# **W**avenology EM

## Full Wave Transient Electromagnetic Field Solver
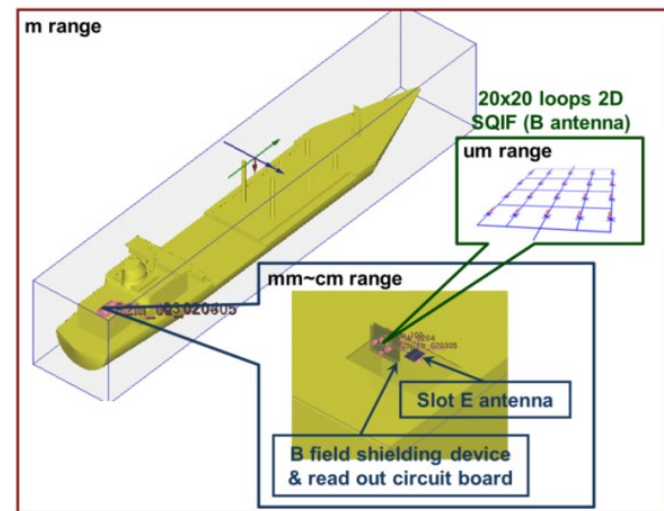
A typical multiscale problem which contains um-level circuit devices, mm~cm-level RF components and m-level platforms
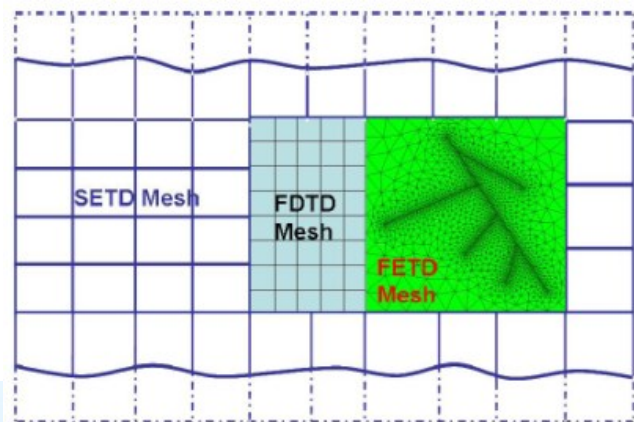


Hybridizing SETD, FDTD, FETD solvers using domain decomposition and discontinuous Galerkin techniques

# Hybrid Multiscale System-Level Simulator

*Wavenology EM* is a general-purpose 3D full-wave based field-circuit-particle co-simulation software package for the design of high-speed electronic circuits, smart antenna systems, non-linear quantum, RF/microwave and optical devices. *Wavenology EM* utilizes 3D full-wave domain decomposition and discontinuous Galerkin techniques combining the enlarged cell technique (ECT, an improved version of the conformal finite difference time-domain method (FDTD)), spectral element time-domain (SETD) method, and finite-element time-domain (FETD) method to simulate electromagnetic wave propagation and scattering behaviors in complex multiscale environments. It also combines SPICE circuit solver and particle in cell trajectory solver within the full-wave package so that the user can perform co-design of circuit controlled, reconfigurable transmitters and receivers, investigate system-level non-linear EMC/EMI issues and model novel quantum devices
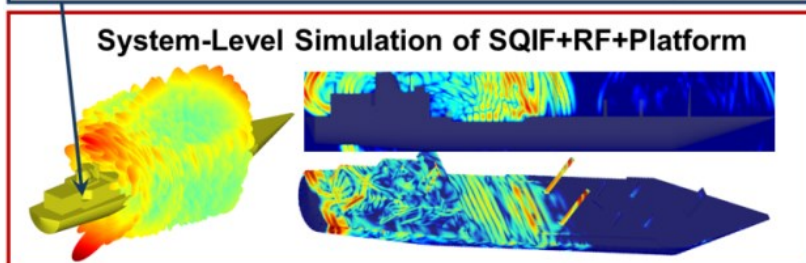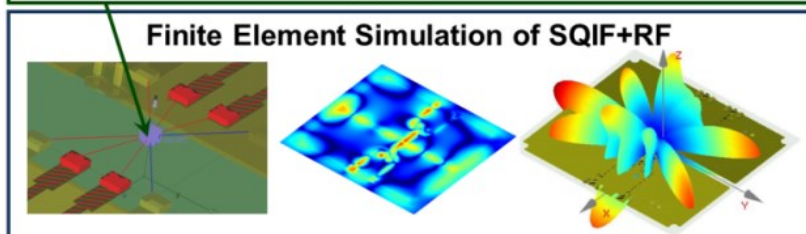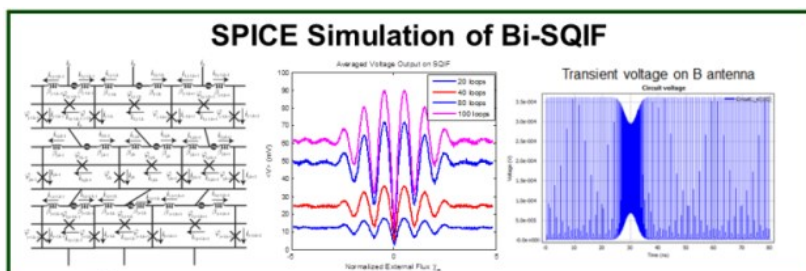


Enabling capabilities of system-level hybrid multiscale simulation

# Features

- Full-wave based field-circuit-particle co-simulation

- Domain decomposition with FDTD, SETD and FETD methods

- Ultra wideband simulation

- Frequency domain spectrum through advanced FFT of the transient results

- Material frequency dependence (i.e. dispersion) and losses

- Voxel material support for bioelectromagnetic applications

- Eigenmode solver for waveguides

- Various source types (plane waves, electric/magnetic dipoles, lumped voltage ports, wave ports, Gaussian, Bessel beams and near field ingestions)

- Multiple transient excitation pulses for the source including user-defined transient signals.

- Forward transient solver supporting time reversal imaging applications

- Support of SPICE sub-circuits in field-circuit co-simulations for smart antenna design and system-level EMC/EMI analysis

- Support particle in cell simulations, co-simulate of Maxwell's equations and Lorentz equation with relativity effect included

- Support the simulation of superconducting Josephson junction (JJ)

- Support large scale 1D and 2D superconducting quantum interference device (SQUID) array simulations in complex 3D environment
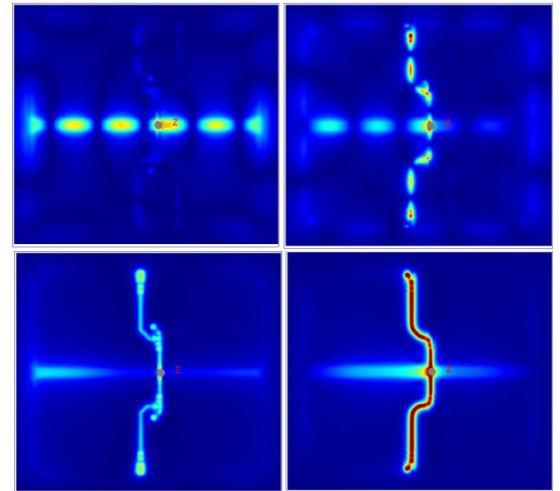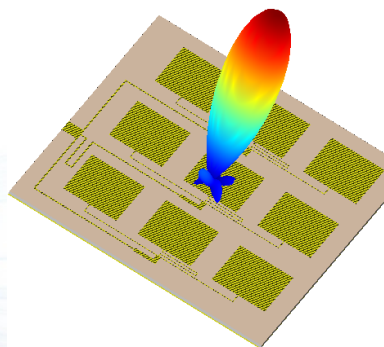


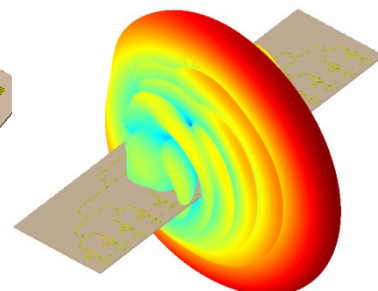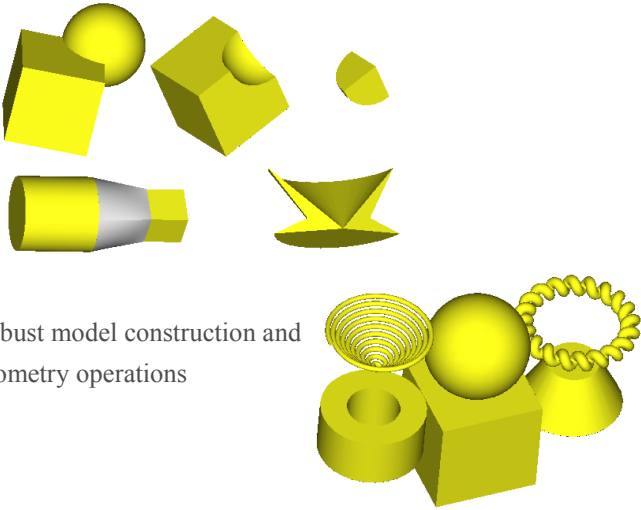Snapshot of current distribution on PCB
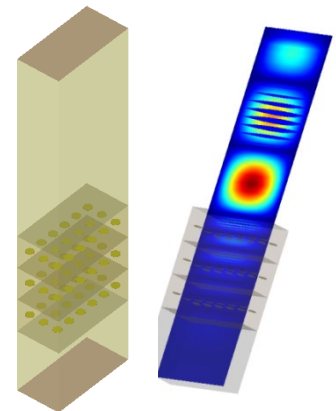


Photonic crystal filter
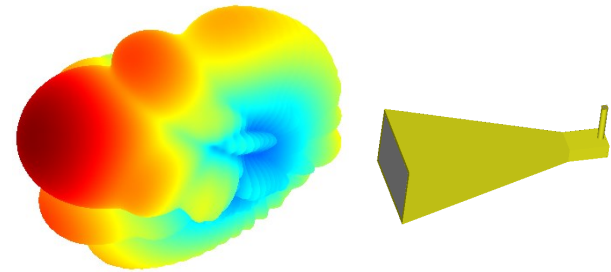


Horn antenna



Antenna Arrays



Wave Computation Technologies

Robust model construction and geometry operations

# Wavenology 3D Modeler

- Boolean operation on solids
- Global and local coordinate systems
- Parametric controlled model construction and scripting support
- Various 3D operations include translation, mirror, rotation, scale, intersection, union, etc.
- 2D and 3D curves and surfaces
- Geometry lofting and sweeping
- CAD model import and export
- Automatic structured / unstructured mesh generation
- Multiple Mesh Controls
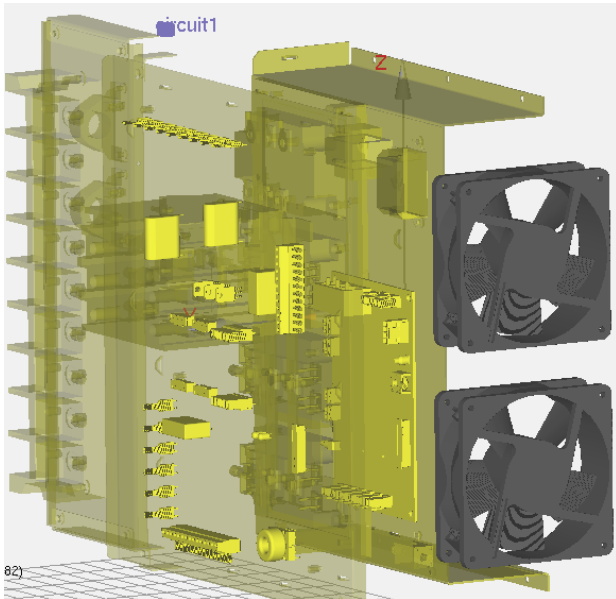


CAD model import
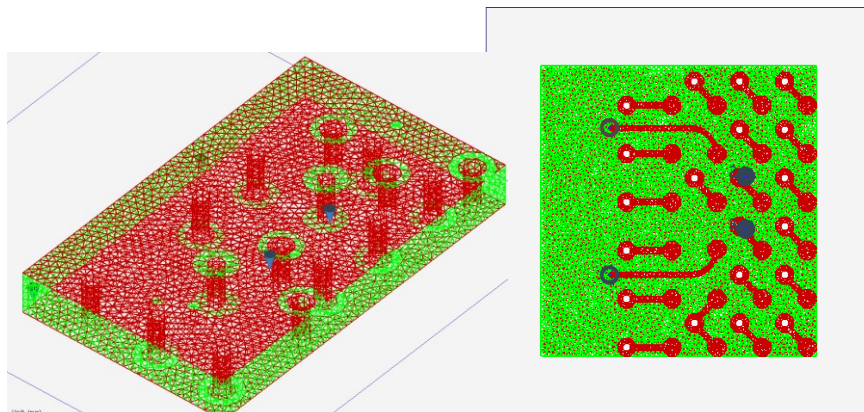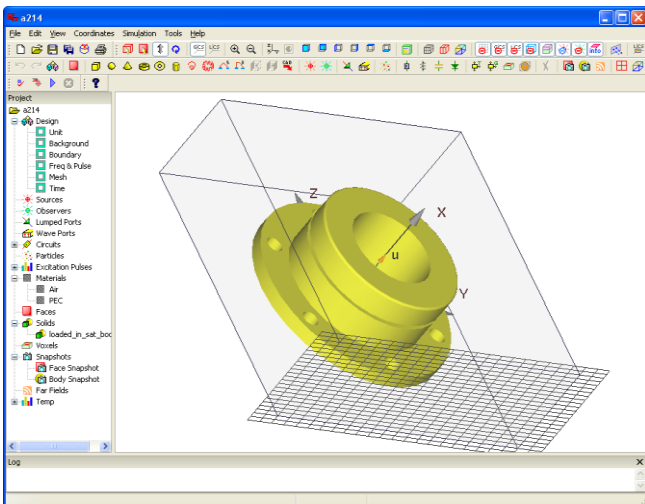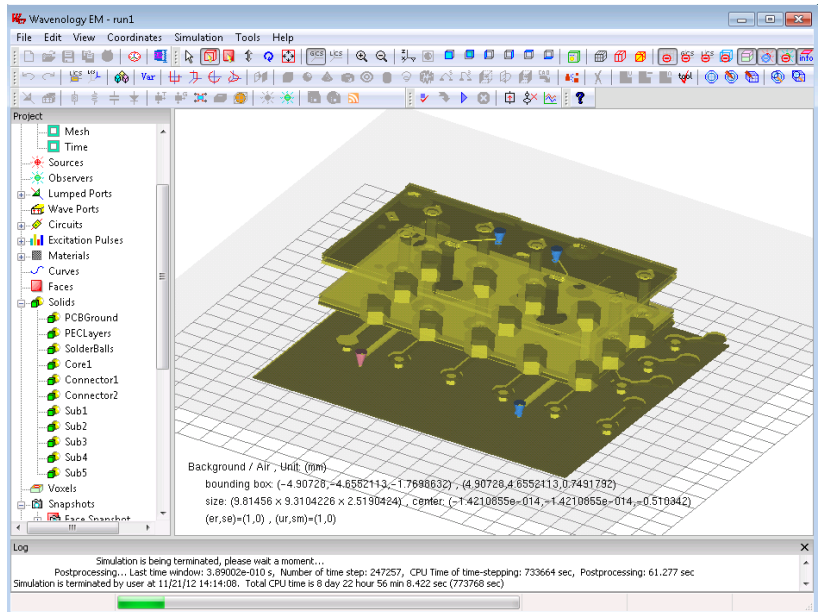




Unstructured finite element mesh

# Wavenology Result Explorer

- Full 3D output of electric and magnetic fields at any location

- Both transient and frequency-domain 3D current snapshots in volumes and on surfaces

- Transient waveforms and frequency-domain impulse responses at observation points

- Far-field calculation at multiple frequencies, along any direction, at any distance

- Far field polarization and time-domain waveform

- Output files compatible with Matlab

- Wave port mode and characteristic impedance calculation
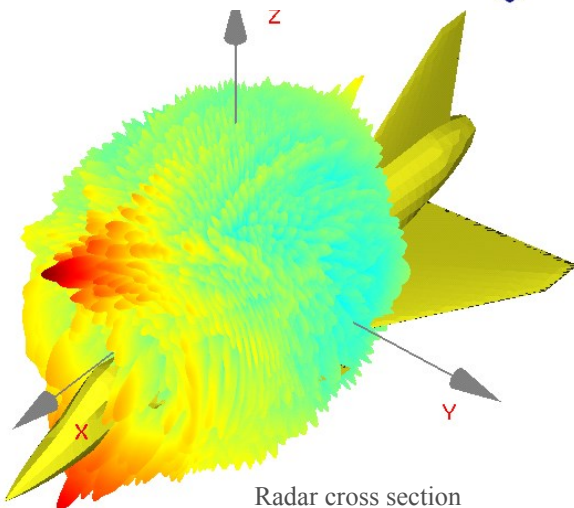
- S-parameter matrix and Y and Z matrices
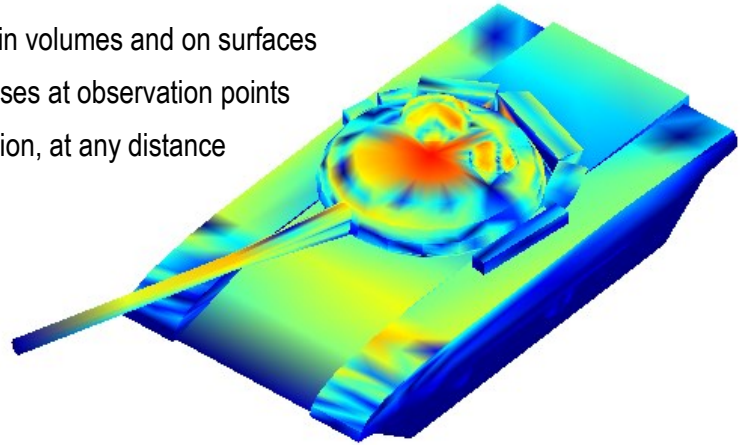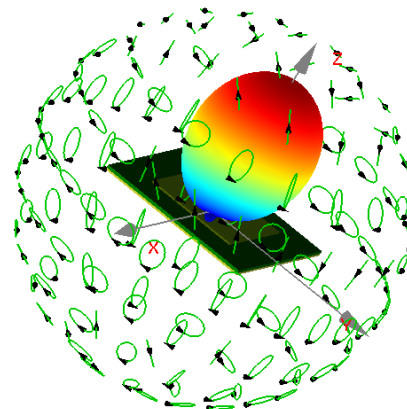


Current distribution on solids
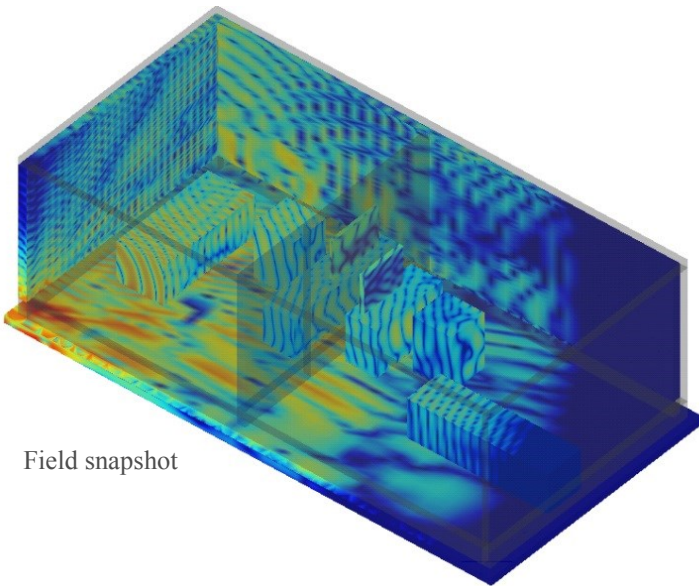


Field snapshot
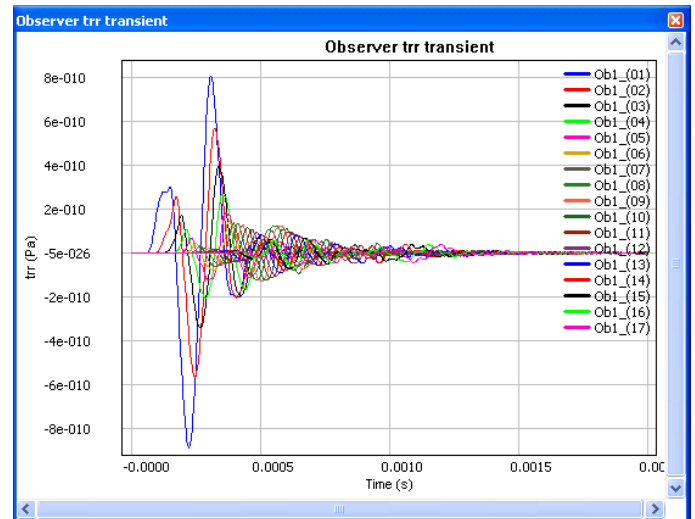


Transient signals at observation points



Radar cross section



Far field polarization

# Reconfigurable Tx / Rx Design

Reconfigurable transmitters (Tx) and receivers (Rx) comprises reconfigurable polarization, reconfigurable resonant frequency and reconfigurable radiation pattern. All of these applications involve circuit and field co-design, since a circuit controlled full wave results are necessary to check during the workflow. Wavenology EM provides an end-to-end solution for this type of design and prototyping with an interactive circuit-field coupling port that link the SPICE and EM field solver into the same full-wave based framework
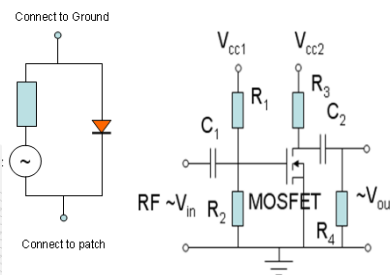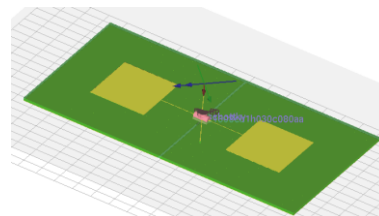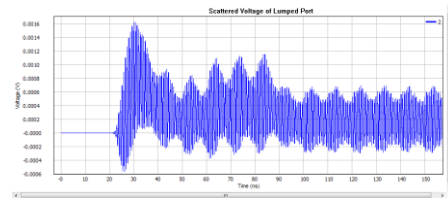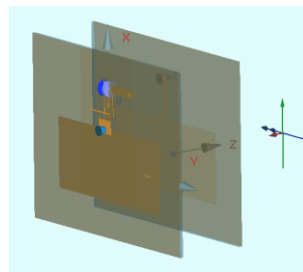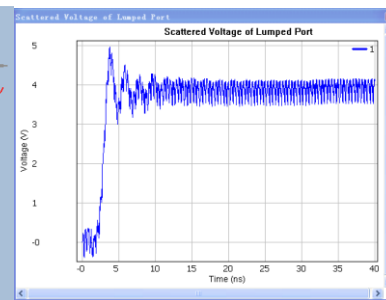
Wireless charging devices
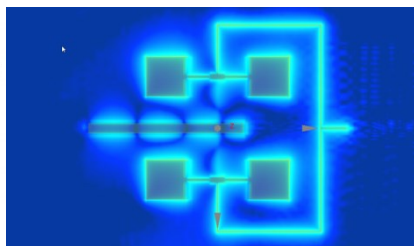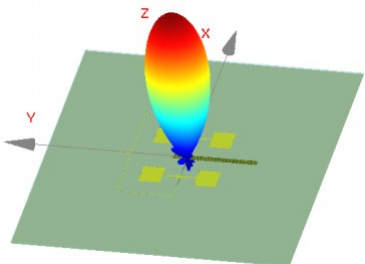
Reconfigurable polarization antenna
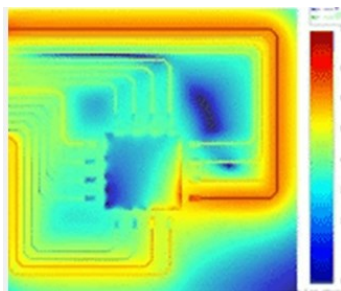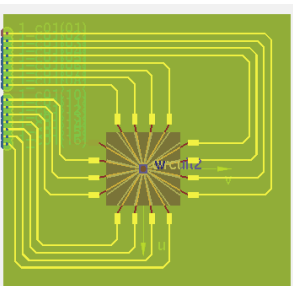
ESD analysis of IC+PCB
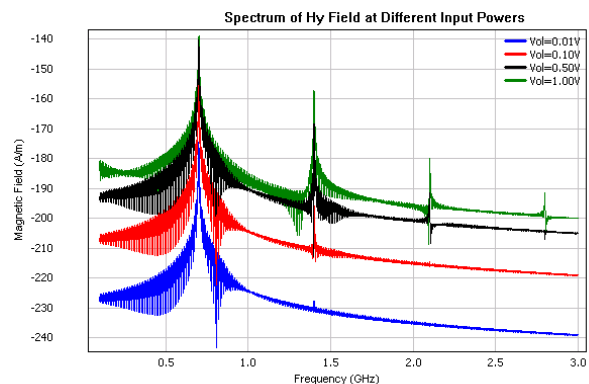
Harmonic balancing of 3D magnetic fields
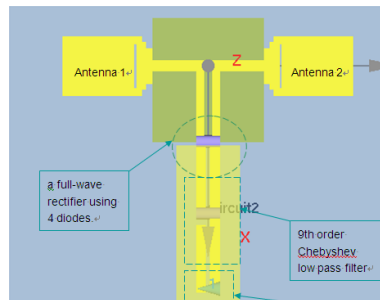
# Non-Linear EMC / EMI Analysis

Device and system level EMC/EMI testing can be very tedious and time consuming in labs for many engineering process. It would be nice to have a CAE tool that can model the system with configurable level of details and simulate the overall performance of the system withstanding in EM immunity and susceptibility. Non-linear harmonics, as well as the complexity of modeling the entire system are major challenges. Wavenology EM is enabling the engineers to combine IC+PCB+Platform into one single simulation environment for the EMC/EMI analysis.
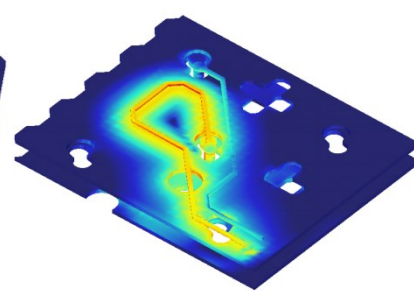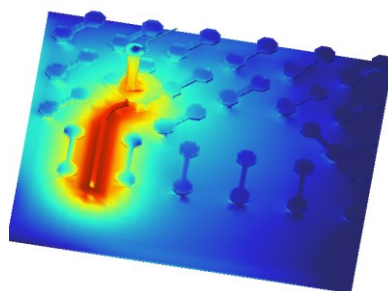
Crosstalk inside IC package

Electromagnetic resonance in long cavity
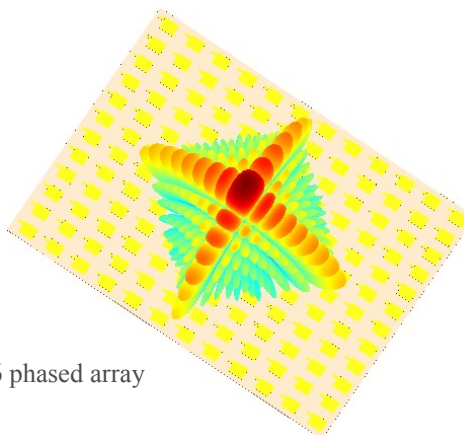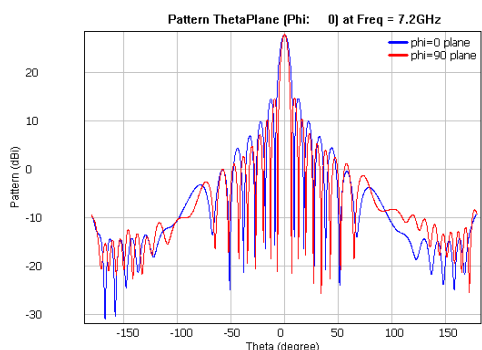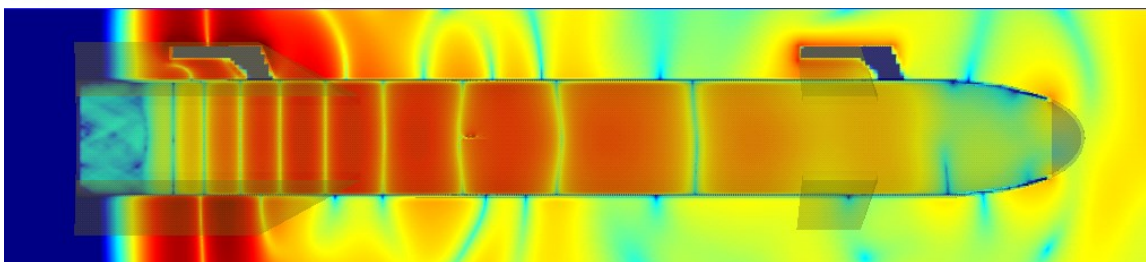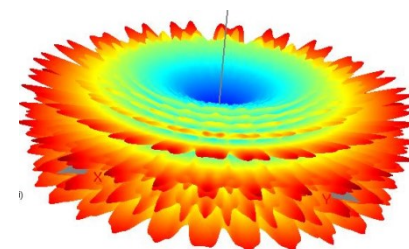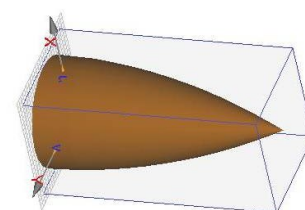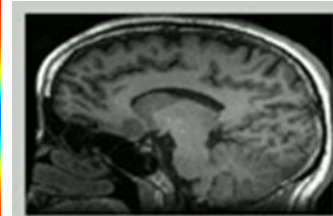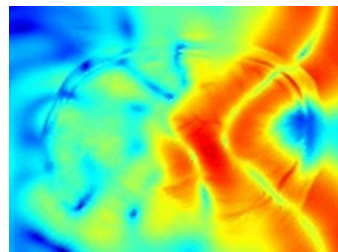




16x16 phased array



Radome

# Applications of Wavenology EM

## *Radio Frequency and Microwave Applications*

- Conventional wire, aperture, spiral, horn, and microstrip antennas

- Reconfigurable smart antennas, phased array and MIMO

- Bioelectromagnetic applications

- Transmitters and receivers for RFID applications

- Circulators, connectors, couplers, filters, and isolators

- Waveguides, microwave hyperthermia, RF radiation, MRI coils

## *Electronics Signal and Power Integrity*

- Capacitors, Inductors, Interconnects

- Wireless charging devices

- Power planes and ground planes

- Transformers, transitions, transmission lines, vias

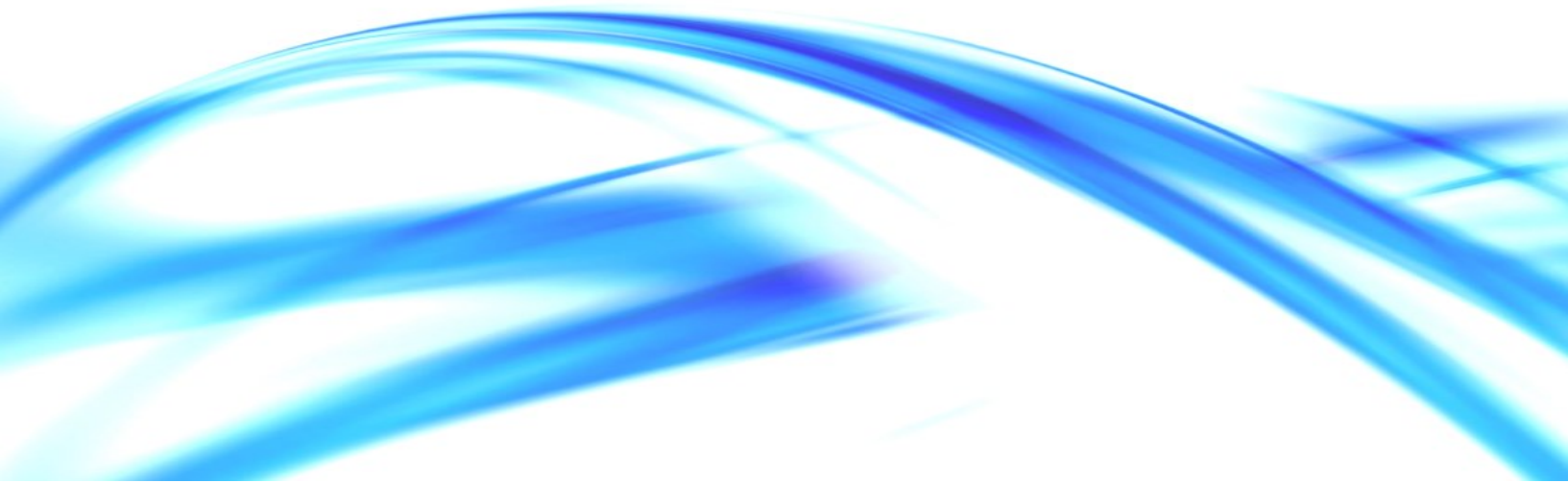- System-level non-linear EMC/EMI analysis

## *Photonics and Quantum Devices*

- Couplers, dielectric waveguides, gratings

- Optical fibers and resonators

- Photonic crystals, surface plasmons

- Memristors, SQUID and SQIF



EM pulse hit on human brain
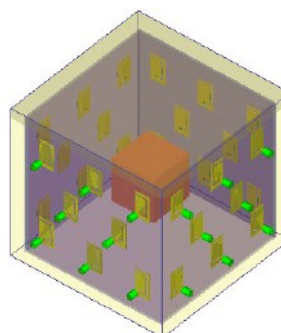


Time reversal imaging chamber design
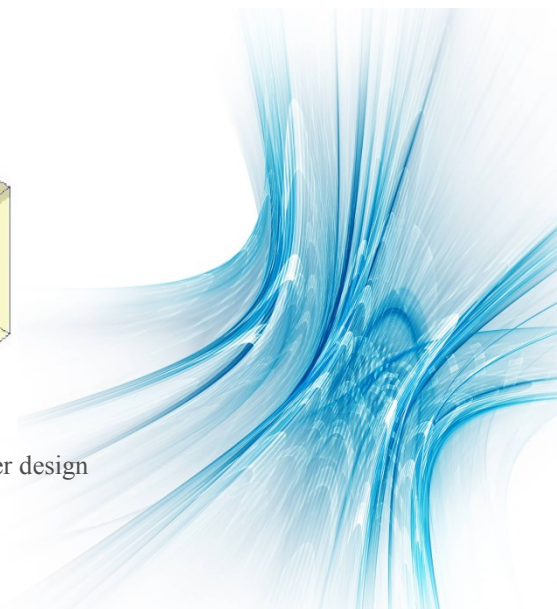
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