Electromagnetic Simulation for Microwave Power Applications Using Micro-Stripes

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How Does Micro-Stripes Work?

Maxwells Equations

Electric Field

$$\nabla \times \overline{E} = \frac{-\delta \overline{B}}{\delta t} = -j\omega\mu \overline{H}$$

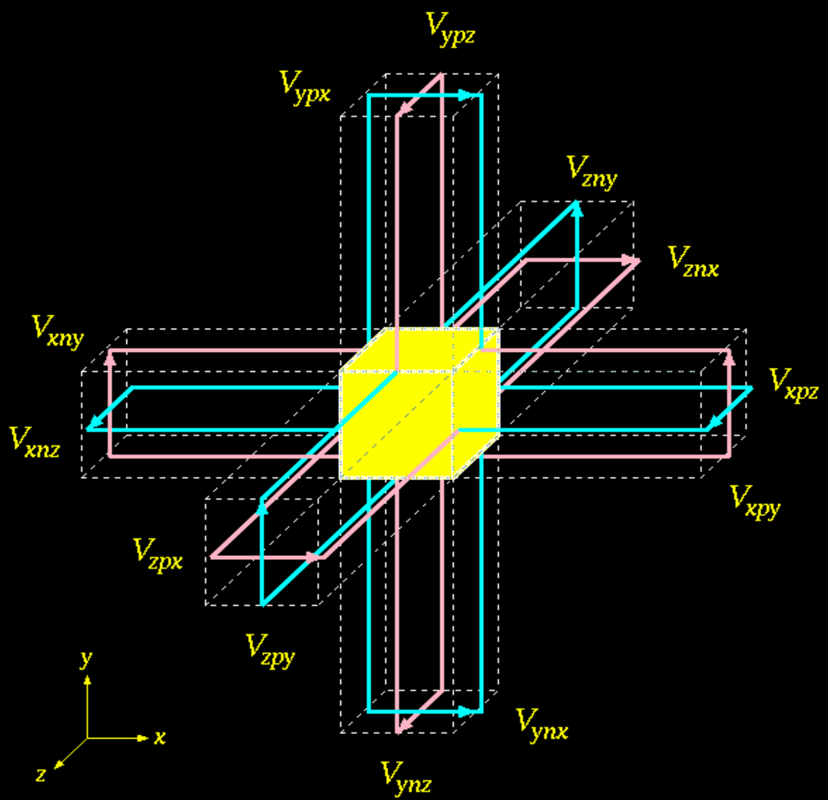
Magnetic Field

$$\nabla \times \overline{H} = \overline{J} + \varepsilon \frac{\delta \overline{E}}{\delta t} = \sigma \overline{E} + j\omega\varepsilon \overline{E}$$

Divergence

$$\nabla \cdot \overline{D} = \rho \qquad \nabla \cdot \overline{B} = 0$$

Transmission-Line Modeling (TLM) Method



- Space divided into cells modeled as the intersection of orthogonal transmission-lines
- Voltage pulses transmitted and scattered at each cell
- Simulation proceeds in time from initial field/voltage excitation
- Electric and magnetic fields are calculated from voltages and currents on the lines at each time-step
- TLM is very efficient
  - Broad-band response
  - Highly graded mesh (1:100 changes in cell size)
  - Small cells recombined
  - Sub-cell features included

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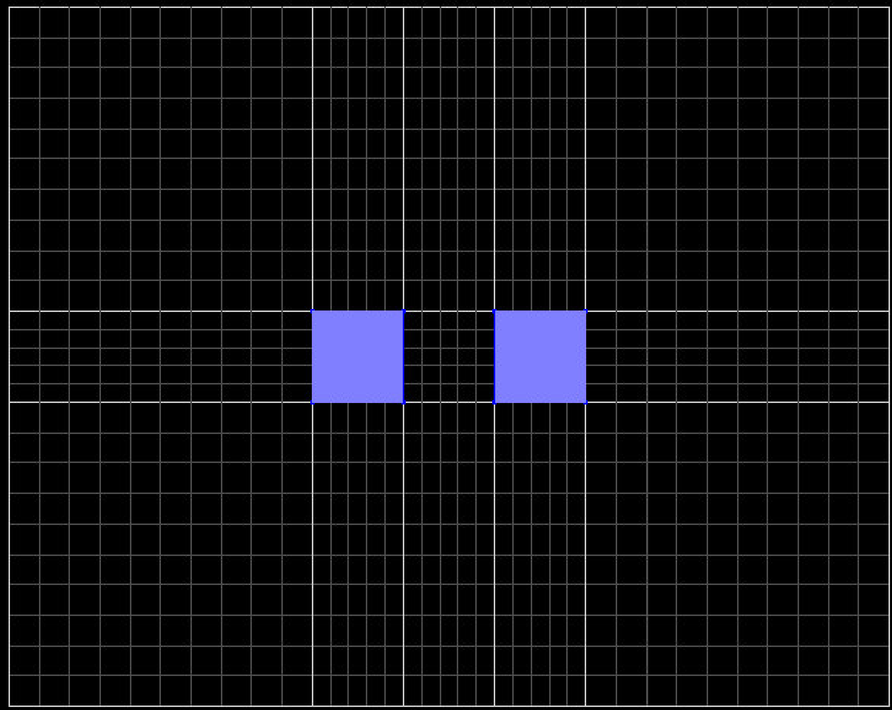
Typical 2-D TLM Mesh



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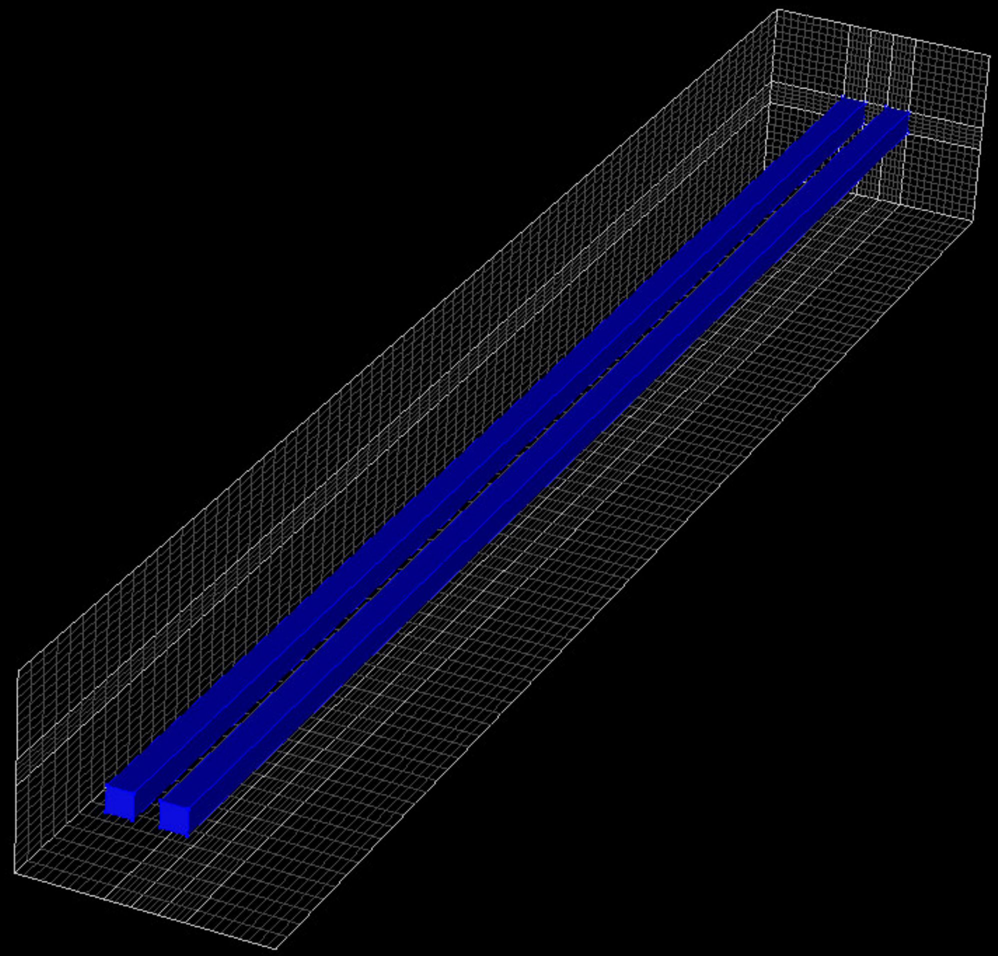
Typical 3-D TLM Mesh



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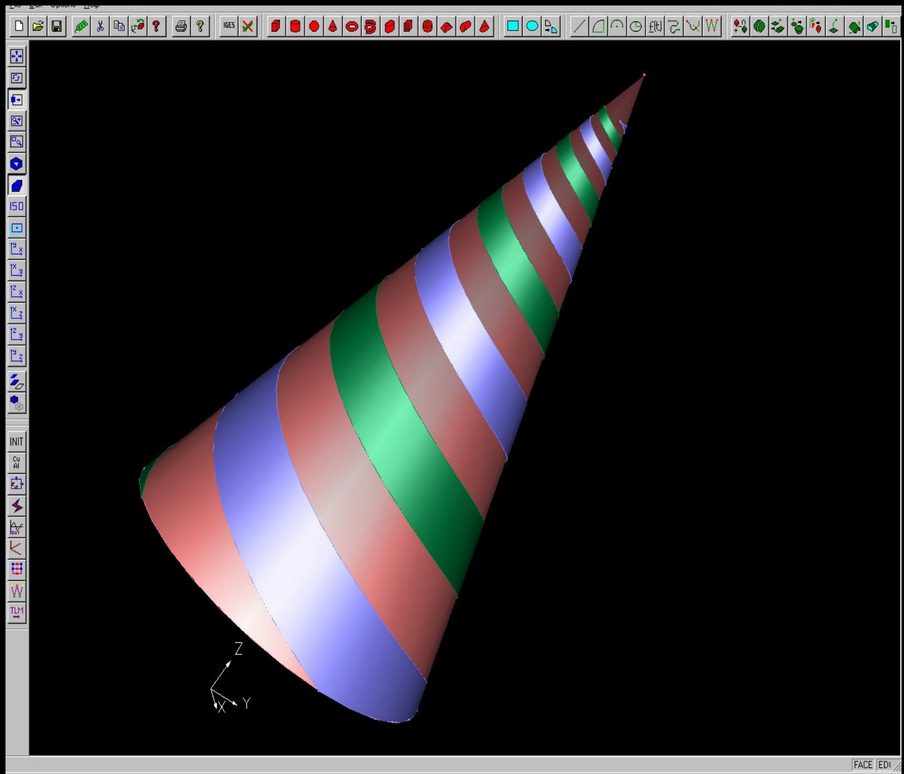
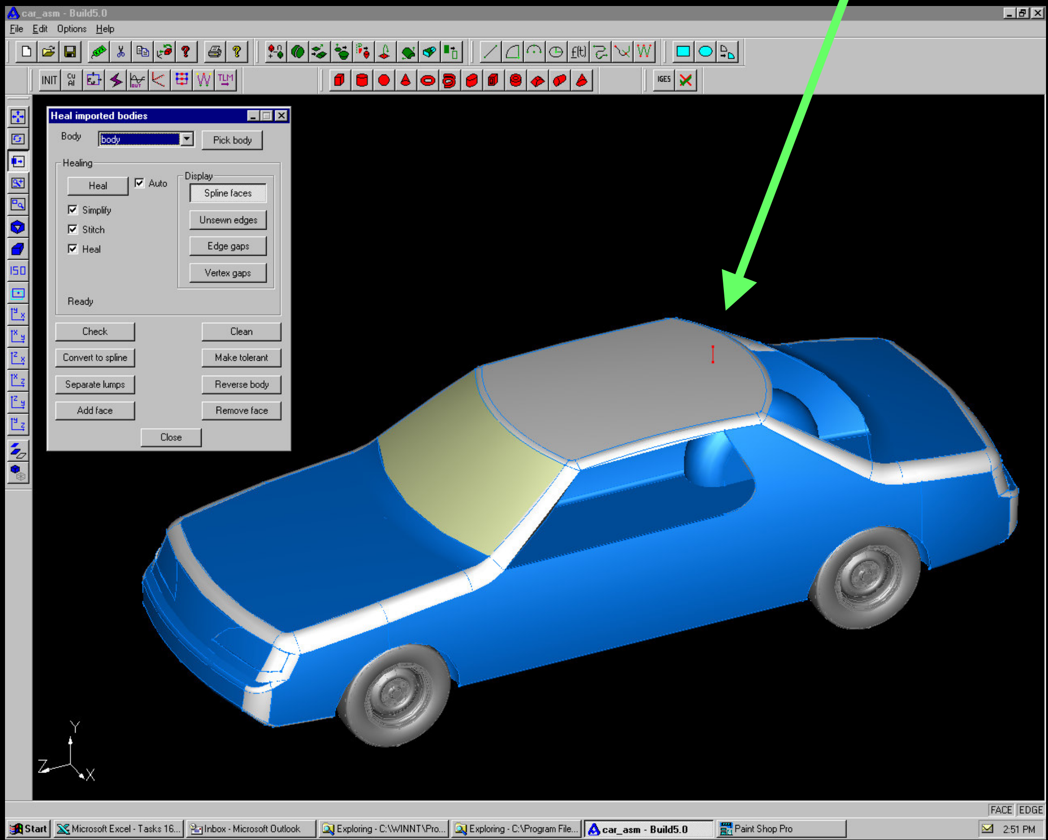
Geometry Modeling Built on ACIS Standard



- Native Windows interface
- Uses industry standard solid modelling kernel, **ACIS** so data can be shared with any other ACIS application (e.g. AutoCAD)
- Library of 12 solid primitive shapes including: cylinder, sphere, cone, torus, helix, pyramid
- Complex shapes can be constructed bottom-up using edges, surfaces, bodies
- Dynamic rotate, zoom, pan, cut-away
- Parts can be copied through translation, rotation etc.
- Pick entities from the screen to interrogate model

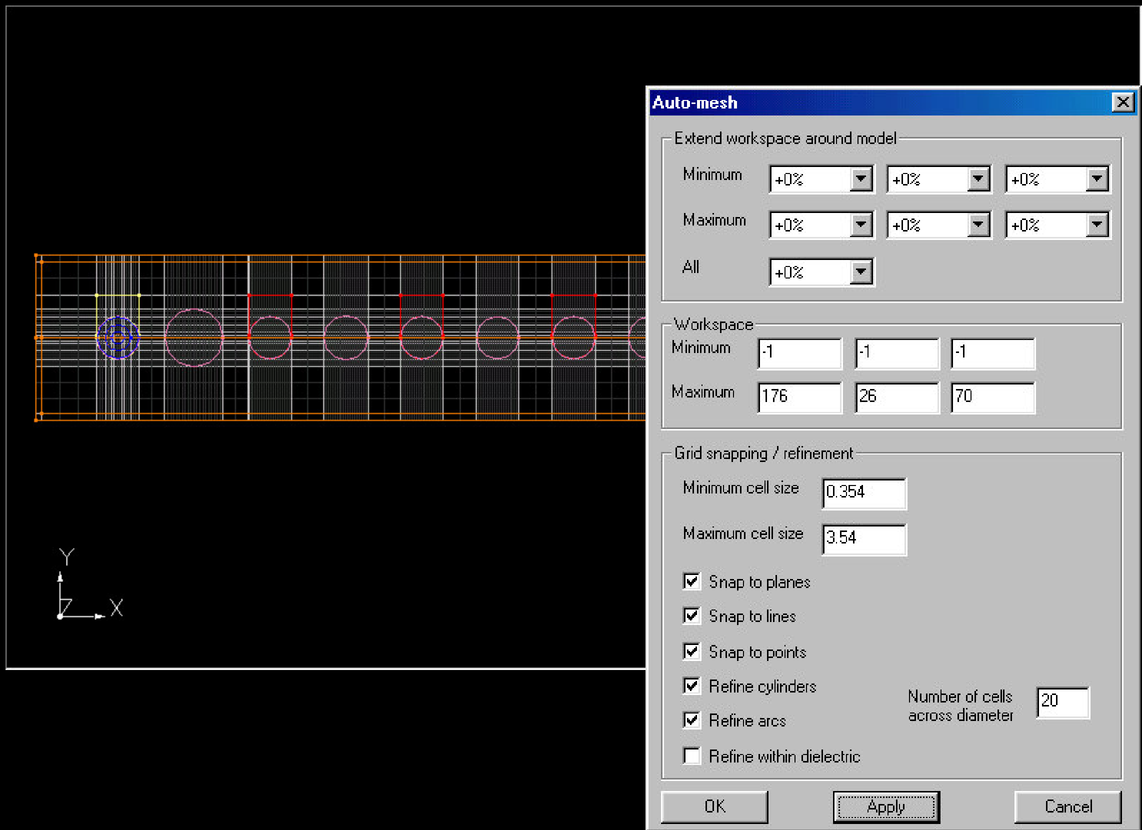
CAD Import

Spline-surfaces indicated by healing tool



- IGES, SAT, STEP, STL and DXF file import and export
- Automated healing tool to check integrity
- Simplify spline surfaces
- Stitch adjacent faces and repair gaps

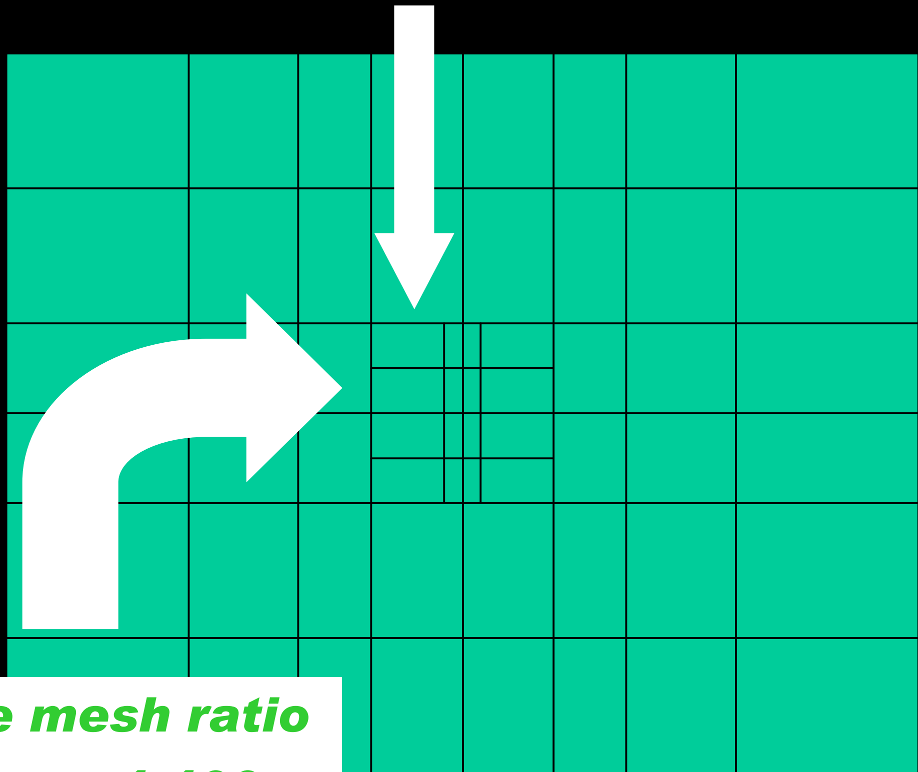
Complete Automatic Meshing



- Extend work-space around model
- Define minimum and maximum cell sizes
- Snap to points
- Snap to lines
- Snap to planes
- Refine cylinders
- Refine arcs
- Refine dielectrics

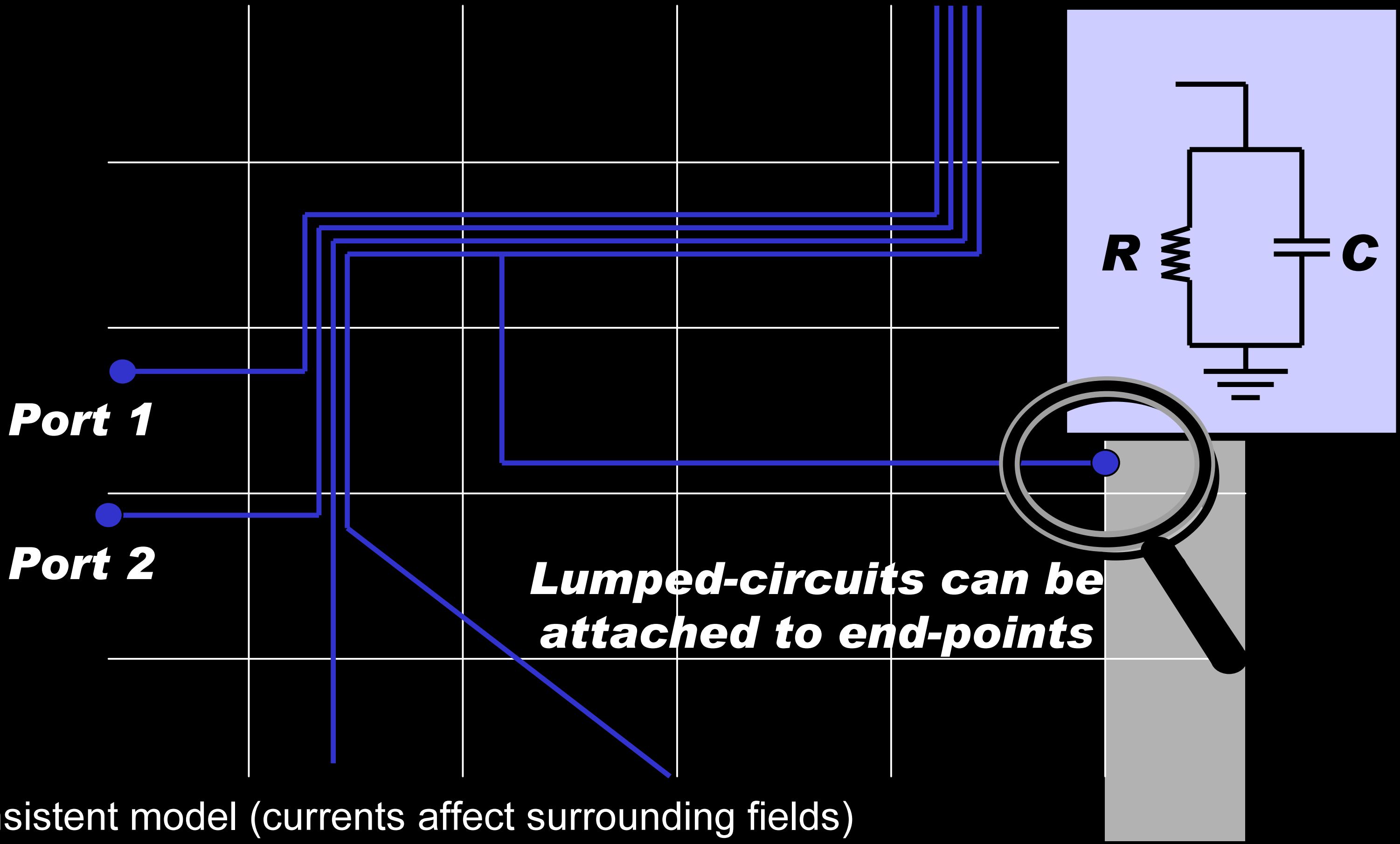
Embedded (Lumped) Mesh

Fine mesh can be embedded in a coarse mesh enabling geometric detail to be resolved locally



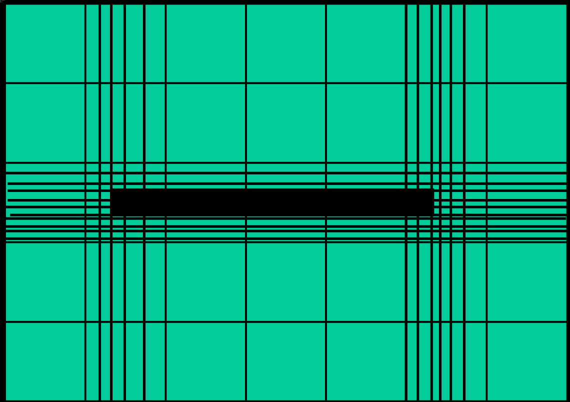
Coarse mesh: Fine mesh ratio can be as severe as 1:100

Sub-Cell Wires

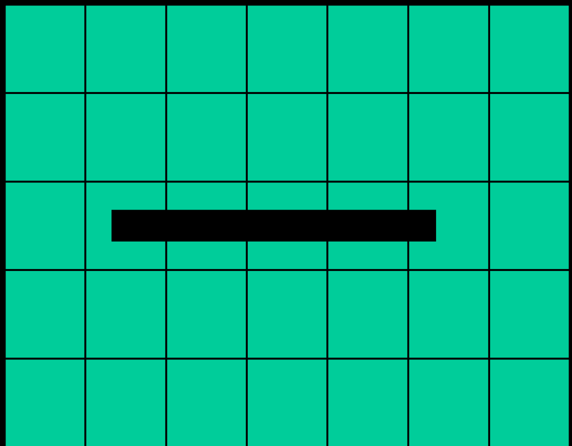


- Self-consistent model (currents affect surrounding fields)
- Up to 50 wires within a cell
- Wires can be modeled on the sub-cell level (wire radii smaller than the cell size)
- Wire-ports can be defined for S-parameter output

Sub-Cell Slot (Aperture)

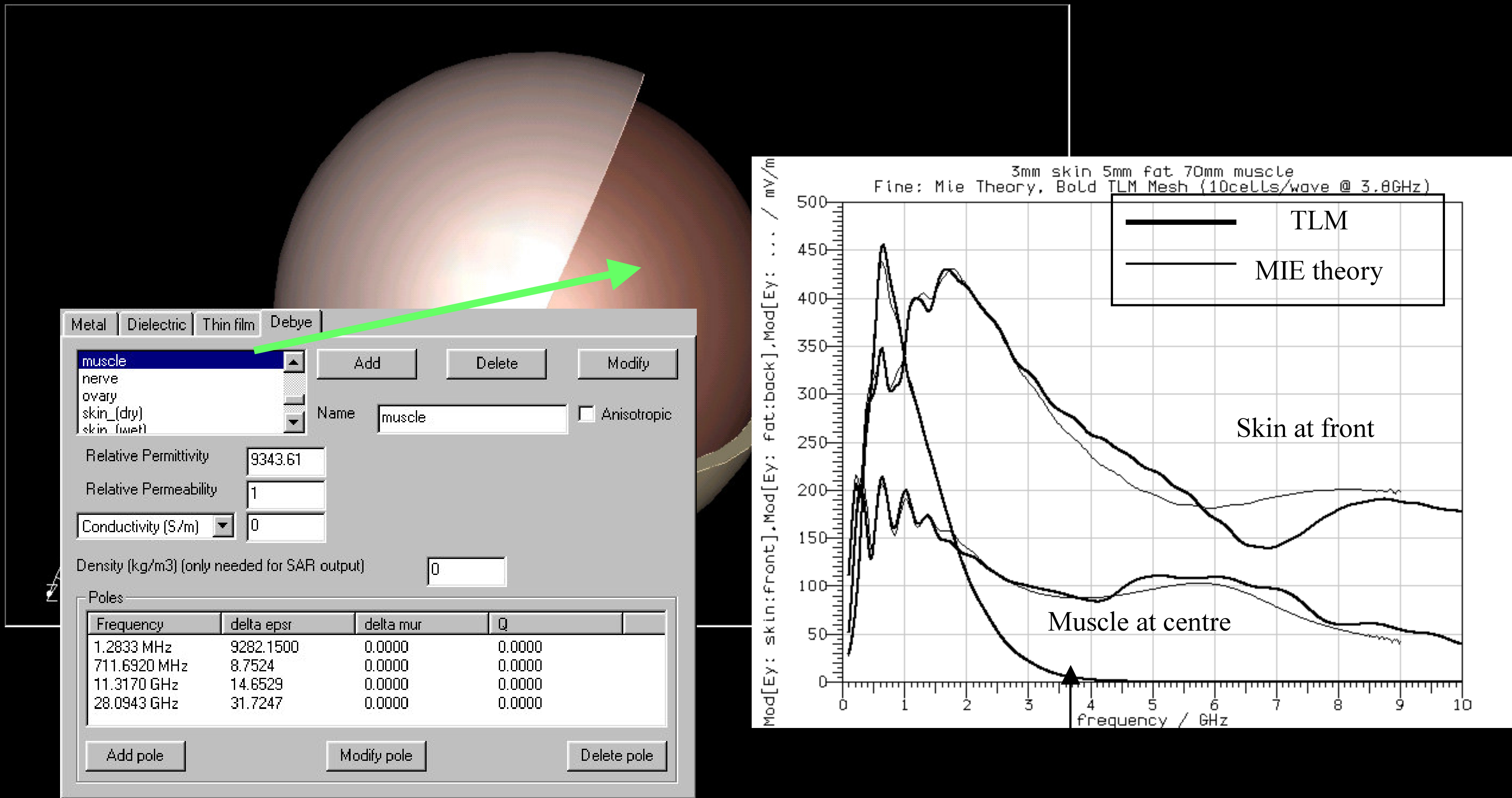


As with most numerical modeling techniques, large numbers of cells and small cells can lead to large solution times.



Thin slots can be modeled at a sub-cell level
Slots can be open or filled with a material to represent gaskets
Overlapping or butted joints
Slot bends and junctions

Frequency Dependent Material Parameters



Advanced Features in Micro-Stripes…

– Embedded (Lumped) Mesh
– Wires
– Slots/Apertures
– Thin Films
– PML
– Frequency Dependant Materials
– Time Domain Solution

… Allow Complex Models to Be Solved Rapidly !!!

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Benchmark problem 1: Electromagnetic processes in a microwave oven(2.45 GHz)

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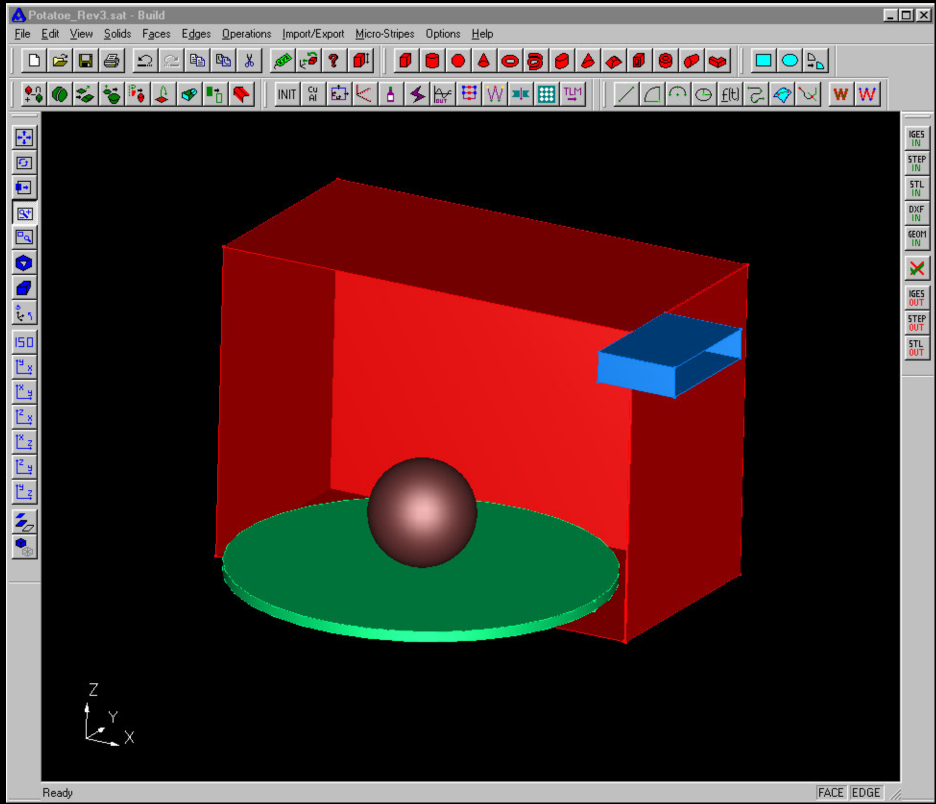
General view of the modeled oven (Uniform Potato)

General Features:

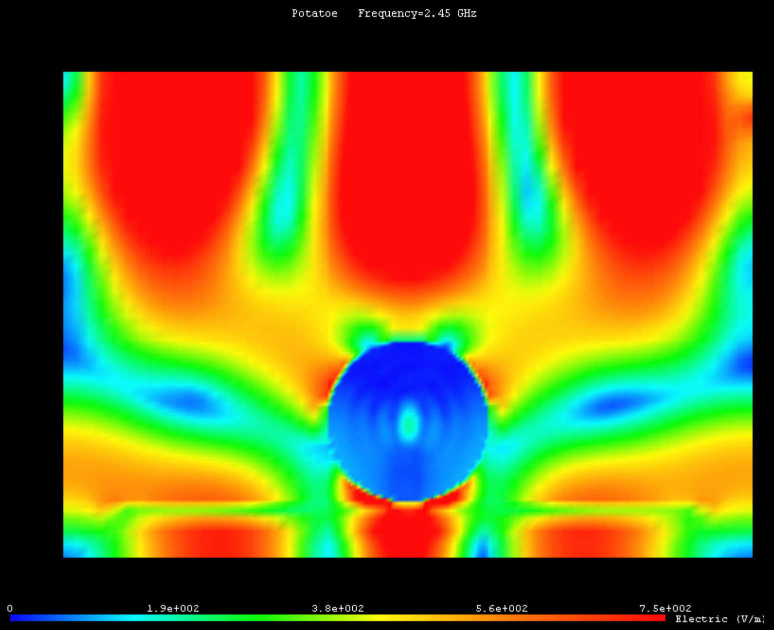
- Microwave oven walls have perfect electric conductivity.
- Excitation of the oven is a waveguide feeder, a magnetron (sinusoidal signal, frequency 2.45 GHz, average power 1 kW) perfectly matched with the waveguide.

Processed Materials:

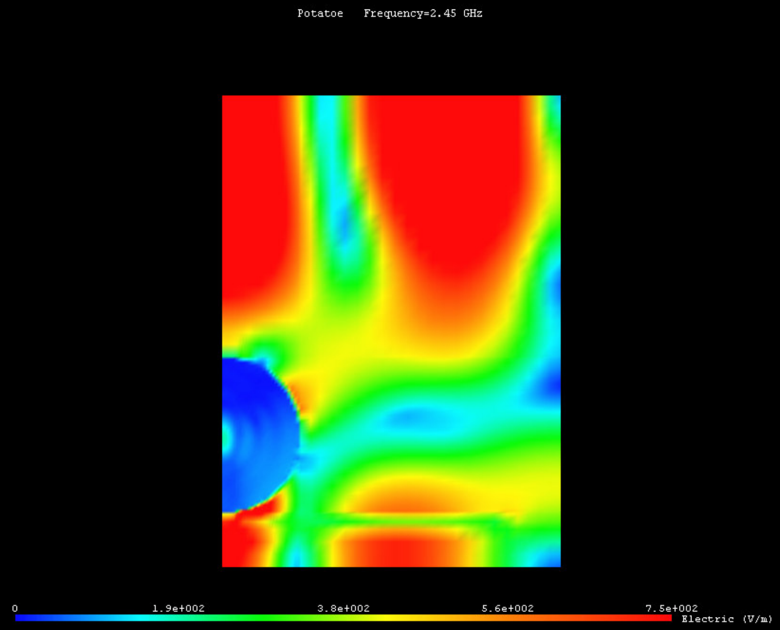
- Uniform potato of spherical model with diameter 63 mm, relative permittivity ε = 65 – j20 and density 1.0 g/cm³ is centered and located directly on the shelf.
- Shelf of cylindrical model with diameter 227 mm, height 6 mm, relative permittivity ε = 2.55 – j0 is centered in the oven. Shelf's top face is 21 mm away from the bottom of the oven.



Patterns of the Electric Field
Vertical Cuts



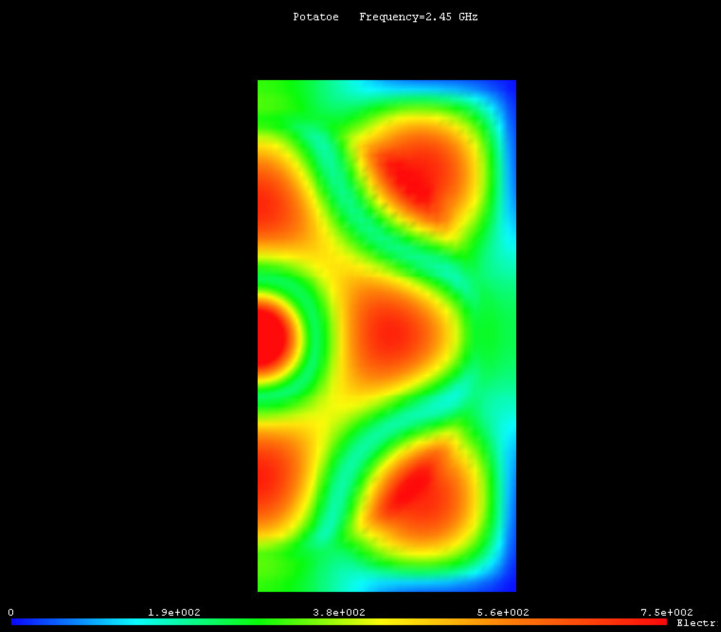
XZ plane (y = 135 mm)



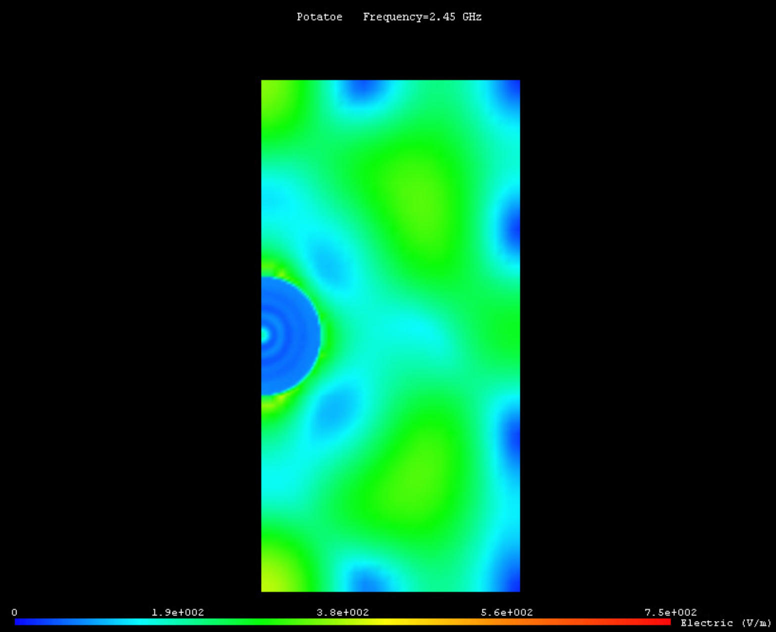
YZ plane (x = 133.5 mm)

Note: Symmetry plane used in x direction.

Patterns of the Electric Field
Horizontal Cuts



YX plane (Z = 10 mm)
10 mm above the bottom of the oven



YX plane (Z = 52.5 mm)
Central plane of the potato

Note: Symmetry plane used in x direction.

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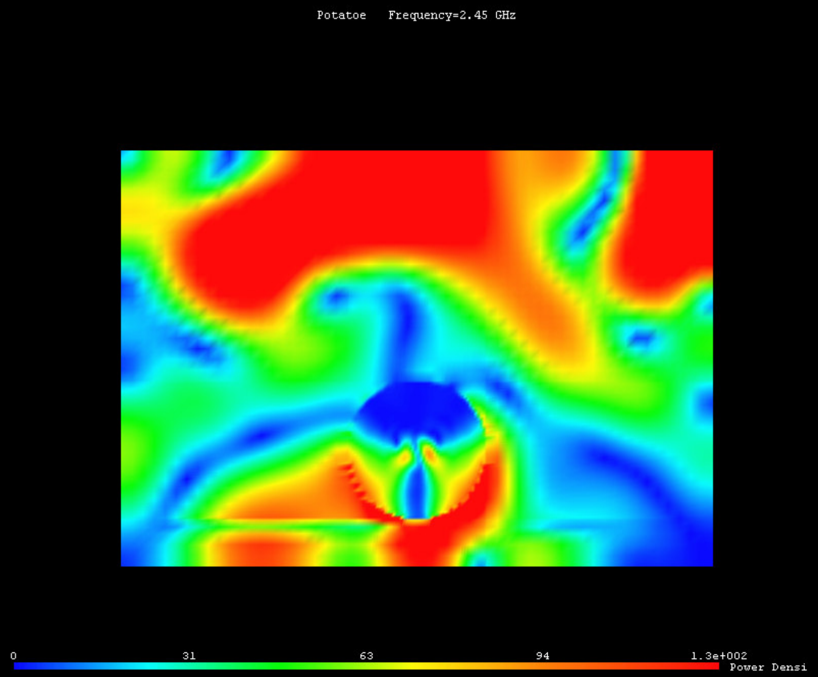
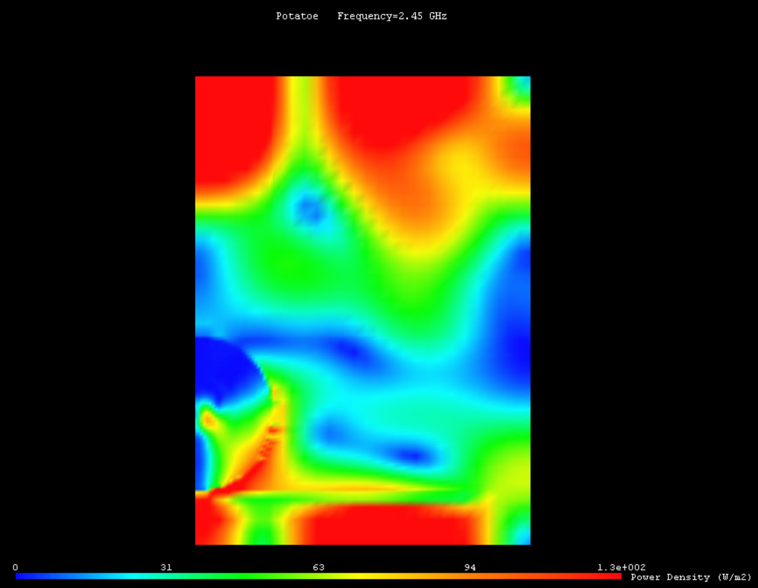
Patterns of the power density - Vertical Cuts





XZ plane (y = 135 mm)

YZ plane (x = 133.5 mm)

Power Dissipated in Potatoe @ 2.45 GHz = Watts

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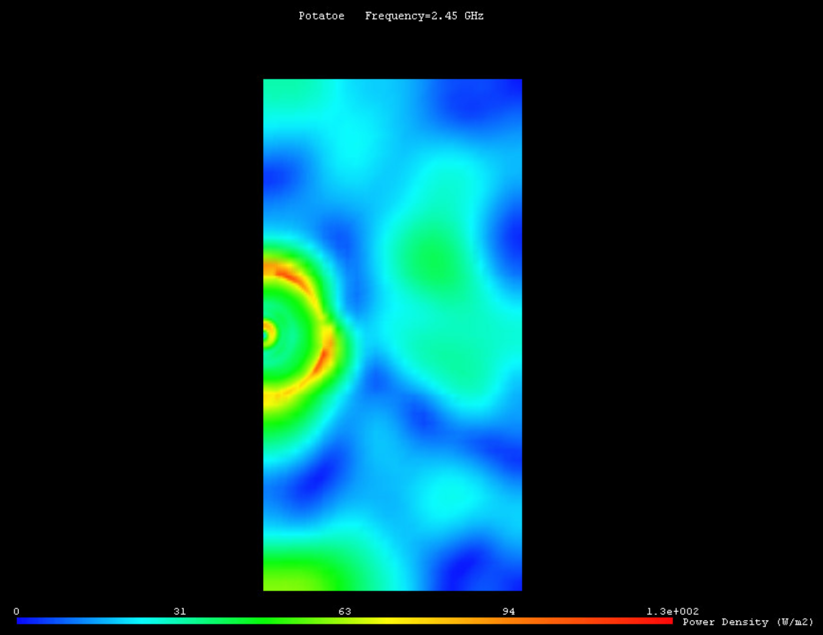
Patterns of the power density - Horizontal Cuts



YX plane (Z = 52.5 mm)
Central plane of the potato

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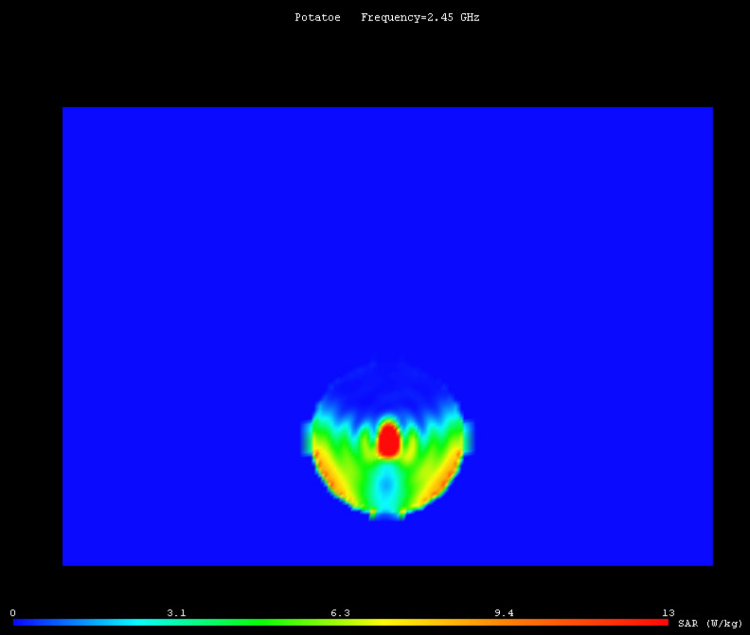
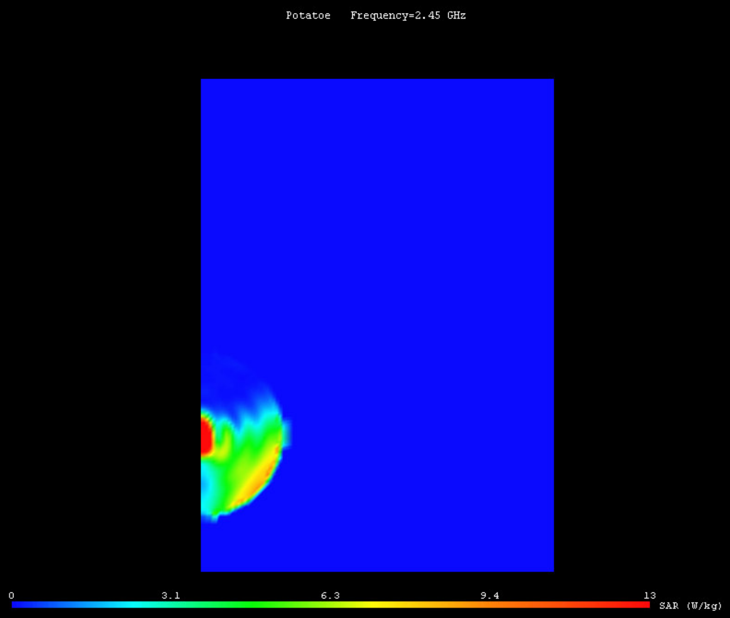
Patterns of SAR - Vertical Cuts



XZ plane (y = 135 mm)



YZ plane (x = 133.5 mm)

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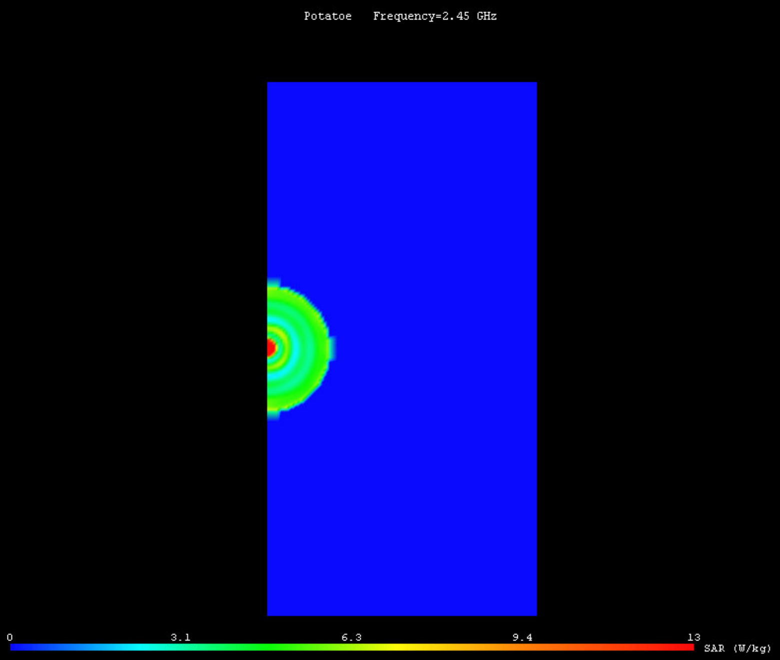
Patterns of SAR - Horizontal Cuts



YX plane (Z = 52.5 mm)
Central plane of the potato

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Matching (coupling)