

MEFISTO-3D PRO™

3D Time Domain Electromagnetic Simulator

WHAT IS MEFISTO ?

MEFISTO is a **M**ulti-purpose **E**lectromagnetic **F**ield **S**imulation **T**ool. This full-wave volumetric time-domain field solver addresses the requirements of **design engineers, researchers and educators** working with RF to mm-wave analog and high-speed digital circuits, antennas, EMC/I, RF heating and processing, and many other applications of electromagnetic fields and waves. It was designed from the start to operate in the PC environment under Windows XP and higher op. systems. It employs high-performance Transmission Line Matrix (TLM) numerical engines that provide second-order accuracy with superior dispersion properties. TLM uses a robust scattering algorithm rather than finite differences to solve Maxwell's equations. SPICE and MATLAB models of devices and circuits can be embedded seamlessly into the 3D TLM field model, and MATLAB optimization and neural network toolboxes can be coupled with MEFISTO for advanced modeling and optimal design tasks.

MEFISTO solves and visualizes fields and waves that depend on three space dimensions and time. It has an easy-to-use, fully parameterized interface, powerful co- and post-processing, and can be controlled externally.

MEFISTO has the functionality of a

- time domain reflectometer,
- microwave vector network analyzer,
- antenna test range,
- spectrum analyzer,
- signal processor, and
- video system.

Note: **MEFISTO** can display results while generating data during a simulation. You see the solution evolve at a speed suitable for human observation. This allows you to monitor all aspects of the simulation and to intervene at any stage! Movies can be generated automatically during simulations.

DESIGNERS, PRACTITIONERS:

MEFISTO is a complete electromagnetic design tool and virtual test laboratory on a PC. Model new concepts and ideas, explore technical feasibility, and visualize physical behavior. Include and minimize the effects of packaging, interconnects, cross-talk, and parasitic coupling in your design. Create full-wave models for embedding in a circuit simulator or SPICE. Understand the electromagnetic field effects associated with high speed and high frequency electronic signals. Pinpoint and diagnose the cause of high-frequency parasitic effects. Demonstrate to your manager, colleague, and client how and why your design works. Seeing is believing!

RESEARCHERS:

MEFISTO is a superb tool for electromagnetic field research as well as for computational electromagnetics. Its extensive sampling, processing, and display features allow you to conduct virtually any imaginable electromagnetic experiment and to explore the characteristics of time and space discrete field models.

EDUCATORS :

Enrich your teaching through live field simulations and virtual experimentation. Project **MEFISTO** in class, embed it in a PowerPoint or HTML presentation, or create inspiring movies. Install it on your lab computers. **MEFISTO** is an educational tool *par excellence*. Inquire about special discounts to educators and students.

SUMMARY OF MEFISTO FEATURES

MEFISTO simulators offer unprecedented flexibility, transparency, and user interactivity. They have the look and feel of typical Windows applications with standard editing features and file operations. **MEFISTO** allows observation of field propagation and interaction with boundaries, materials, and devices, and allows intervention in the simulation at any time. Since **MEFISTO** solves Maxwell's equations in time and space, the solution is life-like; both transient and time-harmonic fields are handled. Numerical engines are optimized for high speed.

GEOMETRIC MODELER:

Parameterized 2D and 3D structure editor (metric and imperial units); boundaries with rectangular, elliptical and polygon cross-sections; cylindrical and pyramidal extrusions; cuboid and cylindrical sub-volumes of materials; Boolean operations on overlapping and contiguous elements. Customized library of parameterized objects.

Cartesian projection, zoom, and rotating 3D view of objects; editable object attributes (dimensions, color, electromagnetic properties); display/hide option for boundaries, materials, sources, probes, and animation surfaces; a window showing the tree of objects facilitates selection and editing their attributes and to change their position in the object hierarchy. Objects can be grouped and nested.

*Geometry, electromagnetic property and simulation data are stored in electronic data files. In addition, editable text files containing the geometry, electromagnetic property information and simulation control data can be imported and exported in text format. Typical applications of the text-file interface include, but are not limited to, the creation and use of element libraries, the generation of complicated structures with user-written programs, and optimization and/or synthesis of structures with external programs. This text-based interface represents a gateway between **MEFISTO** and external programs (MATLAB, SPICE, SCILAB, EXCEL, etc).*

MESHING AND DISCRETIZATION:

Automatic rectangular meshing of 2D structures; automatic cuboid meshing of 3D structures; user-controlled mesh size and center of meshing; smooth boundary fitting through local mesh modification.

For 2D modeling: Choice of three numerical engines: 2D shunt node, 2D series node, 3D GSCN node.

For 3D modeling: Optimized 3D SCN and GSCN TLM engine. (SCN: Symmetrical Condensed Node; GSCN: Generalized Symmetrical Condensed Node).

BOUNDARIES:

Non-Dispersive Boundaries: Perfect electric (PEC) and magnetic (PMC) walls, even and odd symmetry walls, lossy walls, and TEM absorbing walls.

Frequency-Dispersive Boundaries: Lossy conductors with wideband skin effect, superconducting nonlinear boundaries, convolution (Johns) boundaries, perfectly matched wideband waveguide loads, absorbing layers.

MATERIALS AND METAMATERIALS WITH NEGATIVE REFRACTIVE INDEX:

Homogeneous and inhomogeneous electric and magnetic materials with electric and magnetic losses. Isotropic and anisotropic (tensor) permittivity, permeability, electric and magnetic conductivity. Negative ϵ & μ .

LUMPED ELEMENTS AND DEVICES:

Varactor and active diode models, real-time embedding of SPICE circuits and MATLAB functions into 2D and 3D field space (resistors, capacitors, inductors, diodes, transistors and general 1-and 2-port circuits).

SOURCES AND EXCITATION:

Spatial Source Distributions: Point sources, modal sources, provision for boundary and volume template excitations, electric and magnetic field component sources, and matched and hard sources.

Source Waveforms: Impulse, step, Gaussian step and pulse, and sinusoidal waveforms, Gaussian modulated sine and cosine excitations, NEMP waveforms, user-defined waveforms specified in the form of a text file.

An arbitrary number of independent sources with different spatial distributions, waveforms, and phase angles can be implemented simultaneously.

MORE MEFISTO FEATURES

DATA AND FIELD DISPLAY MODES:

3D wire mesh, 3D vector, 2D and 3D color map, and 2D and 3D color contour dynamic visualization of fields, surface currents, and dissipated power density in space (instantaneous and maximum values); dynamic time and frequency graphs of fields, voltages, fluxes and power; magnitude/phase and Smith chart display of complex S-parameters. False color scale with user-defined scaling factor for field, power and SAR displays. Linear and log scale color scales. A delay factor can be specified by the user to slow down the field animation speed for optimal human observation in very fast computers. Update intervals for 2D and 3D can be set by the user

Large font option suitable for full screen display and LCD projection of graphs, precision measurement cursor with coordinate display and option to slide along the displayed trace using the arrow keys. Output from several probes can be displayed simultaneously and compared in a single Analyzer window. Graphs and field maps can be exported in ASCII and bitmap file formats for further processing with external programs; field maps and graphs can be printed with high resolution. All graphs can be custom formatted, copied to the clipboard, and pasted into Windows applications. The content of Animator, Analyzer and Johns Windows can be automatically captured to files for the preparation of movies (formats supported: bmp, gif, png, dib, jpeg and tiff).

WIZARDS:

Conductivity wizard: Computes the conductivity of a material when the loss tangent is given at one frequency.

Microstrip wizard: Computes the parameters of microstrip lines and of their equivalent parallel-plate waveguide model which is a two-dimensional approximation of microstrip.

Waveguide wizard: Computes the cutoff frequency, guided wavelength and dispersive wave impedance of TE_{n0} modes in rectangular waveguides.

Amplifier design wizard: Incorporates all standard formulas for linear transistor amplifier design, matching conditions for unilateral and bilateral design, stability, gain, noise circle data, and other relevant parameters.

E-PLANE WAVEGUIDE FREQUENCY MAPPING:

This feature enables modeling of 3D E-plane waveguide problems (involving only TE_{1n} modes) by solving a two-dimensional TEM model and then performing a nonlinear frequency mapping. This mapping transforms the frequency "zero" into the cutoff frequency of the TE_{1n} mode in a rectangular waveguide of width "a".

MULTI-THREADED ARCHITECTURE:

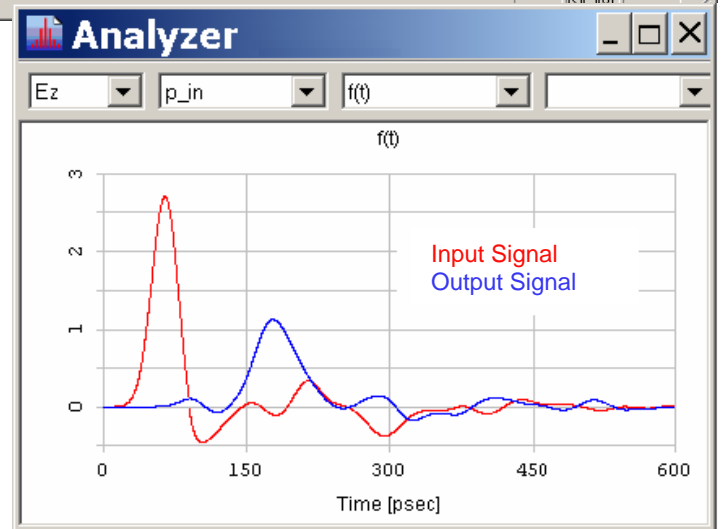
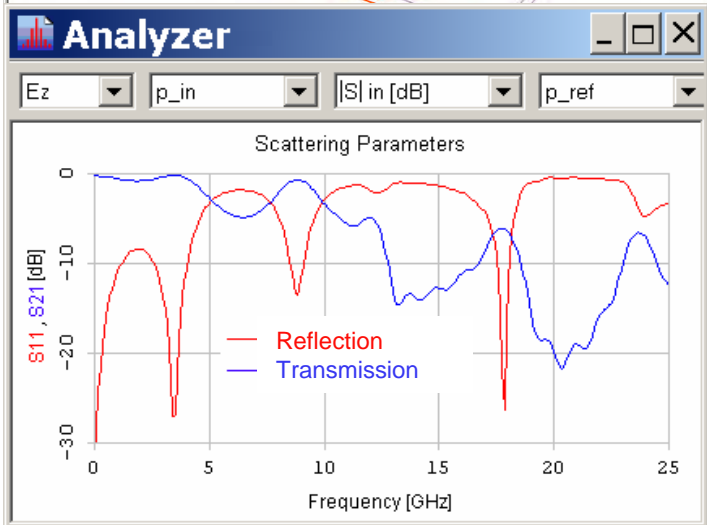
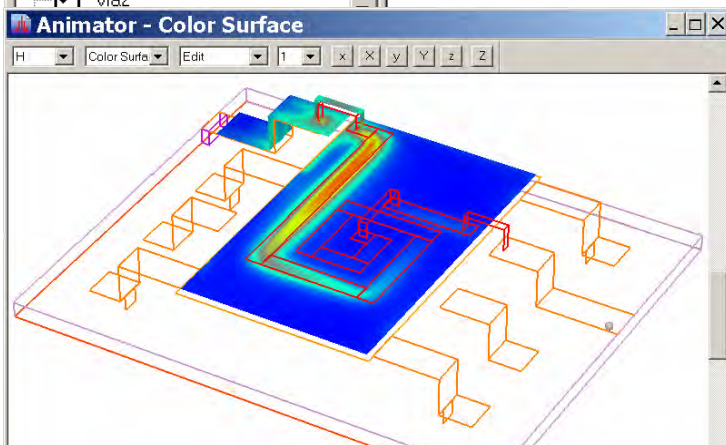
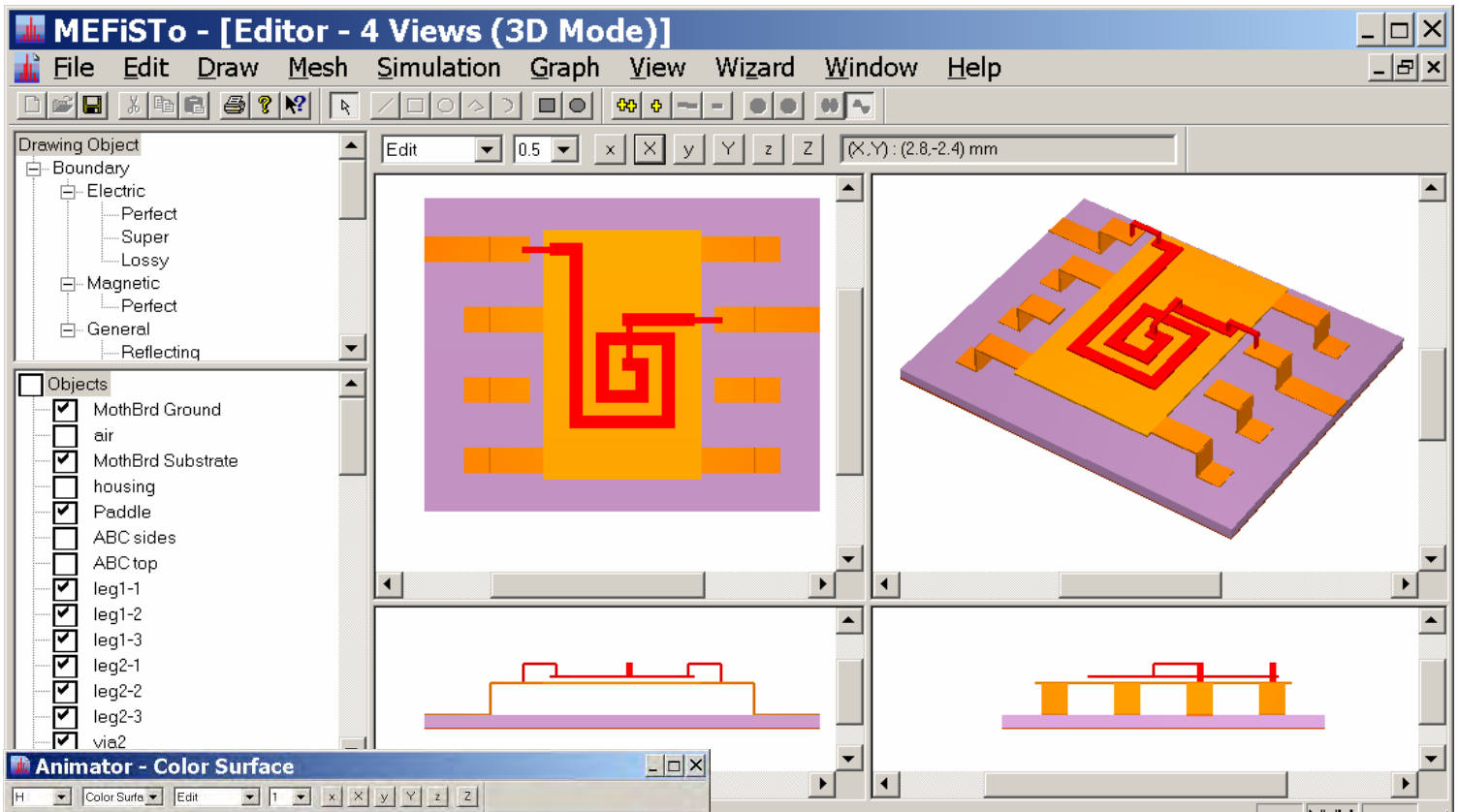
MEFISTO takes full advantage of multiple processor computers by virtue of its multi-thread capability. It allows the user to specify the **number of parallel execution threads** if the program runs on a multiple processor machine, with impressive gains in execution speed. On a single processor machine, multiple threads are simply executed in a time-sharing fashion.

BATCH MODE :

MEFISTO can execute analysis tasks in batch mode. Combined with externally controlled data import and export, this feature enables optimization, for example using the MATLAB optimization and neural network tool boxes.

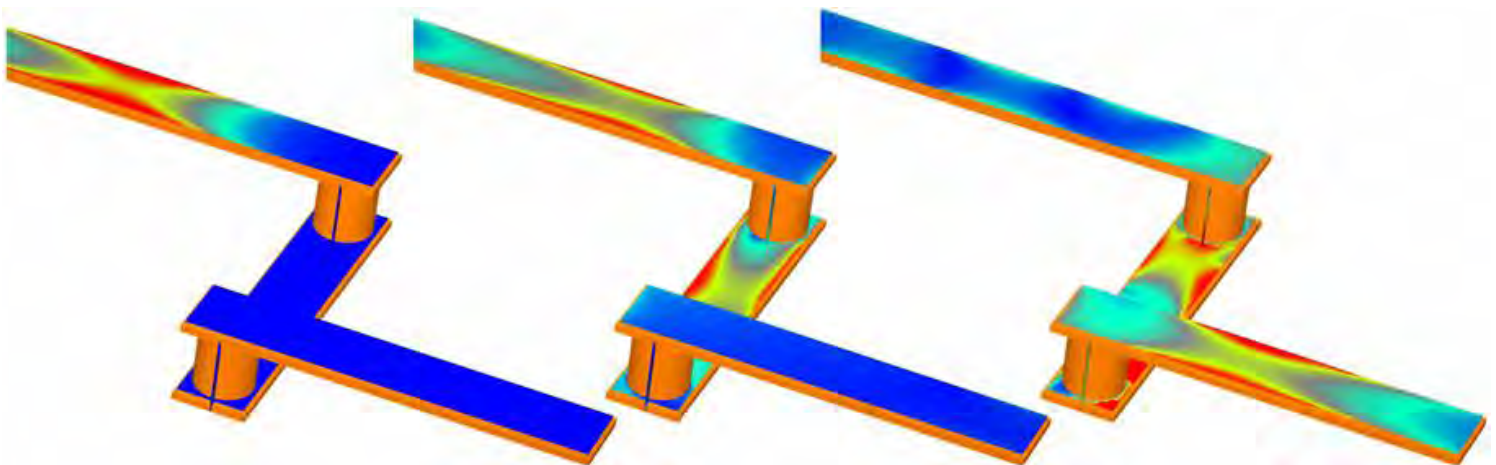
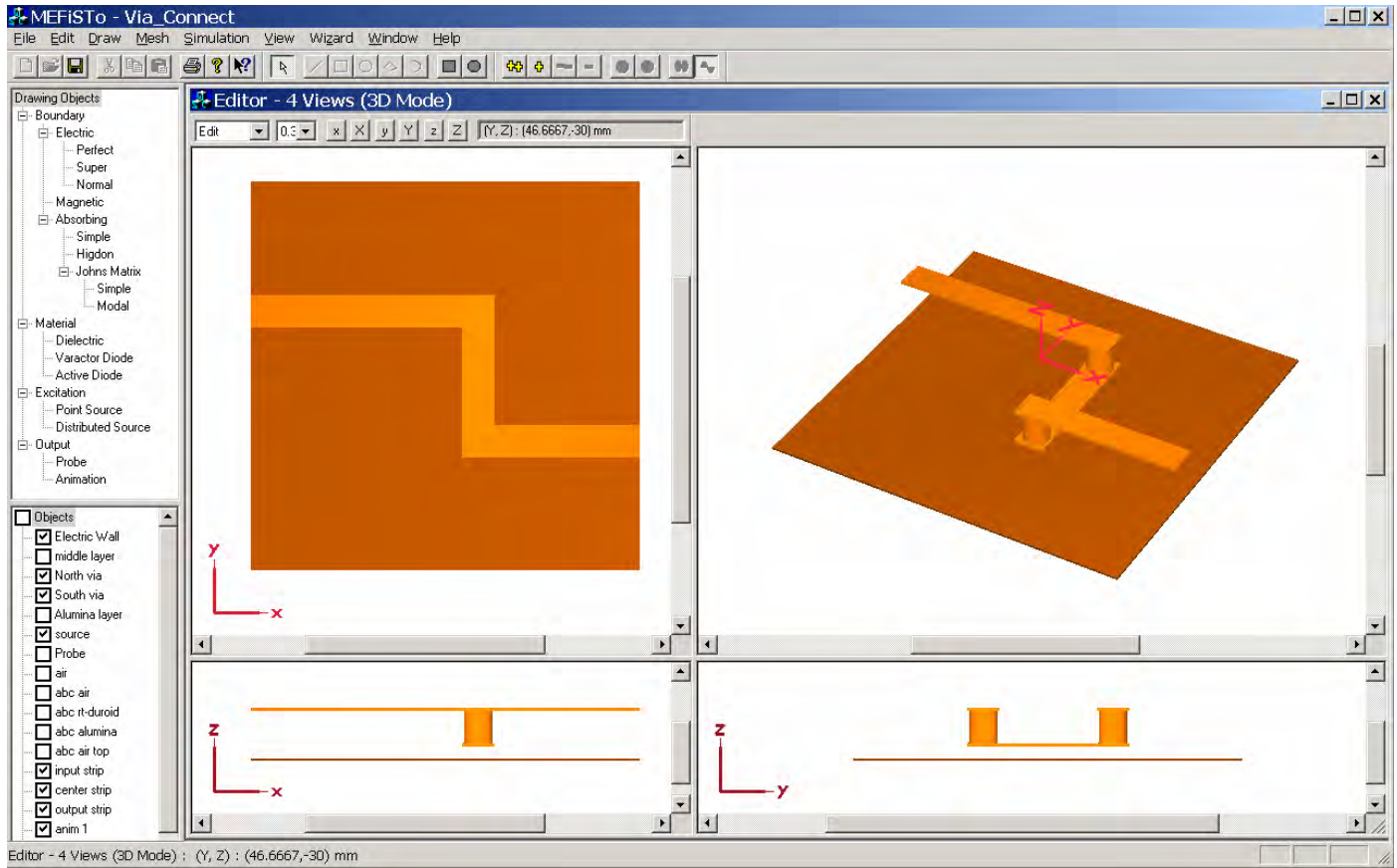
OTHER OUTSTANDING FEATURES:

- Discrete Fourier transform with user-definable time window in co-processing and post-processing mode;
- Post-processing module for accelerated analysis of high-Q structures;
- Frequency domain near-to-far field transformation;
- Time domain near-to-far field transformation;
- Singularity correction at sharp metal edges;
- Partitioning of large structures using time domain diakoptics and discrete convolution;
- Field modeling backward in time;
- Single time steps forward and backward in time.
- 3D antenna radiation pattern.



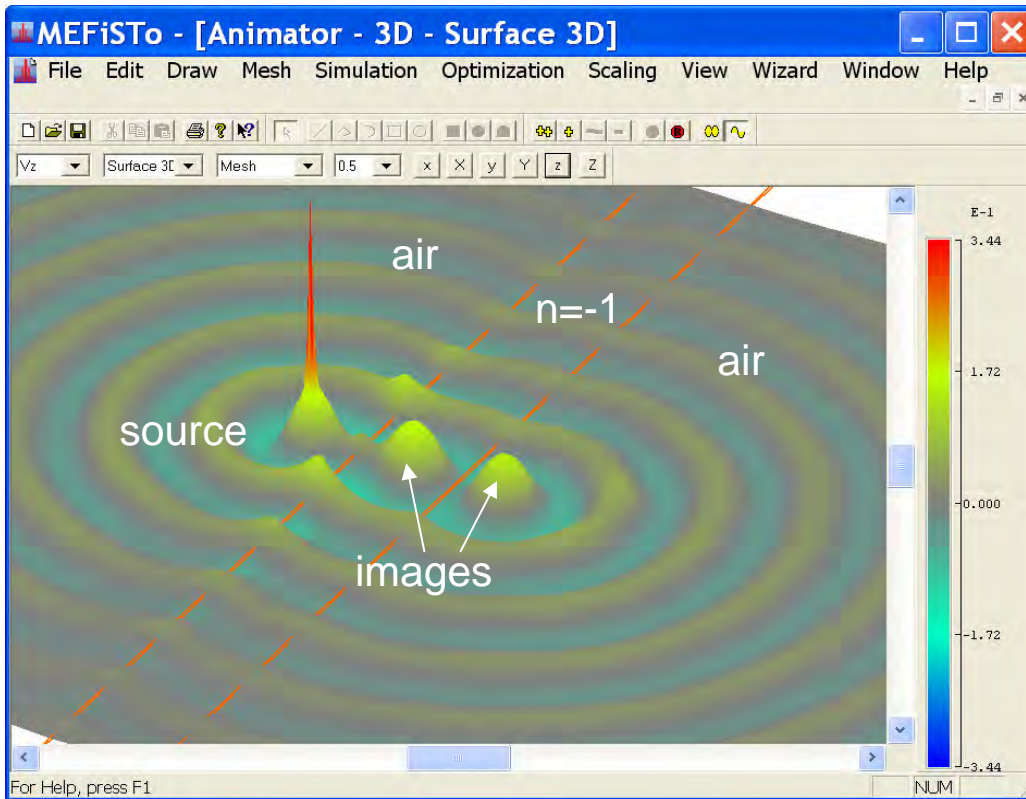
The main editor window of **MEFISTo** shows the geometry of a microstrip inductor in a SOIC-8 plastic package, including its interconnects. The lower pictures show a snapshot of the current density on the paddle in response to a Gaussian excitation, the transient input and output signals, and the scattering parameters from 0 to 25 GHz. All data are generated in a single computer run and visualized dynamically during the simulation.

CURRENT DENSITY IN MULTI-LAYER CIRCUIT BOARD



The main window of MEFiSTo is showing the editor window with the geometry of a via interconnect. The lower three pictures show the current density in the top surface of the strip conductors before, during, and after the scattering of a Gaussian pulse. The color scales are different in the three plots to properly resolve the respective current densities in the structure. The concentration of the current at the edges of the strip conductors is also clearly visible.

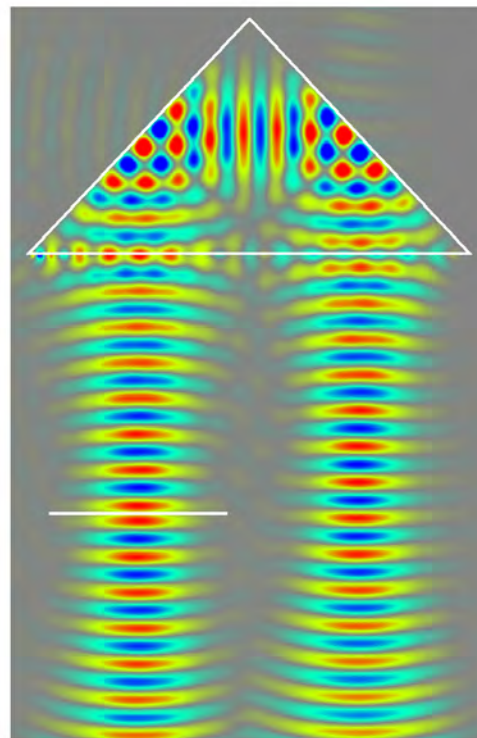
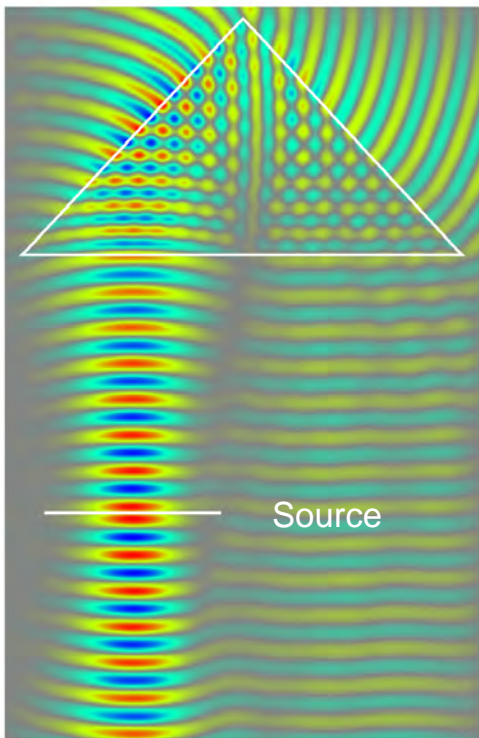
MODELING OF METAMATERIALS



METAMATERIALS WITH NEGATIVE REFRACTIVE INDEX

Negative refraction enables sub-wavelength focusing in Pendry's Perfect Lens: a slab of metamaterial with a refractive index of -1 creates high-resolution images of a point source both inside and outside the slab.

MEFiSTo-3D Pro can visualize not only the steady-state of the fields, but also their transient evolution and the formation of plasmon-like resonances, thus providing insight into the physics of the metamaterial.



Gaussian Beam refracted by prisms made of regular material (left) and of metamaterial (right).

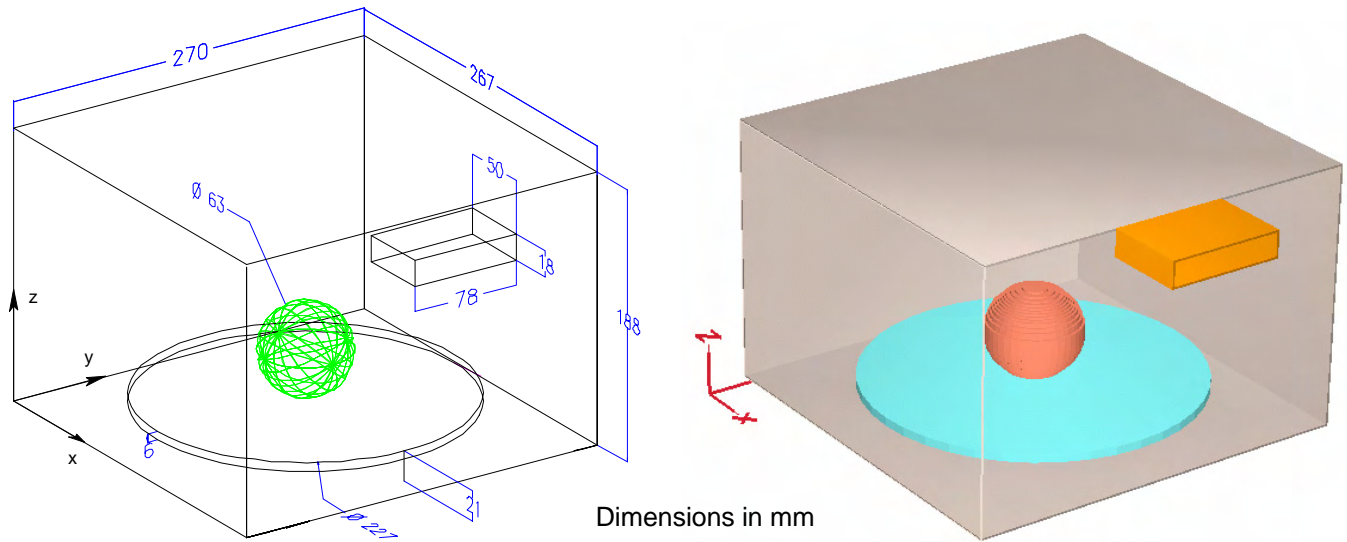
Left: Regular Prism
 $\epsilon_r = \mu_r = n = +\sqrt{2}$

Right: Metamaterial Prism
 $\epsilon_r = \mu_r = n = -1$

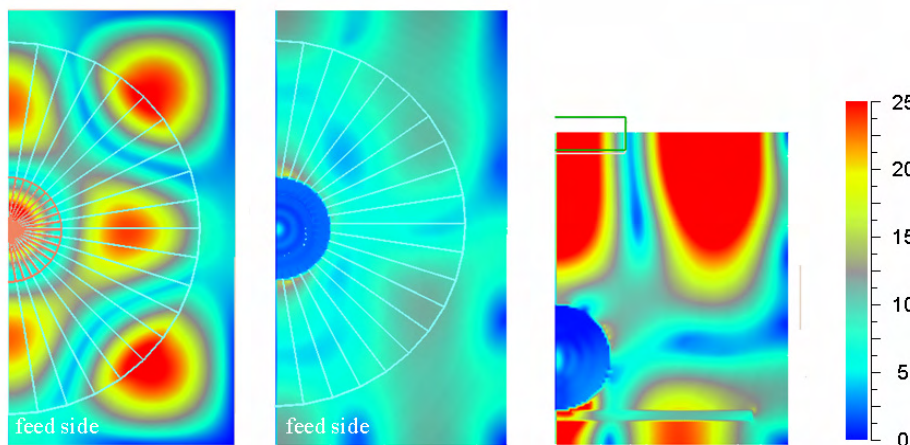
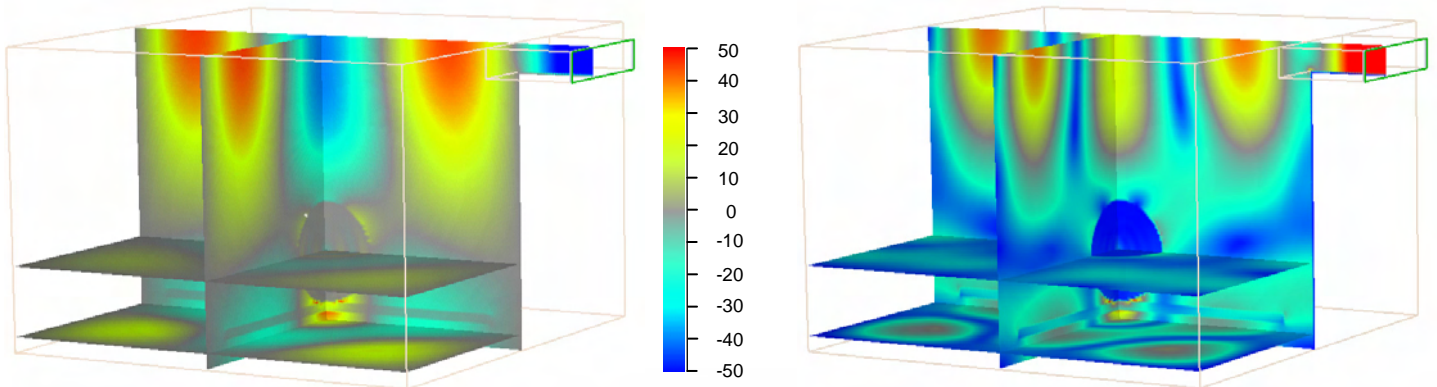
While the regular prism exhibits considerable radiation loss and disperses the beam, the metamaterial prism refocuses the beam without significant loss.

MEFiSTo-3D Pro models the amazing properties of new designer media and allows virtual component prototyping.

MW HEATING – POTATO IN OVEN

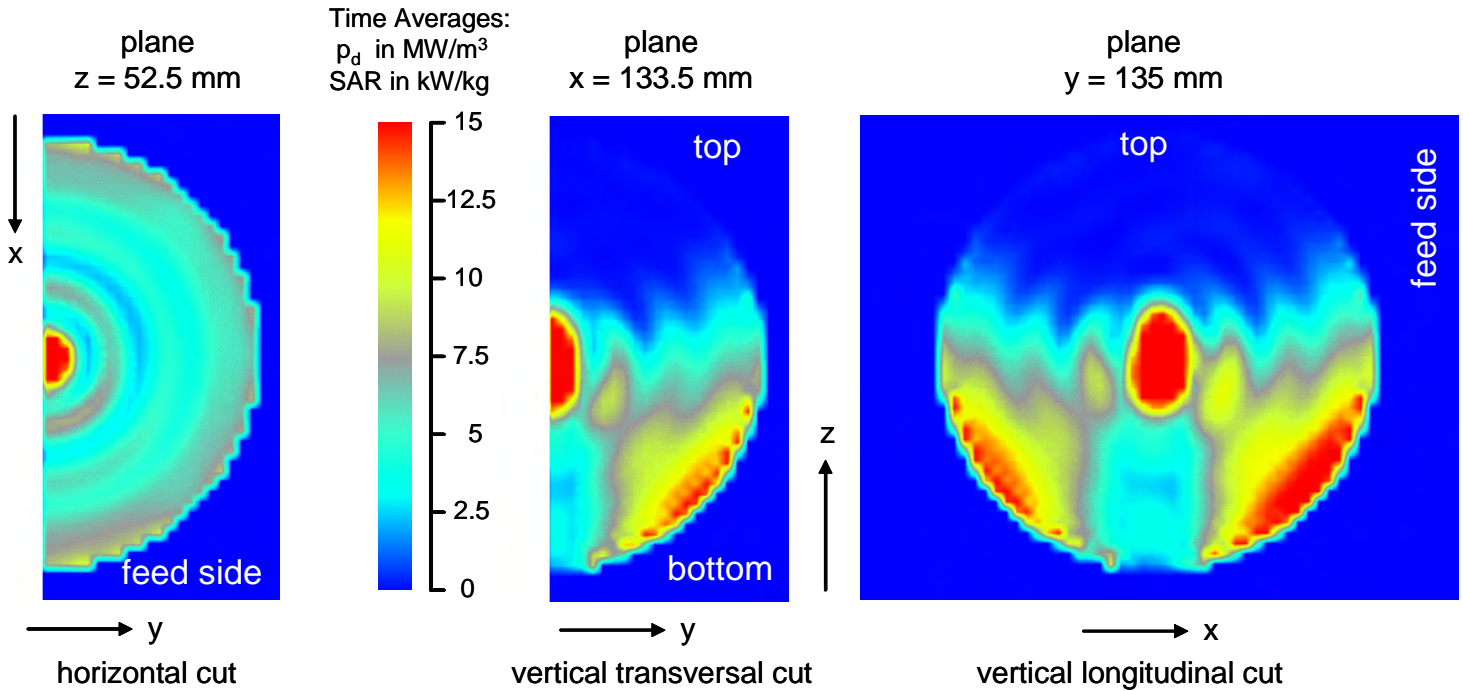


Excitation: waveguide feeder and magnetron (sinusoidal signal, frequency 2.45 GHz, average power 1 kW), perfectly matched to the waveguide;
 Oven walls with perfect electric conductivity. Circular lossless shelf ($\epsilon = 2.55 - i0$);
 Spherical potato, diameter 63 mm, $\epsilon = 65 - i20$, density 1.0 g/cm³, centered on the shelf.

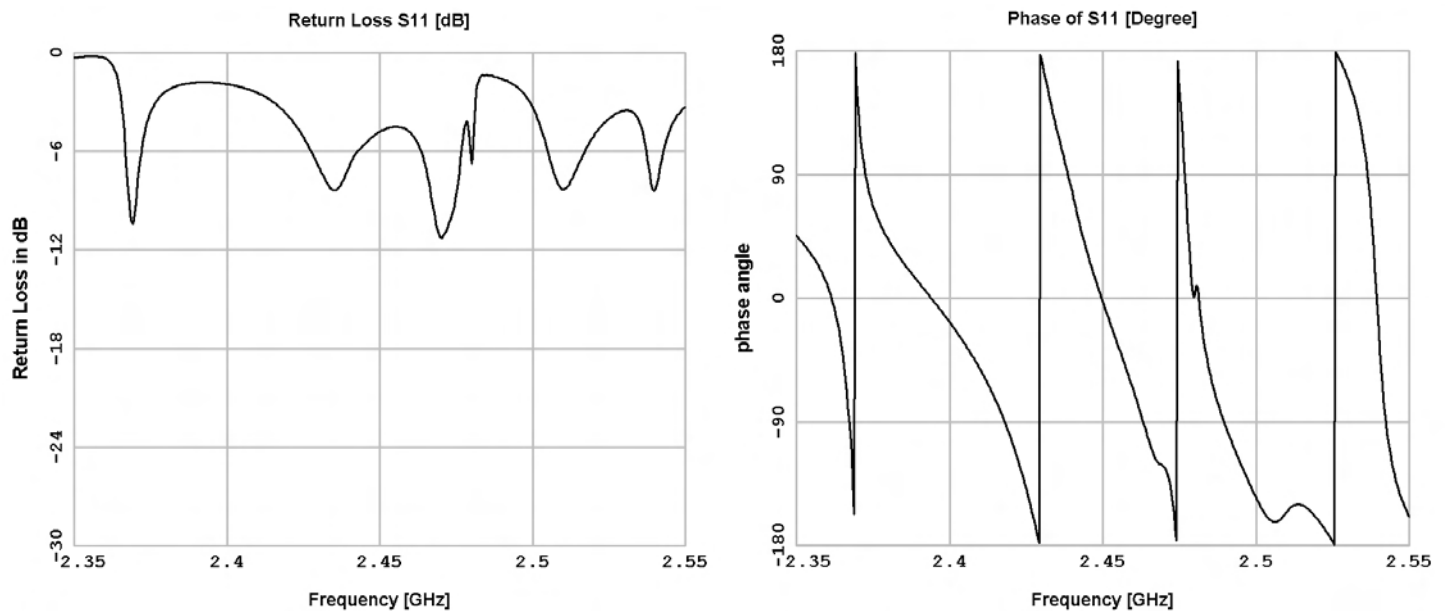


z-component (top left) and magnitude (top right and bottom left) of the electric field in various planes of the oven. Both the wavelength and the electric field strength are considerably reduced inside the potato due to its high dielectric permittivity.

MW HEATING — POTATO IN OVEN



Density of average dissipated power (p_d) and SAR displayed in the vertical and horizontal symmetry planes inside the potato at 2.45 GHz, average power 1 kW delivered by a magnetron perfectly matched to the waveguide. The hot spot in the center of the potato is due to the focusing effect of the spherical high-permittivity dielectric, while the hot lower cheeks are due to the proximity effect of the dielectric shelf and the oven bottom.



Magnitude (return loss in dB) and phase of the complex input reflection coefficient S_{11} of the loaded oven, computed inside the waveguide feed at 50 mm from the inner wall of the oven. A single computation using a band-limited excitation and discrete Fourier transform (DFT) of the transient response covers the band from 2.35 to 2.55 GHz. Several resonances and their associated Q-factors are clearly visible. Such wide-band computations in a waveguide environment are possible due to the modal convolution boundary model available in MEFiSto.

FEATURES

USER AND SYSTEM INTERFACES

- Intuitive scalable GUI (metric and imperial)
- Hierarchical tree and grouping of objects
- Boolean operations on overlapping elements
- Fully parameterized and programmable
- Automatic brick meshing with boundary fitting
- Text-based geometry import and export
- Customized library of parameterized objects
- Export of all graphs, pictures and data
- External control through batch commands
- Compatible with MATLAB toolboxes (Optimization, Neural Network, Signal Proc.)
- On-line help facility and tutorials

BOUNDARY PROPERTIES

- Perfect electric and magnetic boundaries
- Non-dispersive lossy and abs. TEM boundaries
- Lossy conductors with wideband skin effect
- Wideband dispersive convolution boundaries
- Wideband nonlinear superconducting walls
- Perfectly matched absorbing layers (PML)

MATERIAL PROPERTIES

- Homogeneous and inhomogeneous ϵ and μ
- Isotropic and anisotropic (tensor) ϵ and μ
- Electric and magnetic conductivity loss tensors
- Metamaterials with negative refractive index

EXCITATION SOURCES

- Point and spatially distributed (modal) sources
- Hertz dipole and Gaussian beam sources
- Electric, magnetic and TLM impulse excitations
- Matched (soft) and imposed (hard) sources
- Impulse, step, Gaussian step and pulse, NEMP, Gaussian modulated sin and cos waveforms
- User-defined waveform specified in text format
- Multiple independent sources and waveforms

DATA AND FIELD DISPLAY MODES

- Dynamic on-the-fly data and field display
- Simultaneous time & frequency responses
- Wire mesh, 3D vector, 2D and 3D color map, 2D and 3D color contour field display
- S-Parameters (Magnitude/Phase & Smith Chart)
- Field integrals (induced voltage, current, electric and magnetic flux, power flow) in TD and FD
- E-Plane waveguide frequency mapping
- Cartesian and polar radiation pattern
- Dissipated power density and SAR
- Capture of displays for movie creation
- Backward-in-time simulation mode

NUMERICAL SOLVERS AND SCRIPTS

- 2D Shunt and Series Node TLM engines
- 3D SCN and GSCN TLM engines
- Multi-thread architecture for multiple processors
- Smart memory allocation feature
- SPICE-EM-bed and MATLAB-EM-bed features
- FD and TD near-to-far field transformation
- SPICE simulator included free of charge
- MATLAB scripts for optimization, neural network generation and signal processing toolboxes

WIZARDS

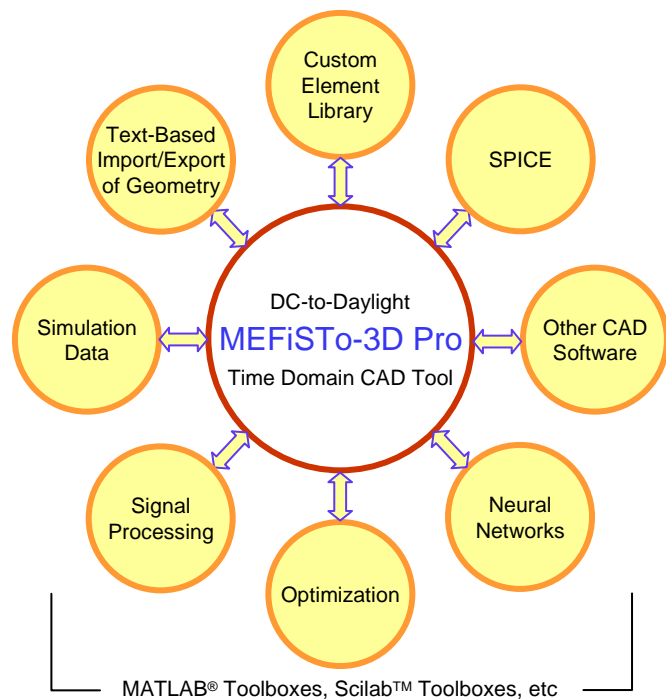
- Conductivity, Microstrip, Waveguide and Amplifier Design computations

MEFiSTo-3D Pro™

Time Domain Electromagnetic CAD tool from DC to Daylight

MEFiSTo means “Multi-purpose Electromagnetic Field Simulation Tool”. This full-wave volumetric time-domain simulator addresses the requirements of design engineers, researchers and educators working with RF/microwave/optical analog and high-speed circuits, antennas, EMC/I, RF heating and biomedical applications of electromagnetic fields. It features robust high-performance TLM numerical engines that provide second-order accuracy and have superior dispersion properties. TLM uses an unconditionally stable scattering algorithm rather than finite differences to solve Maxwell’s equations. Circuits & devices modeled by SPICE or a MATLAB can be embedded in 2D and 3D field space. Data can be co-processed on-the-fly and visualized in real solution time, or post-processed.

MEFiSTo is a virtual TD Reflectometer, a Microwave Vector Network Analyzer, an Antenna Range, a Spectrum Analyzer, a Signal Processor, and a Video System. It runs on Windows XP and higher platforms.

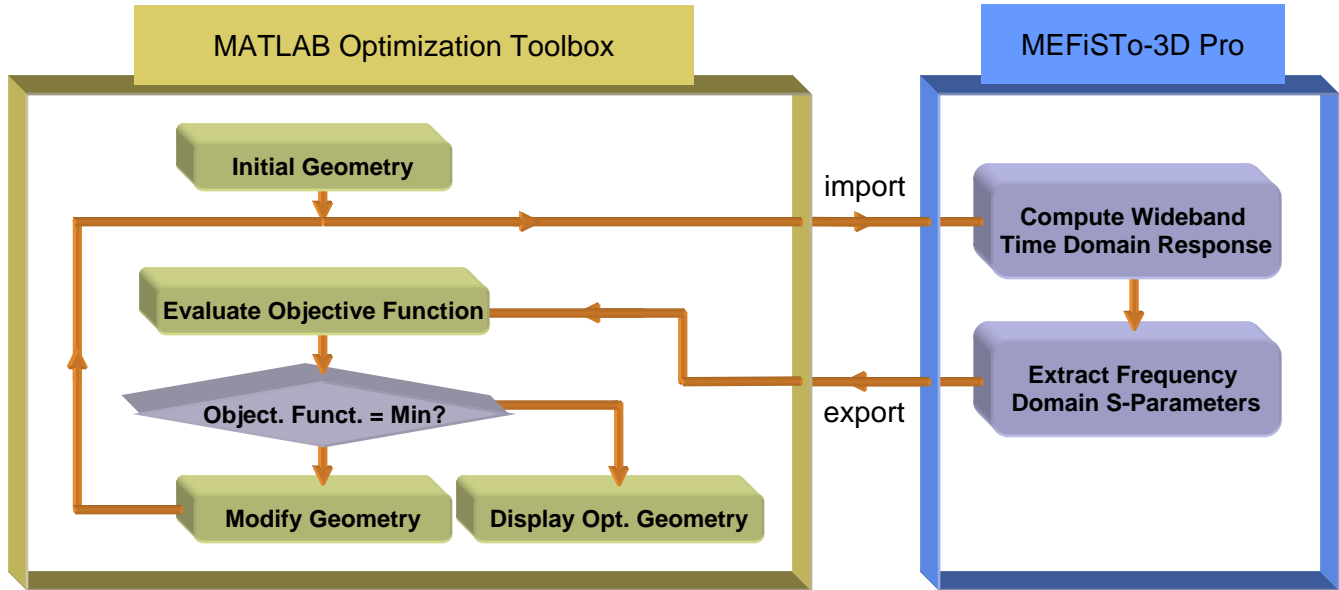


MEFiSTo-3D Pro™ is an autonomous EM CAD tool that provides, at the same time, unprecedented interconnectivity with external simulation/data processing/control software. This gives you the freedom to create your own sophisticated modeling environment and to expand the range of modeling capabilities beyond the bounds of mainstream EM solvers with restricted user access.



OPTIMIZATION & NEURAL NETWORKS

The data import/export capability of **MEFiSTo-3D Pro** enables it to perform field-based optimization of 3D structures using the optimization toolbox of MATLAB. Under the control of a MATLAB script, MEFiSTo imports geometrical data, performs a transient electromagnetic analysis of the structure and returns the wideband frequency response to the optimizer. MATLAB then evaluates the objective function and strategically modifies the geometry until the frequency response satisfies the desired specifications. In other words, MEFiSTo acts like a subroutine that can be called by any external optimization program.



The same data import/export capability of **MEFiSTo-3D Pro** enables it to generate neural network behavioral models using the **MATLAB Neural Network Toolbox** or the **NeuroModeler** (Prof. Zhang, Carleton University). Once the surrogate model has been created and trained, optimization can be performed several orders of magnitude faster than direct field-based optimization.

