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Benchmark Problem 1

ELECTROMAGNETIC PROCESSES IN A MICROWAVE OVEN (2.45 GHz)

Solutions generated with
MEFiSTo-3D Pro
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Statement of Problem

General Features:

- Excitation: waveguide feeder; a magnetron (sinusoidal signal, frequency 2.45 GHz, average power 1 kW) perfectly matched with the waveguide.
- Oven walls with perfect electric conductivity.

Processed Materials:

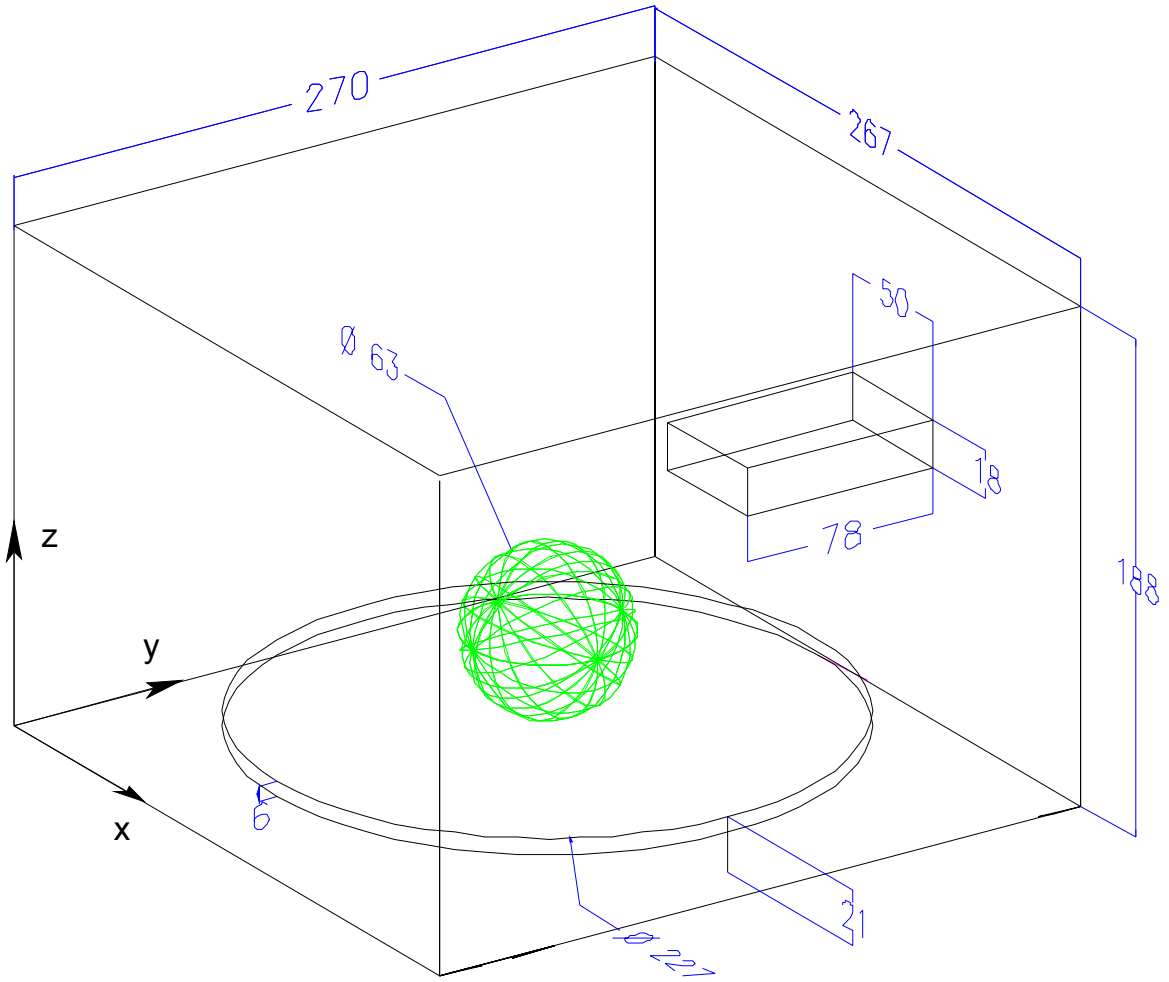
Uniform potato

- Located directly on the shelf (e = 2.55 – i0).
- Spherical model: diameter 63 mm; centered.
- Relative permittivity e = 65 – i20, density 1.0 g/cm3

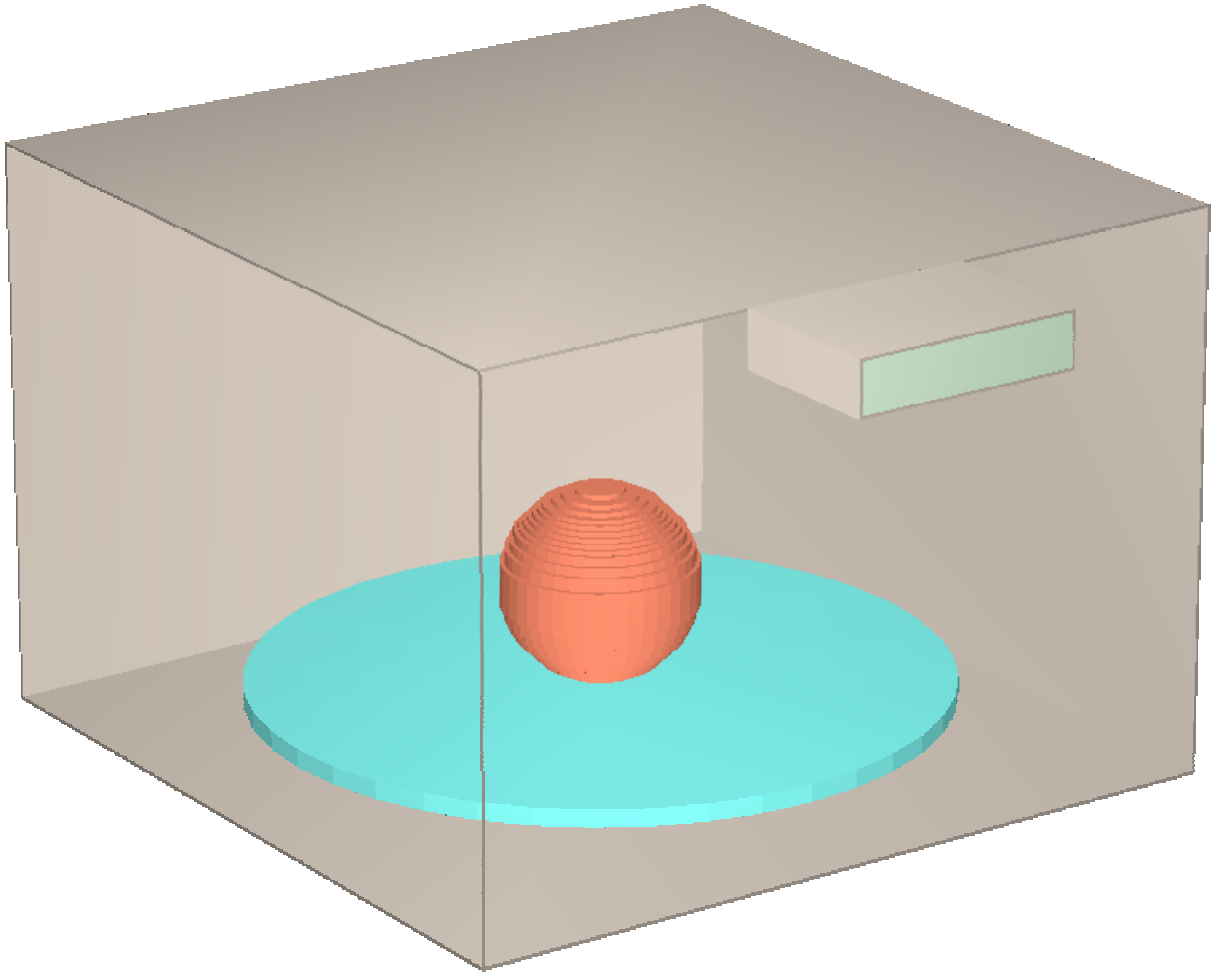
Expected Output

1. General view of the modeled oven generated by the code's preprocessor.
2. Patterns of the electric field (the E_z component, envelope):
   - Vertical cuts – centered (oven-wise and material-wise): in the XZ-plane (y = 135 mm) and in the YZ-plane (x = 133.5 mm).
   - Horizontal cuts – 10 mm above the bottom of the oven (z = 10 mm), and in the central plane of the potato (z = 52.5 mm).
3. Patterns of the density of dissipated power and 4. SAR:
   - Vertical cuts – similar to the cuts for the electric field.
   - Horizontal cuts – centered material-wise, i.e., in the central plane of the potato (z = 52.5 mm).
5. Matching (coupling):
   - The reflection factor for the frequency range 2.35 – 2.55 GHz.
   - The reflection factor specifically at 2.45 GHz.
   - Percentage of the power dissipated in the material at 2.45 GHz.

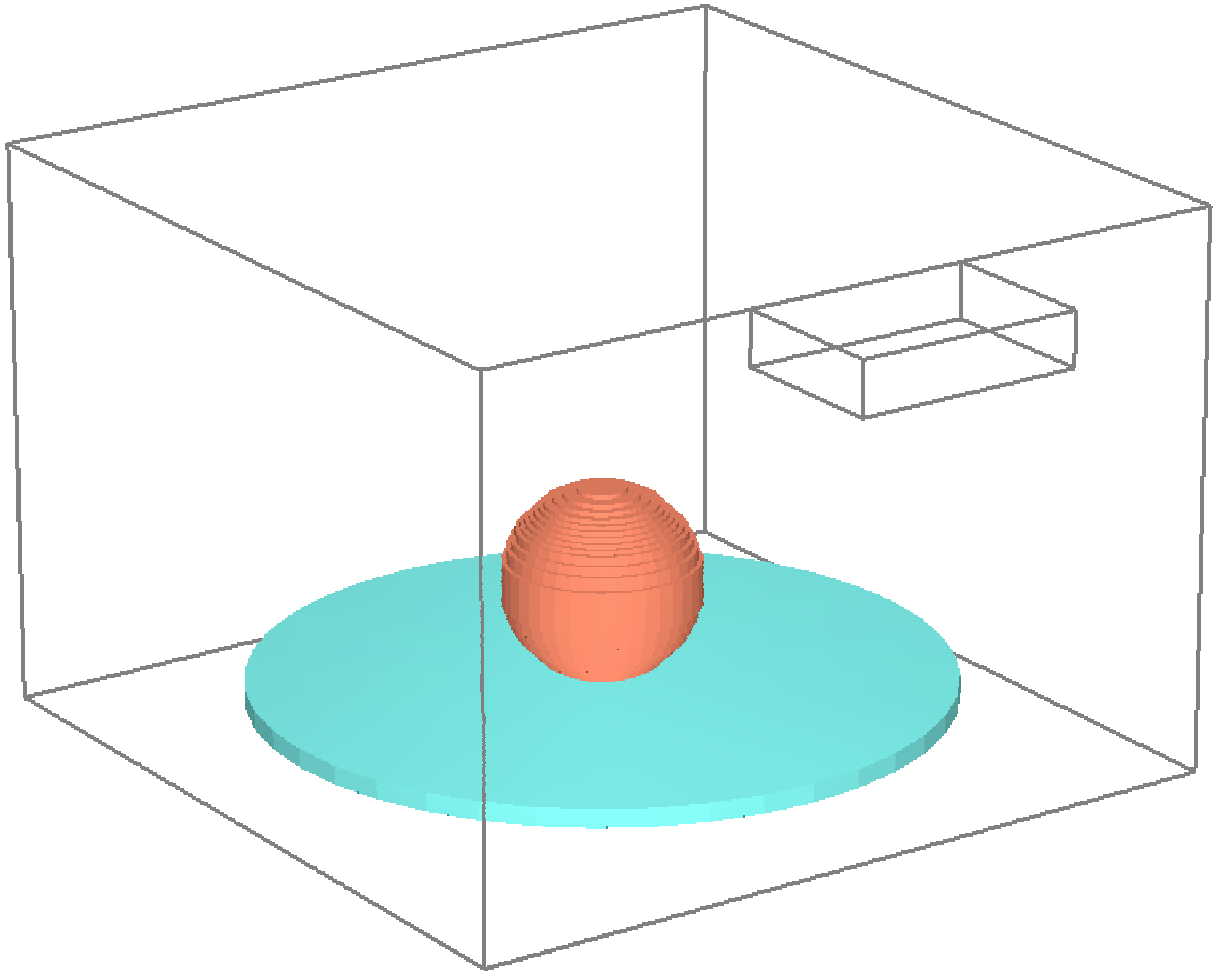
3D View and Dimensions



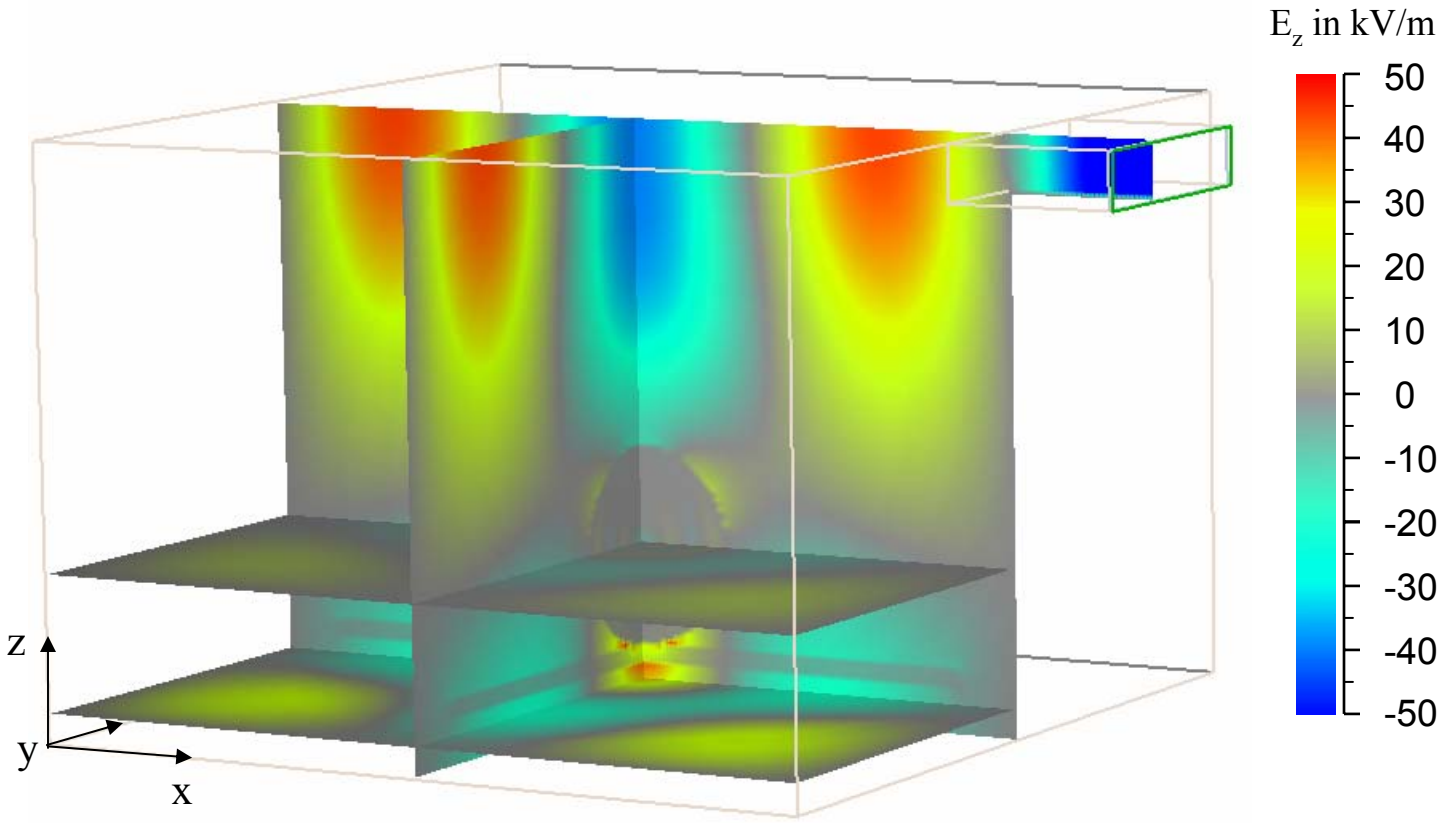
3D Solid View of the Oven



3D Outline View of the Oven



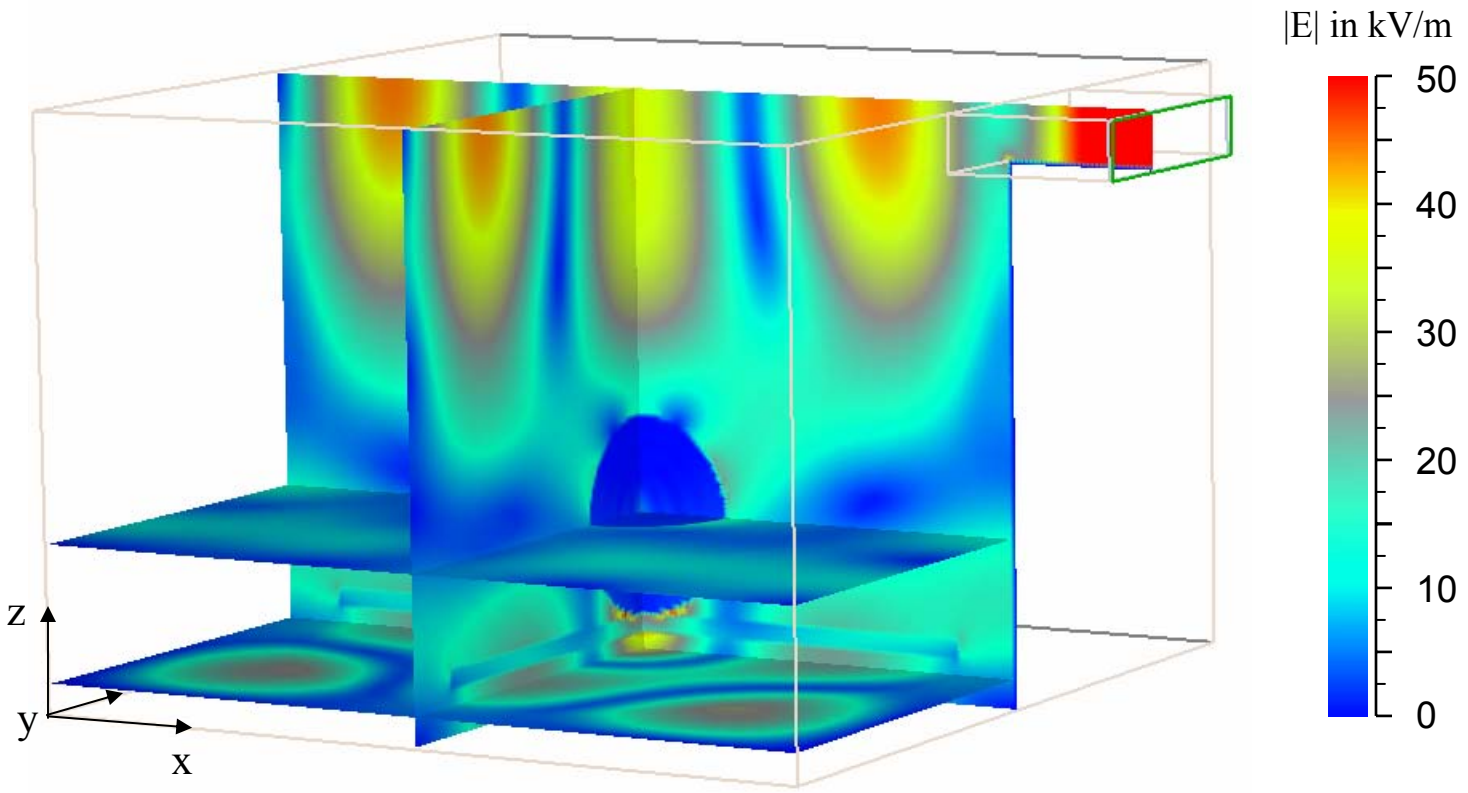
E_z-Distribution at the Peak of the Cycle



Peak value of the vertical electric field component E_z

1 kW magnetron matched to the waveguide, f = 2.45 GHz, steady state

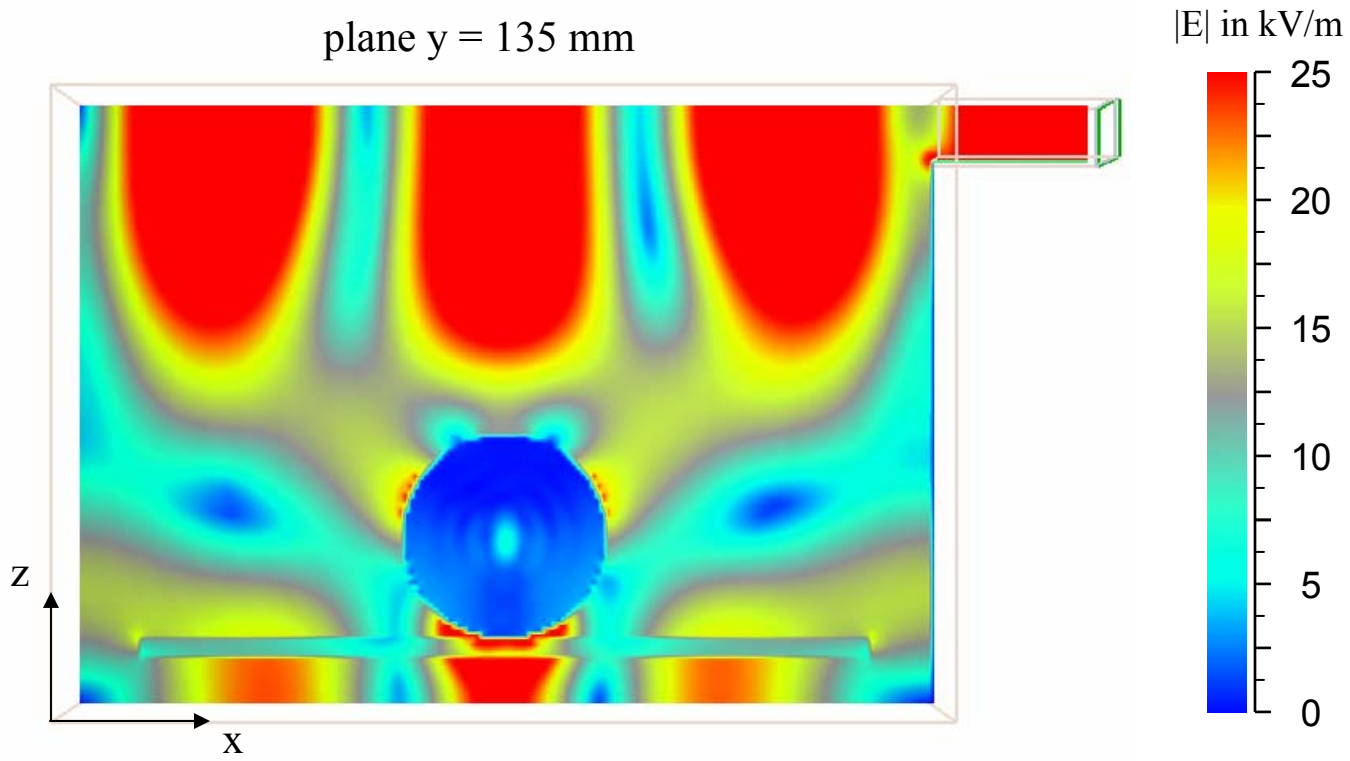
Distribution of the Envelope of |E|



Envelope of the peak value of the electric field $|E|_{max}$

1 kW magnetron matched to the waveguide, f = 2.45 GHz, steady state

Distribution of the Envelope of |E|



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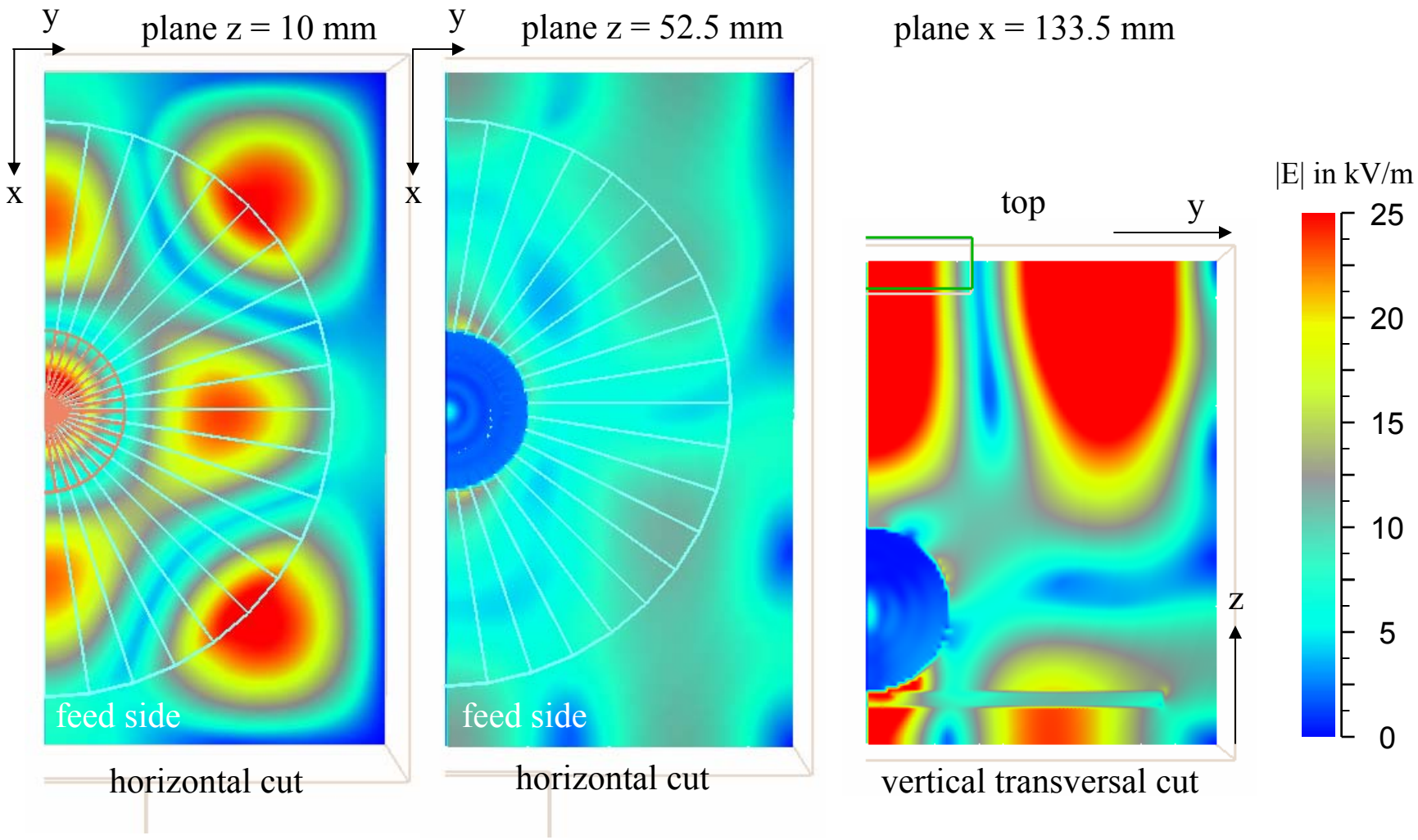
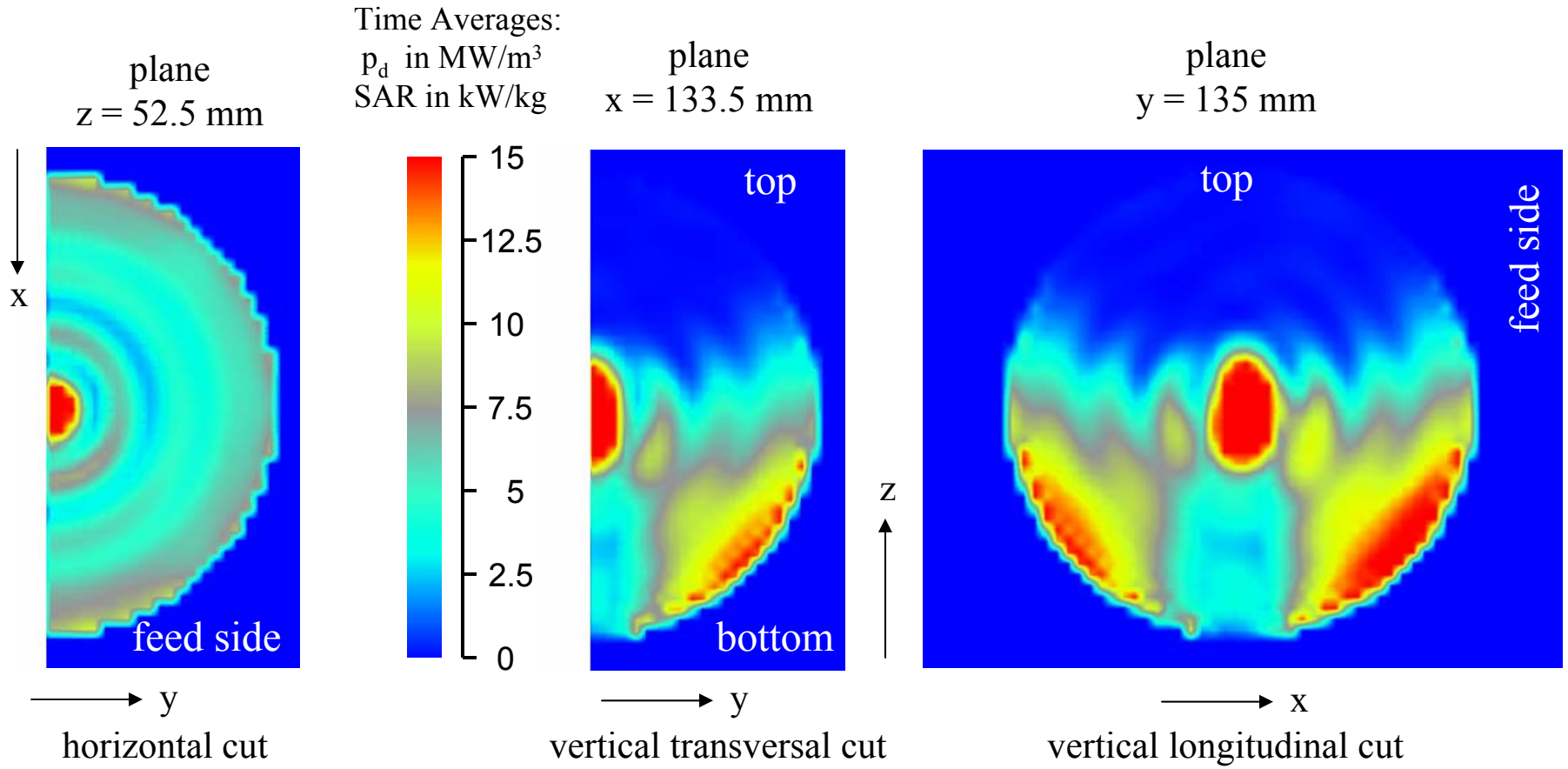


1 kW magnetron matched to the waveguide, f = 2.45 GHz, steady state

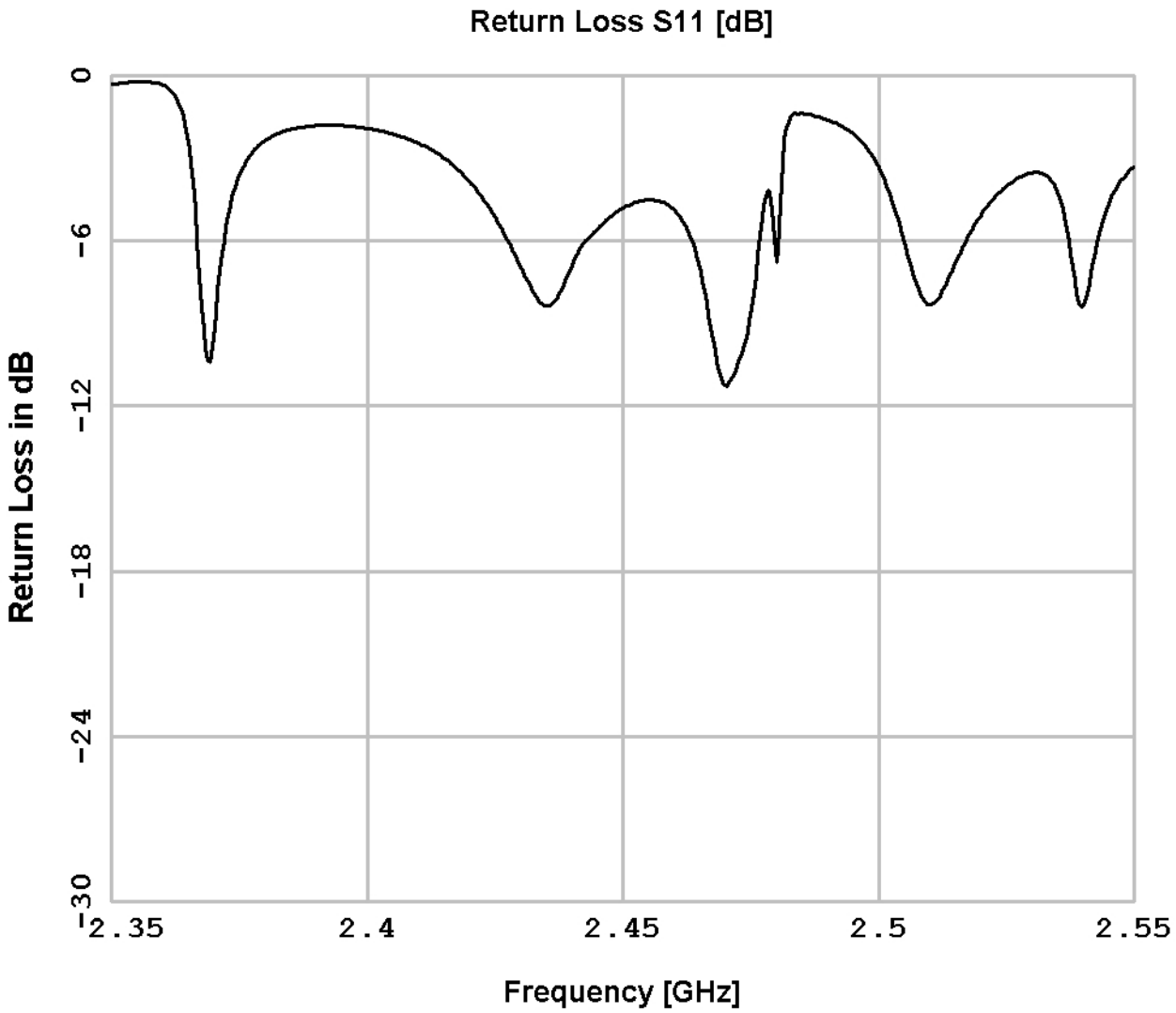
Dissipated Power Density and SAR



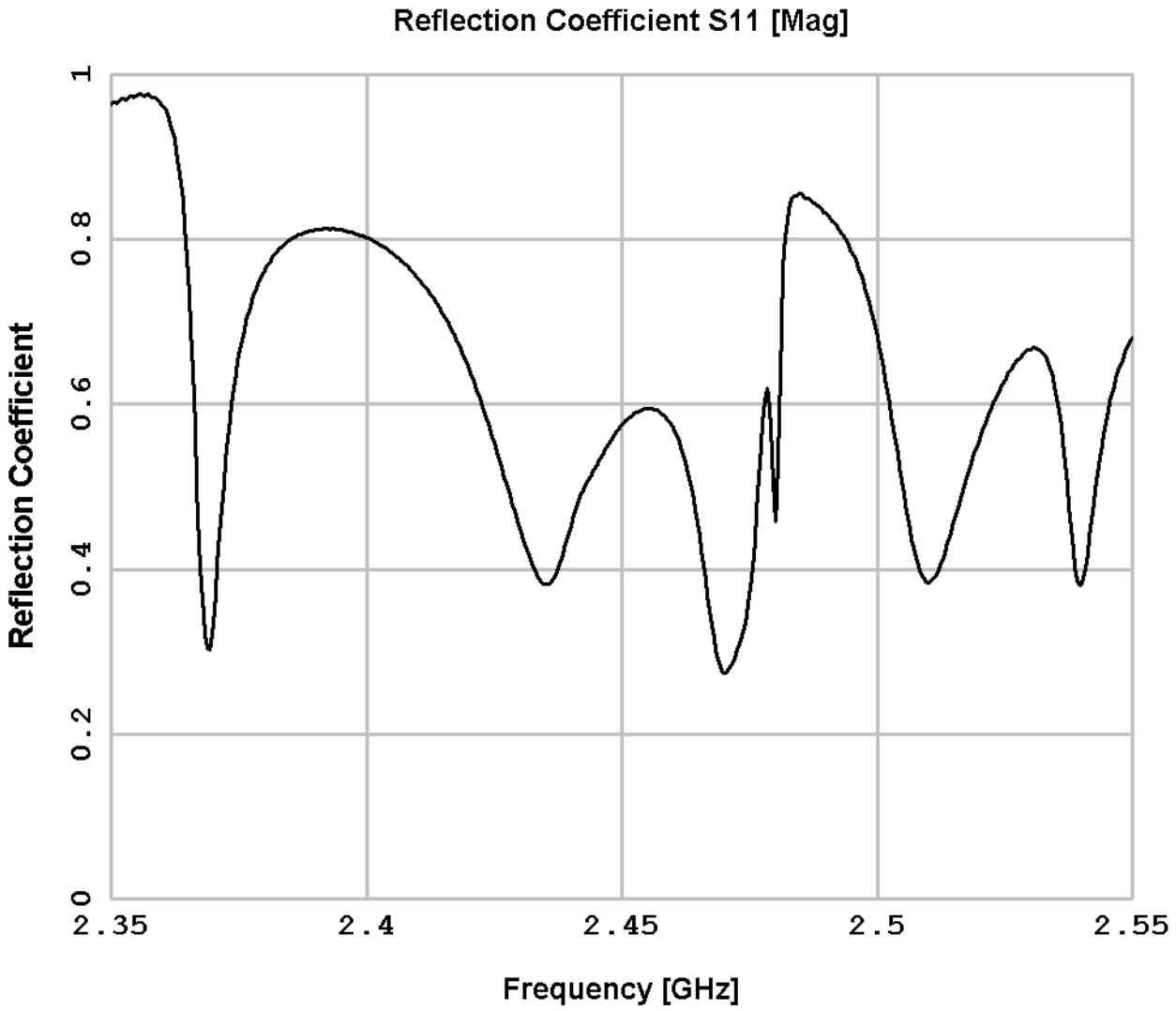
Density of average dissipated power (p_d) and SAR in the potato

1 kW magnetron matched to the waveguide, f = 2.45 GHz, steady state

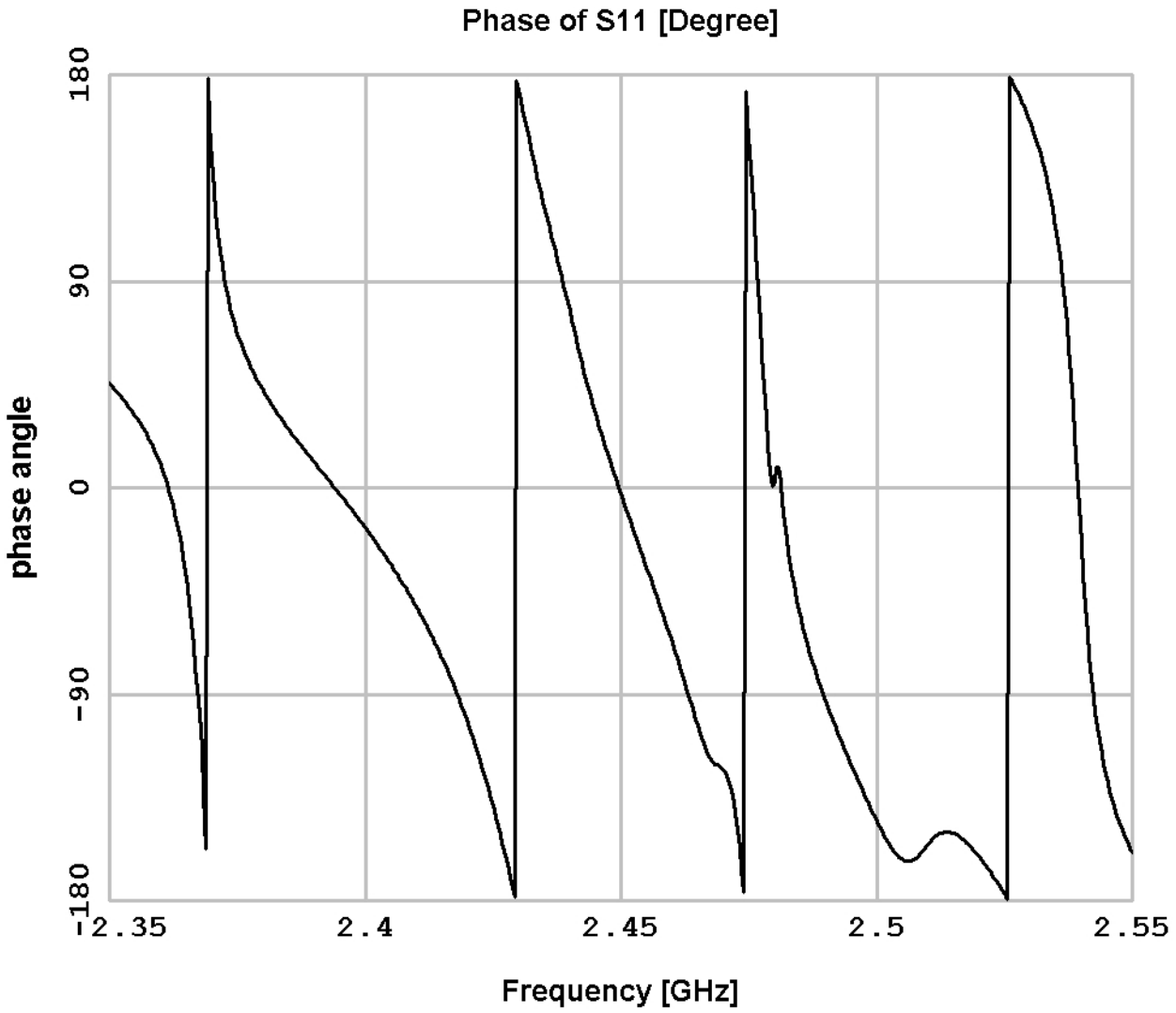
Return Loss Characteristics



Input Reflection Coefficient $|S_{11}|$



Input Reflection Coefficient (angS_{11})



Various Characteristics at 2.45 GHz

Reflection Coefficient at 2.45 GHz at 50 mm from the inner wall of the oven:

$$S_{11} = 0.574\, e^{j0}$$

Return Loss at 2.45 GHz

$$RL = 20 \log |S_{11}| = -4.83\ dB$$

Average power delivered by the magnetron (incident power), reflected, and absorbed by the oven at 2.45 GHz:

$$P_{inc} = 1000 \text{ Watts} \qquad P_{ref} = 329 \text{ Watts} = 32.9\% \qquad P_{abs} = 671 \text{ Watts} = 67.1\%$$

Average SAR for the potato:

$$SAR_{avg} = \frac{P_{abs}}{V_{potato}\,\rho_{potato}} = \frac{671 \text{ W}}{0.131 \text{kg}} = 5.125\ kW / kg$$

Appendix: Formulas and Relationships

$$P_{avg} = |E_{\max}|^2 \frac{ab}{4\eta_0}\sqrt{1-\left(\frac{\lambda}{2a}\right)^2}$$

Average transmitted power (TE_{10} mode in rectangular waveguide)

$$\sigma = \omega\varepsilon_0\varepsilon_r''$$

Conductivity of the lossy potato

$$SAR = \frac{\sigma|E|^2}{\rho_m} = \omega\varepsilon_0\varepsilon_r''\frac{|E|^2}{\rho_m}$$

Specific Absorption Rate