Using HFSS and Linked BCs to Solve N-Fold Rotationally Symmetric Geometries

January 25, 2002

Mike Gilbert
mgilbert@toyon.com

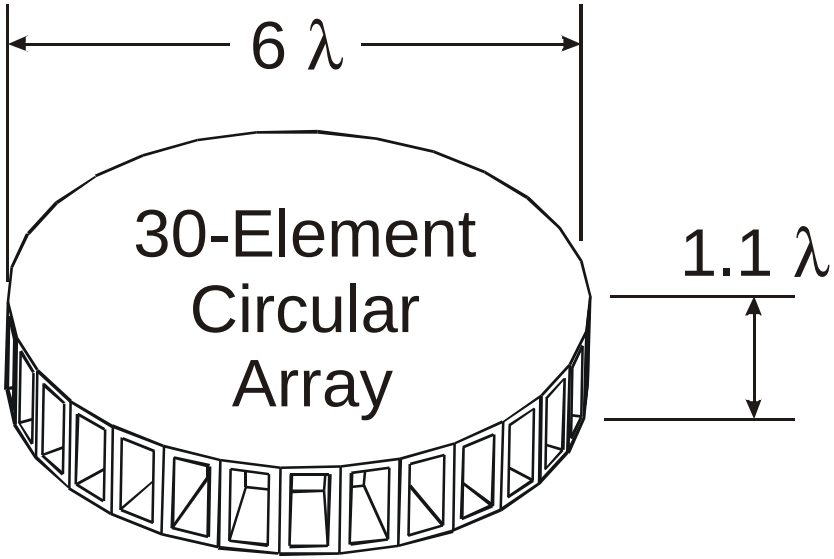
75 Aero Camino Suite A Goleta CA 93117 Phone 805 968-6787 Fax 805 685-8089 www.toyon.com

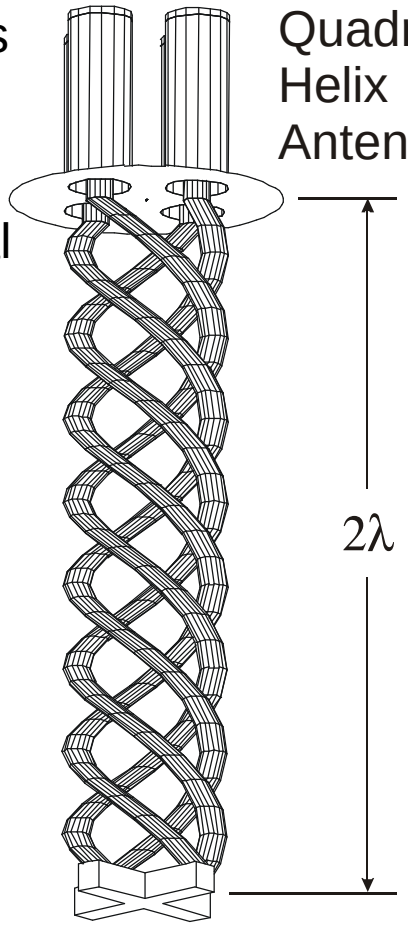
Introduction

- Presentation will show that linked boundary conditions (BCs) can be used to reduce problem size for geometries having N-fold rotational symmetry
- Necessary post-processing formulas will be given
- Significant CPU time savings will be demonstrated

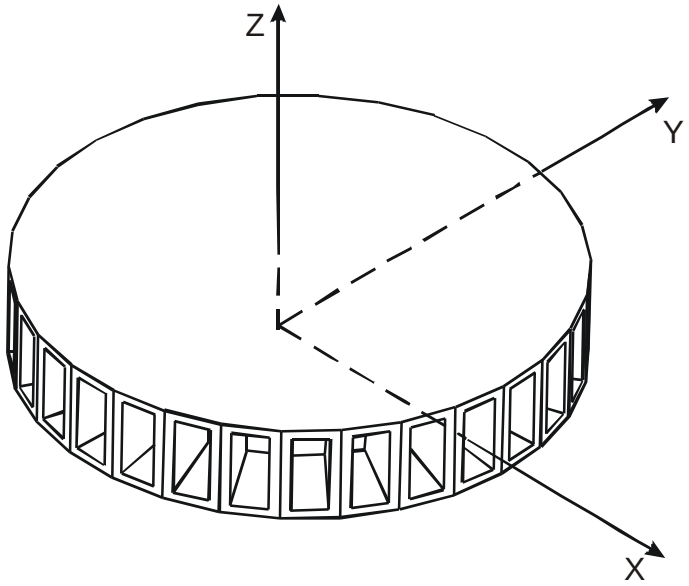
Linked BCs Reduce Problem Size for Antennas Having N-Fold Rotational Symmetry

- CPU time and memory savings can be significant
- Presentation will illustrate with two different examples
  - 30-element circular array – does not have excitation symmetry
  - Quadrafilar helix antenna -- has both geometrical and excitation symmetry

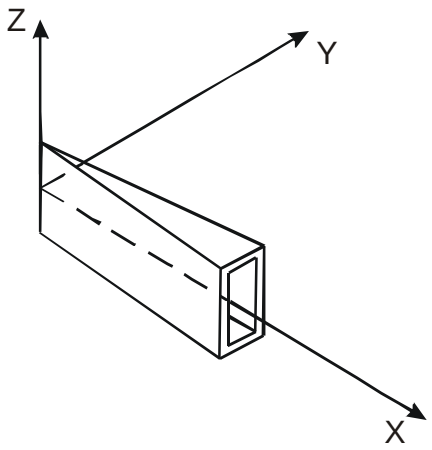




Solving 30-Element Circular Array -- Full geometry vs Linked BCs



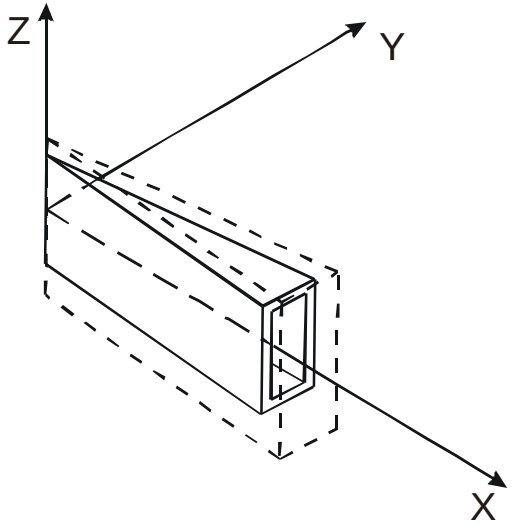
- Full geometry (without linked BCs)
  - Big volume
  - 30 ports
  - Solve project one time

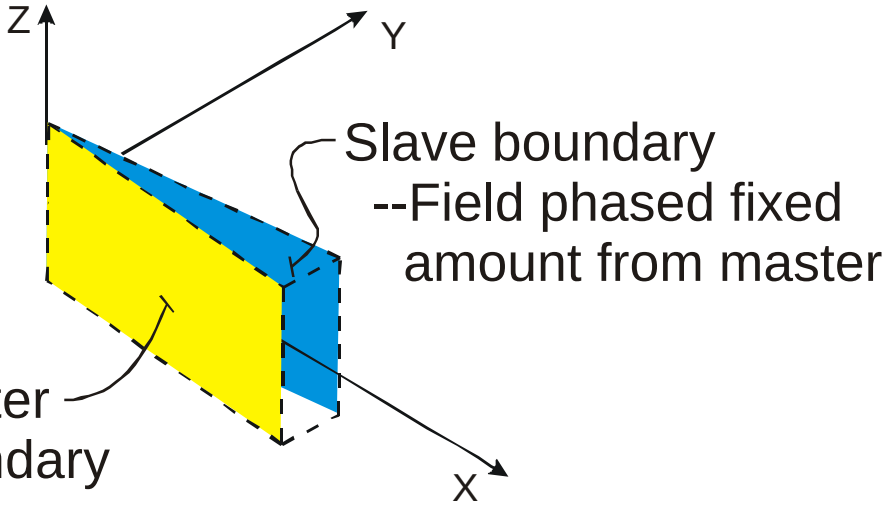


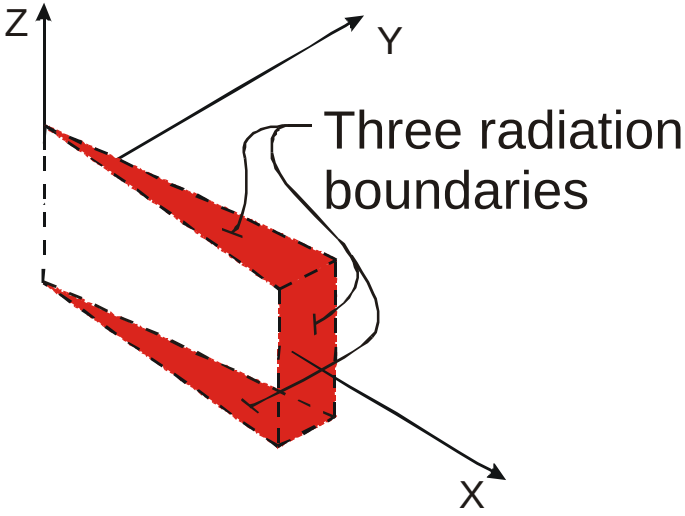
- Linked BCs (12 degree unit cell)
  - Small volume
  - 1 port
  - Solve project 30 times
  - Ideal for parallel processing

Circular Array Requires Solving For 30 Different Linked BCs

- Solve with all possible conditions for phase of slave boundary (0, 12, 24, …, 348 degrees)
- Post-process results to get entire array solution







Post-Processing Is Required To Get S-parameters and Radiation Patterns

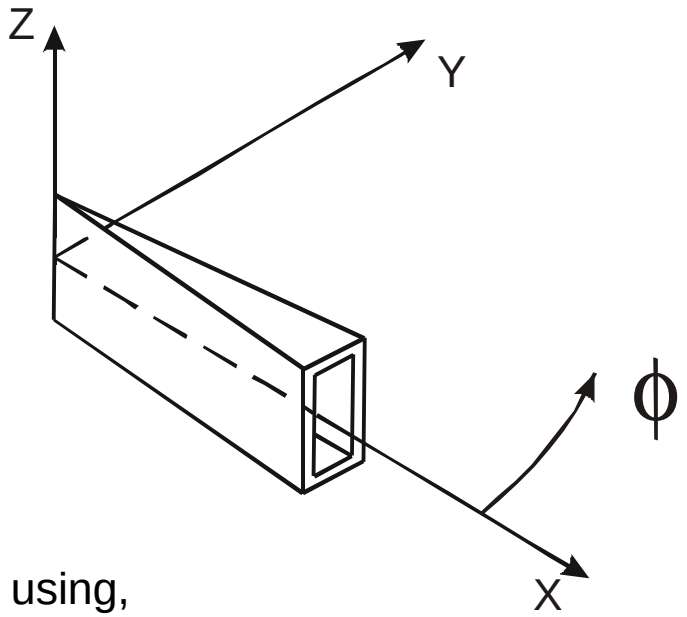
- HFSS outputs active S-parameters

  Passive S-parameters can be found using,

$$S_{lm} = \frac{1}{N}\sum_{i=1}^{N} (S_A)_i \, e^{j2p\,(m-l)i/N}$$

  where $N = \text{number of elements},$

  $(S_A)_i = \text{active impedance for i}^{\text{th}}\text{ mode}$



- HFSS outputs fields for a unit cell

  Embedded element pattern fields can be found using,

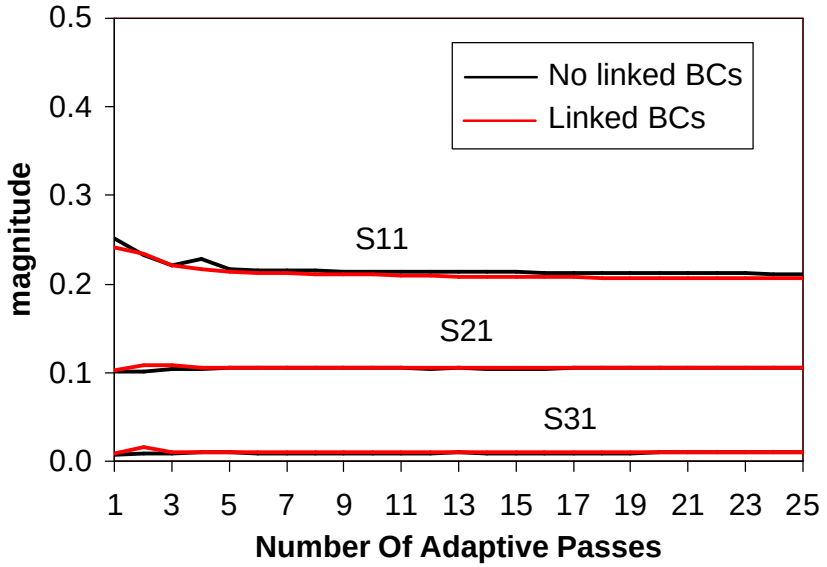
$$\overline{E} = \frac{1}{N}\sum_{i=0}^{N-1}\sum_{m=0}^{N-1} \overline{E_i}(f - 2mp/N)\; e^{j2p\,im/N}$$

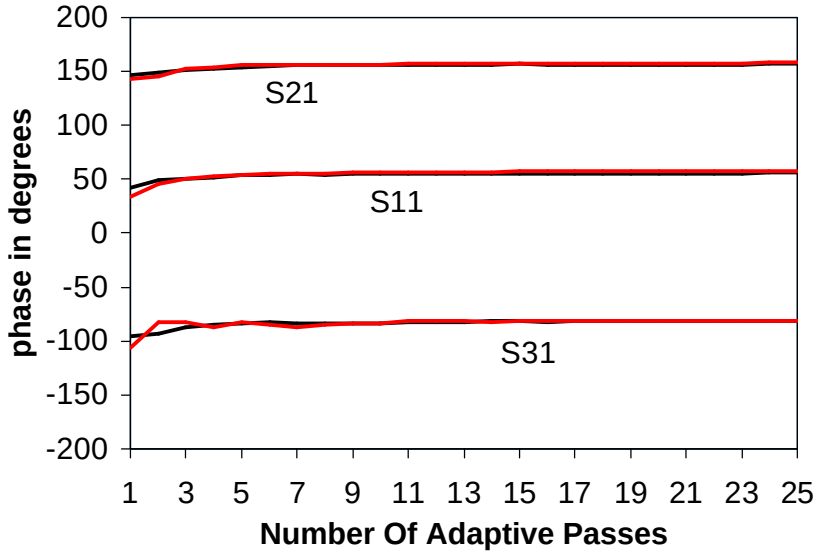
  where $\overline{E}_i = \text{field from i}^{\text{th}}\text{ mode}$

  $f = \text{angle from x - axis in cylindrical coordinates}$

S-parameters Compare Closely For Solutions With And Without Linked BCs

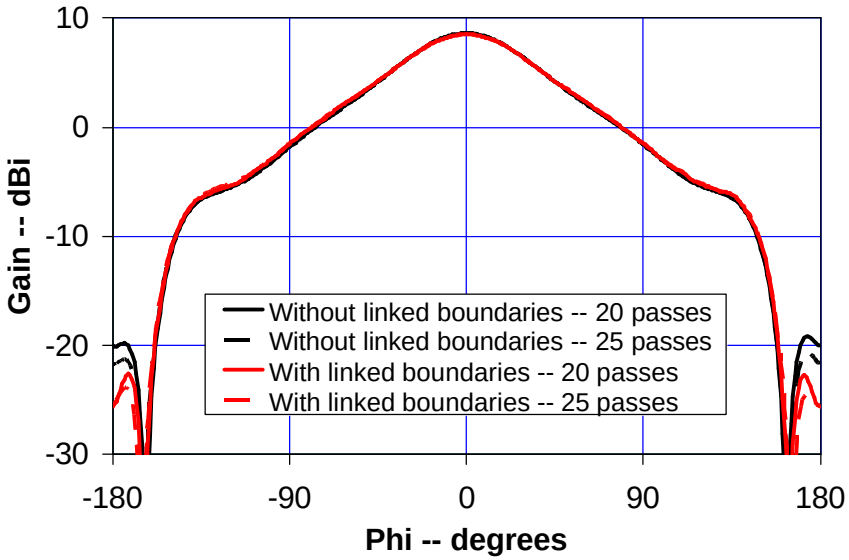
- Plots show S11, S21, and S31 versus number of adaptive passes
- Both solutions converge to same result within about 5 adaptive passes

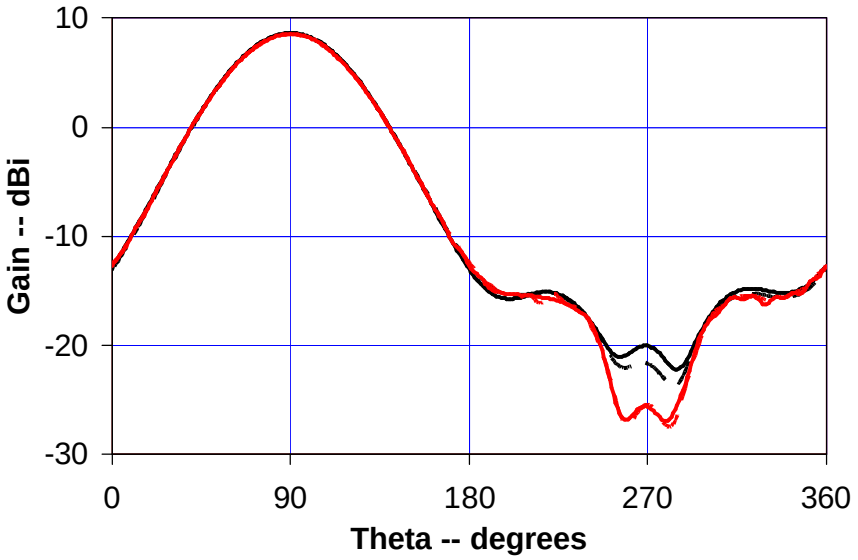




Radiation Patterns Compare Closely For Solutions With And Without Linked BCs

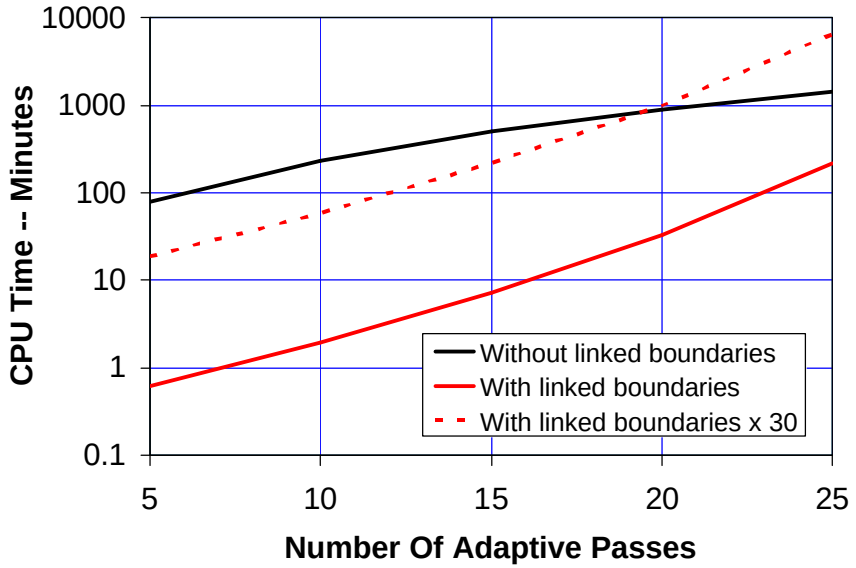
- Plots show embedded element pattern cuts in principal planes
- Only significant differences occur in backlobe region
- Appears that solution with linked boundaries is closer to convergence

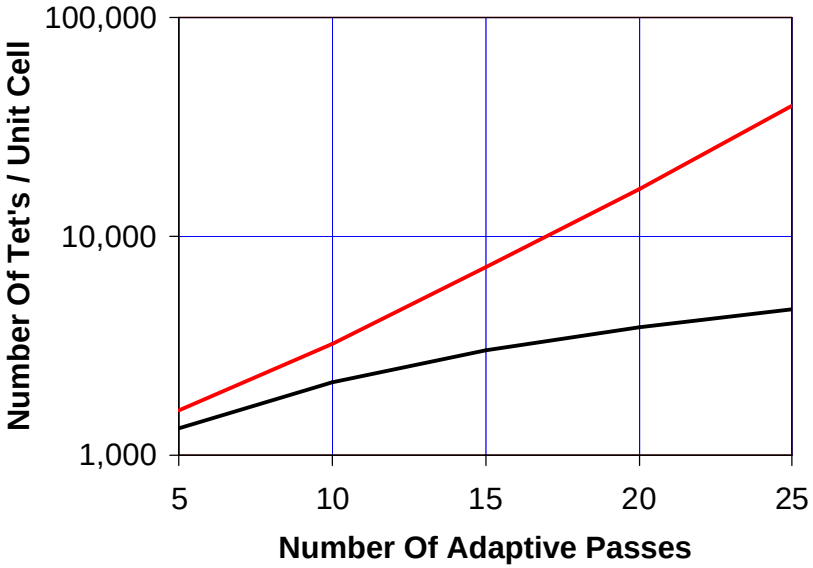




When Compared Against # of Passes, Not Clear That Linked BCs Save CPU Time

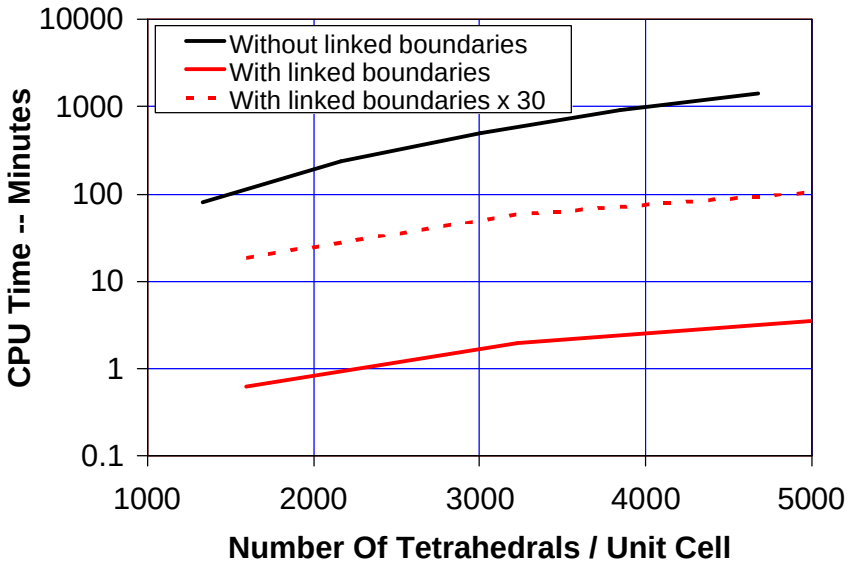
- Used 1.2 GHz processor with 1.5 GBytes of memory
- Plots show CPU time and # Tet's against number of adaptive passes
- Linked BCs solution faster only when # passes < 19

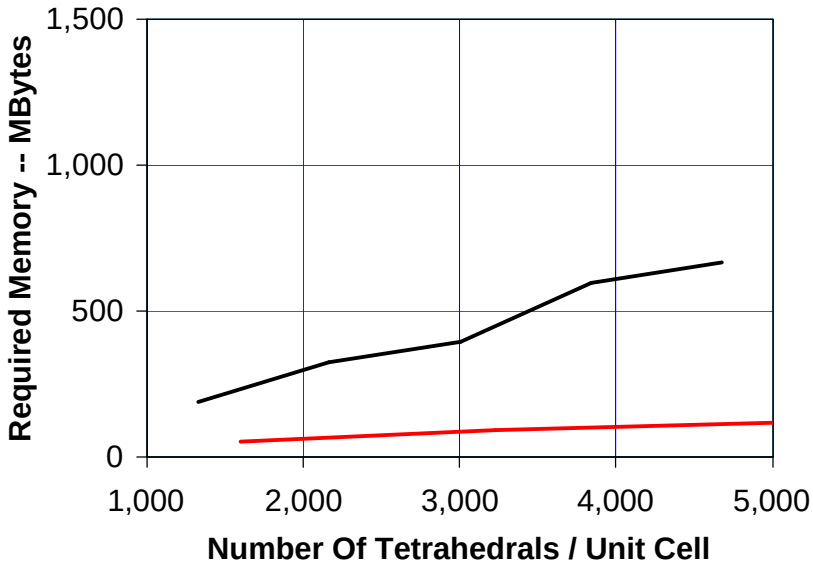




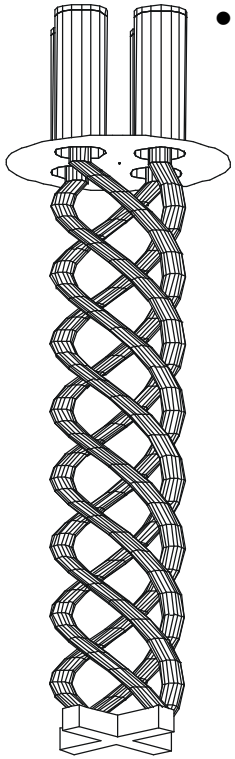
When Compared Against Number of Tet's per Unit Cell, Linked BCs Solution is Always Faster

- A better comparison of CPU times is vs number of tetrahedrals per unit cell
- Solution using linked boundaries is about ten times faster than solution without linked boundaries
- Solution using linked boundaries uses less memory



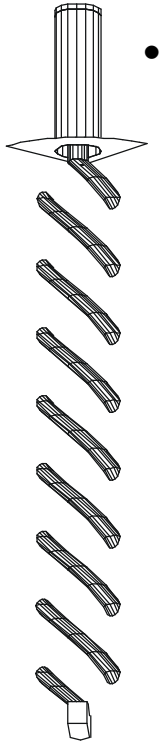


Solving Quadrafilar Helix Antenna -- Full geometry vs Linked BCs



- Full geometry
  - Big volume
  - 4 ports
  - Solve project one time

CUT INTO QUARTER



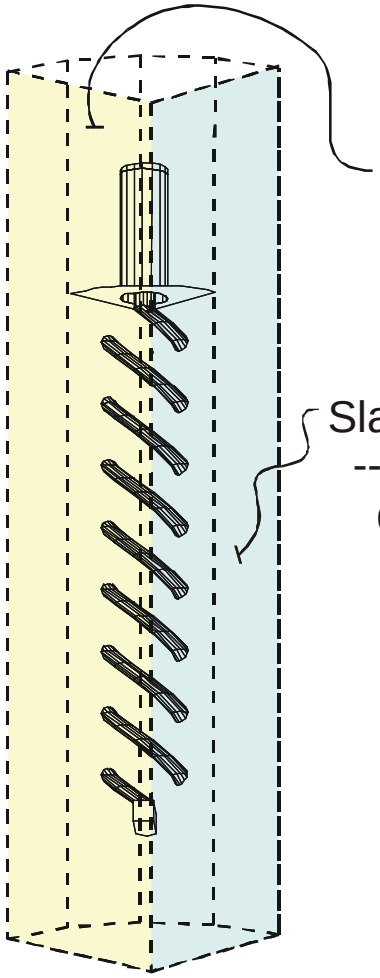
- Linked BCs (90 degree unit cell)
  - Smaller volume
  - 1 port
  - Solve project one time

Quadrafilar Helix Requires Solving Only One Linked BC

- HFSS outputs active S-parameters
- Radiation pattern found using,

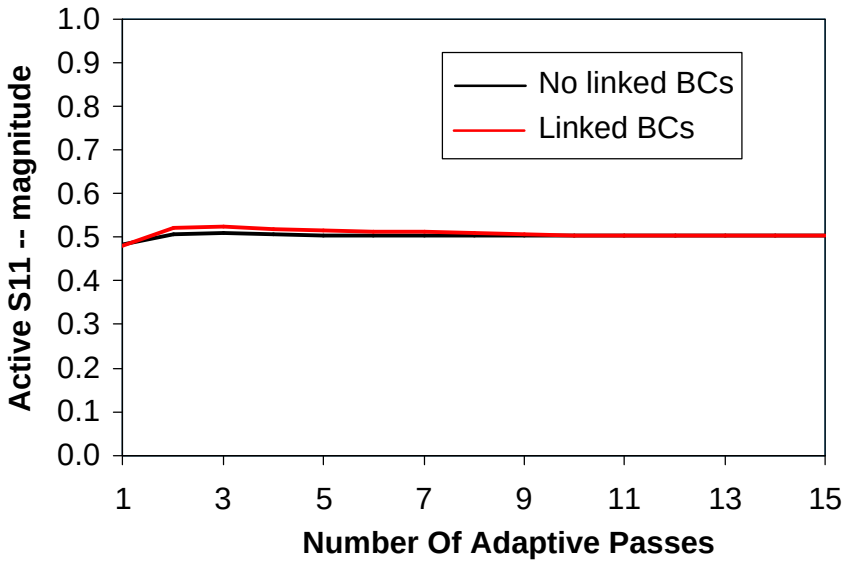
$$\overline{E} = \sum_{m=0}^{3} \overline{E_1}(f - mp/2)\ e^{jp\,m/2}$$

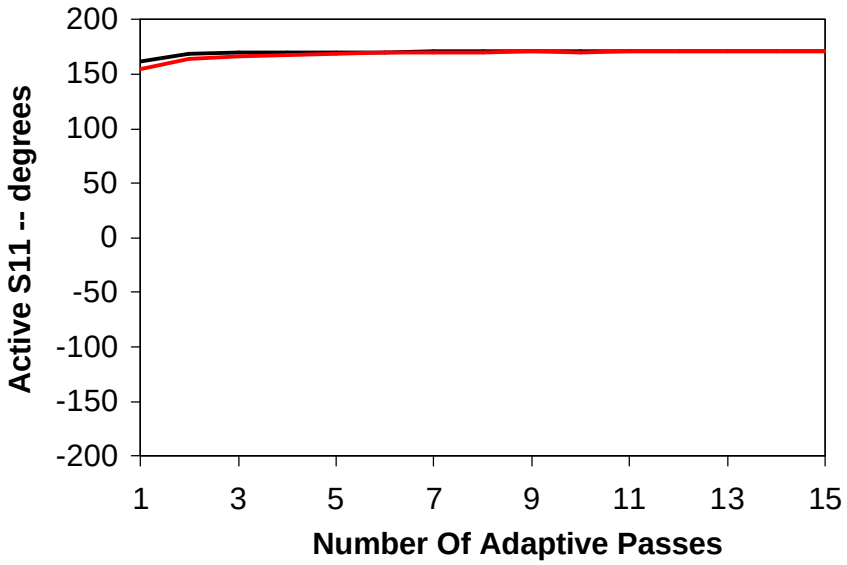
where $\overline{E_1}$ = field from desired mode (either RHCP or LHCP),



S-parameters Compare Closely For Solutions With and Without Linked BCs

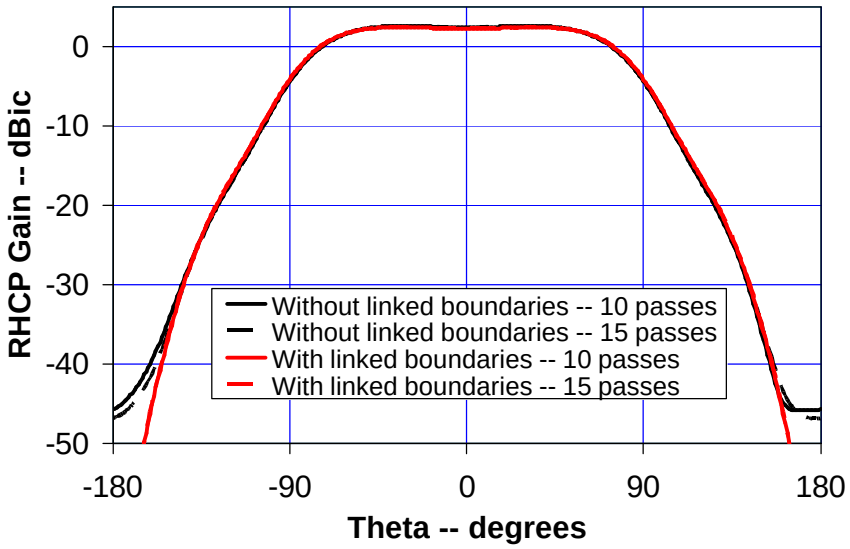
- Plots show active S11 versus number of adaptive passes
- Both solutions converge to same result within about five adaptive passes

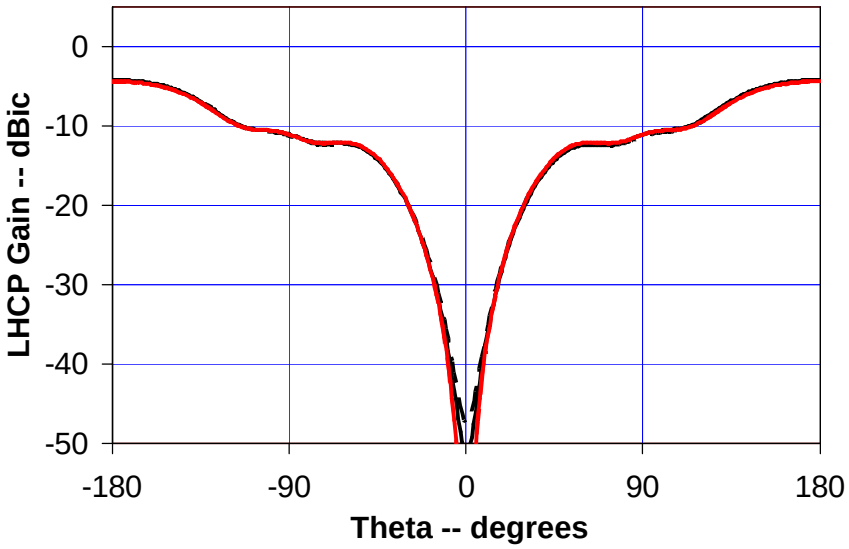




Radiation Patterns Compare Closely For Solutions With and Without Linked BCs

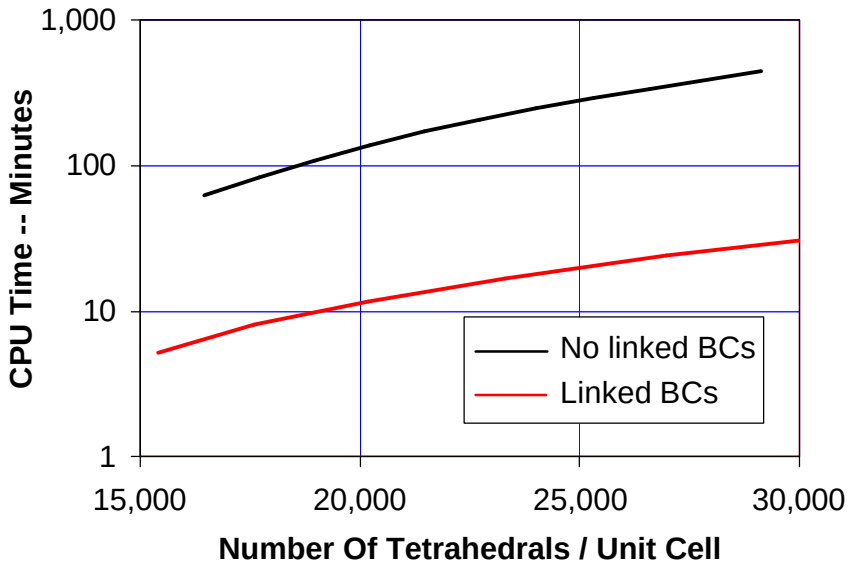
- Plots show RHCP and LHCP pattern cuts versus theta at phi = 0
- Only significant differences occur in backlobe region
- Appears that solution with linked boundaries is closer to convergence

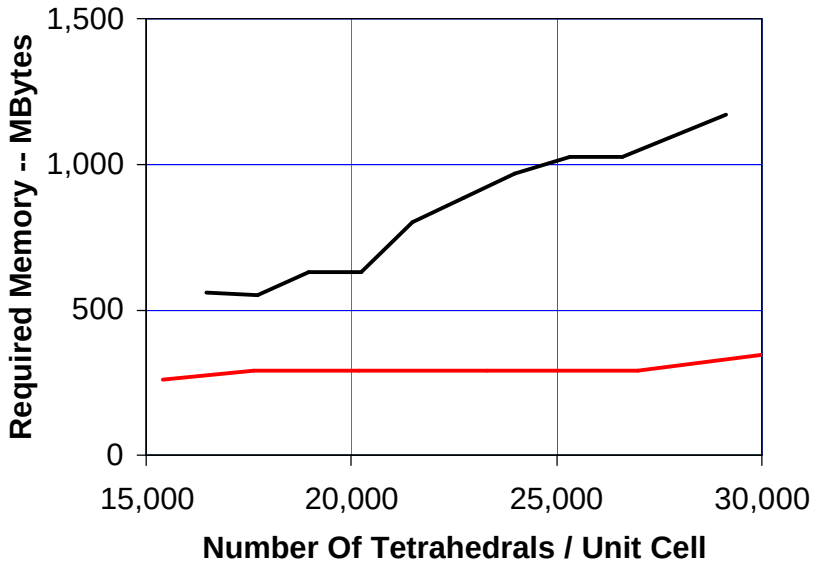




CPU Time and Memory Usage Show Significant Advantage for Using Linked BCs

- Plots show CPU time and memory against number of Tet's per unit cell
- Solution using linked boundaries is about ten times faster than solution without linked boundaries
- Solution using linked boundaries uses less memory





Conclusions

- Demonstrated that linked BCs can reduce the required CPU time for antennas having N-fold rotational symmetry
- Post-processing is required to recover the radiation patterns from the HFSS output
- Largest time savings are for:
  - Problems where solving the entire geometry would exceed the computer memory
  - Problems, like the quadrafilar helix, that have n-fold symmetry in excitation, as well as in geometry