

# **Workshop 6-1: Introduction to Optimetrics**



# **ANSYS HFSS for Antenna Design**



# **Optimetrics: Example**

## • The Shorted Probe-Fed Patch Antenna with Optimetrics

- This example is intended to show users how to set up a parametric study, optimize, and simulate the Analytic derivatives of a probe feed patch antenna using the ANSYS HFSS Environment
- 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 that will be used to find the optimal position for the feed pin
- Analytic derivatives will also be used to perform real time tuning of several dimensions of the patch antenna





# **ANSYS 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 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



- Opening a Project
  - In the ANSYS Electronics Desktop, select the menu item *File > Open* 
    - Browse to the folder containing the file **Optimetrics\_Patch\_Training.aedt** and select **Open**





# **Design Variables**

## Checking Design Variables

- Two design variables have been created that control the location of the feed of the patch antenna, **feed\_pos**, and the length of the patch, **patch\_length**
- To view a list of any design variables that have been created for this design:
  - Go to the menu item *HFSS > Design Properties* 
    - Alternatively, click on HFSSModel1 in the Project Manger Window, the design variables will be displayed in the Properties Window
  - Verify that the variable feed\_pos is assigned the value 11 mm
  - Verify that the variable patch\_length is assigned the value 41.6mm
  - Press the OK button





# **Parametric Analysis Setup**

## Parametric Sweep of Feed Position

 We will now complete the creation of the parametric project using the defined variable 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. So we will effectively change the value of the feed offset until we find a position which presents a 50 Ohm load impedance on the coaxial feed line. The S11 vs. frequency plot has a dip at the patch resonant frequency, the dip is maximized when the optimal offset is found.

## Create Parametric Sweep

- Select the menu item HFSS > Optimetrics Analysis > Add Parametric ....
  - Click the Add... button in the Setup Sweep Analysis window
    - 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
  - Click the **OK** button

Variable feed_pos 💌		Variable	Description	n 0
C		feed_pos Line	ar Step from 9mm to 1	2mm, step=1
O Single value				
<ul> <li>Linear step</li> </ul>	Add >>			
C Linear count	Add //			
O Decade count				
O Octave count	Update >>			
C Exponential count				
Start: 9 mm 💌	Delete			
Stop: 12 mm 💌				
Step: 1				

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<b>\'  </b>	

# **Analysis Configuration**

## High Performance Computing Configuration

 Parametric sweeps can be accelerated by solving multiple variations in parallel. The HPC Analysis Configuration will allow 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

- From the Analysis Options Toolbar, select Local configuration
- Click the Edit Active Analysis Configuration button

### **Analysis Options Toolbar**



- In the Analysis Configuation window, change the following:
  - Uncheck Use Automatic Settings
  - Tasks: **2**
  - Cores: **4**
  - RAM Limit(%): 80
- Click the OK button to finish and close configuration window

## Analyze Parametric Sweep

 In the Project Manager window, select Optimetrics > ParametricSetup1 right click and select Analyze

Analysis Configur	ation				×
Configuration name:	Local				
Use Automatic Set	tings				
Machines Job Distri	ibution Op	otions			
- Machines for Distri	buted Analy	/sis			
Total Enabled Ta	isks: 2 Tota	al Enabled Co	res: 4		
Name	Tasks C	ores RAM L	imit (%) Enab	led	Remove
localhost	2 4	80	<b>▼</b>		Move up
					Move down
					Test Machines
Machine Details:					
C IP Address fr	e mat: 192 1	160 1 21.	Г		
C DNS Name #	omat: www	( sen/er.com):			
C LINC Name (	omat: \\	v.server.com).			
C ONC Name (i	omat. Ase	iver).	L		
Import Mach	iines from Fi	ile		Add Mac	hine to List
				OK	Cancel

**Note:** Additional machines can be added to the configuration to further accelerate solutions. Each machine can be used to solve 1 or more task. If an analysis does not contain a parametric sweep, the solution will distribute frequency points if a frequency sweep has been specified.



#### **Create S-Parameter plot** ٠

- Select the menu item HFSS > Results > Create Modal Solution Data Report > Rectangular Plot ٠
  - Solution: Setup1:Sweep1 \_
  - Domain: Sweep —
  - In the **Trace** tab \_
    - Category: S Parameter ٠
    - 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

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Report: Optimetrics_Patch_Training - HF	SSDesign1 - New Report - New Trace(s)	💌 🚫 Re	eport: Optimetrics_Patch_Training - HFS	SDesign1 - New Report - New Trace(s)	×
Context	Trace Families Families Display	Con	ntext	Trace Families Families Display	
Solution: Setup1: Sweep1	Primary Sweep: Freq 🗾 All	Sol	lution: Setup1:Sweep1 💌	Families : 4 available	
Domain: Sweep	X: V Default Freq	Do	omain: Sweep 💌	● <u>Sweeps</u> ○ <u>A</u> vailable variations	
TDR Options	Y: dB(S(P1,P1))	Range Function	TDR Options,	Value Value feed_pos All	Edit
_Update Report	Category: Quantity:  Variables Output Variables Parameter Y Parameter Z Parameter VSWR Gamma Port Zo Lambda Ensilon	Function:	date Report		
Real time	Group Delay		Real time	Nominals:   patch_length	
Output Variables Options	New Report         Apply Irace         Add Trace	<u>Q</u> lose <u>Q</u> ut	tput Variables Options	New Report Apply Irace Add Trace	<u>C</u> lose
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# **Results**



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# **Optimization Analysis Setup**

- Optimization
  - The Parametric Sweep was useful for generating design curves. For this simple design with only a single variable we could use the design curves to make educated guesses at performance targets that are not contained in the Parametric Sweep. To demonstrate this we will target a minimum of less than -20dB for S<sub>11</sub> 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 around 11mm.

## Create an Optimization Setup

- Select the menu item *HFSS > Design Properties* 
  - Click the **Optimization** radio button:
    - Name: feed\_pos
    - Include: ☑ Checked
    - Min: 10 mm
    - Max: **12 mm**
  - Click the OK button

Prop	perties: Optimetrics_P	atch_Traini	ng - HFSSDesign1				<b>—</b> ———————————————————————————————————
Lo	cal Variables						
	C Value	Coptimizatio	on O Tuni	ng	C Sensitivity	O Stati	stics
	Name	Include	Nominal Value	Min	Unit	Max	Unit
	feed_pos	<b>~</b>	11mm	10	mm	12	mm
	patch_length		41.6mm	20.8	mm	62.4	mm
	<u>A</u> dd	Add Am	ay	Edit	<u>R</u> emove	Show Hid	lden
					OK	Cancel	Apply

## Add Optimization Setup

• Select the menu item *HFSS > Optimetrics Analysis > Add Optimization...* 



# **Optimization Analysis Setup**

## Setup Optimization

- In the **Goals** tab:
  - Optimizer: Pattern Search(Search-based)
  - Click the Setup Calculations... button
    - 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
  - Click the value under Calc. Range and select Edit...
    - Click the Edit button
    - Click the Select values radio button and select 1.8GHz
    - Click OK button
  - Condition: <=</p>
  - Goal = **-20**
  - Weight = 1
- Click the Variables tab:
  - Select View All Columns in lower right corner: I Checked
  - Set Min Step value: 0.01

Setup Optimization					<b>—X</b> —
Goals Variables General	Options				
Optimizer: Pattern Search(S	earch-based)	•			
Max. No. of Iterations: 100	0				
Cost Function:					
Solution	Calculation	Calc. Range	Condition	Goal	Weight
Setup1 : Sweep1	dB(S(P1,P1))	Freq(1.8GHz)	<=	[-20]	[1]
Setup Calculations	Delete			Edit G	oal/Weight
Acceptable Cost: 0	Noise: 0.0001			Show Adv	vanced Option
			HPC an	d <u>A</u> nalysis Op	tions
				ОК	Cancel

Setup Optir	nization											×
Goals Va	ariables G	eneral   Options	1									
Variable	Override	Starting Value	Units	Include	Min	Units	Max	Units	Min Step	Units	Max Step	Units
feed_pos	~	11	mm	~	10	mm	12	mm	0.01	mm	0.9	mm
Cet From												
Set Fixed Variables Linear Constraint												

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# **Optimization Analysis Setup**

- Setup Optimization (continued)
  - Click the General tab:
    - Parametric Analysis: ParametricSetup1
      - This parametric analysis that we solved earlier will be used to seed the optimization
  - Click the **OK** button to complete the optimization setup
- Analyze Optimization
  - In the Project Manager window, select Optimetrics > OptimizationSetup1, right click and select Analyze
- Optimetrics Results
  - Right-click on OptimizationSetup1 and select View Analysis Result
    - In the Result tab, select the radio button for Table
    - Click the Close button when you are finished viewing the results

Optimal solution occurs at ~10.55mm, depending on the points chosen by the optimizer, other values of feed\_pos may satisfy the optimization criteria

tup Op	otimization				×
Goals	Variables Ger	neral Options			
Paran	netrics Analysis:	Parametric Setu	p1	-	
		Solve the pa	arametric sweep before	e optimization	
		C Solve the pa	arametric sweep during	optimization	
<b>₩</b> 0	pdate design pa	rameters' value afte	er optimization		
					C 1
				UK	Cancel
Í	Post Analy	sis Display			
	OptimizationSe	etup 1	- √	Options	1
			-		1
	Result   Profi	le			1
	View: 💽 Ta	able			
	C Pl	or feed nos Cost		<b>F</b> urnet	
	1	9mm 117.28			
	2	10mm 6.3602	-		
	3	11mm 1.0633	-		
	4	12mm 66.376	1	Apply	
	5	11.9mm 57.945	1		
	6	10.1mm 0.15706			
	7	10.55mm 0		Hevert	
				]	
			Close		-
			0.000		



## Results

## Create Reports

- 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 Edit button
      - Click **10.55mm** in the pop-up window
      - Close the pop-up window by clicking the X button
  - Click New Report button
  - Click Close button

Report:	Optimetrics_Patch_Training	- HFSSDesign1 - New Report - New Trace(s)	(	×
Solution	Setup1:Sweep1	Trace Families   Families Display    Families : 1 available		-1
Domain:	Sweep	Variable Value feed_pos 10.55mm	Edit	C Use <u>a</u> ll values
	Report			© Select values © Specify range 9mm 10mm 10.1mm 10.55mm 11mm 11.9mm 12.7mm
Real	time Update 🔻	Nominals: patch_length	<u> </u>	
<u>O</u> utput V	ariables Options	New Report Apply Irace Add Trace	<u>C</u> lo	Sweep: © Default C Edited





# **Analytic Derivatives**

## Analytical Derivatives

From the parametric sweep and optimization of the feed position we can see that the optimal position is at about 10.55mm. 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

- Right click on Setup1 in Project Manager Window and select Properties...
  - Select Derivatives Tab
    - feed\_pos: Use ☑ Checked
    - patch\_length: Use ☑ Checked
  - Click the OK button

Driven Solution Setup	<b>X</b>
General Options Advanced Expression Cache Derivatives	s Defaults
Produce Derivatives for these variables	
Name	Use
feed_pos	<b>v</b>
patch_length	<b>V</b>
	Cancel

- Analyze
  - Select the menu item HFSS > Analyze All

Project Manager				ф	×
Optimetrics_Patcl	h_Tra	ining			
🗄 🤣 HFSSDesign1 (	Drive	nModal)			
- 🚑 3D Componer	nts				
- 🖉 Model					
🕀 🕣 Boundaries					
🕀 🚭 Excitations					
- 🐯 Mesh Operati	ions				
🖃 🔊 🔊 🗛 🕞					
Optimetrics	B2	<u>С</u> ору	Ctrl+C		1
🕀 🔯 Results	ra.	Paste	Ctrl+V		
🕂 🕂 Port Field Dis				_	
Field Overlay		Rena <u>m</u> e	F2		
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🗄 💼 Definitions	r				
		Properties		_	
		Di <u>s</u> able Setup			
		Add Frequency Sweep			
		Add Dependent Solve Setup			
				_	
		Analy <u>z</u> e			
		Revert to Initial Mesh			
		Apply Mesh Operations			
				_	
		Clear Linked Data			
		Create Quick Report			
		Perform FFT on Report			
		Perform TDR on Report			
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		P <u>r</u> ofile			
		<u>C</u> onvergence			
		Matrix Data			
		Mach Statistics			
		Mes <u>n</u> statistics			
		Network Data Explorer			



# **Creating a Tuning Plot**

## Create Nominal Plot for Comparison

- Select the menu item HFSS > Results > 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 Edit button
      - Click 10.55mm in the pop-up window
      - Close the pop-up window by clicking the X button
  - Click the New Report button

Report: Optimetrics_Patch_Training - HF	SSDesign1 - New Report - New Trace(s)
Solution: Setup1:Sweep1	Primary Sweep: Freq 🚽 All
Domain: Sweep	X: 🔽 Default Freq
Derivative: <none></none>	Y: dB(S(P1,P1)) Range Function
Update Report	Category:       Quantity:       ▼       Function:         Variables       ●       ang_deg       ang_deg       ang_rad       ang_rad       arg       ar
Qutput Variables Options	New Report         Apply Irace         Add Trace         Close

• Continued on Next Page



# **Creating a Tuning Plot**

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

Report: Optimetrics_Patch_Training - HFS	SDesign1 - XY Plot 3 - dB(S(P1,P1))	×
Context	Trace Families Families Display	
Solution: Setup1:Sweep1	Primary Sweep: Freq All	
Domain: Sweep 💌	X: 🔽 Default Freq	
Derivative: All	Y: dB(TuneS(P1,P1,All))	ange unction
Update Report	Category:       Quantity:       Function         Variables       Tunes(P1,P1,All) <none>         Output Variables       Tunes(P1,P1,All)       <none>         Tune Y Parameter       Tune Z Parameter       ang_deg         Tune Z Parameter       cang_deg       arg_deg         Tune Port Zo       Design       dB       dB         dB20nord       dB20nord       dB20nord       dB20nord         dB20nord       dB20nord       dB20nord       dB20nord         dB20nord       dB20nord       dB20nord       dB20nord         dB20nord       dB20nord       dB20nord       dB20nord</none></none>	eg id rmalize
Output Variables Options	New Report Apply Trace Add Trace	Close



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# **Tuning Plot**

- 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 patch width and feed position values



**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.



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