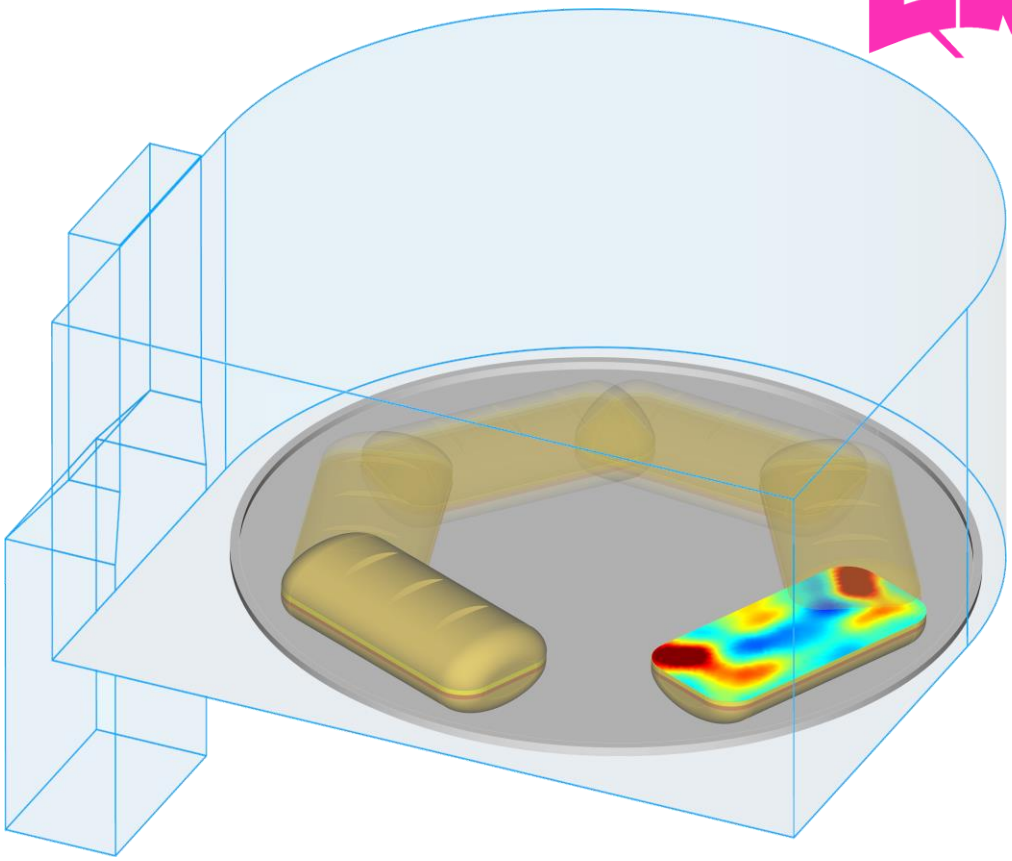


MICROWAVE HEATING

WITH

QUICKWAVE EM SOFTWARE

MICROWAVE HEATING MODULE

MEDIA PARAMETERS MODIFICATION

LOAD ROTATION

LOAD MOVEMENT

SOURCE FREQUENCY TUNING

SOURCE PARAMETERS SWITCHING

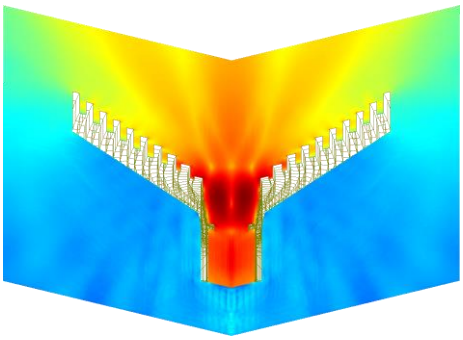
HEAT TRANSFER ANALYSIS

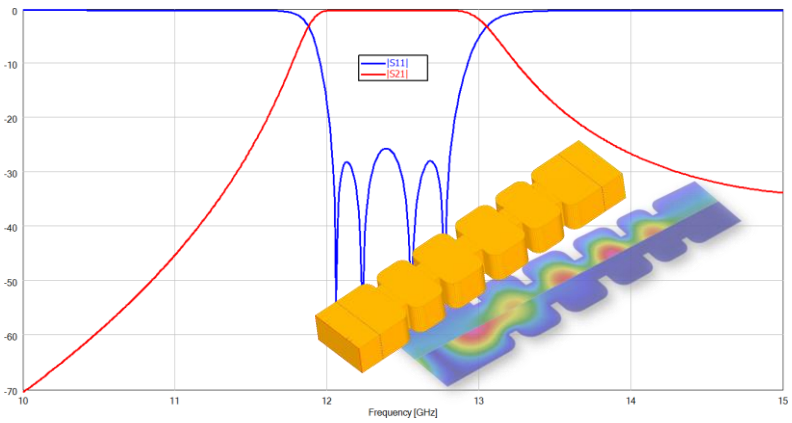
QUICKWAVE

QWED is a dynamic hi-tech company, set up in 1997 and based in Warsaw, Poland, being a happy blend of academic researchers, microwave engineers, and computer experts.

QWED develops and produces electromagnetic software package for design and simulations, called QuickWave. QuickWave is based on decades of research of QWED's researches and efforts of our developing team. The software is based on the proprietory conformal FDTD method and is widely applied to electromagnetic research and industrial design.
QuickWave 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 customers' projects as consultants.

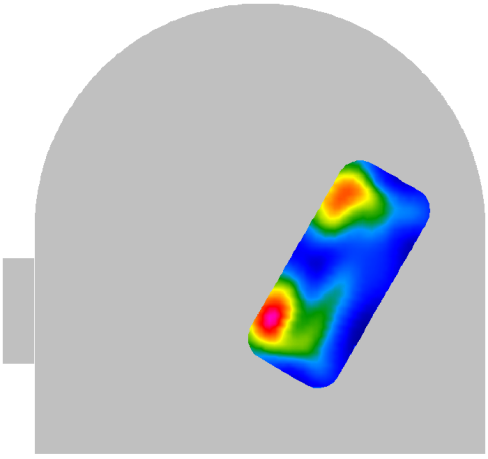
QuickWave is designated for the analysis of 3D structures, including 3D periodic structures, and Bodies of Revolution (axisymmetrical structures), due to an ultra-fast 2D Bessel and FDTD hybrid solver.

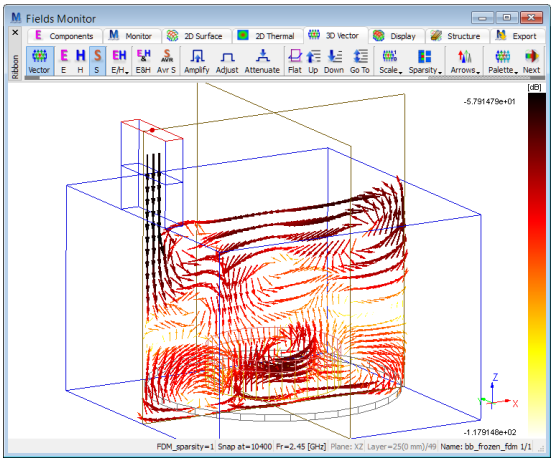




QuickWave software is extended with a variety of specialised optional modules allowing for high accuracy modelling of microwave heating, high-Q structures and loaded-Q calculations, and multiobjective optimisation.

Especially worth noting is **Basic Heating Module** for QuickWave, which is a specialised module designated for multiphysics simulation of microwave heating problems.





Basic Heating Module (QW-BHM) is a specialised 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.

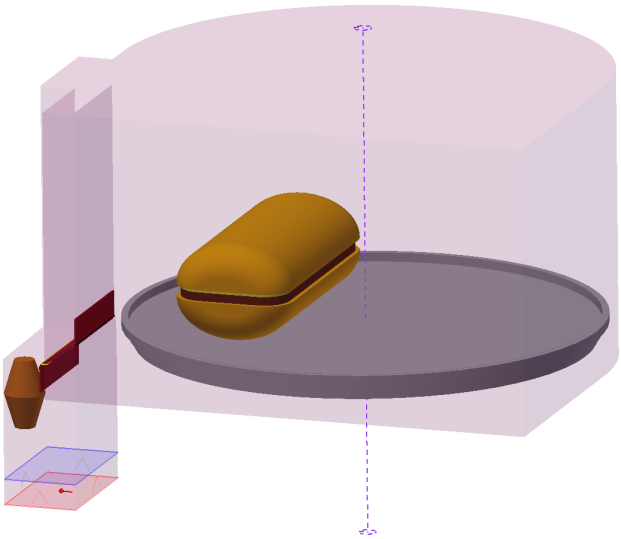
Microwave heating module, automatically modifies media parameters in thousands of FDTD cells filled with different lossy media and heated up differently – all accomplished in a matter of seconds!

In each "thermal" iteration, the new electromagnetic steady state is reached starting from the previous steady state. Such an approach requires less FDTD iterations than would be needed to reach the new steady state starting from the initial zero field distribution.

Many sophisticated regimes of operation and high accuracy of Basic Heating Module calculation has been confirmed by microwave heating industries worldwide, from popular domestic oven manufactures to emerging technologies, giving QuickWave the leading position on the market.

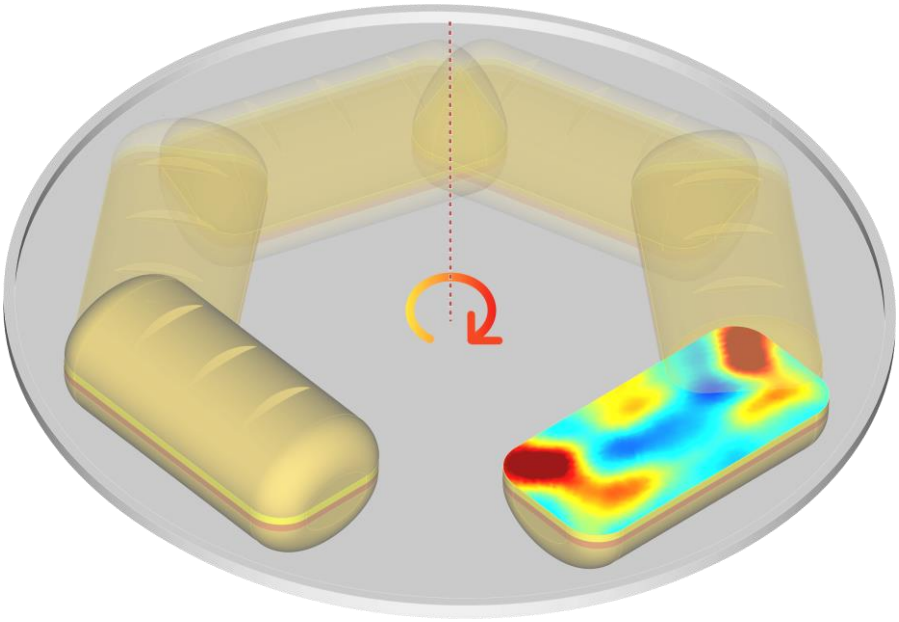
The **Basic Heating Module** for QuickWave is prepared to work in sophisticated regimes like:

- ✓ 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,
- ✓ analysis of heat transfer problems, including phase changes.

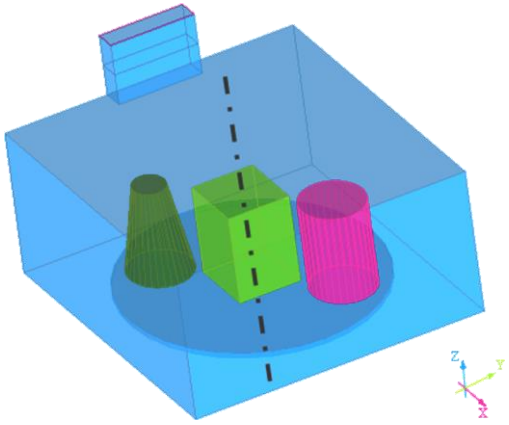


LOAD ROTATION

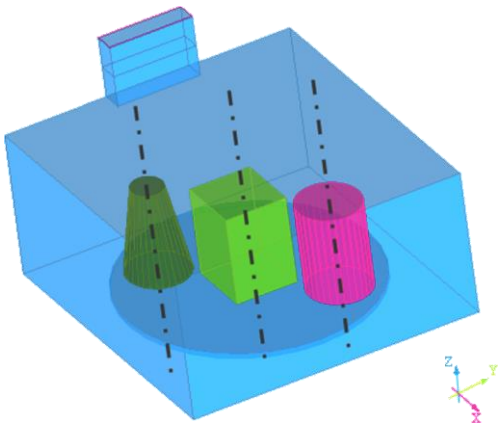
In a typical domestic microwave oven a more uniform temperature distribution within the load is obtained through rotating of the load during heating. Such slow movement of the heated object may to great extent affect the temperature field.



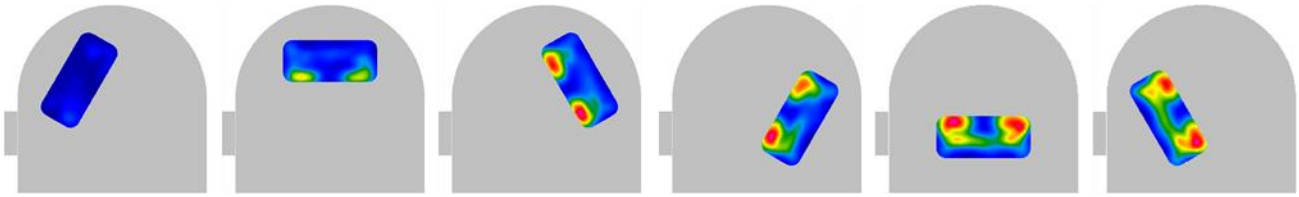
The load rotation mechanism available in Basic Heating Module allows one to simulate heating of arbitrarily shaped objects rotating with the user defined speed around user declared rotation axis. The load rotation regime allows modelling single and multiple objects rotation, with objects rotating around different rotation axes and at different speeds.



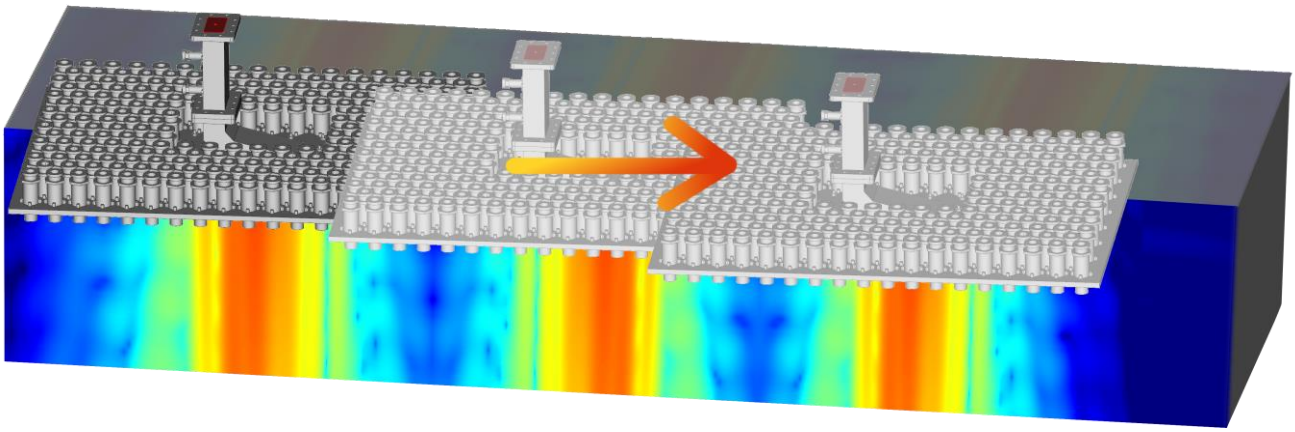
Modelling of rotation of multiple objects rotating around one rotation axis.



Modelling of rotation of multiple objects rotating around different rotation axes at different speeds.

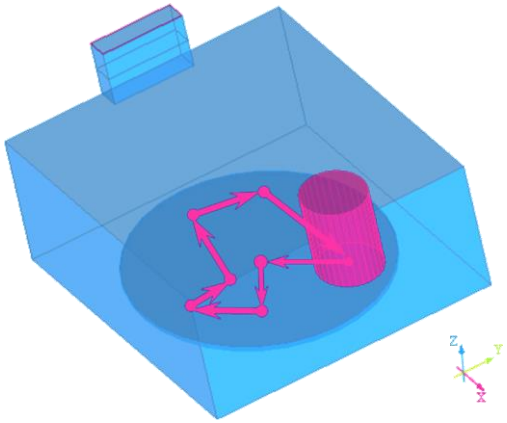


Load rotation is the most popular temperature-equalising mechanism widely used in domestic microwave ovens. However, different types of load movements are also of interest and are used in the engineering practice or are experimented within research, e.g., linear translation is widespread in industrial tunnel installations. Basic Heating Module responds to those needs and allows for modelling the movement of many objects along different trajectories.

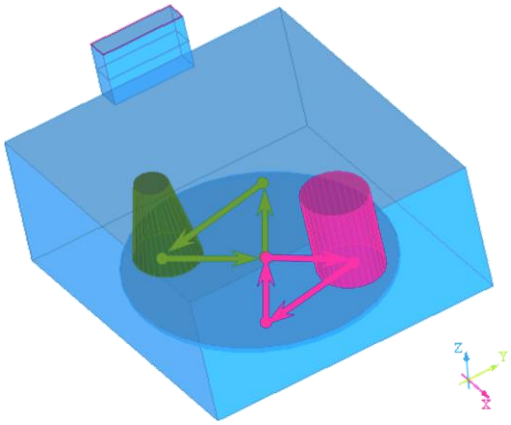


Microwave applicator moving above bituminous pavement.

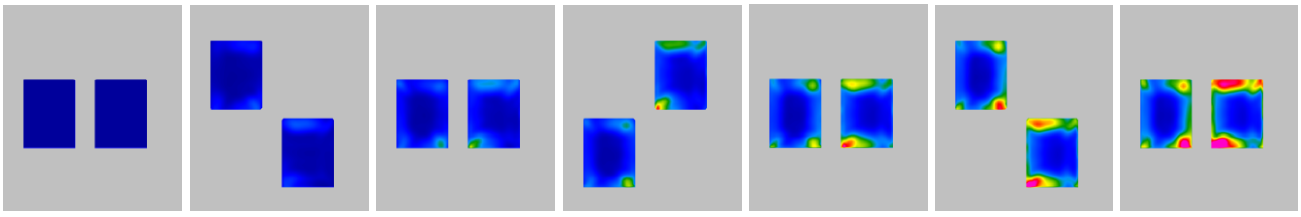
The load movement mechanism available in Basic Heating Module allows one to simulate heating of arbitrarily shaped objects moving along user defined movement trajectory. The load movement regime allows modelling single and multiple objects movement, with objects moving along different movement trajectories.



Modelling of movement of multiple objects moving along one movement trajectory.



Modelling of movement of multiple objects moving along different movement trajectories.

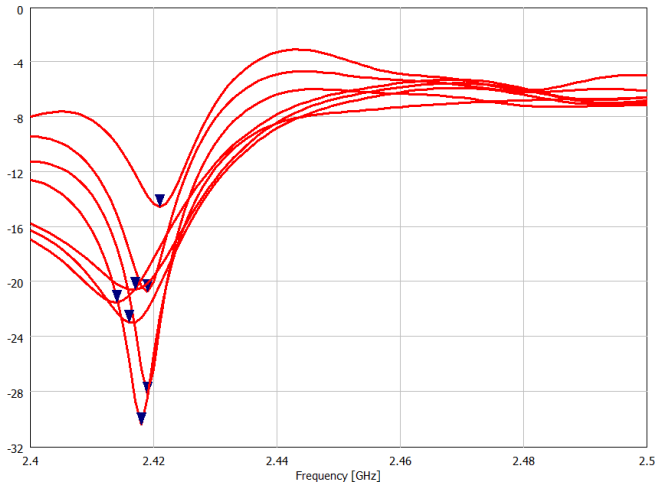


SOURCE FREQUENCY TUNING

Basic Heating Module provides the tuning of the source frequency mechanism. This regime mimics the physical behaviour of various real power sources under various conditions. The most widespread microwave source, a magnetron, is an imperfect device gradually changing its frequency during the heating, and in fact it may even "jump" from one frequency to another.

Two modes of the source frequency tuning are available: automatic source tuning, which assumes that the source tunes automatically to the deepest resonance in the considered frequency band, and manual source tuning, which allows the user to manually indicate which frequency in the considered frequency band the source should be tuned to (should be the new source frequency).

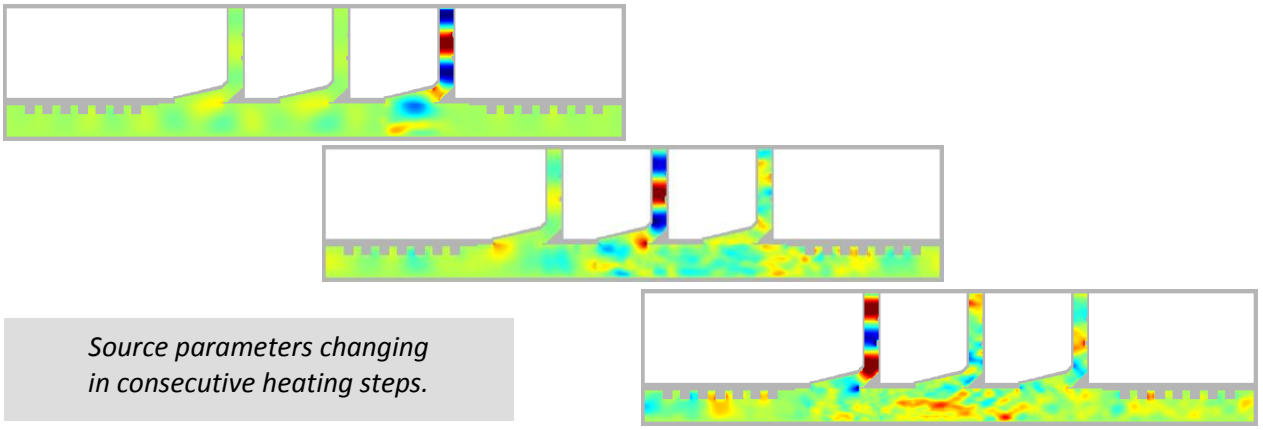
The source frequency tuning mechanism perfectly responds to desing needs of **novel microwave power applications** with solid state power sources. In such desings the return loss versus frequency is typically monitored in time, and the source frequency is tuned by the dedicated controller, so as to maximise the matching or meet other application-specific requirements.



Automatic tuning of the source to the deepest resonance in the considered frequency band.

SOURCE PARAMETERS SWITCHING

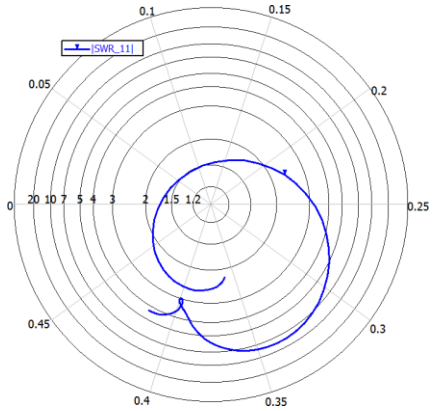
Basic Heating Module provides design engineers and researchers with a mechanism of source parameters switching. This regime is dedicated to microwave heating scenarios with solid-state sources characterised by separate frequencies, amplitudes, and phases. In the consecutive heating steps, Basic Heating Module performs automatic modification of source parameters, according to user specification, made for each source separately.



Source parameters changing in consecutive heating steps.

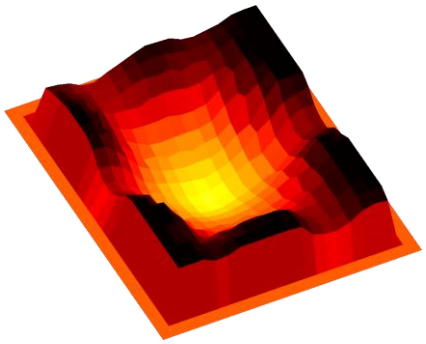
RIEKE CHART FOR SWR

Basic Heating Module enables also Rieke display for Standing Wave Ratio, which is of high interest of microwave heating engineers and heating devices designers.



HEAT TRANSFER ANALYSIS

Basic Heating Module enables analysis of the heat transfer problems including phase changes. The applied algorithms allow for the heat flow analysis using non-linear model and taking into account the conformal meshing. Basic Heating Module accepts three basic boundary conditions in the heat transfer calculations: Dirichlet, Neumann, and Robin boundary conditions.



OTHER FEATURES

Features Coupling

Features enabled in Basic Heating Module can be coupled together in one simulation scenario, e.g. load rotation and source frequency tuning.

Coupling with External Applications

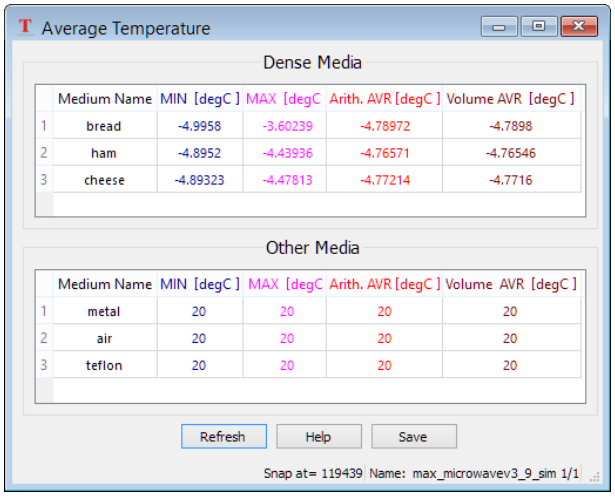
Basic Heating Module has been developed in a way that leaves open the possibility of coupling it with external applications. This feature enables modelling effects, which are currently not supported in Basic Heating Module.

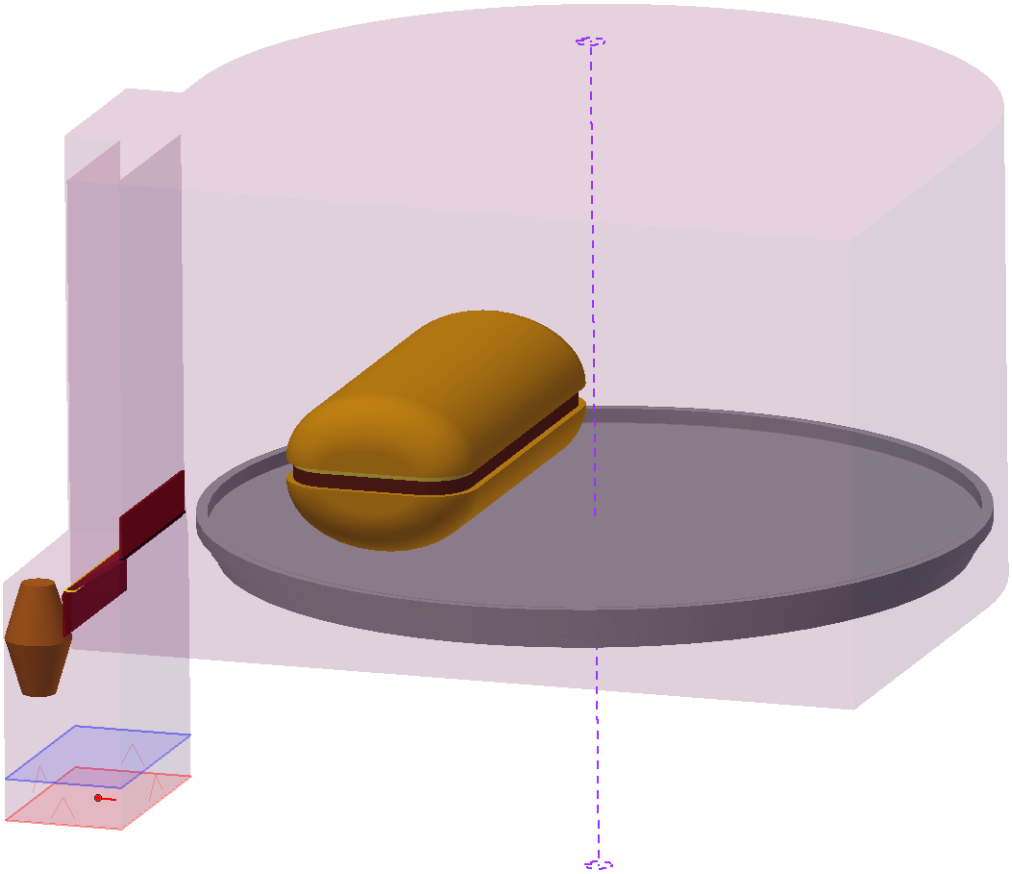
Various Heating Time

The user is allowed to define various heating times for each thermal iteration.

Average Temperature in the Object

Next to the temperature distribution, Basic Heating Module calculates the value of average temperature in an object and does it for each object separately.





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