ANSYS

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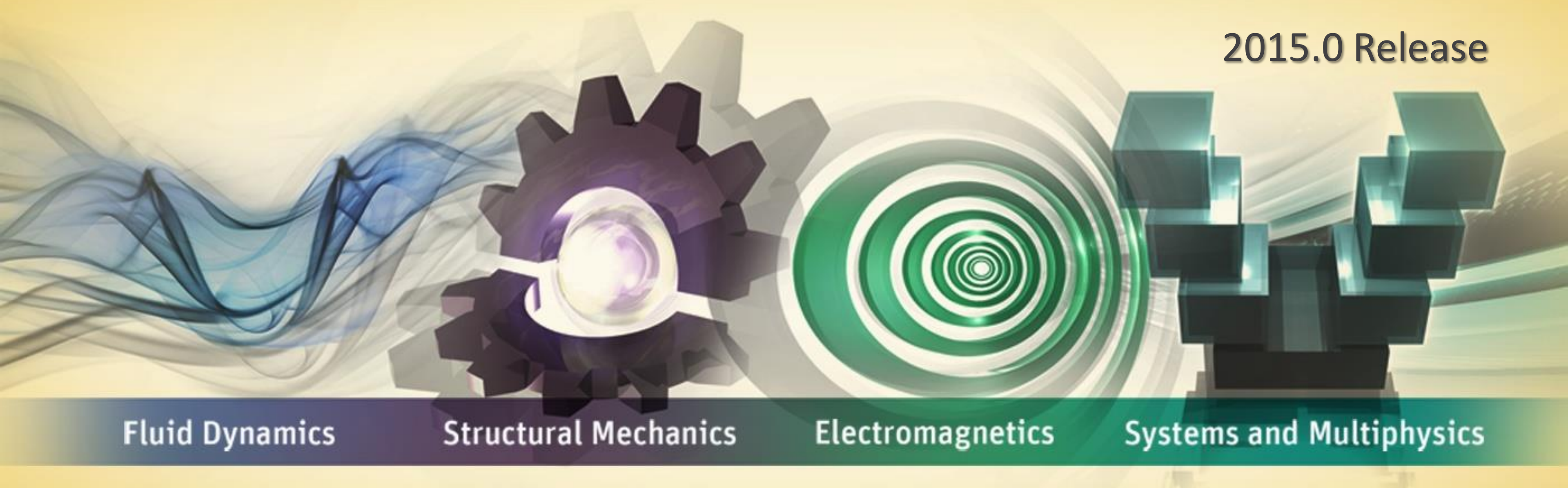
Lecture 6: Introduction to Optimetrics

2015.0 Release

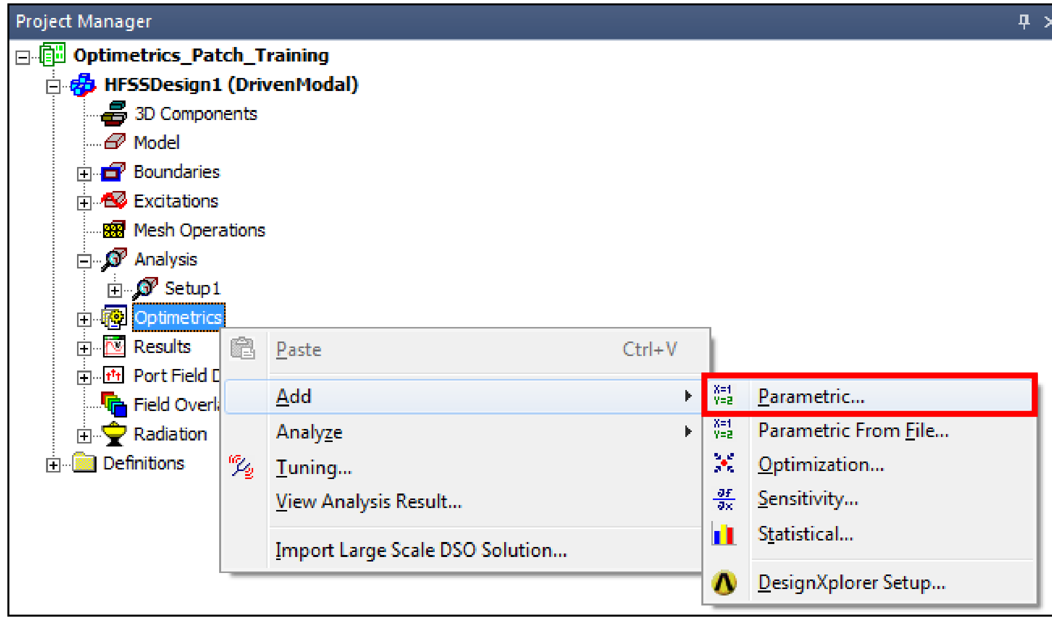


ANSYS HFSS for Antenna Design

Introduction

- **Optimization**
  - A process of finding a better or more suitable design instance among the possible design variations
- **Optimetrics is an add-on module which provides numerous analysis tools**
  - Parametric
  - Optimization
  - Sensitivity
  - Statistical
  - Tuning
  - Analytic Derivatives
  - Enables ANSYS DesignXplorer Link
- **Allows centralized control of design iterations from one common interface**
- **Optimetrics allows the user to:**
  - Automate parametric sweeps
  - Perform real time parameter tuning using Analytic Derivatives
  - Identify performance specifications to optimize
  - Perform sensitivity and statistical analysis on optimized model
  - Link to DesignXplorer for
    - Optimization via a Surface Response using Design of Experiments (DOE)
    - Six Sigma Analysis

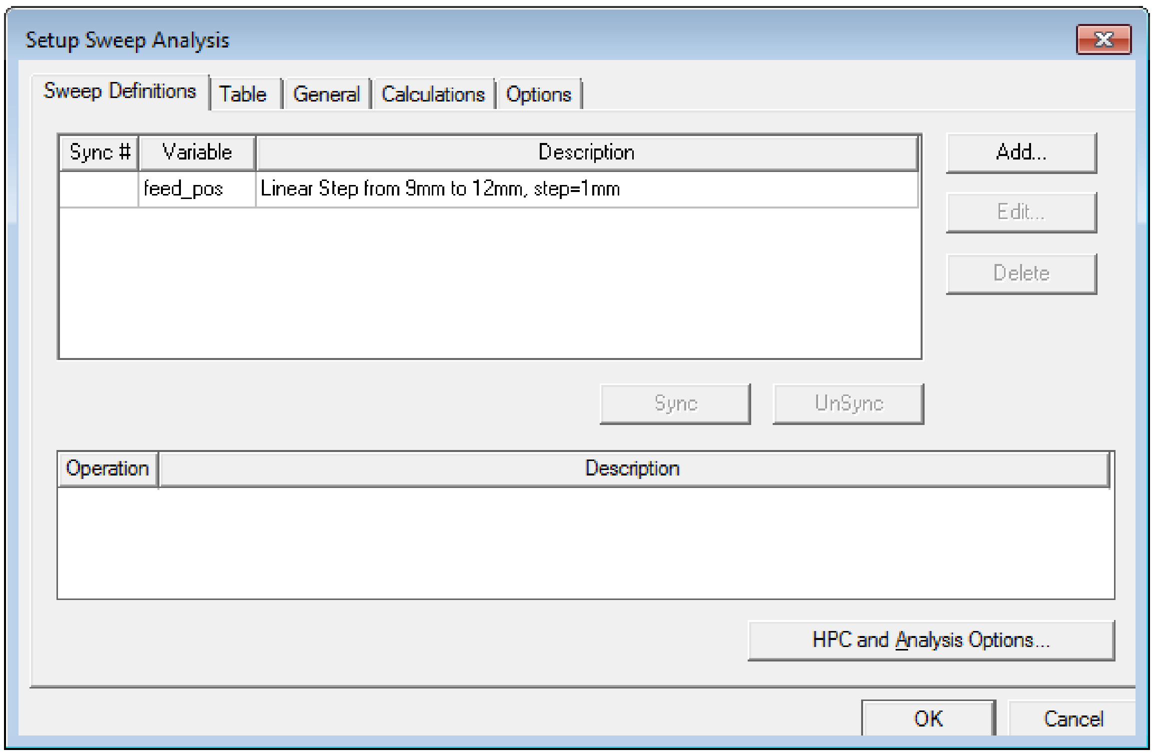
Using Optimetrics



- **Process**
  - Create parameterized model
  - Define design parameters to vary
    - Model geometry, material properties, etc.
  - Perform analyses
    - Parametric
    - Optimization
    - Sensitivity
    - Statistical
    - Tuning
- **Where can it be used?**
  - User may apply parameterization at all modeling stages
    - Geometry (size, shape, orientation, quantity, etc.)
    - Materials (lossless, complex, anisotropic, etc.)
    - Boundaries (impedance/conductance boundaries, linked boundary scan angles, symmetry or mode cases, etc.)
    - Solution setup
    - Post Processing Quantities (Port magnitude/phase, De-embedding, etc.)
  - Once model is parameterized, optimization can be performed toward an extensive array of cost functions
    - Circuit parameters (S, Z, or Y-parameters)
    - Antenna patterns (Directivity, gain, axial ratio, etc.)
    - Emissions
    - Derived field quantities (radiated power, etc.)

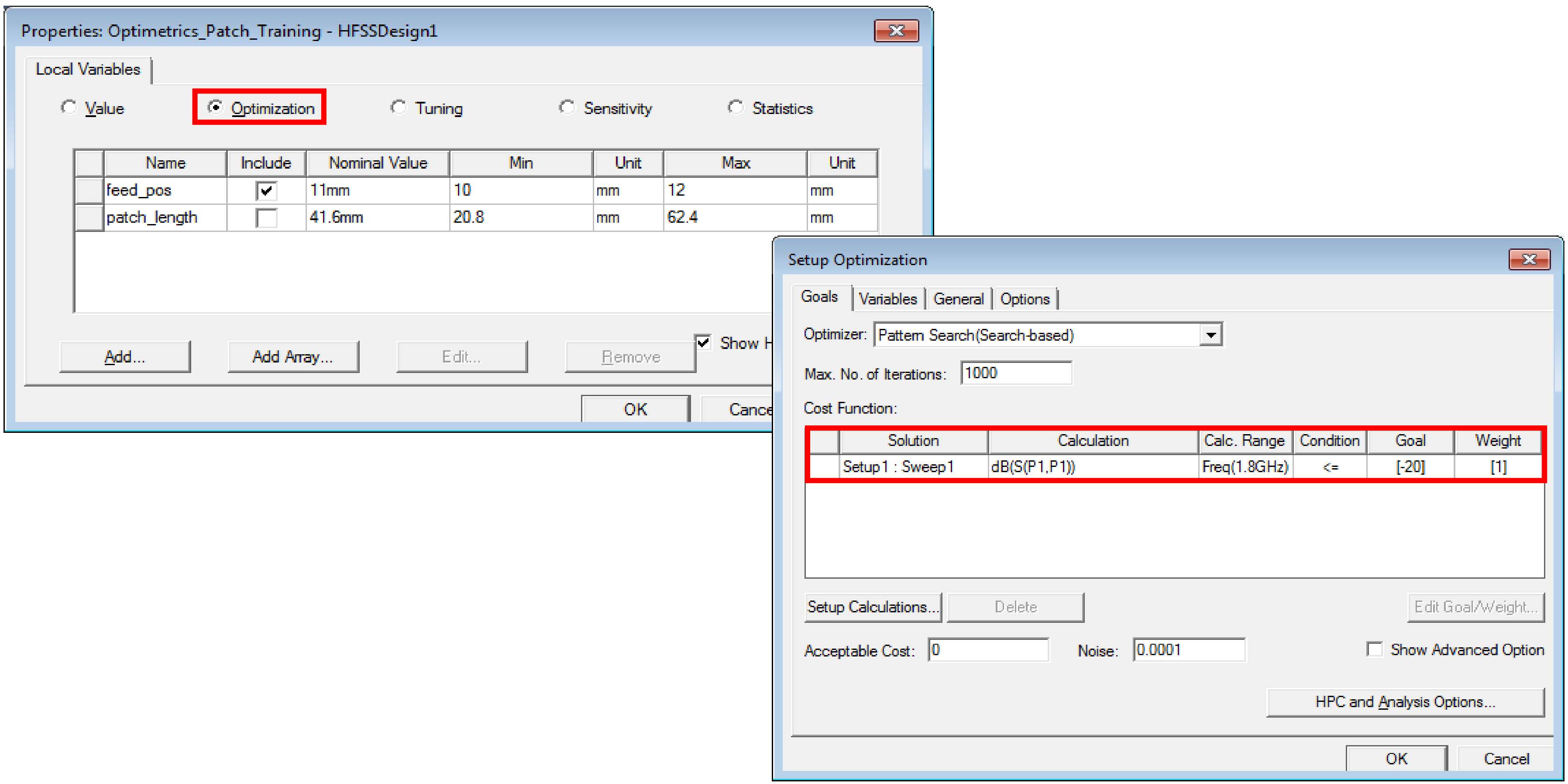
Parametric Analysis

- **Optimetics Setup: Parametric Analysis**
  - Create nominal design with variables assigned to model aspects to change
  - Define one or more variable sweep definitions
    - Each specifies series of variable values within a range
  - Optimetrics solves the design for each variation
    - Compare results to determine how each variation affects performance
  - Number of variations limited only by computing resources
  - Parametric analyses often used as precursors to optimization because they help determine reasonable range of variable values



Optimization Analysis

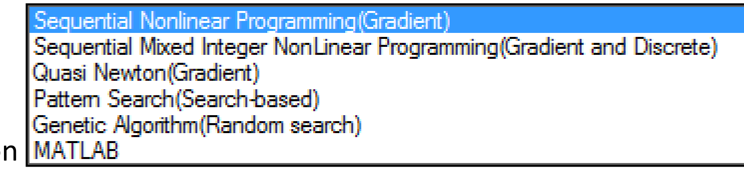
- **Optimetics Setup: Optimization Analysis**
  - Identify cost function and optimization goal
  - Cost function can be based on any solution quantity that HFSS or Designer can calculate
    - Field values, S-parameters, and Eigenmode data
  - Optimetrics changes design parameter values to meet goal



Optimization Analysis Parameters

- **Several analysis parameters must be specified**
  - Cost function
    - Optimetrics minimizes the cost function. Define this so that minimum location is also optimum location. For example, if you desire to maximize transmission from port 1 to port 2 (S21=>1), define cost function to be -mag(S(Port2,Port1)).
  - Acceptable Cost
    - Value of cost function at which optimization stops (may be negative).
  - Goal Weight
    - If cost function with multiple goals, you may assign different weight to each goal. The goal with greater weight is given more importance during cost calculation.
  - Step Size
    - In order to make the search reasonable, the algorithm limits the minimum and maximum step limits for individual optimization variables.
  - Cost Function Noise
    - Numerical calculation of EM fields introduces various sources of noise to cost function due to changes in finite element mesh. The noise indicates whether change is significant enough to support achievement of cost function.

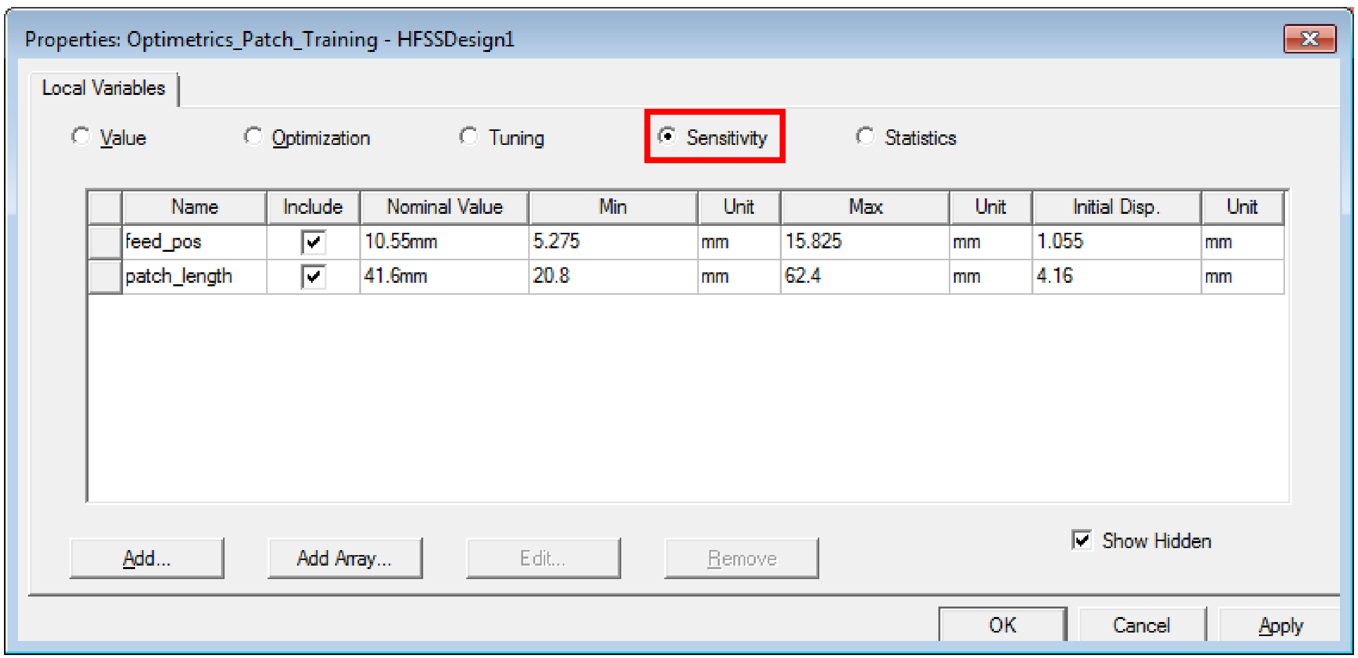
Available Optimizers



- **Quasi Newton**
  - Uses gradient approximation of cost function in search for minimum location
  - "Downhill" search iterative method using second order derivatives to accelerate convergence
  - Only accurate enough if there is little noise involved in cost function
  - Use when SNLP optimizer has difficulty and noise is insignificant
- **Sequential Non-Linear Programming (SNLP)**
  - Uses principle similar to Quasi Newton optimizer
  - Assumes that optimization variables are continuous
  - Handles numerical noise slightly better than Quasi Newton optimizer
  - Will utilize Analytic Derivatives during optimization, if enabled
- **Sequential Mixed Integer Non-Linear Programming**
  - Identical to SNLP except that it is able to deal with discrete integer variables as well as continuous variables
- **Pattern Search**
  - Performs grid-based simplex iterative search using either triangular or tetrahedral simplexes
  - Preferred when numerical noise is significant
- **Genetic Algorithm**
  - Iterative process which progresses through a number of generations with chromosomes representing combinations of parameter values (possible solutions)
  - Robust optimization scheme for large solution spaces
- **MATLAB**
  - Integration with MATLAB for optimization

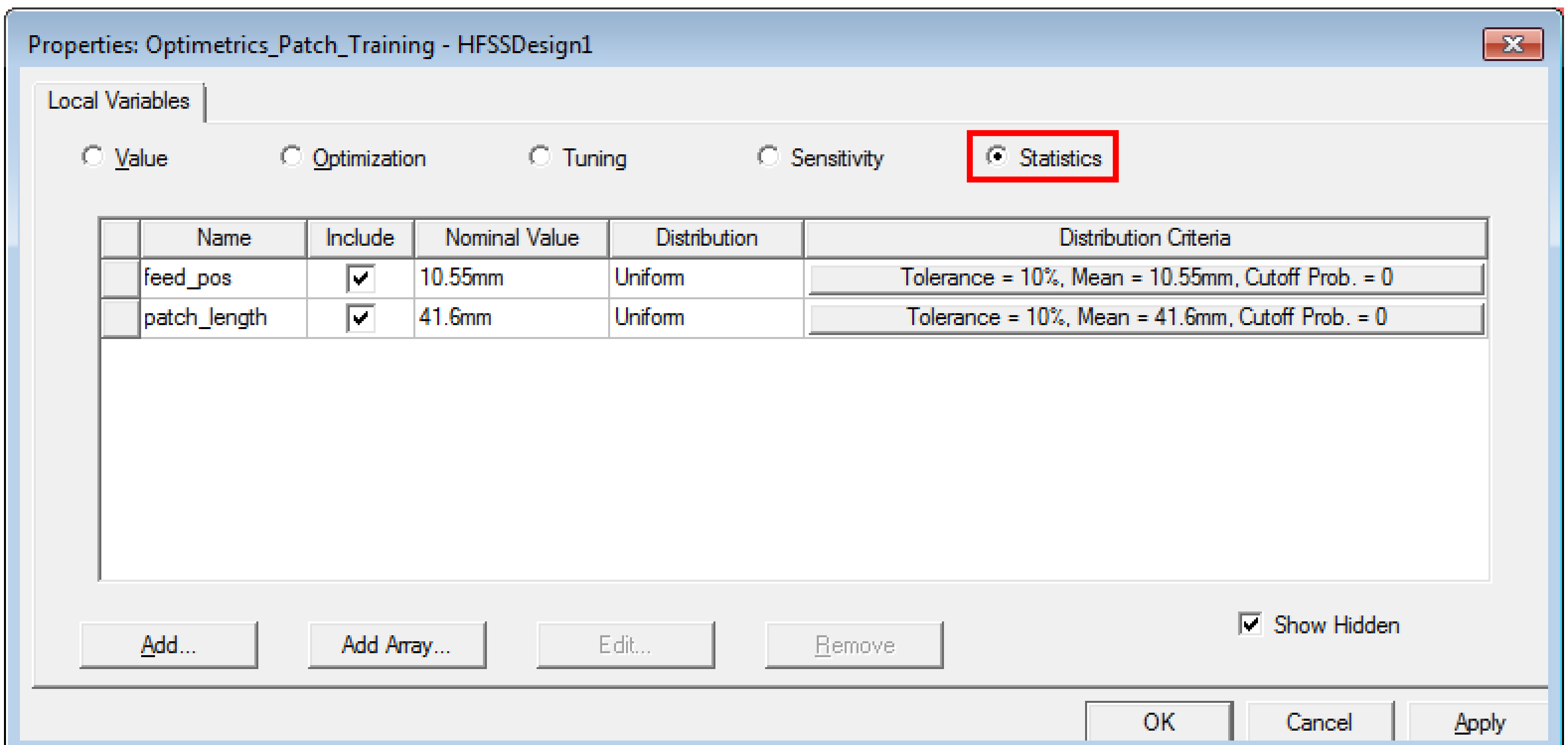
Sensitivity Analysis

- **Sensitivity Analysis**
  - Used to determine design sensitivity to small variations in specific parameters around specific design point
  - Can tolerance a design to ensure design goals are met
    - For example, determine maximum acceptable deviation for substrate permittivity of microstrip line to ensure impedance is well-matched
  - Preferred over parametric analysis for this purpose
    - Careful choice of parameter variations required to determine sensitivity and de-embed this from numerical mesh noise and large scale variations in parameter values
  - Optimetrics varies the parameters about design point and automatically fits second order polynomial to requested output



Statistical Analysis

- **Statistical Analysis**
  - Used to predict yield of component when subject to random variations in parameter values
  - Optimetrics includes uniform and Gaussian distribution functions
    - Uniform distribution: User specifies percentage tolerance from variable's starting value for the analysis. Solves for values within this tolerance range assuming uniform probability
    - Gaussian distribution: User specifies standard deviation of distribution and upper and lower limits. Solves for values between the upper and lower limits assuming Gaussian probability



Analytic Derivatives

- **Analytic Derivatives**
  - Compute the derivatives of SYZ parameters with respect to project and design variables
  - Eliminates need to solve multiple variations with small differences and numerical noise
    - More efficient and more accurate
  - Provides real-time tuning of reports to explore effects of small design changes
  - Improves derivative-based optimization methods

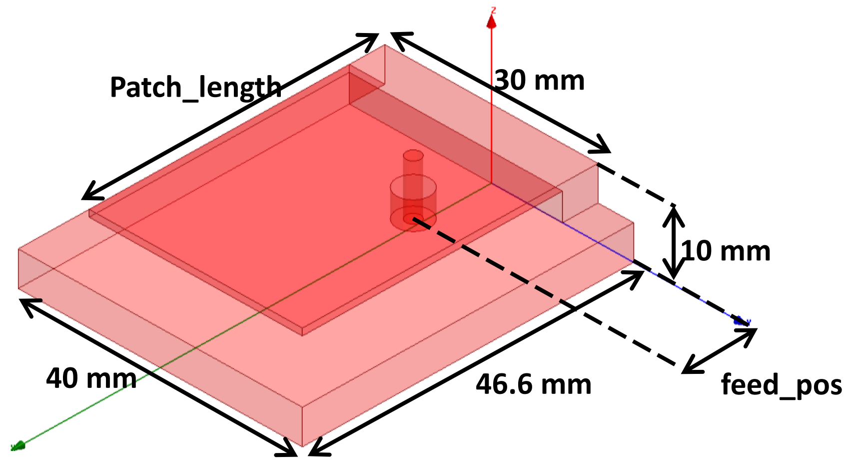
Sensitivity Analysis of S-parameters Including Port Variations Using the Transfinite Element Method

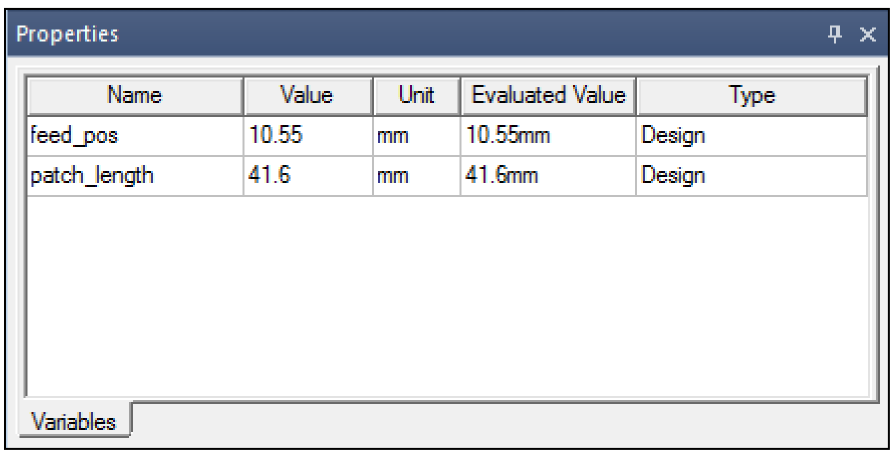
L. Vardapetyan, J. Manges, and Z. Cendes
Ansoft Corporation, Pittsburgh, Pennsylvania 15219, USA

2008 IEEE MTT-S Digest, pp. 527-530

Analytic Derivatives – Example: Coax-Fed Patch

- **Example: Analytical Derivatives**
  - Coax-Fed Patch antenna is a typical antenna with potential for many variables
  - Design variables:
    - feed_pos and patch_length
  - Solve for the derivatives of many variables at once



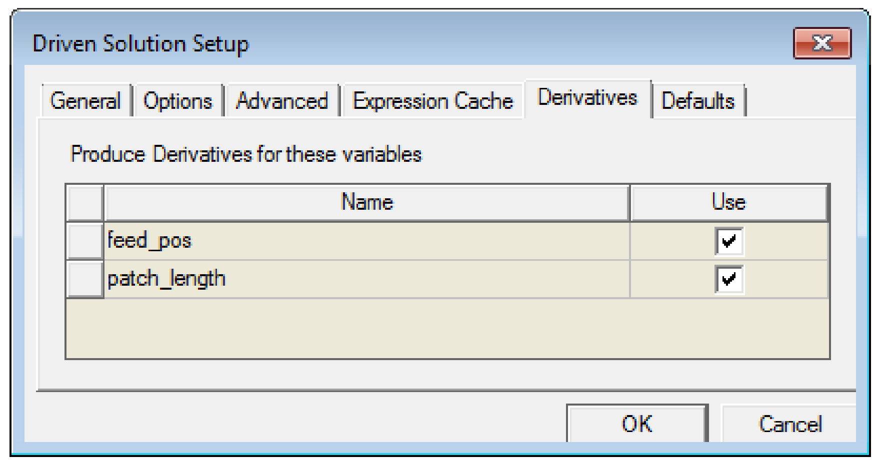


Properties

Name	Value	Unit	Evaluated Value	Type
feed_pos	10.55	mm	10.55mm	Design
patch_length	41.6	mm	41.6mm	Design

Variables

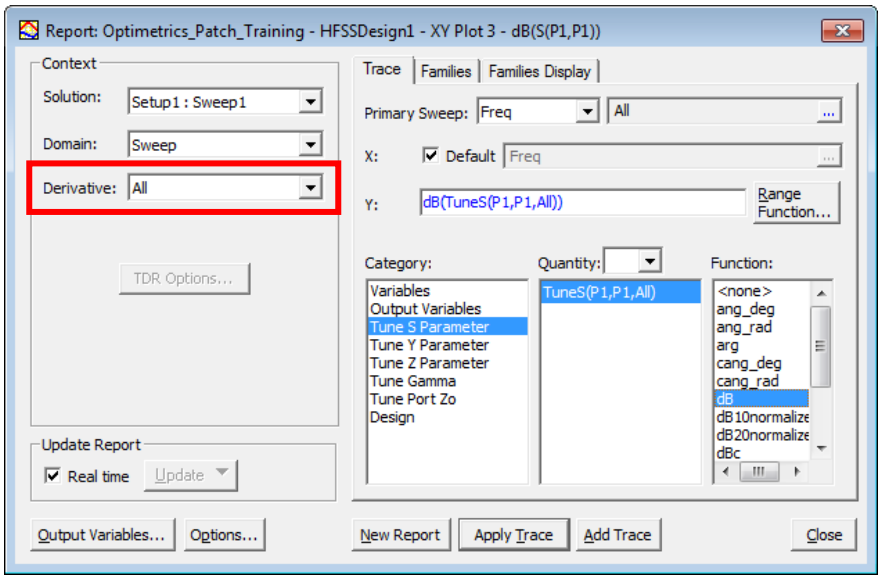
Nominal Values for Design Variables



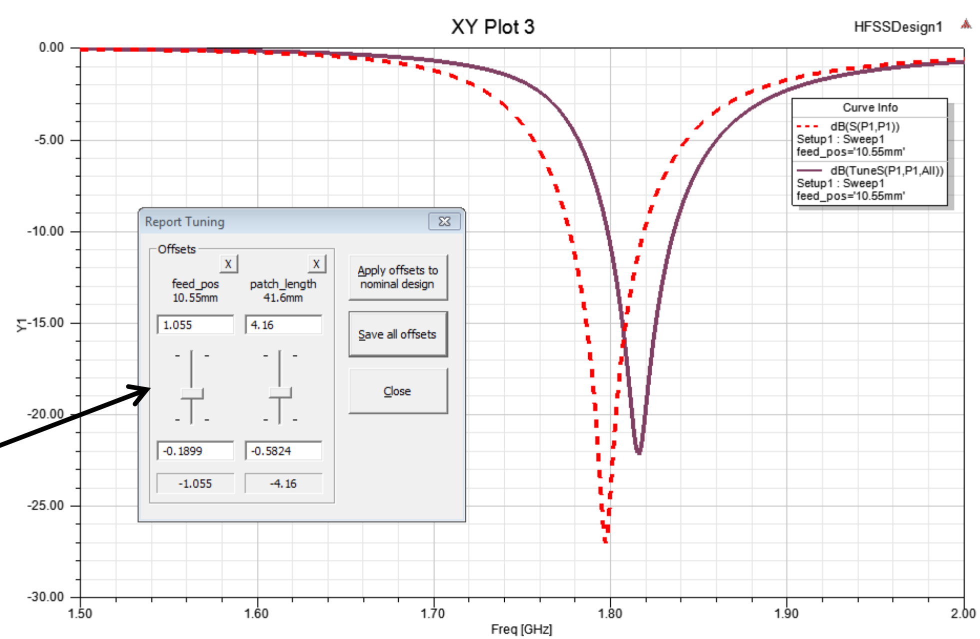
Specify Desired Derivatives in Solution Setup

Analytic Derivatives – Example: Coax-Fed Patch

- **Results: Analytical Derivatives**
  - Real-time tuning shows effects of small changes on S-parameters



Quickly Explore Effects of Small Changes on S-parameters

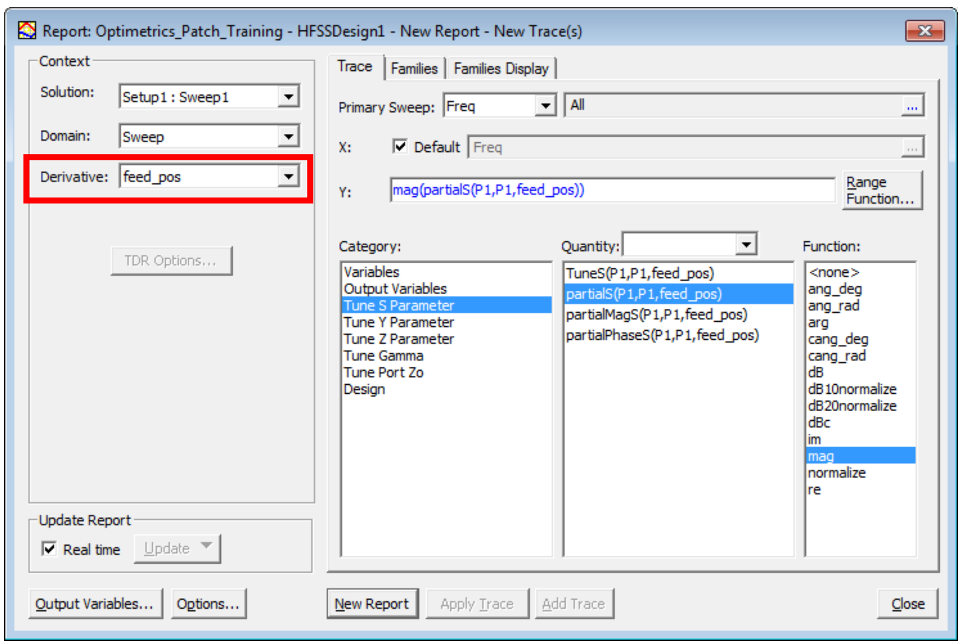


Real-Time Tuning

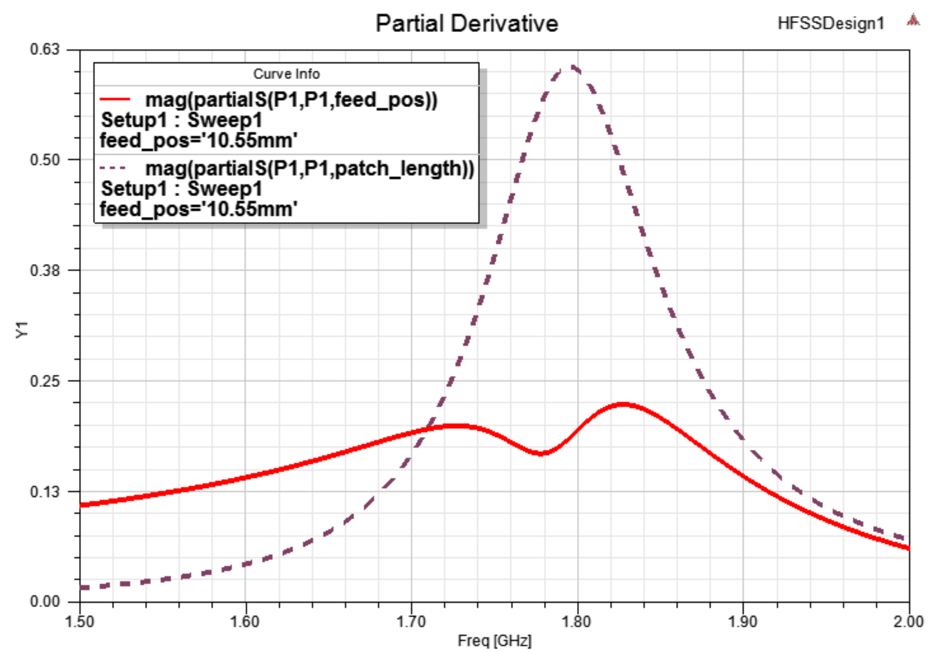
Analytic Derivatives – Example: Coax-Fed Patch

- **Results: Analytical Derivatives**
  - Can plot all partial derivatives (relative) at once for quick sensitivity comparison

Quickly Explore Relative Sensitivities of Various Variables

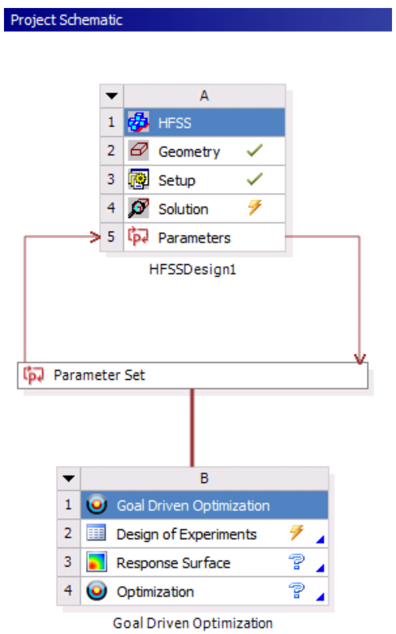


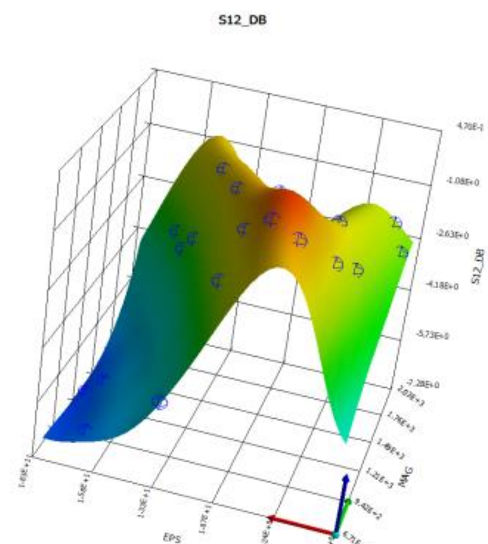
Notice that the patch Return Loss is much more dependent upon 'Patch_length' than 'feed_pos'

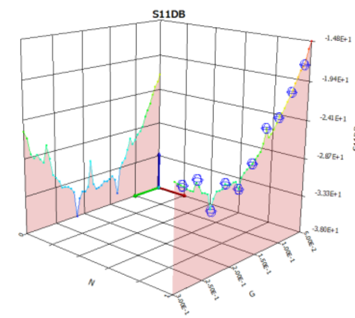


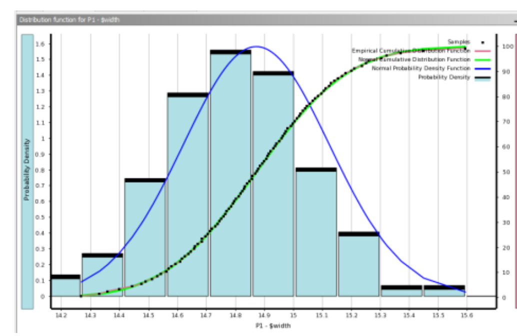
ANSYS DesignXplorer and HFSS Integration

- **Powerful Surface Response based DOE tool suite**
  - Quantifies influence of uncertainty variables on performance
- **Variety of sampling, modeling and optimization routines**
  - Sampling: central composite design and optimal space filling
  - Modeling: full second-order polynomial, Kriging, non-parametric regression, and neural network
  - Optimization: screening, multi-objective genetic algorithm, and nonlinear sequential quadratic programming
- **Create and execute DOE simulations for HFSS from DesignXplorer**
  - Entire solution space of HFSS design can be investigated using built-in or custom DOE algorithms









Summary

- **Optimetrics**
  - Add-on option integrated into interface of all ANSYS 3D tools
  - Includes variety of powerful analysis capabilities
    - Parametric sweeps: defined variables automatically changed and corresponding analysis performed
    - Optimization: properties optimized based on performance goal and defined design variables
    - Sensitivity analysis: yields design sensitivity for range of values about design point
    - Statistical analysis: determines effects of statistical variations of design variables on output
  - Integration of ANSYS HFSS and ANSYS DesignXplorer offers new valuable insights into behavior of EM designs
    - Entire solution space of HFSS design can be investigated using built-in or custom DOE algorithms
    - Provides powerful 3D and 2D visualization of solution space to evaluate performance trends
  - Distributed Solve Option can be used to further increase simulation throughput

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