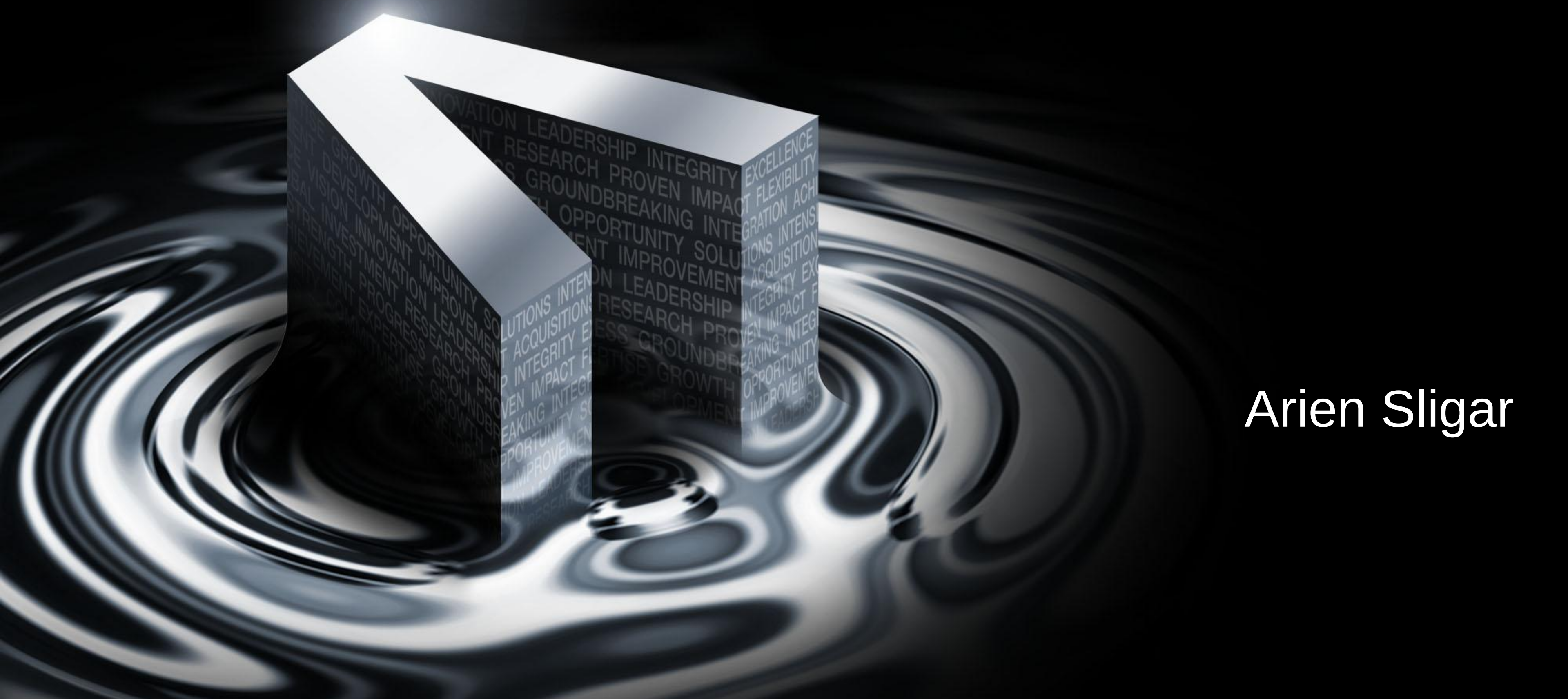
Antenna Modeling Considerations



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Antenna Modeling Guidelines: What you need to know

- **Model setup**
  - Creating geometry
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- **Far field considerations**
  - Radiation boundary vs. PML
  - Infinite sphere setup
  - Custom integration surface
- **Solution setup**
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- **Post processing**
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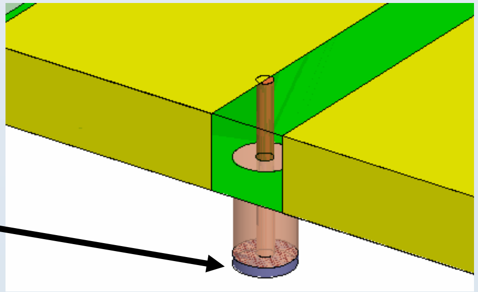
Model Setup

- ## Creating Geometry
  - **2D/3D Metals:** Consider tradeoffs between using 2D vs. 3D metals to model antennas. Typically using 2D objects to represent antenna elements will result in a more efficient simulation without an impact on accuracy. 3D metals are necessary when edge coupling between closely spaced objects is important or when the thickness of the object is on the order of a skin depth.
  - **Model Detail:** Apply engineering judgment to determine the level of detail required to accurately represent the antenna geometry. Modeling features that are very small in comparison with a wavelength, such as small holes, chamfers, and blends, may unnecessarily increase the mesh density in areas that are not important to the electromagnetic behavior of the antenna.

- ## Excitations
  - **Feed Types:** Either Lumped or Wave ports may be used as excitations for antenna simulations. However, certain ports are more suited for particular antenna types. For Example:
    - Waveguides should be fed using wave ports
    - Antennas with differential feeds, such as dipoles and spirals, should be fed using lumped ports
    - Planar antennas fed with coax feeds, microstrip, stripline or other transmission line feeds can use either Wave or Lumped ports
    - Wave ports can be located internal to the solution volume if they are backed by conducting object.



Coaxial antenna feed with coaxial wave port capped by PEC object

Far Field Considerations:
Radiation vs. PML

Solution Volume Size: To properly model the far field behavior of an antenna, an appropriate volume of air must be included in the simulation. Truncation of the solution space is performed by including a radiation or PML boundary condition on the faces of this air volume that mimics free space. The appropriate distance between strongly radiating structures and the nearest face of the air volume depends upon whether a radiation or PML boundary condition is used.

Radiation Boundary Condition (ABC):

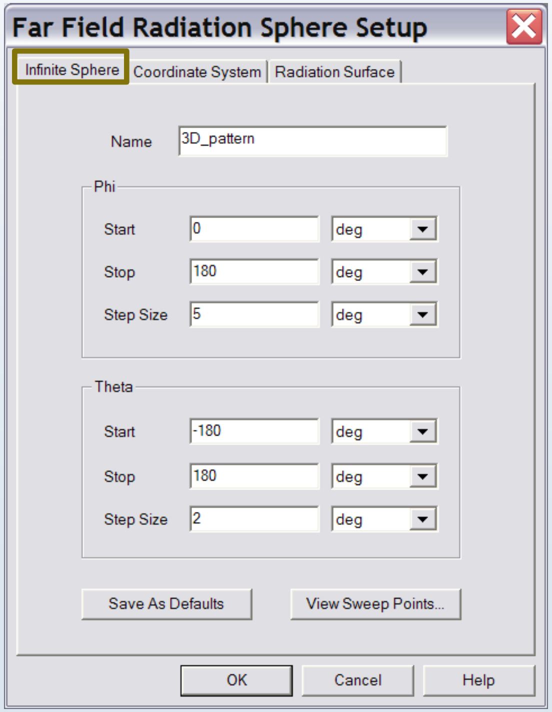
- Absorption achieved via 2nd order radiation boundary
- Place at least λ/4 from strongly radiating structure
- Place at least λ/10 from weakly radiating structure
- The radiation boundary will reflect varying amounts of energy depending on the incidence angle. The best performance is achieved at normal incidence. Avoid angles greater then ~30degrees. In addition, the radiation boundary must remain convex relative to the wave

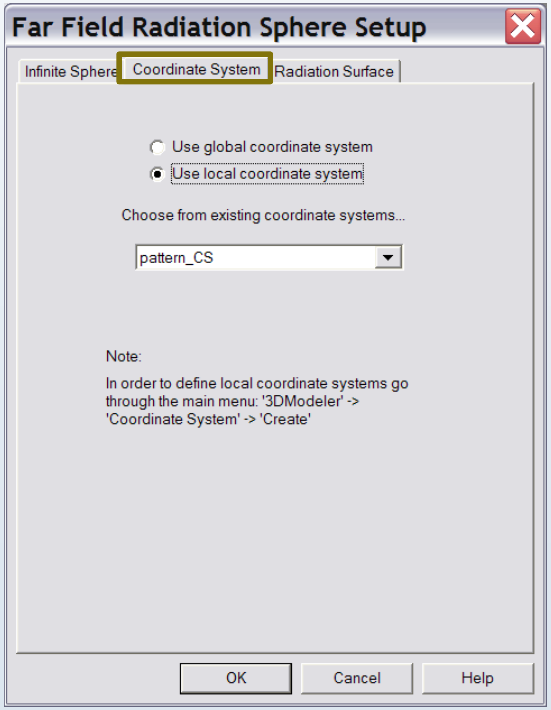
Perfectly Matched Layer (PML):

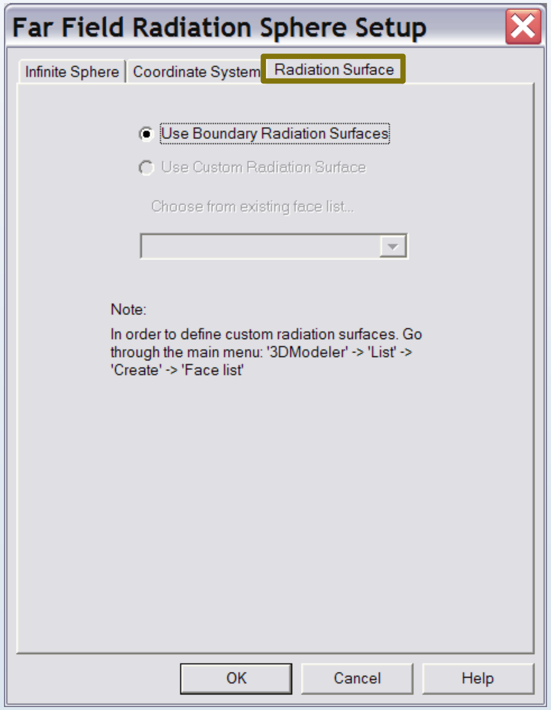
- Fictitious lossy anisotropic material which fully absorbs electromagnetic fields
- Place at least λ/8 from strongly radiating structure
- PML thickness should be approximately λ/3 at the lowest frequency of interest
- Does not suffer from incident angle issues

Far Field Considerations:
Infinite Sphere Setup

- The infinite sphere setup specifies a set of spatial data points in a spherical coordinate system for which HFSS will calculate far-fields. To create an infinite sphere setup:
  - Right-click on **Radiation → Insert Far Field Setup → Infinite Sphere**
- Relative coordinate systems may be used to modify reference orientation in far-field calculations. For example the far field coordinate system does not have to be the same as the global coordinate system.

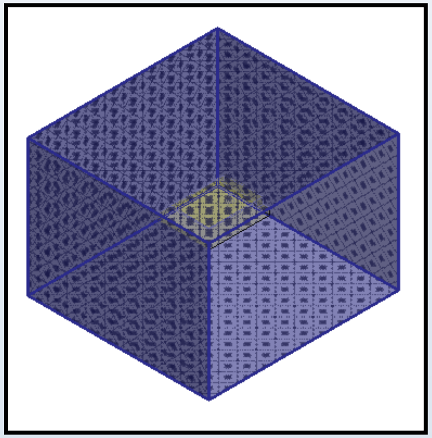




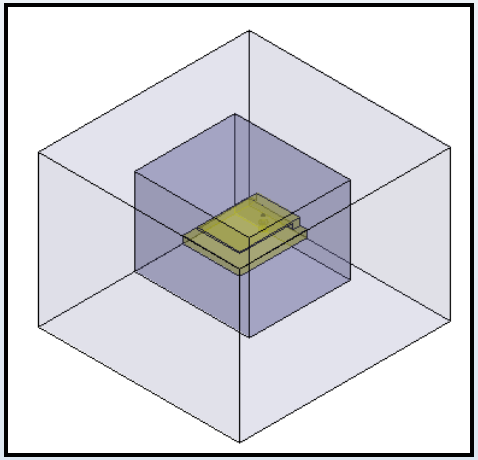


Far Field Considerations:
Custom Integration Surface

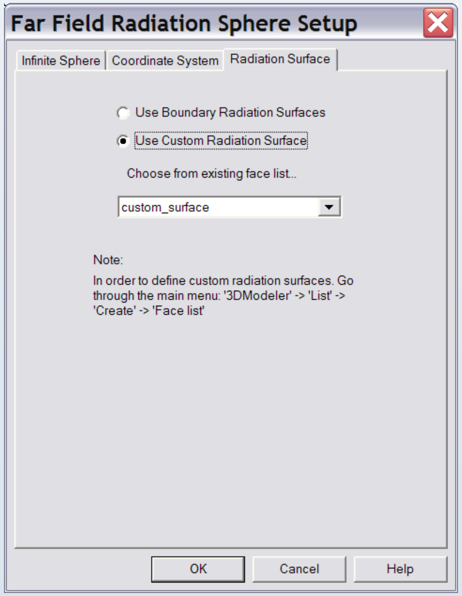
- HFSS calculates far fields using a near to far field transformation. The default integration surfaces for the far-field calculations are faces of radiation boundaries. Radiation surfaces are automatically defined on base object faces of PML objects
- Consider creating custom radiation surface for better accuracy and reduced simulation time. This can be done by creating a "virtual object" having the same properties of the surrounding material. Typically the material is air or vacuum for most antennas.
  - Place an air box at least $\lambda/10$ from all radiating surfaces
  - Create using ***Modeler*** → ***List*** → ***Create*** → ***Face List***
  - Also consider adding a mesh seeding operation with $\lambda/6$ seeding to the faces of the "virtual air box" to improve far field accuracy.
  - This custom integration surface needs to be specified as a custom radiation surface in the Infinite Sphere setup



Default Integration Surface



Custom Integration Surface



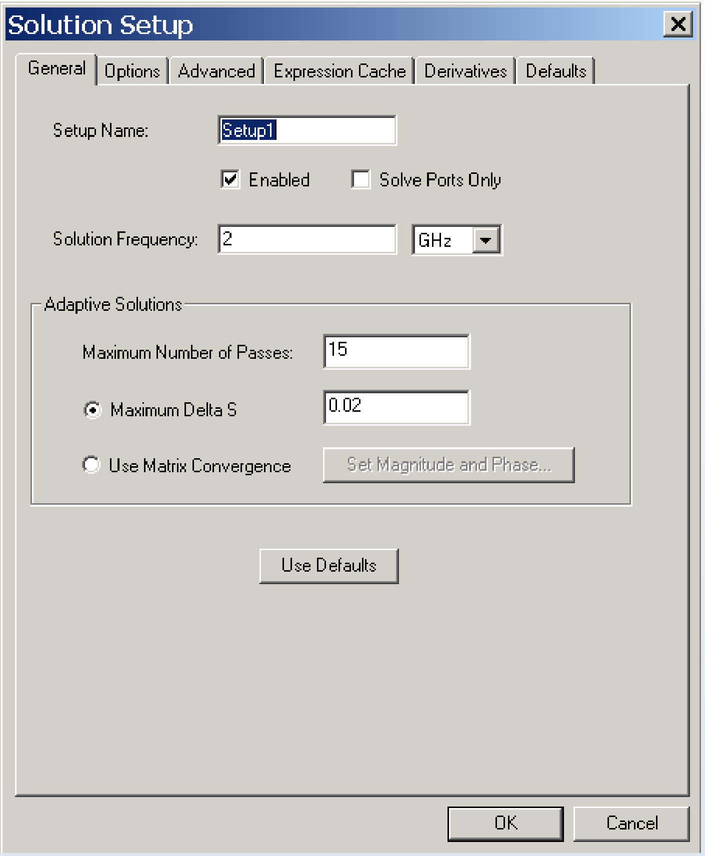
Solution Setup (1)

- **Solution frequency for adaptive meshing:** The solution frequency sets the frequency at which the adaptive meshing process is performed.

  A higher solution frequency yields a more dense initial mesh for the adaptive mesher. A higher frequency mesh is generally valid at lower frequencies, however a low frequency mesh is generally not valid at higher frequencies.

  For resonant or narrow band antennas, the solution frequency should be set to the center frequency. For wideband antennas, the solution frequency can typically be set to a frequency in the upper half of the operating band.

- **Choosing a reasonable accuracy:** Set a reasonable maximum ΔS convergence value to avoid unnecessary simulation time and RAM usage. A value of 1%-2% is usually sufficient for antenna simulations. Consider the limitations on measurement accuracy when specifying this criterion



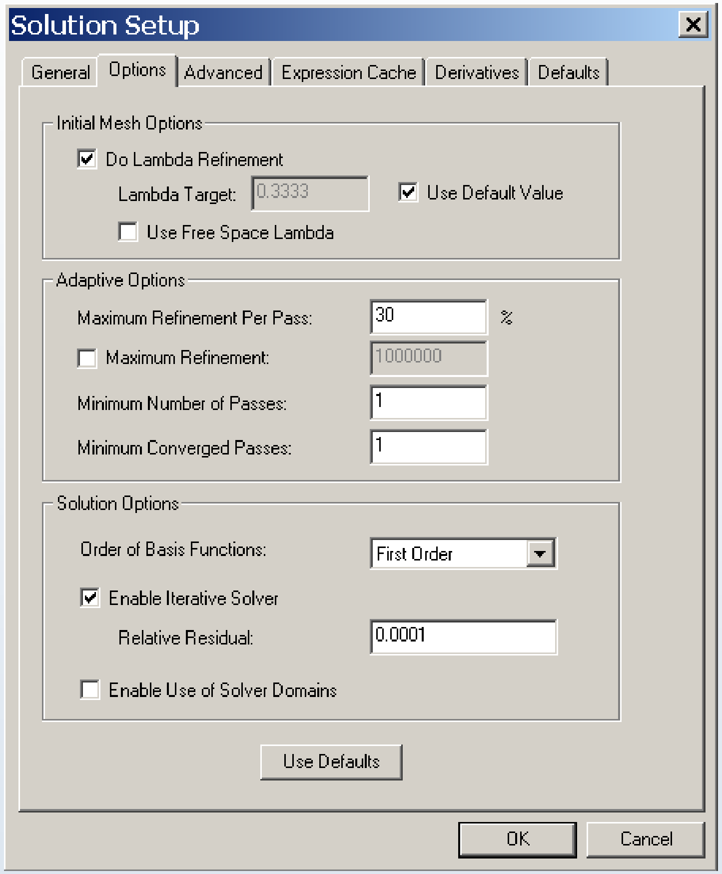
Solution Setup (2)

- **Expression Cache:** In addition to the ΔS convergence criterion used for the adaptive mesher, expressions may be defined which further constrains the stopping point of the adaptive mesh algorithm.

  This is useful for antenna models for which far-field parameters are of primary interest. For these models, output variable convergence can be applied on a far-field quantity in order to make sure that the fields have converged as well as the S-parameters.

- **Direct vs iterative matrix solver:** The iterative matrix solver can be used to reduce the RAM necessary to solve the model. This solver uses an iterative solution method to solve the matrix of unknowns. If the iterative solver is not successful, the matrix is solved using the default direct multi-frontal solver.

- **Higher-order basis functions:** Selecting a higher-order basis function may reduce the mesh density through the use of higher-order polynomials to represent the field behavior in each mesh element. The default setting of first-order basis functions is applicable to most antenna problems. For models that contain large volumes of homogeneous material such as air, the use of second-order basis functions may be more efficient. Mixed order basis functions introduced in HFSS v12 are ideal for problems that have large spaces and small details.



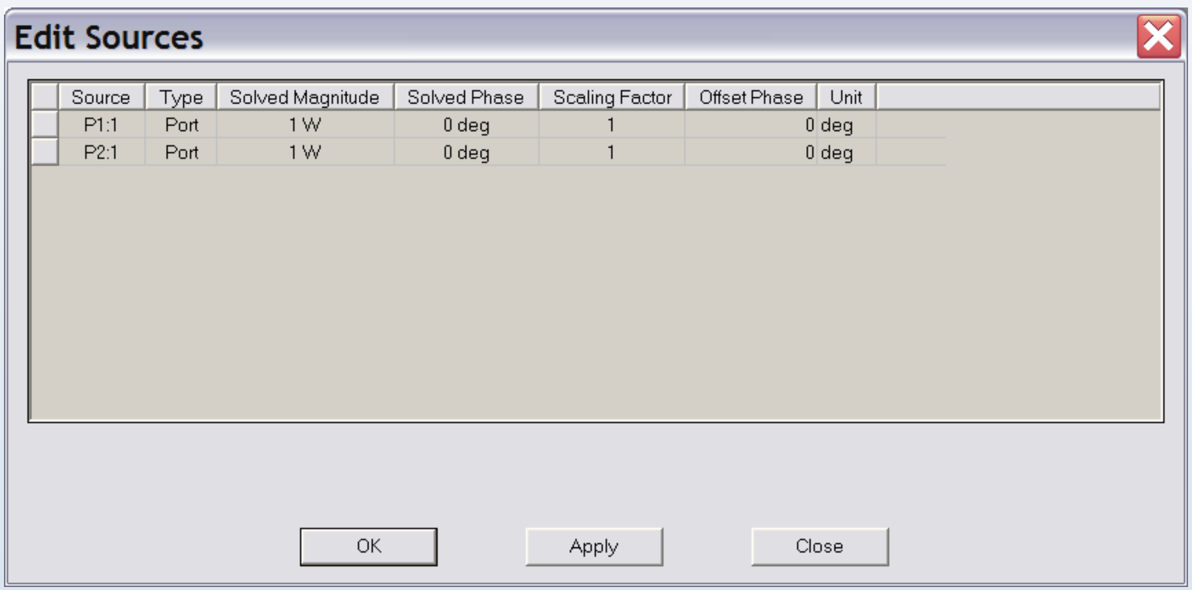
Solution Setup (3):
Frequency Sweep Type

- **Discrete frequency sweep:** The discrete frequency sweep solves the adapted mesh at each user-specified frequency. This is the most accurate method, but the runtime scales linearly with the number of frequencies. This sweep type provides fields and S-parameters for each frequency point.
- **Fast frequency sweep:** The fast frequency sweep typically produces valid results over bandwidth of several octaves. Set the adaptive mesh near or at the center of the desired band since the field solution is extrapolated around the solved frequency. This sweep type provides fields and S-parameters for each frequency point.
- **Interpolating frequency sweep:** The interpolating sweep is applicable to narrowband as well as very wideband sweeps. This sweep type solves the adapted mesh at the start, stop and midpoint of the frequency range and iteratively adds frequency points in order to create a curve-fit for all complex S-parameters. This sweep type provides only S-parameters for each frequency point and the field at the solution frequency.

Sweep Type	Speed	# of Freq. Points*	Bandwidth Limit†	Saved Fields	Memory	Adaptive Frequency
Discrete	Slow for many frequency points	10’s	None	All Frequencies	Same as Last Adaptive	Highest In-band Frequency
Fast	• Fast for large sweeps • Can be slower for small sweeps	<10,000	Octave	All Frequencies	More than Last Adaptive	Center of Frequency Band
Interpolating	Fast	<10,000	None	Only Last Adaptive	Same as Last Adaptive	Highest In-band Frequency

Post Processing:
Edit Sources

- **Edit Sources:** Edit sources is a post processing operation that sets complex power scaling factors for each port
  - Access through menu option **HFSS → Fields → Edit Sources**
- The coefficients specified are only used in post-processing operations. The scaling factor used under edit sources will not affect passive s-parameter results
  - **E, H, and J fields on 3D geometry**
  - **Far-field plots (patterns)**
  - **Active S-parameters**


Edit Sources

Source	Type	Solved Magnitude	Solved Phase	Scaling Factor	Offset Phase	Unit
P1:1	Port	1 W	0 deg	1	0	deg
P2:1	Port	1 W	0 deg	1	0	deg

Post Processing:
Far Field Definitions

- **Active S-Parameters:** Active S-parameters includes all mutual coupling from other ports to produce an "active S11" response at a given port. Passive S-parameters assume all other ports are loaded in terminal impedance and there are no reflections from other terminated ports. Active S-parameters represent port response based on coupled signals from other ports and includes coupling from other ports.

- **Total Gain vs. Realized Gain:** Total Gain is four pi times the ratio of an antenna's radiation intensity in a given direction to the total *power accepted* by the antenna. Realized gain is four pi times the ratio of an antenna's radiation intensity in a given direction to the total *power incident* upon the antenna port(s). Realized Gain includes the impedance mismatch loss associated with the antenna feed.

- **Polarization:** The electromagnetic field which is radiated by an antenna into the far field can be decomposed into various orthogonal polarization components. The following commonly used definitions are based on the direction of the electric field vector as the wave propagates through space: Right Hand Circular Polarization (RHCP), Left Hand Circular Polarization (LHCP), Theta-Polarized, Phi-Polarized and X,Y,Z –Polarized. Complete descriptions of these quantities are available in the HFSS help documentation.

$$ActiveS_{p:m} = \sum_{k-1}^{n} \left[\frac{a_{k:m}}{a_{p:m}} \times S_{p:k} \right]$$

$$Total\ Gain = \frac{4\pi \cdot U}{Accepted\ Power}$$

$$Realized\ Gain = \frac{4\pi \cdot U}{Incident\ Power}$$

Post Processing:
Trace Characteristics

- Radiation trace characteristics can be applied to any 2D radiation plot to quickly obtain beamwidth for any dB threshold (3 dB, etc.) and sidelobe levels and locations
  - Right-click on pattern report to activate menu