Wavenology EM™

Experience Hybrid Techniques

Manual of A New Full-Wave Transient Electromagnetic Field Simulator

Wave Computation Technologies, Inc.
www.wavenology.com
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Outline

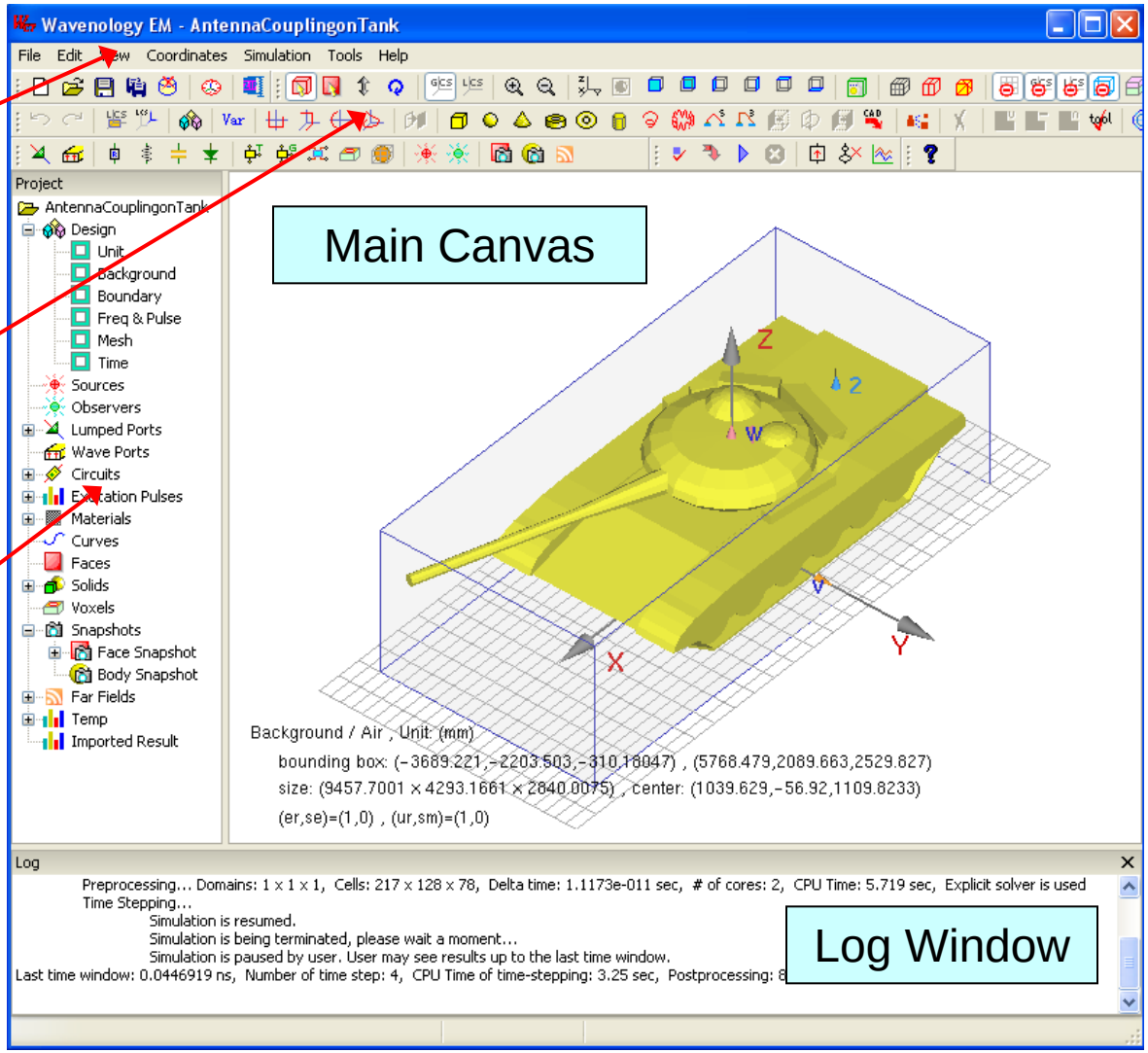
- Overview
- Simulation Setup
- Model Construction
- Result Exploration
- Additional Features
- Summary

Integrated Design Environment

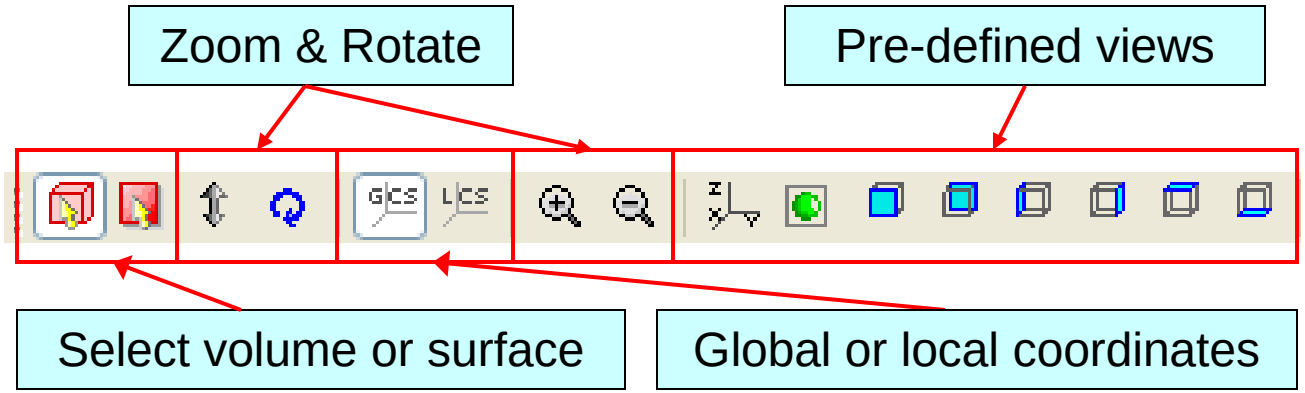
Main Menu

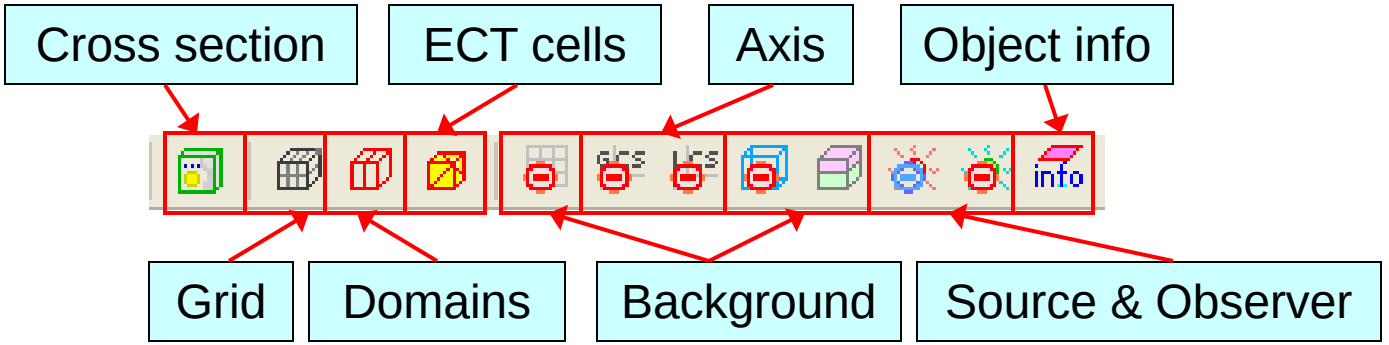
Tool Bars

Project Tree



View Tool Bars





Simulation Setup

- Design
  - Unit
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  - Freq & Pulse
  - Mesh
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    - E / M Polarized Plane Waves
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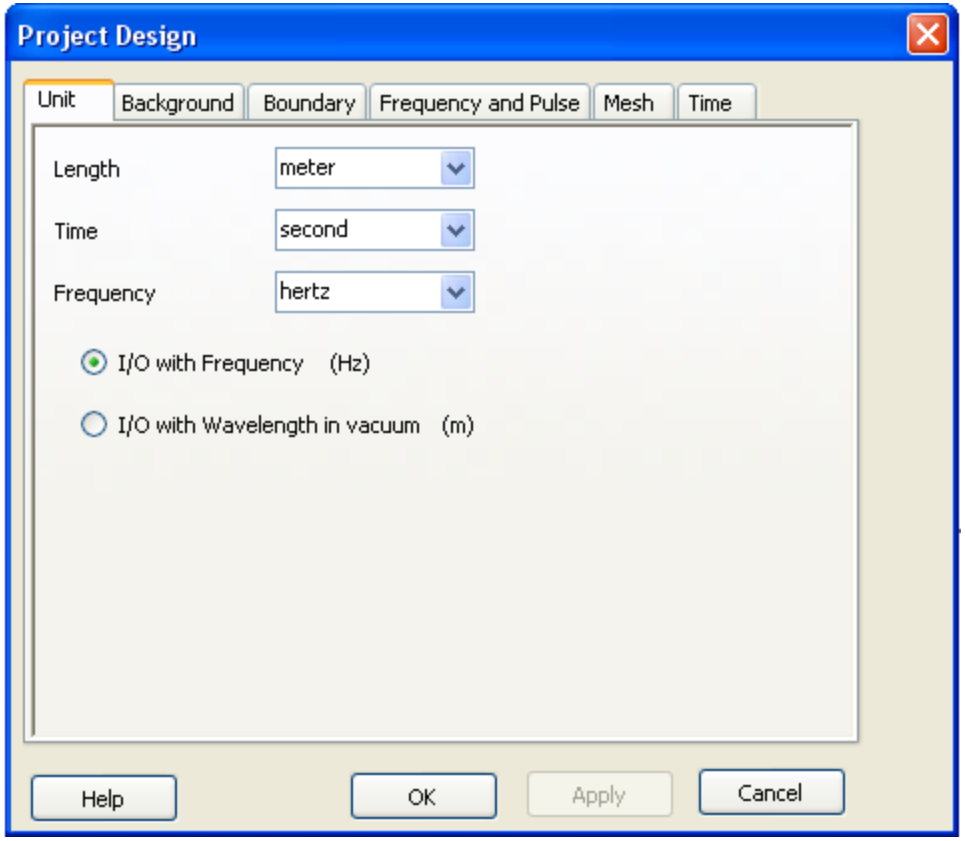
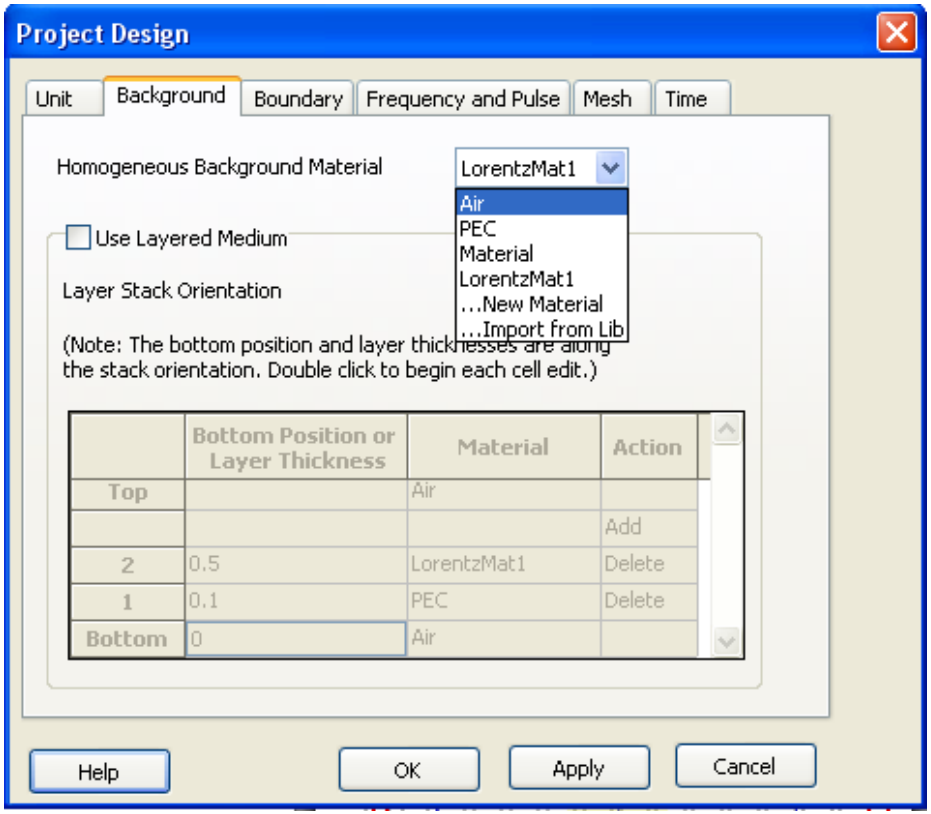
  - PMC
  - Air
  - Dielectric
  - Dispersive
  - Conducting
  - Lossy
  - Inhomogeneous (voxel)
  - (Anisotropic)

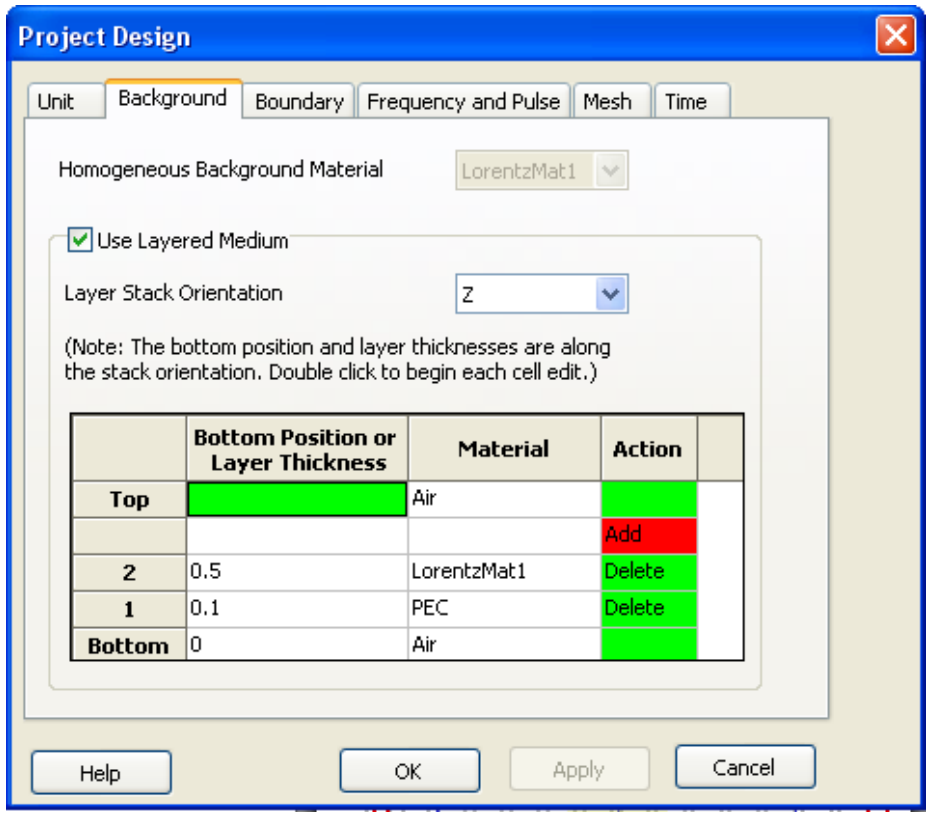
Design - Unit



- I/O with Frequency
  - Determine the bandwidth of the simulation through frequency range
- I/O with Wavelength in vacuum
  - Determine the bandwidth of the simulation through freespace wavelength range

Design – Background

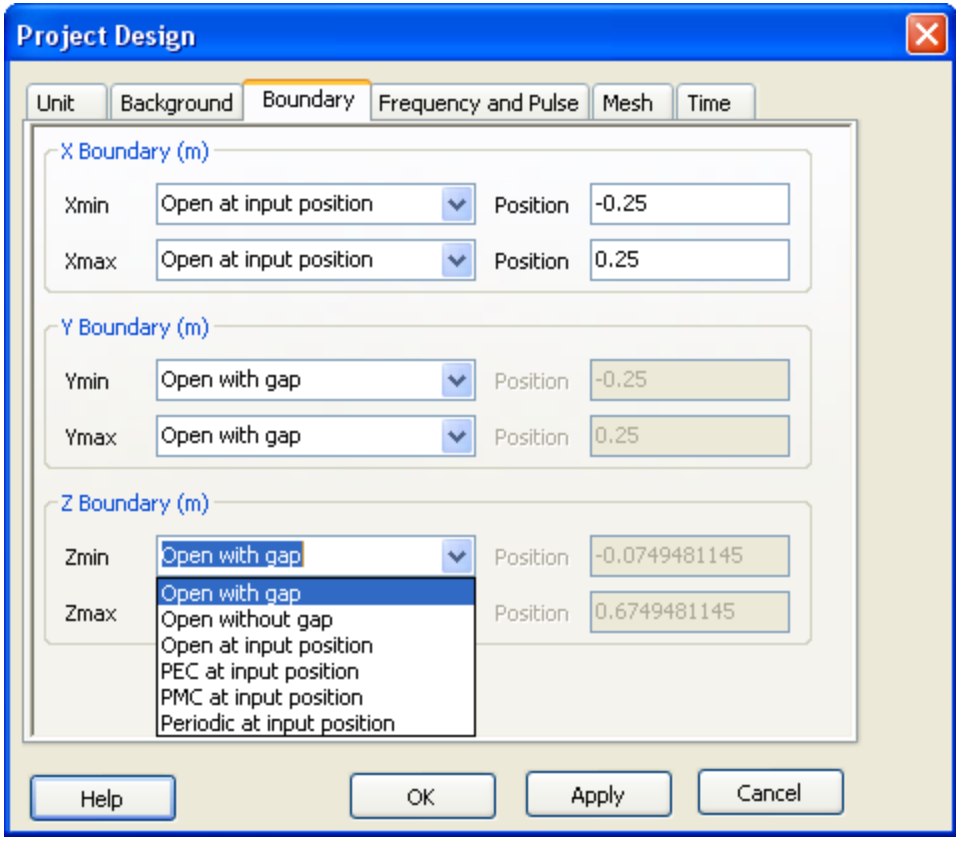




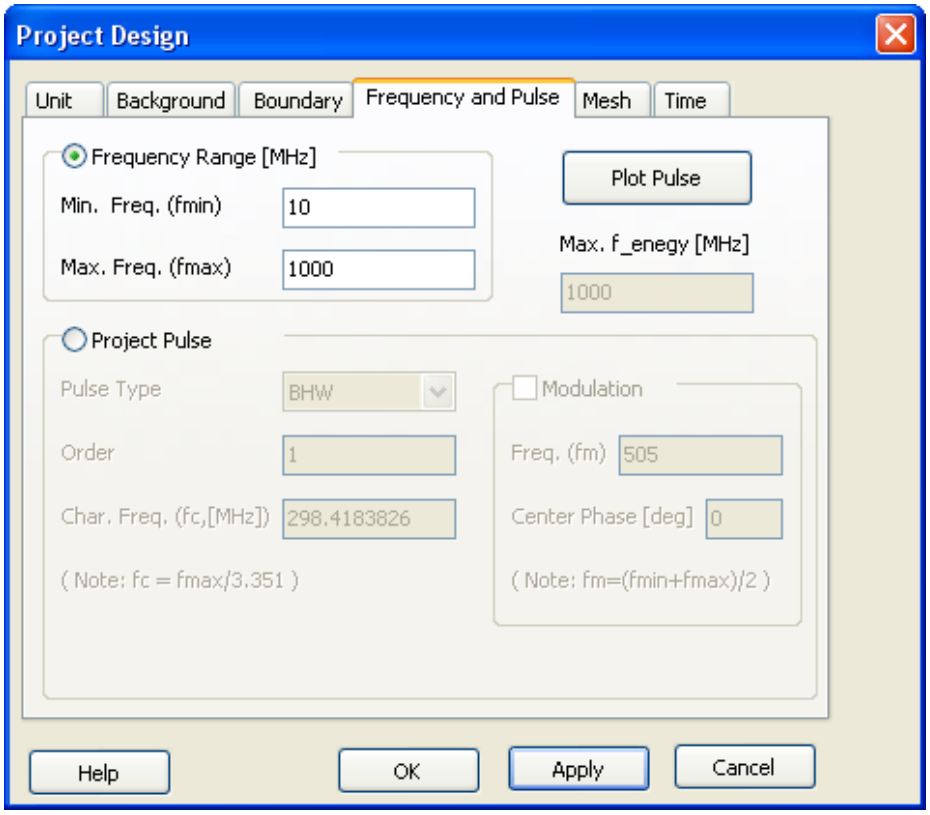
- Support both homogeneous and layered medium as background
- Both user defined and pre-defined material library can be applied

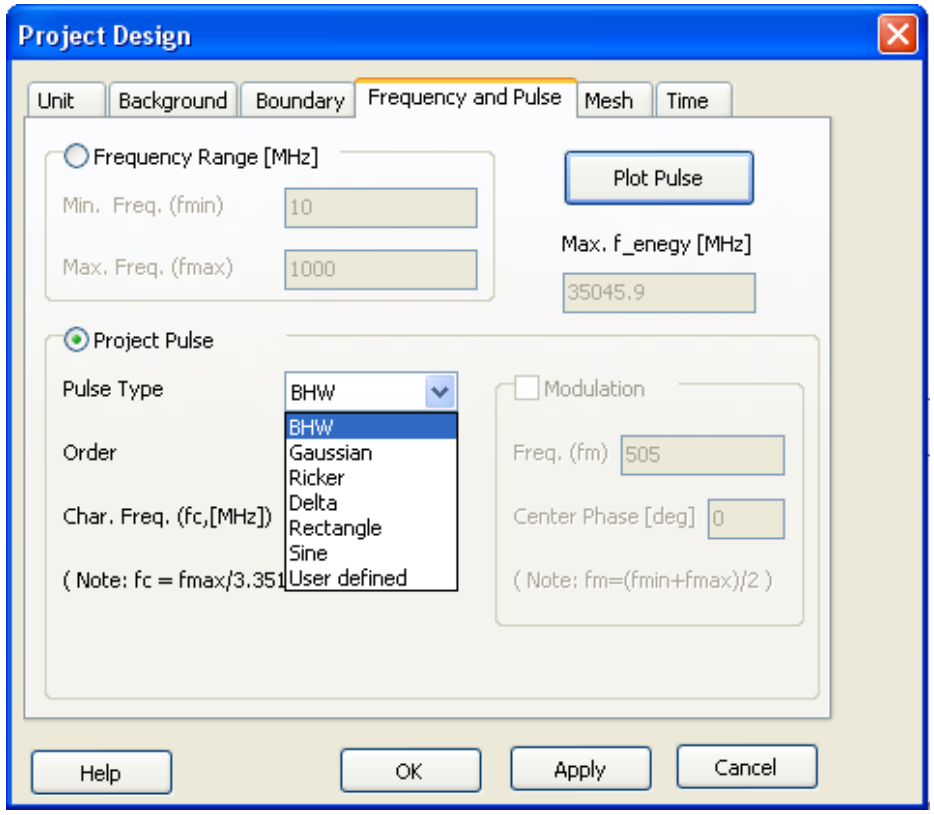
Design – Boundary

- PEC, PMC
- Open
- Periodic



Design – Frequency & Pulse

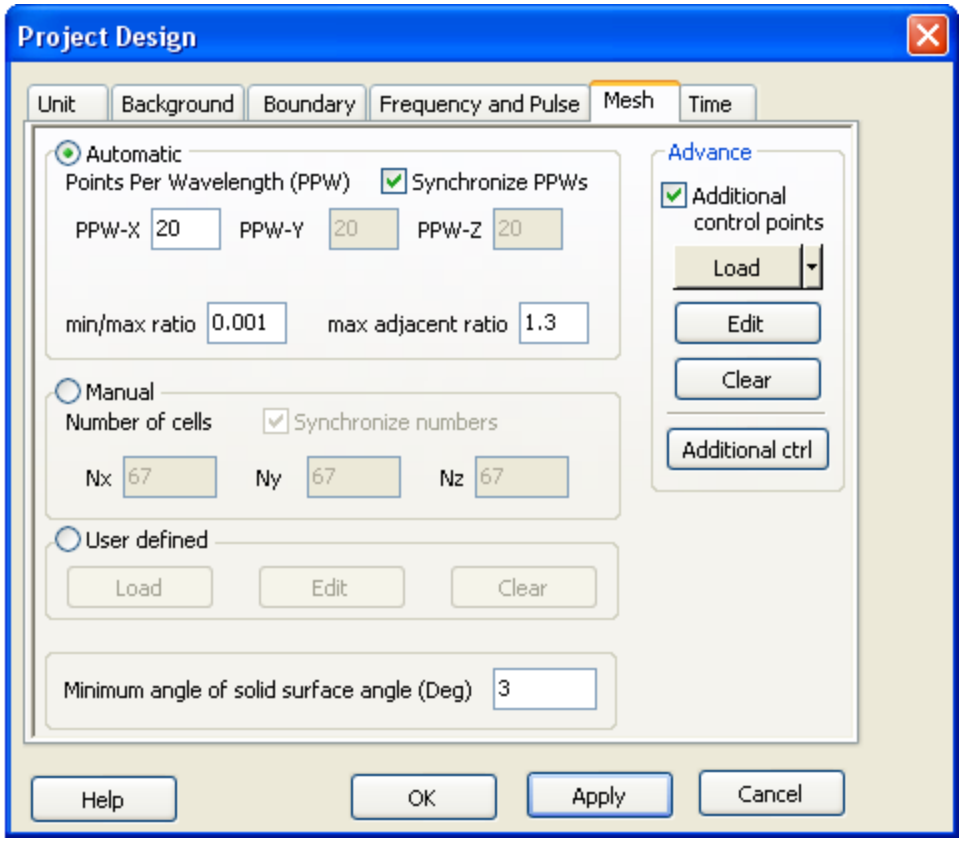




- When specify a frequency range the default wideband source will be applied
- User can also select his/her own project pulse
- Click the “Plot Pulse” button will show the time-domain signal of the source

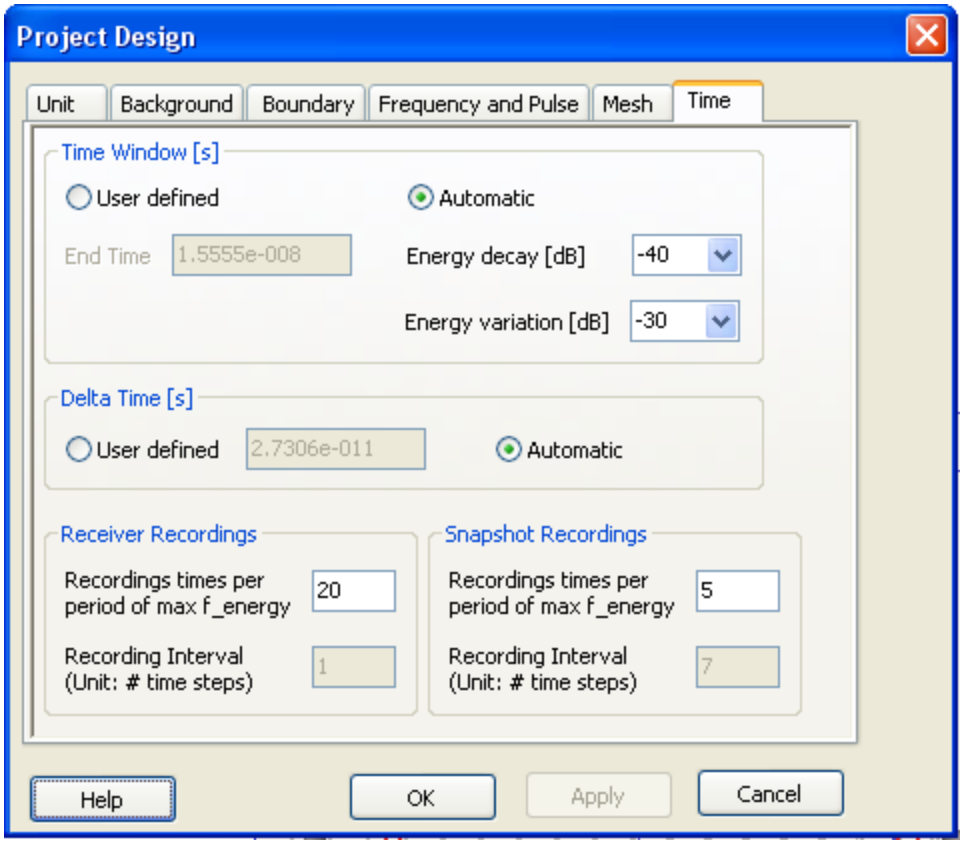
Design – Mesh

- Automatic
  - User only need to specify the points per wavelength (PPW). Everything else will be automatically determined
  - User can also further control the automatic mesh by customizing the min/max cell ratio and max adjacent cell ratio
  - Additional control points can be added to the automatic mesh as well
- Manual
  - User can also manually control the mesh density along each dimension
- User defined
  - A fully customized mesh can also be defined by the user with a mesh point file

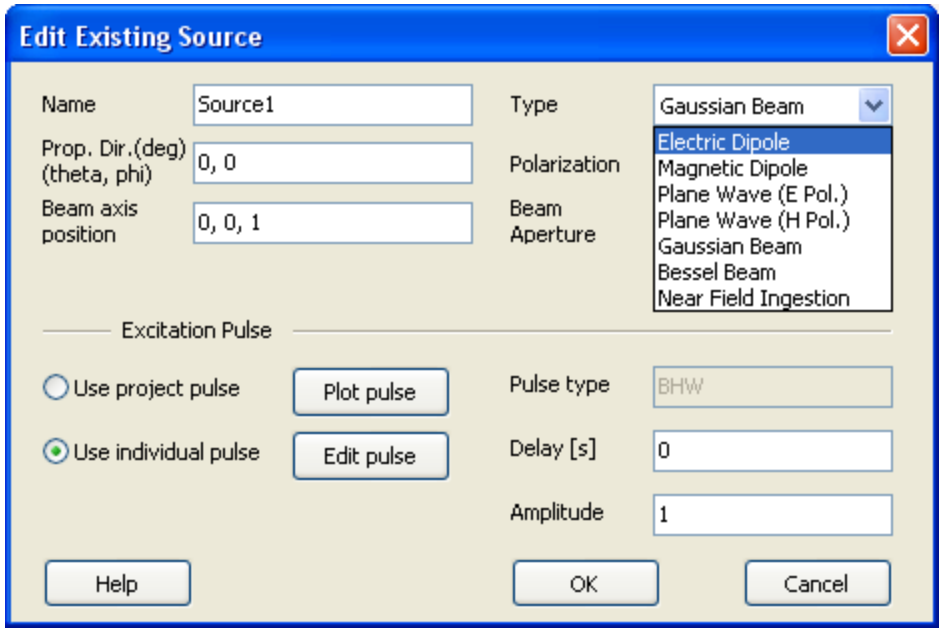


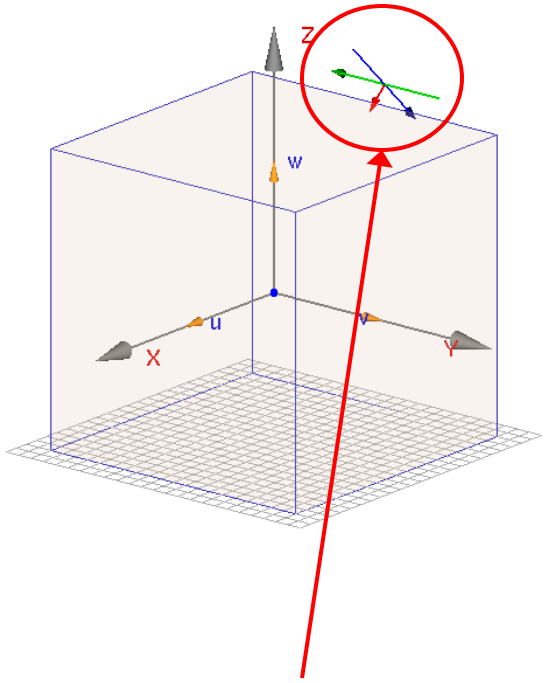
Design – Time

- Time Window
  - Controls the simulation time
  - User defined time window will force the simulator stop at the time barrier specified by the user
  - Automatic will estimate the energy decay and variation level, the simulation will stop when the specified threshold is reached. (Carefully used for high-Q system)
- Delta Time
  - Time step for the simulation
- Recording Intervals
  - Allow the user to control the recording intervals of the solution
  - This will impact the resolution of the displayed result



Sources – Types

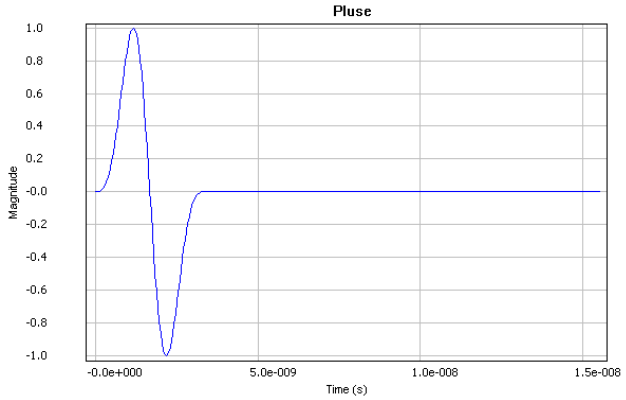




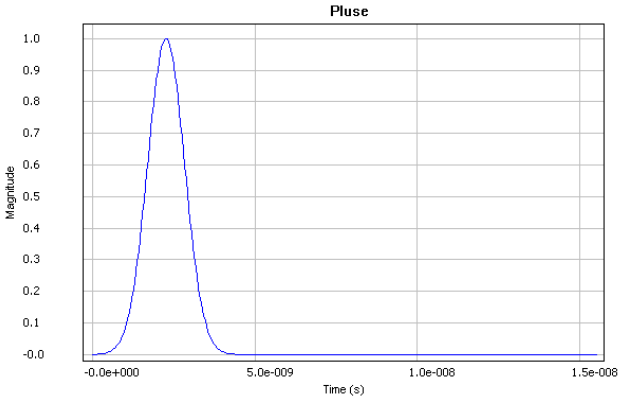
- Dipole
- Plane Wave
- Beams
- Near Field Ingestion

- For plane wave and beams, an indicator will be displayed of its propagation and polarized directions

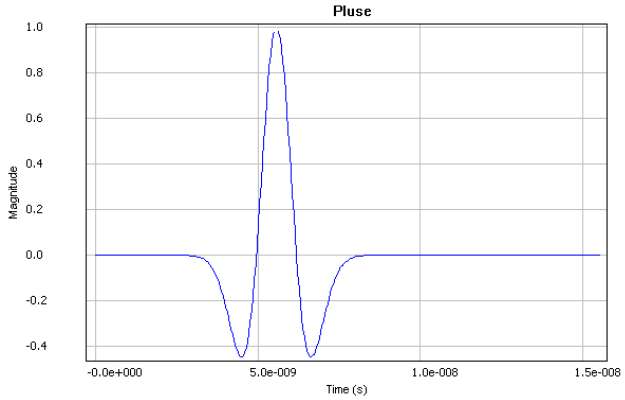
Sources – Time Domain Signatures



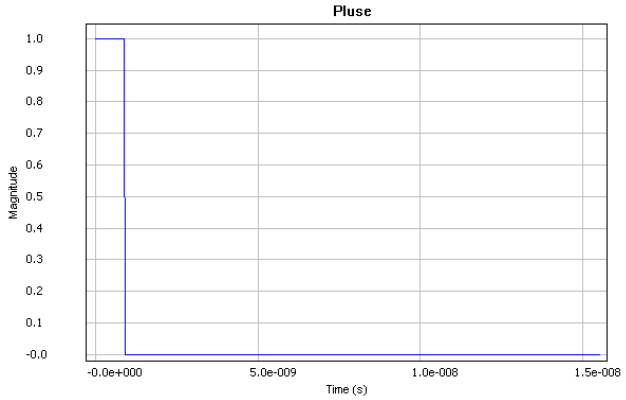
BHW



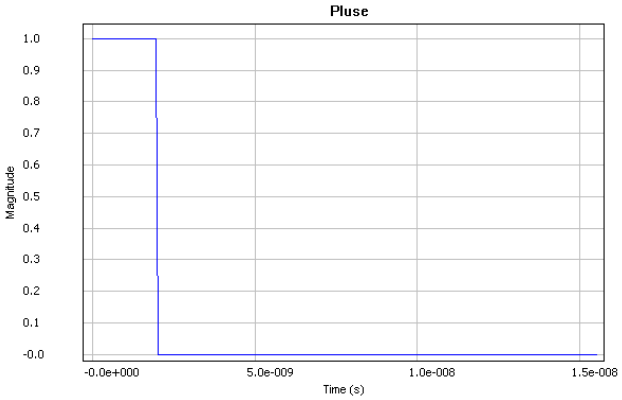
Gaussian



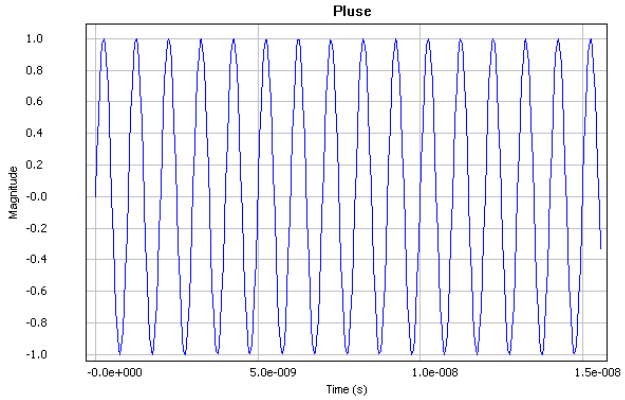
Ricker



Delta

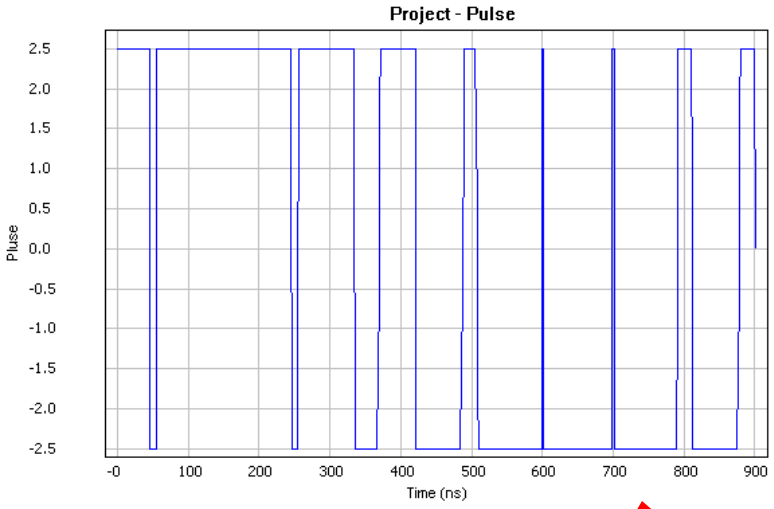


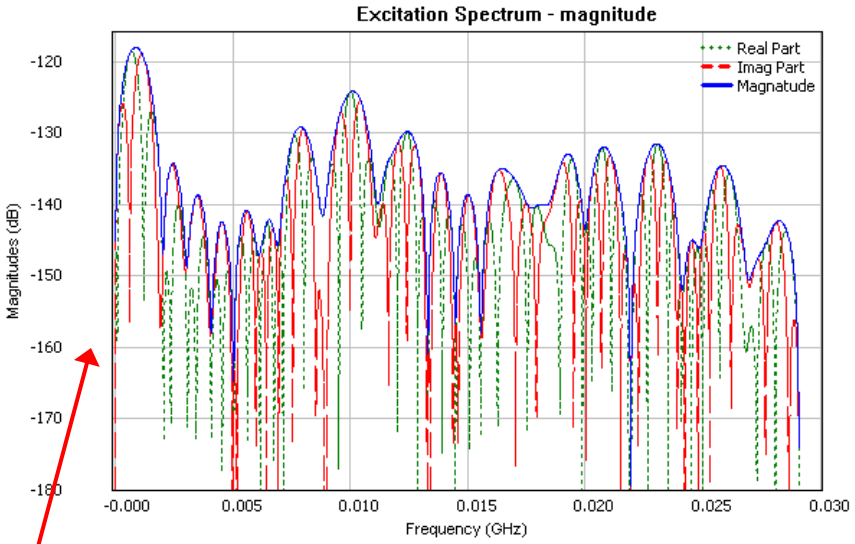
Rectangle



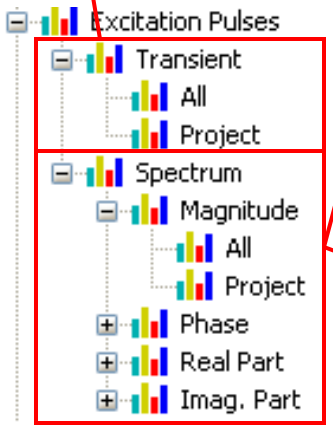
Sinusoid

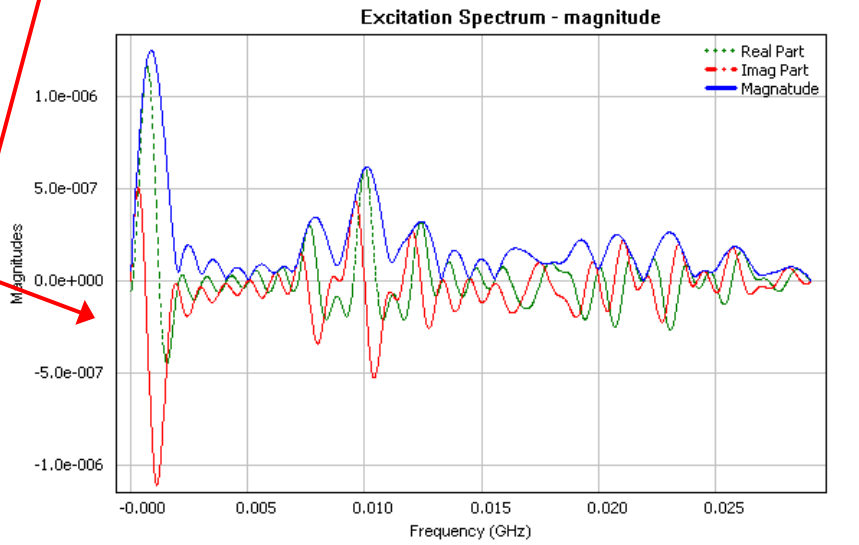
Sources – User Defined Pulses





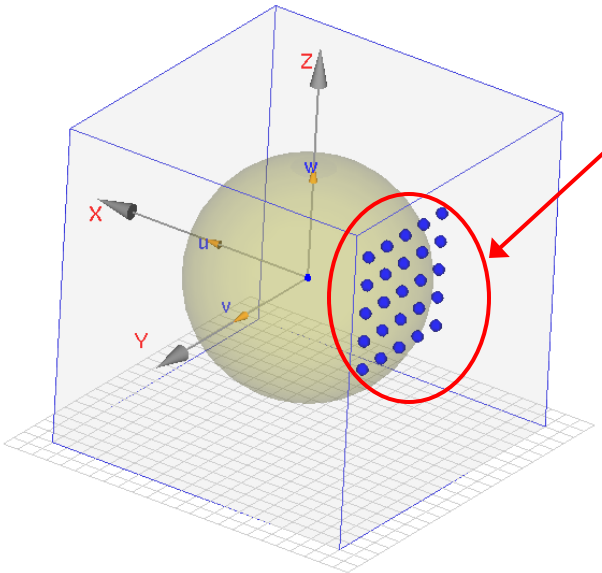
- User can provide a fully customized time domain signal and load it into Wavenology EM
- Automatic interpellation and re-sampling will be performed
- The spectrum of the user defined signal will be automatically performed

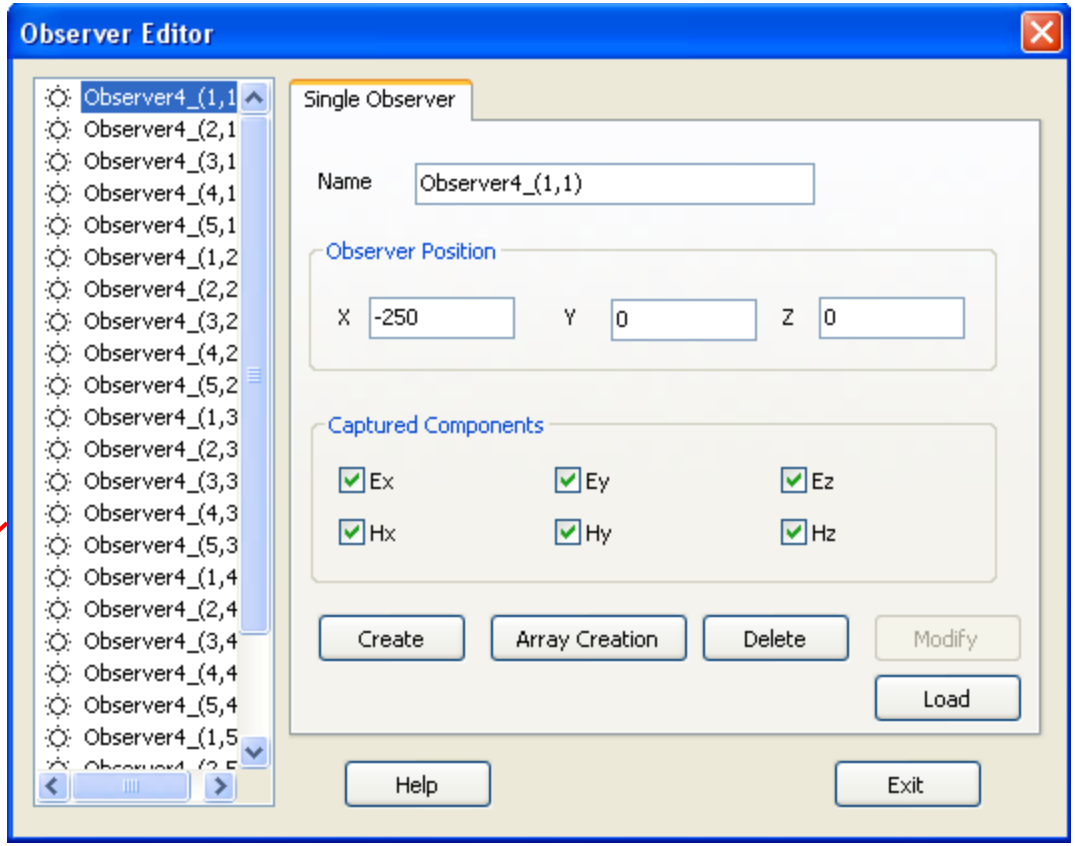




Observers

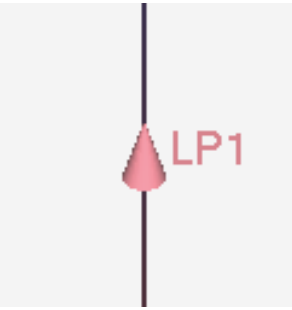
- Field components can be selected based on user's interest
- Array Creation is supported
- Fully customized observer position can be loaded from a external file

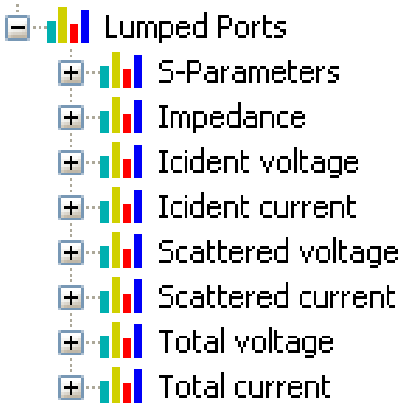


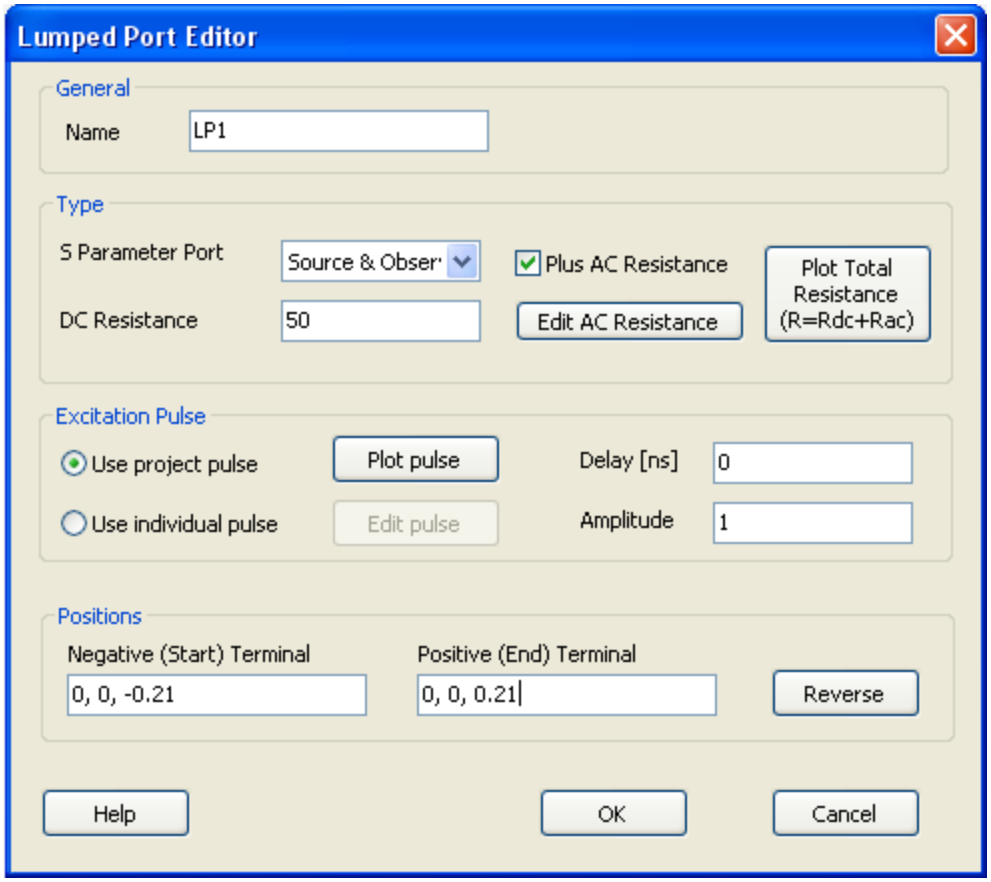


Ports – Lumped Ports

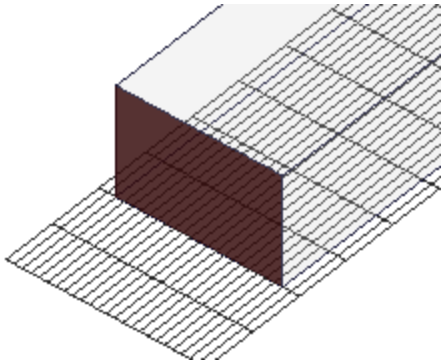
- Can be used as source and/or observer
- S-parameters, impedance, incident voltage/current, scattered voltage/current and total voltage/current will be automatically calculated after the simulation

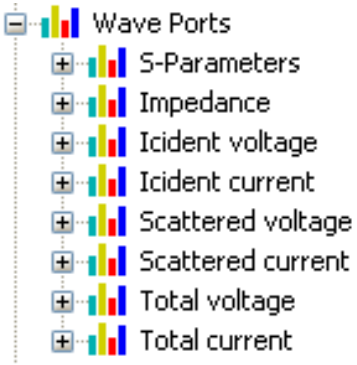


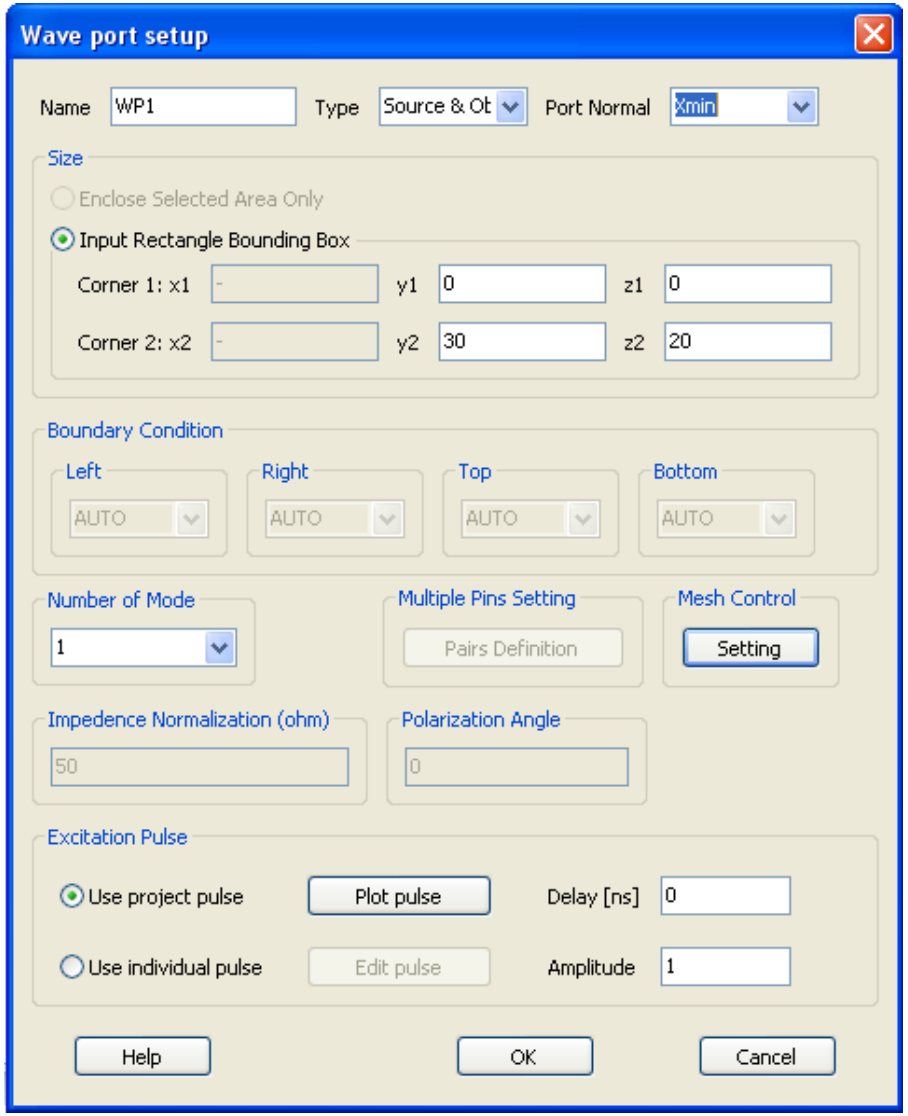




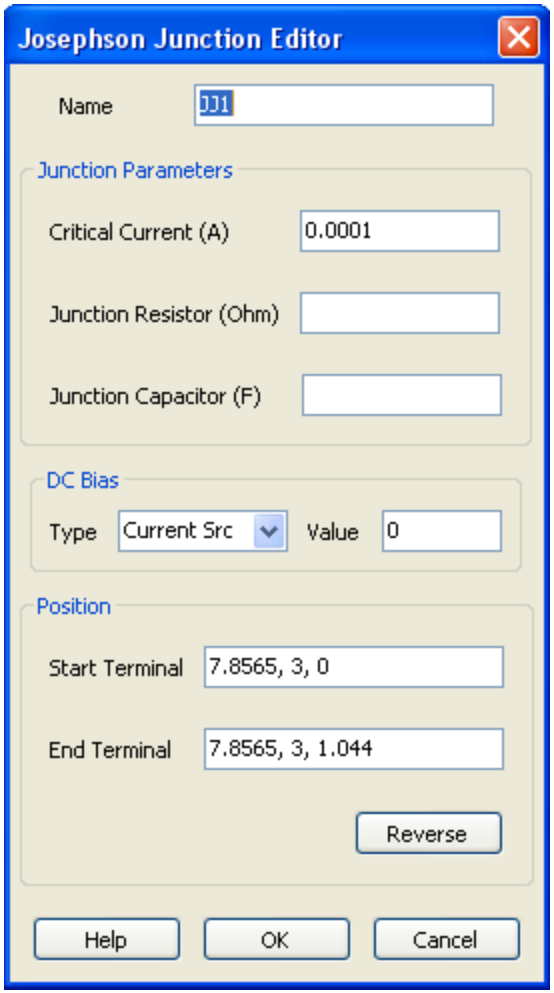
Ports – Wave Ports

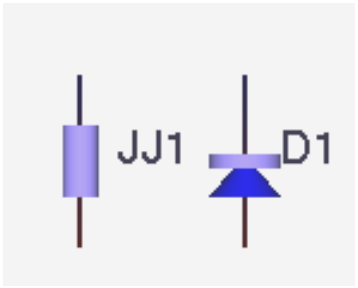




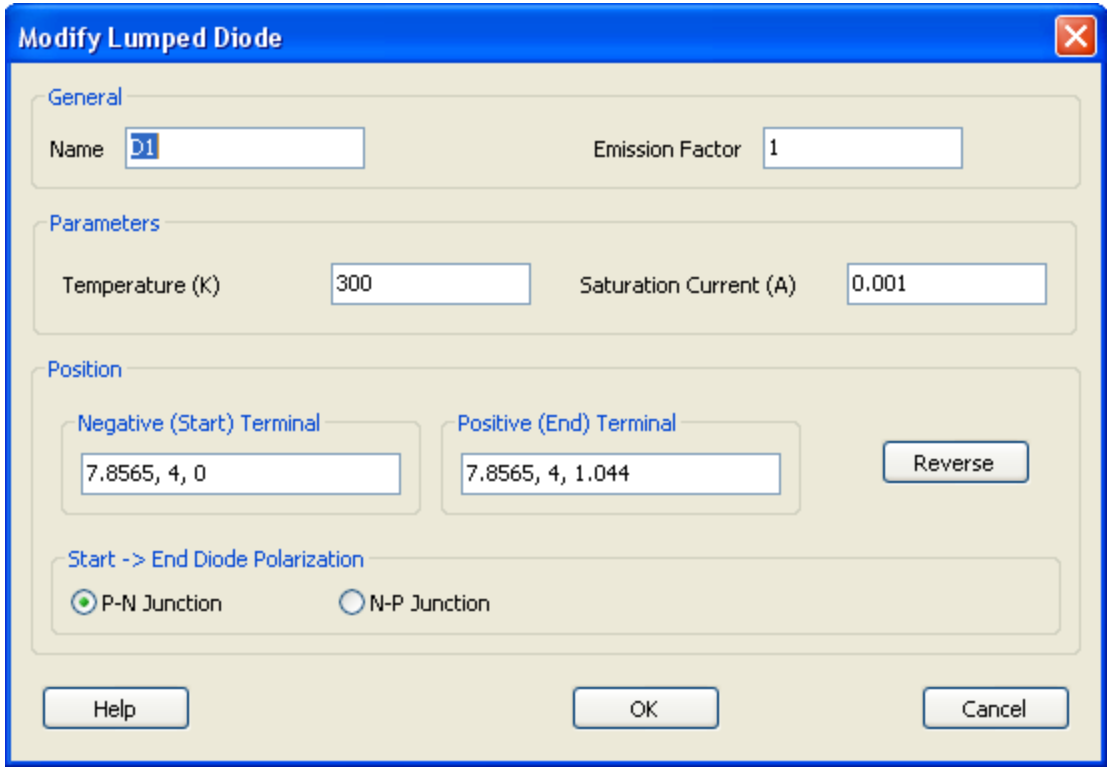


Circuits – Josephson Junction & Diode

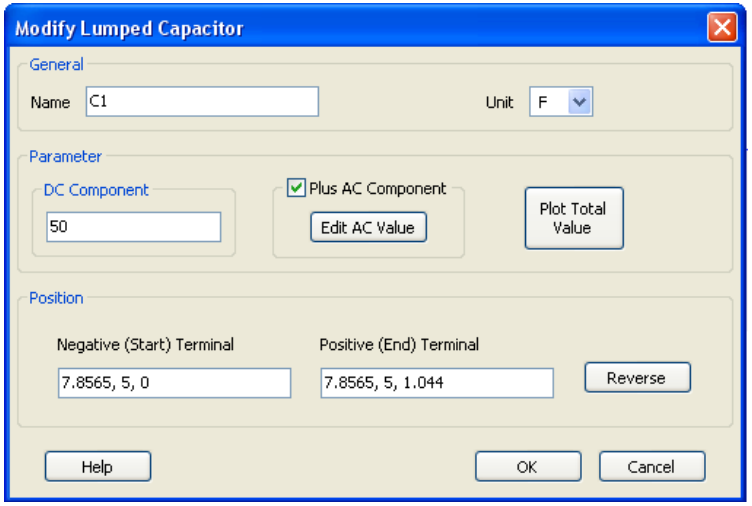




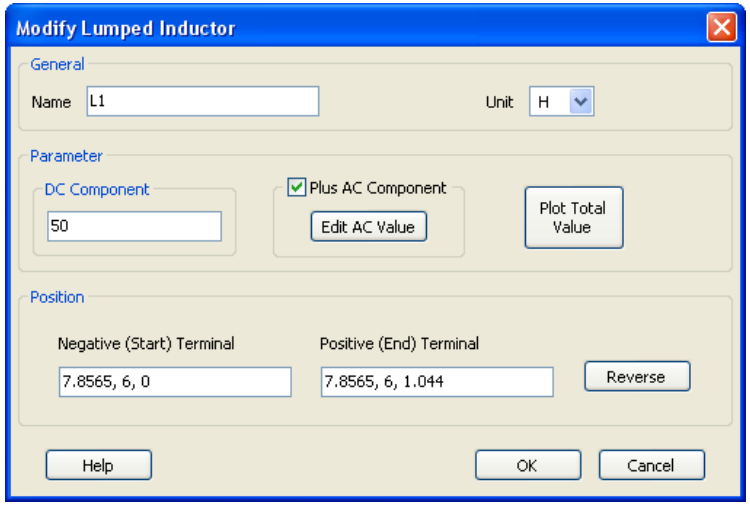
Definition of internal Josephson Junction and Diode

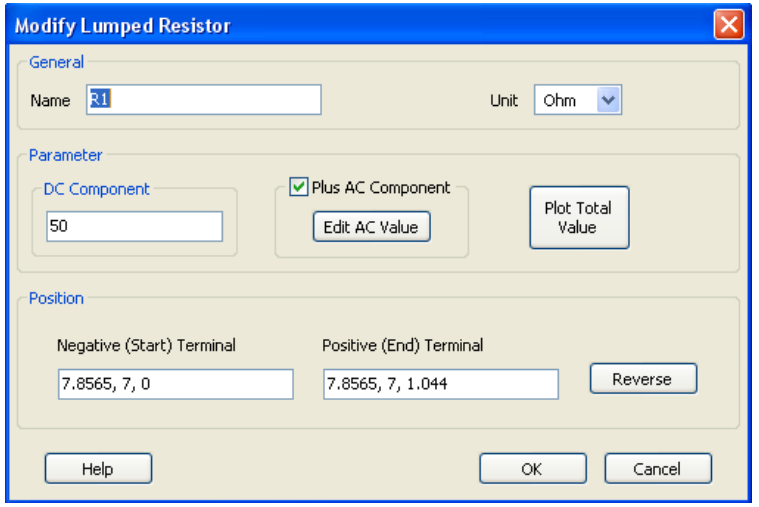


Circuits – R, L, C

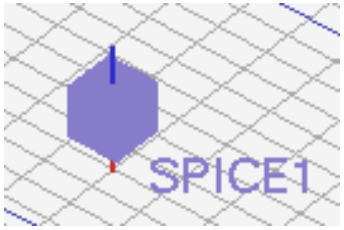


Definition of internal capacitor, inductor and resistor

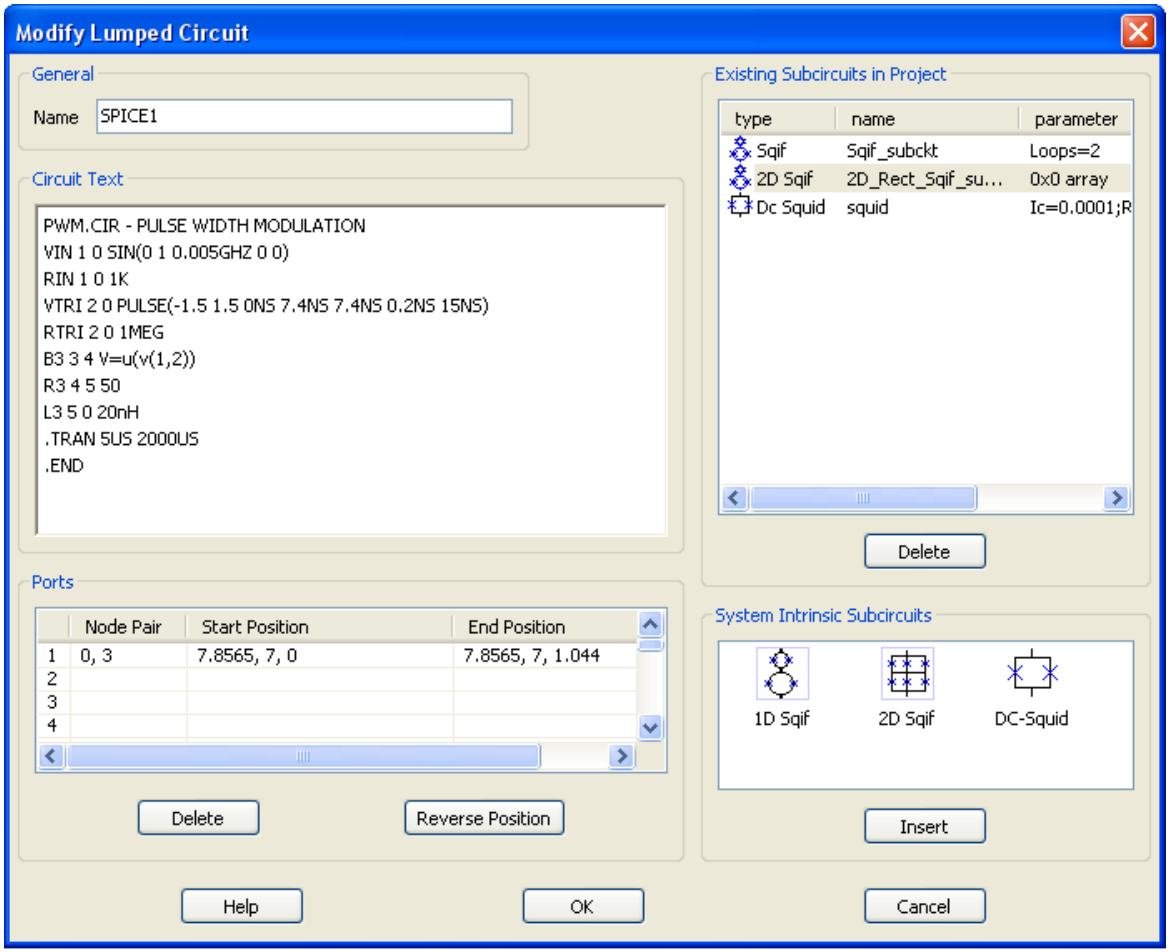




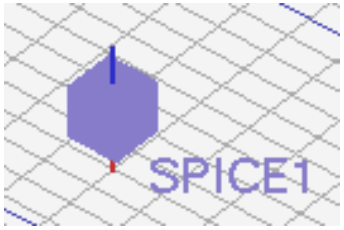
Circuits – SPICE (1)



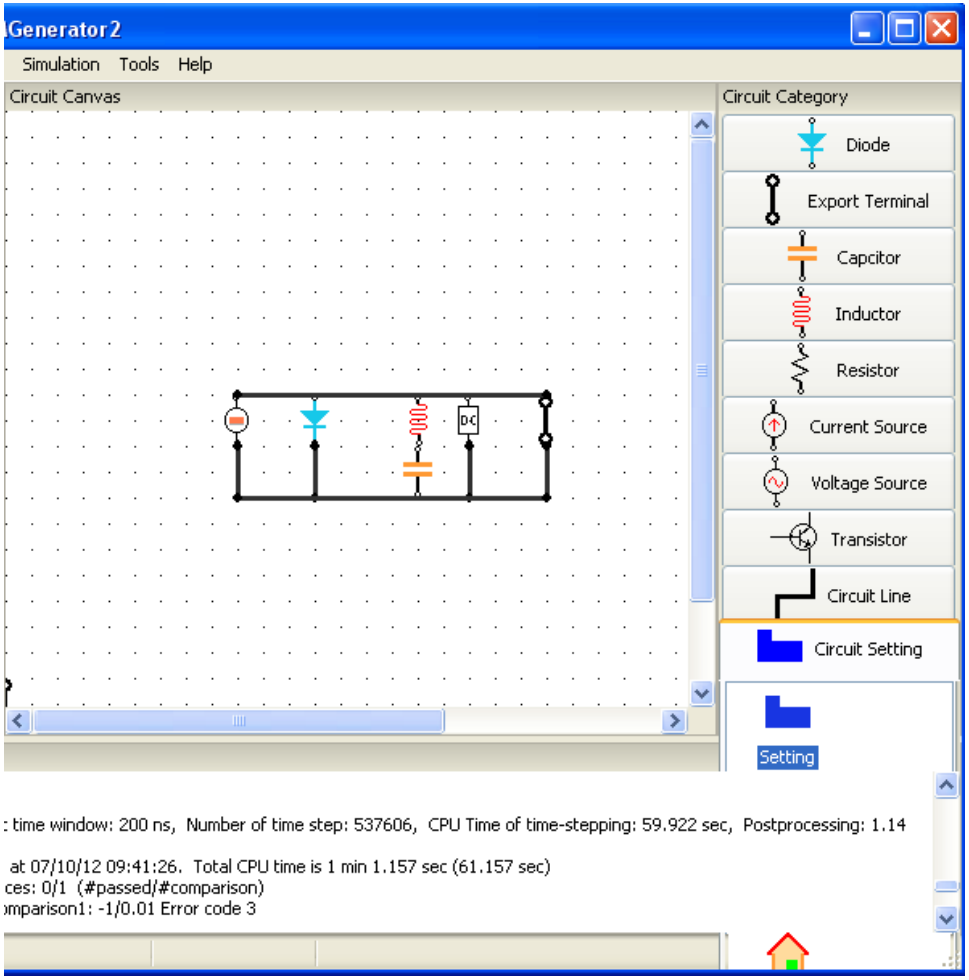
- SPICE circuits can be defined through standard SPICE netlist file
- The port that communicate with the EM solver must be defined if the circuit is co-simulated together with other components
- Sub-circuits are supported
- Intrinsic quantum circuit elements such as 1D and 2D SQIF and DC SQUID



Circuits – SPICE (2)

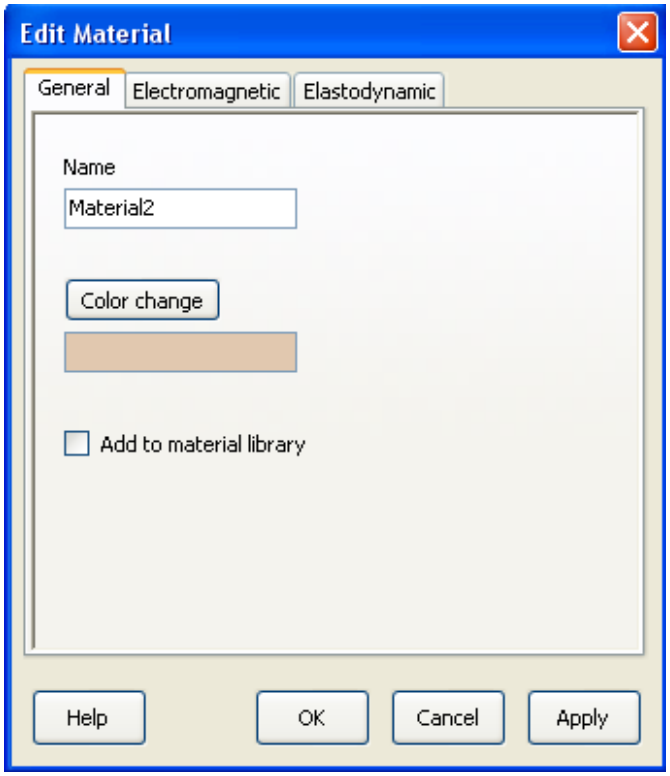


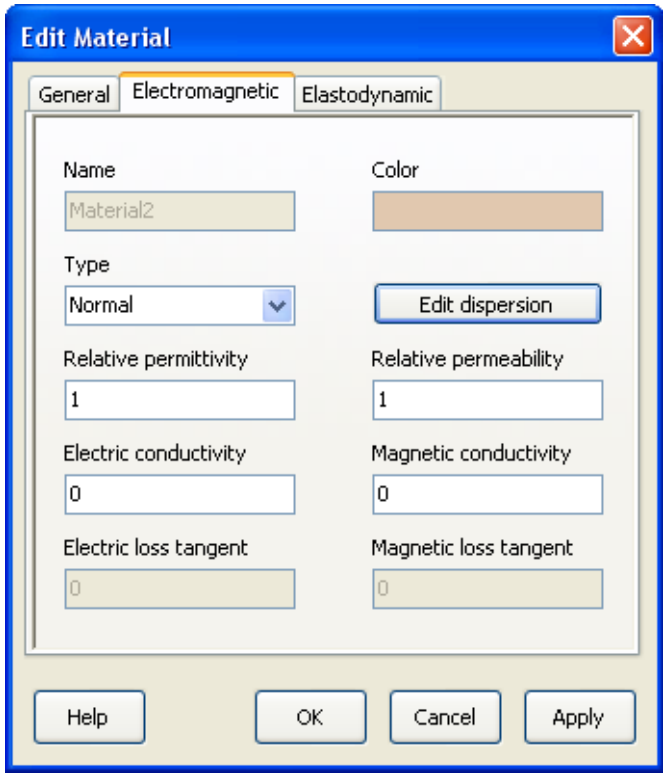
- SPICE circuits can also be defined through a GUI
- User can draw their circuits instead of using circuit definition files



Materials – User Defined

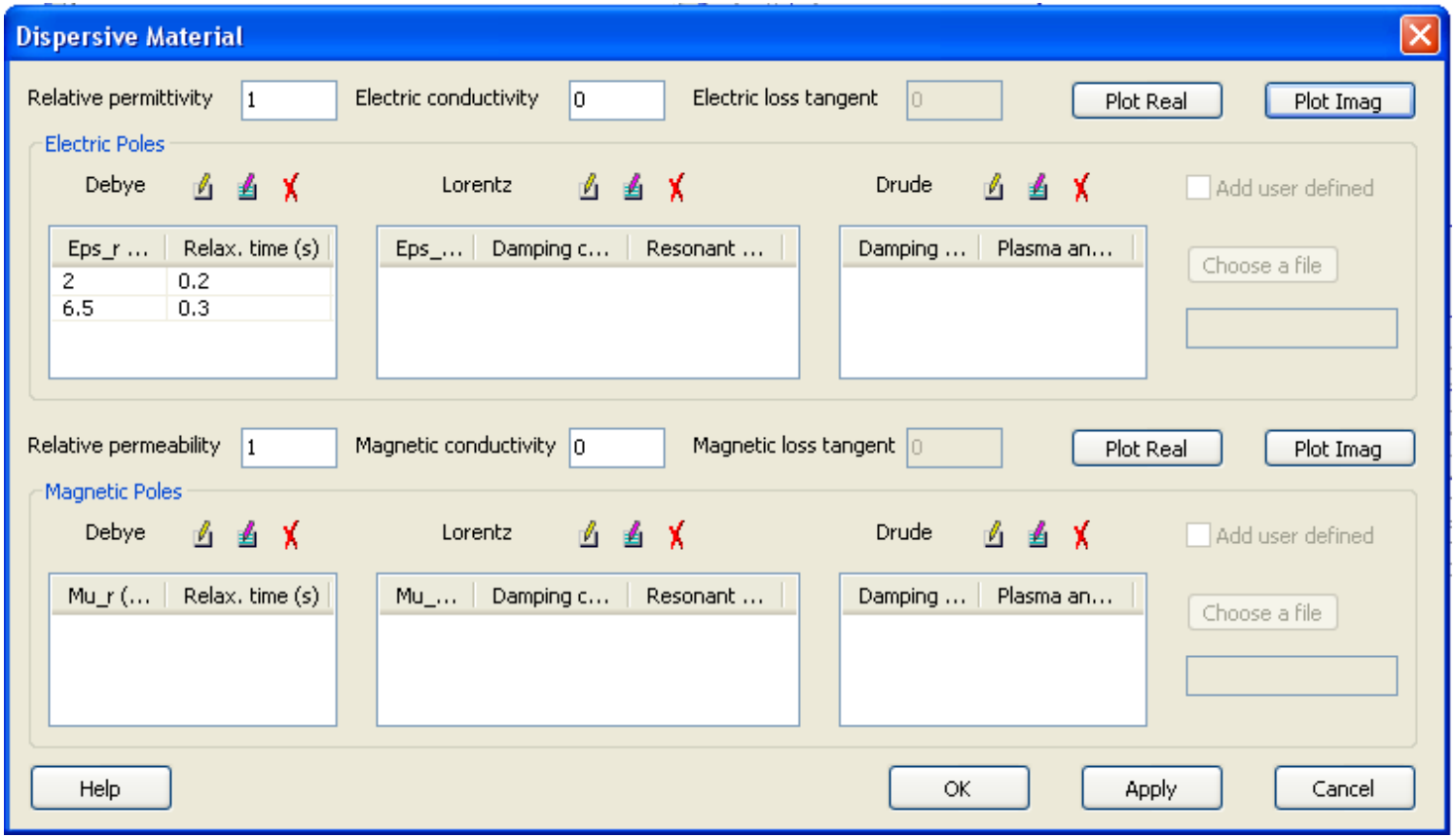
- Material types
  - Normal
  - PEC / PMC
  - Conductor
  - Dispersive





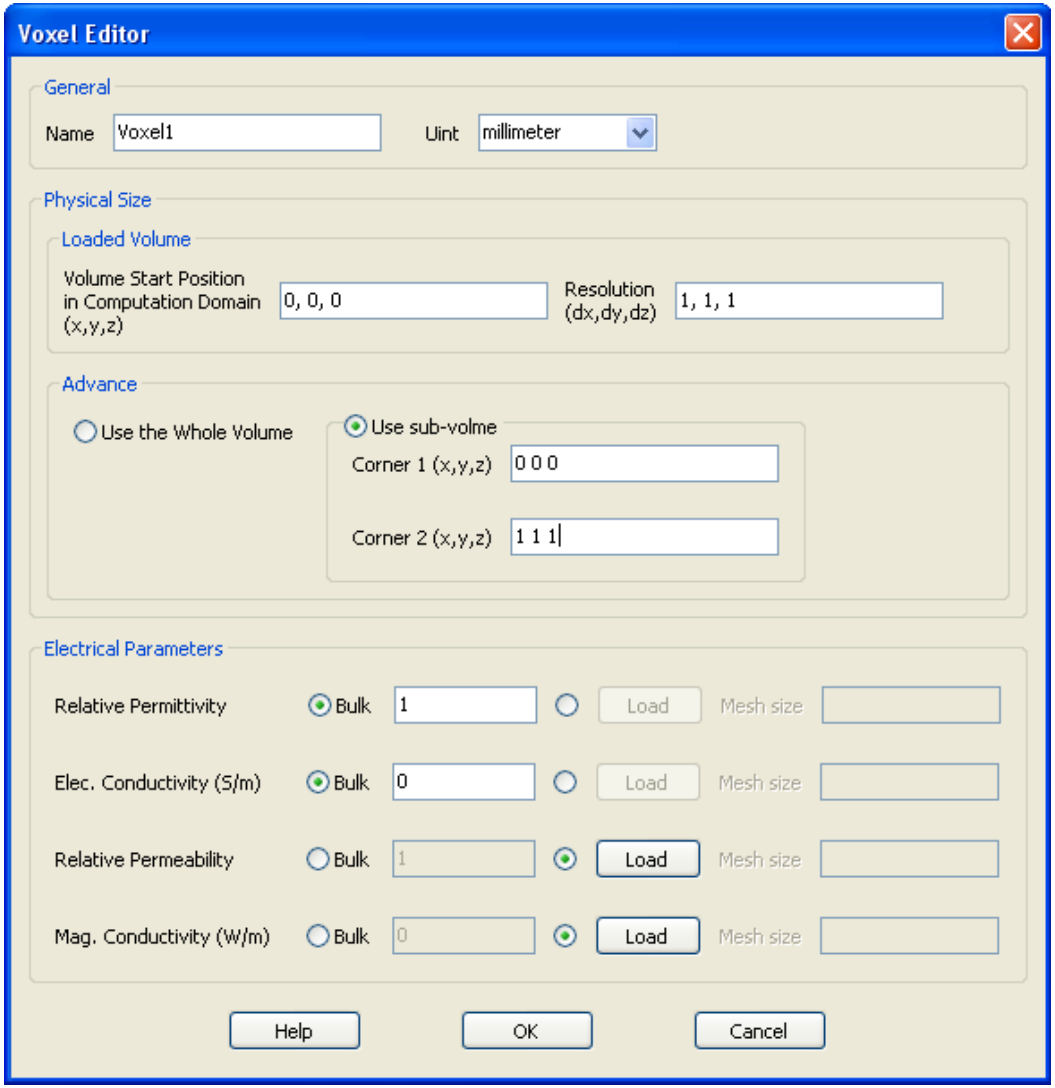
Materials – Dispersive

- Debye, Lorentz and Drude



Materials – Voxel

- Voxel definition is also supported
- Either entire volume or sub-volume can be specified with voxel definitions
- The material properties can either be specified or loaded from the external file

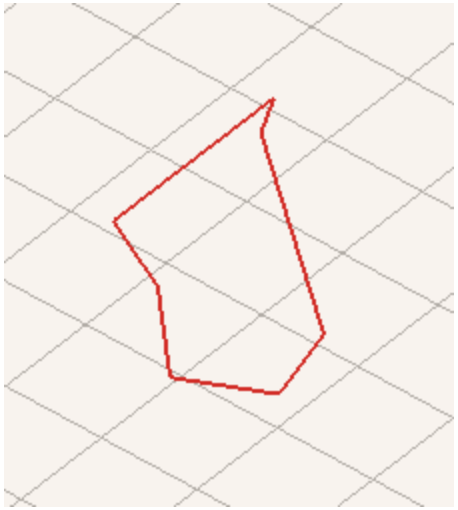


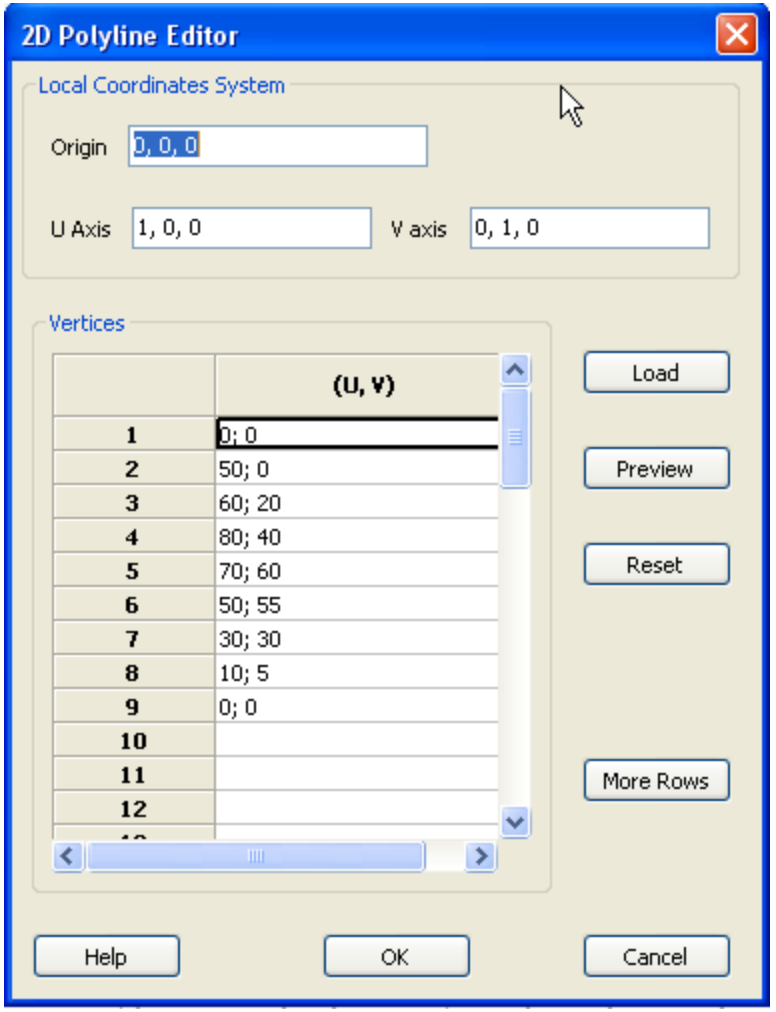
Model Construction

- Define Geometries
  - Curves
    - 2D Poly Line & Parametric Curve
    - 3D Poly Line & Parametric Curve
  - Faces
    - Cover Curve as Face
  - Solids
    - Box
    - Ellipsoid
    - Cone
    - Elliptical Cylinder
    - Polygon Cylinder
    - Torus
    - Archimedean Spiral
    - Toroidal Spiral
    - Spine Line Bondwire
    - JEDEC 3 Pints Bondwire
    - Body by Sweeping Face along Curve or Axis
    - Body by Lofting Face
  - Import from CAD Models
- Operations on Geometries
  - Union
  - Subtract
  - Intersect
  - Disassemble
  - Array Copy
  - Translate
  - Mirror
  - Rotate
  - Scale

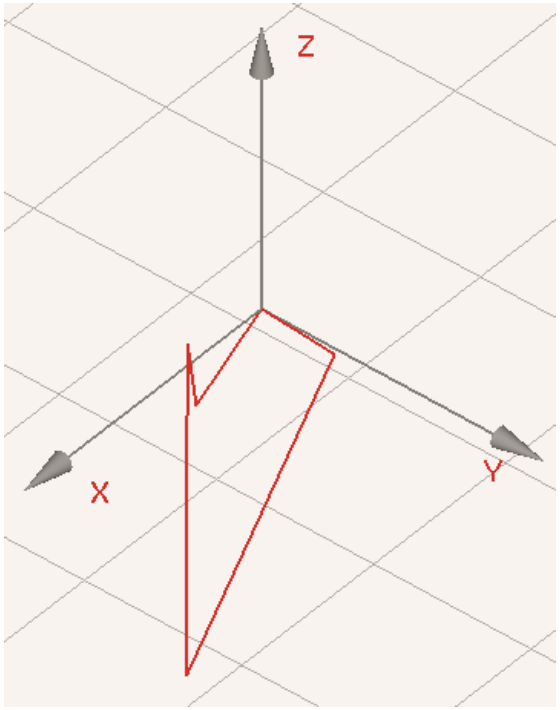
Curves – 2D Poly Line

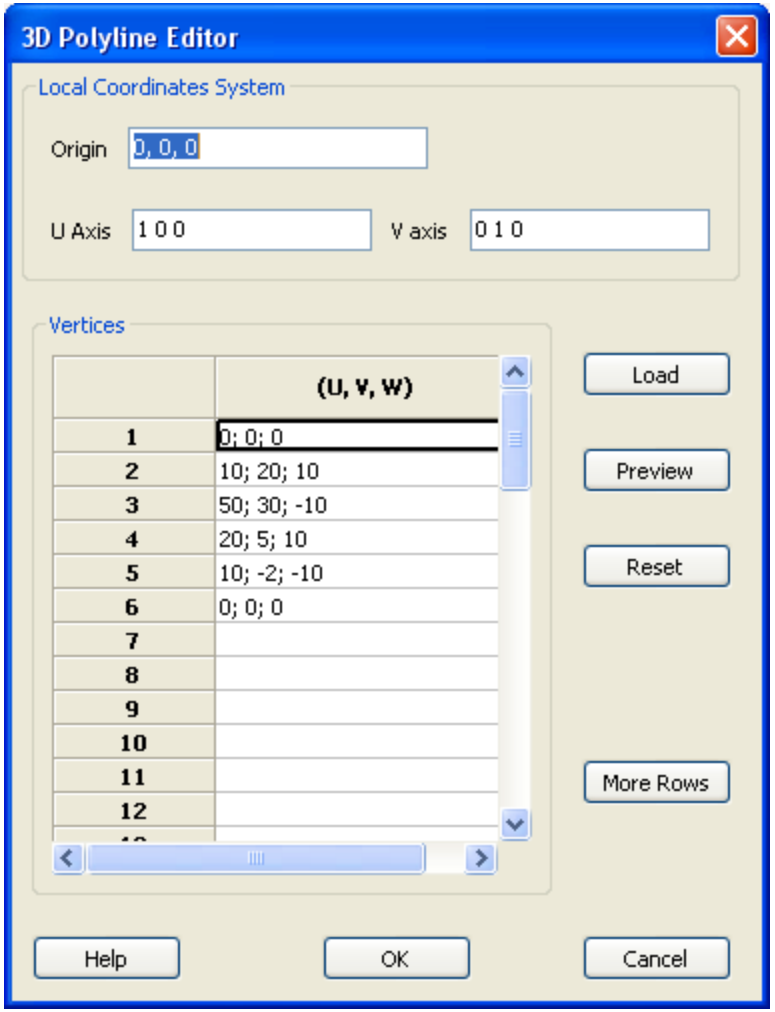
- Poly line is defined according to the local coordinate system (u,v)
- User can define its own u and v axis
- Poly line points can be loaded from an external file



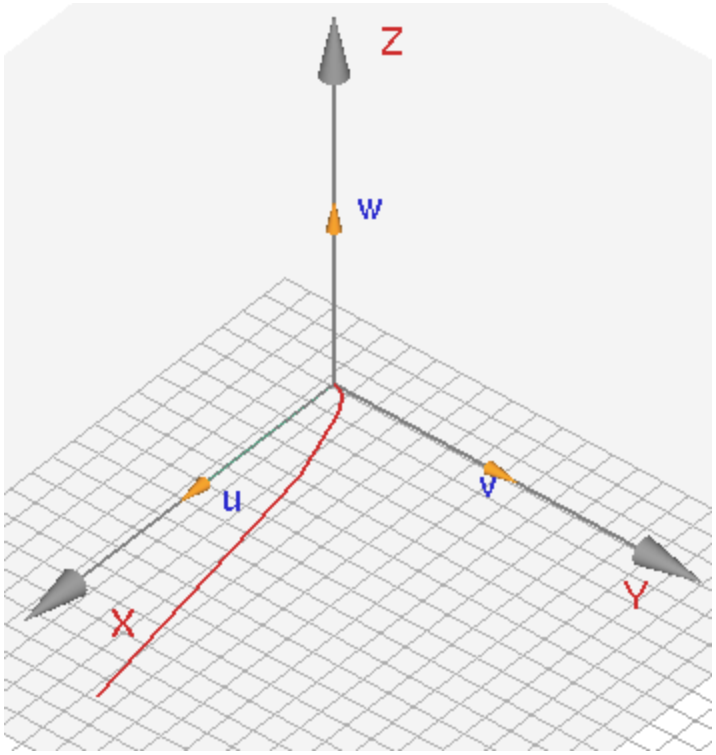


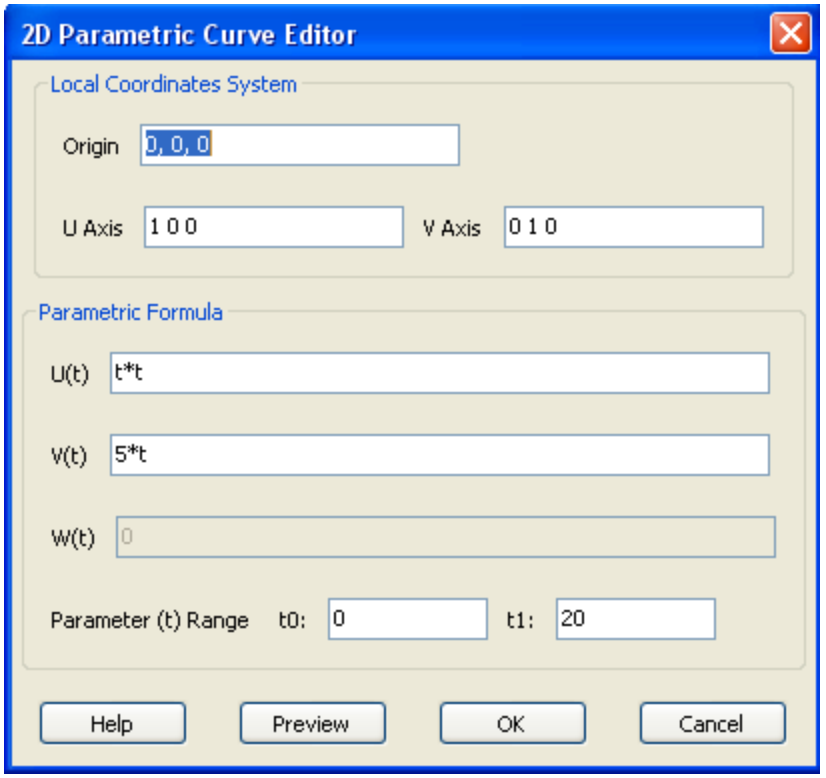
Curves – 3D Poly Line



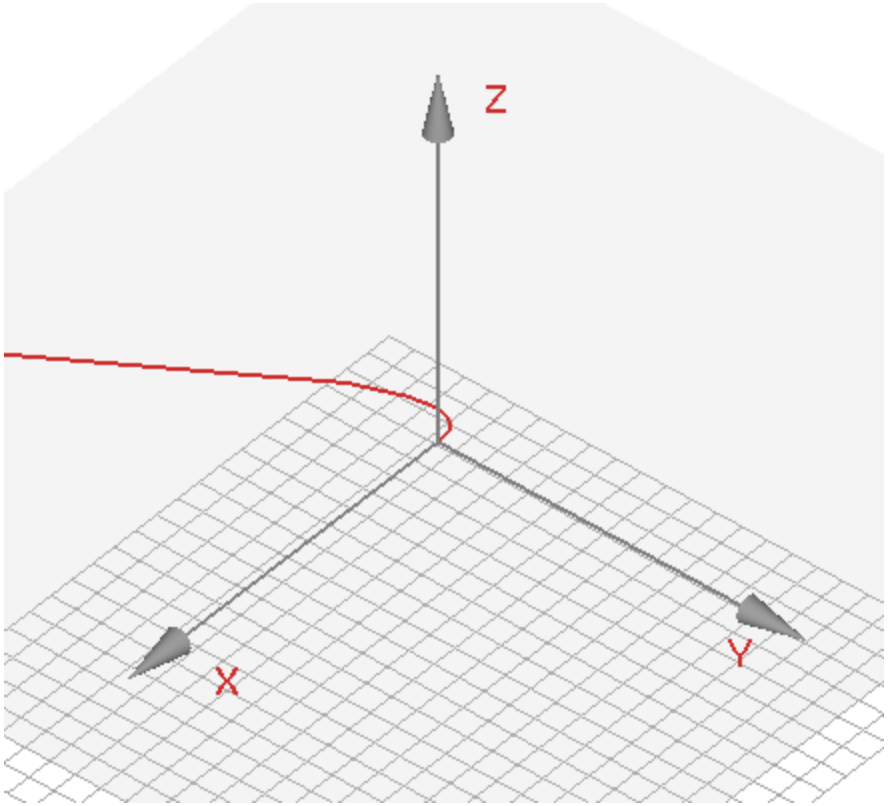


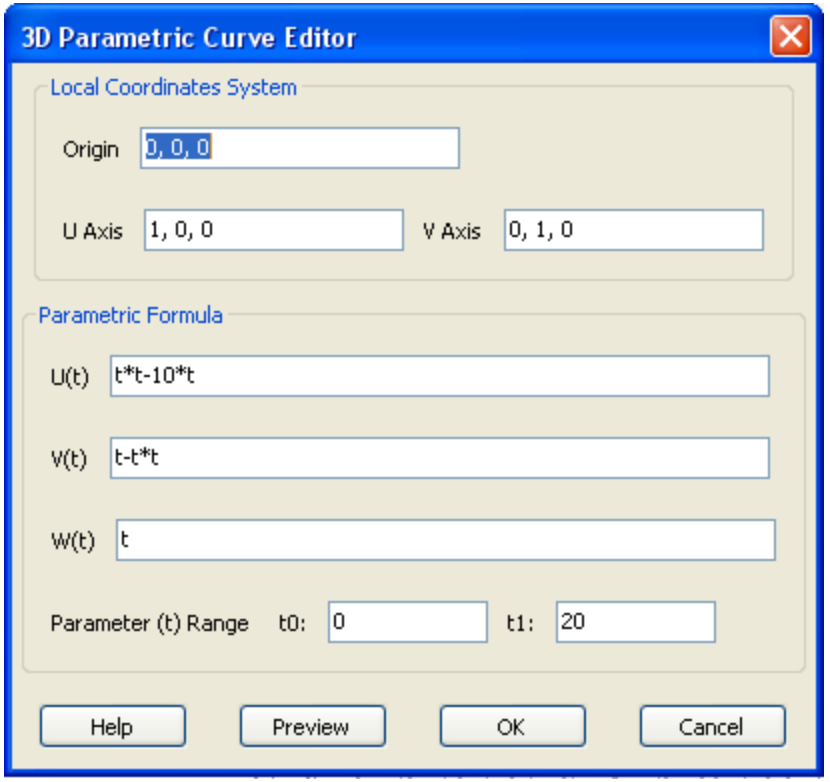
Curves – 2D Parametric Line





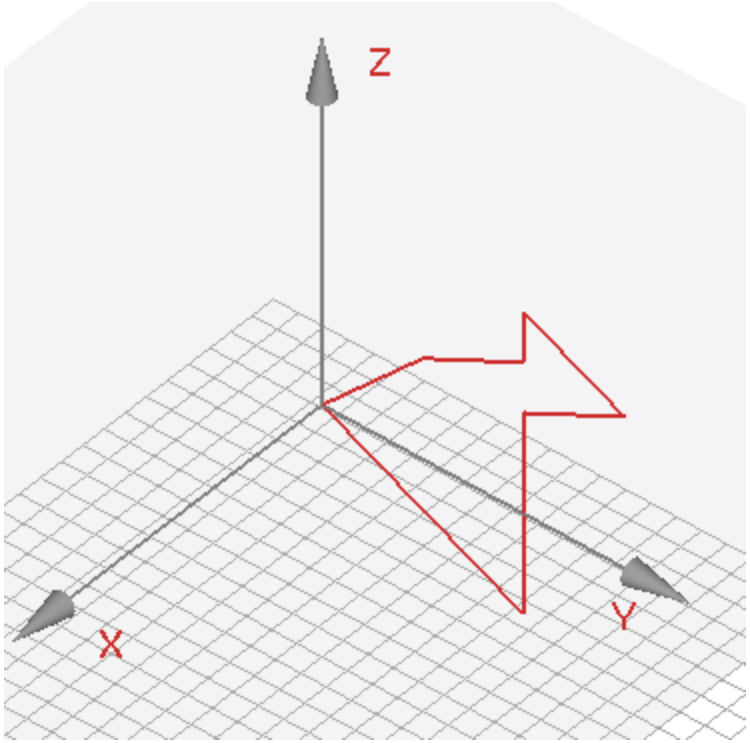
Curves – 3D Parametric Line

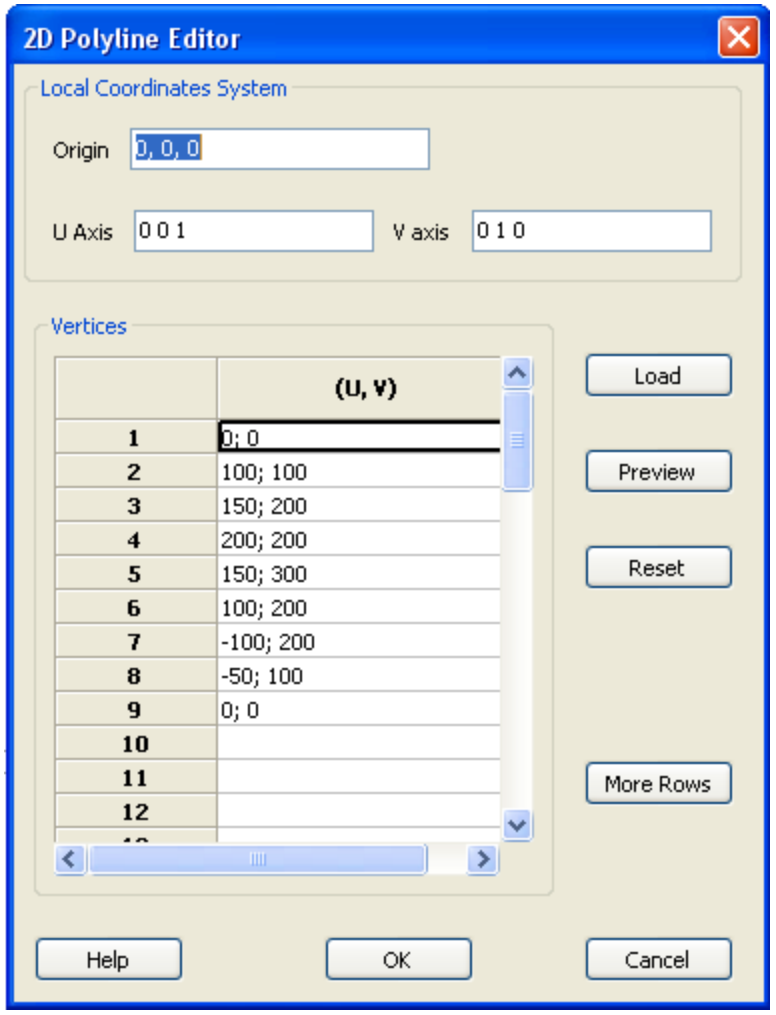




Faces – Cover from Curves (1)

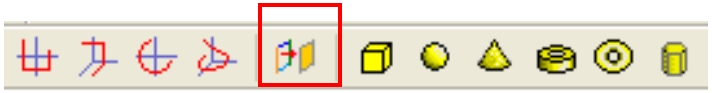
- Create a 2D poly line
- Such bounding curve must be closed

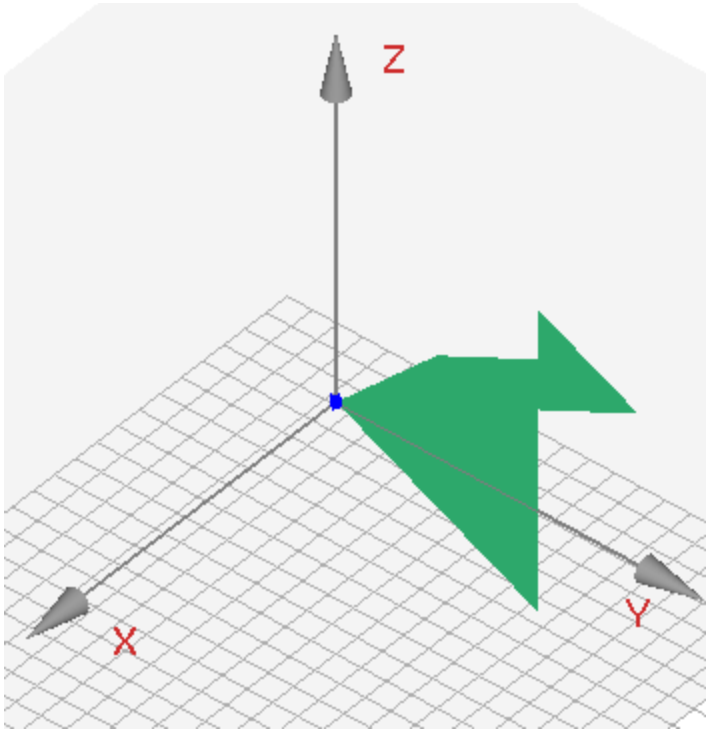


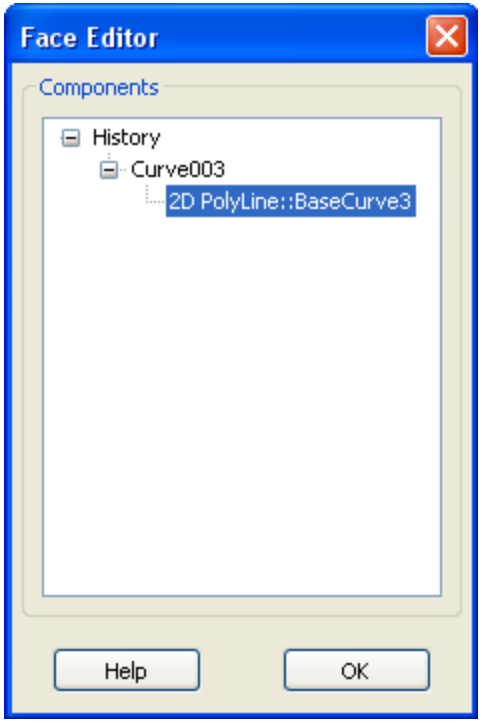


Faces – Cover from Curves (2)

- Select the bounding curve
- Click the “Cover from Curves” button
- A face will be created as shown
- User can also modify the bounding curves after the face is crated, and the new face will be updated based on the modified curve

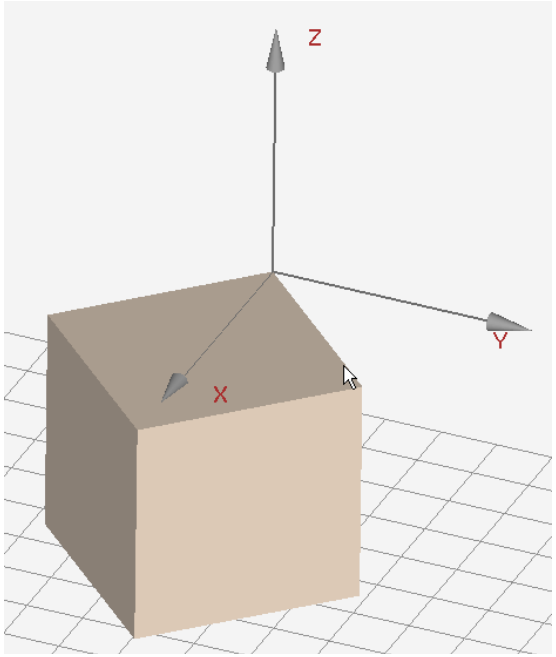


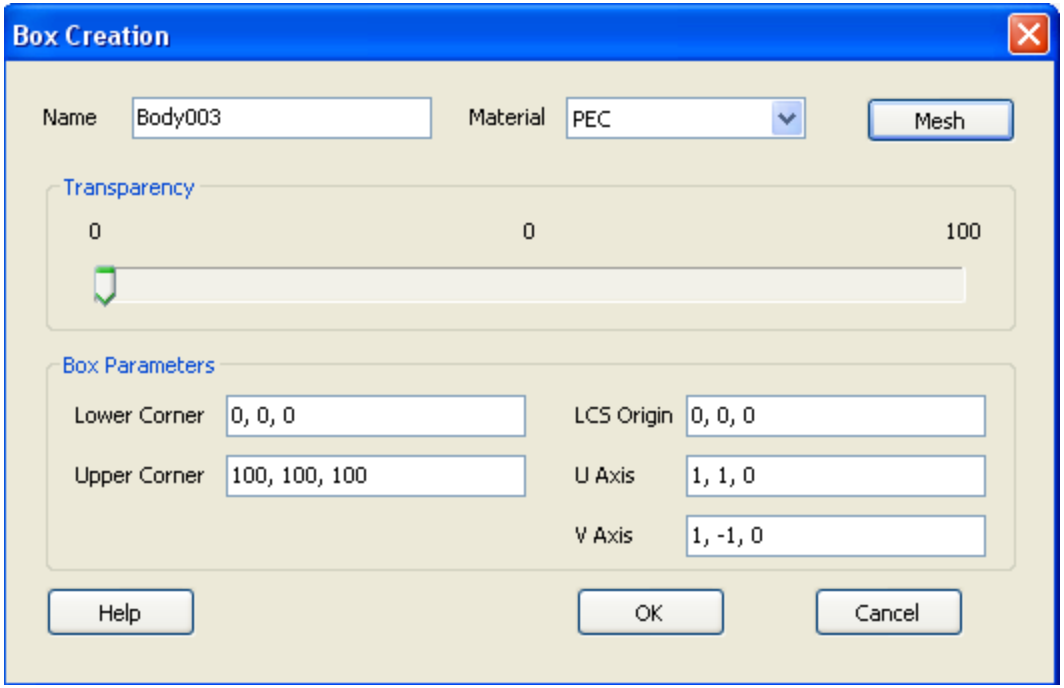




Solids – Box

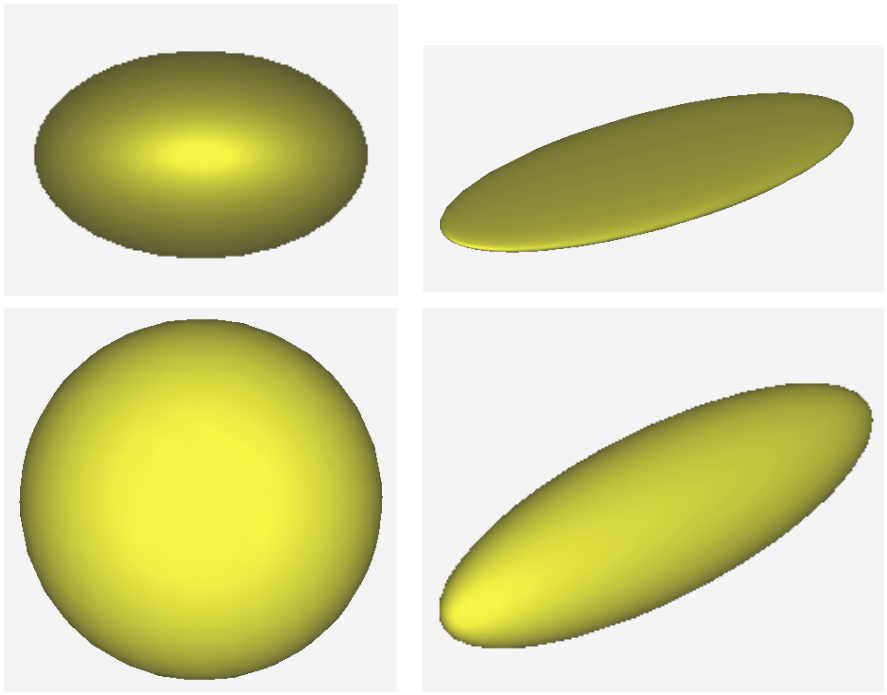
- Box is defined by specifying the lower and upper corner
- Box also has its own local coordinate system
- User has to specify the local u and v axis

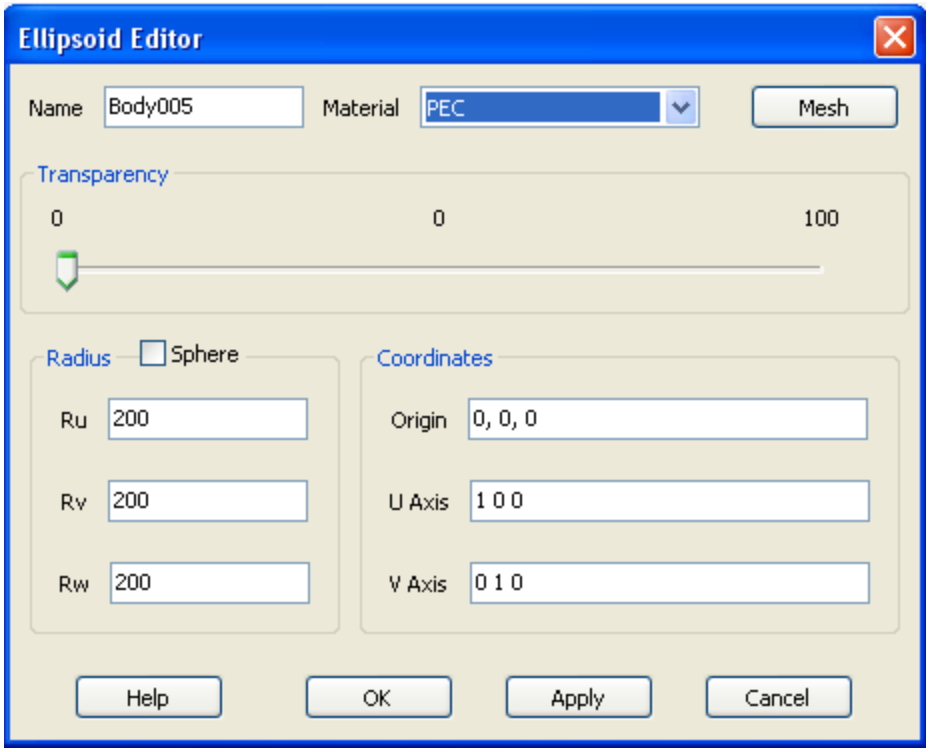




Solids – Ellipsoids

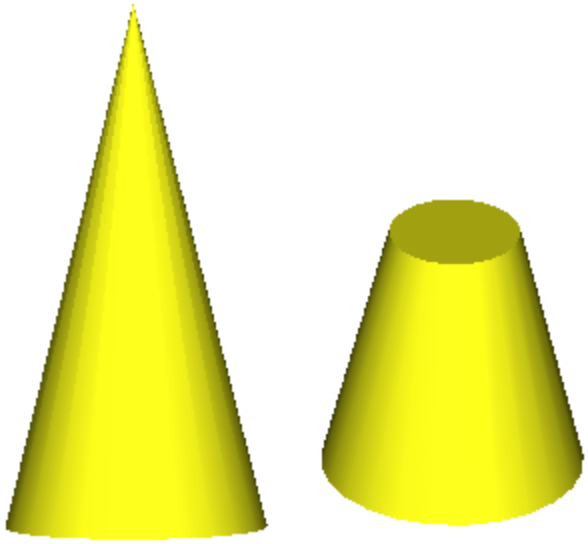
- Ellipsoids can be created by specifying 3 radius Ru, Rv and Rw
- For sphere, simply check the “Sphere” box

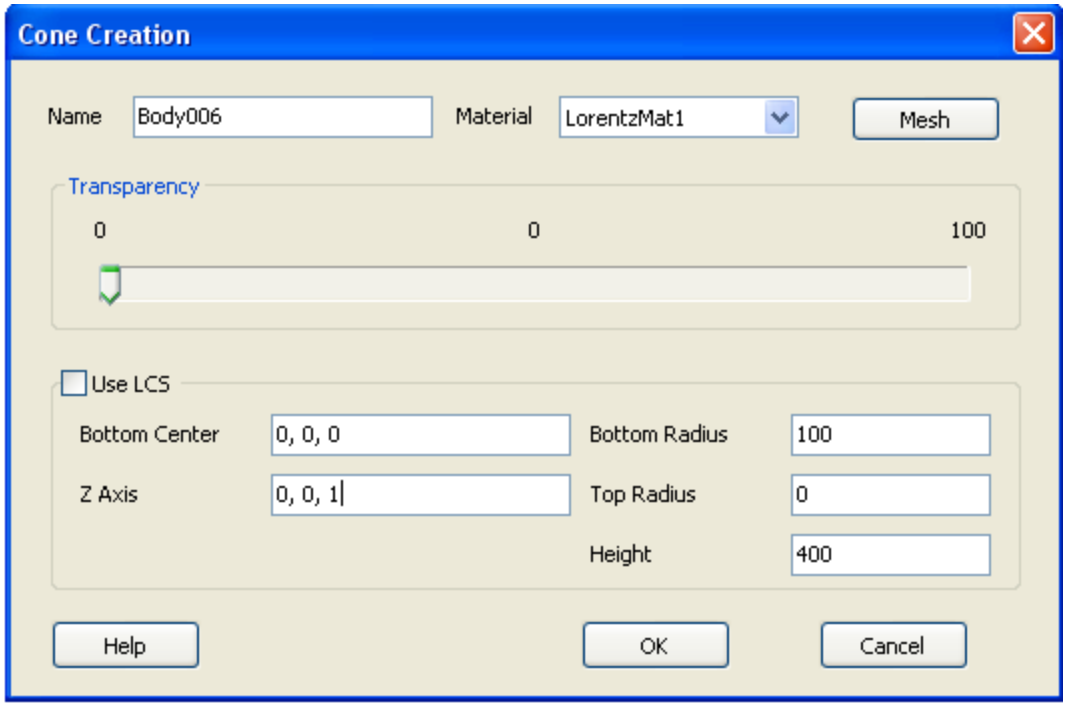




Solids – Cones

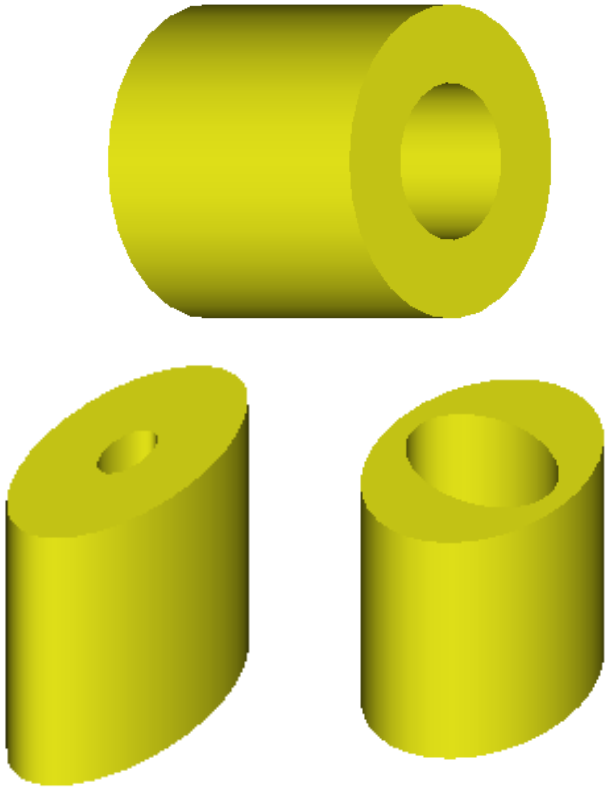
- Cones are defined by specifying height, top and bottom radius
- User also needs to specify the bottom center and Z-Axis to position the cone

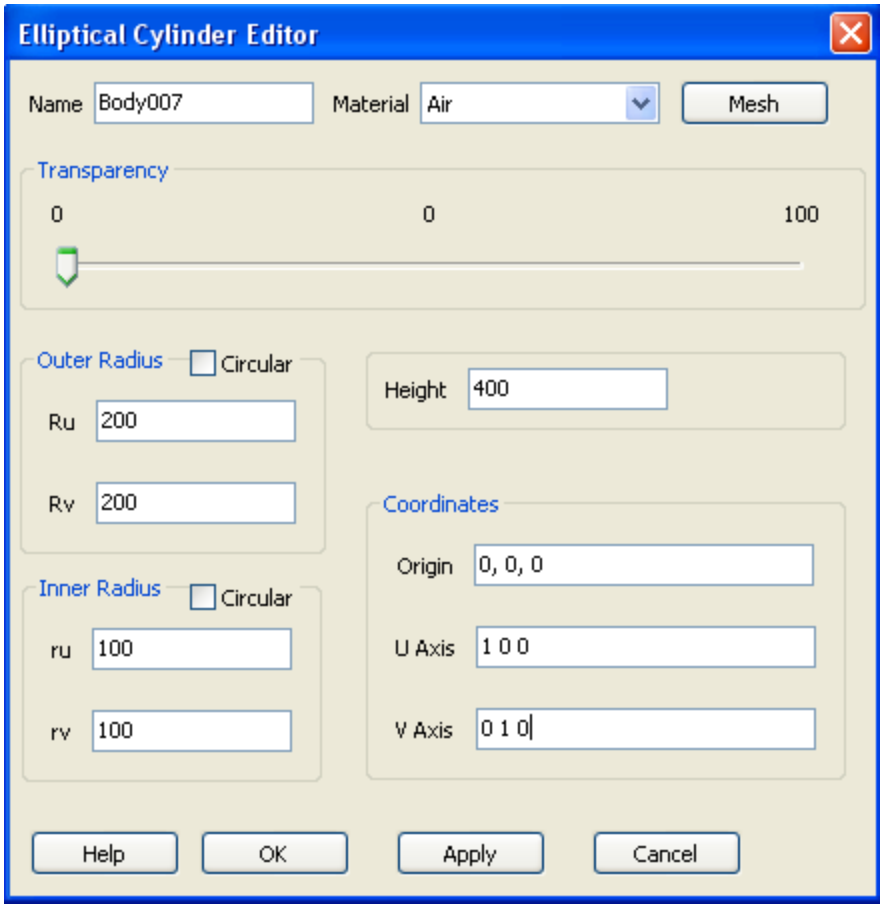




Solids – Elliptical Cylinders

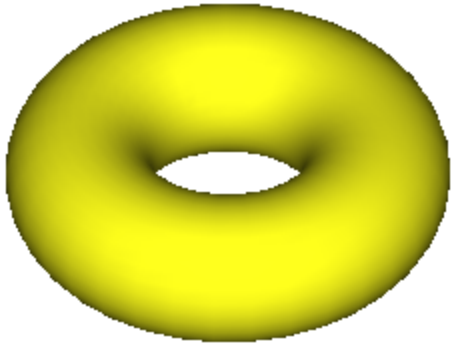
- Elliptical cylinder is defined by specify the inner and outer radius
- Change Ru and Rv of inner and outer radius to create elliptical shapes

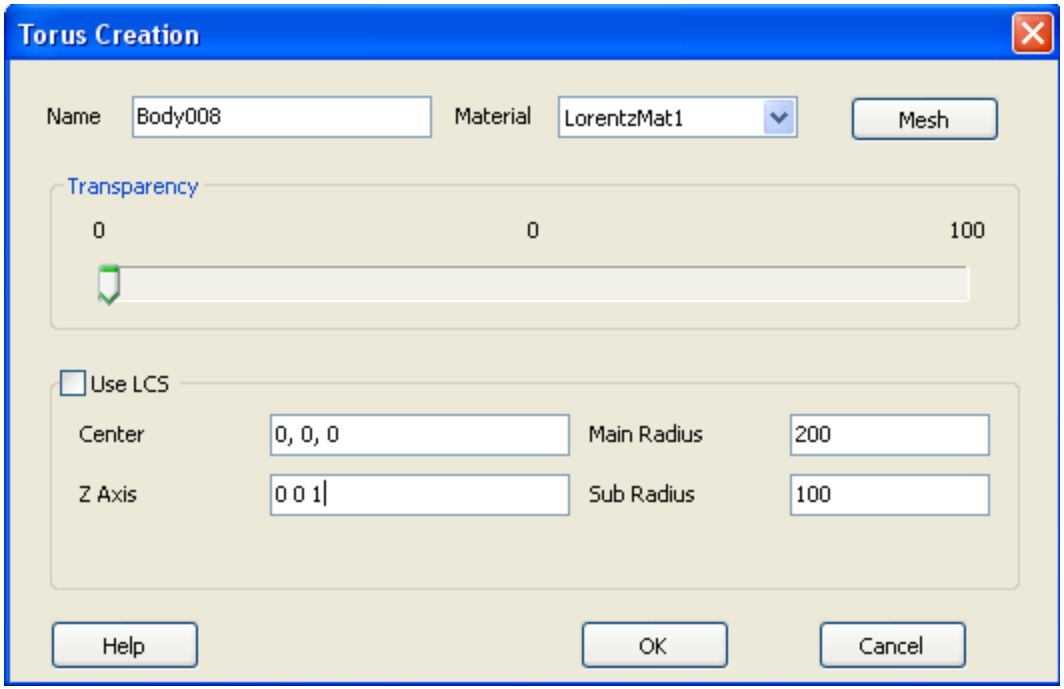




Solids – Torus

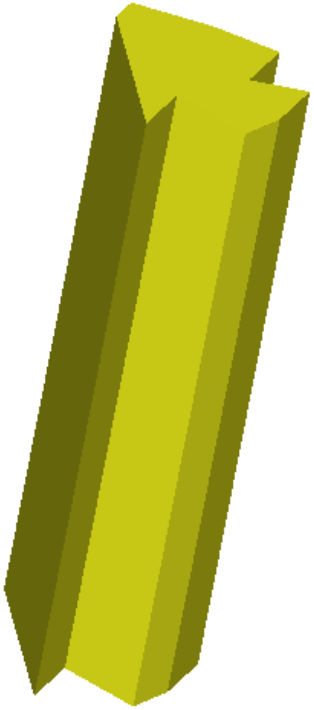
- Torus is simply defined by giving main and sub radius

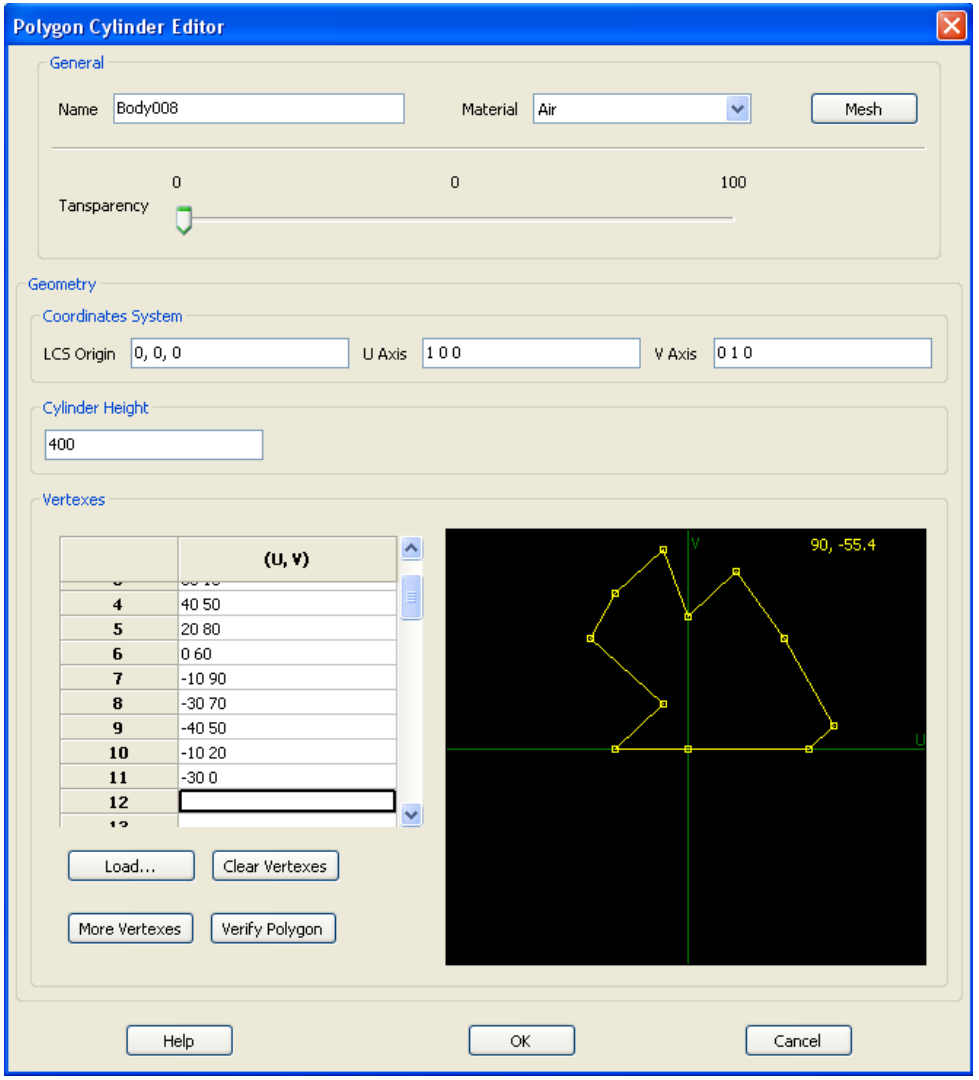




Solids – Polygon Cylinders

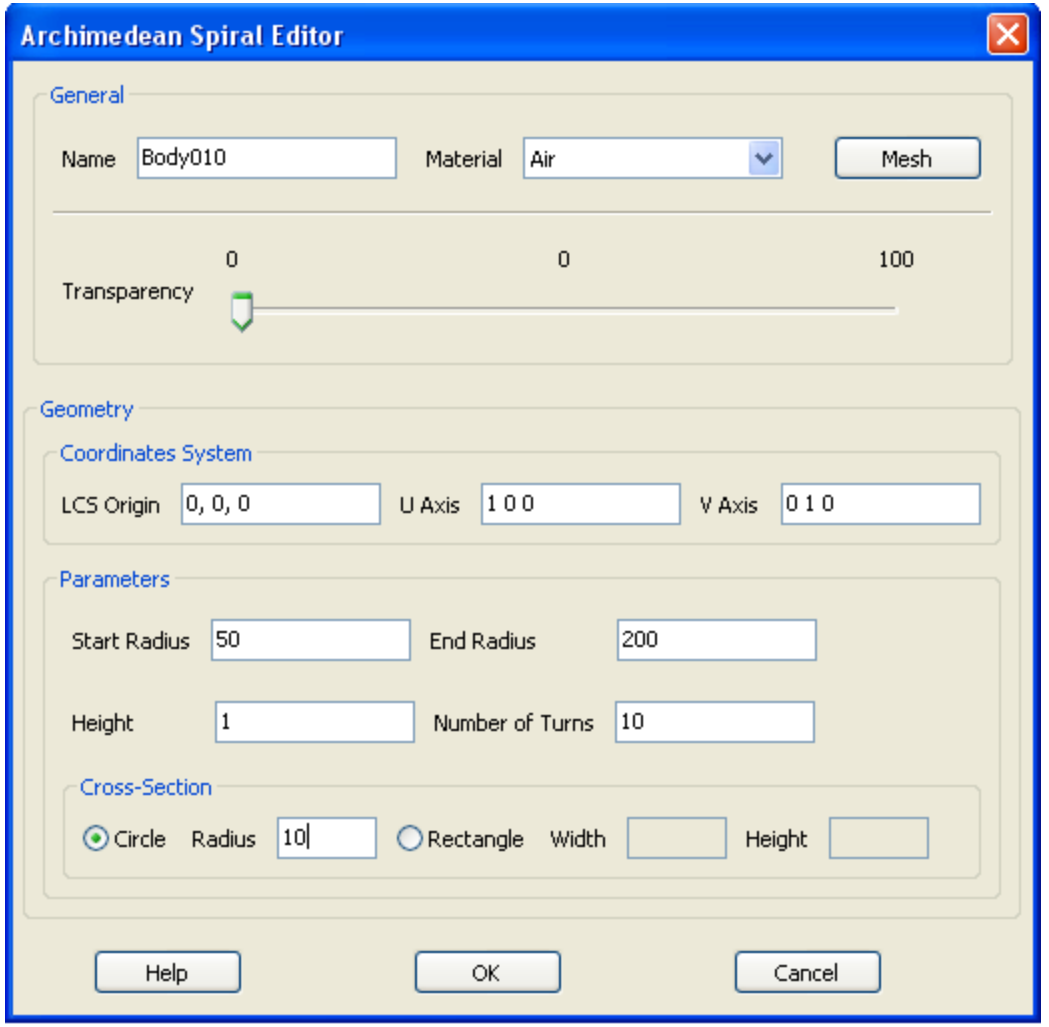
- User can create polygon cylinders by drawing the polygon curve and the cylinder will be created based on the defined curve



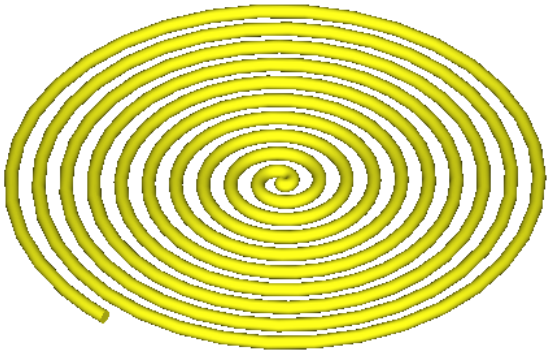
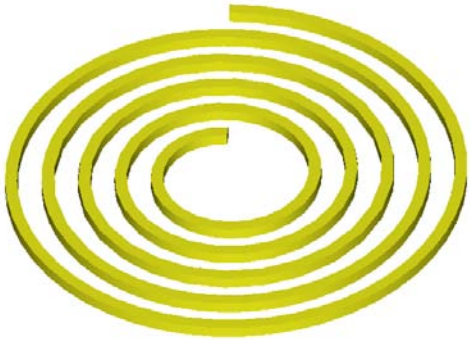
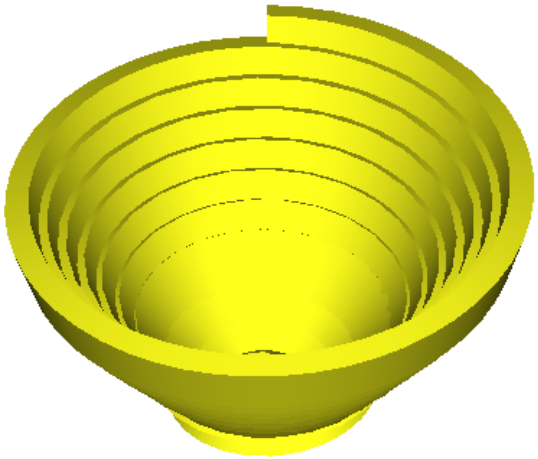
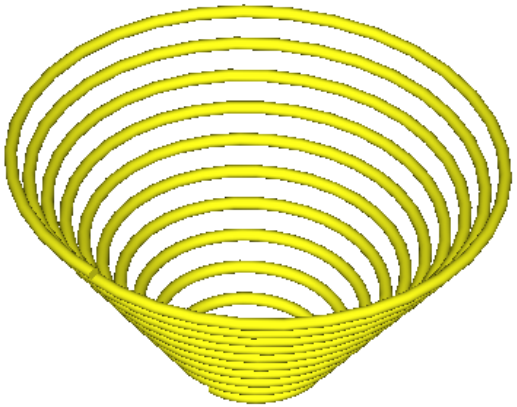
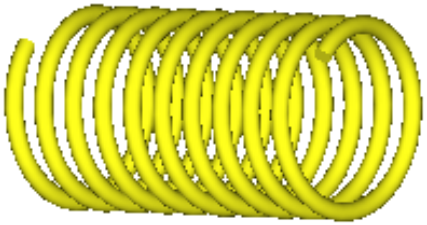
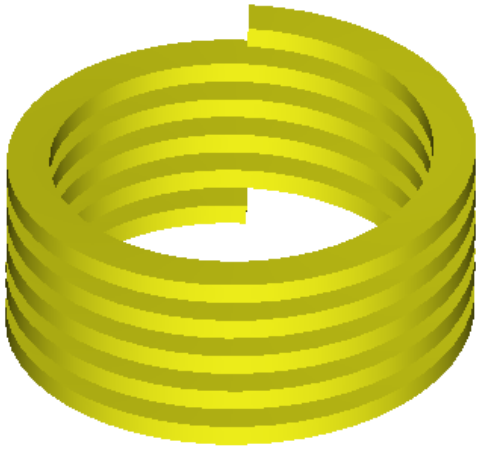


Solids – Archimedean Spirals (1)

- User can create Archimedean spirals by specifying start/end radius, height and number of turns
- The wire shape of the spirals can also be changed as circle or rectangle
- Modify these parameters will create various spiral shapes

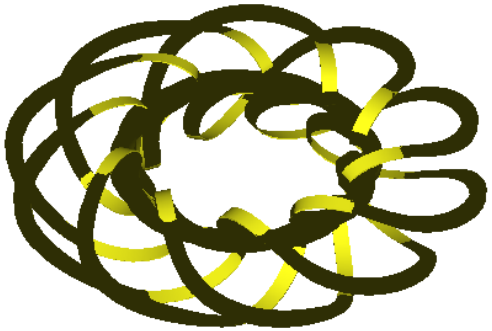


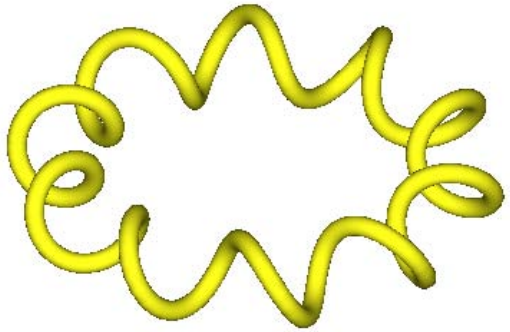
Solids – Archimedean Spirals (2)

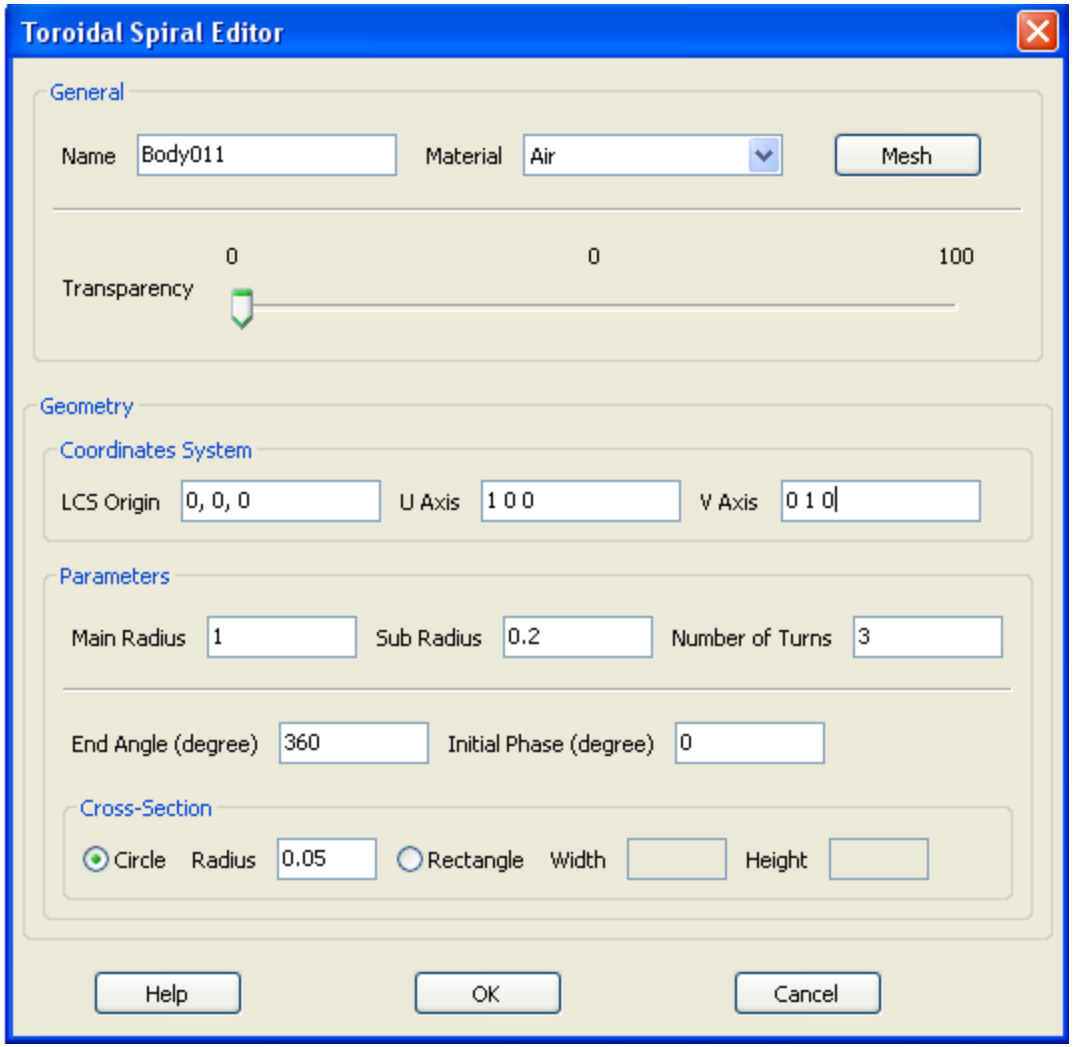







Solids – Toroidal Spirals

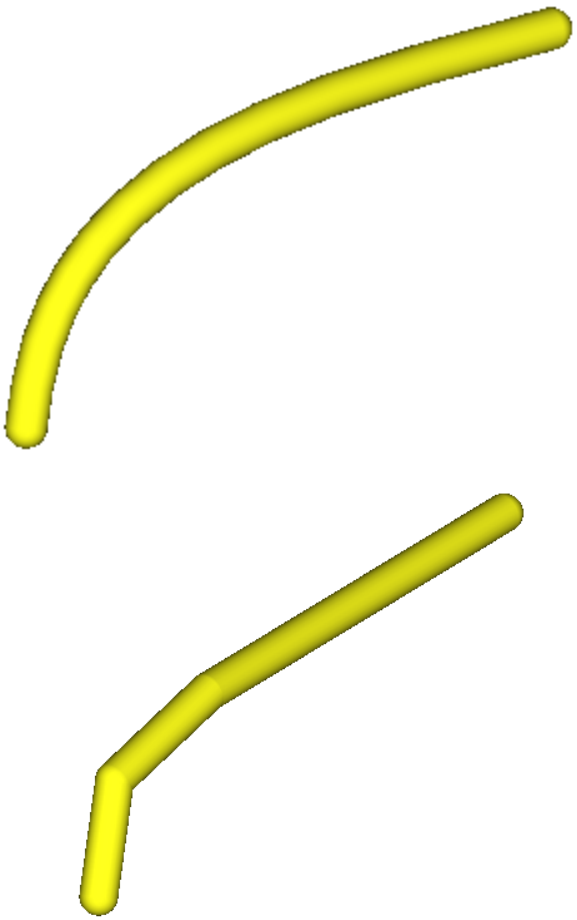
- User can create toroidal spirals by specifying start/end radius, height and number of turns
- The wire shape of the spirals can also be changed as circle or rectangle

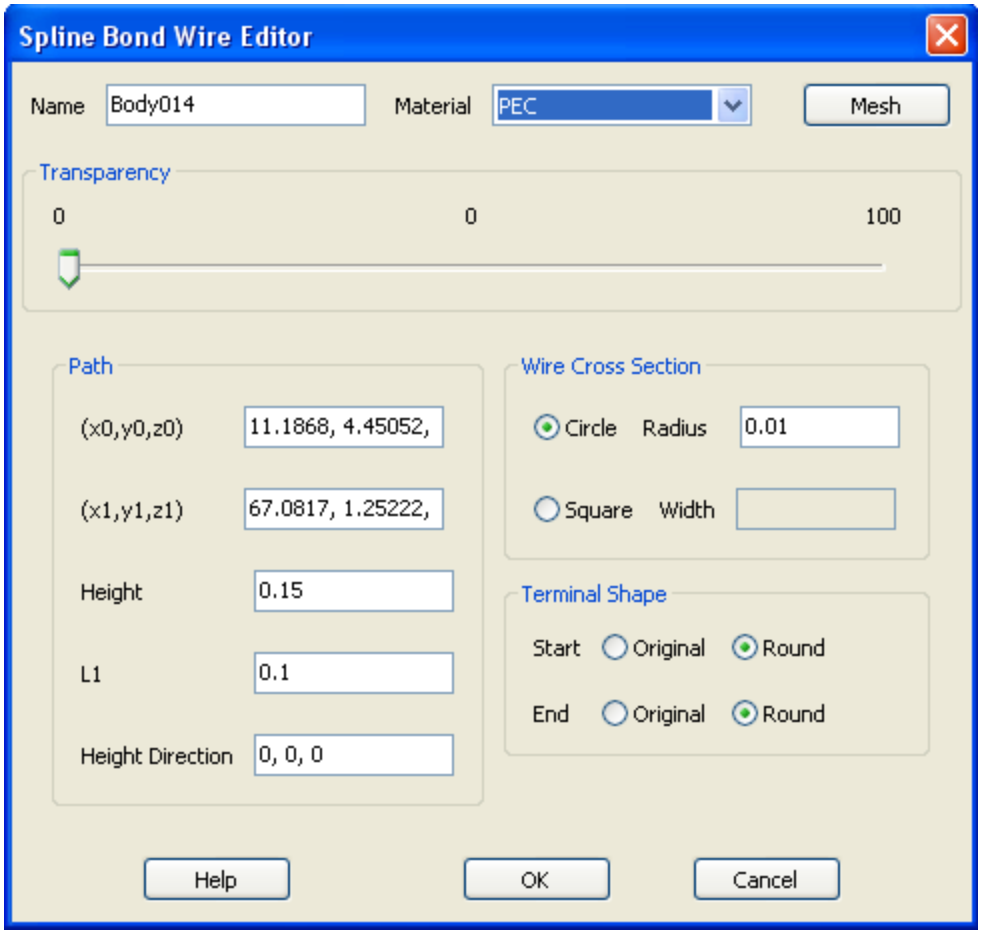






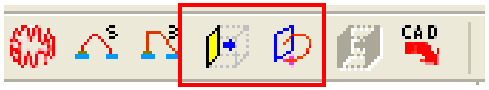
Solids – Bondwires



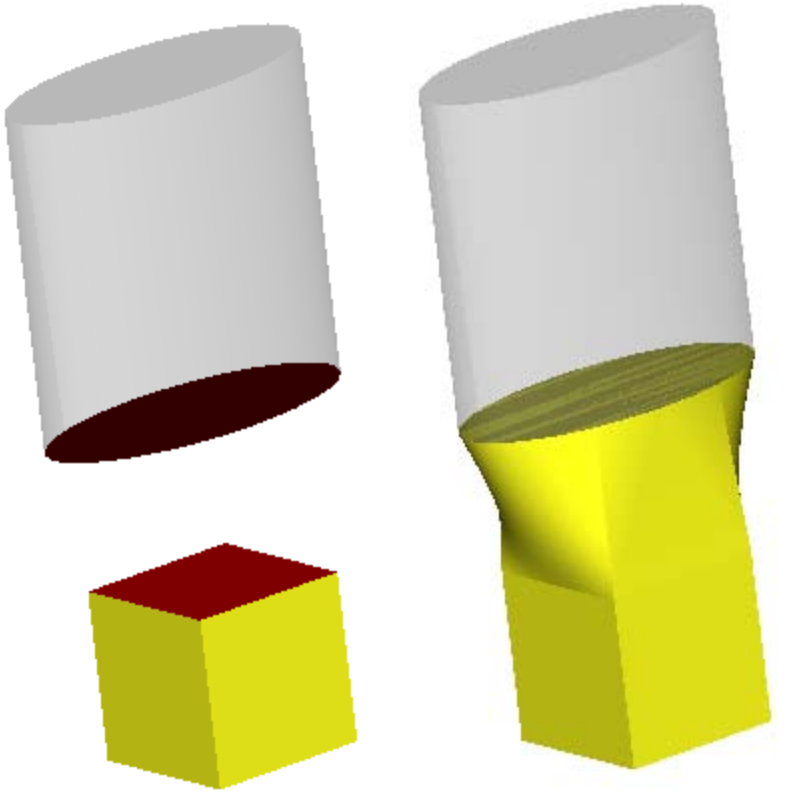


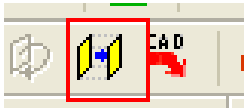
Solids – Sweeping Faces

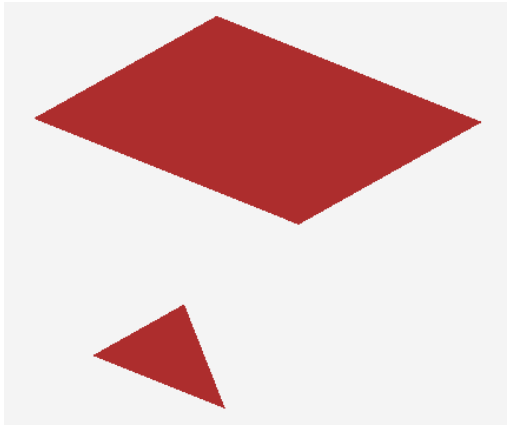
- To create body by sweeping faces
- User has to first define the parent face
- Then define the curve that will be used as the sweeping path
- Then click button “Create body by sweeping face along curves”

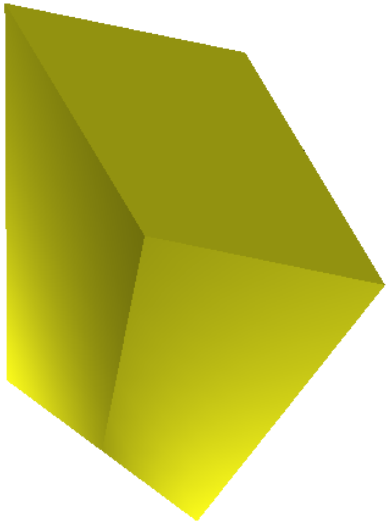


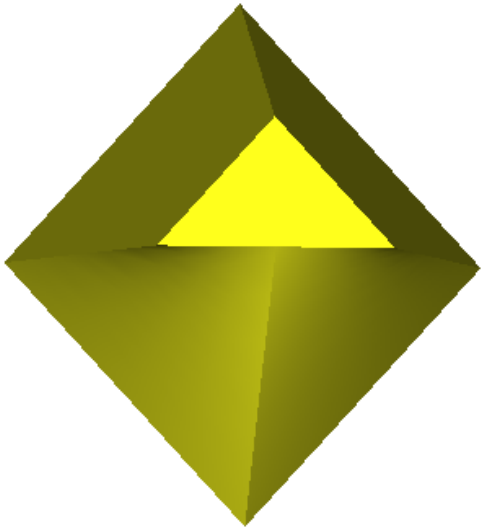
Solids – Lofting



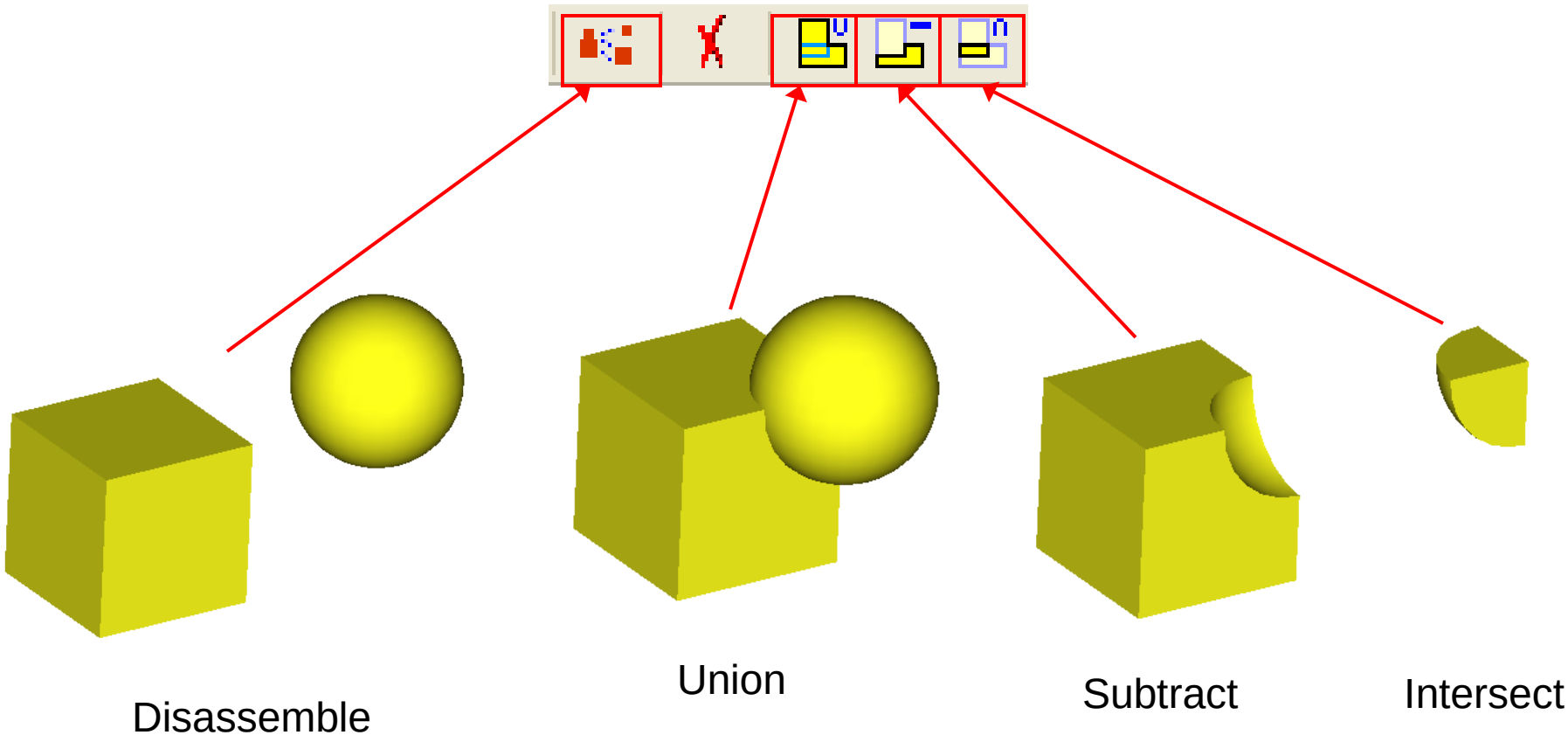




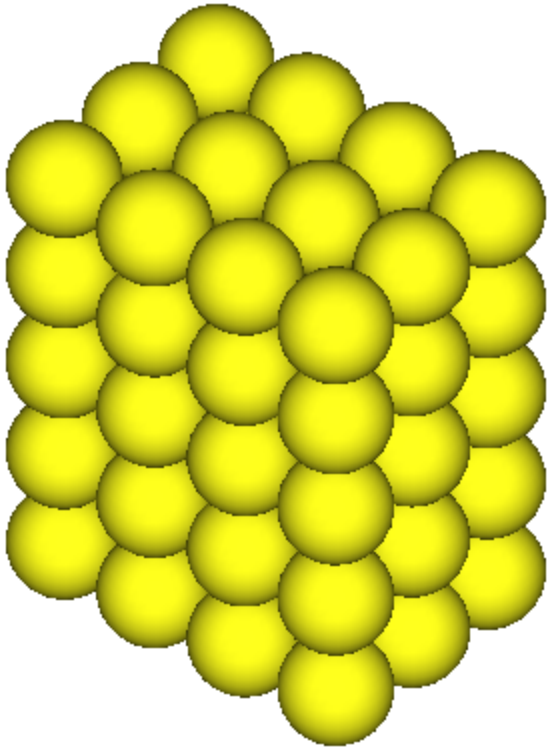




Operations – Union, Subtract, Intersect, Disassemble

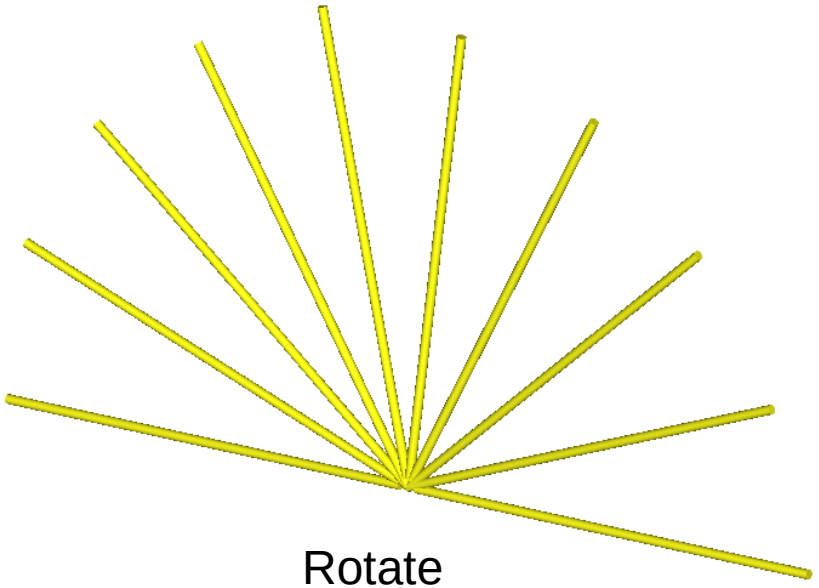


Operations – Array Copy, Mirror, Rotate



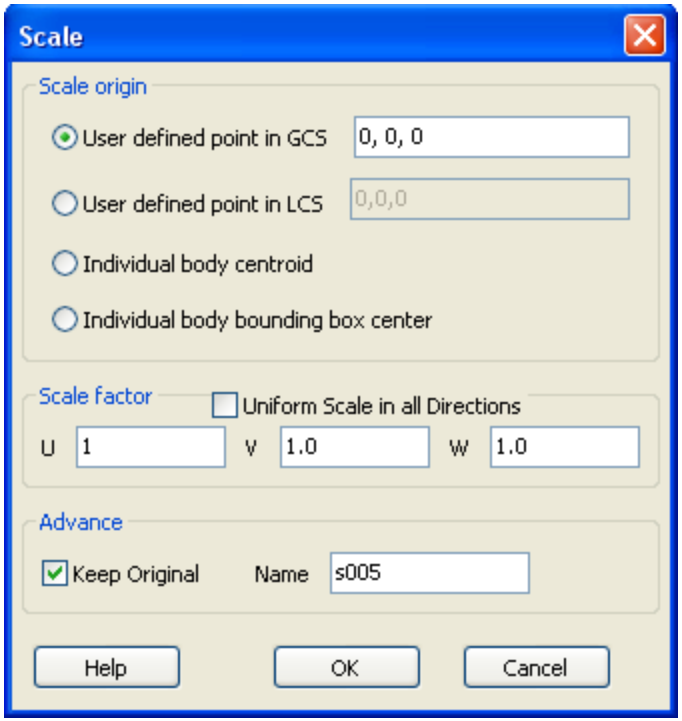
Array Copy

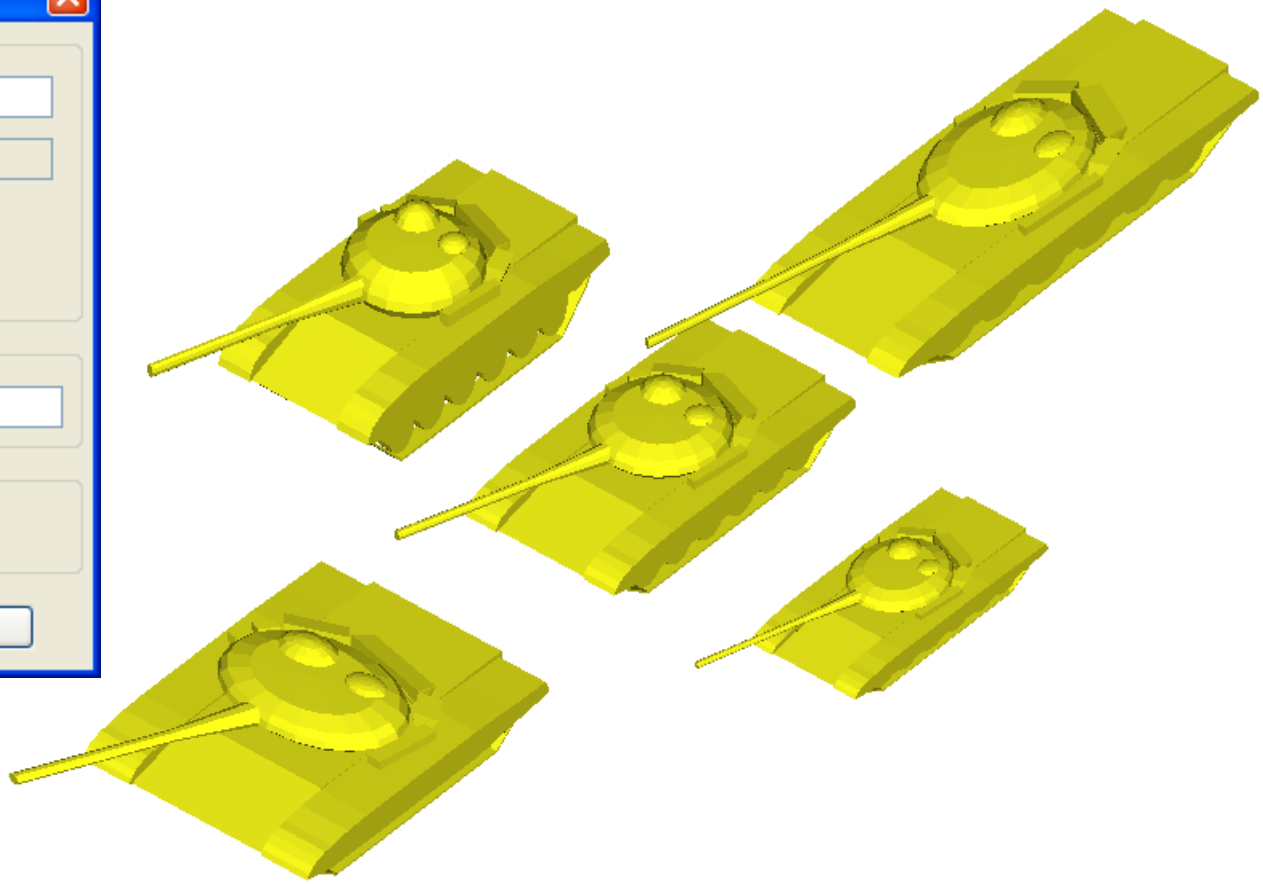
Mirror



Rotate

Operations – Scale

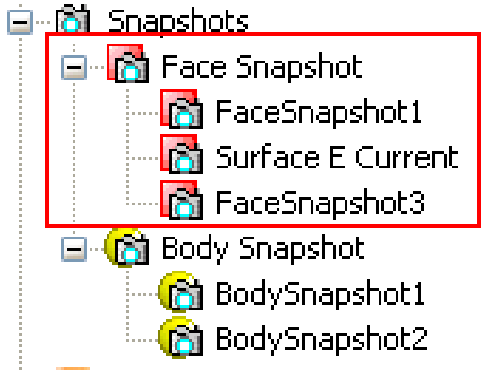


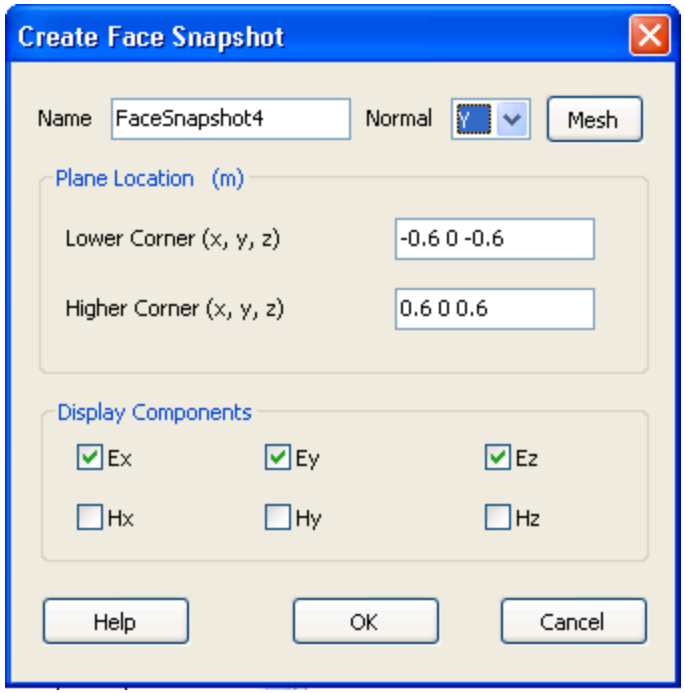


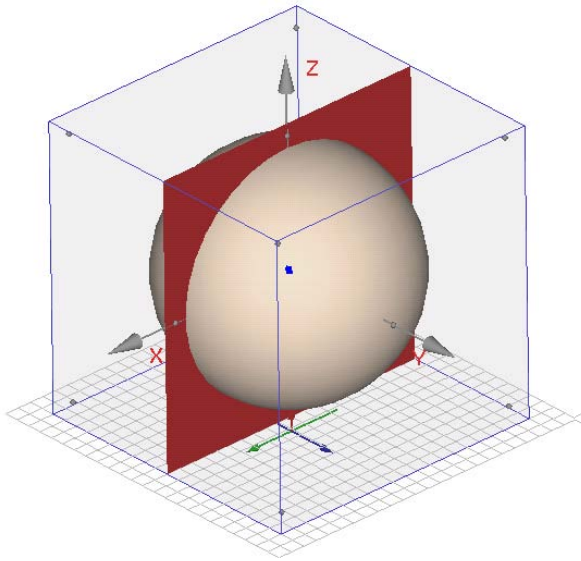
Result Exploration

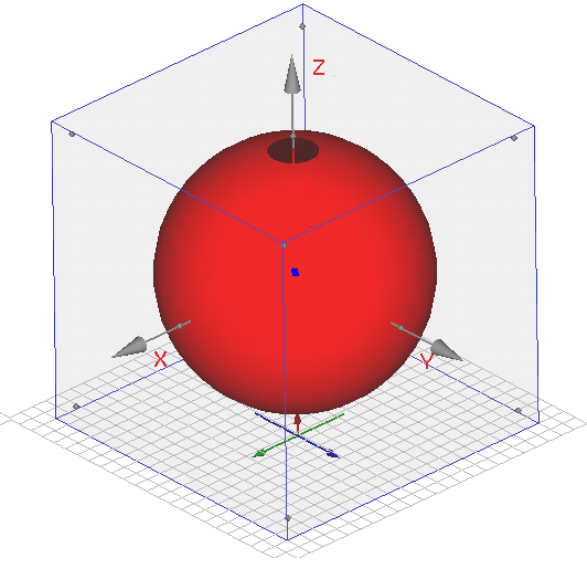
- Snapshots
  - Face
    - EM Field on Face Cut
    - EM Field on Object Surface
    - EM Current on Object Surface
  - Volume
    - EM Field on Volume
    - EM Field on Object
- Far Field
  - 3D view of far field pattern
  - Bi-Static RCS at multiple frequencies and different theta and phi planes
  - Wideband RCS at multiple locations
- 2D Curves
  - Observers
    - EM fields and its x, y, z components
  - Lumped Ports and Wave Ports
    - S-Parameters
    - Impedance
    - Incident current and voltage
    - Scattered current and voltage
    - Total current and voltage
  - Circuits
    - Voltage at all nodes
    - Current at all branches
    - Circuit terminal current and voltage
  - All above listed items support both transient and spectral results

Snapshots Defined on Face



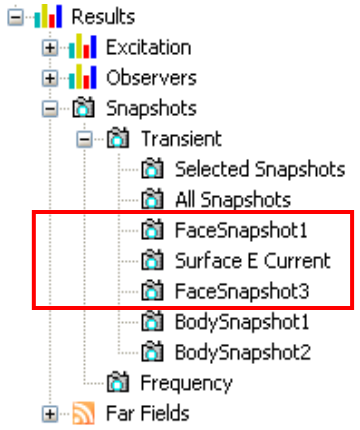




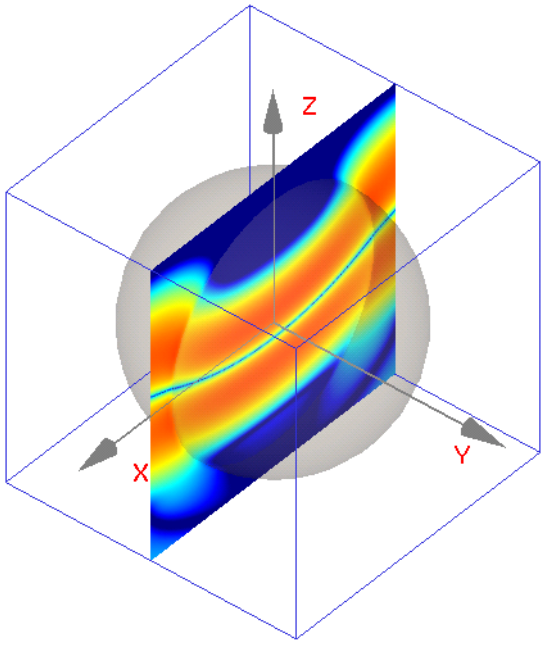


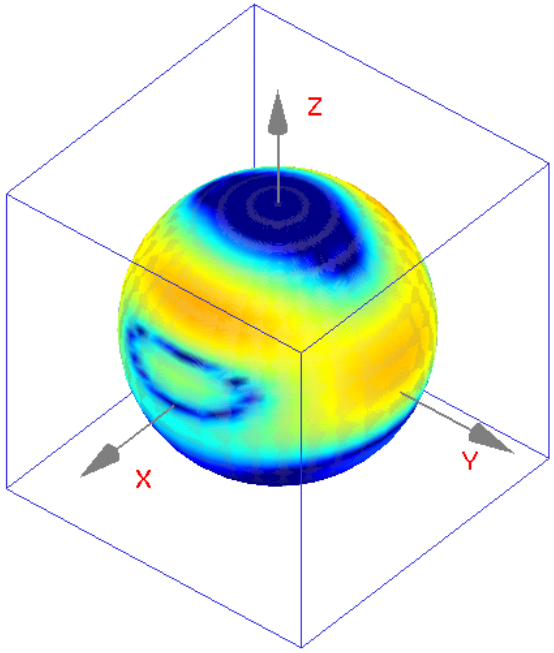
- Can be defined on both face cut and object surface
- User can select the field components (Ex, Ey, Ez, Hx, Hy, Hz) to display

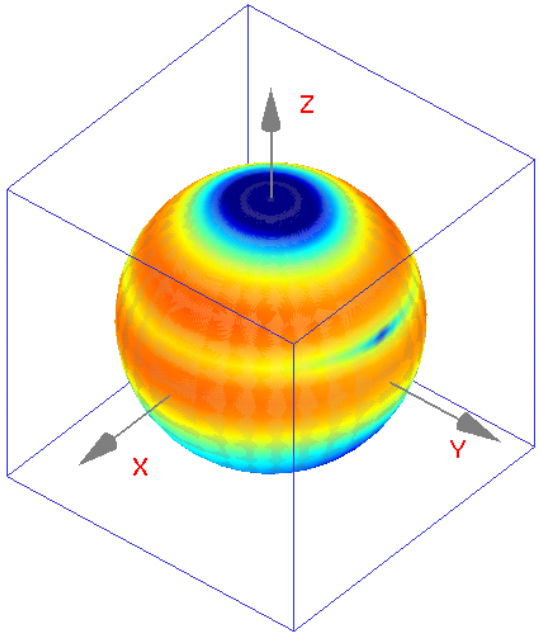
Snapshots – Face Field and Current



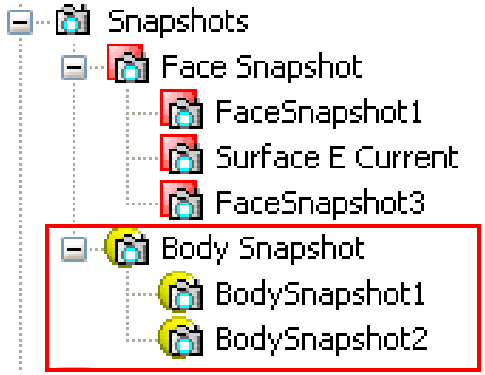
- Left: X component of the E field defined on XoZ plane
- Middle: Electric current J defined on sphere surface
- Right: Total electric field defined on sphere surface

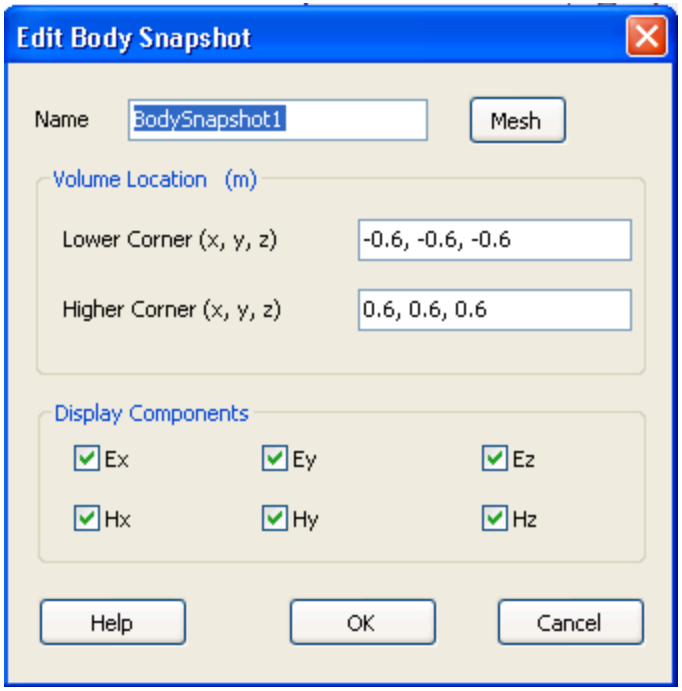


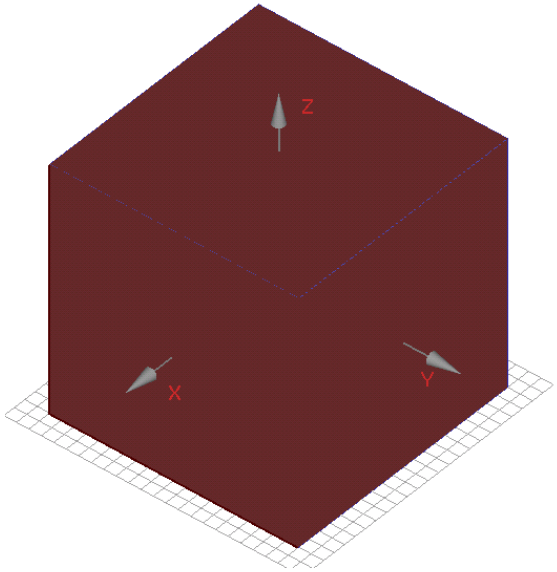


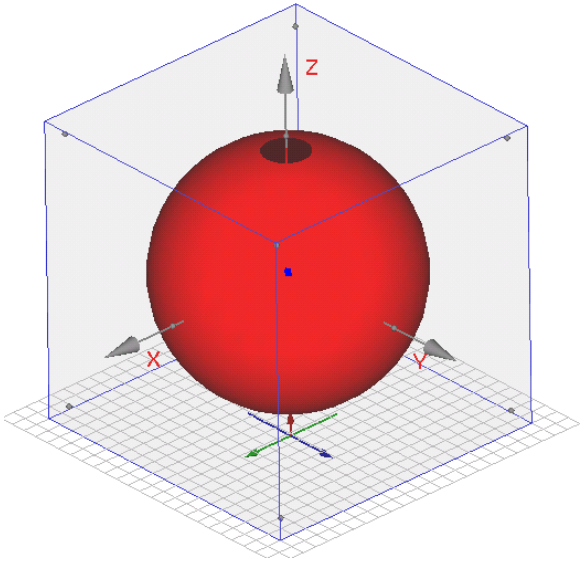


Snapshots Defined over Volume



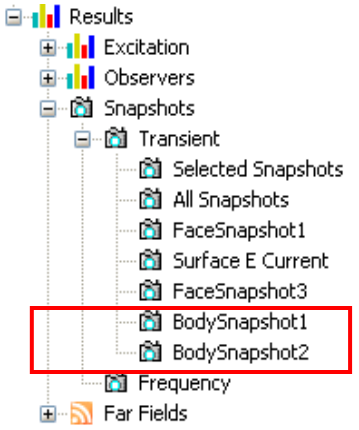




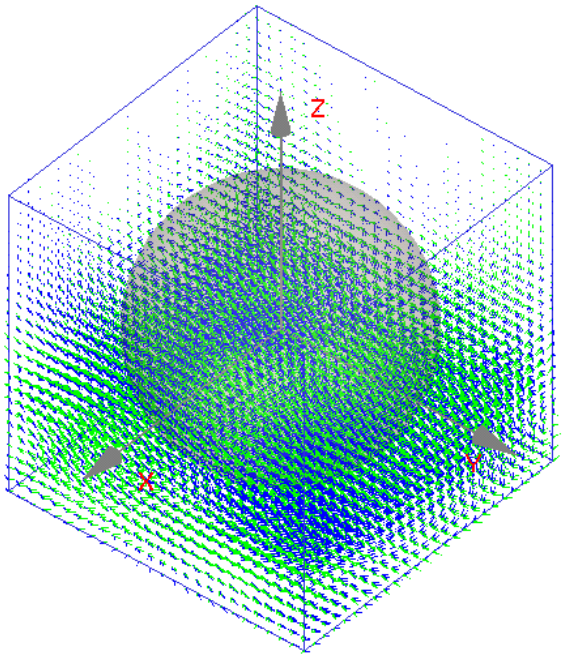


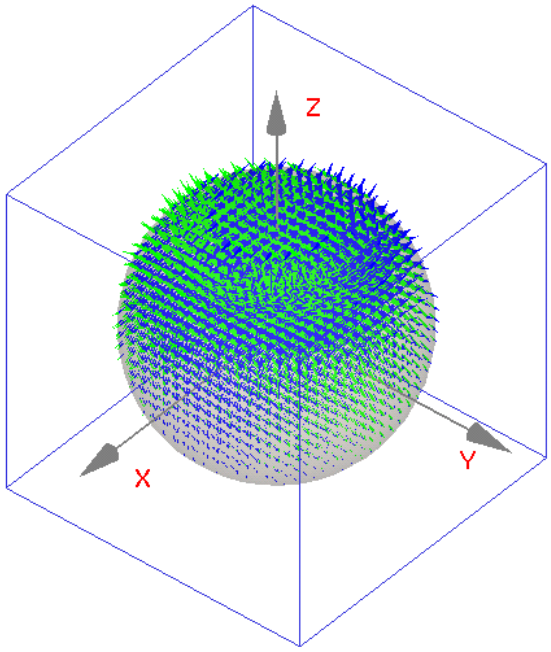
- Can be defined on both computational domain and object volume
- User can select the field components (Ex, Ey, Ez, Hx, Hy, Hz) to display

Snapshots – Volume Field

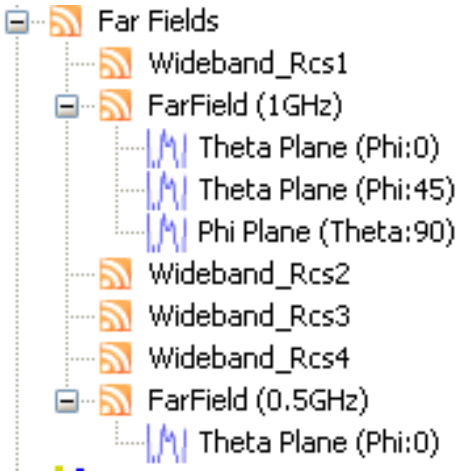


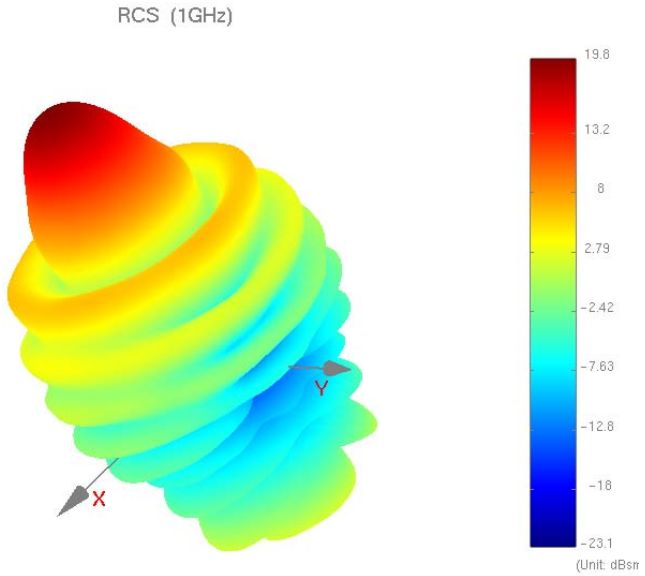
- Left: Total E and H field defined over the entire domain
- Right: Total E and H field defined within the shpere

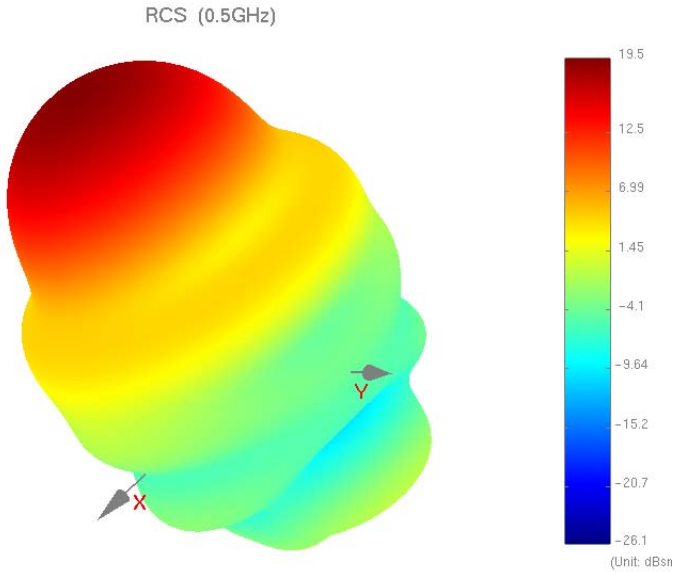




Far Fields – 3D Pattern

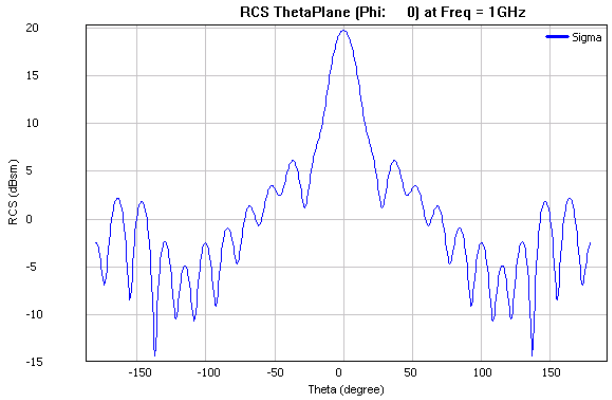


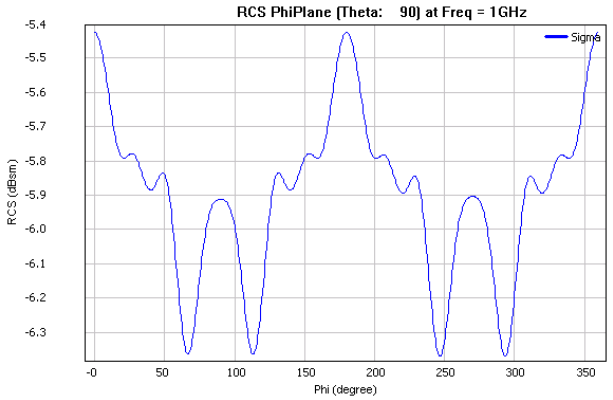


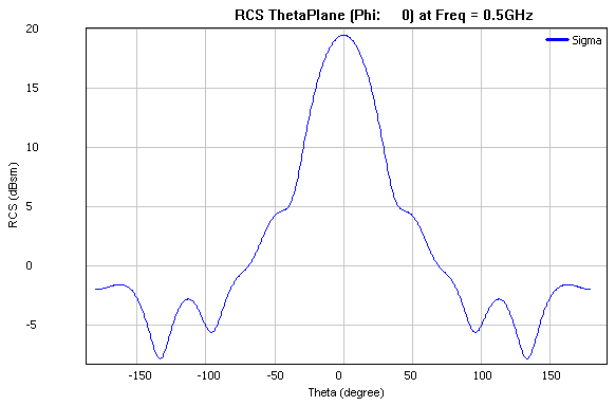


- Simply specify the frequency and the Bi-Static RCS will be automatically calculated after simulation
- The 3D far field pattern can be displayed
- RCS on phi / theta planes can also be calculated
- Wideband RCS at given location can also be calculated

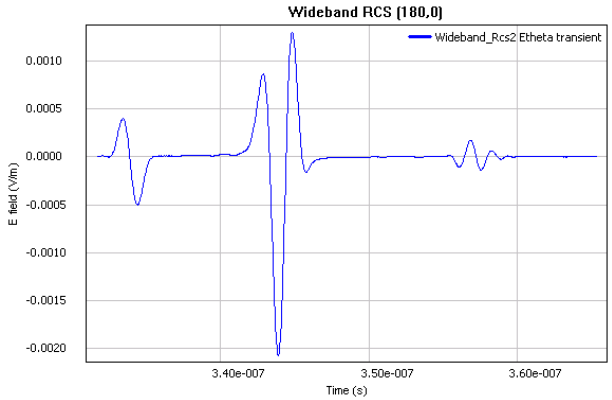
Far Fields – RCS

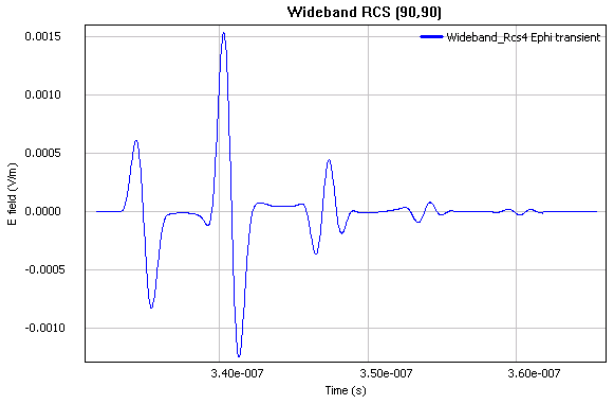


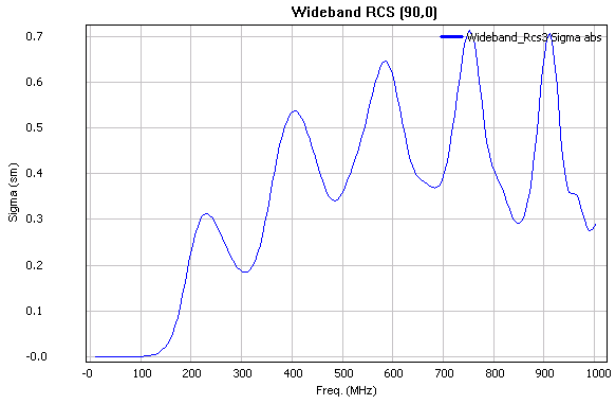




RCS at single frequency

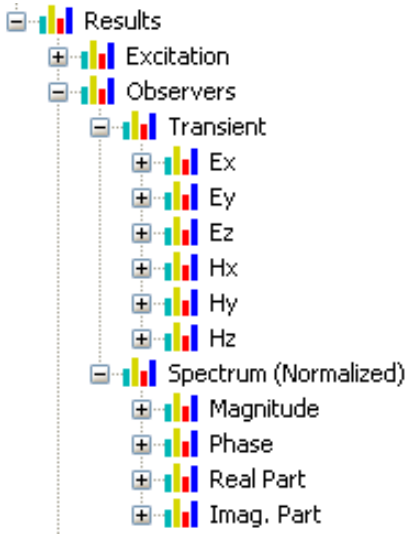




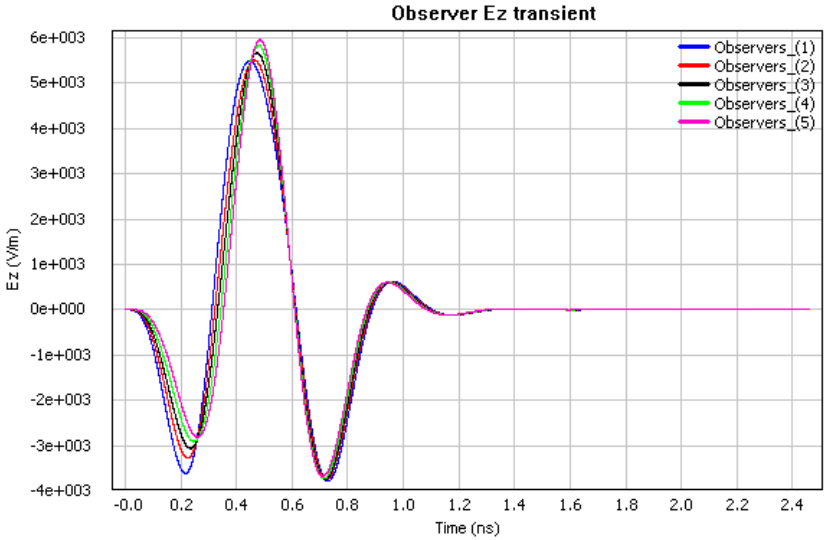


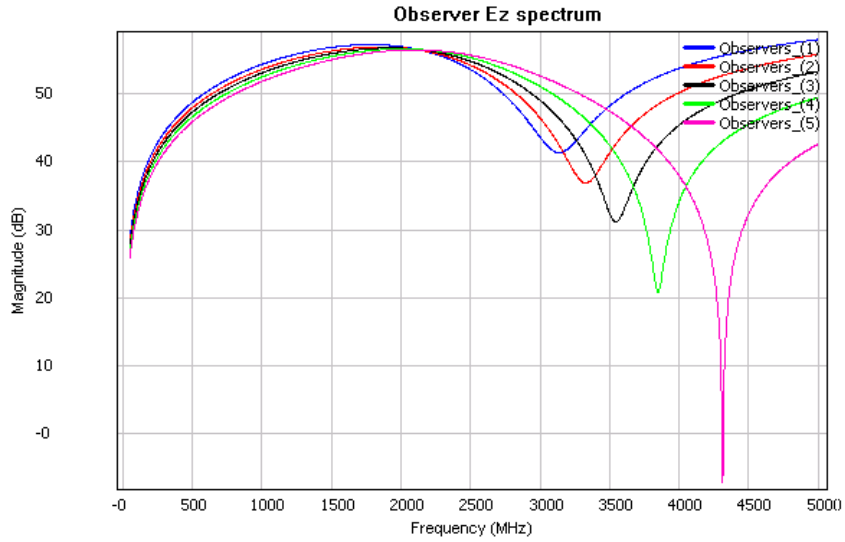
Transient far field and wideband RCS

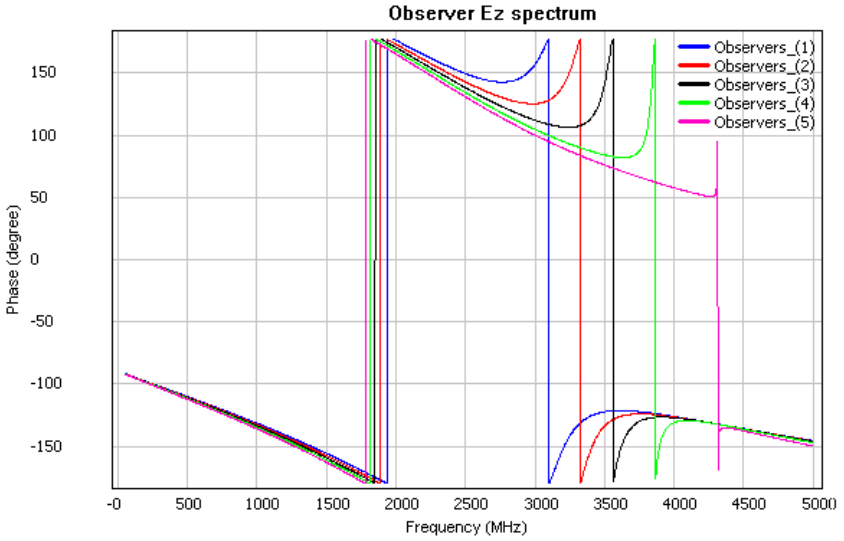
Curves – Observers



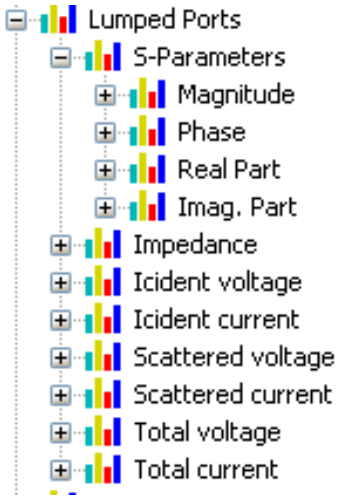
- xyz components of E/H fields
- Transient signals and their spectrums



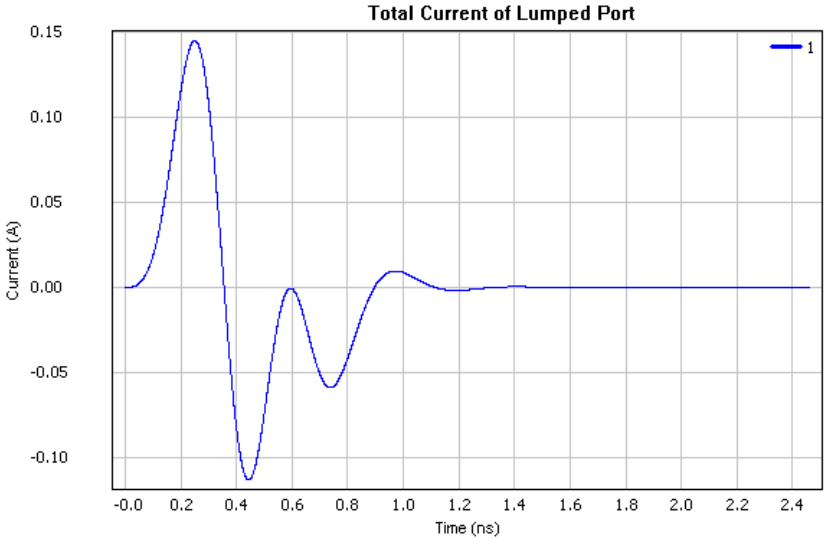


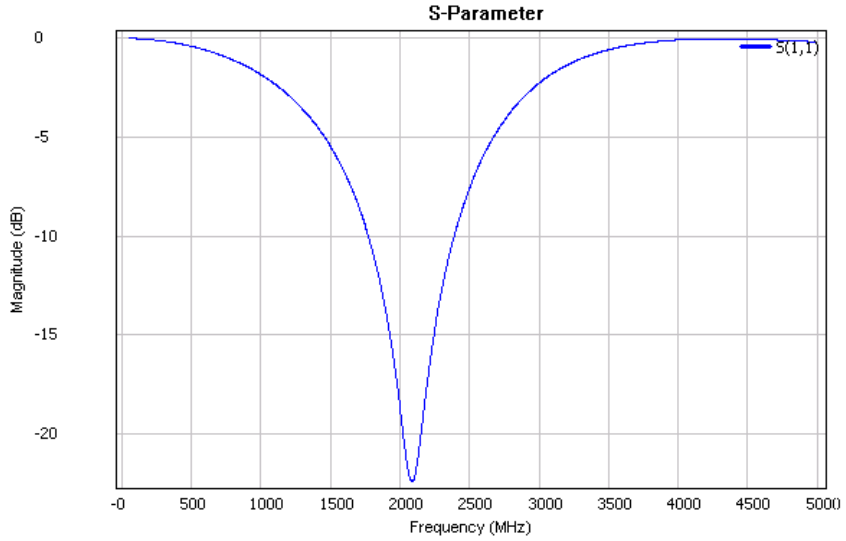


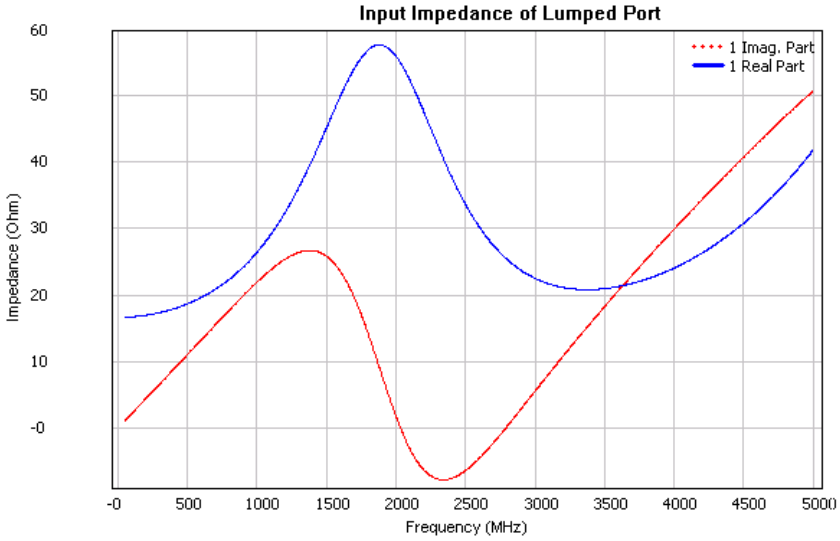
Curves – Lumped Ports



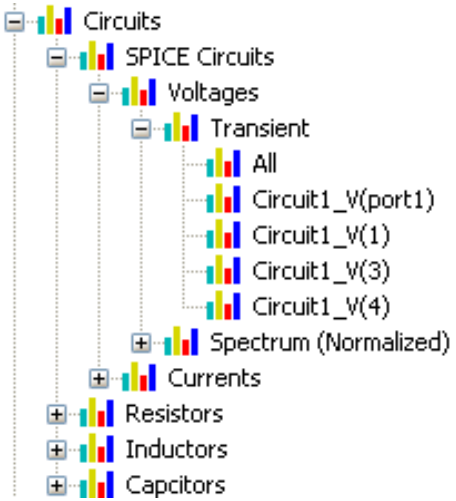
- S-Parameters
- Input impedance
- Incident, scattered, total voltage/current
- Both transient and spectrum



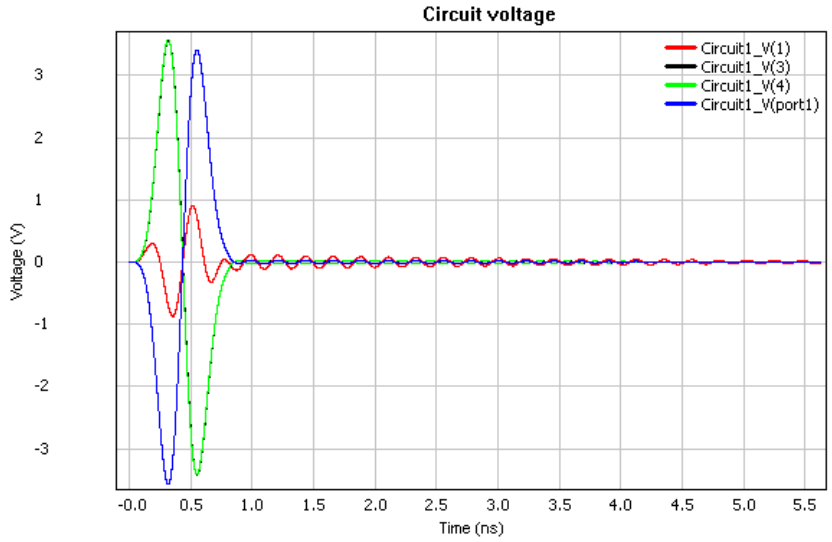


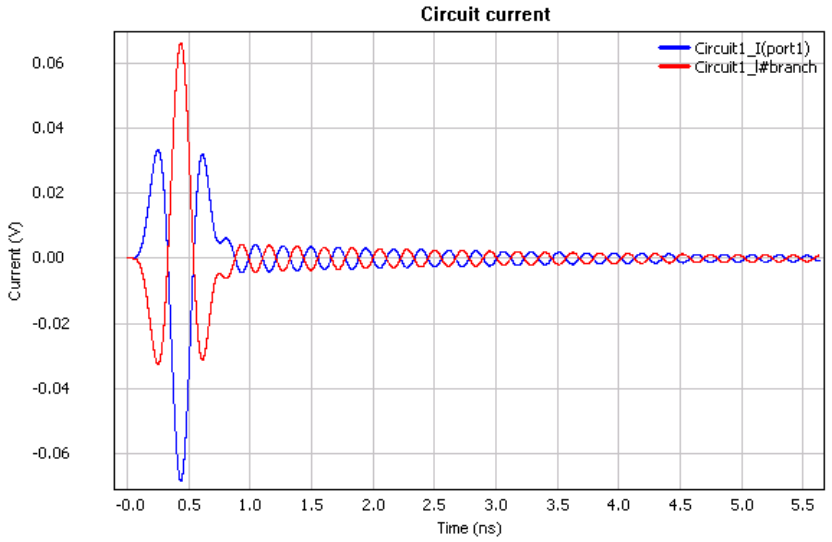


Curves – Circuits



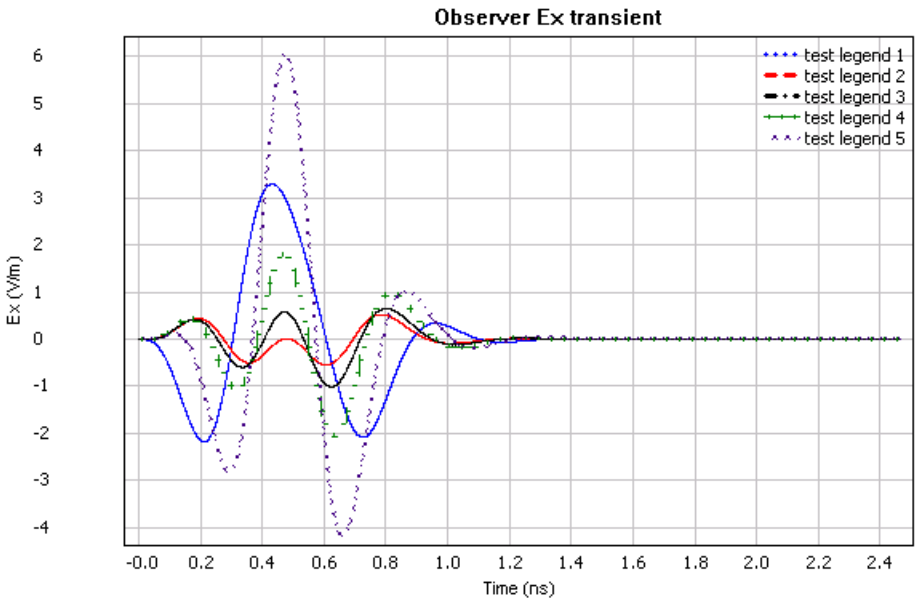
- All node voltages and branch currents of the circuit components will be calculated and displayed
- Both transient signals and their spectrum are calculated

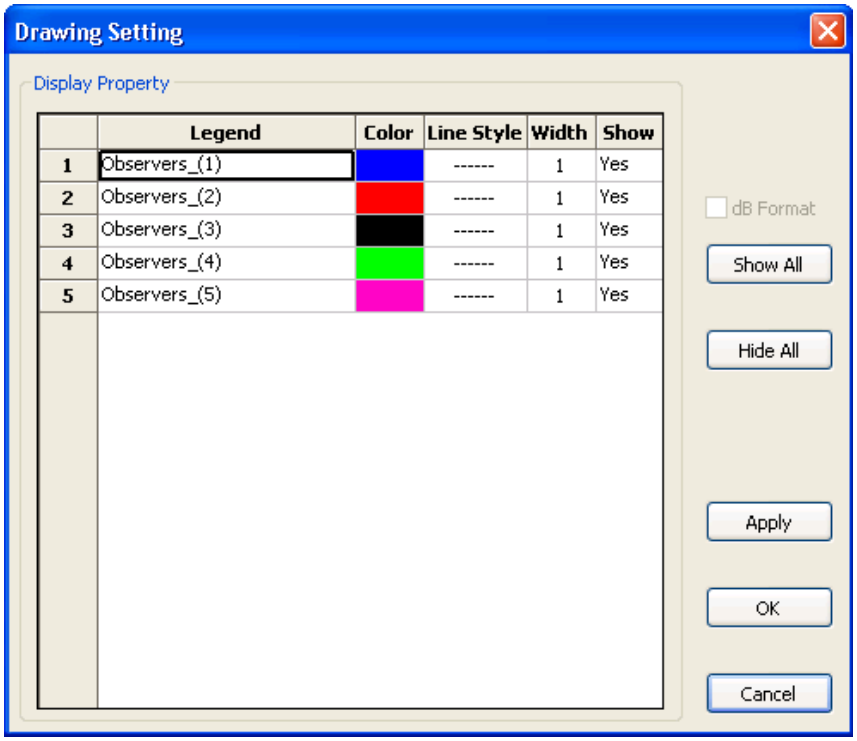




Curves – Additional Operations

- Legend
- Line color
- Line style
- Line width
- dB format
- Import or export curves
- Zoom in/out
- Save curve to images

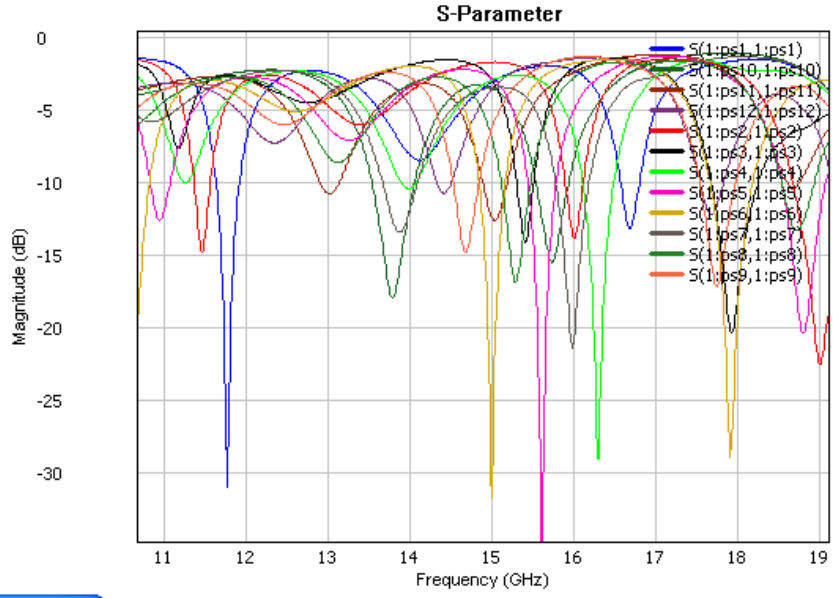


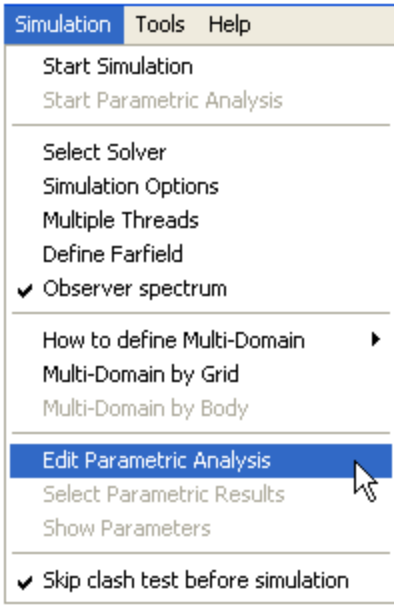


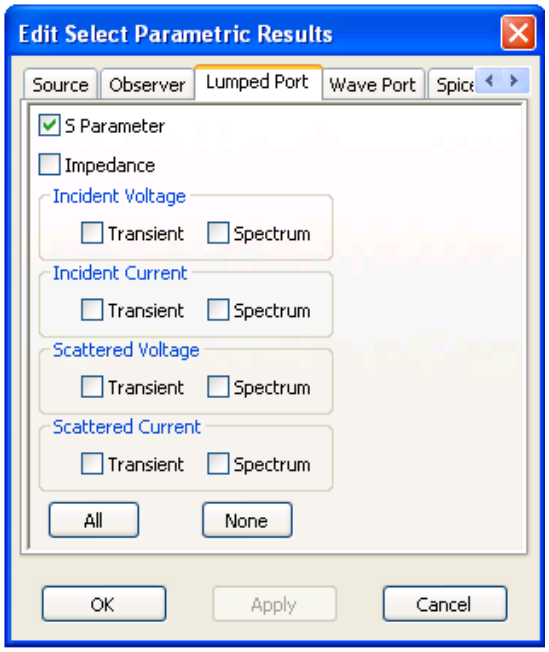
Additional Features

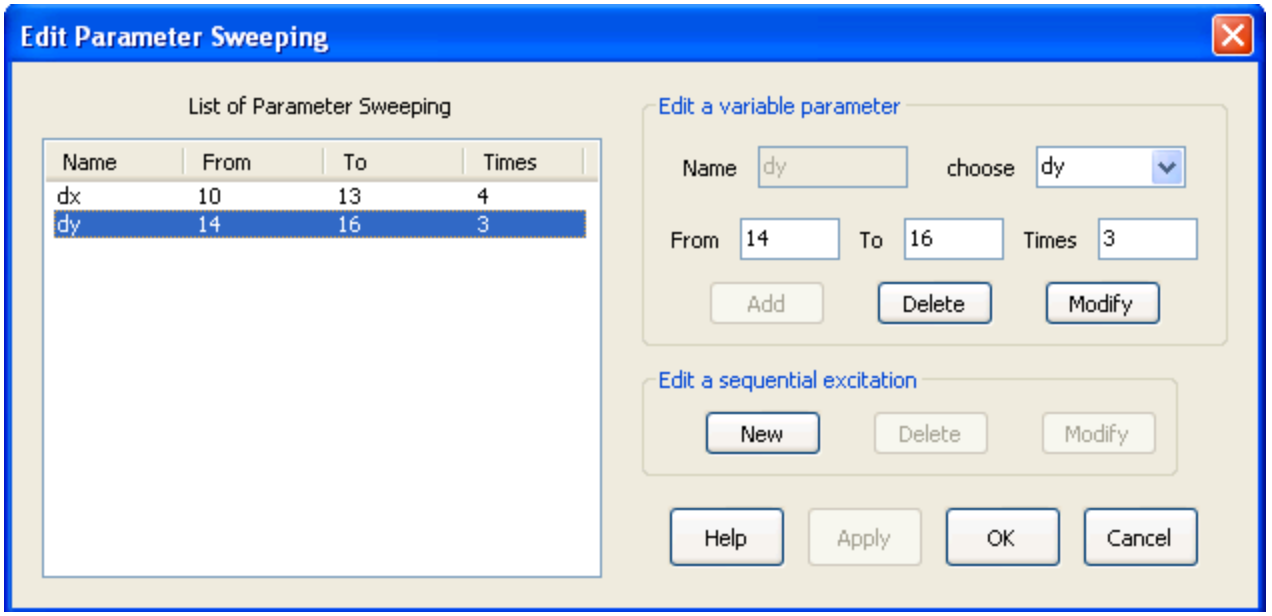
- Parametric Analysis
- Simulation Manager
- Result Comparison
- Pause and Resume
- Project Backup
- Multi-Threading
- Design Template
- Hybrid Explicit-Implicit Solvers
- Hybrid FDTD-SETD-FETD Solvers

Parametric Analysis

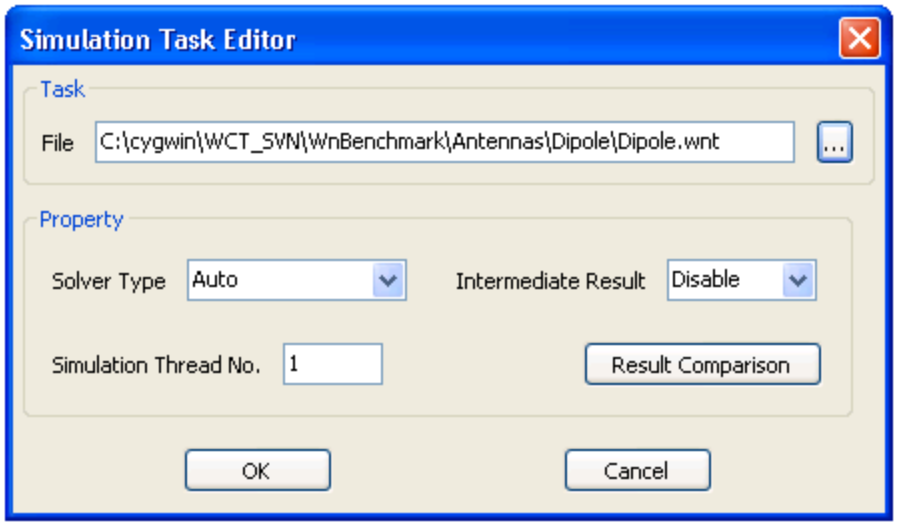


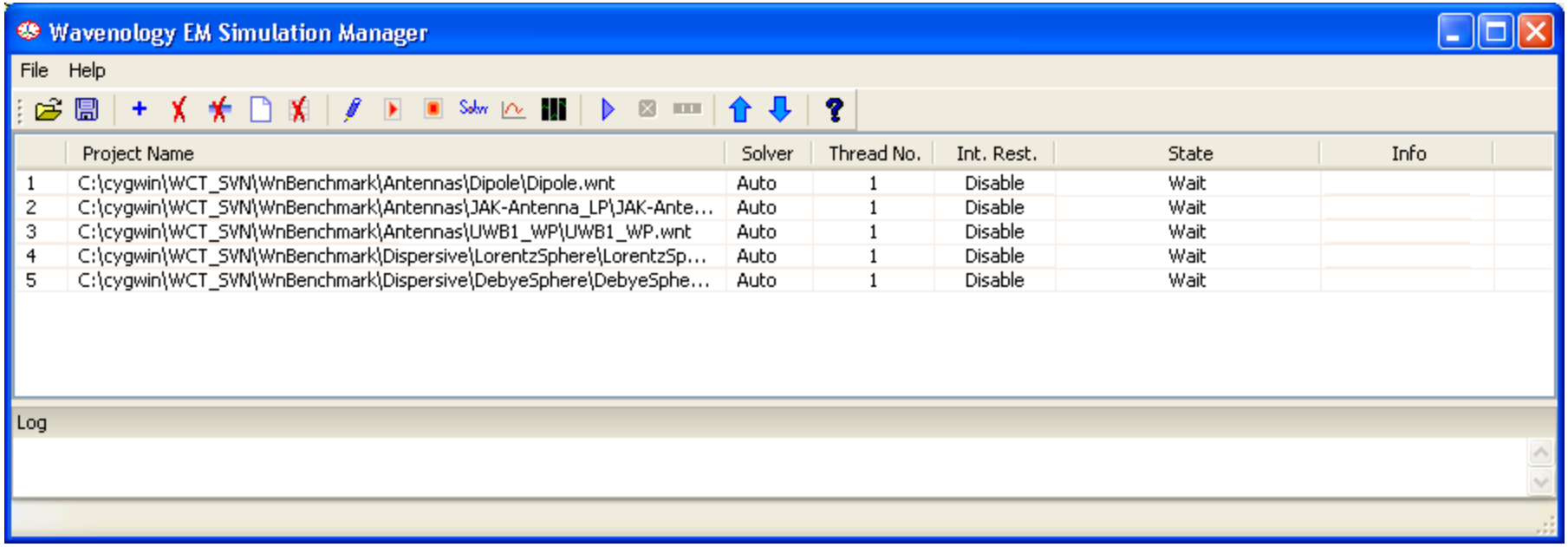






Simulation Manager





Result Comparison