Outline

- Overview
- Simulation Setup
- Model Construction
- Result Exploration
- Additional Features
- Summary
Integrated Design Environment

Main Menu

Tool Bars

Project Tree

Main Canvas

Log Window
View Tool Bars

- Zoom & Rotate
- Pre-defined views
- Select volume or surface
- Global or local coordinates

Cross section  ECT cells  Axis  Object info

Grid  Domains  Background  Source & Observer
Simulation Setup

- **Design**
  - Unit
  - Background
  - Boundary
  - Freq & Pulse
  - Mesh
  - Time

- **Sources**
  - Types
    - E / M Dipoles
    - E / M Polarized Plane Waves
    - Gaussian Beam
    - Bessel Beam
    - Near Field Ingestion
  - Time-Domain Signatures
    - BHW
    - Gaussian
    - Ricker
    - Delta
    - Rectangle
    - Sine
    - User Defined

- **Observers**

- **Ports**
  - Lumped Ports
  - Wave Ports

- **Circuits**
  - SPICE Circuits
  - Sub-Circuits
  - Internal Resistor
  - Internal Inductor
  - Internal Capacitor
  - Internal Diode
  - Internal Josephson Junction

- **Materials**
  - PEC
  - 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
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 an 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

Wave port setup

Name: WP1
Type: Source
Port Normal: Xmin

Size
- Enclose Selected Area Only
- Input Rectangle Bounding Box

Corner 1: x1: 0, y1: 0, z1: 0
Corner 2: x2: 30, y2: 20, z2: 20

Boundary Condition
- Left: AUTO
- Right: AUTO
- Top: AUTO
- Bottom: AUTO

Number of Mode: 1
Multiple Pins Setting: Pairs Definition
Mesh Control: Setting

Impedance Normalization (ohm): 50
Polarization Angle: 0

Excitation Pulse
- Use project pulse
- Use individual pulse
- Plot pulse
- Delay [ns]: 0
- Amplitude: 1

Help OK Cancel
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 created, 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 specifying 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.

![Toroidal Spiral Editor Menu](image)
Solids – Bondwires

Spline Bond Wire Editor

- Name: Body014
- Material: PEC

Transparency:
- 0

Path:
- (x0,y0,z0): 11.1868, 4.45052
- (x1,y1,z1): 67.0817, 1.25222

Height: 0.15

L1: 0.1

Height Direction: 0, 0, 0

Wire Cross Section:
- Circle Radius: 0.01

Terminal Shape:
- Start: Original
- End: Round

Help
OK
Cancel
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

Disassemble

Union

Subtract

Intersect
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
  - **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 sphere
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

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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

Diagram showing S-Parameter, Input Impedance, and Total Current of Lumped Port graphs.
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

Edit Select Parametric Results

Edit Parameter Sweeping

List of Parameter Sweeping

Edit a variable parameter

Edit a sequential excitation
Simulation Manager
Result Comparison