HFSS - Antennas, Arrays and FSS's

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Synopsis

- Some Excerpts from “What’s New”
  - Enhancements to HFSS
- Wave Guide Simulator (WGS)
  - What is it?
  - Why you would use it?
- Analytical Simulator (AS)
  - Good compliment to WGS
- Perfect Matched Layer (PML)
What’s New in Recent Versions of HFSS
HFSS Graphics: Animation Exports

- Animated Magnitude or Vector Plots can be exported as animated *.gif files
- Macro wizard interfaces walks user through animation settings
- Animations are cross-platform and can be used in presentations
HFSS Graphics: Post-Processor Improvements

- Lighting Control Option prevents 3D object lighting or shadows from washing out magnitude field plots.
- 3D Polar Antenna Patterns scale shape as well as color to plot min/max settings.
Macro Language Enhancements

- User-customizable menu structure via macro commands
- Bitmaps in Wizard graphical windows
  - “Splash” screens
  - Graphical diagrams to aid macro data entry
- Local or private scoped variables
- Macro debugger executable
- …and MORE! Please refer to separate Macro presentation for additional details.
Lumped RLC Circuit Elements

- Additional boundary condition permits inclusion of lumped circuit elements in HFSS
  - Model assumes parallel RLC circuit
  - Build several in a row for serial circuit topography
RCS/Scattering Solution Improvements

- Direct computation of “Total” field, rather than computation of “Scattered” field only
- Higher Accuracy, Fewer Unknowns per excitation
**HFSS 8 Interpolative Sweep**

- Provides wide-band sweep results
  - Calculator tool aids sweep setup if using FWS
- Falls between ‘fast’ and ‘discrete’ in capabilities
  - Multi-decade bandwidth
  - Faster than Discrete
  - No modal cutoff issues
  - Fields only at mesh frequency

![HFSS 8 Interpolative Sweep Interface](image)
Wide-band behavior including several sharp resonances was properly identified using very few frequency points (approximately 20).
**Internal Ports**

- Internal ports defined with a single sheet object at the end of the trace - no cap required.

- 2 options on how to define these ports:
  - Traditional-style ports assume a perfect-H boundary on all edges that do not contact metal (*wave ports*).
  - Gap source style (*lumped ports*).
Gap Source - Dipole

- Utilizing a Gap Source at feed point can improve accuracy
Meshing Improvements

- Lambda Refinement now recognizes object material assignments
  - Less need to seed simply due to material conditions
  - Improved convergence
- Improved mesh generation for high aspect ratios and true curved surfaces

Initial Lambda-Refined Mesh on a block of Vacuum and a block of Alumina, displaying material-sensitive refinement.
Post3 - Moving the origin

- The origin can be moved and far/near field results computed without resolving.
Enough Of What’s New - So How Do I Use This Stuff?
Large Arrays Modeled as Infinite

- So what is “large” anyway?
  - How many adjacent elements cause most of the coupling?
  - How much of the array sees edge affects?

- 1948 Wheeler published “The radiation resistance of an antenna in an infinite array or waveguide”… A waveguide simulator
- 1960’s others followed

NOT!

Probably Still Not
Waveguide Simulators

- Approximation of large array with an infinite array
- No edge affects
- Pairs of Perfect E’s or Perfect E’s and Perfect H’s
Modes in a Waveguide Simulator

- Waveguide modes correspond to plane waves at angles
- Various sizes of cross sections result in different scan angles

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Waveguide & Analytical Simulator

- Waveguide simulators (WGS) solve for multiple scan angles
- Analytical simulator (AS) solves for one scan angle. User SELECTS this angle!

* Spreadsheet is available!
**HFSS Boundary Descriptions: Master/Slave Boundaries**

- **Parameters:** Coordinate system, master/slave pairing and phasing
  - Master and slave boundaries used to model a unit cell of a repeating structure
  - Master and slave boundaries always paired: one master to one slave
  - The fields on the slave surface are constrained to be identical to those on the master surface, with phase shift

- **Constraints:**
  - The master and slave surfaces must be of identical shapes and sizes
  - A coordinate system must be identified on the master and slave boundary to identify point-to-point correspondence
Periodic Boundaries in Ansoft HFSS

- Periodic BC, Linked BC, Master/Slave Pairs
  - Yeah they are all the same thing!
- Adds to ability to model phased array antennas
  - Useful for any large uniform or periodic structure
  - Use to impose phase shift between two boundaries
- Multiple pairs (two or more) of matching boundaries
  - Can solve “staggered” antenna arrays
- Arbitrary orientation of matching boundaries in model coordinate system
How Does a LBC Operate?

- The LBC enforces a phase difference $\Phi$ between the two linked boundaries.

- $\phi$ angle measured from X axis
- $\theta$ angle measured from Z axis

- $E_{\text{slave}} = e^{i\Phi} E_{\text{master}}$
  - where $\Phi = \frac{d}{\lambda} \sin \theta \cos(\phi)$
  - here $\Phi$ depends on scan angles, $\theta$ and $\phi$
Periodic Boundaries in Ansoft HFSS (cont)

- Boundary manager screen allows easy set-up of master and slave boundaries
  - Checks that u-v coordinate choices for master and slave planes are consistent
  - User provides scan angles $\theta$ and $\phi$ in model coordinate system
- Automatic calculation of array parameters based on model geometry
  - Only model coordinate system
- Works with ABC, PML and impedance boundaries on “space port”
Unit Cell Boundary Conditions

Space Port

Port Boundary
(should NOT touch periodic boundary in HFSS)

Matching Boundary (slave)

Matching Boundary (master)
Example of Skewed Array, Top View

Wondering how to create this unit cell? A macro exists to help with this!
Skewed Array (2)

- The triangular spaced array - other methods

App Note is Available
Applications of Simulators

- Arrays of driven elements
  - Excitation
    - Traditional port
    - Gap Source port
  - Space ports
    - WGS can use ports or PML’s
    - AS must use appropriate termination

- Frequency Selective Surface (FSS)
  - Excitation
    - Traditional port or incident wave for WGS
    - Incident wave for AS
      - Transmission/Reflection characteristics computed using the POST 3 calculator
      - Macro exists to aid in this effort (fsswiz4.mac)
  - Space ports
    - Same as above
**PML and How to Approach the Setup**

- **Perfect Matched Layer (PML)**
  - fictitious material that fully absorbs the electromagnetic field impinging upon it
  - independent of incident angle

- **PML requirement:**
  - both the permeability and the permittivity be complex anisotropic

Use “pmlcoversetup” or “dpPML” macros
Solution Space Terminations

- Absorbing Boundary Condition (ABC)
  - Most effective when incident waves normal to the absorbing surface
  - ABC surface should be placed approx $\lambda/4$ away from radiating surface $z$

![Graph showing Reflection Coefficient (dB) vs. theta (deg)](image-url)
**Solution Space Terminations**

- **PML**
  - Works well for steep angles of incidence (often occurs with wave guide simulators)
  - PML does not suffer from $\lambda/4$ separation requirement (main concern is meshing)
Integration Surface for Far-Field Computation

- **Default**: far-fields computed through an integration over the radiation boundary or inside of PML surface
- **User defined interior surface**: alternate integration surface can be chosen
  - “Custom Surface” must enclose all radiating surfaces
  - Advantages: potential for better accuracy
    - Useful for mesh manipulation
    - Due to material discontinuity and meshing, integration on inside of PML surface is not typically the best choice
Alternate Interior Surface (AIS)

- AIS Defined in Post-Processing
- Far-Field computation only allowed by Post 3 if:
  - Radiation boundary exists
  - or
  - PML with objects names beginning with “PML…”

**Suggestion** - Define face list (customer surface) first

**Method:**
1) In the Post Processor, select radiation > compute > far field/near field
2) In the “Compute Far Field” menu, check box next to “Customer Surface” then click “Set”
3) This will direct you to define a set of faces from which the far fields will be calculated
Farfield Plots of FINITE arrays

- Array calculations use unit cell farfield as element pattern
So What about FSS’s?

- Use unit cell approximation
- Can use either WGS or AS
- Space port at both top and bottom
- Transmission/Reflection Characteristics
  - Ports + WGS - S-parameters
  - Incident Wave + AS - integrate poynting vector (*fsswiz.mac and app note available)
Further Material Available

Docs
- AppNotePhasedArrays2.doc  App Note on infinite triangular array
- MicroJournPML.doc  Discussion of LBC’s and PML’s
- PeriodicBCsGuide8/28/00.doc  Discussion of infinite arrays in HFSS
- UnitCellWriteup2.doc  Discusses unit cell shapes
- PML-LBC pres.pdf  Further info on LBC’s and PML’s
- CalcCookBook.doc  Great writeup on Post3 Calculator WITH EXAMPLES!!
- FSSTesting3.Doc  How to for FSS’s in HFSS (draft form)

References (Essential to understanding WGS/AS)
- Hansen, Microwave Scanning Antennas Vol 2 if they are separate
- IEEE AP 13 1965 page 342 Hannan Simulation of Phased Array Antenna in Waveguide
- Proc IRE Vol 36 1948 Wheeler The Radiation Resistance of an Antenna in an Infinite Array or Waveguide
- IEEE AP 13 1965 page 475 Phased Array Simulators in WG for Triangular arranged elements
- IEEE AP 11 1963 page 377 A Technique to Simulate the Self and Mutual Impedances of an Array
Further Material Available Cont.

- **Macros** (Only a partial list ... Ask your favorite AE for further details)
  - ArrayCalcWiz4.mac: Macro to calc array pattern based on Unit Cell solution
  - UnitCellWiz2.mac: Macro to assist setting up unit cell for triangular array
  - FSPatGen.mac: Generates many plots from a fast swept project
  - Pmlcoverstepup: Built in macro in Draw that creates PML Objects
  - Pmlmatsetup: Built in macro in Material Manager to set materials
  - dpPMLWiz5.mac: Will create Rectangular as well as quasi Cylindrical or Spherical PML’s
    - Should be more accurate than pmlcoversetup
  - dpPMLMat2.mac: Works with PMLGeom4.mac to set material parameters
  - FarFieldFix.mac: Post3 will not allow computation of farfield without PML or radiation BC
  - FSSWiz.mac: Calculates transmitted and reflected power from incident wave

- **Spreadsheets**
  - PMLWorksheet.xls: Aid to calc PML parameters for non rect
    - Also available in formats for MapleV, Mathcad, EqnEval
  - WvGdSim.xls: Aid to calc wg mode - scan angle
Closing

- HFSS V8 provides both evolutionary and revolutionary improvements to an already-powerful tool in the antenna engineer’s arsenal
  - Usability Enhancements improve day to day interaction with the software
  - Improvements to Existing Features speed solution times, improve accuracy, and expand the usage possibilities
  - New Features permit analysis applications previously unavailable to antenna designers
- Please continue to request enhancements and added capabilities. Ansoft realizes this software is for YOUR use!