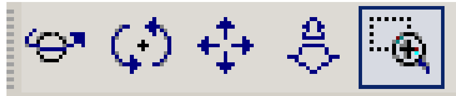
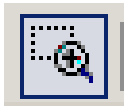
CST MICROWAVE STUDIO
Overview

Ben-Gurion University.
Course “Antennas and Radiation”.

Berezin Maksim



View Options

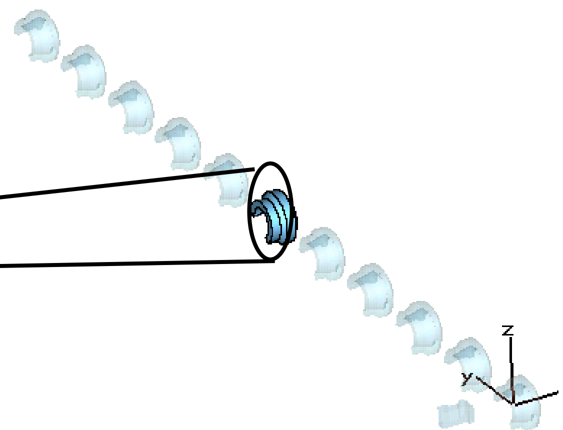
Set view to „Rectangle zoom“:  Use mouse to select area to zoom.

Change the view by dragging the mouse while pressing the left button and a key:

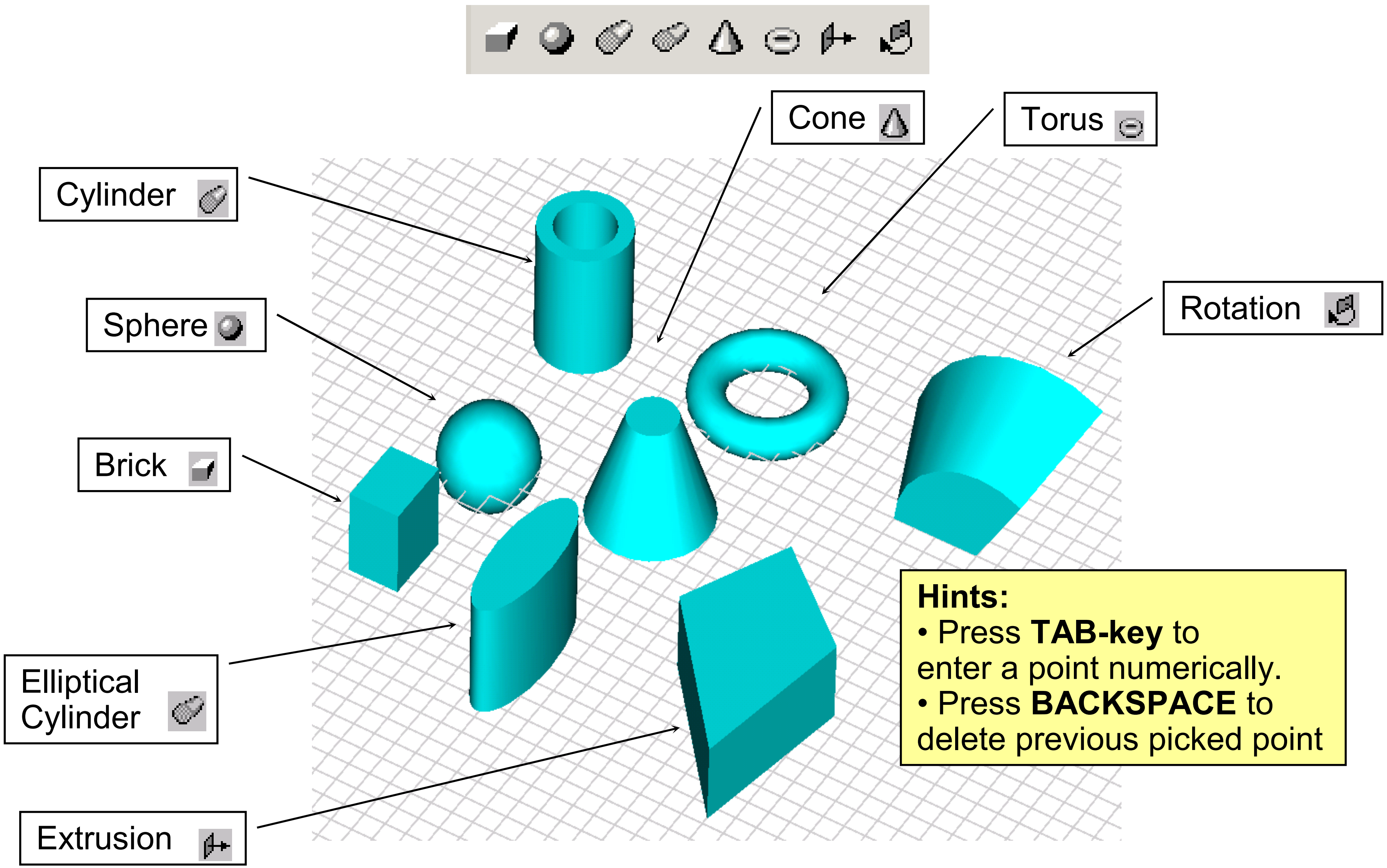
- Ctrl: Rotation
- Shift: In-plane rotation
- Ctrl+Shift: Panning

Other useful options:

- SPACE-bar: Reset View (undo zoom)
- Roll (middle) mouse button: dynamic zoom
- **Shift – SPACE:**
  Zooms into selected shape



Primitives



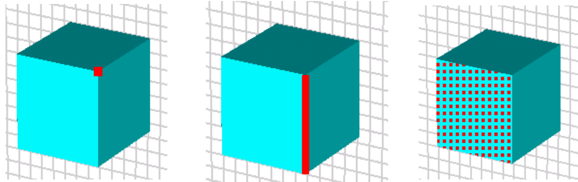
Hints:

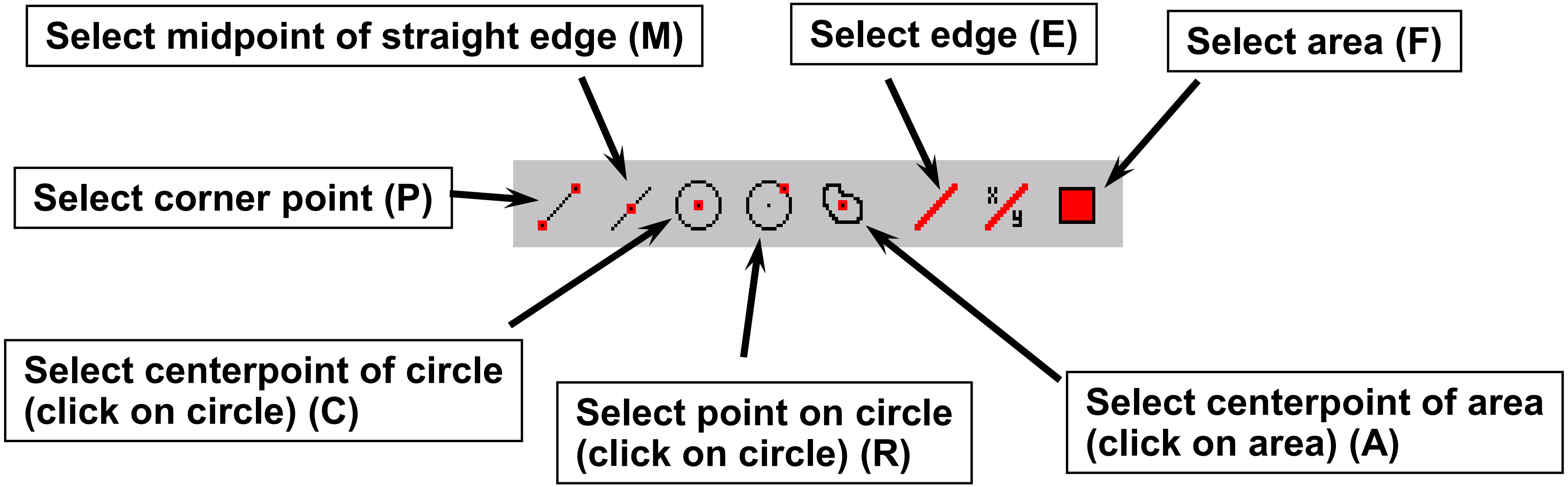
• Press **TAB-key** to enter a point numerically.

• Press **BACKSPACE** to delete previous picked point

Picks

Pick a point, an edge or an area in the structure



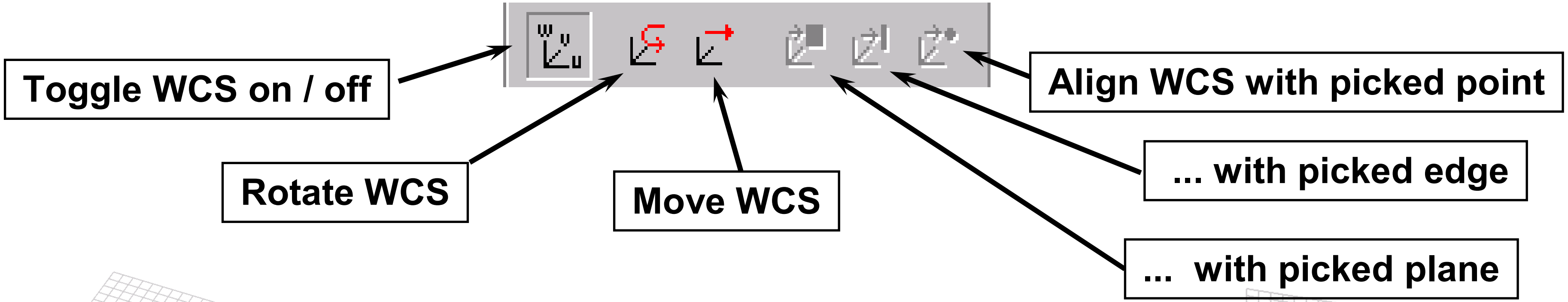


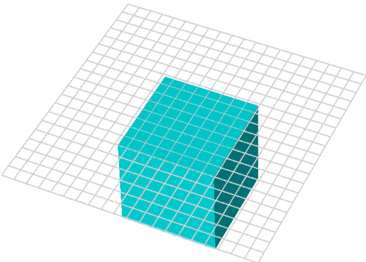
1. Activate the tool (via Icon, Menu Objects->Pick or Shortcut)
2. Double click on the point, edge or area

The Local Coordinate System

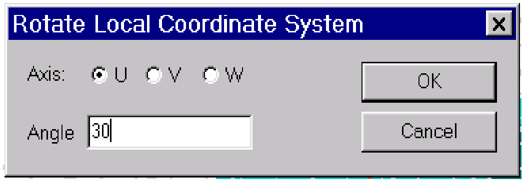
To align the WCS: pick face, edge or point, then: ShortCut = W

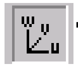
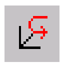
Alternative: use buttons

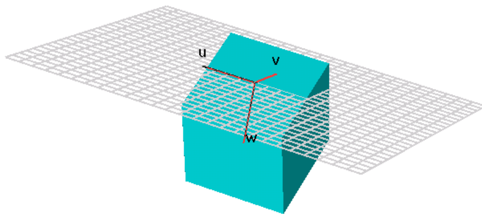




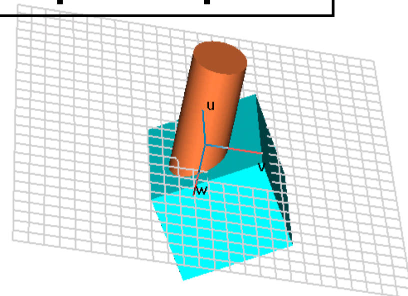
Brick in global CS



Activate and rotate WCS  **+** 

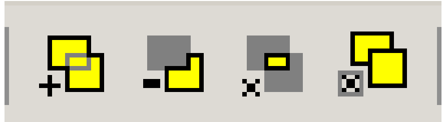


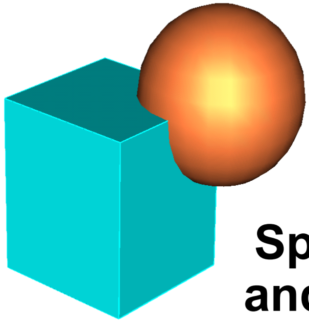
New WCS (drawing plane)



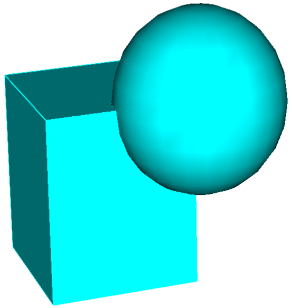
Draw a cylinder

Boolean Operations

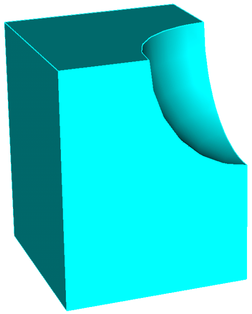




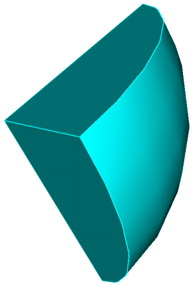
Sphere (new shape)
and Brick (old shape)



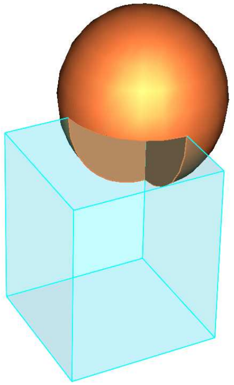
Add
sphere + brick



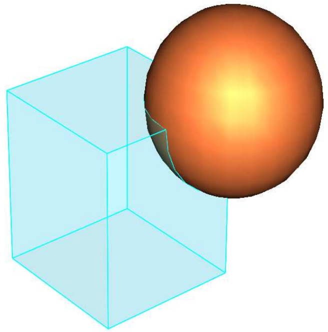
Subtract
brick - sphere



Intersect
brick * sphere

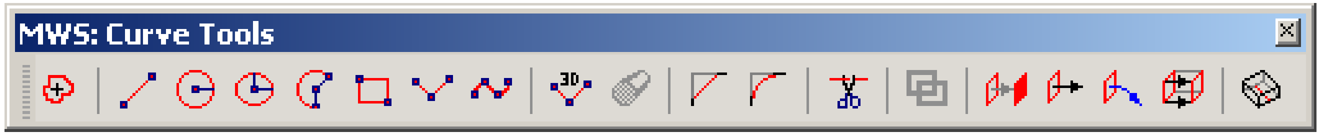


Trim
modifies **new** shape
sphere / brick



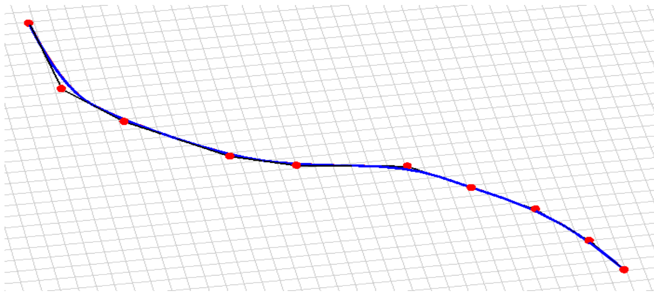
Insert
modifies **old** shape
brick / sphere

Trace from Curve

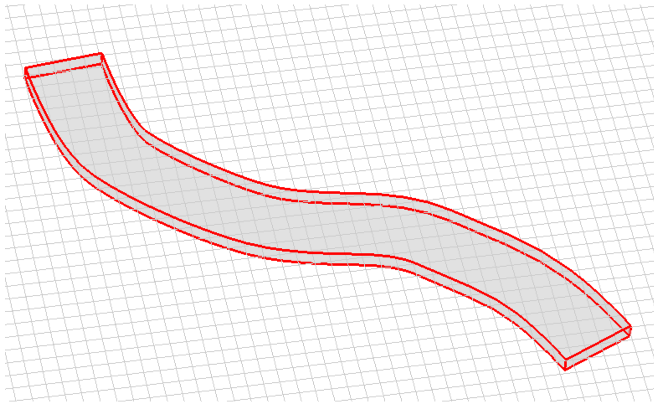


Step 1: New Curve

Step 2: New Polygon

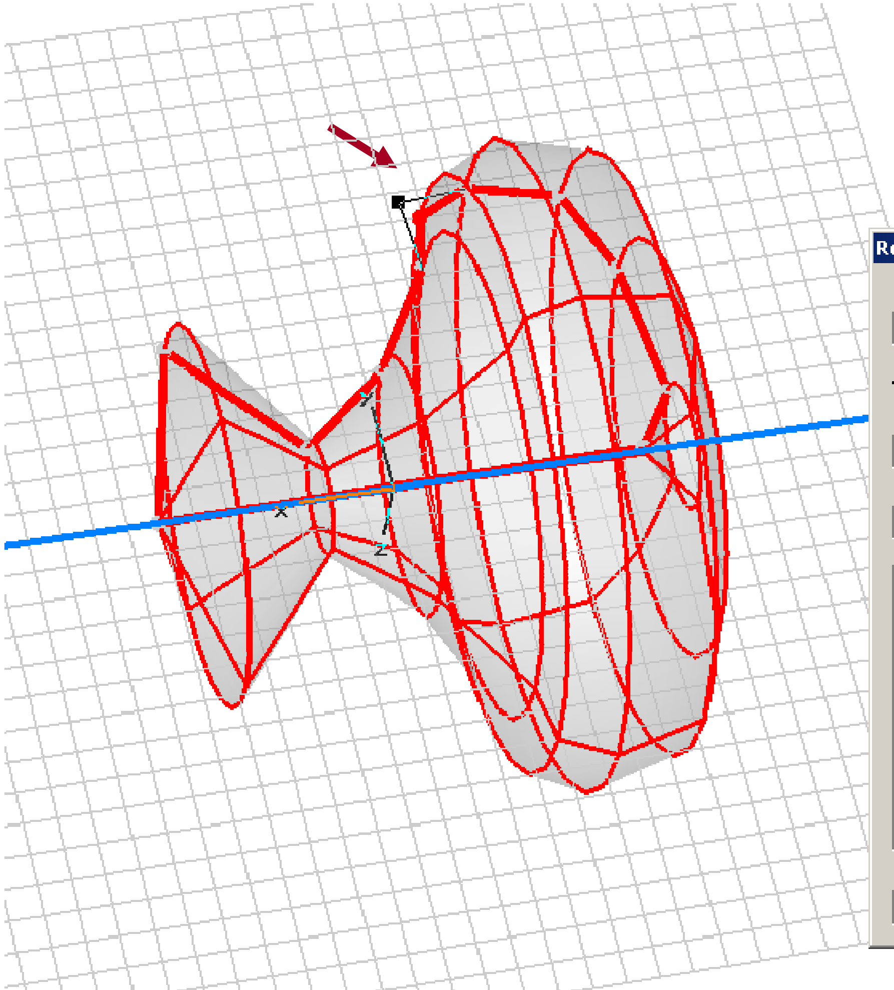


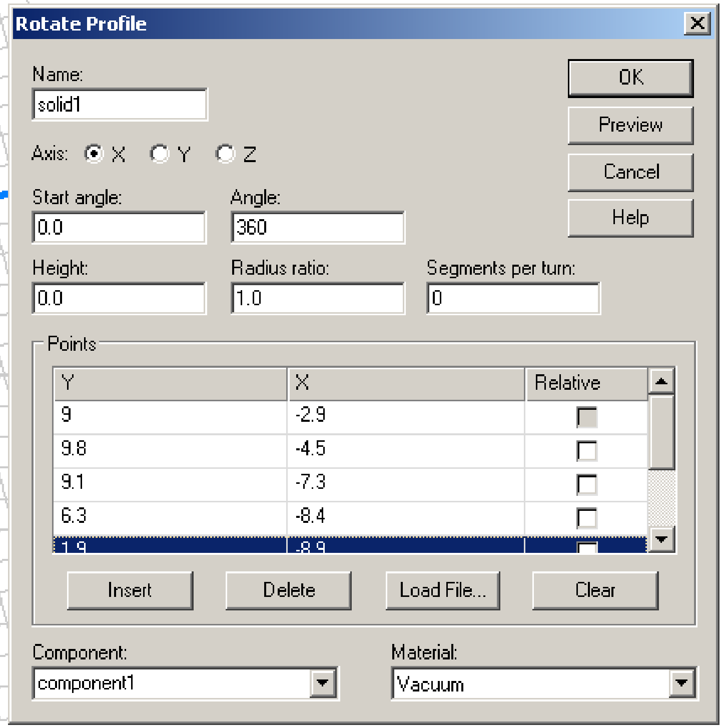
Step 3: Trace from Curve



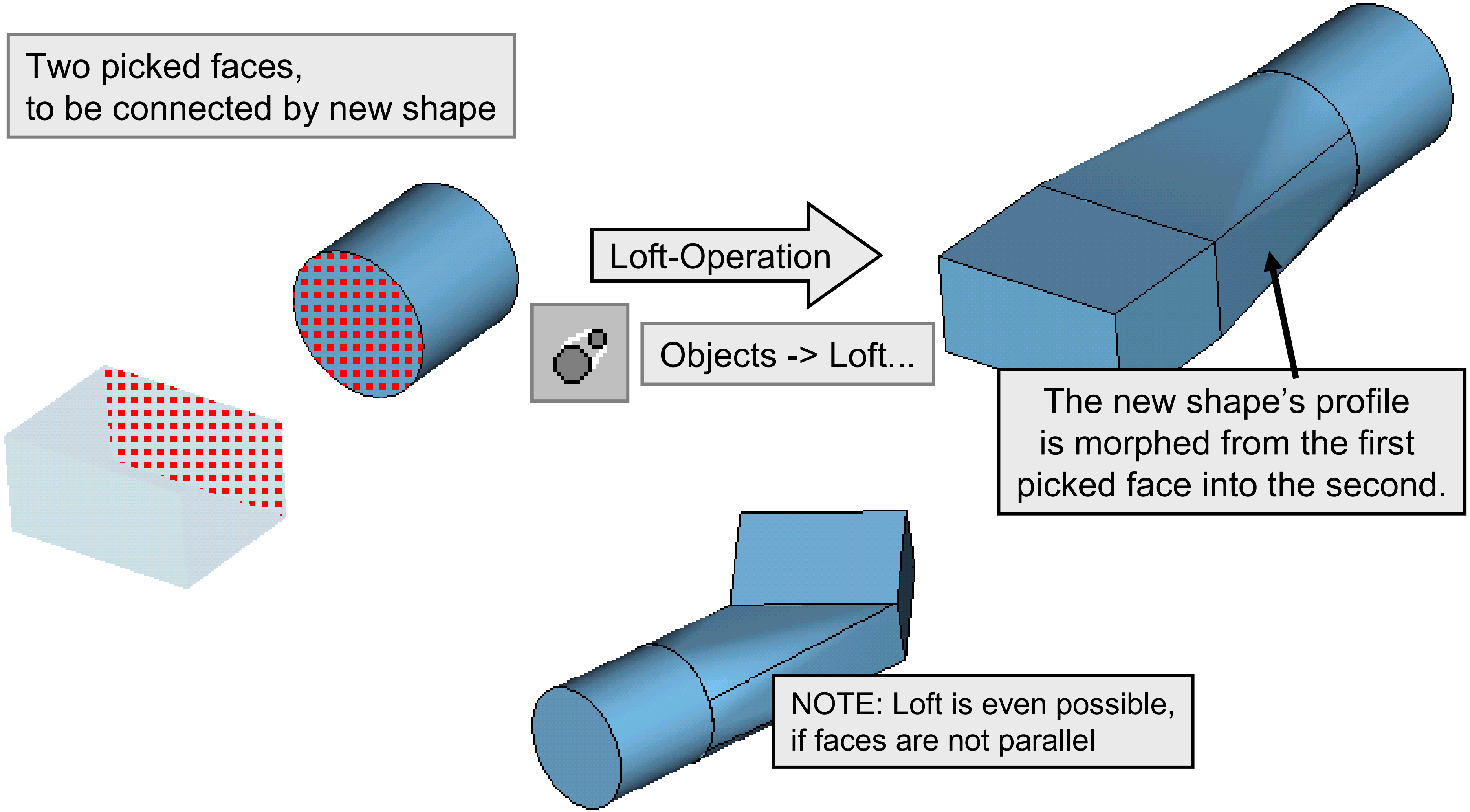
Rotation of Profile

- Select icon and enter profile
- Avoid intersections
- Press **BACKSPACE** to delete previous picked point
- Double click corner points to move them around

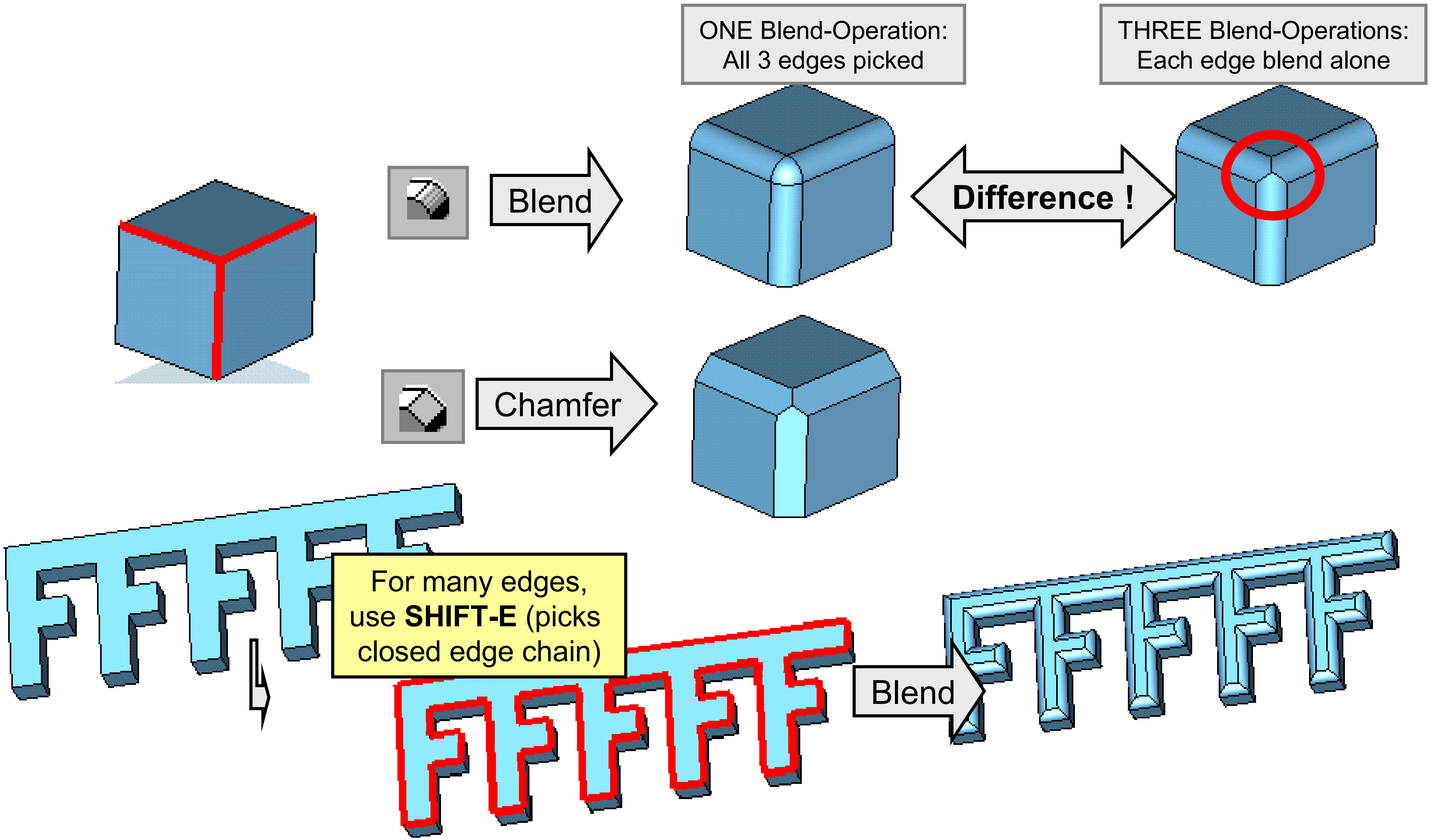




Loft-Operation

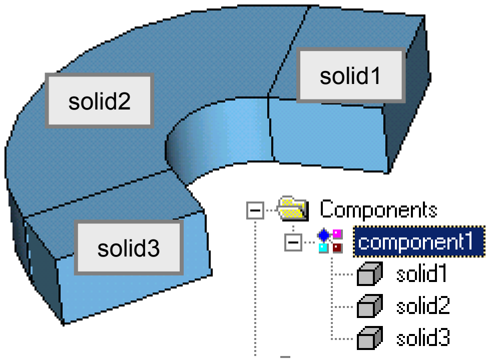


Blend and Chamfer Edges



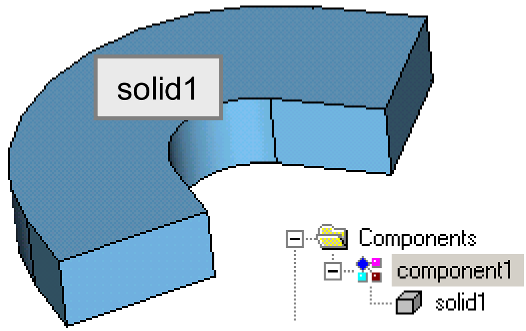
Shell-Operation

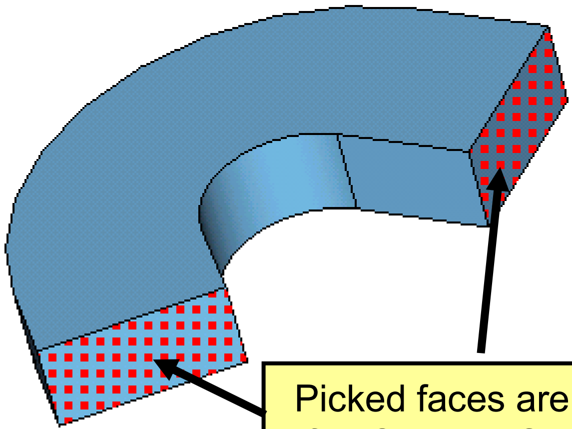
TASK: Waveguide-Bend, consisting of three shapes, should be shelled



Combine to ONE shape

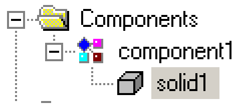
1. Select component1
2. Objects ->
   Merge Materials on Component



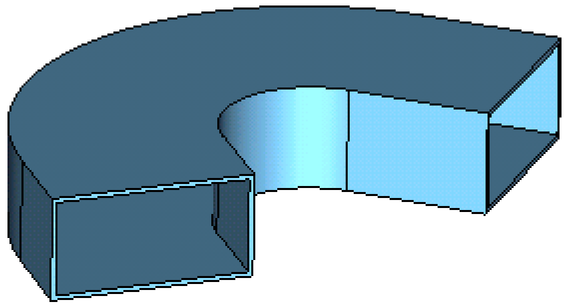


Picked faces are **open** after Shelling-Operation

Objects -> Shell...



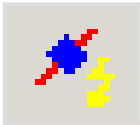
1. Picked faces, to be open after shelling
2. Select solid1, to be shelled

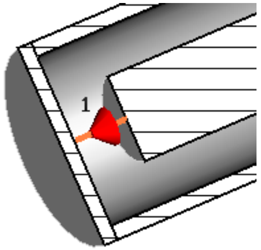


Definition of Ports

Ports for S-parameter computation

Discrete Ports (lumped element)

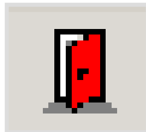


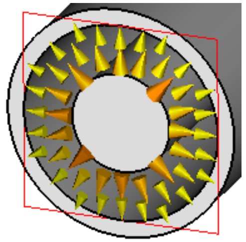


Input: Knowledge of TEM-Mode Line Impedance

Output: Voltage and Current

Waveguide Ports (2D eigenmode solver)





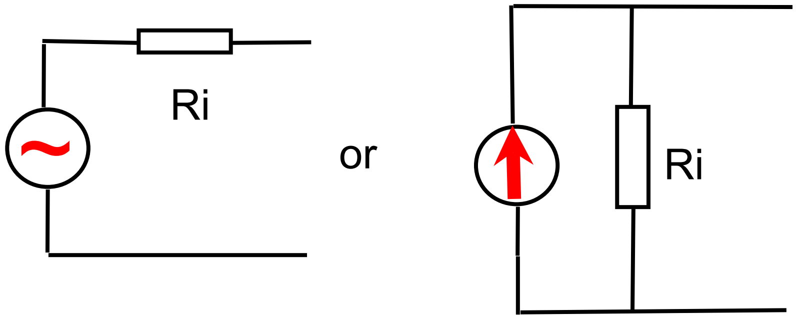
Input: Area for eigenmode solution

Output: E and H-Pattern, Line Impedance, Prop.constant (beta+alpha)

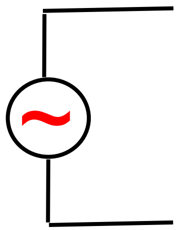
- Discrete ports can be used for TEM-like modes, not for higher modes (f_{cutoff}>0).
- Waveguide Ports deliver better match to the mode pattern as well as higher accuracy in S-Parameters.

Discrete Ports

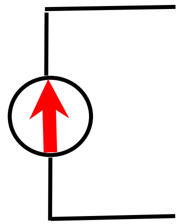
S parameter port



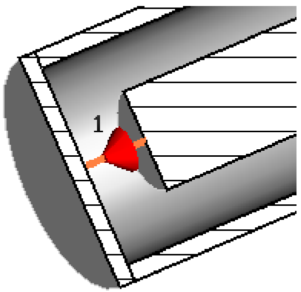
2. Voltage port



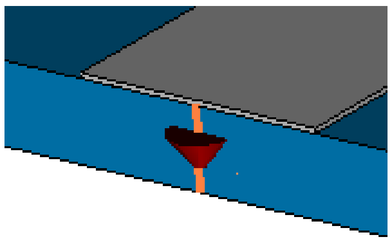
3. Current



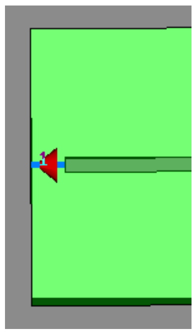
Coaxial



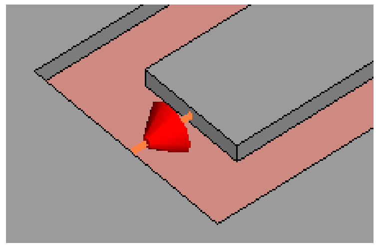
Microstrip

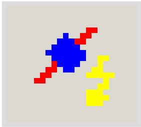


Stripline



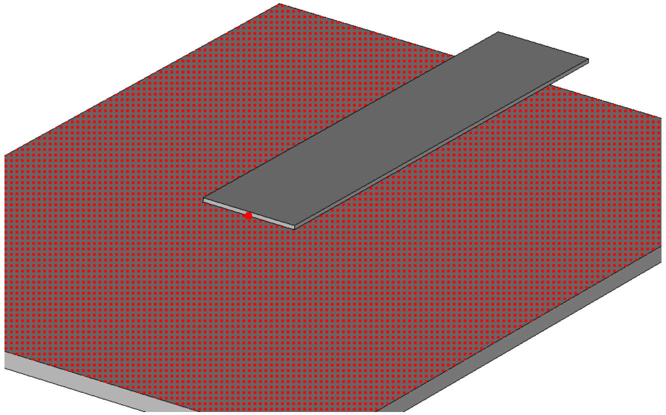
Coplanar Waveguide

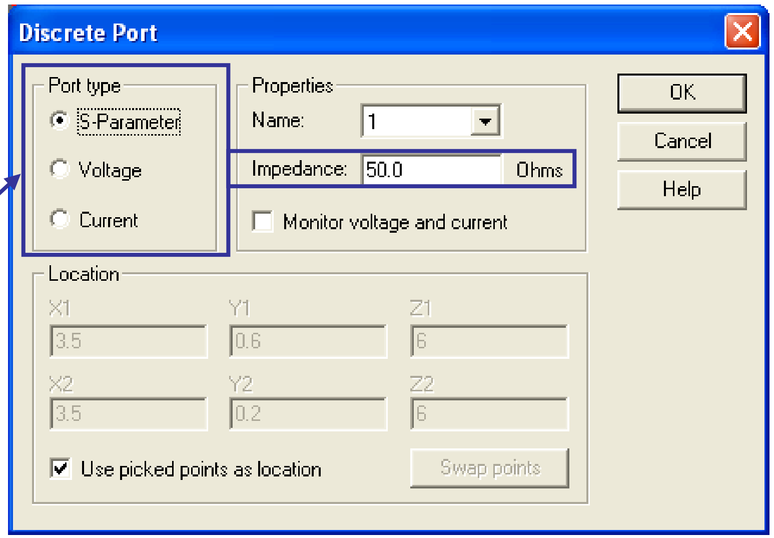




Discrete Port Definition

pick 2 points
(or)
1 point and a face
(or)
enter coordinates
(not recommended)

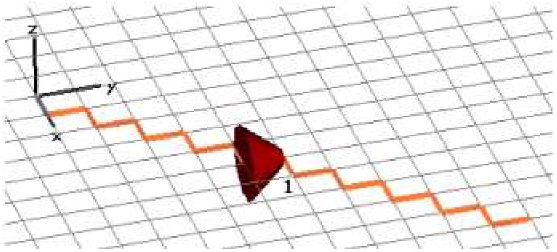




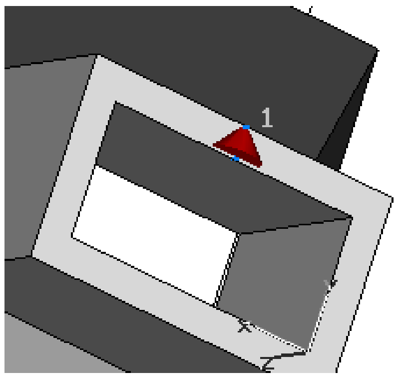
Select Port Type and Impedance

Discrete Port Details

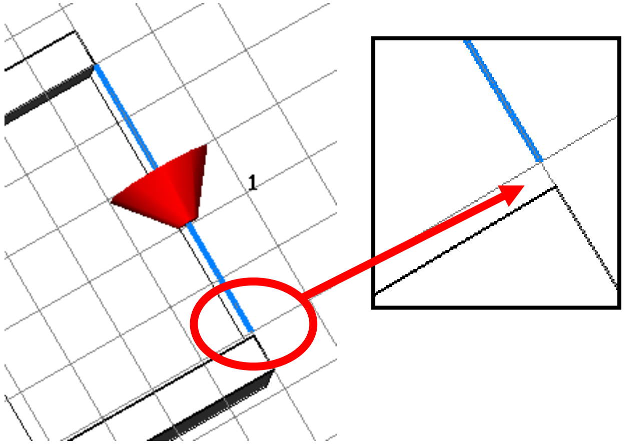
Mesh



1. The port is the cone on the mesh edge
2. That edge must be a dielectric edge
3. The wires attach the port to the structure

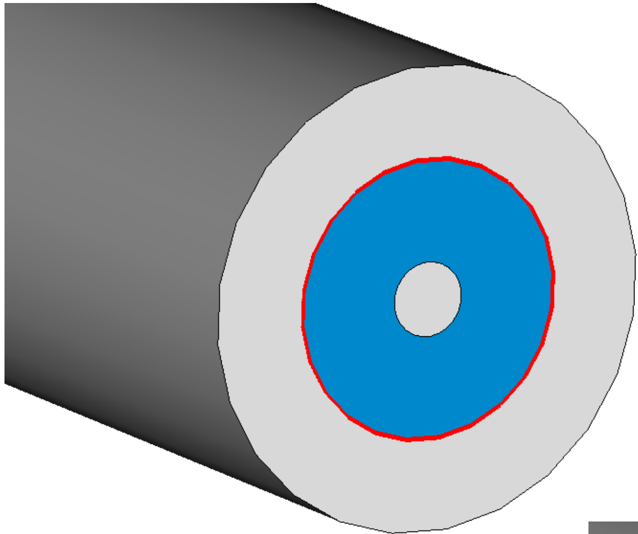


In metal

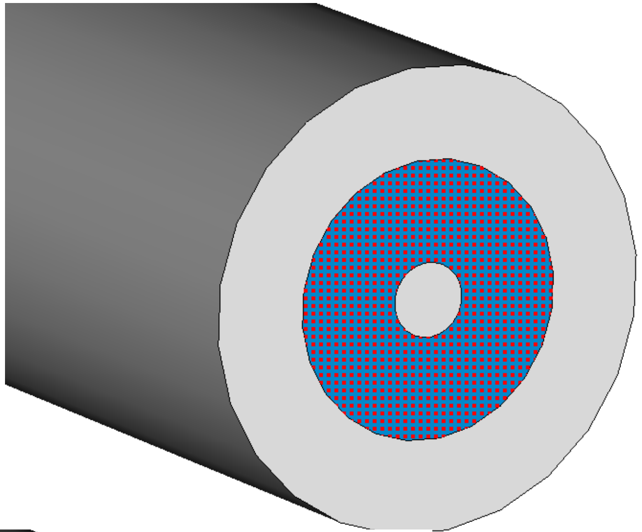


Open

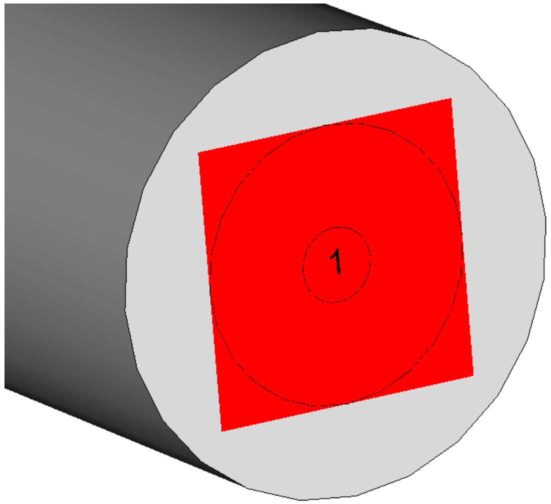
Waveguide Port Definition



Pick Edge

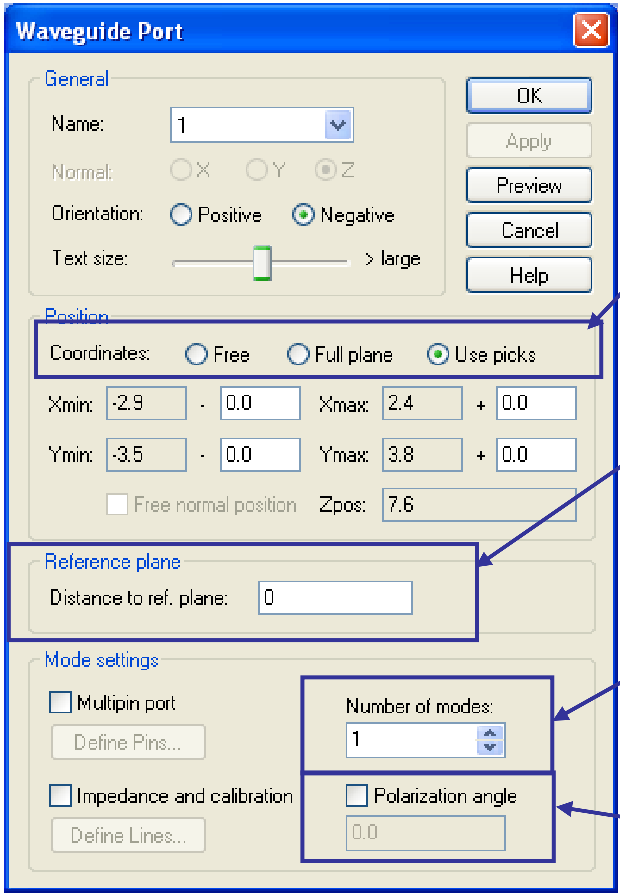


Pick Face



Also possible: any combination
of pick points, edges, faces

Waveguide Port Definition



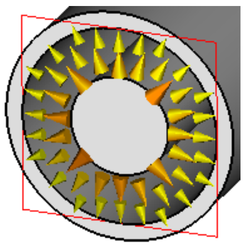
In addition to pick point, Full Plane or Free Coordinates can also be specified

For Phase Deembedding

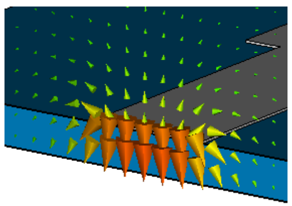
Number of desired Higher Order Modes

For Separation of Degenerate Modes in Circular Waveguides

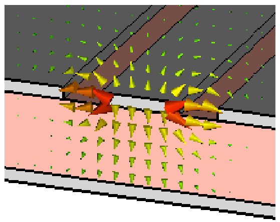
Coaxial



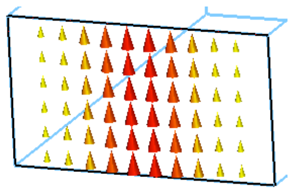
Microstrip



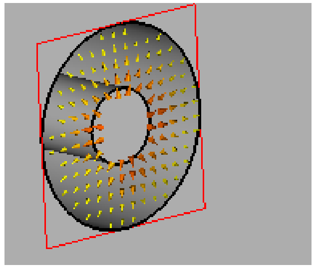
Coplanar Waveguide



Hollow Waveguide

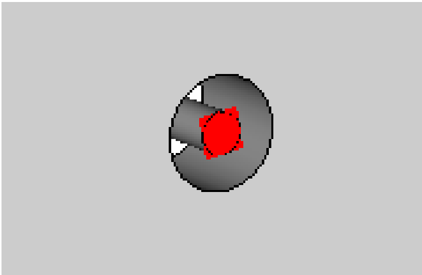


Waveguide Port Details

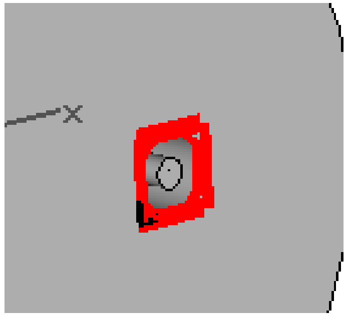


Port must be large enough to cover the fields of the port mode of interest.

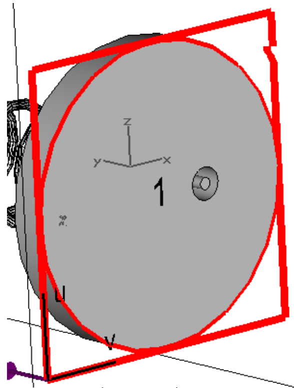
NO, Too small



YES, Good

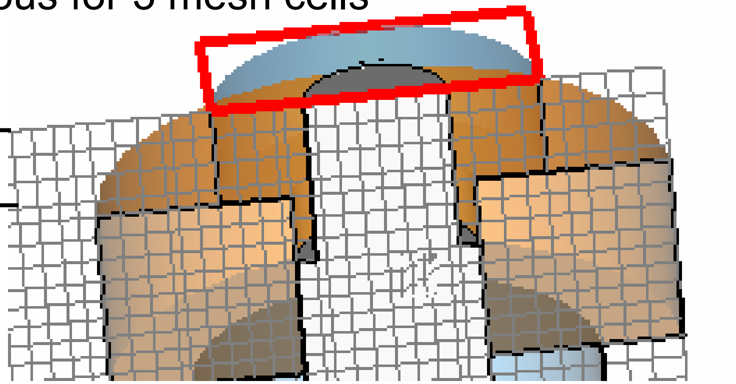


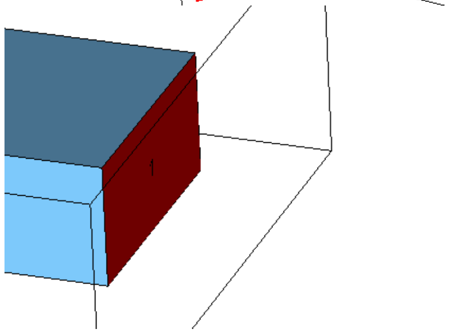
NO, Unnecessarily large



Time Domain: Geometry must be homogenous for 3 mesh cells

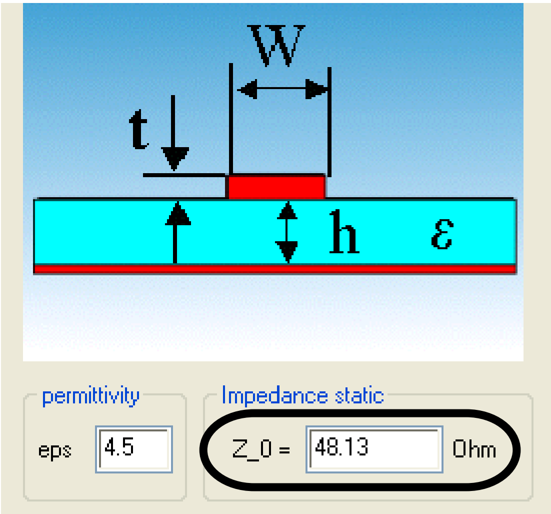
3 mesh cells

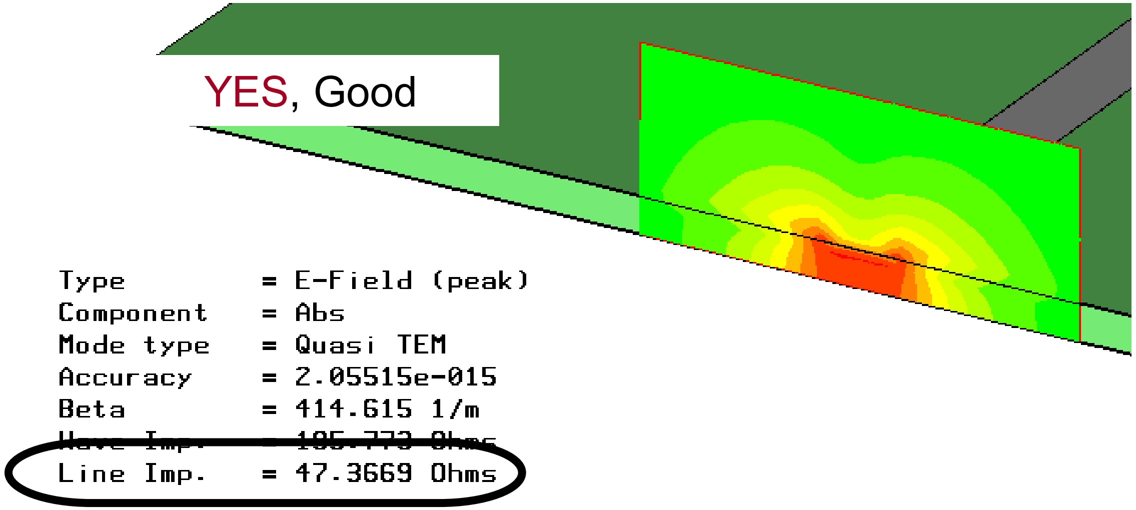


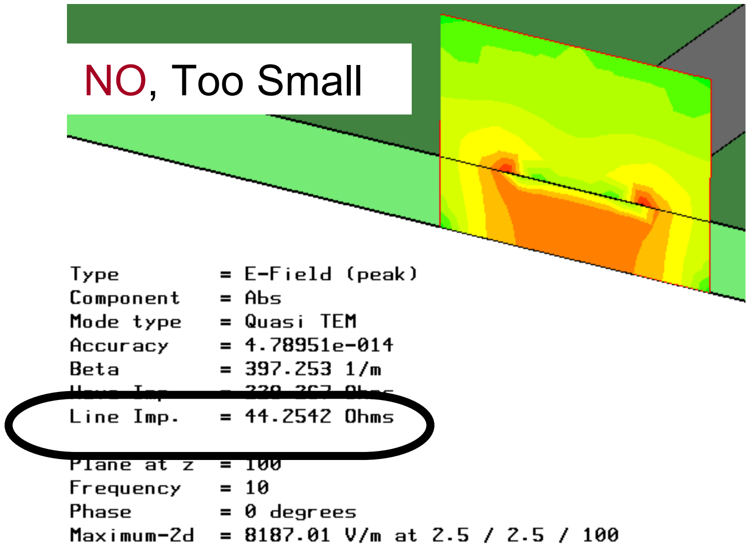


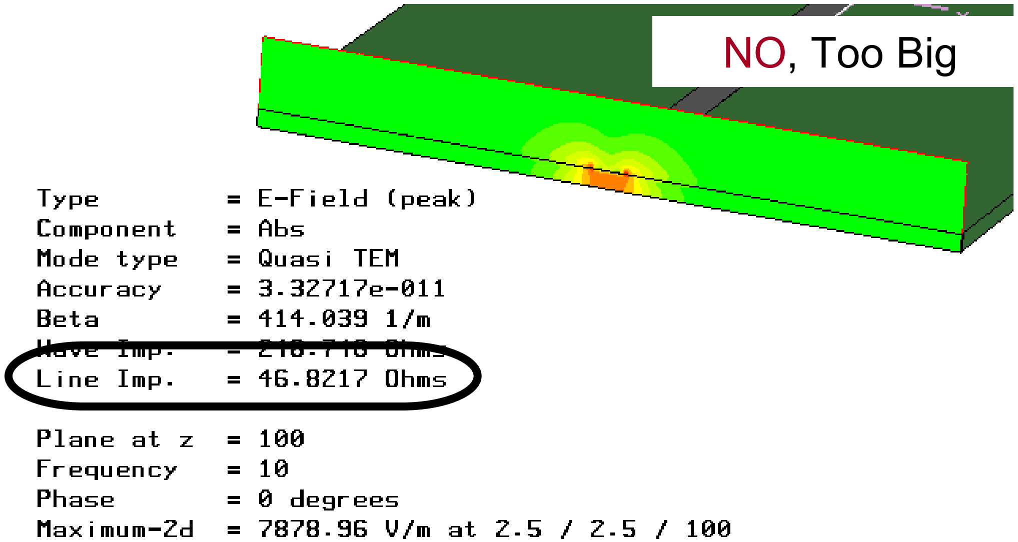
Frequency Domain: Internal port must be backed by PEC

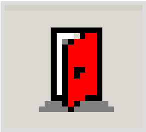
Port Impedance Evaluation



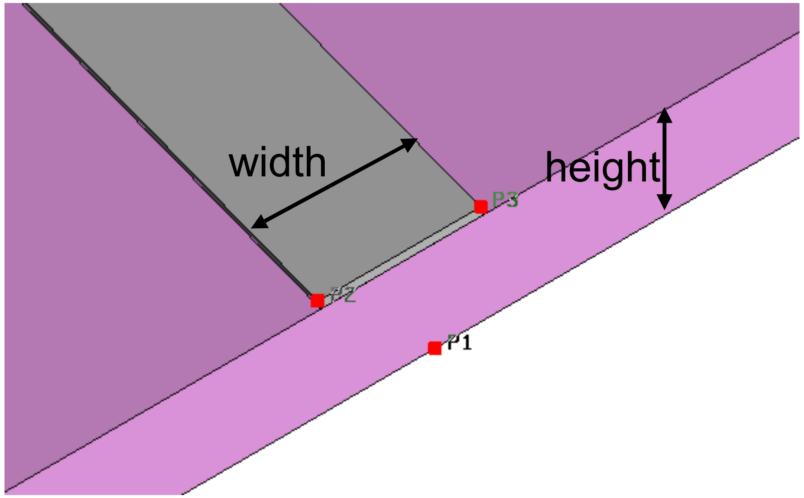


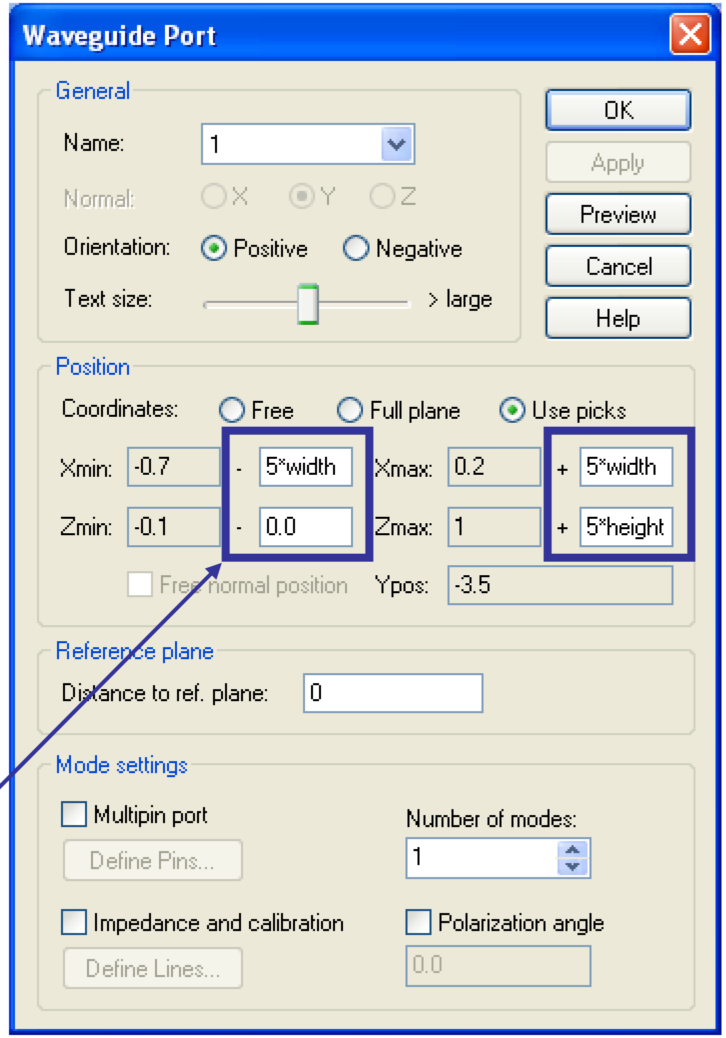






Port Definition - Microstrip Line

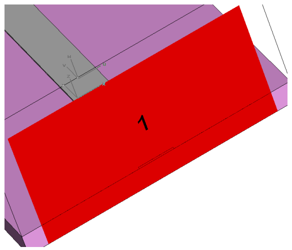




1) Pick 3 Points

2) Enter Port menu

3) Adjust additional port space (+- 5 width, +5 height)

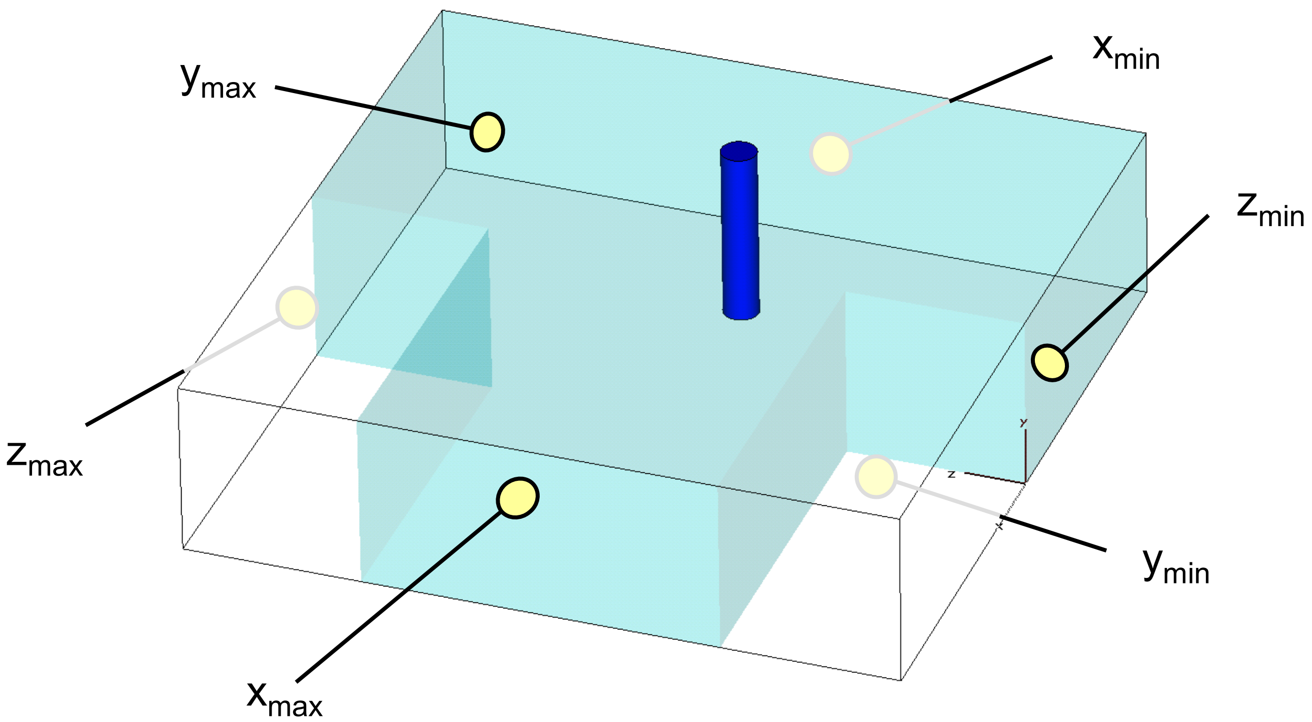


Boundary Conditions

Boundaries

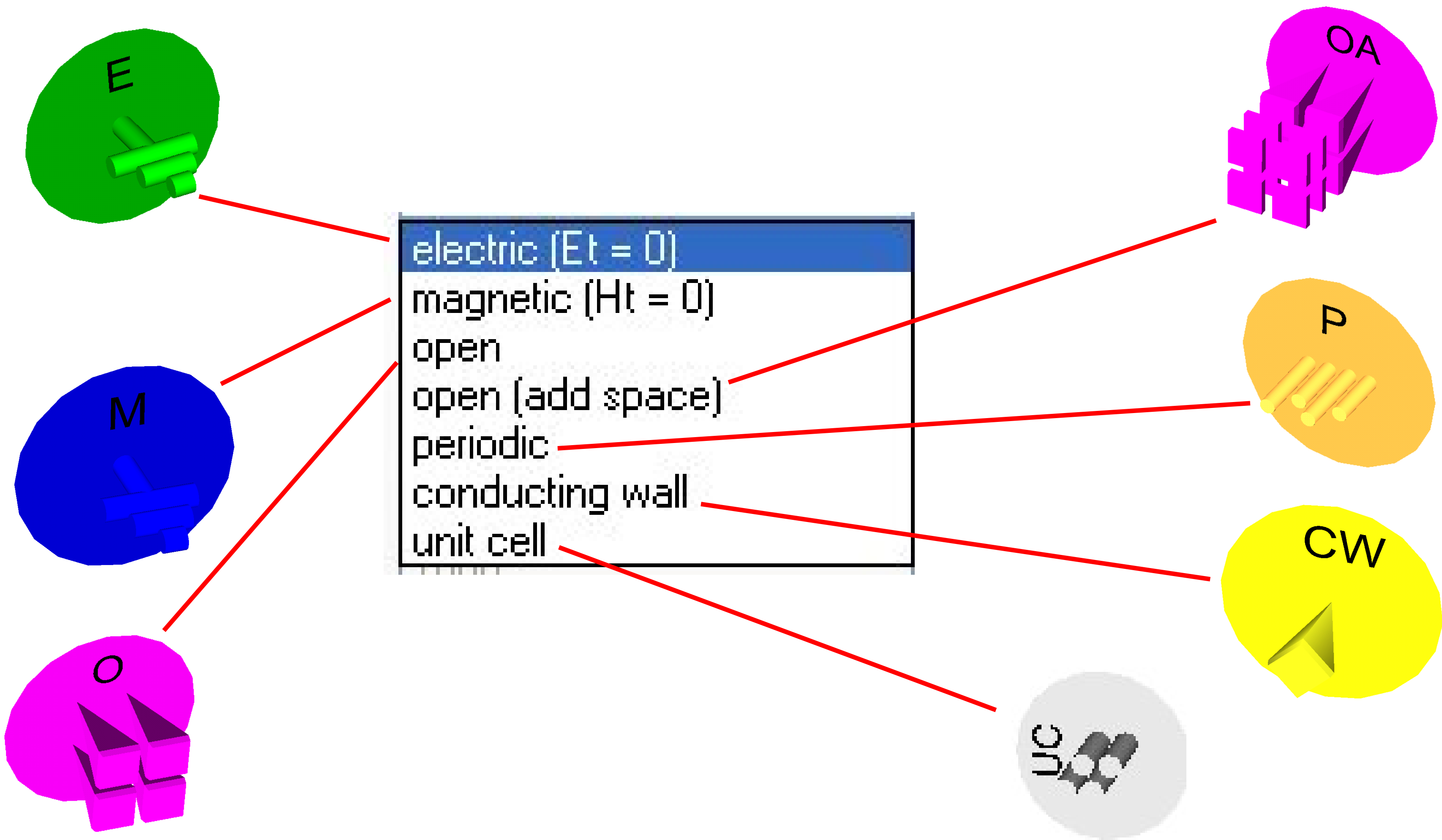
CST MWS uses a rectangular grid system, therefore also the complete calculation domain is of rectangular shape => 6 boundary surfaces have to be defined at the minimum and maximum position in each co-ordinate direction (x_{min}, x_{max}, y_{min}, y_{max}, z_{min}, z_{max}).

Example: T-Splitter

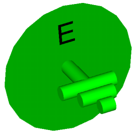


Boundary settings (1)

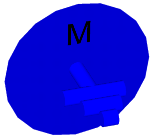
7 different settings are available



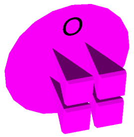
Boundary settings (2)



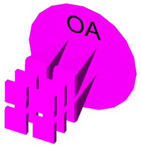
Electric boundaries (Default setting): No tangential electric field at surface.



Magnetic boundaries: No tangential magnetic field at surface. Default setting for waveguide port boundaries.



Open boundaries: Operates like free space – waves can pass this boundary with minimal reflections. Perfectly matched layer (PML) condition.

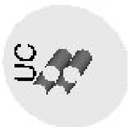


Open add space boundaries: Same as Open, but adds some extra space for farfield calculation (automatically adapted to center frequency of desired bandwidth). *This option is recommended for antenna problems*.

Conducting wall: Electric conducting wall with finite conductivity (defined in Siemens/meter).

Boundary settings (3)

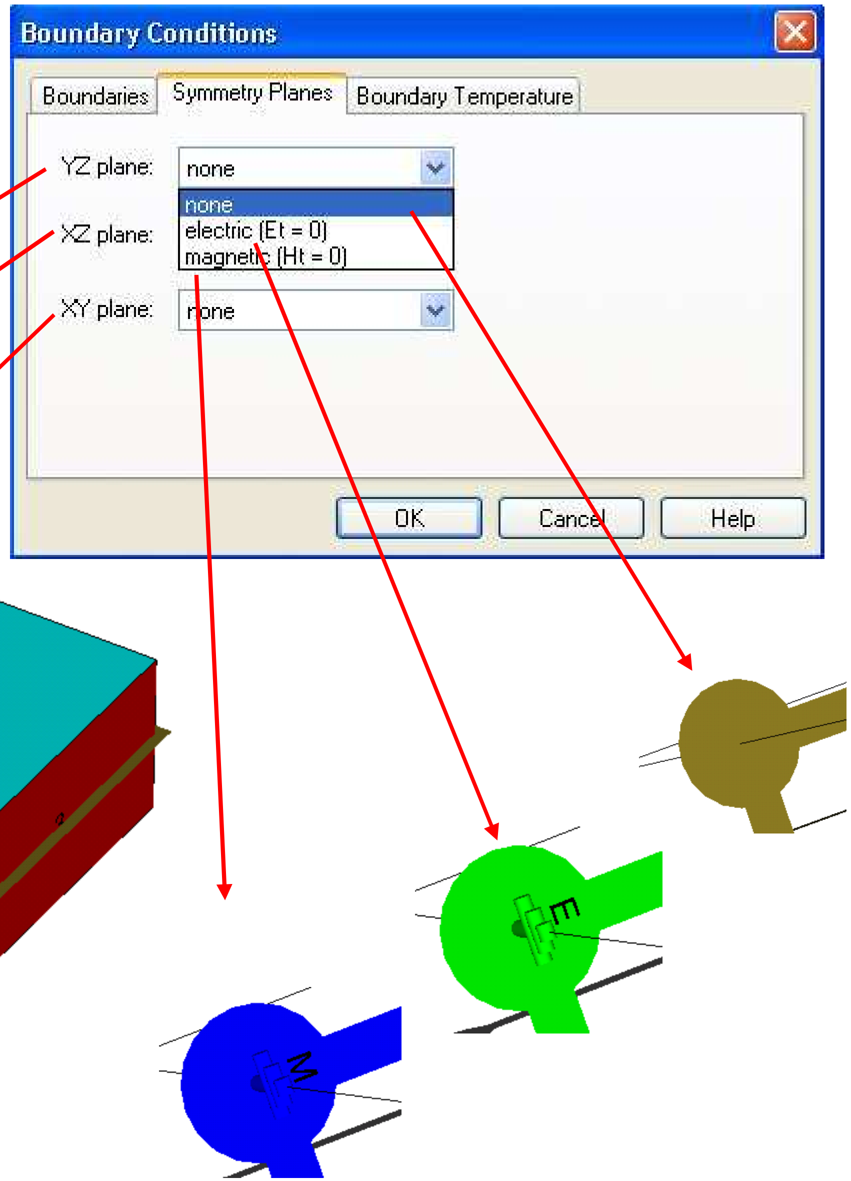
Periodic boundaries: Connects two opposite boundaries so that the calculation domain is simulated to be periodically expanded in the corresponding direction. Thus it is necessary that both boundaries facing each other are always indicated as periodic. *The resulting structure represents an infinite expanded antenna pattern, phased array antennas*. F! Hex mesh, T! + 0 phase shift

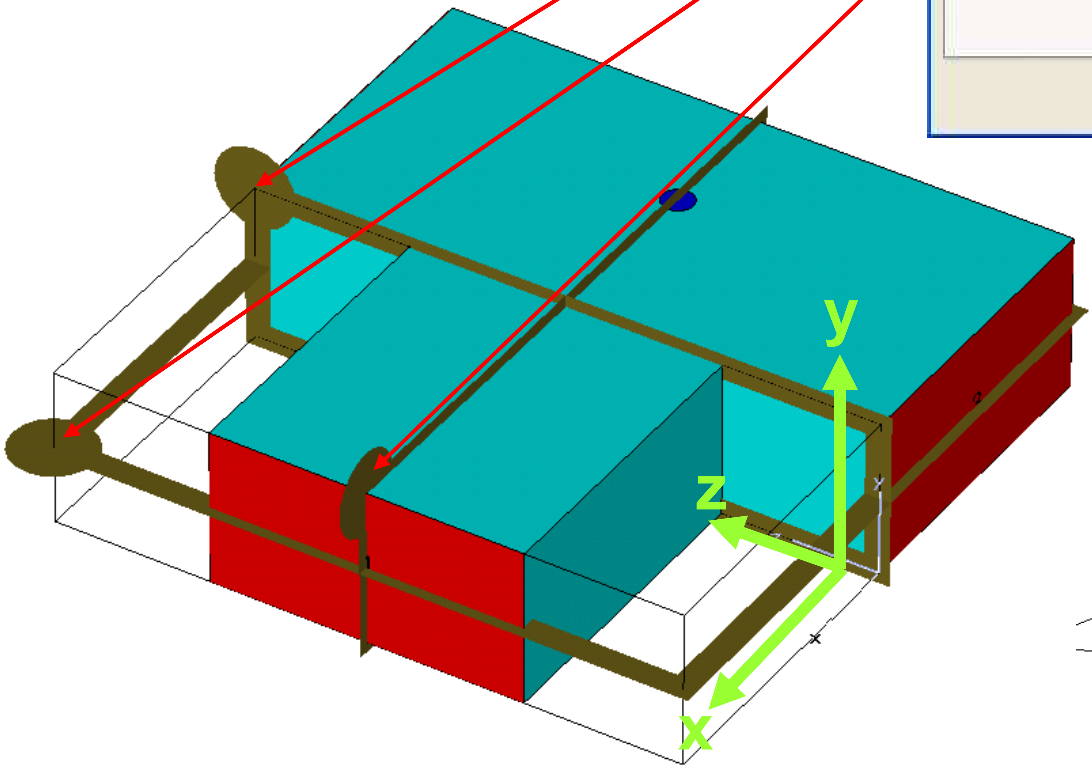


Unit Cell: Used with F! Solver, Tet mesh, similar to F! Periodic boundary with Hex mesh. A two dimensional periodicity other than in direction of the coordinate axes can be defined. If there are open boundaries perpendicular to the Unit Cell boundaries, they are realized by Floquet modes, similar to modes of a wave guide port .

Boundaries : Symmetry planes

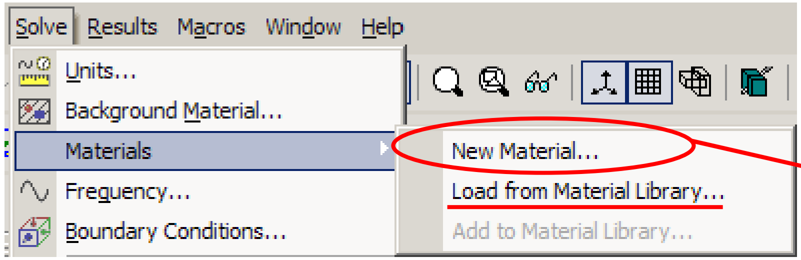
3 different settings are available for
3 possible symmetry planes:

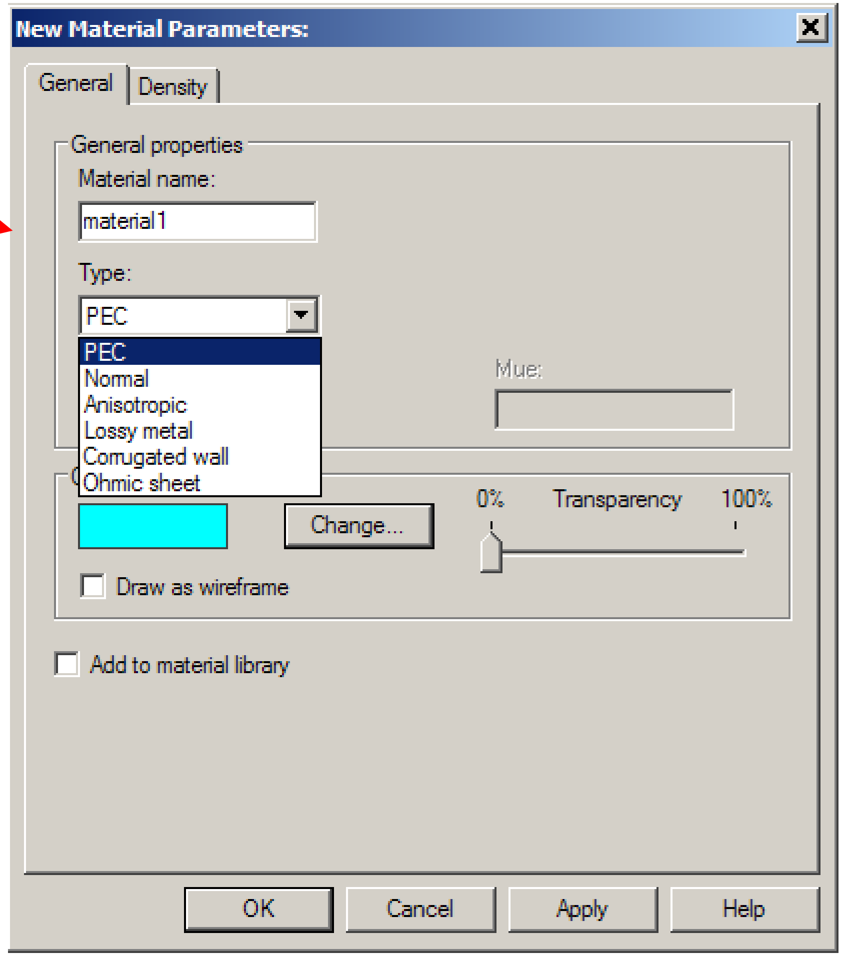




Materials

Basic Materials





PEC: **P**erfect **E**lectric **C**onductor → $\sigma = \infty$

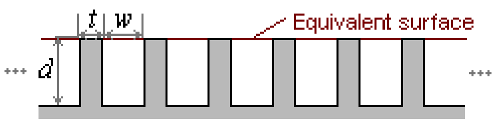
Normal: General material model → Typically used for dielectric materials

Anisotropic: ε and μ are directionally dependent

Lossy Metal: Conductor → $\sigma \neq \infty$

Corrugated wall: Surface impedance

$$Z = j\frac{w}{w+t}\sqrt{\frac{\mu_0}{\varepsilon_0}}\tan(k_0 d)$$



Ohmic sheet: Surface impedance [Ω/□]

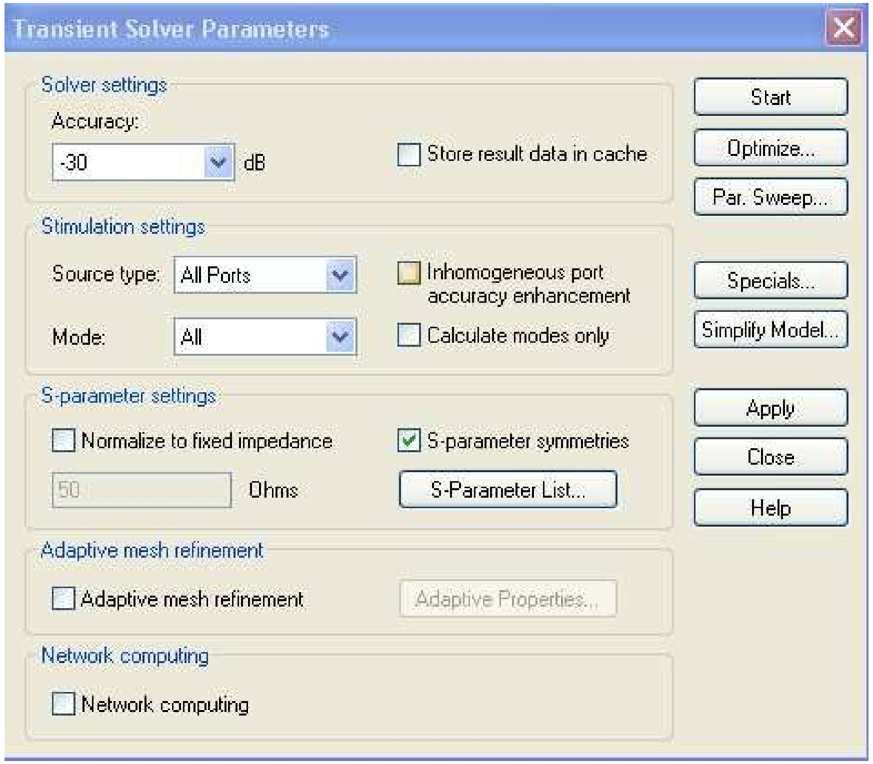
Lossy Metal

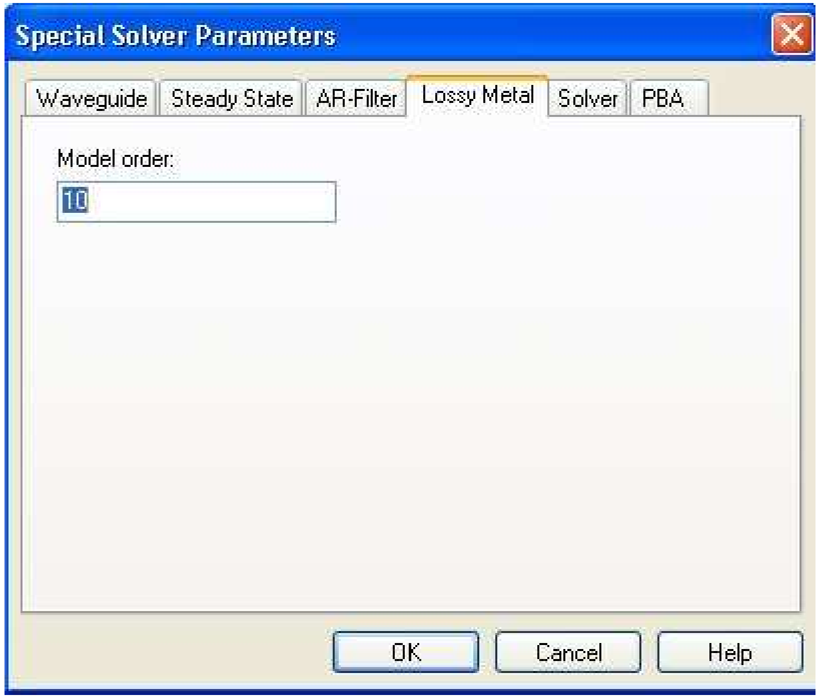
- Why is it required?
  - Sampling of skin depth would require very fine mesh steps at the metal surface and definining conductor as a normal material

    (skin depth for copper at 1 GHz approx. 2 um)
  - This results in a very small timestep, which leads to a very long simulation time

- Solution:
  - 1D Model which takes skin depth into account without spatial sampling.

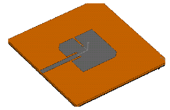
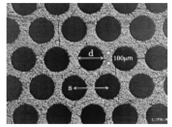
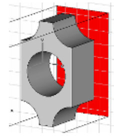
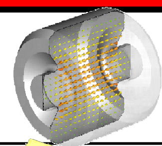
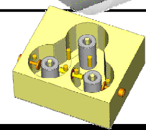
Lossy Metal


Transient Solver Parameters
Solver settings
Accuracy:
-30
dB
Store result data in cache
Start
Optimize...
Par. Sweep...
Stimulation settings
Source type:
All Ports
Inhomogeneous port accuracy enhancement
Mode:
All
Calculate modes only
Specials...
Simplify Model...
S-parameter settings
Normalize to fixed impedance
S-parameter symmetries
50
Ohms
S-Parameter List...
Apply
Close
Help
Adaptive mesh refinement
Adaptive mesh refinement
Adaptive Properties...
Network computing
Network computing

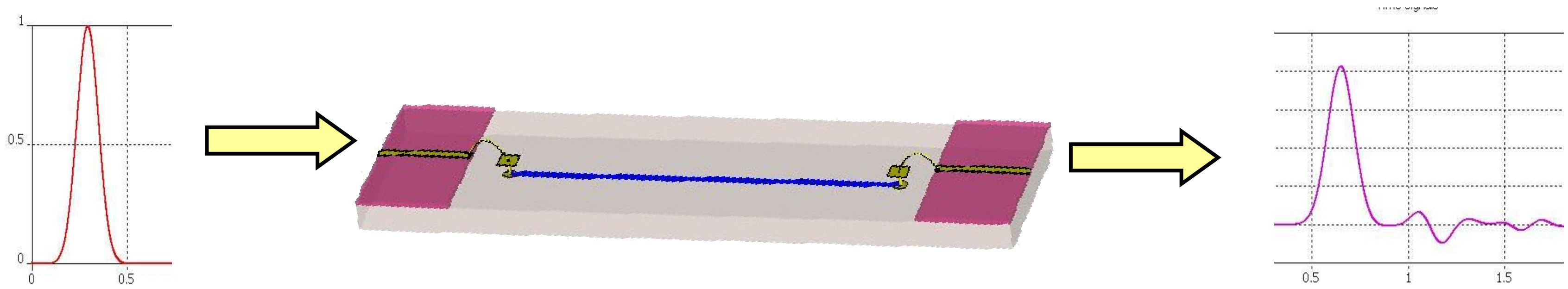

Special Solver Parameters
Waveguide
Steady State
AR-Filter
Lossy Metal
Solver
PBA
Model order:
10
OK
Cancel
Help

Solver Selection

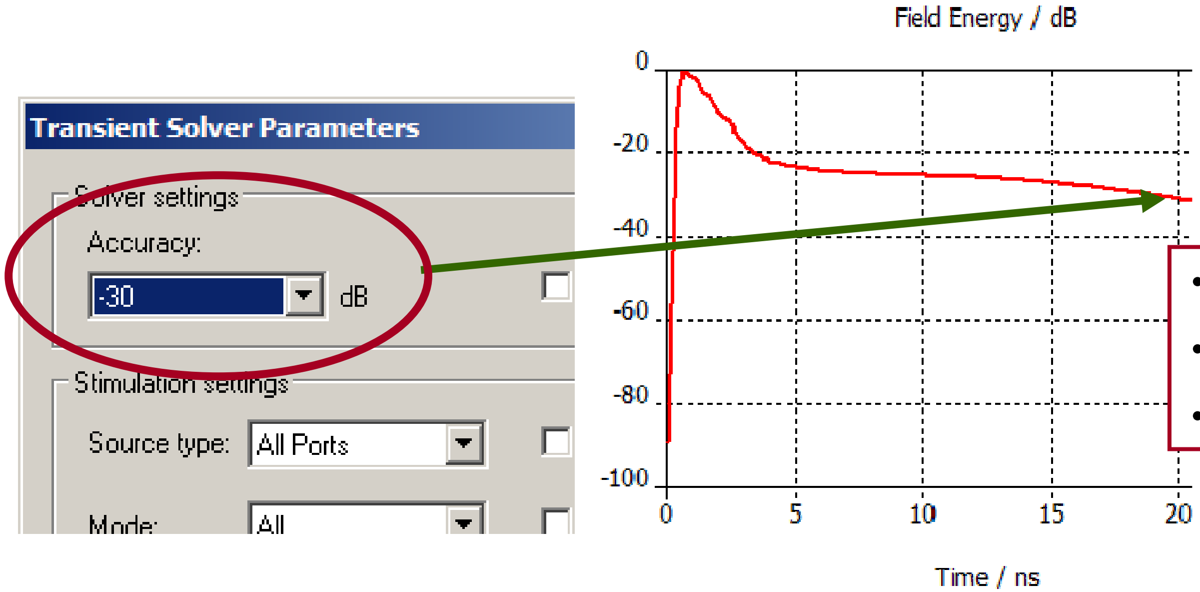
CST MICROWAVE STUDIO® Solvers

General Purpose Solver 3D-Volume	
Transient	▪ Large problems • Broadband • Arbitrary time signals  
Frequency Domain	▪ Narrow band / single frequency • Small problems • Periodic structures with Floquet port modes  
Special Solver 3D-Volume: Closed Resonant Structures	
Eigenmode	▪ Strongly resonant structures, narrow band • Cavities 
Resonant **FD,Resonant**	▪ Strongly resonant, closed structures 
Special Solver 3D-Surface: Large open metalic structures	
Integral Equation solver (based on MLFMM)	▪ Large structures ▪ Dominated by metal  

Transient Solver Introduction



- Begin with no energy inside calculation domain
- Inject energy and step through time
- As time progresses, energy inside calculation domain decays
- When energy decays "far enough," the simulation stops

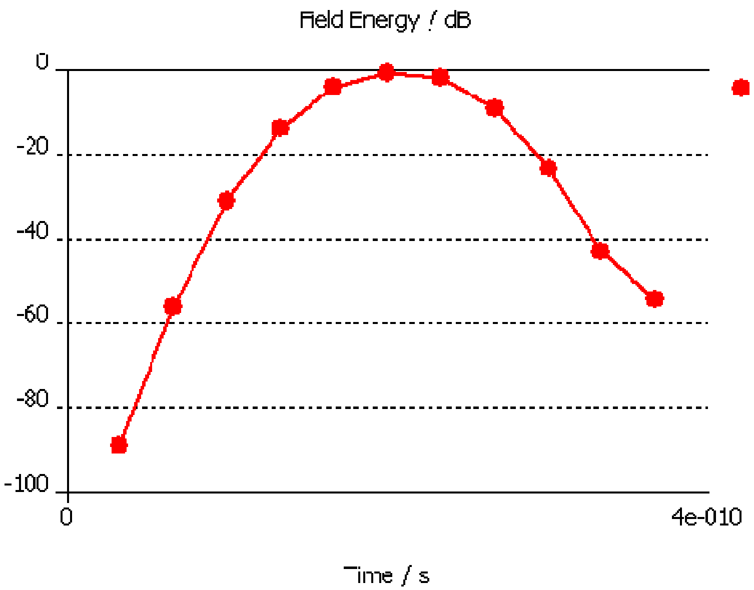


- Hexahedral mesh only
- Time and Frequency Domain Results
- All frequencies in one simulation

!T – Time Domain Solver

Overview

- Arbitrary input signal
- Inject energy and watch it leave
- Solve for unknowns without matrix inversion
- Hexahedral Mesh: Broadband meshing and results
- Simulation is performed on a port-by-port basis
- Smaller mesh cells = longer solve times
- Energy storage for high Q structures prolongs simulation time

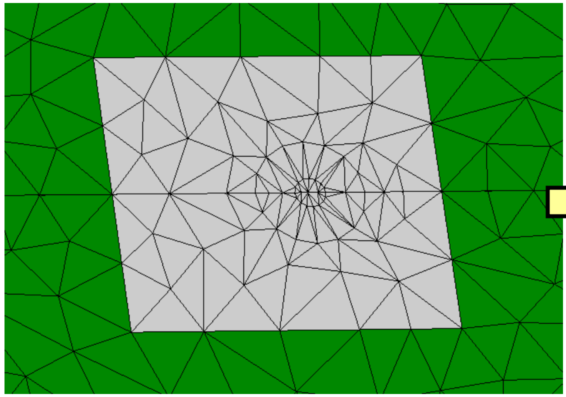


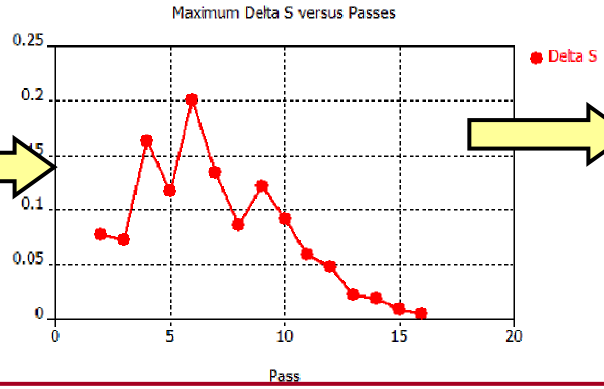
The transient solver is very robust and can handle most applications.

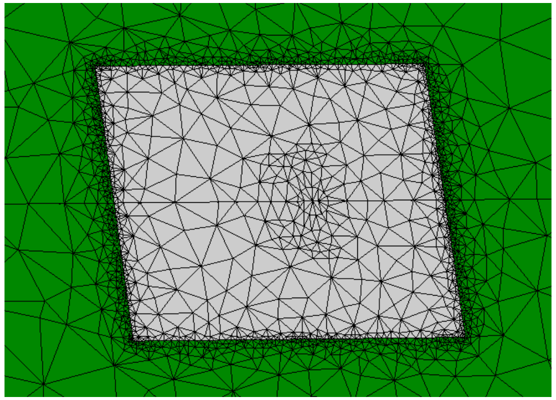
Well suited applications: Broadband, electrically large structures.

Highly resonant, electrically small structures may be better suited to the frequency domain solver.

Frequency Solver Introduction

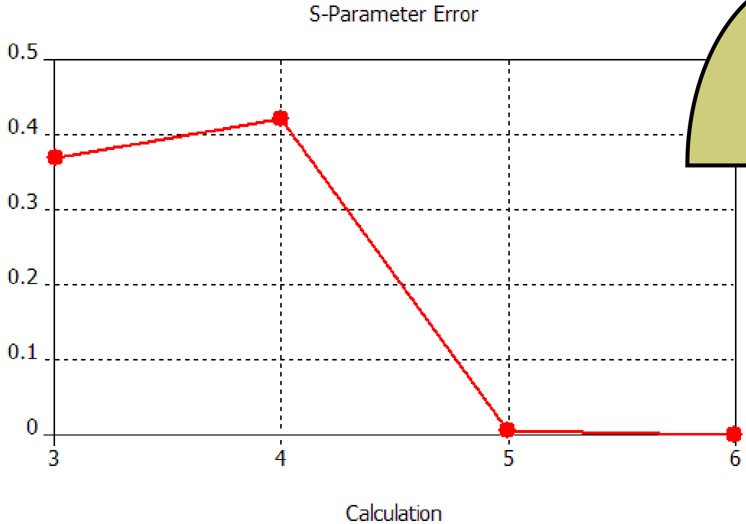


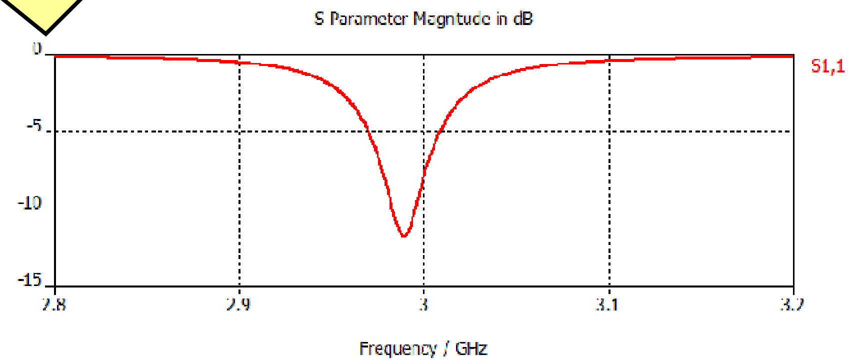




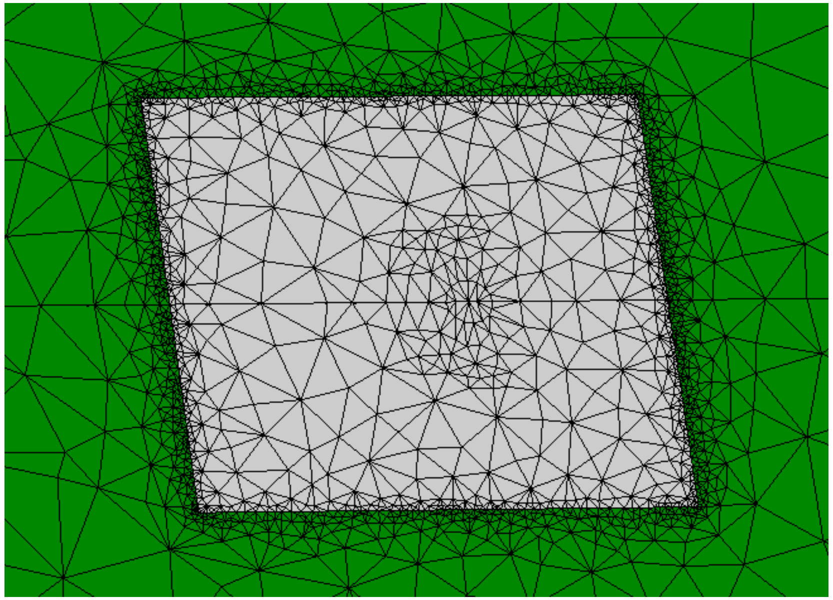
- Simulation performed at single frequencies
- Broadband Frequency Sweep to achieve accurate S-Parameters
- very robust automatic mesh refinement (easy to learn)

➔ 2nd General Purpose Solver (besides Time Domain)





!F – Frequency Domain Solver

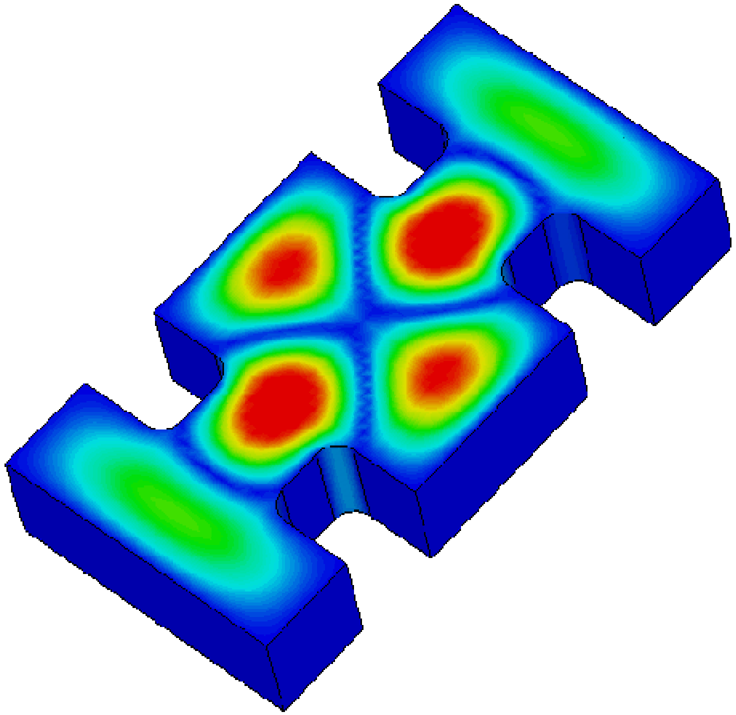


The frequency domain solver is very robust and can handle most applications.

Well suited applications: Narrowband, electrically small structures.

Limited computational resources make it necessary to use the time domain solver for electrically large structures.

!E – Eigenmode Solver

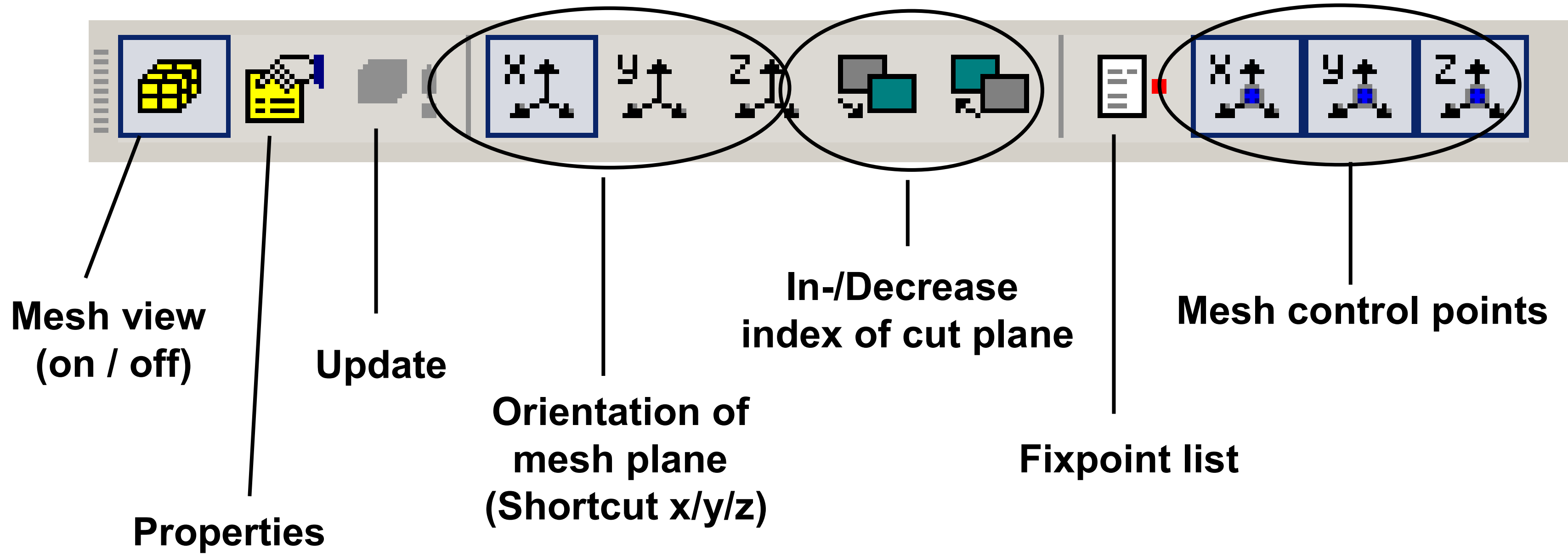


The eigenmode solver is a very specialized tool for closed cavities. No s-parameters are generated, only eigenmodes which are single frequency results.

Well suited applications: Narrow band, resonant cavities.

Meshing: The Basics

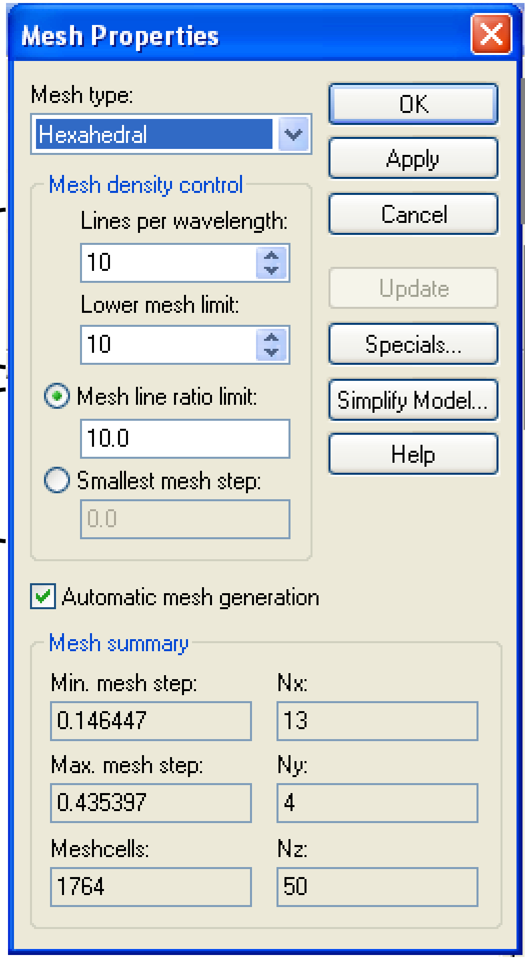
Mesh Generation



Global Mesh Properties- Hexahedral

Define size of the ***biggest*** mesh step

Limitation for the ***smallest*** mesh step



Lines Per Wavelength defines the minimum number of mesh lines in each coordinate direction based on the highest frequency of evaluation.

Lower Mesh Limit defines a minimum distance between two mesh lines for the mesh by dividing the diagonal of the smallest bounding box face by this number.

Ratio Limit defines ratio between the biggest and smallest distance between mesh lines. Increase for mesh quality when high aspect ratios exist, e.g. edge coupled microstrip.
Alternative to ratio limit, the **Smallest mesh step** can be entered directly as absolute value rather than defining it relatively via biggest mesh step and ratio limit.

Smallest mesh step determines simulation speed !

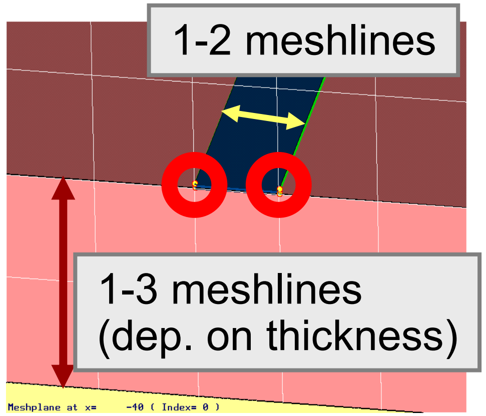
Required Initial Discretization

1) Microstrip + cpw

Required meshlines:

- **each straight PEC-edge (for each slot + stripline)**

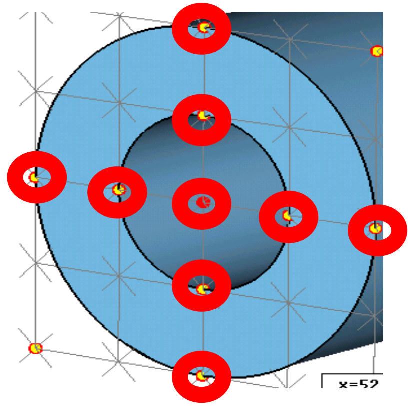
(metal thickness does not need 2 meshlines)



2) Coaxial

Required meshlines:

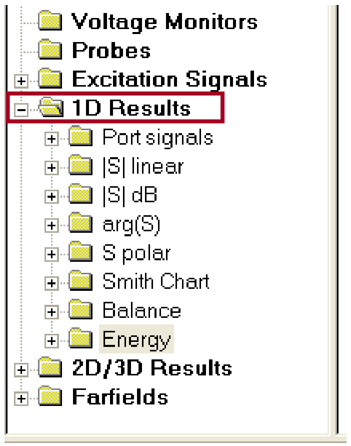
- **coax-center**
- **INNER radius of dielectric**
- **OUTER radius of dielectric**

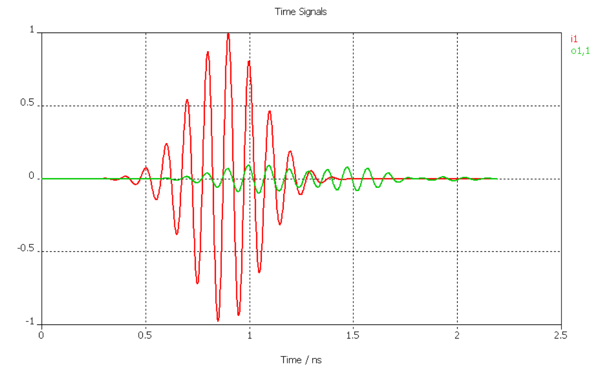


CST MWS - Standard workflow

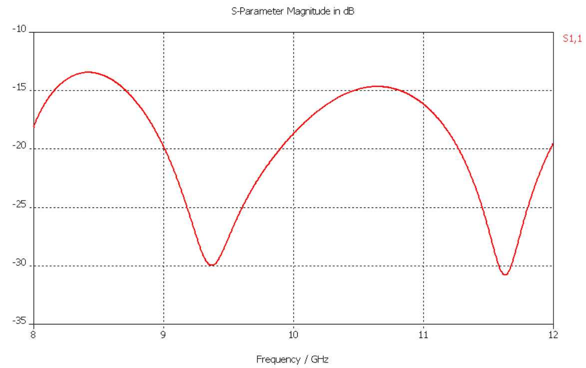
- Choose Project Template
- Parameters + Geometry + Materials
- Ports
- Frq-Range + Boundaries / Symmetries
- Monitor Definition
- Quick Check Meshing
- Run Simulation

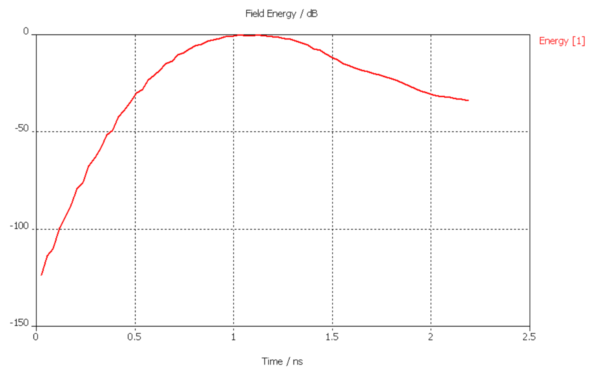
Analyze 1D Results





Port Signals

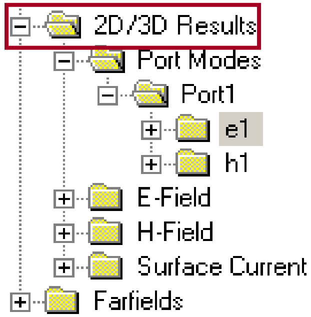


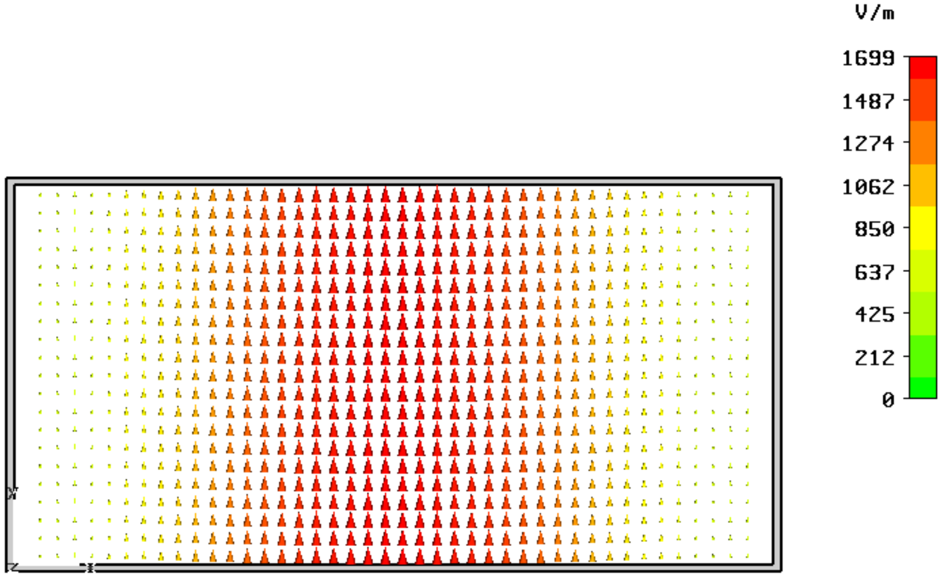


S Parameter

Energy

Analyze 2D/3D Results



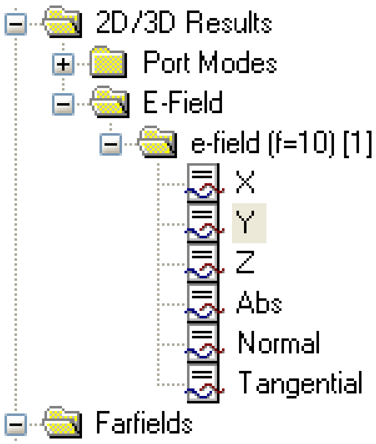


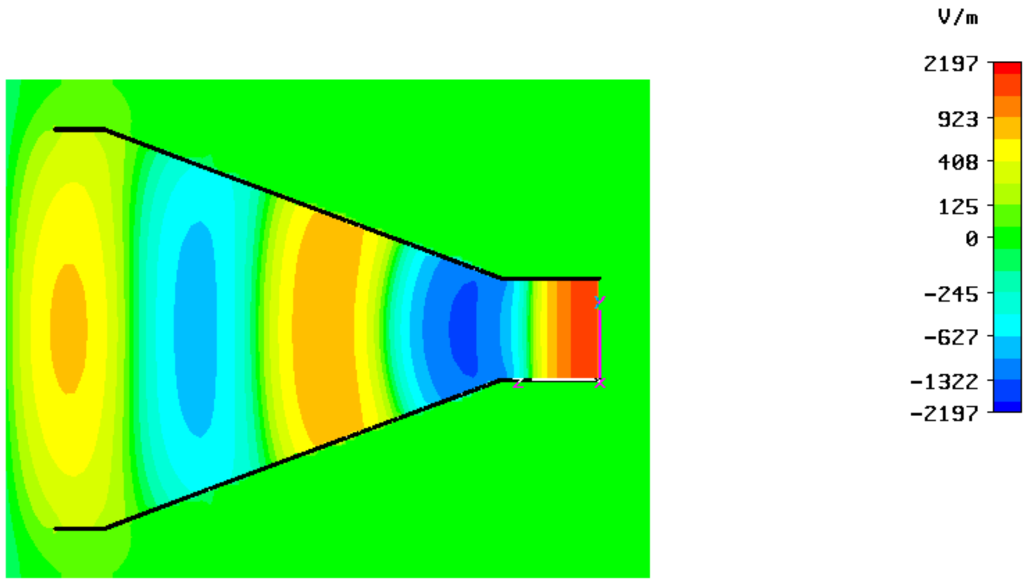

```
Type          = E-Field (peak)

Mode type     = TE
Accuracy      = 4.20634e-015
Fcutoff       = 5.87719
Beta          = 169.568 1/m
Wave Imp.     = 465.637 Ohms

Plane at z    = 0
Frequency     = 10
Phase         = 0 degrees
Maximum-2d    = 1699.1 V/m at 0.5 / 0.25 / 0
```

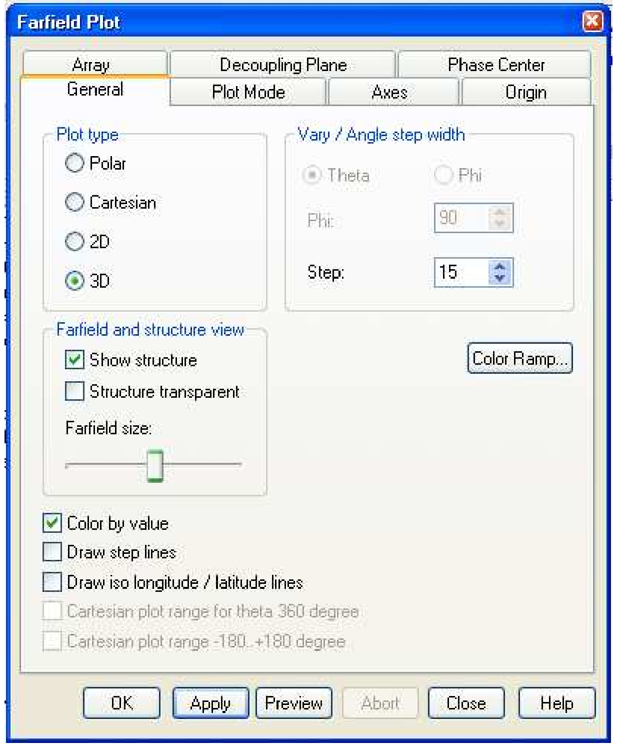
Electric Field @ 10GHz

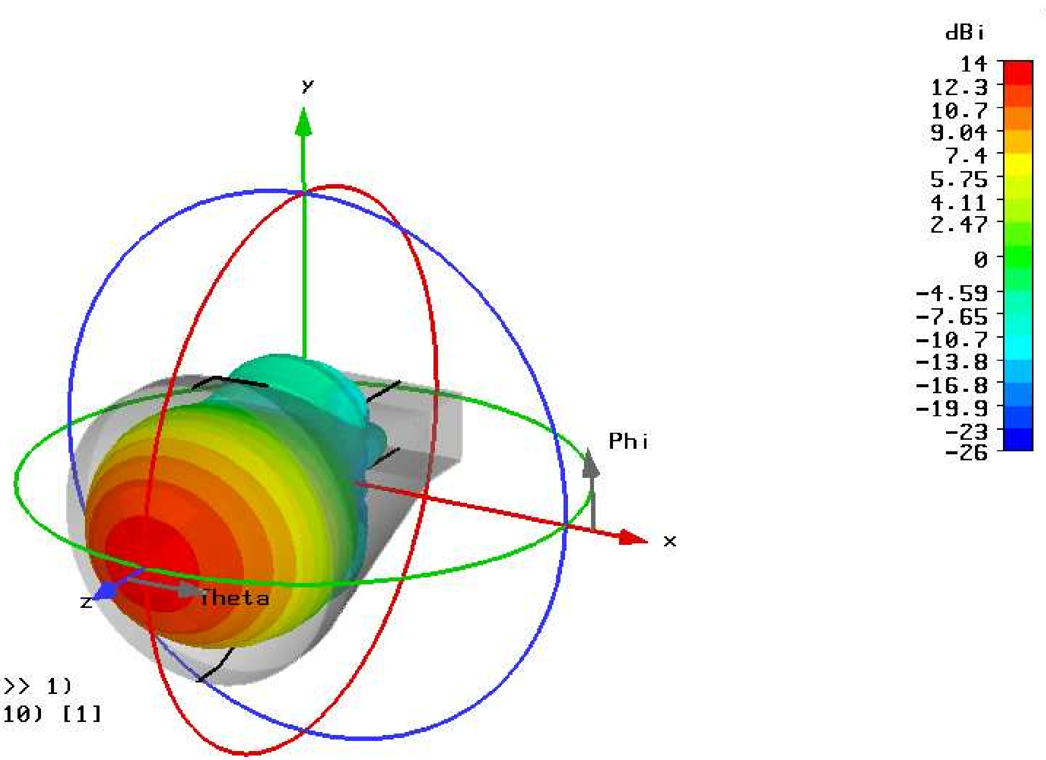





```
Type          = E-Field (peak)
Monitor       = e-field (f=10) [1]
Component     = y
Plane at x    = 0.5
Frequency     = 10
Phase         = 0 degrees
Maximum-2d    = 2197.5 V/m at 0.5 / 0.5 / 0.499522
```

Far Field @ 10GHz






```
Type          = Farfield
Approximation = enabled (kR >> 1)
Monitor       = farfield (f=10) [1]
Component     = Abs
Output        = Directivity
Frequency     = 10
Rad. effic.   = 0.9980
Tot. effic.   = 0.9959
Dir.          =  13.97 dBi
```

Copy / Paste of Result Curves

Signal plots and farfield curves can now be copied by using standard copy / paste