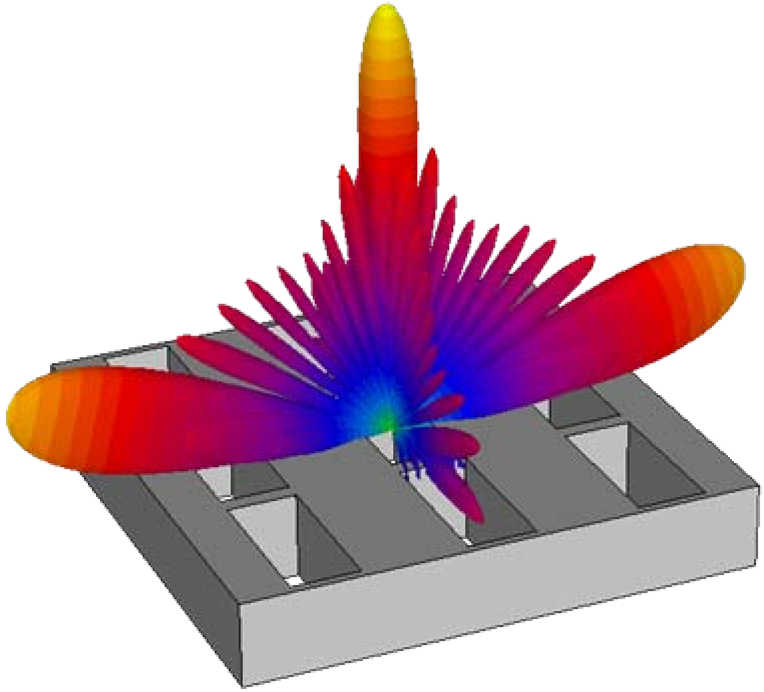
CST STUDIO SUITE™ 2006B
Application Note

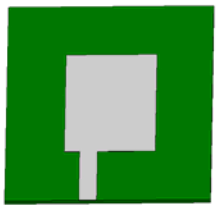
Antenna Arrays



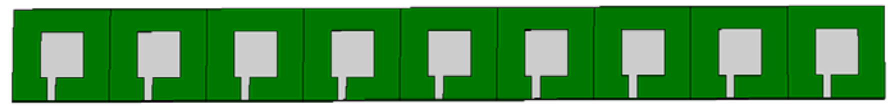
- Introduction
- Finite Arrays
  - Simultaneous excitation
  - Combine Results
  - Farfield-Array
- Infinite Arrays
  - Unit Cell Modeling

Introduction

Rectangular Patch Antenna



Linear Array

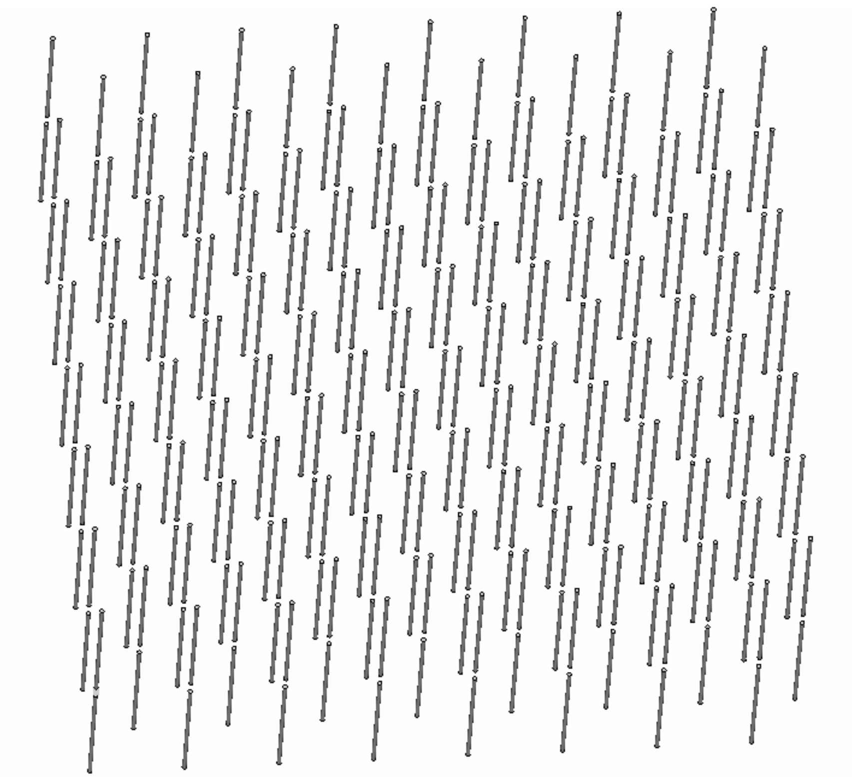


Advantage:
Freedom of excitation

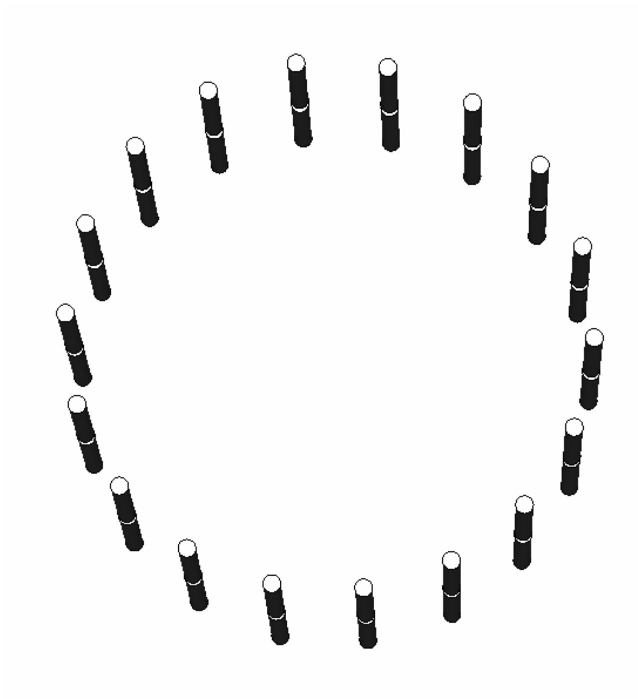
1. Equal excitations: more gain
   - Channel capacity ~log(N)
   - Less expensive amplifiers
2. Phased excitation:
   - Multiple beams: Channel capacity ~(N)
   - Adaptive beamforming
     - Reduced Multipath propagation
     - Tracking of objects (e.g. Radar)

Array Types

Planar Arrays



Circular Arrays



Focus on planar arrays

Antenna Array Terminology

- Element = One antenna element of the antenna array
- Scan = Phased excitation / change direction of incident wave
- Endfire = Scan at $\theta = \pi/2$
- Pattern Synthesis: Determine excitation function for the desired beam pattern.
- Mutual Coupling = Coupling from one element to others

Topics in Array Design

- Beamforming, Blind spots, Coupling between elements, Active impedance
- Pattern optimization, Side lobe suppression
  - Circular Pattern Synthesis (Taylor, Bayliss)
  - Planar Pattern Synthesis (Fourier, Schelkunov, Woodward, Dolph-Chebyshev, Taylor, modified sinc, Bayliss line source, Elliot iterative)
- Signal processing, Adaptive arrays

Antenna Arrays for Radar

Evolution

Goals:
- Reduction of mechanical parts
- Flexible Resolution
- Tracking of multiple objects

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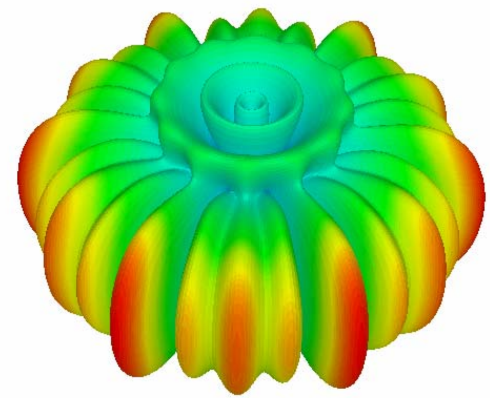
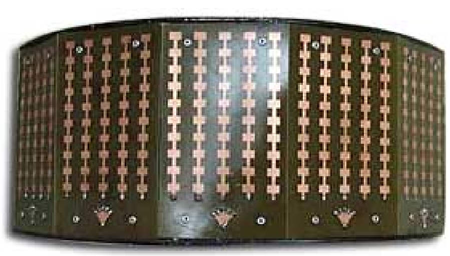
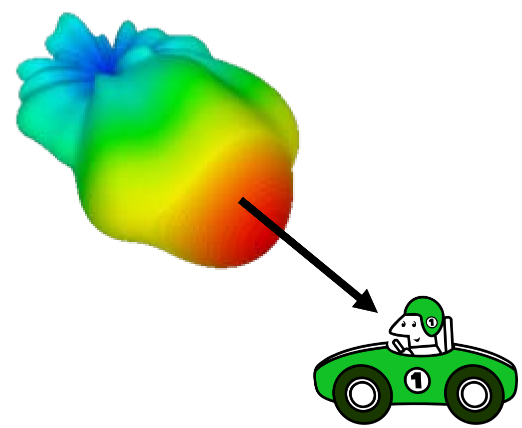
Antenna Arrays for Communication
Smart antennas

Switched Beam Approach:
Switching between a finite number of predefined patterns



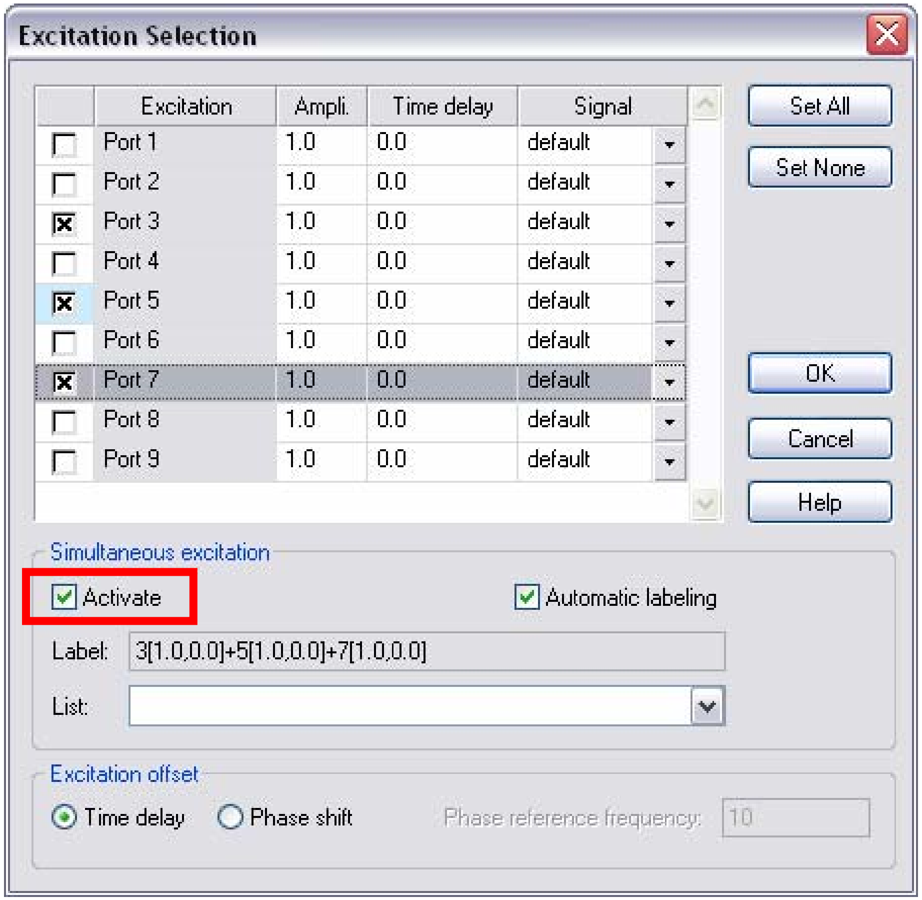


Adaptive Array Approach:
Continuously adapting the pattern towards the optimal characteristic



Finite Arrays

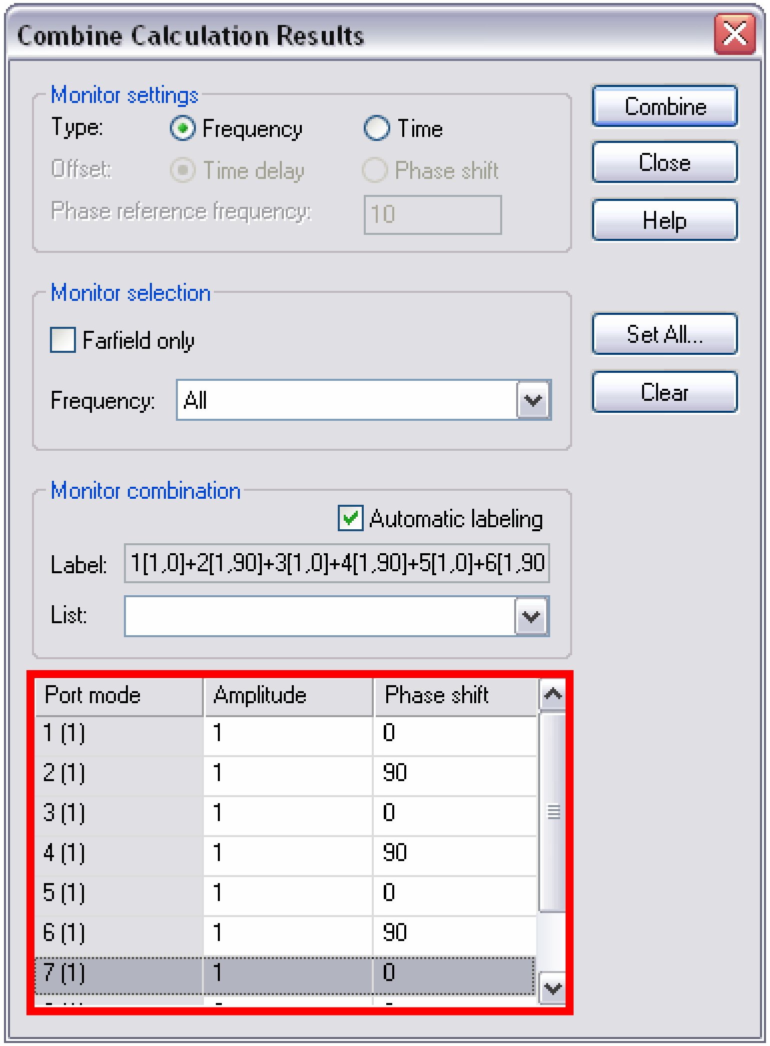
Simultaneous Excitation



- Simultaneous port excitation with certain amplitude/phase relationships between ports.
- Produces F-Parameter
- Phase shift valid for one frequency only.
- Recommended if Number of elements > Number of excitations

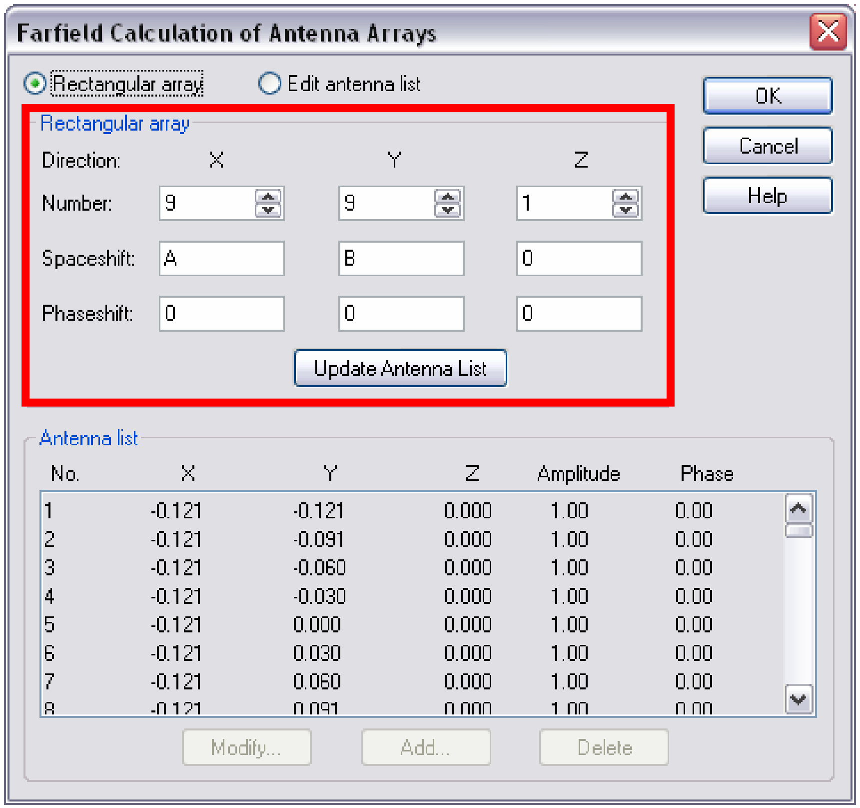
Finite Arrays

Combine Results-Farfields

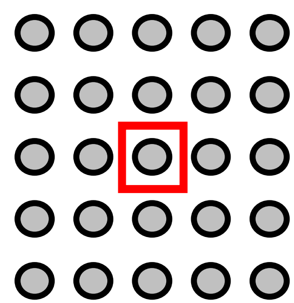


- Calculation of all ports and "combine results" in post-processing.
- All desired amplitude/phase relationships between the ports can be easily calculated as a postprocessing step.
- Broadband phase shift possible.
- Compute active S-Parameters/Impedances by given excitation and known S-Parameters.
- Recommended if Number of excitations > Number of elements
- Distributed Network Computing shortens the simulation time.

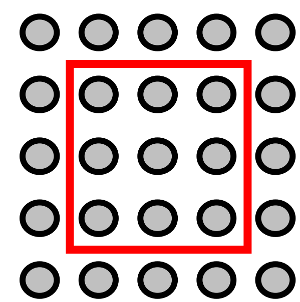
Finite Arrays
Farfield-Array



- No coupling between the simulated elements. Simulation of a bigger array part necessary
- Different excitations easily realized by using the macro language for the Antenna Array feature

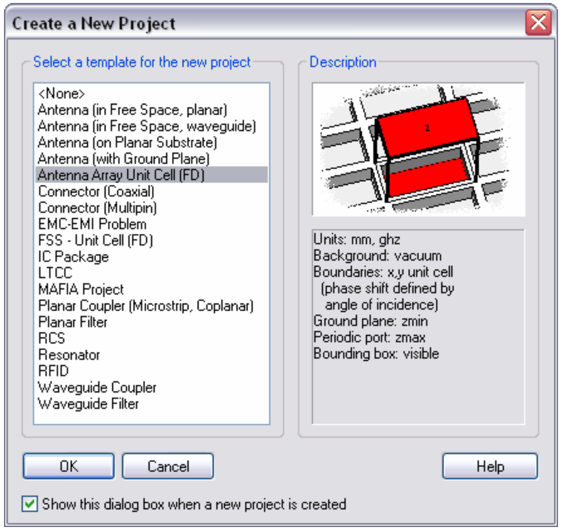


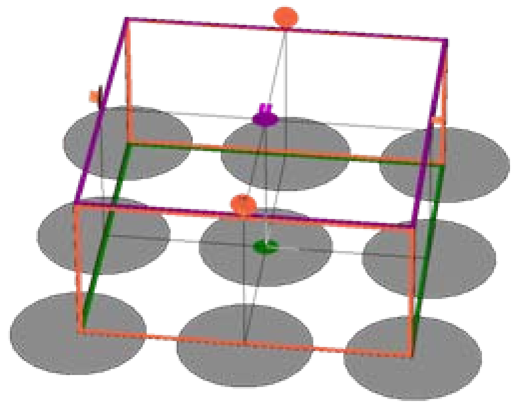
no coupling between elements



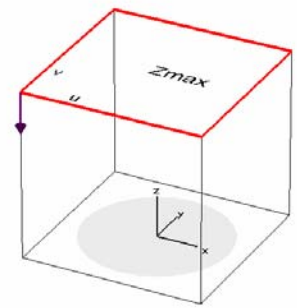
coupling to next elements considered

Infinite Arrays
Unit Cell Project Template



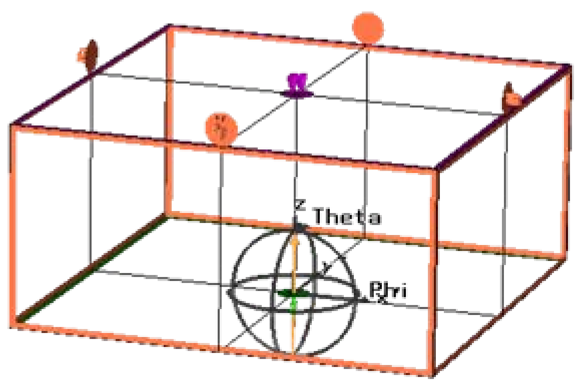


Unit Cell boundary condition x,y



Floquet port Zmax

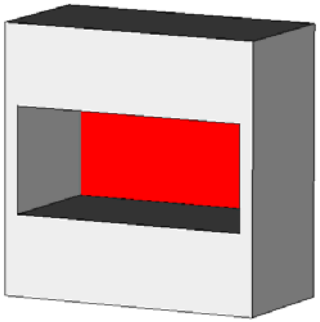
Antenna Array
Unit Cell (FD):
Units: mm, ghz
Background: vacuum
Boundaries: x,y unit cell
(phase shift defined by
angle of incidence)
Ground plane: zmin
Periodic port: zmax
Bounding box: visible

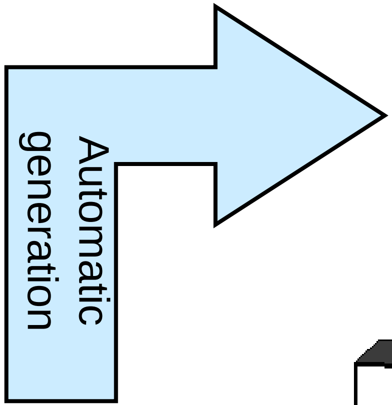


Scan angle definition (ϕ, θ)

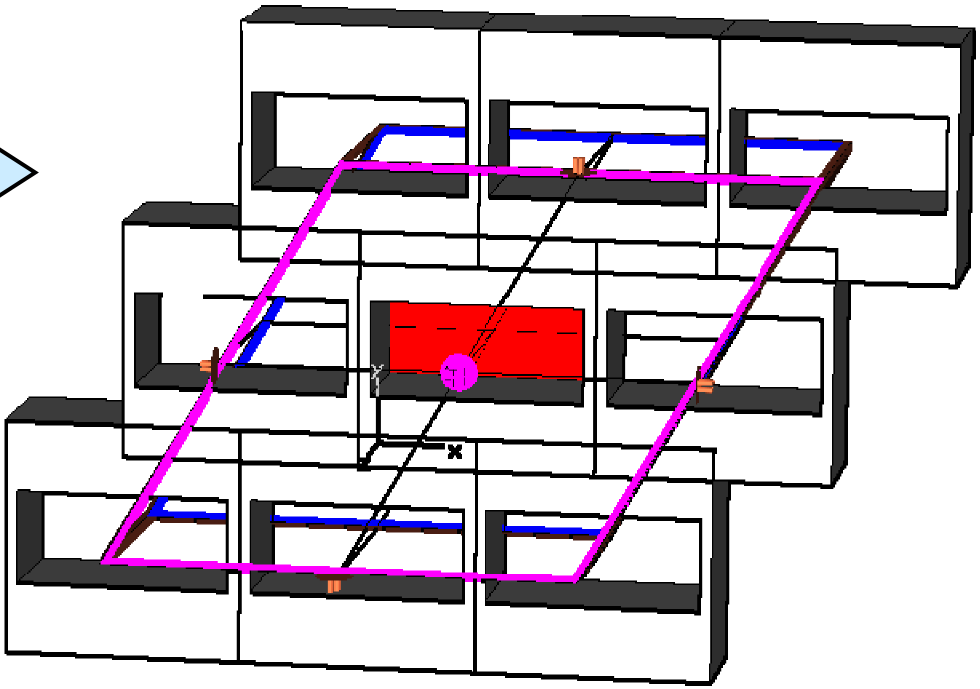
Infinite Arrays
Unit Cell Definiton

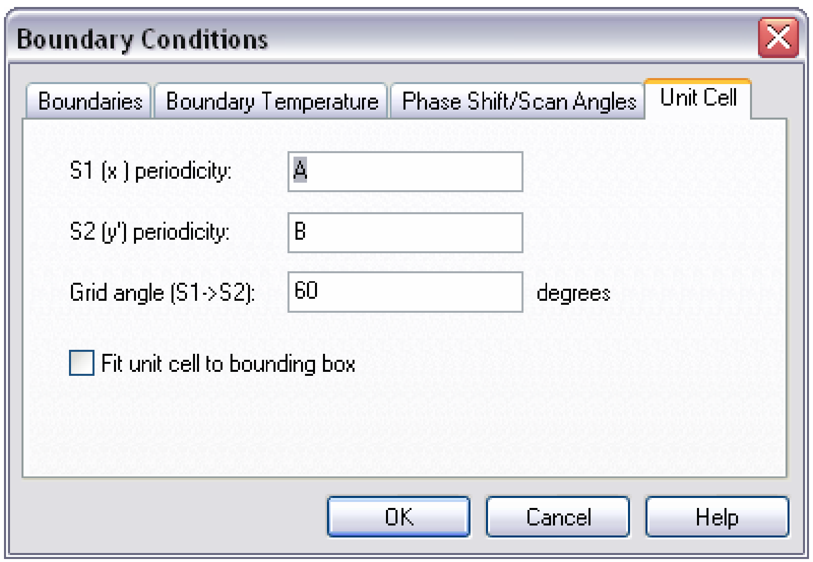
Single element:





Array:




Boundary Conditions

Boundaries | Boundary Temperature | Phase Shift/Scan Angles | Unit Cell

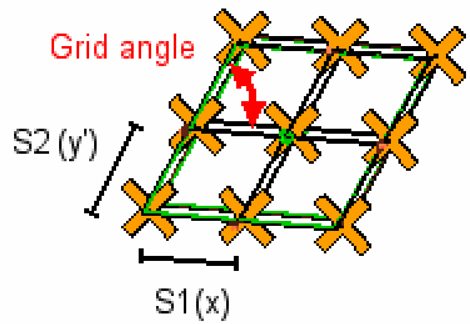
S1 (x) periodicity: A

S2 (y') periodicity: B

Grid angle (S1->S2): 60 degrees

Fit unit cell to bounding box

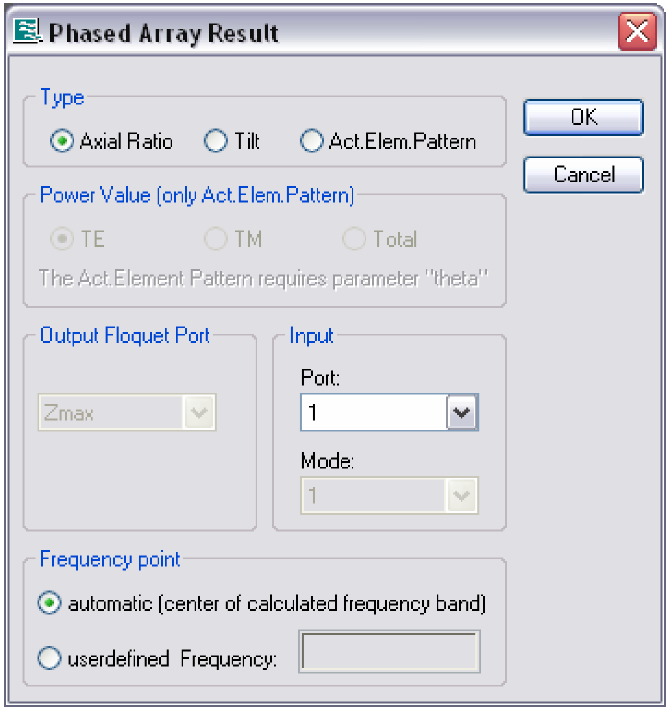
OK | Cancel | Help



Infinite Arrays

Templates

0D Result Template



Definitions:

$$\delta_{\phi\theta} = \pi + \psi_{TE} - \psi_{TM}$$

$$\gamma = \tan^{-1}\frac{|E_\phi|}{|E_\theta|} = \tan^{-1}\frac{\left|A_{00}^{TE}\right|}{\left|A_{00}^{TM}\right|}$$

$$\varepsilon = \frac{1}{2}\sin^{-1}\left(\sin 2\gamma \sin \delta_{\phi\varphi}\right)$$

Axial Ratio:

$$:= \cot(\varepsilon)$$

Tilt:

$$:= \frac{1}{2}\tan^{-1}\left(\frac{\sin 2\gamma \cos \delta_{\phi\theta}}{\cos 2\gamma}\right)$$

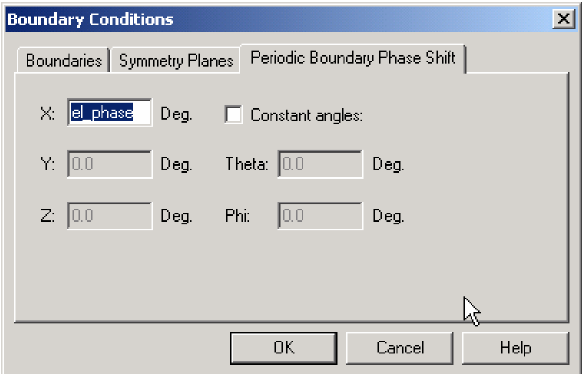
Active element pattern:

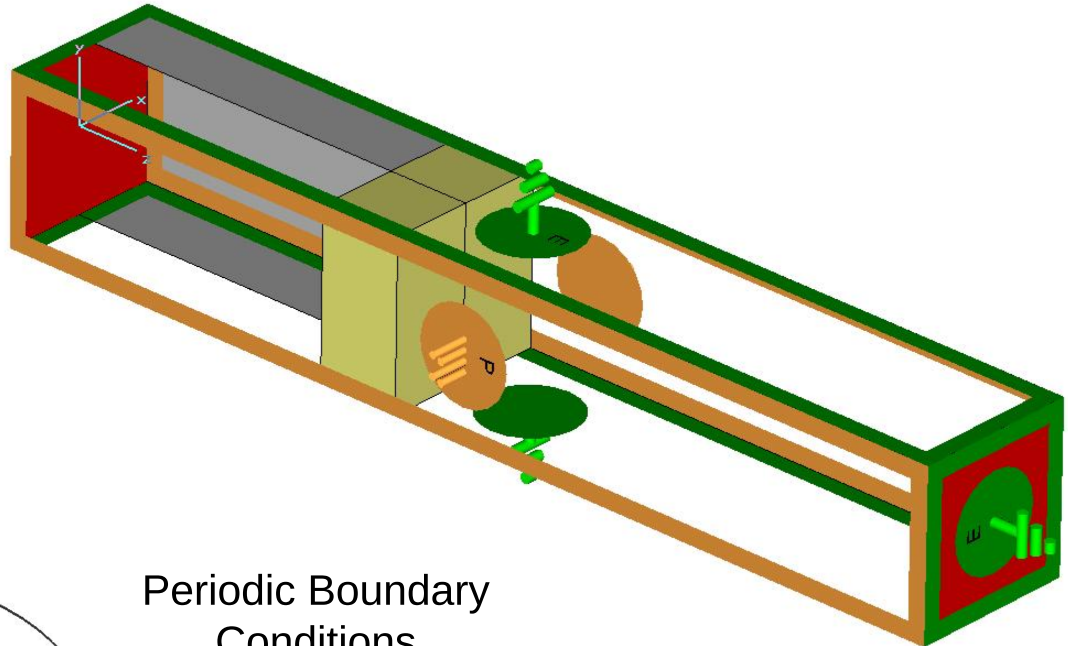
$$TE := \left|A_{00}^{TE}\right|^2 \cos^{-1}(\theta)$$

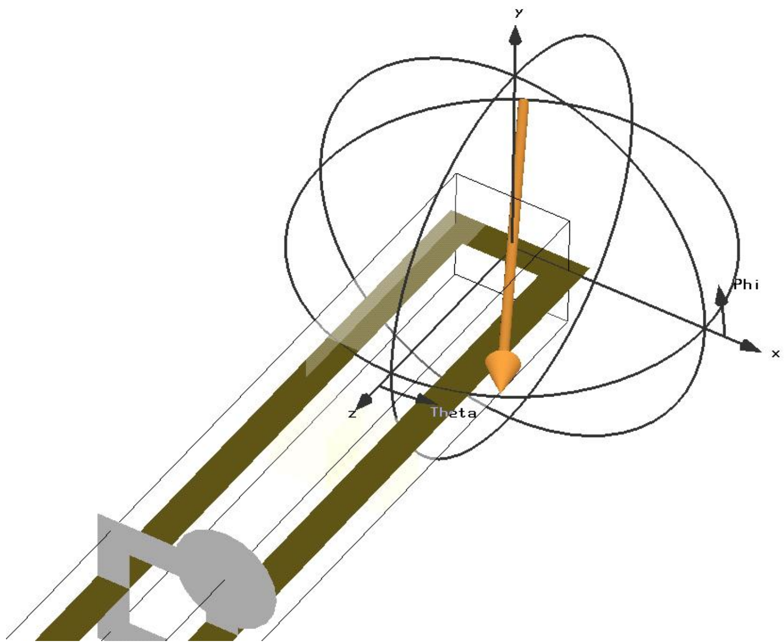
$$TM := \left|A_{00}^{TM}\right|^2 \cos^{-1}(\theta)$$

$$total := \left(\left|A_{00}^{TE}\right|^2 + \left|A_{00}^{TM}\right|^2\right)\cos^{-1}(\theta)$$

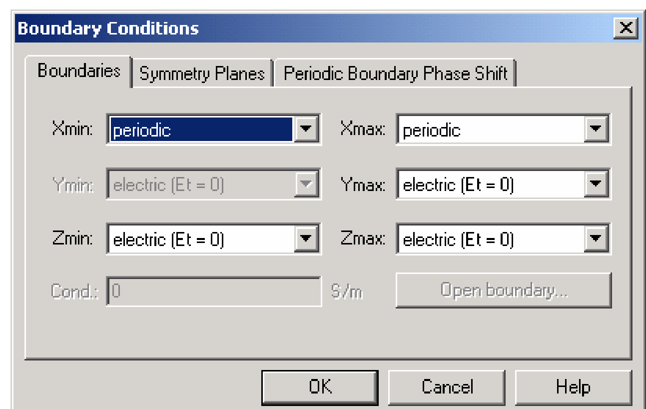
Open-ended Waveguide Array





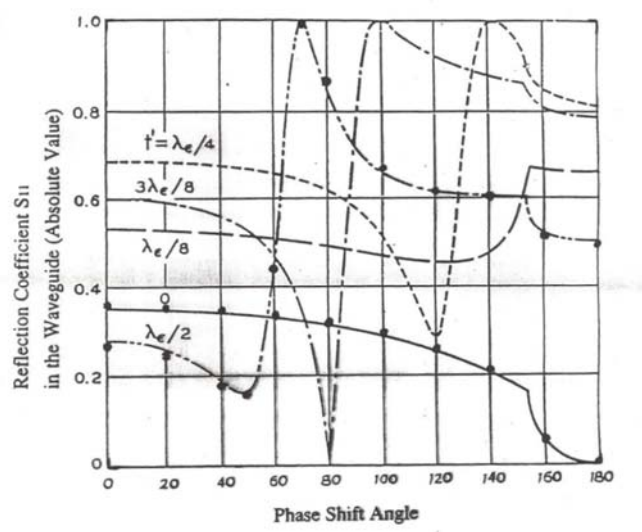


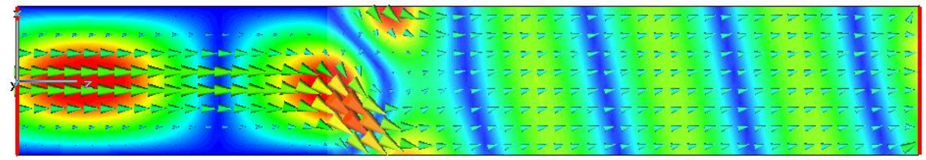
Periodic Boundary Conditions



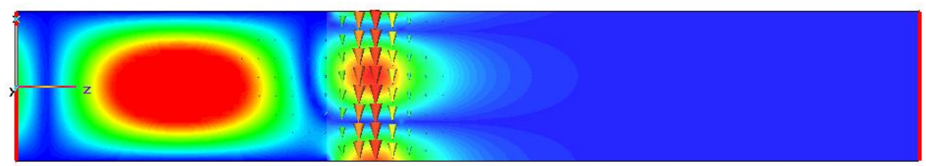
Open-ended Waveguide Array

Published results:



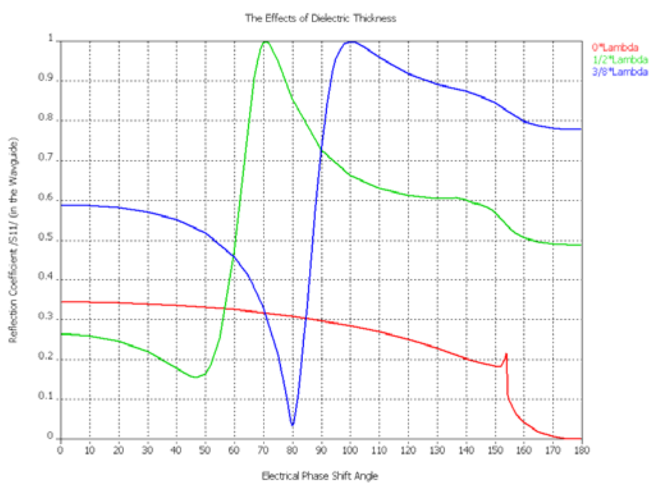


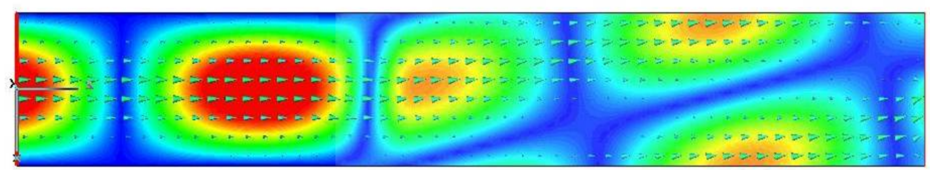
Electrical Phase Shift Angle = 45 deg



Blind Spot occurs at an electrical Phase Shift Angle = 71 deg

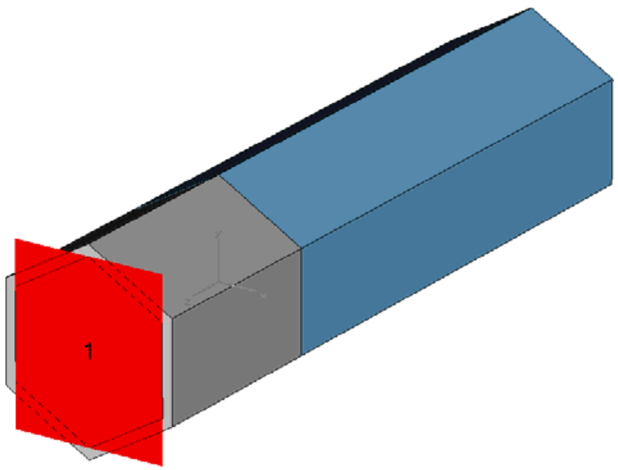
Simulation:

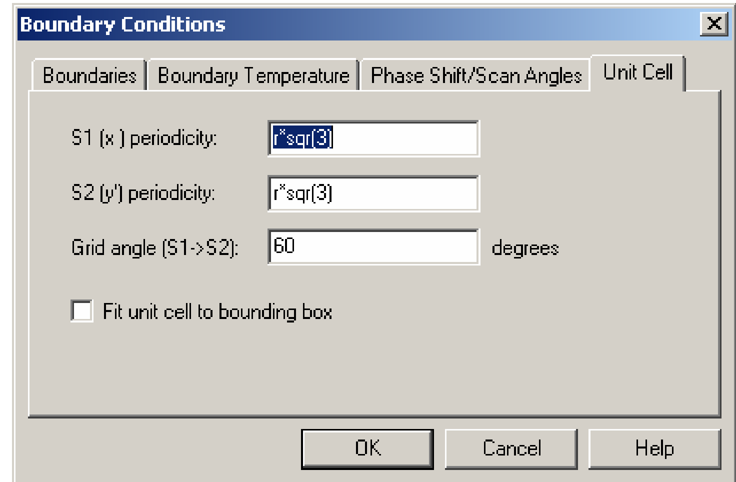


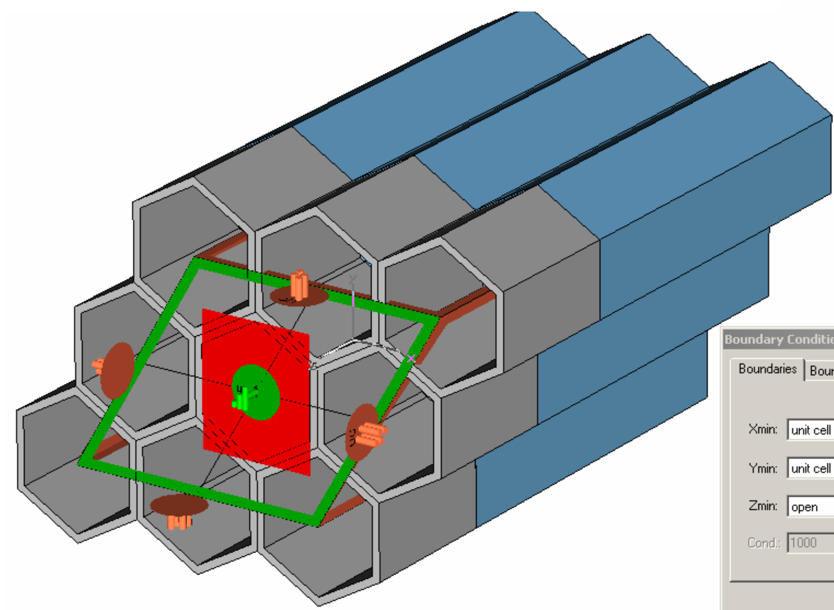


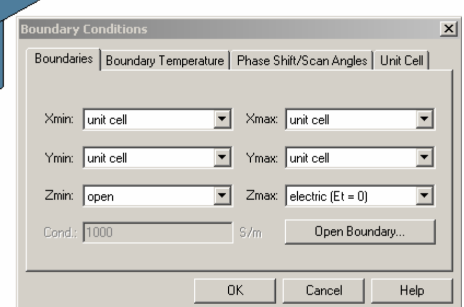
Grating lobes occur at electrical Phase Shift Angles > 150 deg

Infinite Arrays
Honeycomb Example

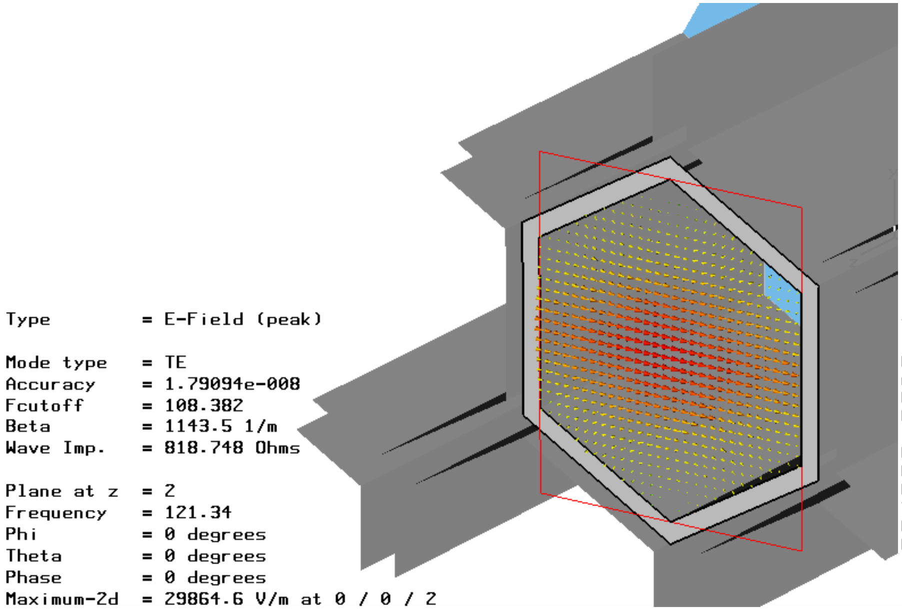


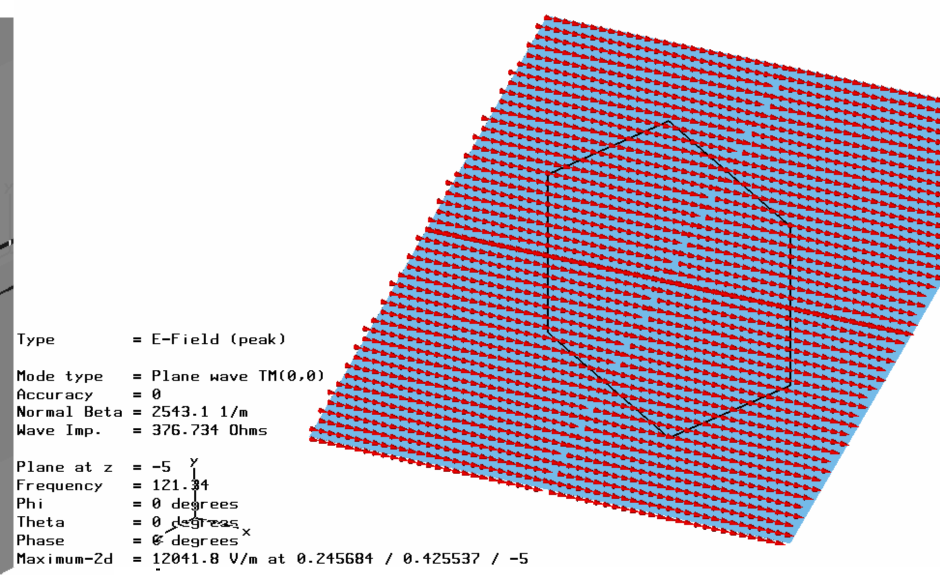


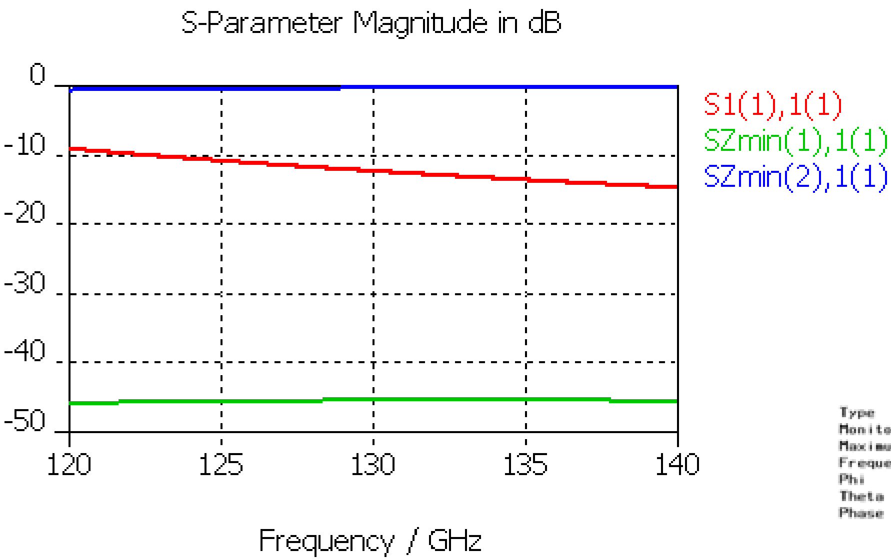


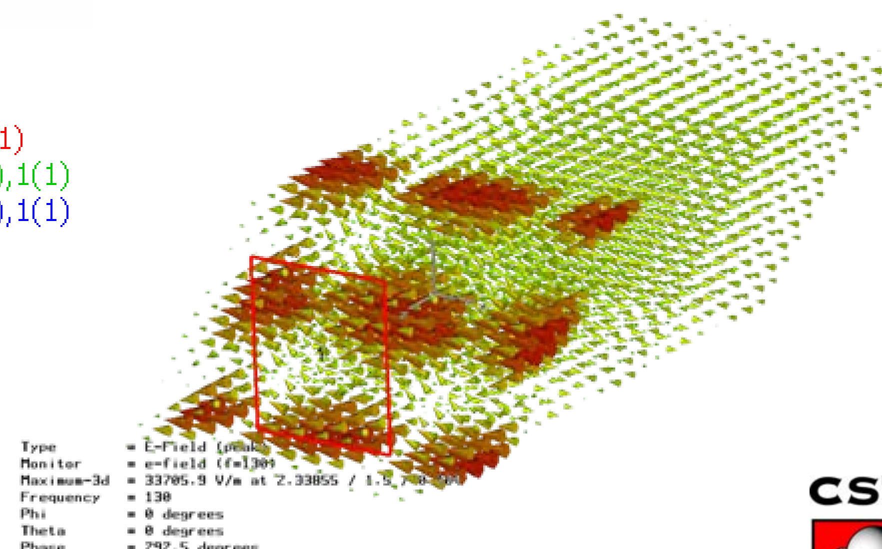


Infinite Arrays
Honeycomb Example









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Summary

Antenna array simulations with CST MICROWAVE STUDIO®

- The time domain solver is a powerful tool for the simulation of finite antenna arrays. The array size is only limited by the available memory resources.
- The features simultaneous excitation, combine results and farfield array offer a variety to find the best approach for a given problem.
- The frequency domain solver can simulate arbitrary infinite arrays using a unit cell. Project and result templates are helpful to model and extract results.