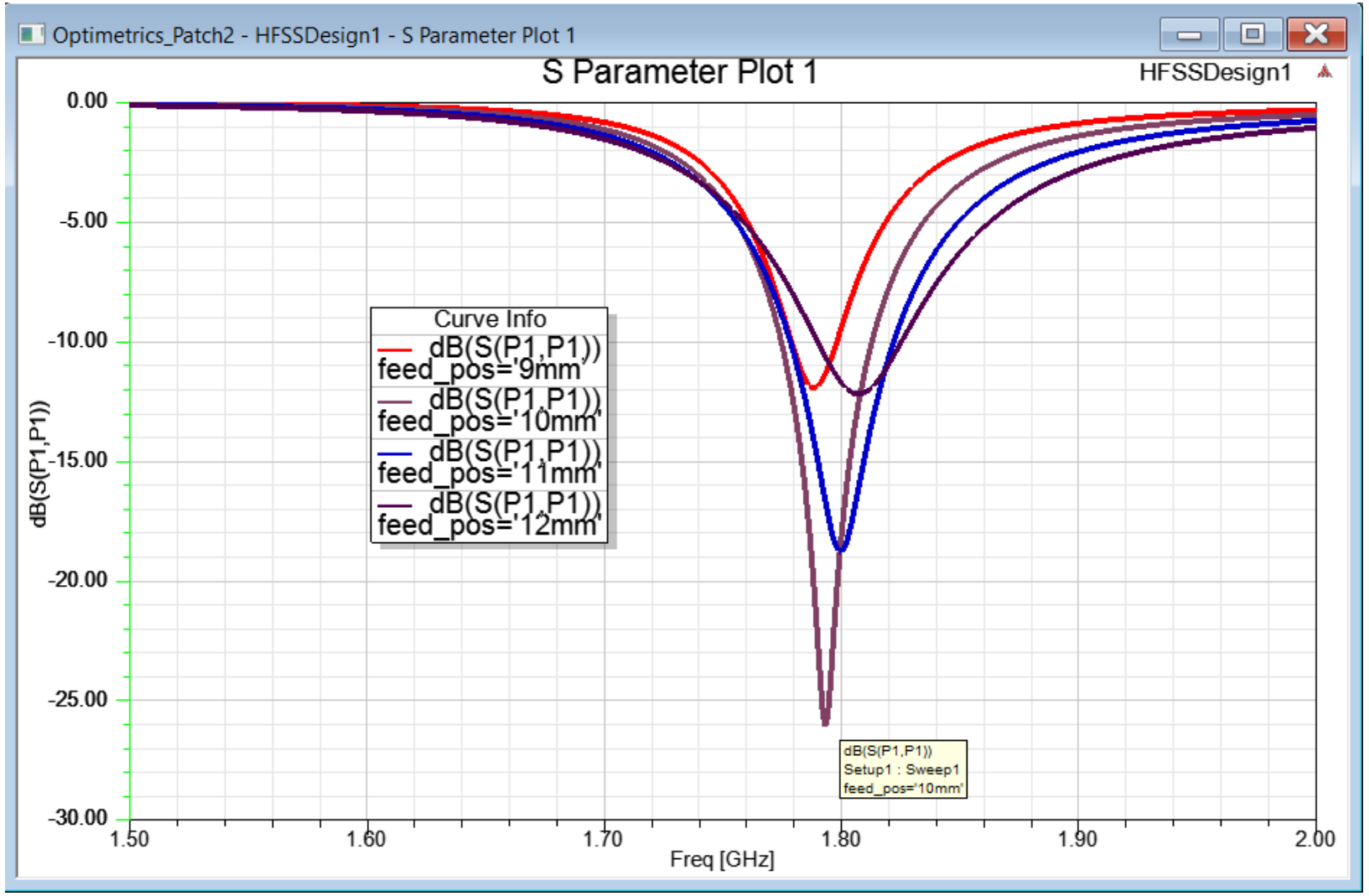
Create S-Parameter Plot for Optimetrics_Patch1 Variations

- In the ***Project Manager***, right-click on ***Results*** and select the menu item ***HFSS > Results > Create Modal Solution Data Report > Rectangular Plot***
  - ***Solution: Setup1:Sweep1***
  - ***Domain: Sweep***
  - In the ***Trace*** tab
    - ***Category: S Parameter***
    - ***Quantity: S(P1,P1)***
    - ***Function: dB***
  - Click the ***Families*** tab
    - Make sure the ***Value*** for variable **feed_pos** is selected to ***All.***
  - Click ***New Report*** button
  - Click ***Close*** button
  - Save project to **Optimetrics_Patch2**.





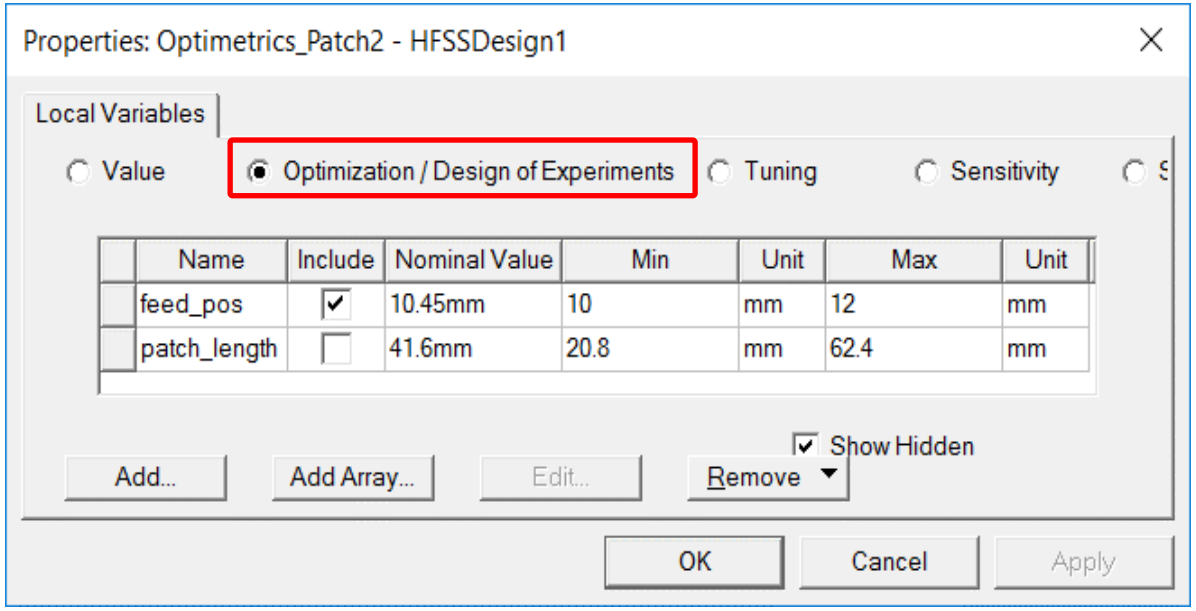
View S-Parameter Results - Optimetrics_Patch2



Start Optimization Analysis Setup - Optimization / DOE

- The ***Parametric Sweep*** was useful for generating design curves. We can use the design curves to make educated guesses at performance targets that are not contained in the ***Parametric Sweep.*** We will target a minimum of less than -20dB for S_{11} at 1.8GHz for this shorted patch antenna. From the ***Parametric Sweep*** results, we can see that the minimum return loss at 1.8 GHz will be achieved when the variable **feed_pos** is approximately **11mm.**

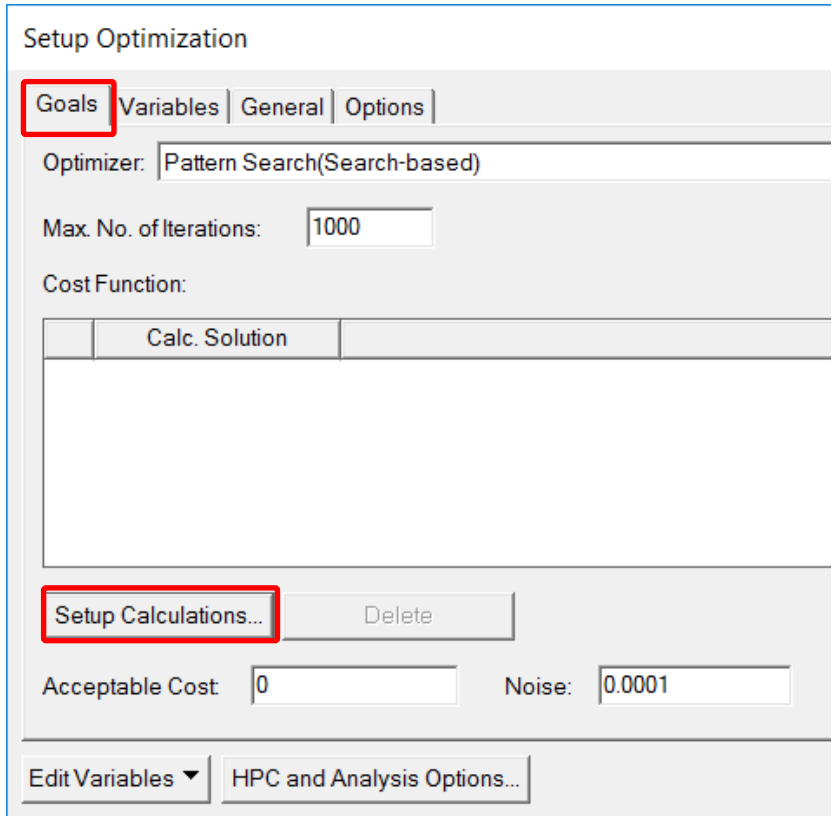
- **Setting Optimization / Design Of Experiments Properties**
  - Select the menu item ***HFSS > Design Properties…***
    - Click the ***Optimization / Design of Experiments*** radio button:
    - ***Name:*** **feed_pos**
    - ***Include:*** ☑ **Checked**
    - ***Min:*** **10 mm**
    - ***Max:*** **12 mm**
    - Click the ***OK*** button



Open Optimization Analysis Setup Dialog Box - Goals Tab

- In the ***Project Manager***, right-click on ***Optimetrics*** and select ***Add > Optimization…*** to bring up the ***Setup Optimization*** dialog box.
- In the ***Goals*** tab:
  - ***Optimizer: Pattern Search(Search-based)***
  - Click the ***Setup Calculations…*** button to bring up the ***Add/Edit Calculation*** dialog box.

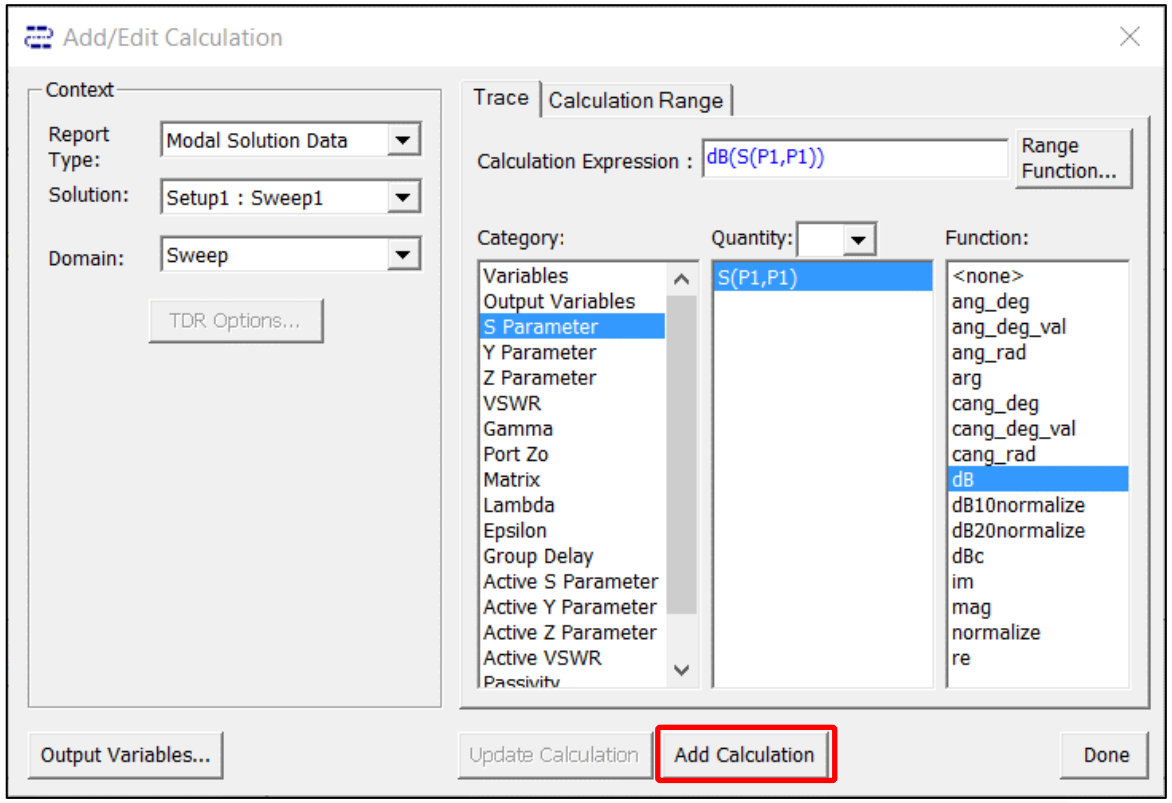
  …continued…

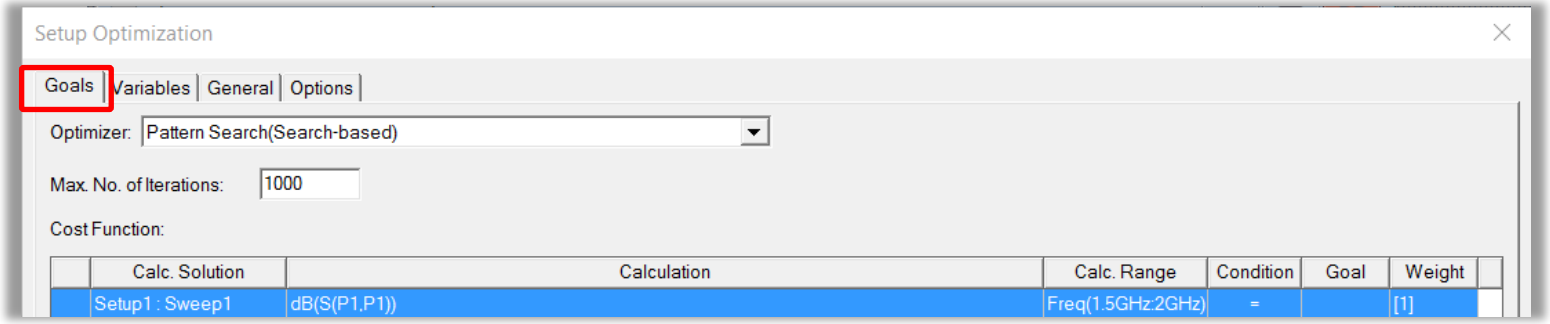


Optimization Setup *Add/Edit* Dialog Box - Optimetrics_Patch2

- In the ***Add/Edit Calculation*** dialog:
  - ***Report Type: Modal Solution Data***
  - ***Solution: Setup1: Sweep1***
  - ***Domain: Sweep***
  - ***Category: S Parameter***
  - ***Quantity: S(P1,P1)***
  - ***Function: dB***
  - Click the ***Add Calculation*** button
  - Click the ***Done*** button to close the ***Add/Edit Calculation*** dialog box

    (…and go back to the ***Setup Optimization*** dialog box)





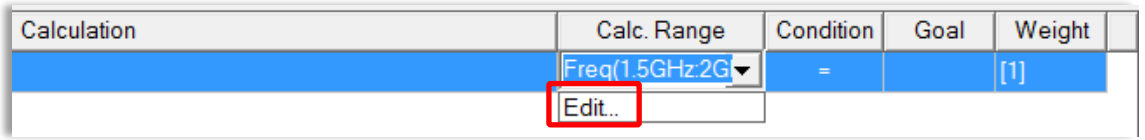
Optimization Setup Edit Calculation Range - Select 1.8 GHz

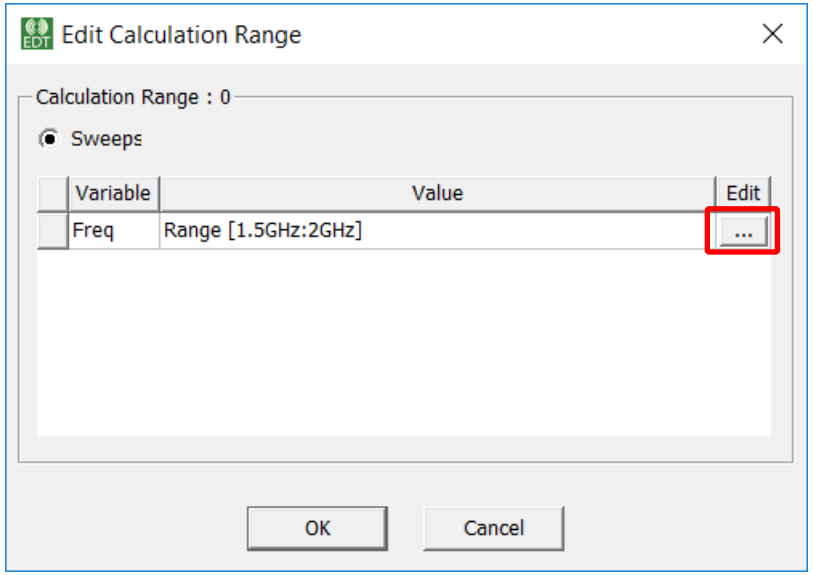
…back in the *Setup Optimization* dialog box,

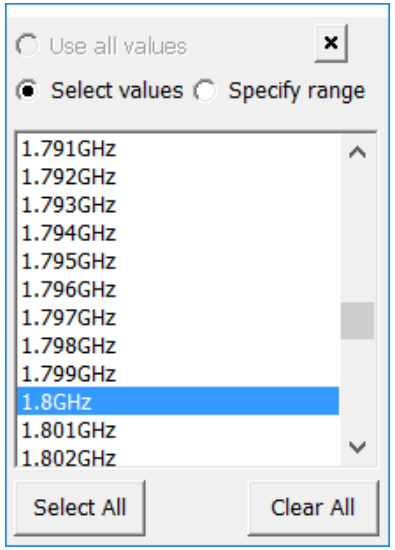
- Click the value under ***Calc. Range*** and select ***Edit…*** bringing up the ***Edit Calculation Range*** dialog box.
  - In the ***Edit Calculation Range*** window, Click the button ... below ***Edit***.
  - Click the ***Select values*** radio button and select **1.8GHz**
  - Click ***OK*** button to choose 1.8 GHz and close the ***Edit Calculation Range*** dialog box.

    (which takes back to the ***Setup Optimization*** dialog box)

    …continued…





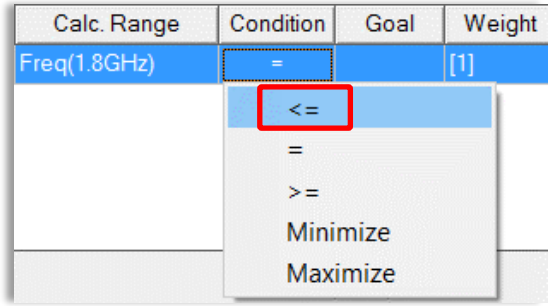


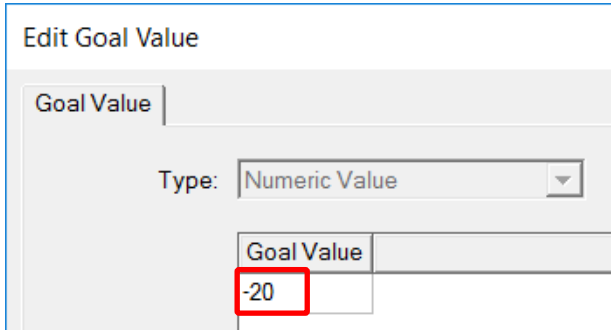
Optimization Setup Dialog Condition Goal Weight

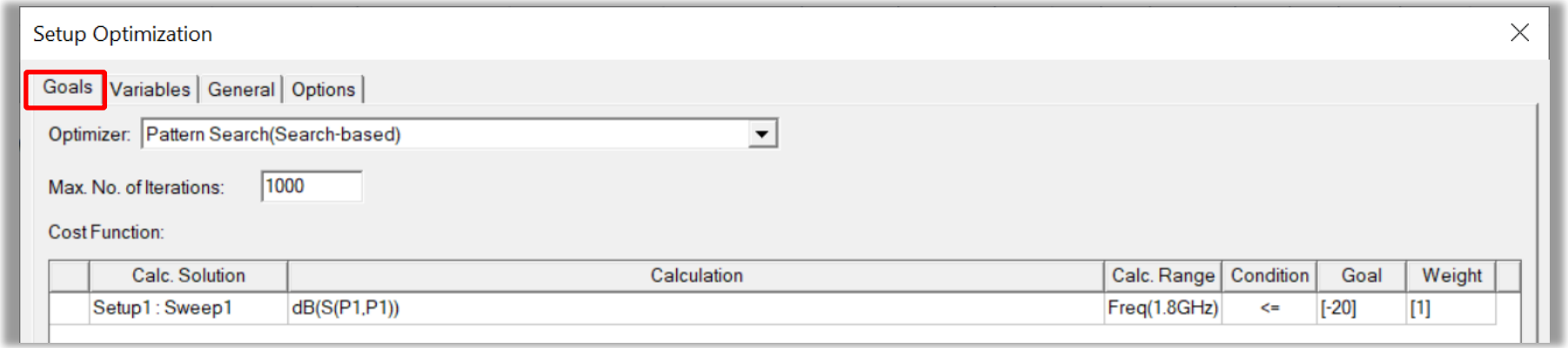
…back in the Setup Optimization dialog box,

- Click the value under ***Condition*** and select *<=.*
- Click under ***Goal*** and select ***Edit*** *as* ***Numeric Value…*** to bring up the ***Edit Goal Value*** pop up window.
- In the ***Edit Goal Value*** pop up, set ***Goal*** *Value* to **-20.**
- Click *OK* to close the ***Edit Goal Value*** dialog box and return to the ***Setup Optimization*** dialog box.
- In the ***Setup Optimization*** dialog box, set or verify that the value for ***Weight*** is **1.**

…continued….next is the Variables tab…





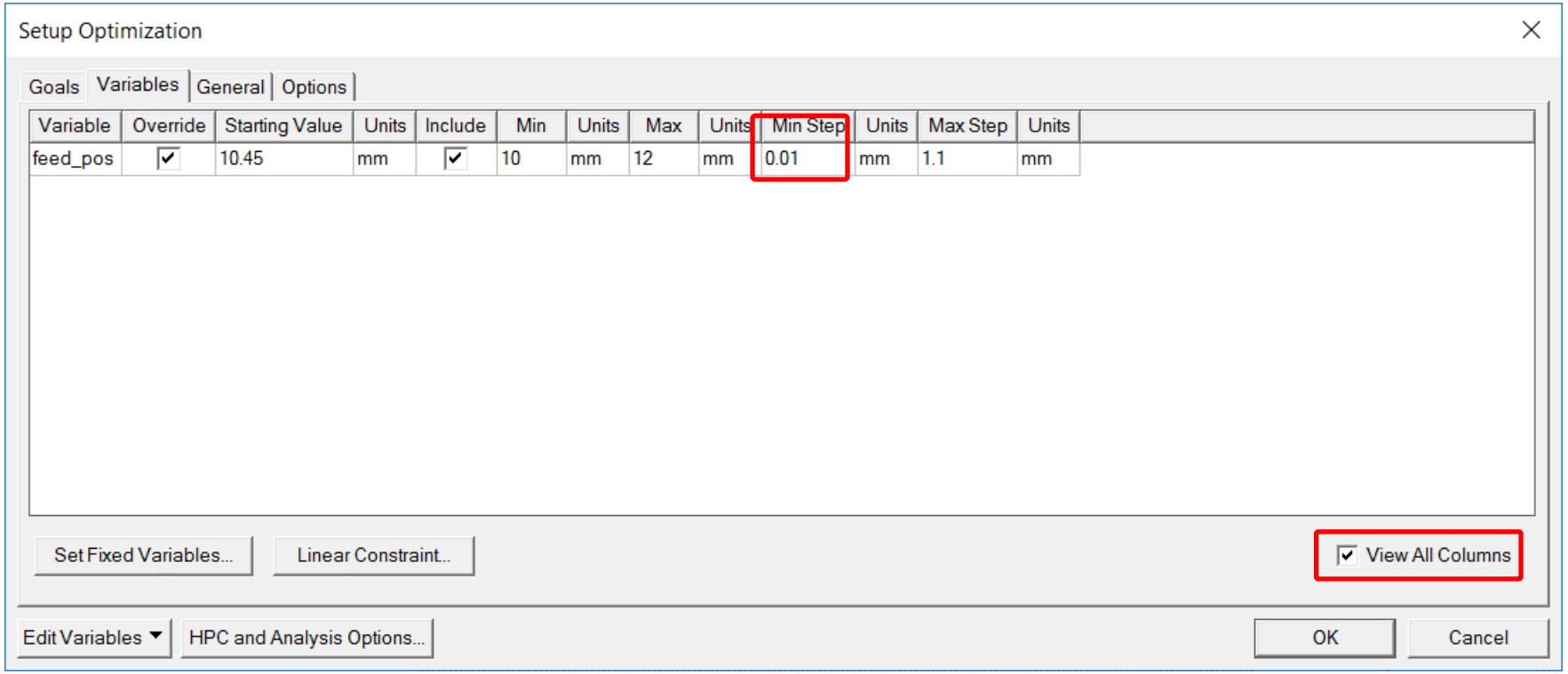


Optimization Setup Dialog - Variables Tab - Optimetrics_Patch2

In the *Setup Optimization* dialog box, click the *Variables* tab:

- Select ***View All Columns*** in lower right corner: ☑ **Checked**
- Set ***Min Step*** value: 0.01

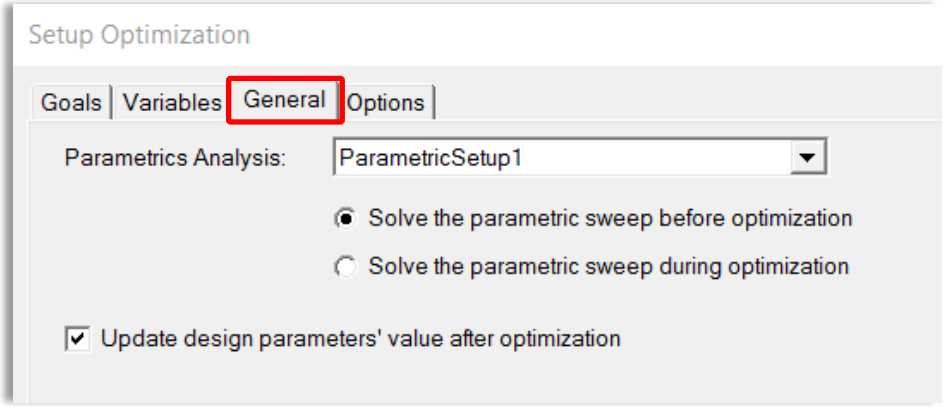
…continued…next is General tab…



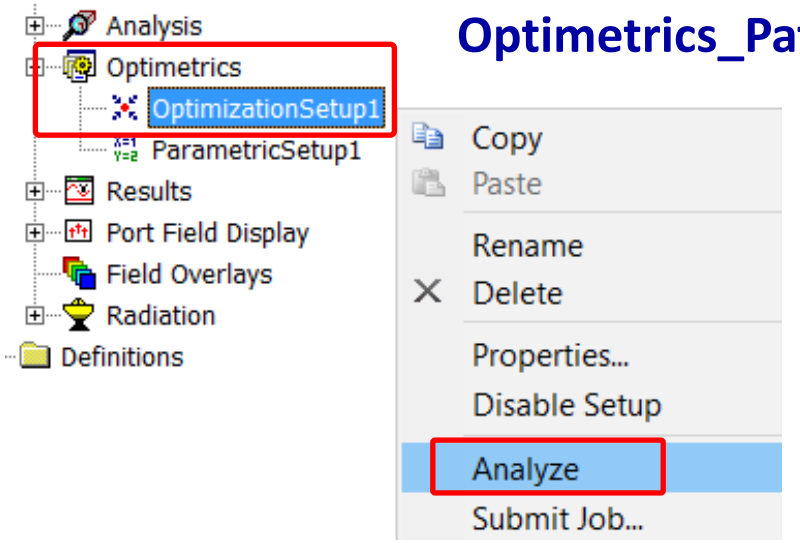
Optimization Setup - General Tab - Analyze Optimetrics_Patch3

In the ***Setup Optimization*** dialog box, click the ***General*** tab:

- For ***Parametrics Analysis:***, select **ParametricSetup1**.
- Select the radio button ***Solve the parametric sweep before optimization.***
  The parametric analysis that we solved earlier will be used to seed the optimization.
- Click the ***OK*** button to complete the optimization setup and close the ***Setup Optimization*** dialog box.
- In the ***Ribbon***, with the Simulation tab selected, click on the green check mark to validate the simulation.
- Save project to **Optimetrics_Patch3**.
- In the ***Project Manager*** window, select ***Optimetrics > OptimizationSetup1,*** right click and select ***Analyze***.
- Save project **Optimetrics_Patch3** again when the simulation finishes.

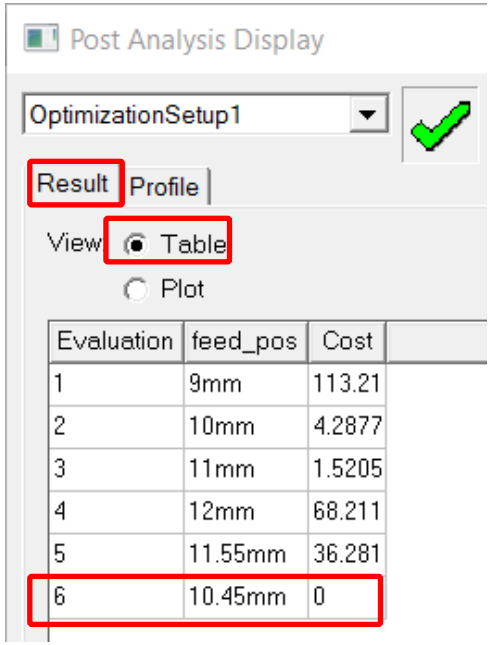


Analyze Optimetrics_Patch3



Optimization Results Table - Optimetrics_patch3

- After the simulation finishes, right-click on ***OptimizationSetup1*** and select ***View Analysis Result*** to bring up the ***Post Analysis Display***.
- In the ***Result*** tab, select the radio button for ***Table***.
- Click the ***Close*** button when you are finished viewing the results.



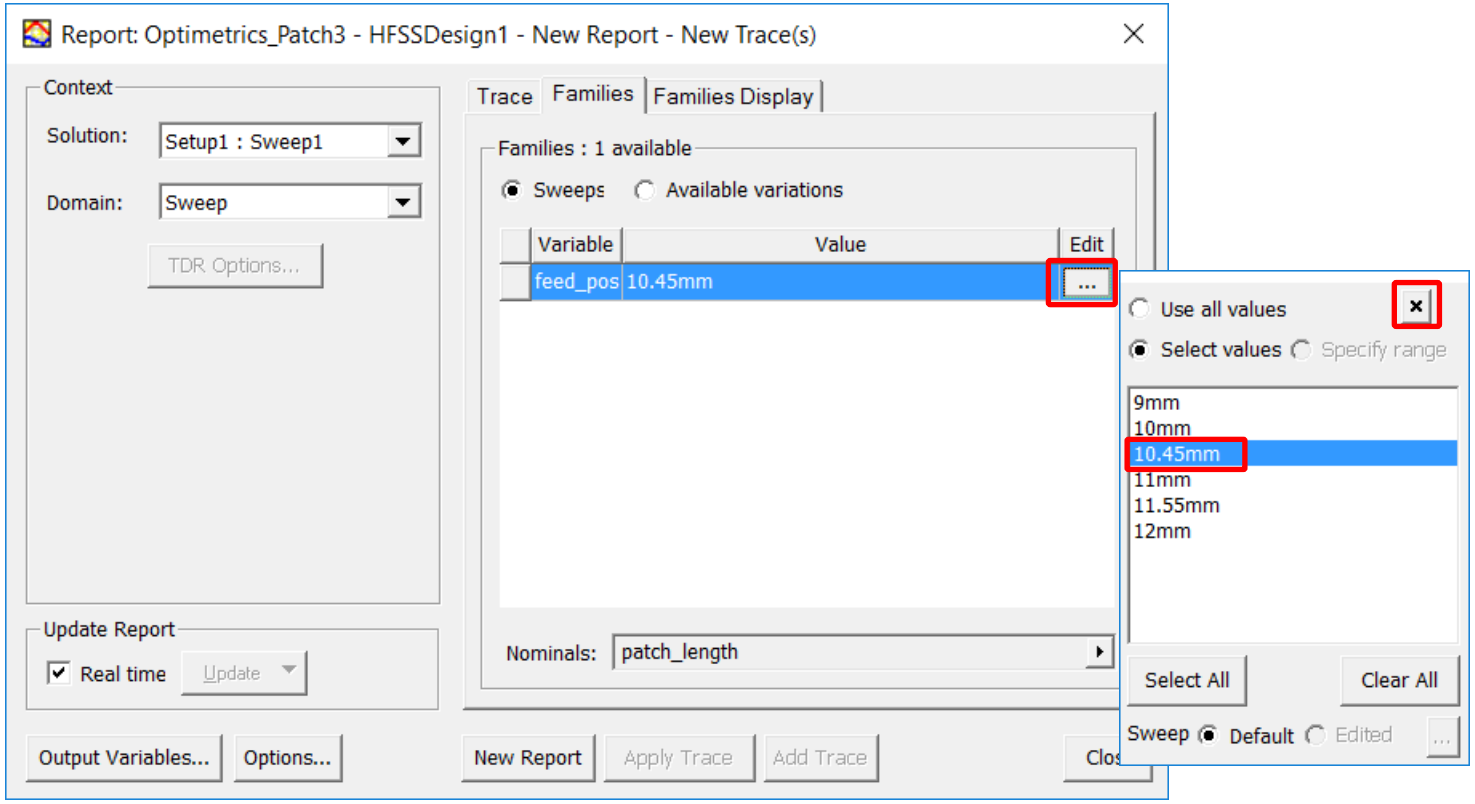
An optimal solution occurs somewhere near 10.45, depending on the points chosen by the optimizer.

Your simulation results may not match the exact numbers you see here.

S-Parameter Results Setup

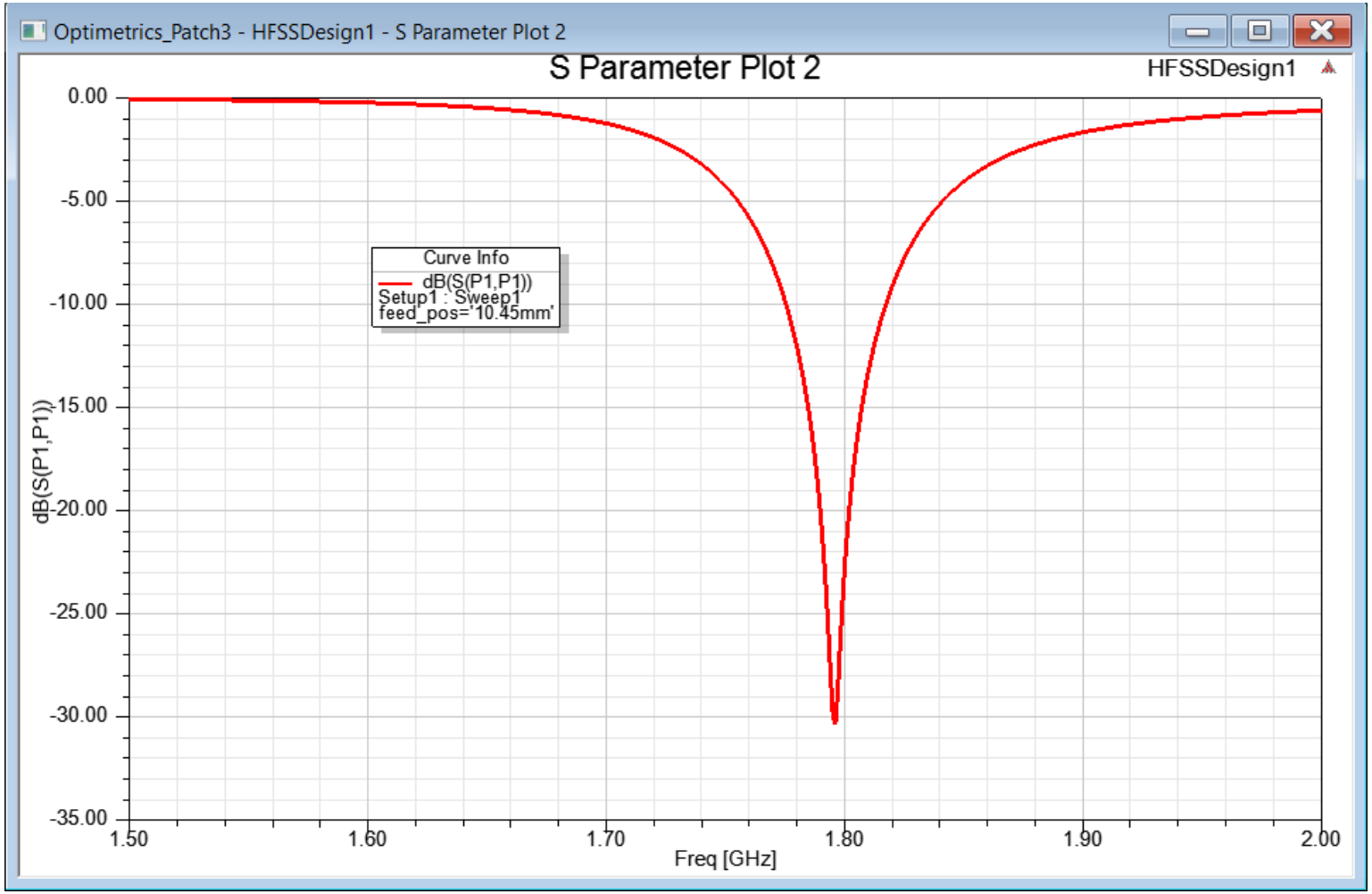
- Select the menu item ***HFSS > Results > Create Modal Solution Data Report > Rectangular Plot***
  - ***Solution: Setup1:Sweep1***
  - ***Domain: Sweep***

    In the ***Trace*** tab…
  - ***Category: S Parameter***
  - ***Quantity: S(P1,P1)***
  - ***Function: dB***
- Click the ***Families*** tab
  - Click the … button below ***Edit***
    - Click ***10.45mm*** (or whatever was the optimal value in the simulation) in the pop-up window
    - Close the pop-up window by clicking the *X* button
  - Click ***New Report*** button
- Click the ***Close*** button.



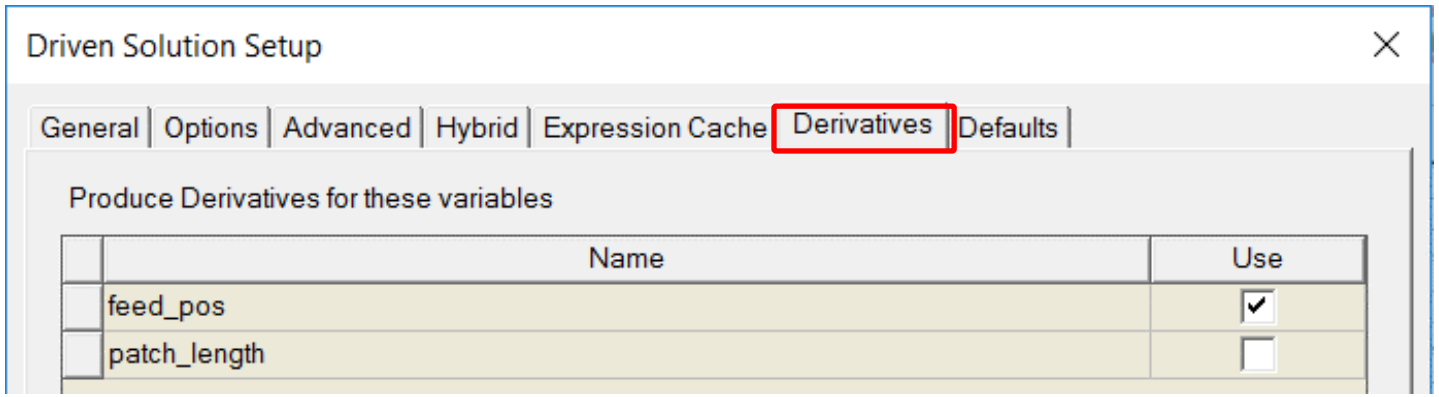
S-Parameter Results Plot - Optimetrics_Patch3

- Save project **Optimetrics_Patch3**.



Analytic Derivatives Setup and Analyze Optimetrics_Patch4

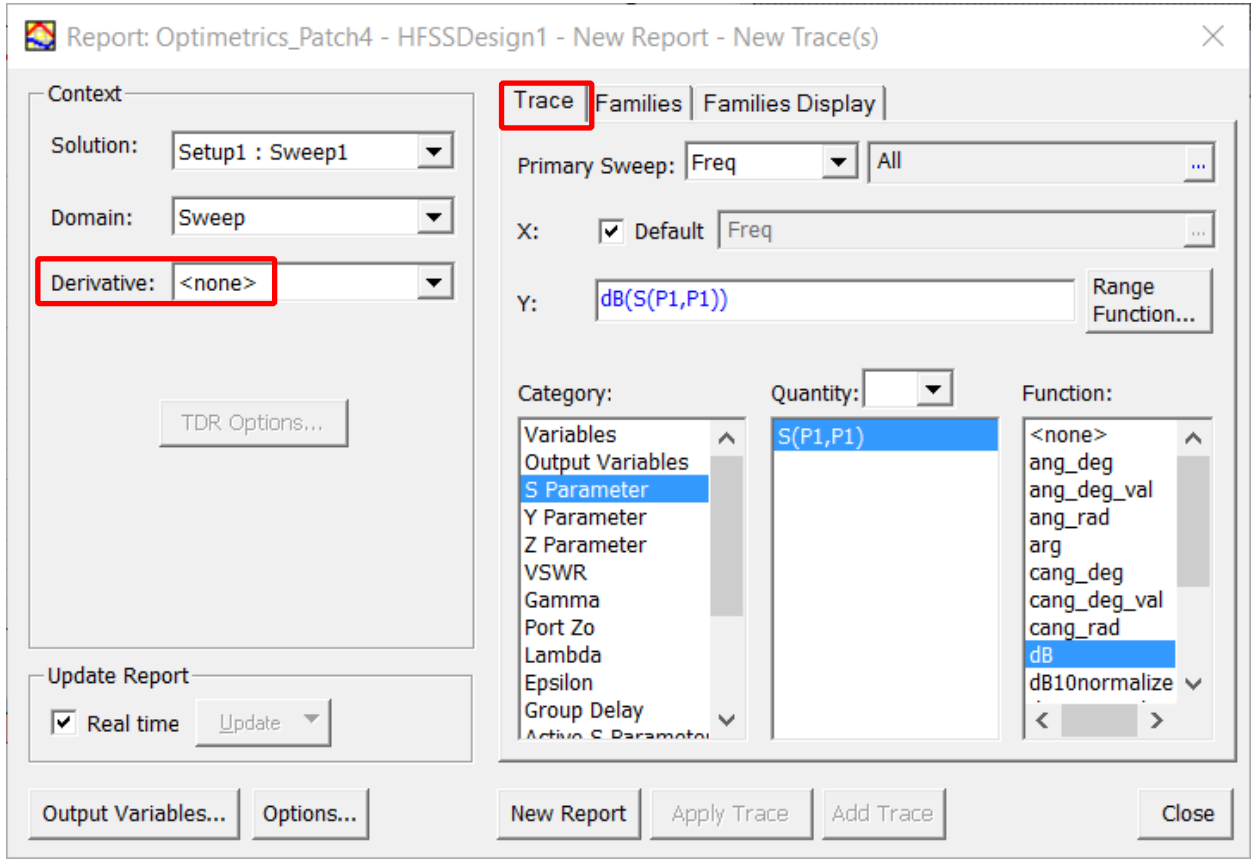
- From the parametric sweep and optimization of the **feed position** we can see that the optimal position is at about **10.45mm.** To further investigate or an alternative to the optimization, we could use analytical derivatives to predict the behavior of our model with respect to small changes in design variables.
- Enable Analytic Derivatives
  - In the ***Project Manager*** window under ***Analysis***, Double-click on ***Setup1*** to bring up the ***Driven Solution Setup*** dialog box.
    - Select the ***Derivatives*** tab
      - **feed_pos: Use ☑ Checked**
  - Click the ***OK*** button



- **Save and Analyze**
  - Save project as **Optimetrics_Patch4**.
  - Right-click on ***Setup1*** and select ***Analyze***
  - Save **Optimetrics_Patch4** again after simulation finishes.

Analytic Derivatives: S-Parameters Nominal Plot (1 of 2)

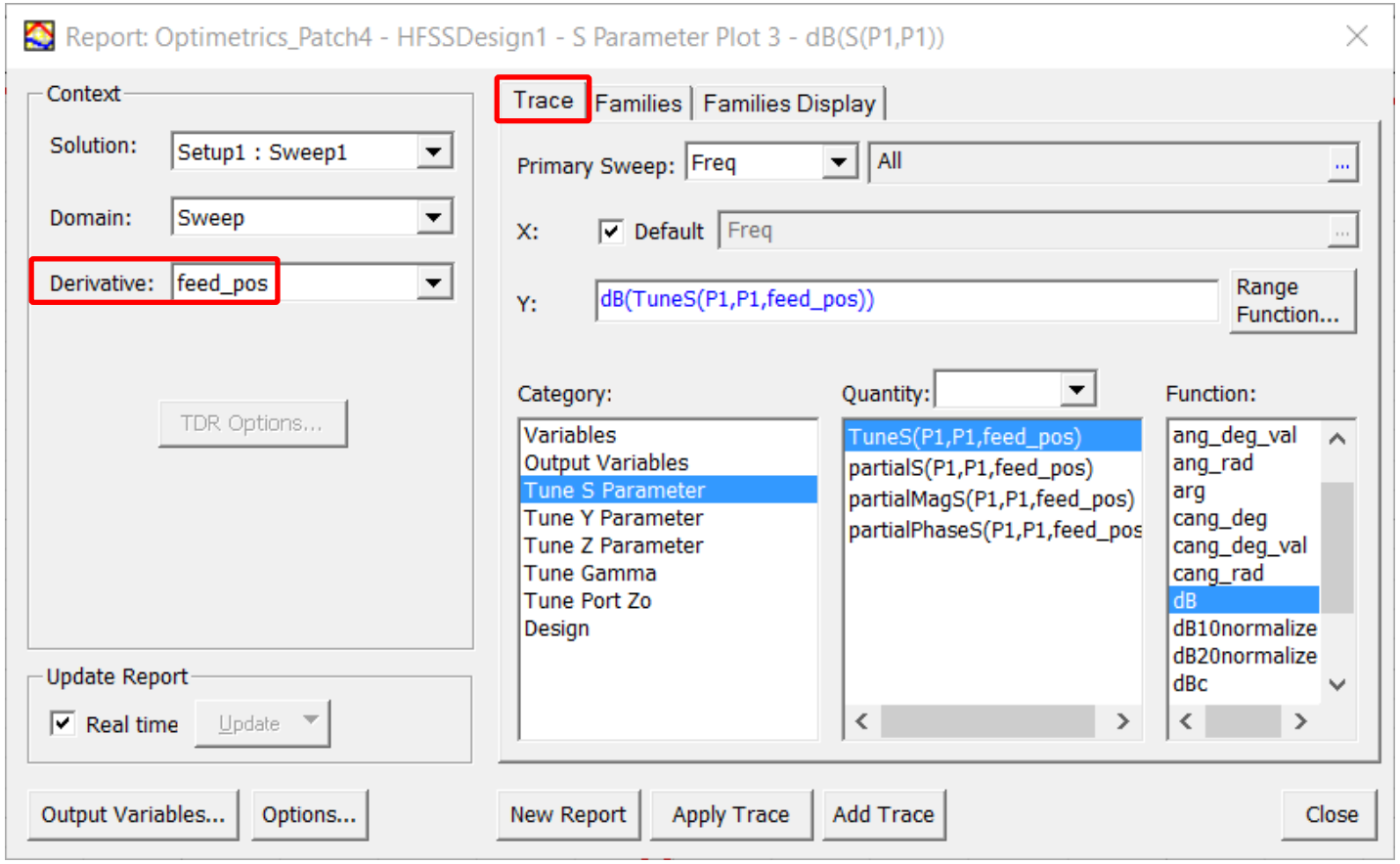
- In the ***Project* Manager**, right-click on **Results** and select **Create Modal Solution Data Report> Rectangular Plot**
  - ***Solution: Setup1: Sweep1***
  - ***Domain: Sweep***
  - ***Derivative: <none>***
  - In the ***Trace*** tab
    - ***Category: S Parameter***
    - ***Quantity: S(P1,P1)***
    - ***Function: dB***
  - Click the ***Families*** tab
  - Click the … button below ***Edit***
    - Click **10.45mm** in the pop-up window
    - Close the pop-up window by clicking the ***X*** button
  - Click the **New Report** button
  - do NOT close ***…continued…***



Add Tuning Plot (2 of 2) to S-Parameters Optimetrics_Patch4

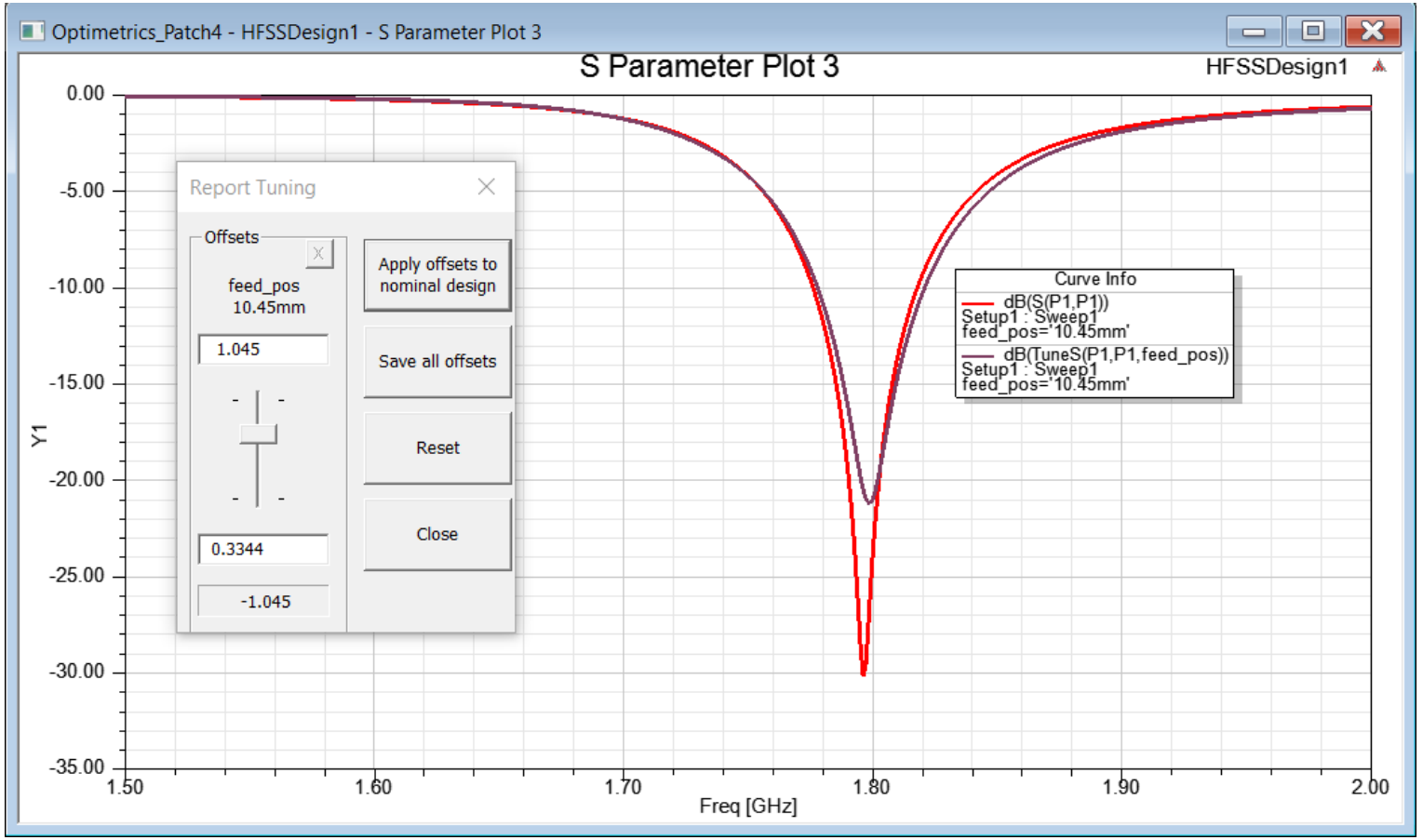
Add a Second Tuning Trace to Same Plot

- In the Create Rectangular Plot ***Report***, change the ***Derivative*** option
  - ***Solution: Setup1: Sweep1***
  - ***Domain: Sweep***
  - ***Derivative: feed_pos***
- In the **Trace** tab…
  - ***Category: Tune S Parameter***
  - ***Quantity: Tune S(P1,P1,feed_pos)***
  - ***Function: dB***
- Click the ***Add Trace*** button
- Click the ***Close*** button
- Save project **Optimetrics_Patch4**.



Analytic Derivatives - Tuning Plot

- Select the menu item ***HFSS > Results > Tune Reports …***
- Move the scroll bars in the ***Report Tuning*** window to predict the performance for various feed position values.
- Click the ***Close*** button when finished.



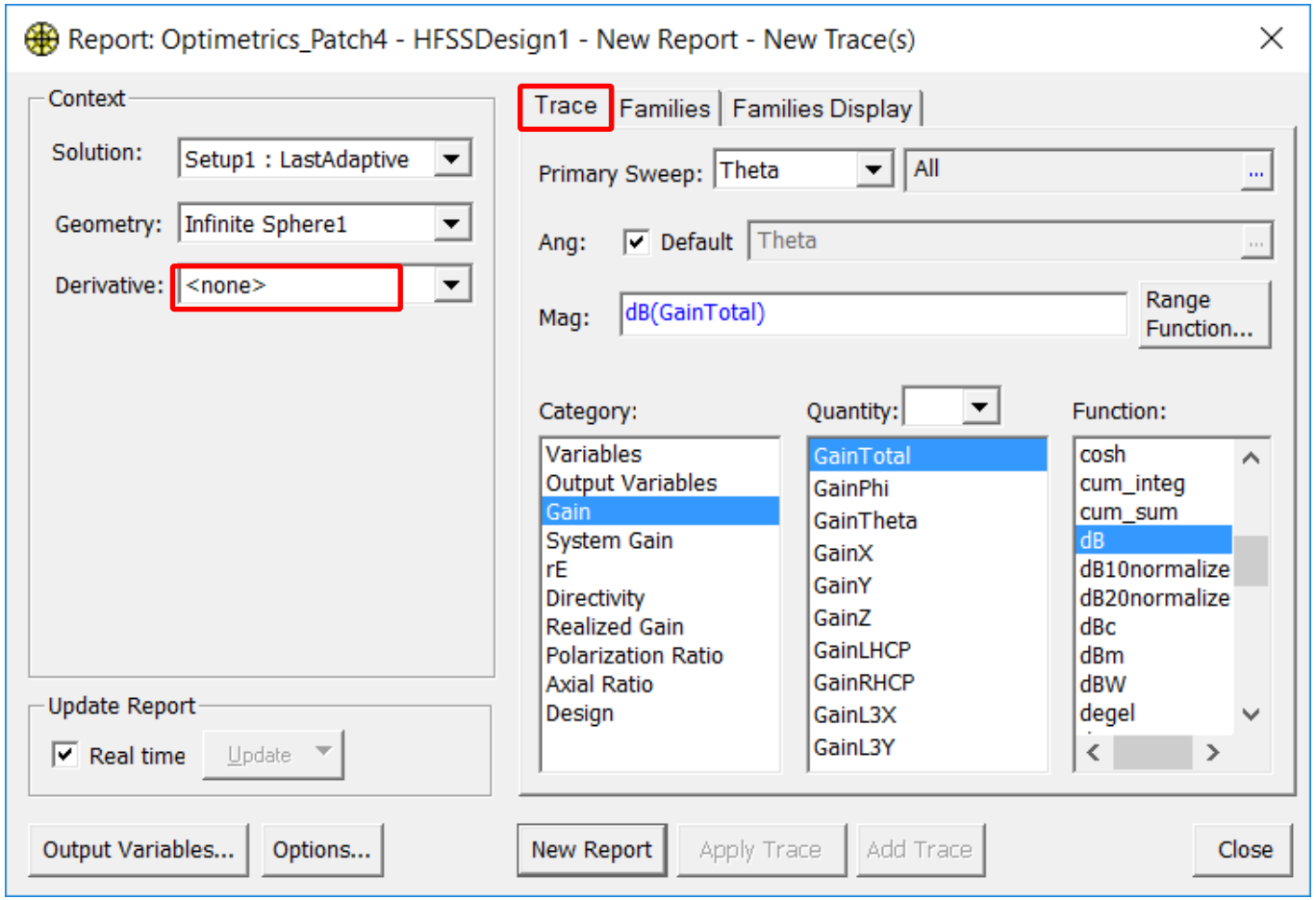
: Nominal

: Tuning

Note: The predicted response is based off the nominal solution and partial derivative that was computed during the solution process. Analytic Derivatives could have been used before any optimization to more quickly narrow the solution space by testing how individual parameters will affect the antenna performance.

Analytic Derivatives: Radiation Pattern Nominal Trace (1 or 2)

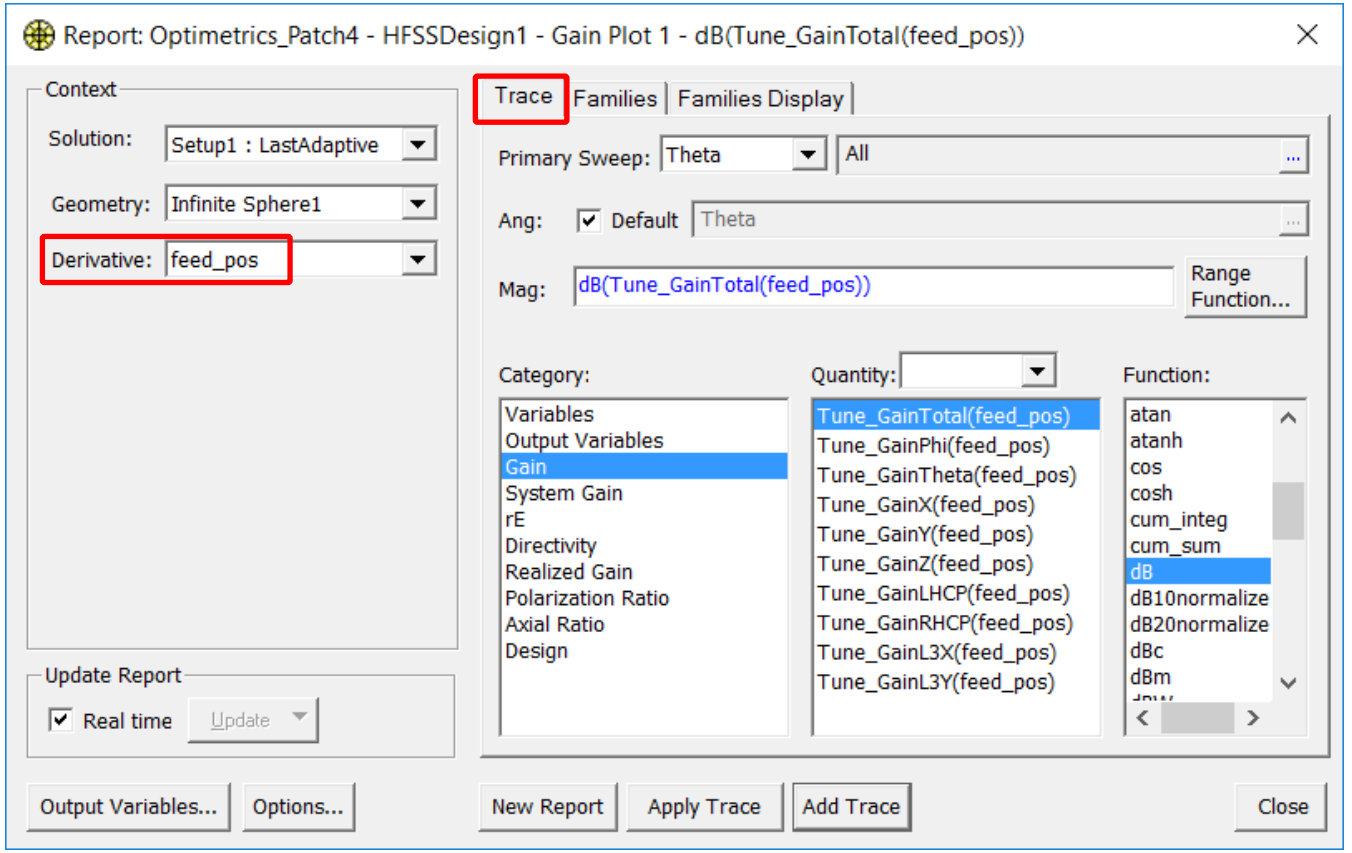
- Select the menu item ***HFSS > Results > Create Far Fields Report> Radiation Pattern***
  - *Solution:* ***Setup1: Last Adaptive***
  - ***Geometry: Infinite Sphere 1***
  - ***Derivative: <none>***
  - In the ***Trace*** tab
    - ***Category: Gain***
    - ***Quantity: GainTotal***
    - ***Function: dB***
  - Click the ***New Report*** button
  - do **NOT** close…*continued…*
  - **Continued on Next Page**



Analytic Derivatives: Radiation Pattern Tuning Trace (2 of 2)

Add a Second Tuning Trace to Same Radiation Plot

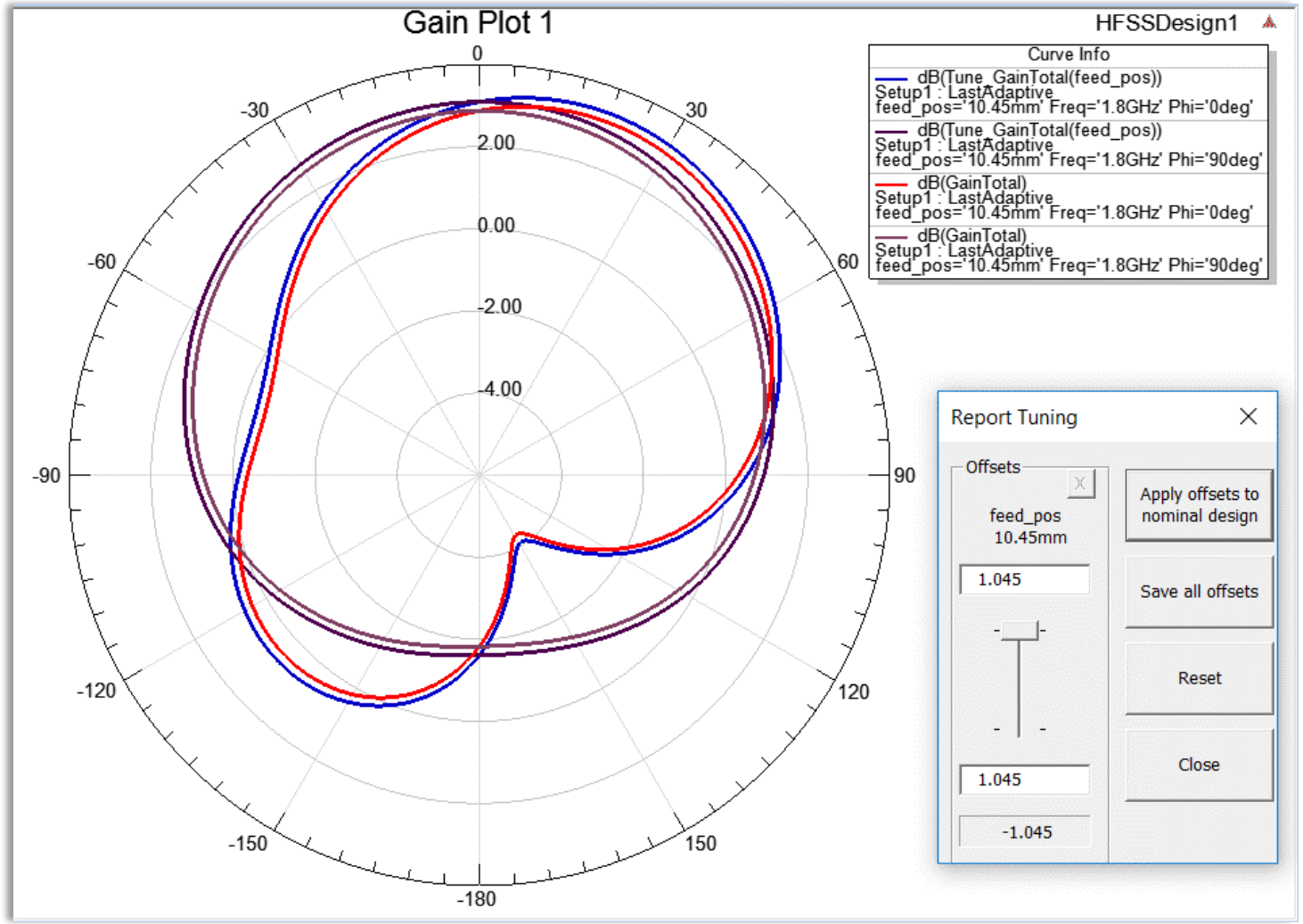
- In the Create Radiation Pattern ***Report***, change the ***Derivative*** option
  - *Solution:* ***Setup 1: LastAdaptive***
  - ***Geometry: Infinite Sphere 1***
  - *Derivative:* ***feed_pos***
- In the ***Trace*** tab…
  - ***Category: Gain***
  - ***Quantity: Tune_GainTotal(feed_pos)***
  - ***Function: dB***
- Click the ***Add Trace*** button
- Click the ***Close*** button



Analytic Derivatives Radiation Pattern Tuning Plot

- In the ***Project Manager***, right-click on ***Results***, and select *Tune Reports …*
- Move the scroll bars in the ***Report Tuning*** window to predict the performance for various patch width and feed position values.
- Click the ***Close*** button.

: Nominals
: Tuning



Appendix

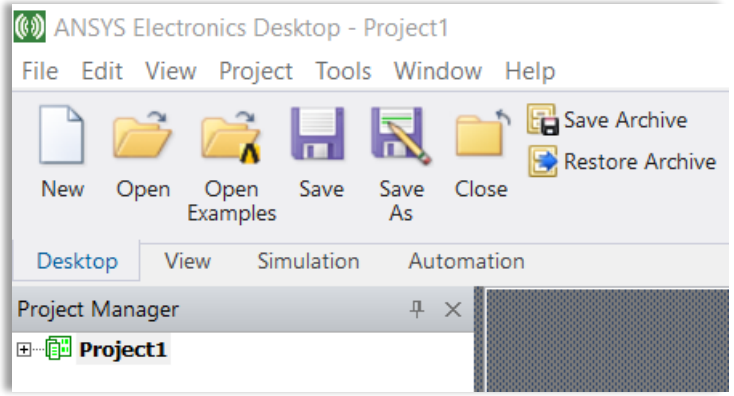
Options Settings

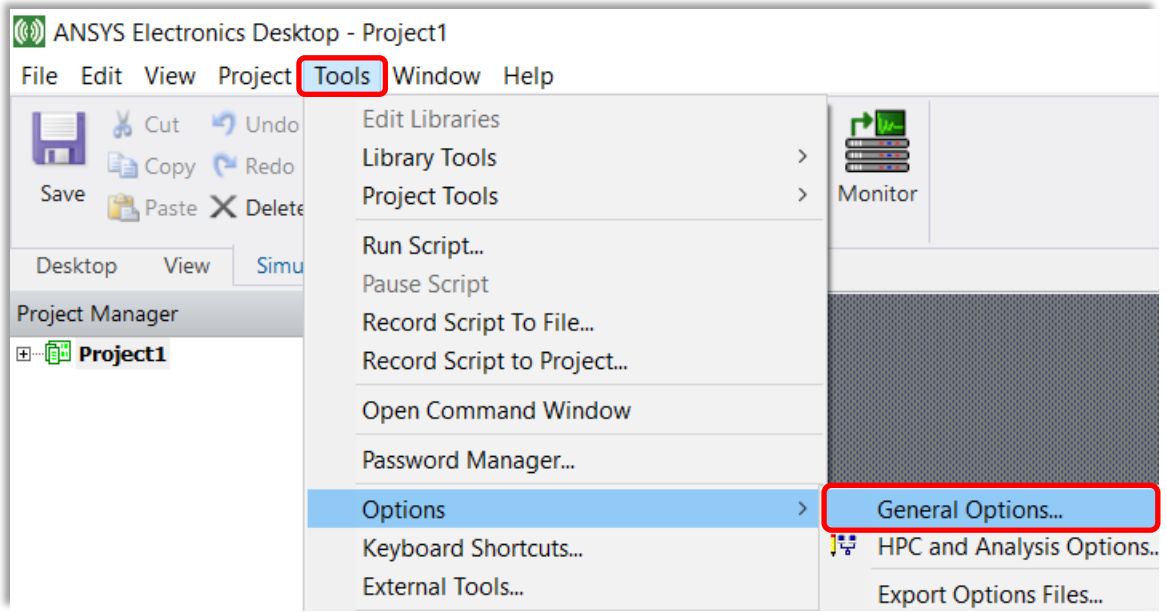
HFSS: Launching Ansys Electronics Desktop

- **Open HFSS project and Set Options**
  - To access HFSS, click the Microsoft Start button, Select:

    Programs > Ansys Electromagnetic Suite > Ansys Electronics Desktop

    A new Project1 appears under the *Project Manager*.
  - Setting **Tool Options**
    Select the menu item ***Tools > Options > General Options***





Option settings suggested here ensure that the user can consistently follow the steps in the Workshop. A user can prefer his/her own option configuration.

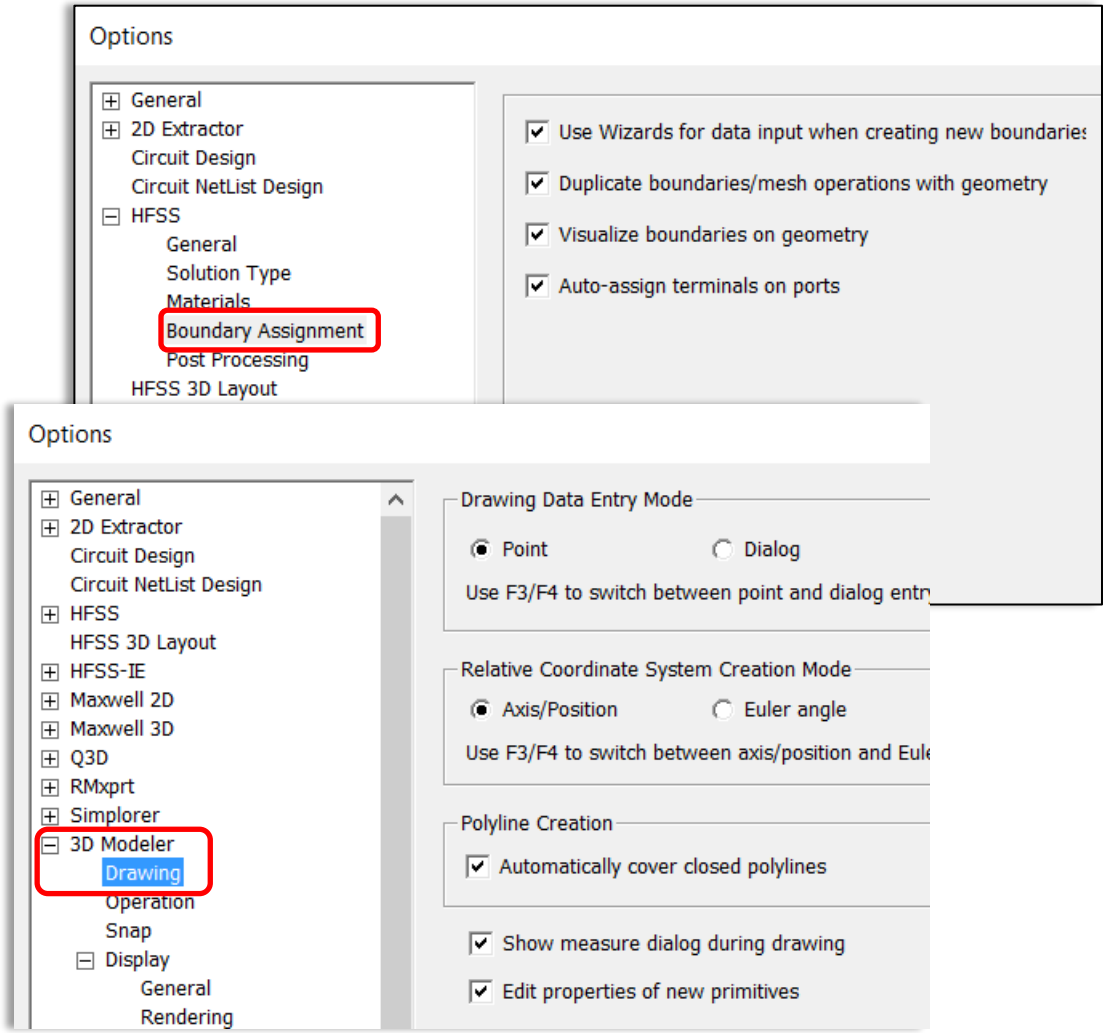
Setting *Tool > Options* for HFSS 1 - Boundary and Drawing

- Selected: ***Tools > Options > General Options***

  - Expand ***HFSS*** (by clicking on the + sign) and select ***Boundary Assignment***
  - ***Check all entries***

- Expand 3D Modeler and click Drawing
  - ***Automatically cover closed polylines: ☑ Checked***
  - ***Edit properties of new primitives: ☑ Checked***

Option settings suggested here ensure that the user can consistently follow the steps in the Workshop. A user can prefer his/her own option configuration.

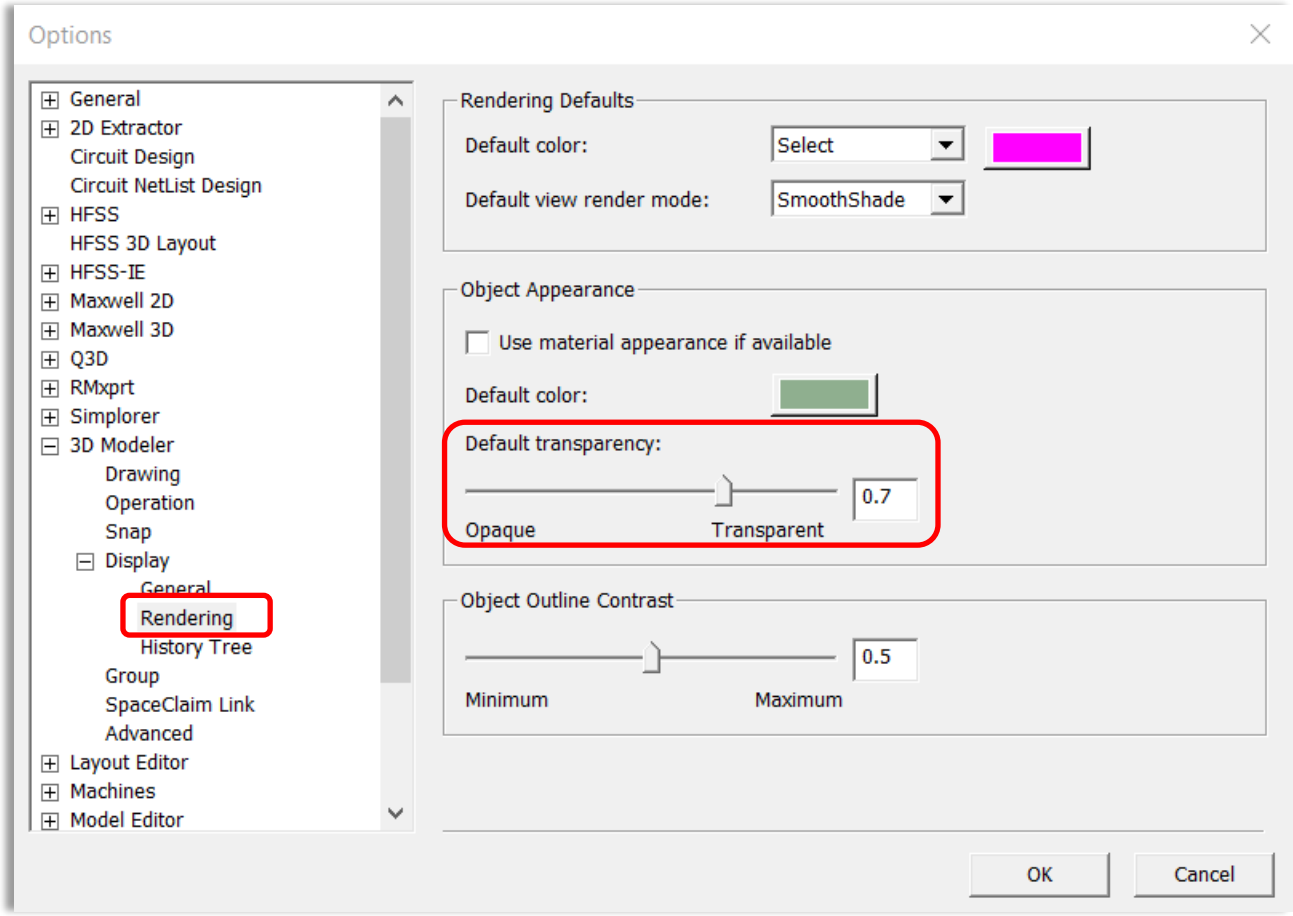


Setting Tool > Options for HFSS 2 - Display History and Transparency

- Expand ***Display***
  - Click ***Rendering*** and set ***Default Transparency*** to ***0.7***
  - Click ***History Tree*** and ***check all entries*** (not shown here)

- Click the ***OK*** button to close the Options dialog box

Option settings suggested here ensure that the user can consistently follow the steps in the Workshop.



End of Presentation