*In the name of God.*

# HFSS

(High Frequency Structure Simulator)

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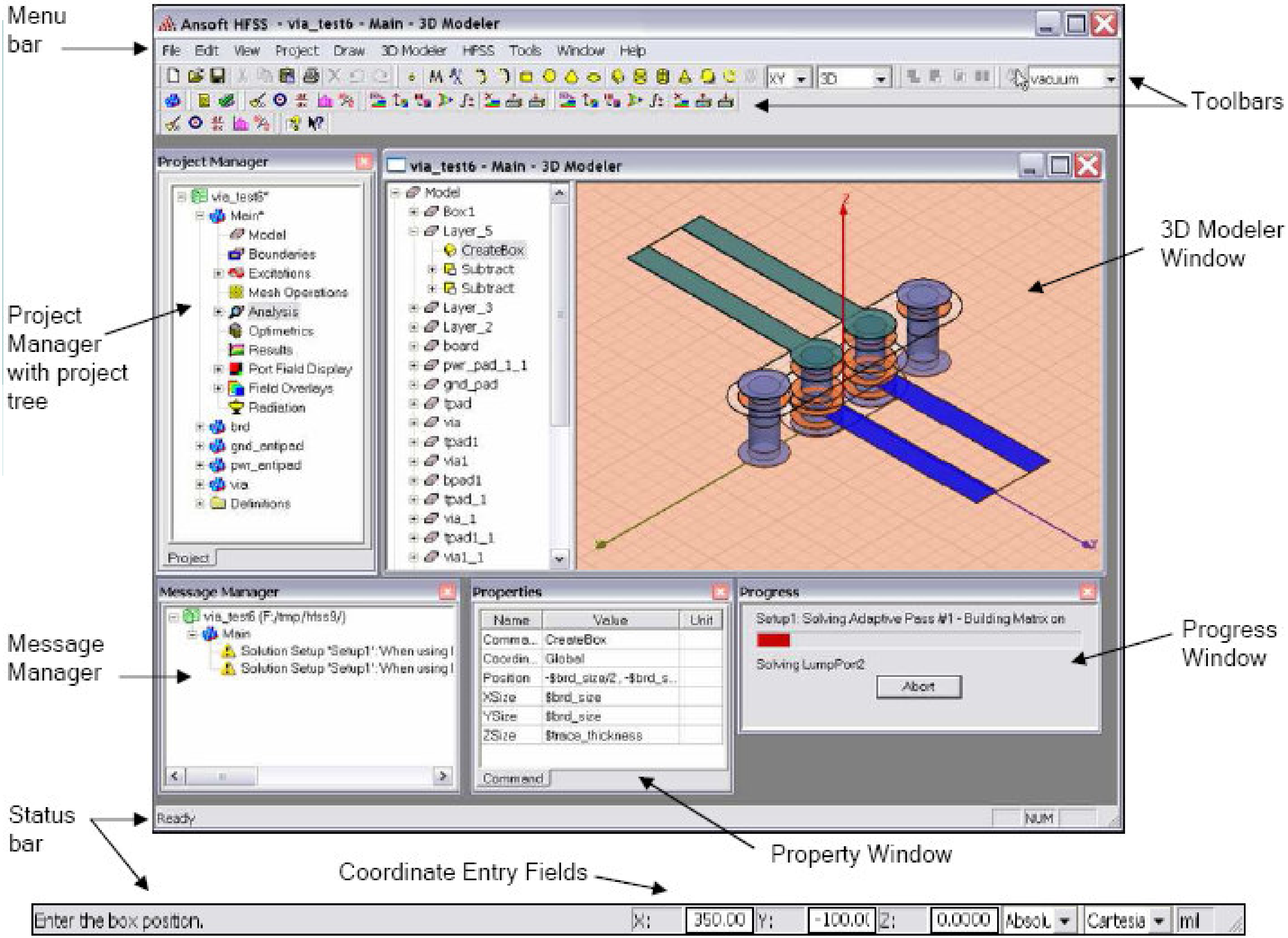
# *HFSS*

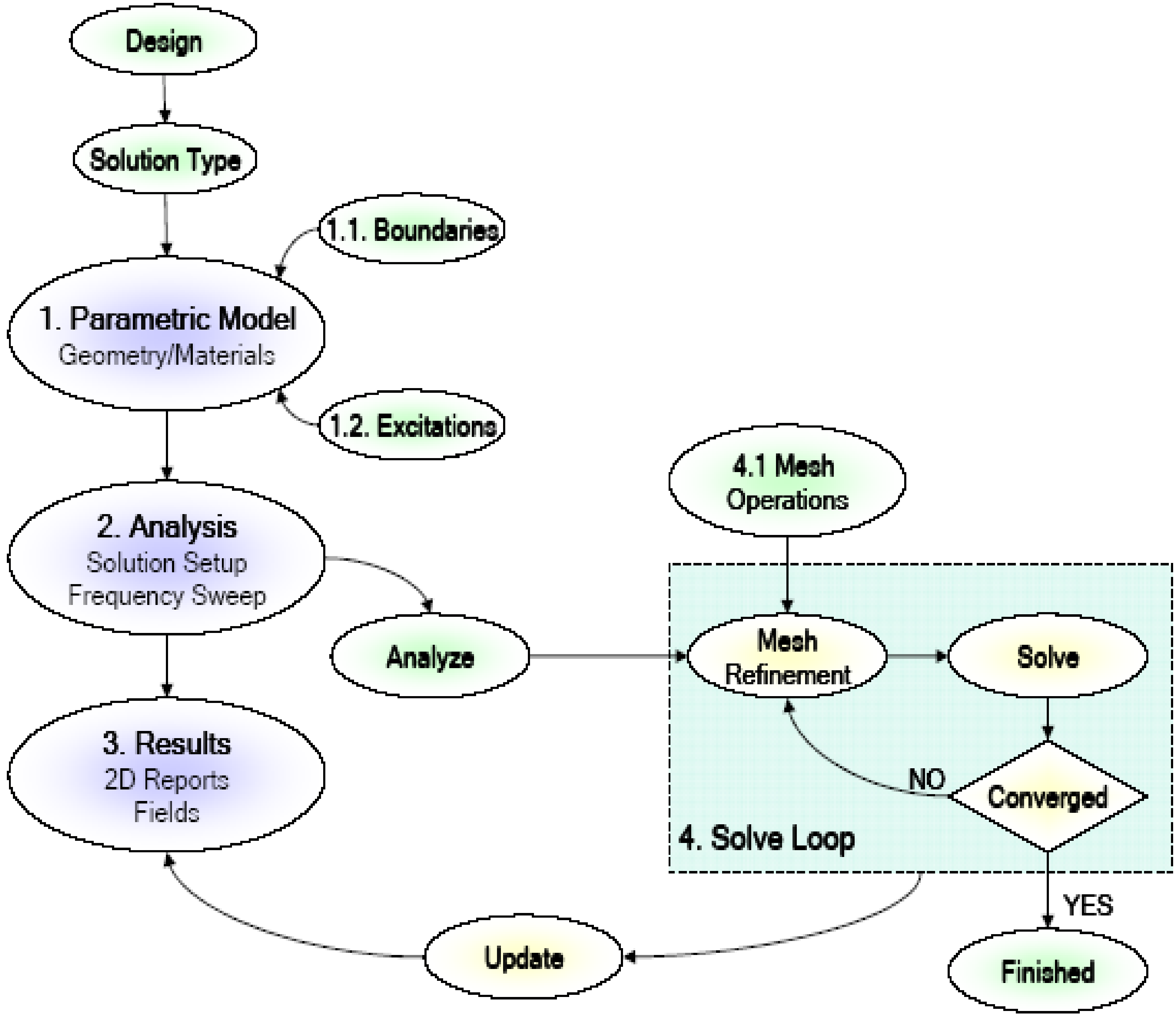
- for arbitrary 3D volumetric passive device modeling
- Finite Element Method (FEM)
- adaptive meshing
- brilliant graphics
- calculate parameters such as S-Parameters, Resonant Frequency, and Fields.

# *Typical uses*

- **Package Modeling:** BGA, QFP, Flip-Chip
- **PCB Board Modeling:** Power/Ground planes, Mesh Grid Grounds, Backplanes
- **Silicon/GaAs:** Spiral Inductors, Transformers
- **EMC/EMI:** Shield Enclosures, Coupling, Near- or Far-Field Radiation
- **Antennas/Mobile Communications:** Patches, Dipoles, Horns, Conformal Cell Phone Antennas, Quadrafilar Helix, Specific Absorption Rate(SAR), Infinite Arrays, Radar Cross Section (RCS), Frequency Selective Surfaces(FSS)
- **Connectors:** Coax, SFP/XFP, Backplane, Transitions
- **Waveguide:** Filters, Resonators, Transitions, Couplers
- **Filters:** Cavity Filters, Microstrip, Dielectric



Menu bar
Toolbars
3D Modeler Window
Project Manager with project tree
Message Manager
Progress Window
Status bar
Property Window
Coordinate Entry Fields
Ansoft HFSS - via_test6 - Main - 3D Modeler
File Edit View Project Draw 3D Modeler HFSS Tools Window Help
Project Manager
Message Manager
Properties
Progress
Setup1: Solving Adaptive Pass #1 - Building Matrix on
Solving LumpPort2
Abort
Ready
Enter the box position.



Design
Solution Type
1.1. Boundaries
1. Parametric Model
Geometry/Materials
1.2. Excitations
2. Analysis
Solution Setup
Frequency Sweep
Analyze
4.1 Mesh
Operations
Mesh
Refinement
Solve
NO
Converged
4. Solve Loop
YES
3. Results
2D Reports
Fields
Update
Finished

# *Set Solution Type*

- The *Solution Type* defines the type of results, how the excitations are defined, and the convergence.

- **1. Driven Modal:** calculates the *modal-based S-parameters*. The S-matrix solutions will be expressed in terms of the *incident and reflected powers of waveguide modes.*
- **2. Driven Terminal:** calculates the *terminal-based S-parameters* of multiconductor transmission line ports. The S-matrix solutions will be expressed in terms of *terminal voltages and currents.*
- **3. Eignemode:** calculate the *eigenmodes, or resonances*, of a structure. The Eigenmode solver finds the resonant frequencies of the structure and the fields at those resonant frequencies.

# *Convergence*

- ***Driven Modal:*** Delta S for modal S-Parameters. This was the only convergence method available for Driven Solutions in previous versions.
- ***Driven Terminal:*** Delta S for the single-ended or differential nodal S-Parameters.
- ***Eigenmode:*** Delta F

# *Boundary Conditions*

- ***Boundary conditions*** enable you to control the characteristics of planes, faces, or interfaces between objects. Boundary conditions are important to understand and are fundamental *to solution of Maxwell's equations*.
- The wave equation that is solved by HFSS is derived from the *differential form of Maxwell's Equations*. For these expressions to be valid, it is assumed that the field vectors are single-valued, bounded, and have *continuous distribution* along with their derivatives. Along boundaries or sources, the fields are discontinuous and the derivatives have no meaning. *Therefore boundary conditions define the field behavior across discontinuous boundaries*.

# *Boundary Conditions*

- HFSS can be thought of as a virtual prototyping world for passive RF devices. Unlike the real world which is bounded by infinite space, the virtual prototyping world needs to be made finite. In order to achieve this *finite space*, HFSS applies a *background or outer boundary condition* which is applied to the region surrounding the geometric model.

- **Boundary Condition Precedence:** Latter assigned boundaries take precedence over former assigned boundaries. Ports will always take the highest precedence.

# *How the Background Affects a Structure*

- The background is the region that surrounds the geometric model and fills any space that is not occupied by an object. Any object surface that touches the background is automatically defined to be a Perfect E boundary and given the boundary name outer. You can think of your structure as being encased with a thin, perfect conductor.
  - To model losses in a surface, you can redefine the surface to be either a Finite Conductivity or Impedance boundary.
  - To model a surface to allow waves to radiate infinitely far into space, redefine the surface to be radiation boundary.

# *Common Boundary Conditions*

- **1. Excitations**
  - Wave Ports (External)
  - Lumped Ports (Internal)
- **2. Surface Approximations**
  - Symmetry Planes
  - Perfect Electric or Magnetic Surfaces
  - Radiation Surfaces
  - Background or Outer Surface
- **3. Material Properties**
  - Boundary between two dielectrics
  - Finite Conductivity of a conductor

# *Technical Definition of Boundary Conditions*

- ***Excitation:*** An excitation port is a type of boundary condition that permits energy to flow into and out of a structure.
- ***Perfect E:*** Perfect E is a perfect electrical conductor, also referred to as a perfect conductor.
  - Any object surface that touches the background is automatically defined to be a Perfect E boundary and given the boundary condition name **outer**.
  - Any object that is assigned the material **pec** (Perfect Electric Conductor) is automatically assigned the boundary condition Perfect E to its surface and given the boundary condition name **smetal**.

# *Technical Definition of Boundary Conditions*

- ***Finite Conductivity***: A Finite Conductivity boundary enables you to define the surface of an object as a lossy (imperfect) conductor. It is an imperfect E boundary condition, and is analogous to the lossy metal material definition. Loss is calculated as a function of frequency.

- ***Impedance:*** a resistive surface that calculates the field behavior and losses using analytical formulas.

- ***Infinite Ground Plane:*** Generally, the ground plane is treated as an infinite, Perfect E, Finite Conductivity, or Impedance boundary condition. If radiation boundaries are used in a structure, the ground plane acts as a shield for far-field energy, preventing waves from propagating past the ground plane.

# *Technical Definition of Boundary Conditions*

- ***Radiation:*** Radiation boundaries, also referred to as absorbing boundaries, enable you to model a surface as electrically open: waves can then radiate out of the structure and toward the radiation boundary.

- ***Other Boundary Conditions:***
  - Layered Impedance
  - Lumped RLC
  - Symmetry
  - Master / Slave

# *Excitations*

- By default Ansoft HFSS assumes that all structures are completely encased in a conductive shield with no energy propagating through it. You apply **Wave Ports** to the structure to indicate the area were the energy enters and exits the conductive shield.

- As an alternative to using Wave Ports, you can apply **Lumped Ports** to a structure instead. Lumped Ports are useful for modeling internal ports within a structure.

# *Wave Port*

- The *port solver* assumes that the *Wave Port* you define is connected to a *semiinfinitely long waveguide* that has the same *cross-section* and *material* properties as the port. Each Wave Port is excited individually and each *mode* incident on a port contains *one watt* of time-averaged power. Wave Ports calculate *characteristic impedance, complex propagation constant*, and *generalized SParameters.*

# *Calibrating Wave Ports*

- Wave Ports that are added to a structure must be *calibrated* to ensure consistent results. This calibration is required in order to determine *direction* and *polarity* of fields and to make voltage calculations.

- ***Driven Modal:*** For Driven Modal simulations, the Wave Ports are calibrated using Integration Lines. Each Integration Line is used to calculate the following characteristics:

  - **Impedance:** As an impedance line, the line serves as the path over which HFSS *integrates* the *E-field* to obtain the *voltage* at a Wave Port. HFSS uses the voltage to compute the *characteristic impedance* of the Wave Ports, which is needed to renormalize generalized S-matrices to specific impedances such as 50 ohms.
  - **Calibration:** As a calibration line, the line explicitly defines the up or positive direction at each Wave Port. At any Wave Port, the direction of the field at wt = 0 can be in at least one of two directions. At some ports, such as circular ports, there can be more than two possible directions, and you will want to use Polarize E-Field. If you do not define an Integration Line, the resulting S-parameters can be out of phase with what you expect.

# *Calibrating Wave Ports*

- ***Solution Type: Driven Terminal:***

  The *Modal S-matrix* solution computed by HFSS is expressed in terms of the *incident* and *reflected powers* of the waveguide modes. This description does not lend itself to problems where several different quasitransverse electromagnetic (TEM) modes can propagate simultaneously. For structures like *coupled transmission lines* or *connectors*, which support *multiple, quasi-TEM modes* of propagation, it is often desirable to compute the Terminal S-Parameters.

# *Considerations for Defining Wave Ports*

- ***Wave Port Locations***
  - It is recommended that only surfaces that are exposed to the *background* be defined as Wave Ports. The background is given the boundary name *outer*. Therefore a surface is exposed to the background if it touches the boundary *outer*. You can locate all regions of outer by selecting the menu item **HFSS**, **Boundary Display (Solver View)**. From the **Solver View of Boundaries**, check the **Visibility** for *outer*.

- ***Ports are Planar***
- ***Wave Ports Require a Length of Uniform Cross Section***

# *Analysis Setup*

- ***Convergence***

  After each adaptive pass, HFSS compares the *S-Parameters* from the current mesh to the results of the previous mesh. If the answers have not changed by the *user defined value* or *Delta S*, then the solution has converged and the current or previous mesh can be used to perform a frequency sweep.

- ***Delta S***

  The Delta S is the default criteria used to determine mesh/solution convergence. The Delta S is defined as the maximum change in the magnitude of the S-parameters between two consecutive passes.

# *Analysis Setup*

- Since the adaptive meshing is based on the E-field, choosing the proper adapt frequency can be critical.

- **Broadband Structures**
  - For broadband structures, the *end frequency* should be used since the finer mesh should be valid at all lower frequency points.

- **Filters**
  - For *filters* or *narrow-band* devices, a frequency within the *pass-band* or operating region should be used since in the stop-band the E-field is only present at the ports.

# *Analysis Setup*

- **Fast Frequency Sweeps**
  - For Fast Frequency Sweeps, typically use the *center* of the *frequency band*. The Fast Frequency Sweep uses the mesh/solution at the adaptive frequency point. Since the error in the Fast Frequency Sweep typically increases as you move away from this point, the center of the frequency band is usually the preferred solution frequency to extrapolate the entire band from. It is also important to center the frequency sweep around a center point that will produce an adequate mesh. This is especially true for very high Q devices such as *narrow-band filters*. If the center frequency is not in the filters pass-band, the *bandwidth* and *resonant* frequency will *not* be *accurate*.

# *Analysis Setup*

- **Solve Ports Only:** The Port Solution uses an arbitrary, adaptive 2D eigenmode solver to determine the *natural frequencies* or *modes* that will be used to excite the structure. The ports only solution can be used to calculate only the modal field patterns for the 2D cross sections defined to be ports. This is useful for determining the *number* of *modes*, *modal fields*, the *port length*, and/or *proper port setup* prior to running a full solution.

- **Maximum Number of Passes:** This number controls the maximum number of passes the adaptive mesh routine will perform as it attempts to satisfy the convergence criteria.

- **Maximum Delta S Per Pass:** This number defines the convergence criteria for the adaptive meshing process.

# *Analysis Setup*

- **Lambda Refinement:** The Initial Mesh is based only on the 3D solid model, it has no bearing on the electrical performance of the device to be simulated. The Lambda Refinement process refines the Initial Mesh until most mesh element lengths are approximately *one-quarter wavelength for air* and *one-third wavelength for dielectrics*. A wavelength is based on the Single Frequency value entered in the Solution Frequency. In almost all cases Lambda Refinement should be used.
- **Refinement Per Pass:** The mesh growth for each adaptive pass is controlled by the Refinement Per Pass. The Refinement Per Pass is a percentage. This ensures that between each pass the mesh is sufficiently perturbed and guarantees that you will not receive false convergences.

- **Minimum Number of Passes:** An adaptive analysis will not stop unless the minimum number of passes you specify has been completed, even if convergence criteria have been met

# *Analysis Setup*

- **Minimum Converged Passes:** An adaptive analysis will not stop unless the minimum number of converged passes you specify has been completed. The convergence criteria must be met for at least this number of passes before the adaptive analysis will stop.

# *Frequency Sweeps*

- **Discrete:** performs a *full solution* at *every frequency* using the current mesh. The time required is the single frequency solve times the number of frequency points. Fields can be displayed at any frequency within the sweep range if the Save Fields Box is checked.
- **Fast:** uses an Adaptive Lanczos-Pade Sweep (ALPS) based solver to extrapolate an entire bandwidth of solution information from the *center frequency*. Very good for high-Q devices but it can not be used to solve for devices that pass through cut-off. Once the band has been extrapolated, a high number of frequency points can be calculated without a penalty. In addition, the Fields can be displayed at any frequency within the sweep range. The time and memory required to solve a fast frequency sweep may be much larger then the single frequency solve.
- **Interpolating:** performs solves at discrete frequency points that are fit by interpolating. HFSS determines the frequency points to solve at based on the error in the interpolation between consecutive passes. The interpolation error and maximum number of points is defined by the user in the Edit Sweep. As with the fast frequency sweep, the Interpolating Sweep can generate a larger number of frequency points. But you only have the field solution for the last solved frequency. The maximum solution time is the single frequency solve times the maximum number of points.