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Accurate modeling of the microwave treatment in reverberating chamber. Sanitation of agro food material

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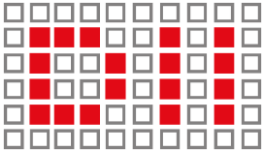

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Talk layout

- Introduction
  - Microwave heating
  - Goals
- Electromagnetic simulation and thermal problem
  - Resonance phenomena
- Results
  - Analysis of the resonance for spherical models
  - Application Example
  - Ellipsoidal models
- Conclusion

Microwave Heating

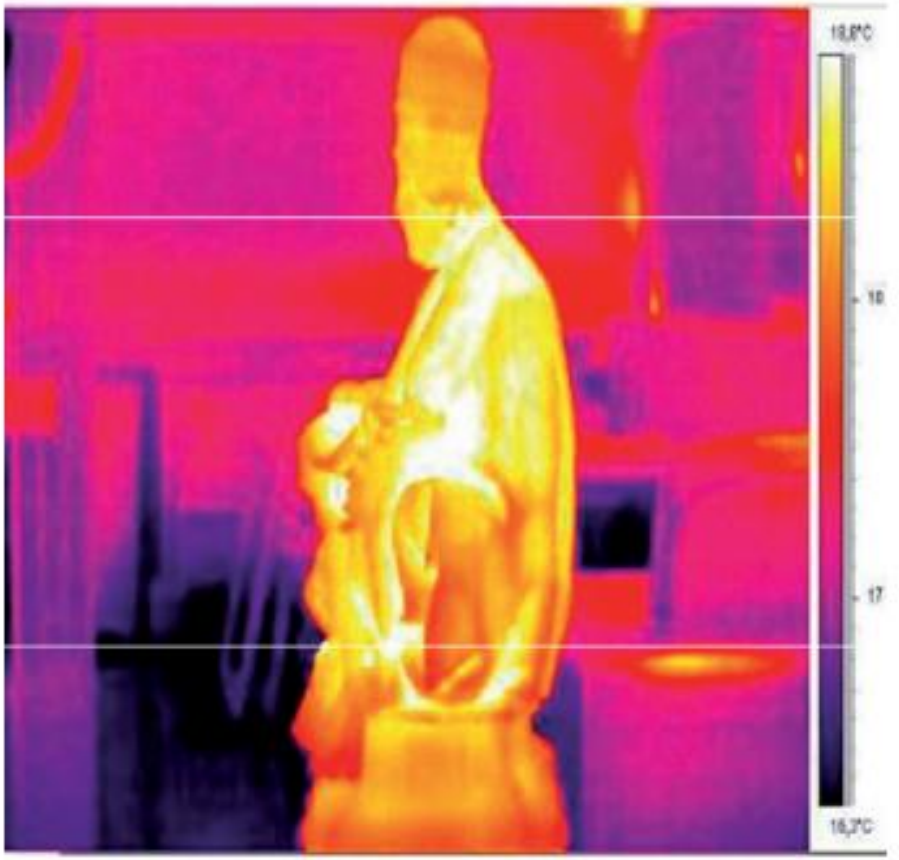
The microwave heating is useful for drying of foodstuff, disinfestation of works of art, phitosanitary treatment and disinfection of packaging [1], [2] according to current international guidelines.

[1] B. Bisceglia, R. De Leo, A. P. Pastore, S. von Gratowski, and V. Meriakri, “Innovative systems for cultural heritage conservation. Millimeter wave application for non-invasive monitoring and treatment of works of art,” Journal of Microwave Power and Electromagnetic Energy, vol. 45, no. 1, pp. 36–48, 2011.
[2] B. Bisceglia, R. De Leo, and N. Diaferia, “Mw pallets disinfestations,” Journal of microwave power & electromagnetic energy online.

Microwave Heating

- Promising application for treatment of agro food material.
- The food safe for consumption.
- The food no radioactive or contaminated.
- No residual radiation remaining in the food.

Treatment of works of art



The statue of S. Leone Magno before treatment and after treatment

Treatment of works of art

(a) *Weed before treatment*

(b) *Weed during treatment*

MW treatment of a wall in Paestum archaeological site

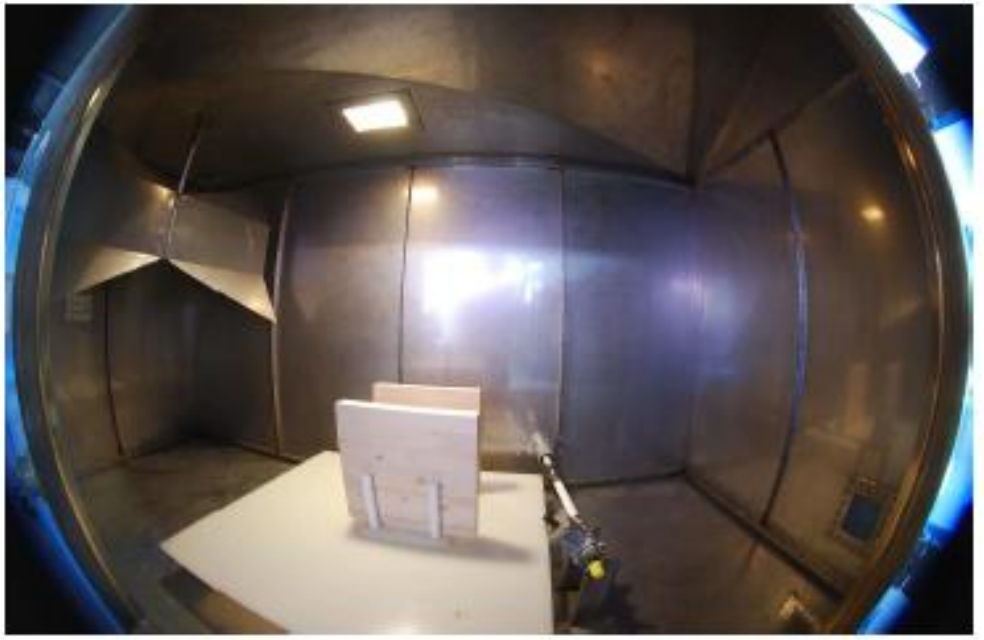
Microwave Heating

The microwave treatment may nevertheless present some surprises such as the presence of highly heated areas (hot spots) or areas with poor radiation due to particular shapes. [3,4]

[3] Bacchiani, R., Bisceglia, B., De Leo, R., (2012), “Microwave treatment of biological systems: Simulation of heating in reverberating chamber”, *BFE 2012, International Conference Bio & Food Electrotechnologies*, September 26-28, Salerno, Italy.
[4] Balanis, C., (1989), “Advanced Engineering Electromagnetics”, *John Wiley & Sons, Publishers, Inc.*, New York.

Reverberation chamber

- Room with metal and reflective walls;
- Constant irradiance in each point and from all directions;
- Heating efficiency.



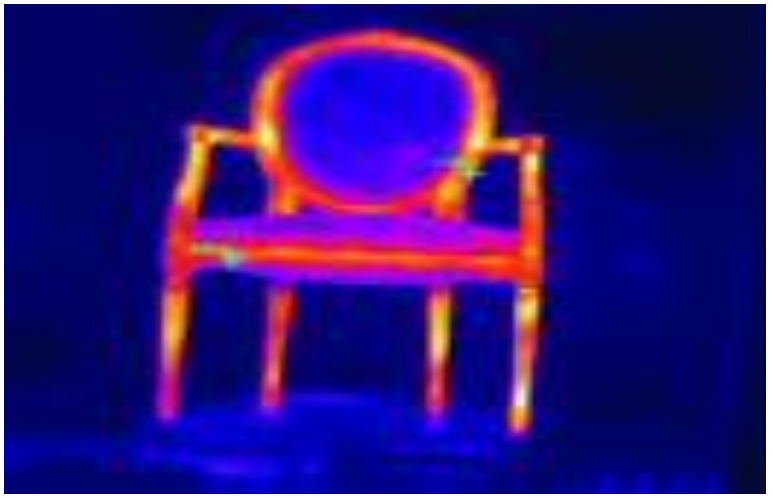
Open Applicators

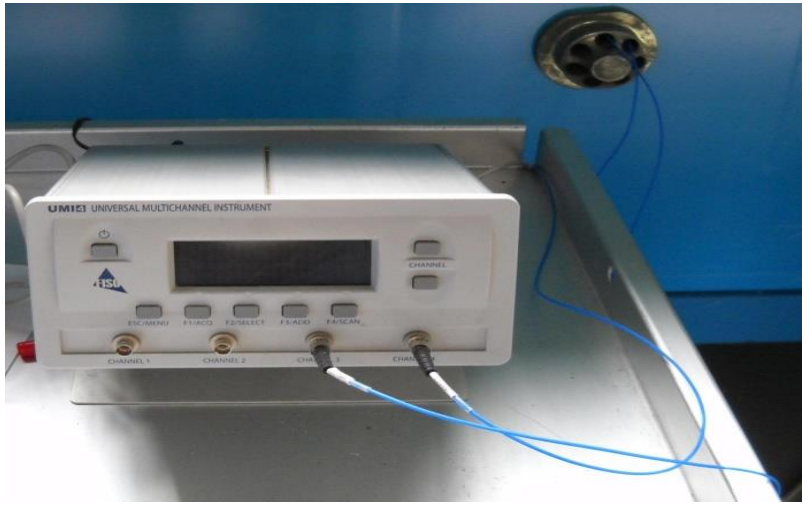
- Objects to be treated are large or not movable.
- The antennas direct electromagnetic waves towards the points to be heated.

Temperature Evaluation

Thermography

- Surface temperatures;
- Non-invasive.





Optical fiber Probes

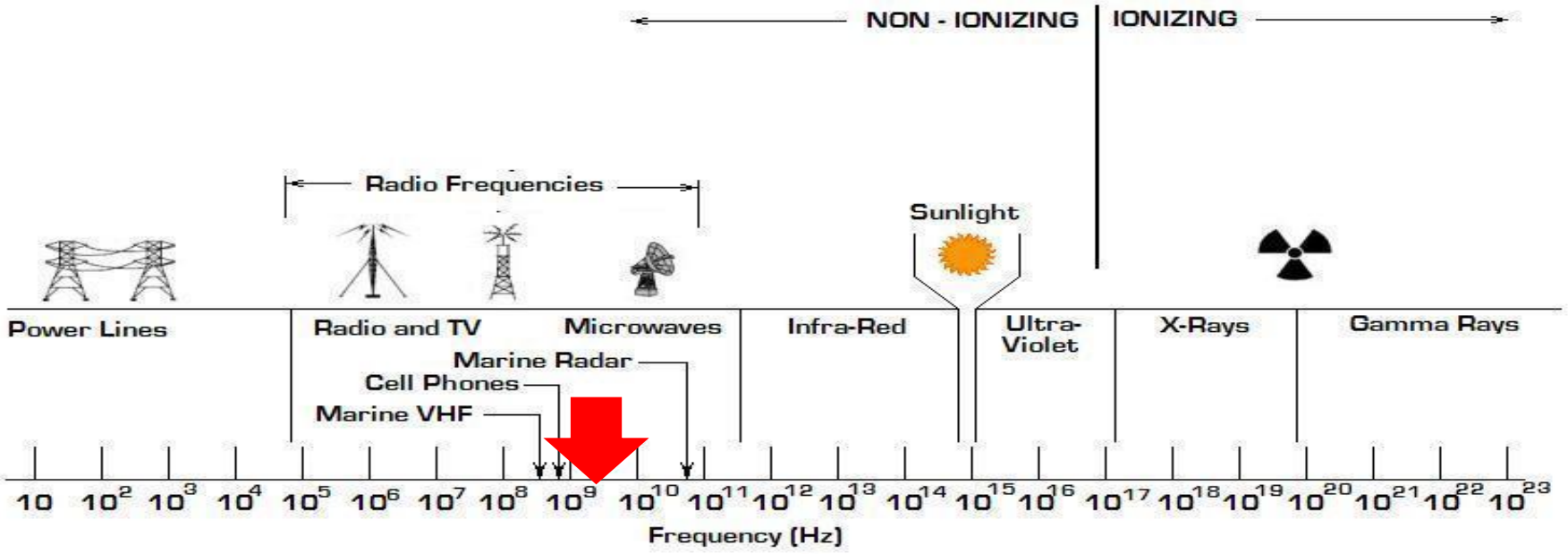
- Internal temperatures;
- Invasive;
- Real-time.

Goals

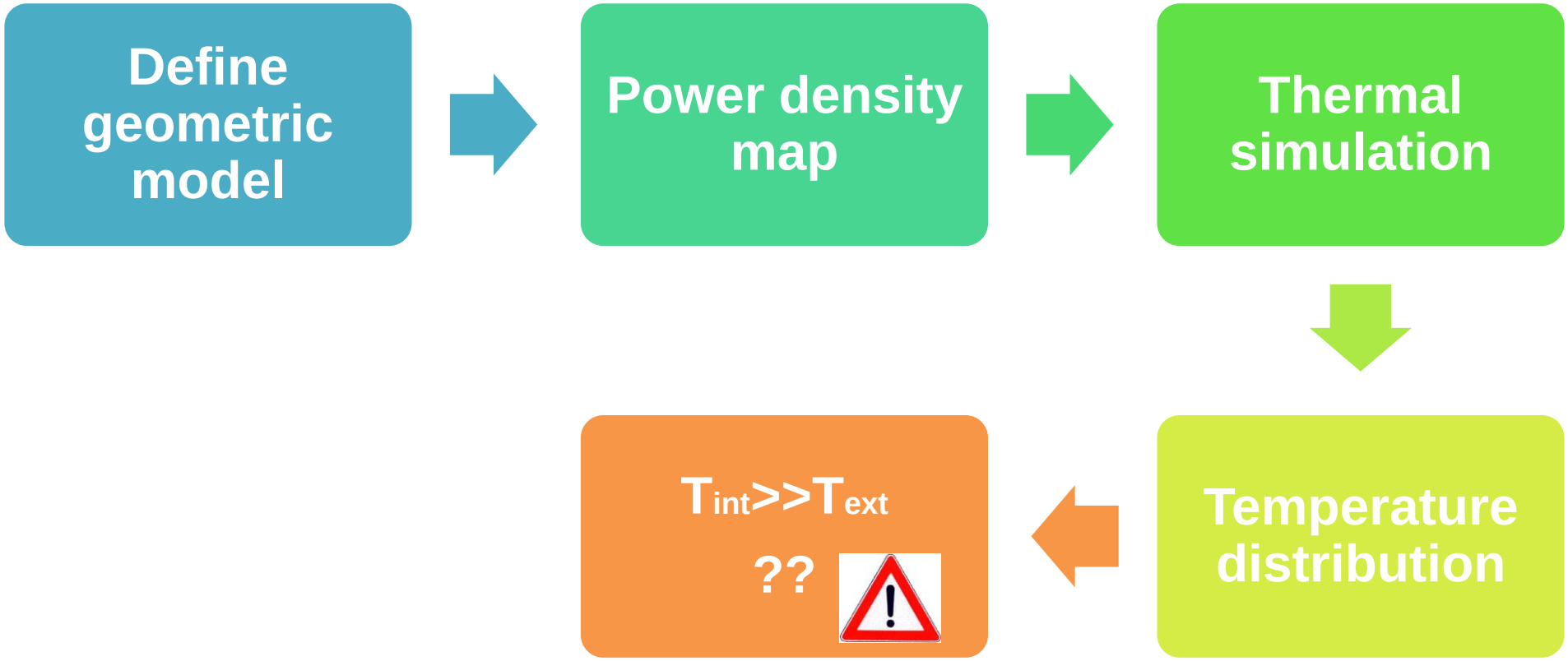
The aim of this work is, through simulation techniques, to investigate the **change of the power developed** by a pest, first approximated to a sphere, then to an ellipsoid, incorporated in a material with different dielectric characteristics.
With the values obtained will try to get the **temperature distribution**.

Goals

For this kind of treatments using the 2.45GHz ISM frequency (or other values close in countries with different legislation).



Electromagnetic simulation and thermal problem



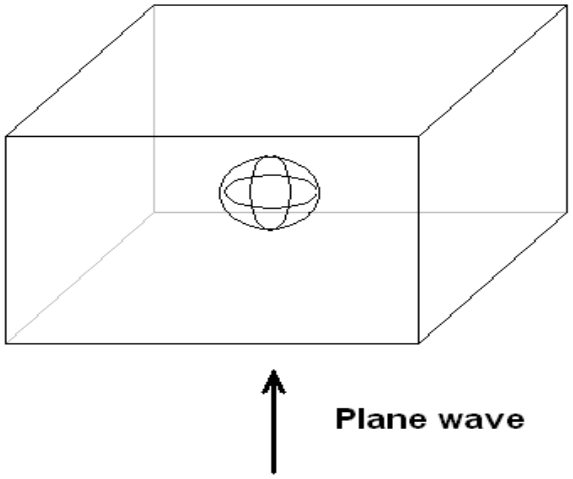
Resonance Phenomena

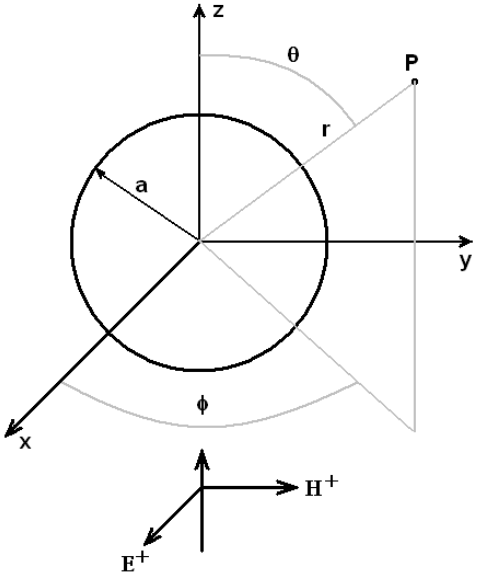
$T_{int} >> T_{ext}$ ➡ **Resonance**

- Phenomena triggered by the shape and size of pests;
- The power density much higher than the surrounding material;
- ΔT also double compared to external;
- Generates hotspots with consequent damage

Research Resonances

A model study of the resonances of objects subjected to electromagnetic fields is a sphere of dielectric material with losses that is embedded in a medium with different dielectric properties, but also with losses. This model has an exact solution of Maxwell's equations.





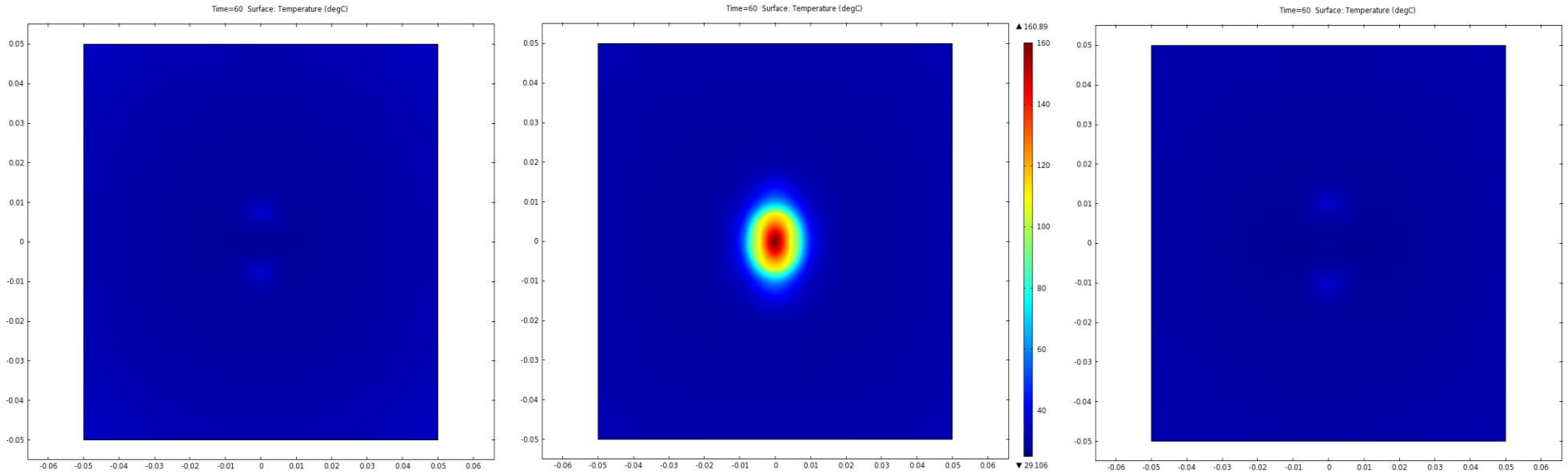
Analysis of the resonance for spherical models

We examine three different cases:
a) at the resonance Radius = Rris = 6.8 mm;
b) out of resonance Radius = 5.4 mm < Rris;
c) out of resonance Radius = 8.1 mm > Rris;
where the values of the rays 5.4 mm and 8.1 mm have been chosen considering +20% and -20% from the radius in which the resonance occurred.
The wood considered for the block is the oak, and its dielectric parameters are $\varepsilon_r = 3$ and $\sigma = 0.18$ S/m.

Analysis of the resonance for spherical models

Wood: Oak

$R_{resonance}$: 6.8 mm



$R < R_{ris} = 5.4$ mm
$T_{wood} = 31.4°C$
$T_{sphere} = 30.0°C$

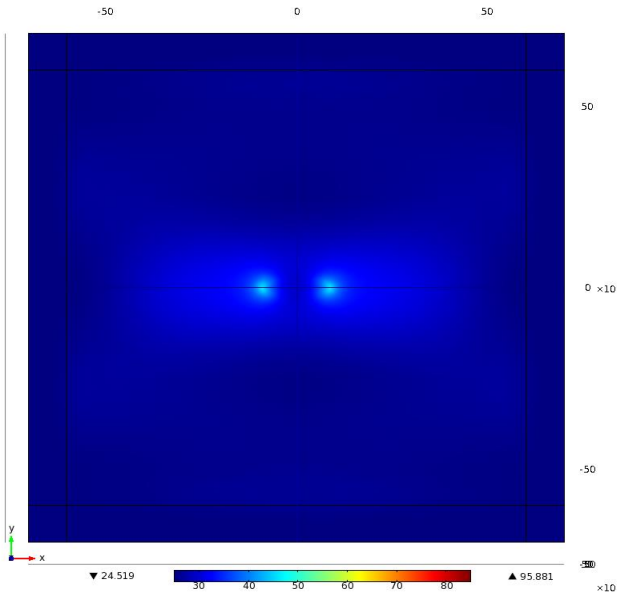
$R = R_{ris} = 6.8$ mm
$T_{wood} = 30.7°C$
$T_{sphere} = 123.5°C$

$R > R_{ris} = 8.1$ mm
$T_{wood} = 30.2°$
$T_{sphere} = 30.0°C$

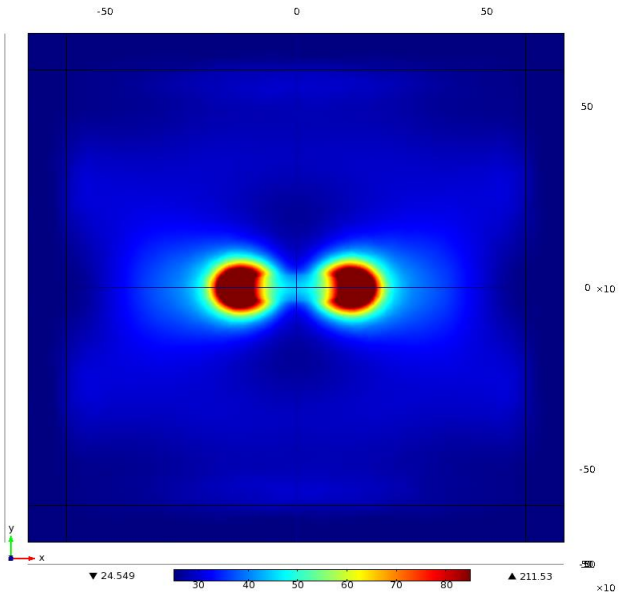
Analysis of the resonance for Ellipsoidal Model

Wood: Oak

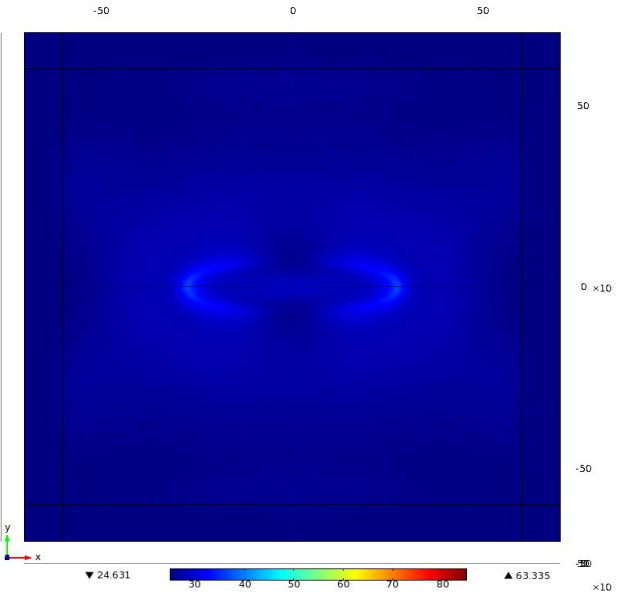
$R_{resonance}$: 6.8 mm



Temperature chart of a transversal plane (XY)
a = 8.68 mm(< a_{ris})
T_{wood} = 40°C
$T_{ellipsoid}$ = 49.0°C



Temperature chart of a transversal plane (XY)
a = 16.7mm(= a_{ris})
T_{wood} = 40°C
$T_{ellipsoid}$ = 63.1°C



Temperature chart of a transversal plane (XY)
a = 26.7mm(= a_{ris})
T_{wood} = 40°C
$T_{ellipsoid}$ = 35.7°C

Conclusion

The presence of biological organisms in the agro food products subject to disinfection by means of microwaves can lead to problems of permanent damage. This occurs if their dimensions and characteristics are such to bring to the resonance frequency of the pests. Their prediction is not easily implemented due to the uncertainty of these events.

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Thanks for your attention!

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