

QUICKWAVE

COMPLETE EM SIMULATION

QUICKWAVE 3D QUICKWAVE BOR

QW-MODELLER

QW-ADDIN FOR AUTODESK® INVENTOR® SOFTWARE

QW-BHM QW-GPUSIM QW-MULTIGPUSIM QW-OPTIMISERPLUS QPRONY

QUICKWAVE

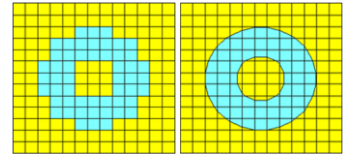
QuickWave is a general-purpose **electromagnetic simulator** based on the **conformal FDTD method** and supplemented with a range of unique models for curved boundaries, media interfaces, modal excitation, and parameter extraction. It has a well-established position on the world's market due to approaching specific, challenging problems (often bound to QWED's specialists participation in the customer's projects as consultants). That kind of approach causes that *QuickWave* has a **very broad variety of information** which can be extracted from the simulations in a form of different pre-processings, co-processings and post-processings.

Functionality

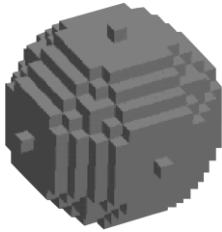
- ✓ **Full 3D EM solver.**
- ✓ **Ultra-fast vector 2D Bessel and FDTD hybrid solver** for Body of Revolution structures (axisymmetrical structures) as large as 2100 wavelengths, including antennas (SATCOM, dual-mode tracking antennas, etc.), circular waveguides discontinuities, coaxial lines and resonators.
- ✓ The specific features of *QuickWave 3D* include the possibility of simulating **microwave heating problems**. The software has been prepared to work in sophisticated regimes, modelling the movement of the heated load(s) even along complicated trajectories, etc. Transfer of the heat generated by electromagnetic fields can be modelled with internal Heat Transfer Module or by coupling *QuickWave 3D* simulations to external computational fluid dynamics packages.
- ✓ *QuickWave* is very flexible in so called co-processings. The user can open arbitrary number of windows for display of field components, dissipated power, Poynting vector etc. (in **various graphical display systems and at any simulation stage**). The decisions about the number and type of the windows showing values deliverable from the instantaneous filed components do not need to be taken prior to launching the simulation. The co-processings data are available (for viewing, storing, etc.) **at any time during the simulation**.
- ✓ Powerful *Freeze* option enabling **saving the state of the simulation** in the purpose to restore this state or continue the calculations in the future.
- ✓ **Breakpoints** and tasker mechanism of executing user defined sequence of commands, allowing performing the defined operations, e.g. *freezing* simulation, saving simulation results, automatically.
- ✓ **Batch operation** for both *QW-Editor* and *QW-Simulator*.
- ✓ **QW-Modeller** - free general purpose parametric 3D CAD modeller for creating geometry, assigning the materials, adding ports, boundary conditions, wires, setting mesh, excitation parameters, postprocessings, etc.
- ✓ **QuickWave plug-in for popular CAD environment**, Autodesk® Inventor® Software. Graphical definition of 3D/V2D structures in CAD environment, mesh generation, and specification of simulation parameters.

Speed

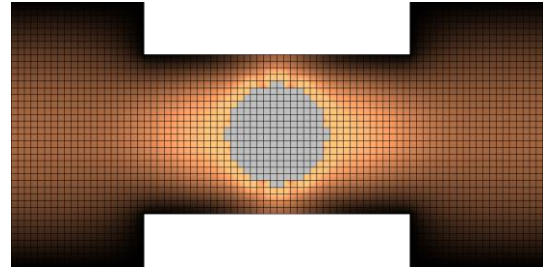
- ✓ Speed of computing has been in the focus of *QuickWave* software developers since its early days. We are putting a lot of effort to keep pace with hardware development. Thus we have a variety of options for optimum speed of computing on various **multiprocessor/multicore, GPU and MultiGPU** configurations.
- ✓ **Optimal cell indexing** allowing for very fast FDTD calculations.
- ✓ **QuickWave BOR** allows for hundreds times faster simulation for Bodies of Revolution structures than classic 3D analysis.



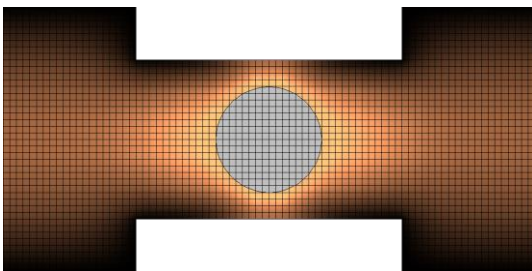
CONFORMAL APPROXIMATIONS FOR IRREGULAR GEOMETRIES



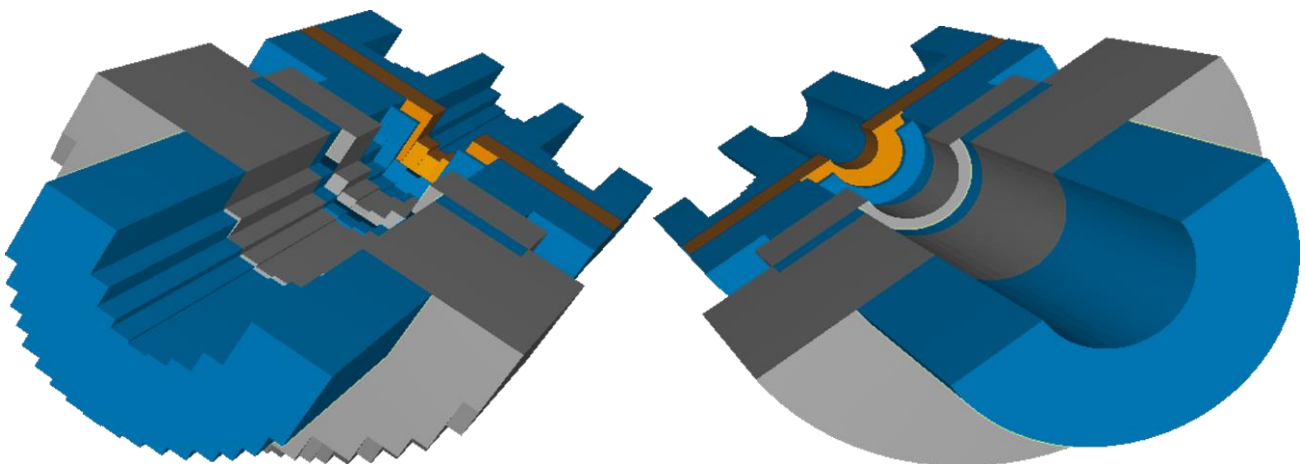
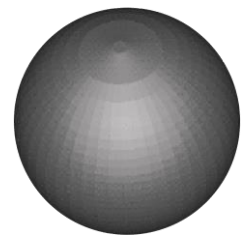
Classical stair-case meshing radically corrupts the physical geometry. Good shape imitation can be approximated by mesh refinement, but it drastically increases memory occupancy and simulation time.



There are various conformal FDTD techniques for better approximation of curved shapes, but they usually require time-step reduction (proportional to the smallest cell maintained) and hence longer simulation time.



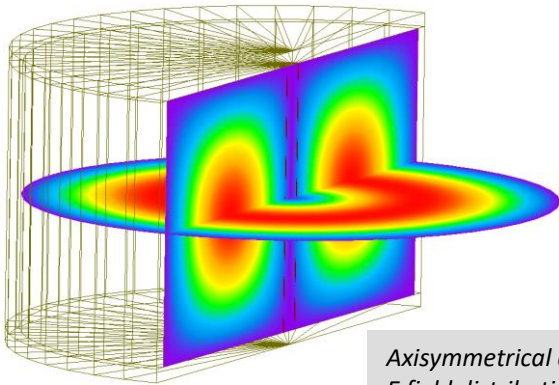
QuickWave uses advanced conformal boundary models, which allow precise and accurate modelling of curved shapes and obtaining high accuracy simulation results **without time-step and simulation speed reduction!**



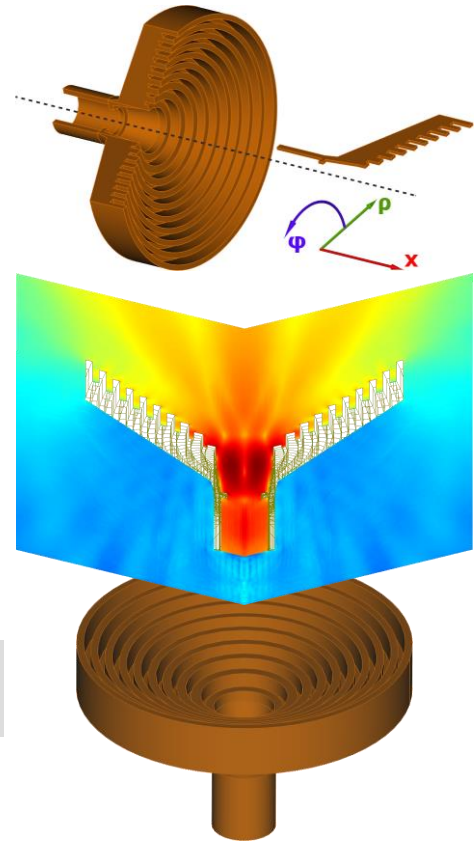
Travelling wave tube with classical stair-case and advanced QuickWave conformal FDTD approach.

QUICKWAVE BOR

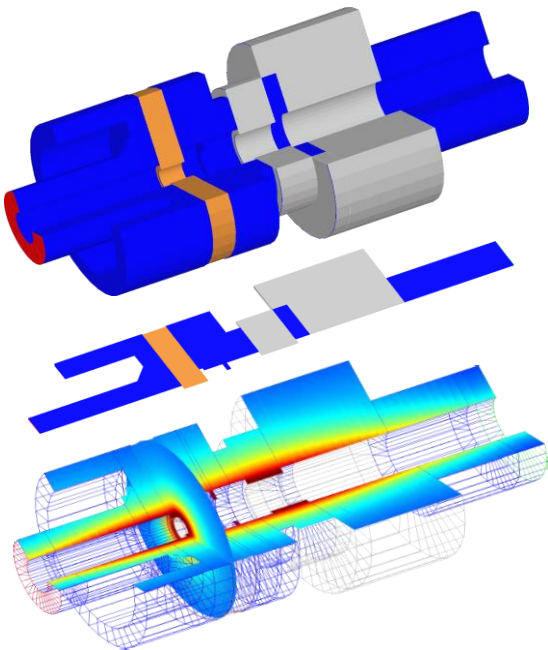
Unique on the market, ultra-fast vector 2D Bessel and FDTD hybrid electromagnetic solver, applicable to the analysis of Bodies of Revolution (axisymmetrical structures) as large as 2500 wavelengths, including antennas (horns, rods, biconical), circular waveguide discontinuities, and resonators. It is based on the Maxwell equations re-expressed in cylindrical coordinates. Unique problem implementation allows for **hundreds times** faster simulation than a brute force 3D analysis.



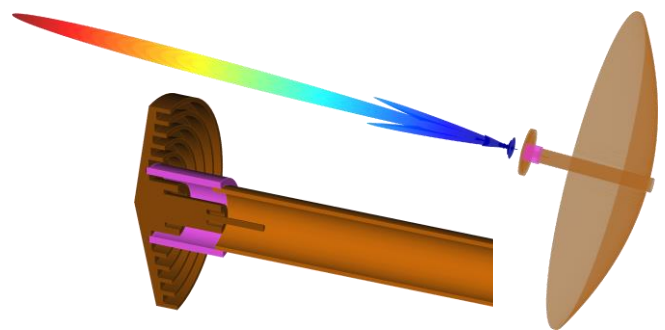
*Axisymmetrical dielectric resonator:
E field distribution*



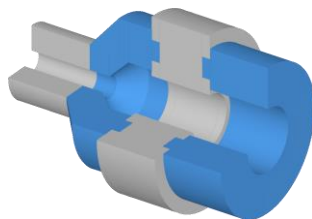
*Axisymmetrical corrugated horn antenna:
envelope of E field.*



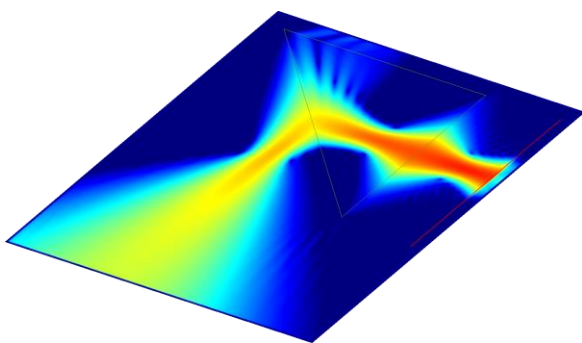
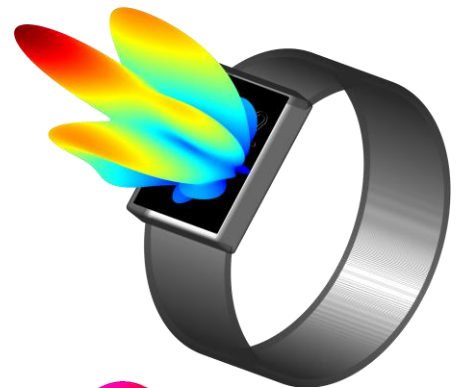
Coaxial structure used as an output of a travelling wave tube (TWT).



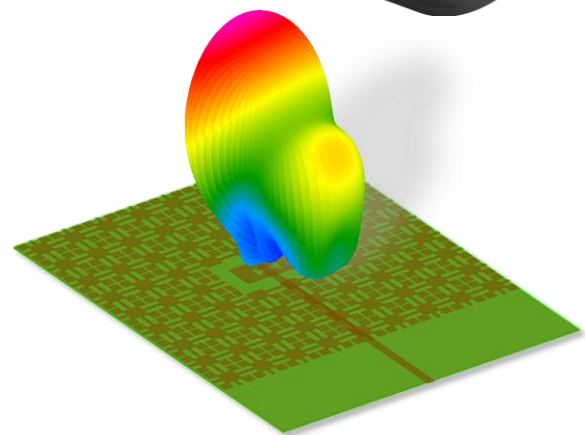
QuickWave BOR is a must-have tool for designing two-reflector antennas (e.g. Cassegrain) used in telescopes as well as SATCOM, dual-mode tracking antennas, etc.



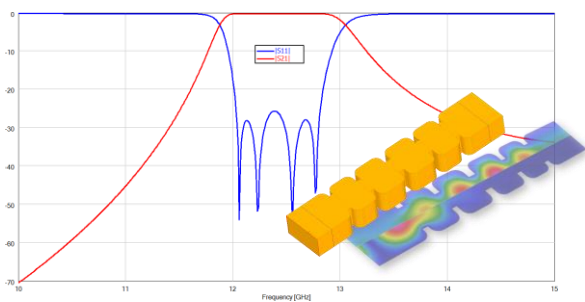
A complete 3D electromagnetic simulation offers a set of various results from wide area of applications. A lot of processing/postprocessings present a complete offer of comprehensive solutions from the analysis of typical microwave components (filters, couplers, resonators, etc.) and parameter sweep, through specialised analysis of high Q structures and antennas (5G, arrays, SATCOM, double reflector, etc.), to simulation of microwave heating process with temperature dependent media, static, rotated or moved heated object(s), and heat transfer.



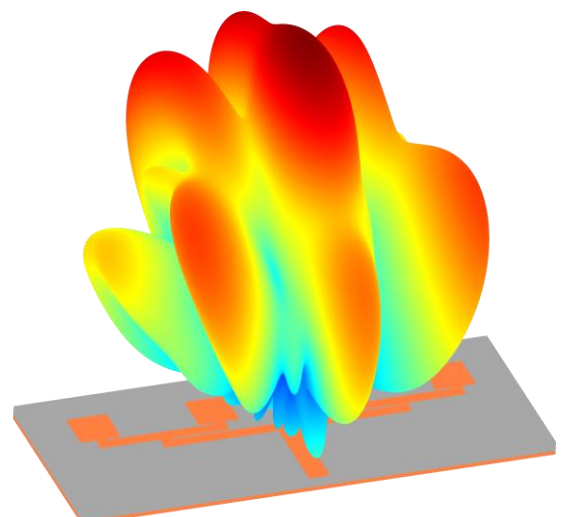
Envelope of the Poynting vector of a triangular prism composed of a left-handed material (represented with a Drude dispersive model) and illuminated with a 2D Gaussian beam.



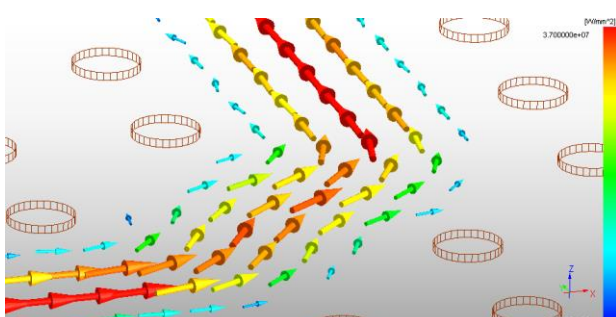
An aperture-coupled patch antenna on a uniplanar photonic-bandgap substrate and its 3D radiation pattern at 12 GHz.



S-parameters of the rectangular waveguide filter and electric field distribution for 12.39 GHz (passband) and 11 GHz (stopband).



Microstrip patch antenna for 5G mobile communication (1x4 array) and 3D radiation pattern at 52.9 GHz.

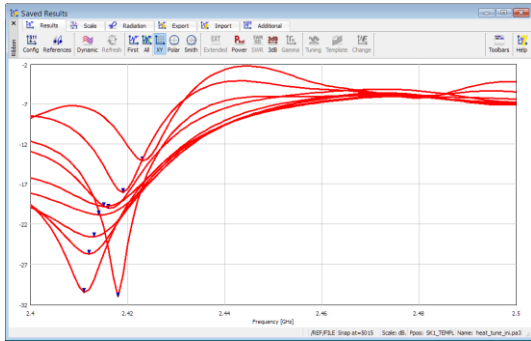
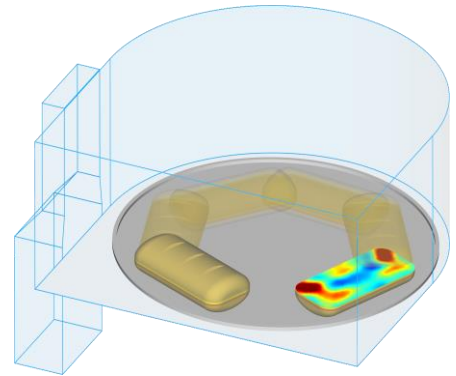


Vector display of time-maximum envelope of Poynting vector at 193.414 THz ($\lambda = 1550$ nm) for 2D photonic crystal waveguide bend.

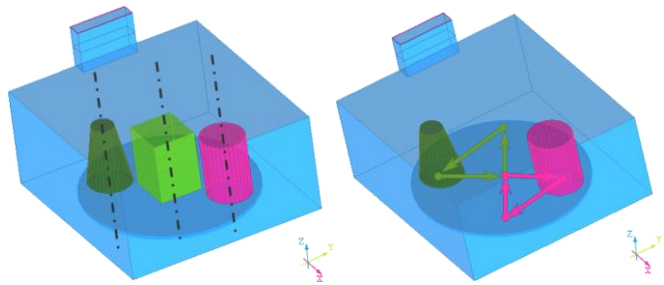
MICROWAVE HEATING

QW-BHM (Basic Heating Module) is a specialized module for *QuickWave* electromagnetic software that provides a novel regime of operating the FDTD solver, with modification of media parameters as a function of dissipated energy (temperature or enthalpy), allowing for high accuracy modelling of microwave heating problems.

QW-BHM automatically modifies media parameters in thousands of FDTD cells filled with different media and heated up differently - all accomplished in a matter of seconds!

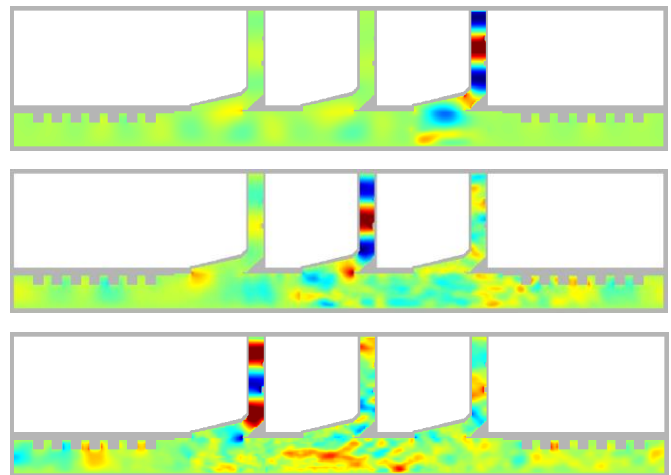


*The source frequency tuning mechanism perfectly responds to design needs of novel microwave power applications with **solid state power sources**.*

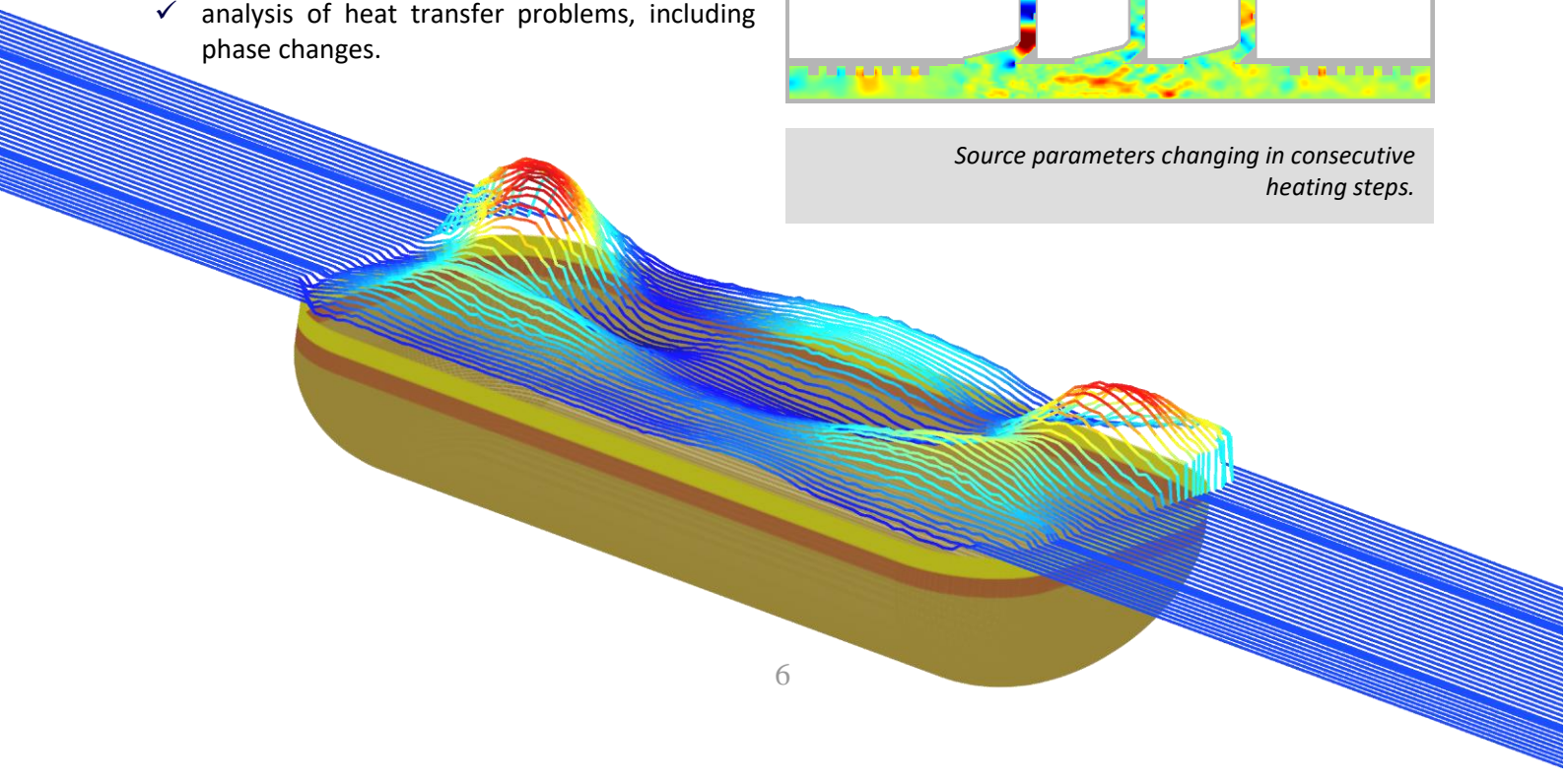


Modelling of rotation and movement of multiple objects rotating around different rotation axis with different speeds or along different trajectories.

- ✓ modification of media parameters as a function of dissipated energy,
- ✓ modelling the rotation in domestic ovens,
- ✓ movement of the heated object(s) in industrial applicators, along complicated trajectories,
- ✓ changing the source frequency, amplitude, phase in consecutive heating steps,
- ✓ tuning of the source frequency,
- ✓ Rieke display for SWR,
- ✓ analysis of heat transfer problems, including phase changes.

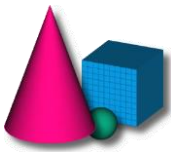


Source parameters changing in consecutive heating steps.

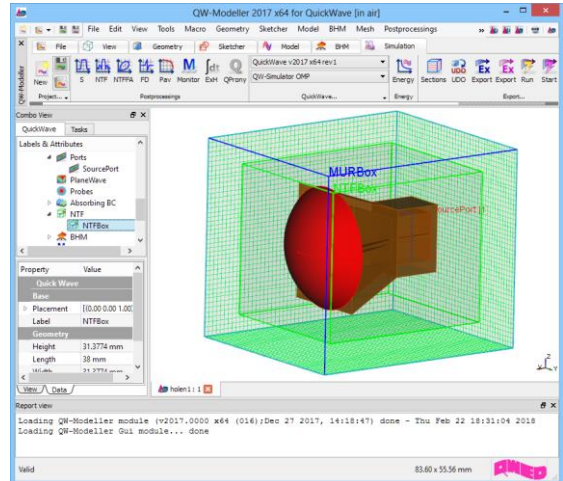


QW-MODELLER

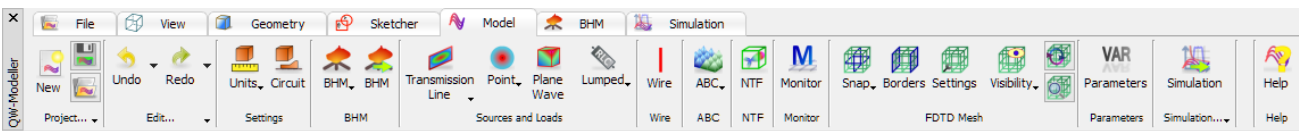
QW-Modeller for QuickWave is a plug-in for the open source FreeCAD general purpose parametric 3D CAD modeller and allows preparing a **complete project** for electromagnetic simulation with *QuickWave* software. It is **free** and can be used without any restrictions for creating geometry, assigning the materials, adding ports, boundary conditions, wires, setting mesh, excitation parameters, postprocessings, etc.



A horn antenna with dielectric lens project in QW-Modeller.

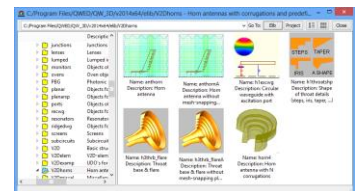
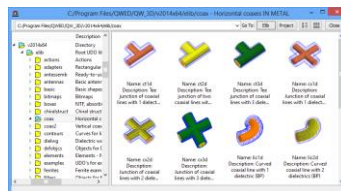
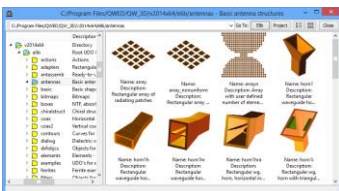


QW-Modeller Ribbon with Model tab.



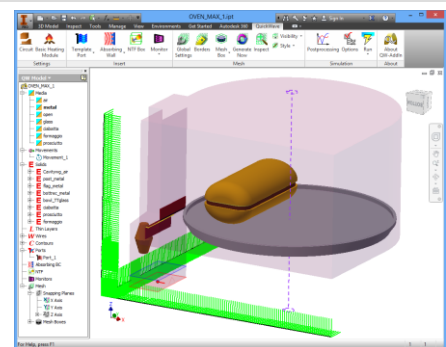
QW-EDITOR

Geometry design in *QuickWave* is as simple as possible. *QW-Editor* (supported by *QW-Modeller* and *QW-AddIn for Autodesk® Inventor® Software*) is a unit, which permits graphical definition of 3D/BOR structures, mesh generation, and specification of simulation parameters. Projects can be build very quickly using basic *QW-Editor* interface, a set of ready-to-use objects from UDO library or writing your own script in User Defined Objects mechanism.



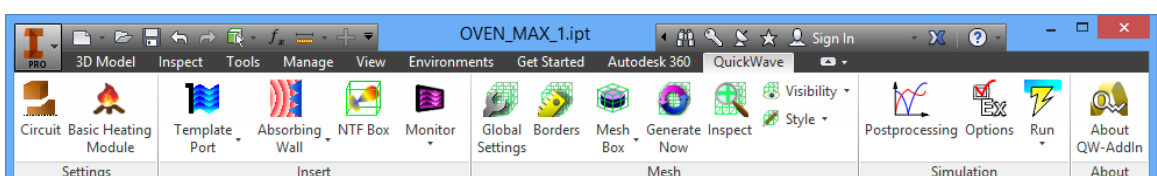
QW-ADDIN FOR AUTODESK® INVENTOR® SOFTWARE

QW-AddIn for Autodesk® Inventor® Software is a *QuickWave* plug-in for Autodesk® Inventor® Software, a wide-spread mechanical tool, allowing defining a complete project for electromagnetic simulation directly in the popular CAD environment. Automatic mesh generation using Automatic Meshing Intelligent Generation Option (*AMIGO*) optimises the meshing taking into account requested wavelength resolution in all media, while avoiding unnecessarily small cells.



Additional QuickWave toolbar in Autodesk® Inventor® Software.

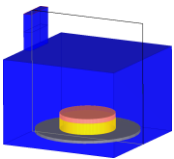
Commercially available Whirlpool-Max microwave oven (view in Autodesk® Inventor® Software).



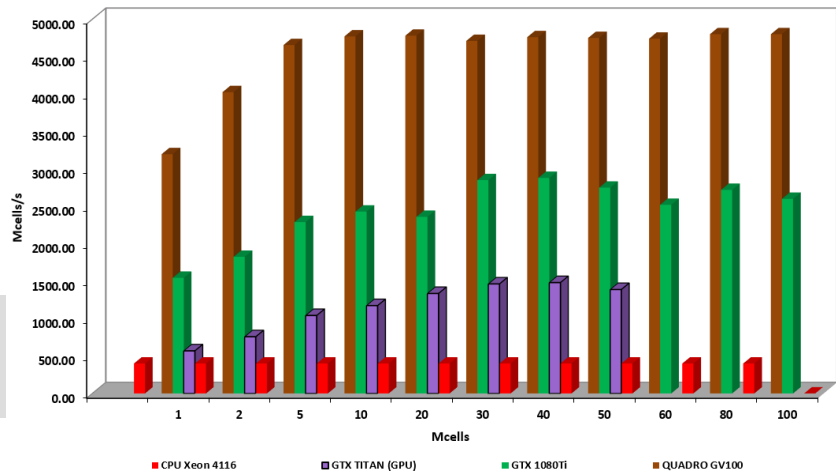
GPU AND MULTIGPU COMPUTING

QW-GPU Simulator is a very fast version of *QW-Simulator* designated for massive parallel computing hardware, which can be executed on modern graphic cards (GPUs). Acceleration by approximately a factor of 14 for 3D examples and of 28 for BOR examples has been observed, with respect to multithread implementations run on comparably modern CPUs.

QW-MultiGPU Simulator is a very fast version of *QW-Simulator* designated for multiple massive parallel computing hardware. *QW-MultiGPU Simulator* performs spatial decomposition and divides analysed circuit into subregions, which are simulated on separate GPU cards. Using multiple GPU cards of a massively parallel architecture extends the available memory and significantly reduces the simulation time.

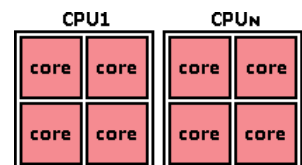


Beefburger placed in a cavity oven (3D example), GPU FDTD speed of 5 [GCells/s].



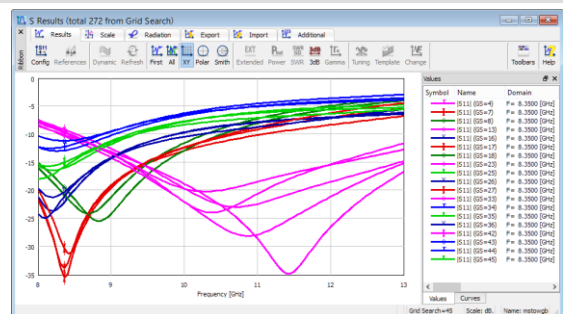
MULTIPROCESSOR / MULTICORE COMPUTING

Multiprocessor/multicore solutions include several multithread versions of *QW-Simulator*. *QW-Simulator OMP* is a very convenient and efficient tool for speeding up preprocessing and FDTD calculations. *QW-Simulator MTGOMP* is a special version for the users who need to watch dynamic field distribution without slowing down FDTD calculations.



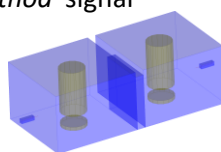
OPTIMISATION AND PARAMETER SWEEP

- ✓ multi-objective optimisation with *QW-OptimiserPlus*, fully integrated with *QW-Simulator*,
- ✓ parameter sweep (for geometry and material parameters grid, radiation frequency grid and for parameter range or specific values),
- ✓ optimisation/parameter sweep cache,
- ✓ compatibility with external applications, e.g. Matlab,
- ✓ batch mode for optimisation and parameter sweep,

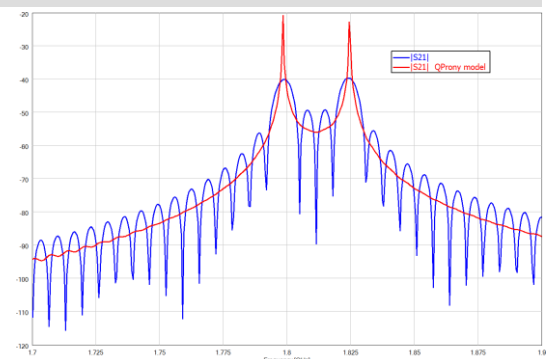


QPRONY – MODULE FOR HIGH Q-FACTOR STRUCTURES ANALYSIS

- ✓ fast analysis of a high Q structures using *Generalised Pencil of Function Method* signal processing technique,
- ✓ loaded Q calculations,

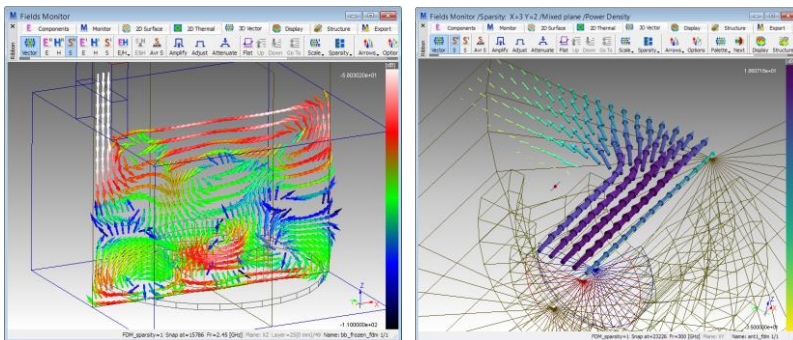


Comb-line filter consisting of two cavity resonators coupled via a rectangular aperture. QProny delivers the results 20 times faster than traditional 3D simulation.

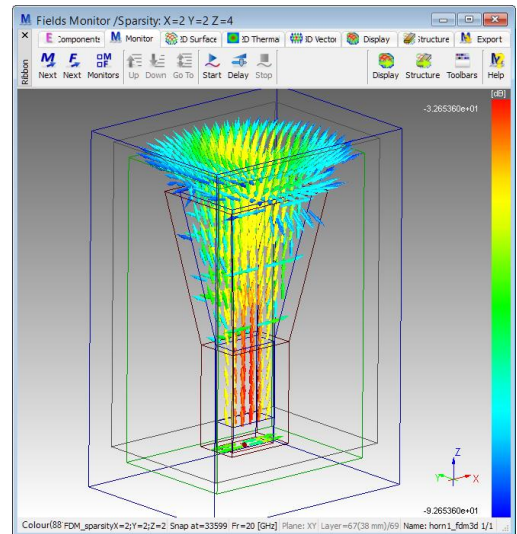


FREQUENCY DOMAIN MONITORING

- ✓ monitoring the field distribution at multiple frequencies,
- ✓ sparsity factor in space and time,
- ✓ animation of the time domain field distribution



Real part of complex Poynting vector at 2.45 GHz in the XZ cross-section of cavity and distribution of Poynting vector at 300 GHz in the axisymmetrical circular dielectric antenna.

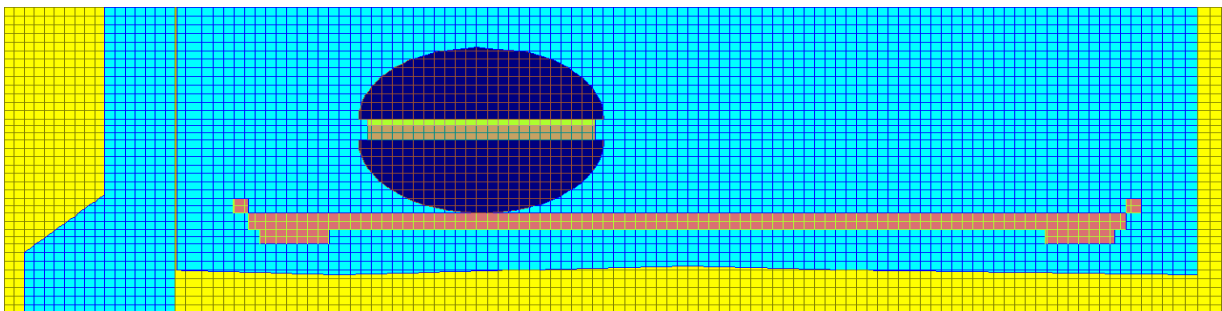


Real part of the complex Poynting vector at 20 GHz of horn antenna.

TEST FDTD MESH

An important tool for verification if the mesh used in simulation corresponds to the intentions of the user.

The Test Mesh allows watching and testing the effective conformal FDTD mesh grid and coefficients used in FDTD simulation. A set of testing tools allow checking the position and dimensions of different simulation objects like, e.g. transmission line ports, MUR wall/box, NTF box, etc.



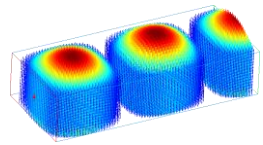
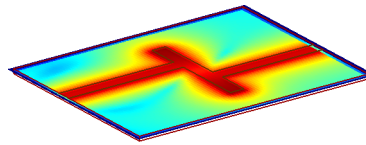
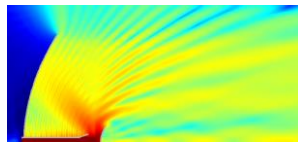
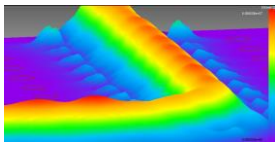
Test Mesh of microwave oven with sandwich and glass plate.

FREEZE

Powerful *Freeze* option enabling **saving the state of the simulation** in the purpose **to restore** this state or **continue** the calculations **in the future**. All *QW-Simulator* functions work in the same normal manner after *defreeze* operation. This feature is very convenient in many situations, typical when the user wants to:

- ✓ replace the calculations from one computer to another,
- ✓ save calculations that are time consuming,
- ✓ present a stable state of the calculations for a very large project without a necessity of running the simulation anew.

CO-PROCESSINGS



E_z

3D electromagnetic fields – time domain monitoring of directional and total electric and magnetic field components

H_ϕ

BOR electromagnetic fields – time domain monitoring of directional and total electric and magnetic field components in BOR (Bodies of Revolution) structures

S

Poynting vector – time domain monitoring of directional components and total Poynting vector

J_s

Surface currents – amplitude of surface current flowing on the metal walls

T

Temperature – monitoring of temperature distribution and average temperature (in [°C]) in the heated objects in microwave heating simulations

H

Enthalpy density – monitoring of enthalpy density (in [J/cm³]) in the heated objects in microwave heating simulations

P_d

Dissipated power – time domain monitoring and calculation of dissipated power (also dissipated power density), dissipated electric and magnetic power

$\int P_d$

Time integral of power dissipated – time domain monitoring and calculation of the time integral of dissipated power (also dissipated power density), dissipated electric and magnetic power

SAR

Specific Absorption Rate (SAR) – time domain monitoring of SAR in [W/kg]

E

Energy stored – calculation of energy stored in electric and magnetic field

Q

Q-factors – calculation of Q-factor in electric and magnetic field

Attn

Attenuation, |S₁₁| and SWR – calculation of the Attenuation between two points in the circuit, reflection coefficient and SWR in the considered part of the circuit

TDR

Time-Domain Reflectometry – watching signals directly in the time domain like it is done in Time Domain Reflectometry (TDR) technique

Exc

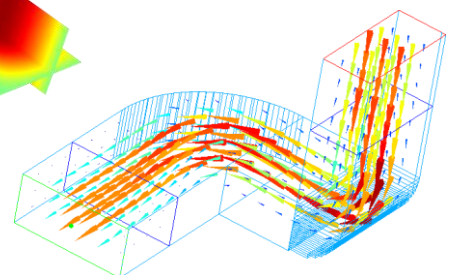
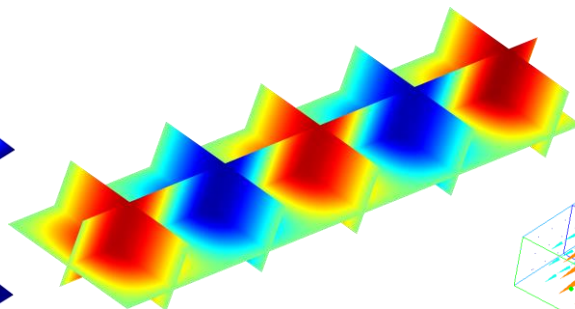
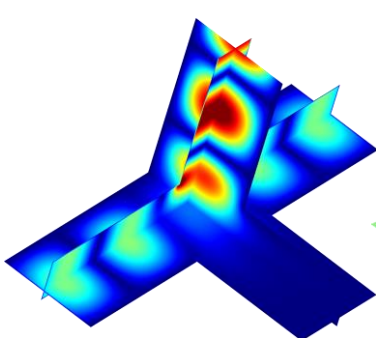
Excitation waveform – time-waveform of the excitation signal

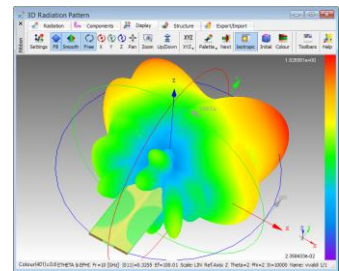
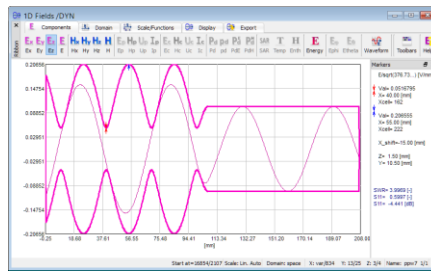
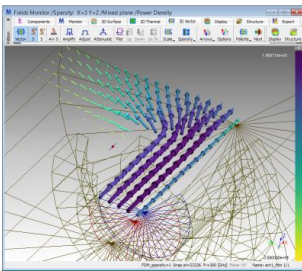
Mon

Monitoring EM quantities – along specified line and versus time

$\mu\epsilon_{eff}$

Effective Media Parameters – spatial distribution of the effective media parameters





S-Parameters – broadband S-parameters extraction including full S-parameters matrix calculations, reciprocity option, virtual shift of the 'reference plane', reflection coefficient calculations for several excitations operating simultaneously



Below cutoff calculations



Frequency dependent wave impedance – actual frequency dependent complex wave impedance of transmission lines



Frequency dependent propagation constant – actual frequency dependent complex propagation constant in transmission lines



Power Balance – balance between power entering and leaving the N-port circuit through the ports



Frequency dependent Standing Wave Ratio and Group Delay – actual frequency dependent SWR for the source port and GD between source port and each load port



Power available from the source – actual spectrum of the selected excitation pulse



Energy available from the source – total energy of the input pulse



Radiation and Scattering – radiation/scattering patterns in arbitrary isotropic medium, gain scaling, radiated power, efficiency, linear and circular polarisation, axial ratio



Radiation at Fixed Angle versus frequency – pulse spectrum in the far zone



Impulse response in the far-field – pulse shape in the far zone



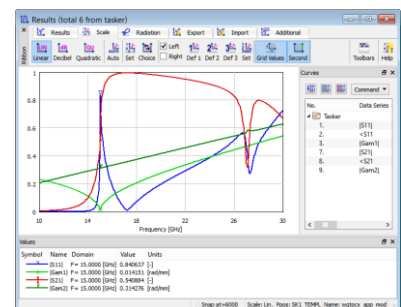
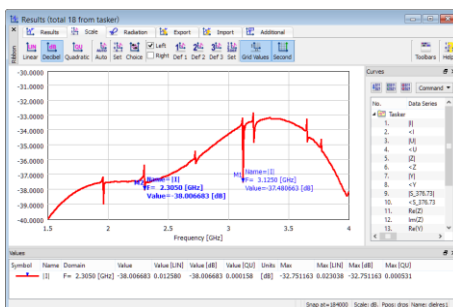
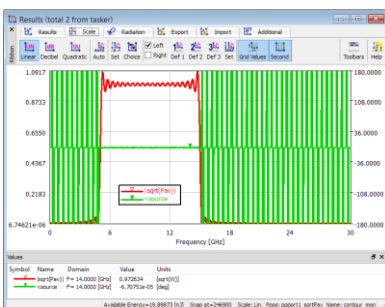
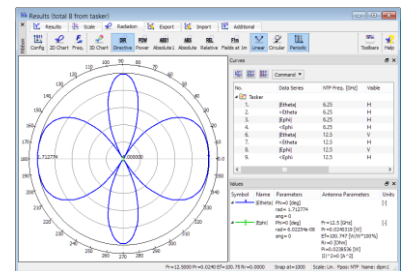
Fields Monitoring – frequency domain fields monitoring



Time integral of the Poynting vector – power flux in [J/m²]



Fourier transforms of voltage/current, field integrals





Design is as simple as it can be.

Simulation is as fast as you want it to be.

Results are as accurate as they should be.

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