

## QW-Features

QuickWave software is based on 3 decades of research of our head researcher Professor Wojciech Gwarek, 25 years of his main co-workers, and now 80 man-years. It is successfully used by 160 users all over the world. Our staff have published their works in over 240 papers.

### 1. Typical applications

- ✓ microwave and milimeter wave problems
- ✓ S-parameters extraction involving dispersion, multimodal propagation, and evanescent modes
- ✓ radiation patterns
- ✓ scattering patterns
- ✓ microwave heating problems

### 2. Major packages

#### QuickWave 3D

- ✓ universal general purpose software for electromagnetic design and simulations based on the conformal FDTD method, supplemented with a range of unique models for curved boundaries, media interfaces, modal excitation, and parameter extraction

#### QuickWave V2D

- ✓ ultra-fast Vector 2D (V2D) solver for axisymmetrical structures (BOR - Body of Revolution) including antennas, circular waveguides discontinuities, and resonators
- ✓ S-parameters, radiation patterns, etc. calculations
- ✓ structures as large as 2000 wavelengths

#### Multiphysics 3D (coupled EM, thermodynamic, mechanical)

- ✓ Basic Heating Module (BHM)

### 3. Conformal FDTD engine

- ✓ no time step reduction!
- ✓ correction of field singularities appearing at metal edges, corners, and wires
- ✓ unique models for curved boundaries



- ✓ automatic and adaptive (taking into account material parameters) mesh generation
- ✓ local mesh refinement option
- ✓ FDTD grid available for viewing
- ✓ actual FDTD mesh available for viewing
- ✓ conformal FDTD algorithm parameters available for viewing (useful for experienced users)

#### 4. Input user interface

##### In-house (QW-Editor)

- ✓ graphical definition of 3D and V2D structures, mesh generation, and specification of simulation parameters via a convenient system of dialogue boxes

##### QW-Modeller

- ✓ QuickWave plug-in for popular free CAD environment, FreeCAD
- ✓ graphical definition of 3D structures, mesh generation, and specification of simulation parameters
- ✓ **free** and can be used without any restrictions for creating geometry, assigning the materials, adding ports, wires, boundary conditions, setting postprocessing, excitation parameters, etc.

##### QW-AddIn for Autodesk® Inventor® Software

- ✓ QuickWave plug-in for popular CAD environment, Autodesk® Inventor® Software
- ✓ graphical definition of 3D and V2D structures in CAD environment, mesh generation, and specification of simulation parameters

#### 5. Objects and geometries

- ✓ ready-to-use elements and objects (antennas, waveguides, etc.) library
- ✓ flexible and convenient User Defined Object (UDO) language for defining geometry
- ✓ lumped impedance library (parallel RLC, series RLC, Drude, Debye, and Lorentz)
- ✓ accurate and stable conformal representation of curved metal boundaries
- ✓ higher-order modelling of media interfaces

#### 6. Materials

- ✓ PEC and PMC
- ✓ isotropic and anisotropic dielectrics
- ✓ thin metal layers
- ✓ lossy metals and wideband modelling of skin effect
- ✓ lossy wires



- ✓ multipole (up to 3 poles) frequency dependent materials (Drude, Debye, Lorentz electric and magnetic dispersion)
- ✓ cold plasma can be described as the dielectric dispersive material with Drude dispersion
- ✓ anisotropic dispersive dielectrics
- ✓ third-order nonlinear polarization given by Kerr-Raman model can be set for dispersive material described with Lorentz model
- ✓ negative index materials (LH materials, metamaterials)
- ✓ magnetised ferrites
- ✓ temperature dependent materials (BHM)

## 7. Boundary conditions and initial conditions

### Boundary

- ✓ electric
- ✓ magnetic
- ✓ PML
- ✓ MUR with superabsorbing
- ✓ periodic
- ✓ anisotropic boundary conditions (wire grids)

### Initial

- ✓ starting from zero fields
- ✓ starting from initial steady state

## 8. Excitations

- ✓ dynamic/manual/analytical (using an analytic formulas) mode generation
- ✓ port impedance calculation
- ✓ modal excitation in arbitrary transmission lines (also multi-modal, in lossy media, supporting evanescent modes)
- ✓ ideal voltage and current source
- ✓ lumped resistive source
- ✓ free space incident wave in various environment media (air, dielectric, magnetic, low-loss)
  - plane wave excitation
  - 2D & 3D Gaussian beam excitation
- ✓ excitation waveforms:
  - pre-defined signal library (sinusoidal, Gaussian pulse, etc.)
  - user defined signal excitation



## 9. Co-processings

*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 valued deliverable form of 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 simulation stage**.

### Display

- ✓ various display types for field distribution viewing (quasi-three-dimensional, fields intensity represented by colours, vector form)
- ✓ linear and decibel scales
- ✓ automatic and manual scales
- ✓ one and two dimensional displays
- ✓ two dimensional displays available for each cells layer
- ✓ 3D presentation of the antenna radiation pattern
- ✓ 3D presentation of the field components distribution, currents, material parameters etc. using QViewer module
- ✓ instantaneous and envelope (time-maximum and time-averaged) values of the displayed component

### Data

- ✓ fields ( $E$  and  $H$  field components), Poynting vector and power dissipated distribution available at any simulation stage (time domain monitoring)
- ✓ fields ( $E$  and  $H$  field components), Poynting vector and power dissipated distribution for real and imaginary grids, available for the periodic structures
- ✓ SAR calculations
- ✓ temperature and enthalpy distribution for microwave heating problems
- ✓ effective media parameters distribution
- ✓ watching field components along a specified line in space/versus time/along pre-defined contour
- ✓ virtual measurements of attenuation and SWR
- ✓ Time-Domain Reflectometry results (with virtual measurements of reflection coefficient and location of the discontinuity)
- ✓ power dissipated and energy stored in electric and magnetic field, and the resultant Q-factor calculations (also for real and imaginary grids for periodic structures)
- ✓ power dissipated and stored energy calculations for the entire lossy volume or in the specified objects
- ✓ energy dissipated over the entire duration of a pulse of limited duration (power dissipated integration in time)



## 10. Post-processings

Here the tasks requiring calculation of the Fourier transformation of fields (S-parameters, radiation patterns or field distribution of a particular frequency extracted from pulse excitations) are included. In this case an a priori knowledge about the data to be accumulated during simulations is required (user chooses data that should be calculated before running the simulation).

All the post-processing data can be viewed, stored, etc., **at any simulation stage**.

### Display

- ✓ linear, decibel, and quadratic (for S-parameters, radiation and scattering patterns) scales
- ✓ automatic and manual scales
- ✓ Smith and polar chart
- ✓ loading reference results for S-parameters, radiation and scattering patterns

### S-parameters

- ✓ broadband S-parameters extraction (results available at any simulation stage)
  - full S-parameters matrix calculations (exciting the consecutive ports in sequential or multi-simulator regimes)
  - reciprocity option available for S-parameters calculation
- ✓ reflection coefficient calculations for several ports simultaneously, during a single simulation run (applicable for multi-source networks when N sources operate simultaneously, and consequently the S-matrix cannot be calculated)
- ✓ virtual shift of the “reference plane” (the plane where the S-parameters extraction is performed)
- ✓ frequency dependent wave impedance (reference impedance for S-parameters calculations) and propagation coefficient of transmission lines
- ✓ power balance calculation
- ✓ standing wave ratio (SWR) and group delay calculations
- ✓ S-parameters embedding and deembedding

### Radiation and scattering

- ✓ antenna radiation patterns and scattering patterns of a scattering structures for wide angle range, at multiple frequencies, for any plane
- ✓ gain (directive, power, absolute, relative, fields scaled to 1m), radiation efficiency, radiation resistance and radiated power calculations
- ✓ radiation patterns for linear and circular polarisation
- ✓ radiation patterns for antenna arrays
- ✓ radiation pattern at a chosen near-to-far transformation (Huygens) surface
- ✓ far field 3D radiation patterns calculations
- ✓ radiation pattern calculations in an arbitrary isotropic medium
- ✓ radiation patterns for a specified directions versus frequency
- ✓ impulse response in the far-field



## Lumped

- ✓ Fourier transforms of terminal voltage across/current through resistor at any circuit point
- ✓ Fourier transforms of field integrals along defined contours
- ✓ power available from the source calculations (Fourier transform of the excitation waveform)
- ✓ energy available from the source

## Fields

- ✓ monitoring the field distribution at multiple frequencies in one simulation (frequency domain monitoring) with a sparsity factor in space and time
- ✓ animation of the time domain field distribution (at chosen frequencies) for frequency domain monitoring
- ✓ time integration of the Poynting vector

## 11. Special BHM functionalities

- ✓ modification of material parameters as a function of dissipated energy
- ✓ modelling of the load rotation and movement along an arbitrary trajectory
- ✓ modelling of rotation and movement of multiple objects rotating around different rotation axis and with different speeds or along different trajectories
- ✓ modelling of the rotation of metal objects
- ✓ automatic tuning of the source to the deepest resonance in the considered frequency band (this option mimics the physical behaviour of the real microwave power sources like magnetrons)
- ✓ manual tuning of the source (user indicates the new frequency)
- ✓ Rieke display for SWR
- ✓ automatic source parameters changing (frequency, amplitude and delay) in the consecutive heating steps, according to user specification, performed for each source separately
- ✓ analysis of the heat transfer problems taking into account divided cells (internal Heat Flow Module using non-linear model)
- ✓ possibility of coupling Basic Heating Module with external applications modelling effects not supported in BHM

## 12. Special functionalities for high-Q problems (QProny module)

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

## 13. Optimisation and parameter sweep

- ✓ automatic multi-objective optimisation (also for QProny and for multiprocessor/multicore and GPU implementations)



- ✓ grid search:
  - geometry parameters grid
  - material parameters grid
  - radiation frequency grid
  - for parameter range or specific values
- ✓ compatibility with external applications, e.g. Matlab
- ✓ batch mode for optimisation and parameter sweep

#### 14. Advanced operation regimes

- ✓ 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
- ✓ batch operation for both *QW-Editor* and *QW-Simulator*
- ✓ tasker mechanism of executing user defined sequence of commands, allowing performing the defined operations, e.g. saving simulation results, automatically
- ✓ batch run for simulations
- ✓ “slow down” option enabling slowing down the simulation; useful in case of small projects and fast computers when the user wants to watch the transient of the fields and due to the simulation speed the fields are moving “too fast”
- ✓ “Create” option enables performing the consecutive *QW-Simulator* tasks one by one (suspending the simulation after each task); the user initiates start of the next task

#### 15. Import/Export

##### Geometry

- ✓ \*.sat, \*.dxf files import
- ✓ \*.sat file export
- ✓ popular CAD formats like STEP files, IGES files, DXF files, etc. (via *QW-Modeller*)
- ✓ popular CAD formats like SAT files, STEP files, CATIA files, Pro/ENGINEER files, SolidWorks files, IGES files, etc. (via *QW-AddIn* for Autodesk® *Inventor*® Software)



### Time- and frequency-domain results

- ✓ exporting S-parameters to *SuperCompact*, *TouchStone*, *CSV data* or *Pure data* (pure numerical data) formats
- ✓ *TouchStone*, *CSV* and *Pure data* formats import
- ✓ exporting radiation patterns to *CSV data* and *Pure data* formats for 3D structures, and additionally to *SAC* and *GRASP* formats for Vector 2D (V2D) problems

### 16. Speeding solutions

- ✓ multiprocessor and multicore computing
- ✓ GPU and MultiGPU acceleration

### 17. Operating systems and hardware

- ✓ Microsoft Windows
- ✓ Linux (for request)
- ✓ GPU (nVidia and ATI cards)
- ✓ multiprocessor/multicore platforms

### 18. Interfaces to...

- ✓ Matlab
- ✓ FreeCAD
- ✓ Autodesk® Inventor® Software