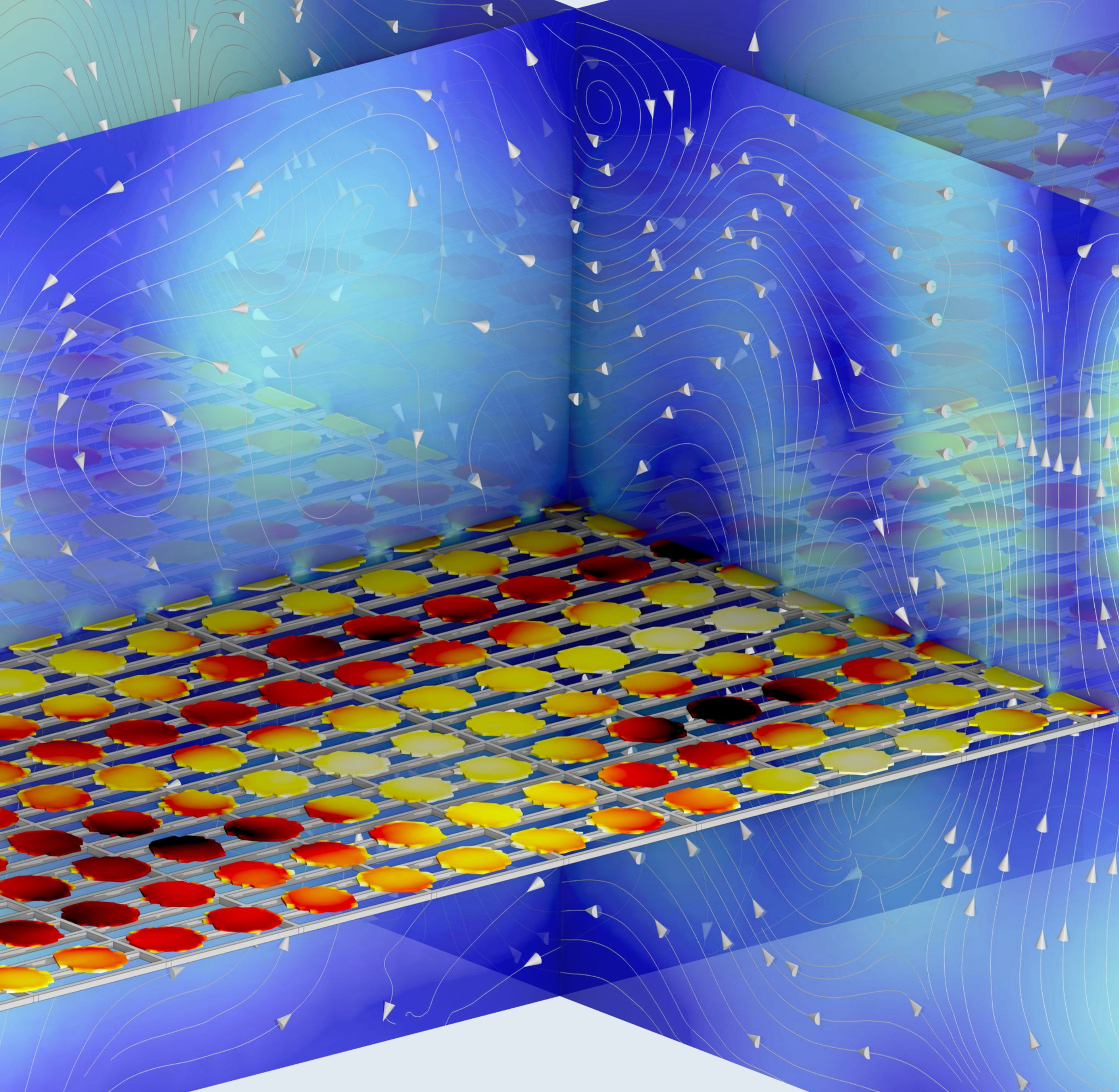




Implicit geometry representation of dielectric loads in microwave heating analysis

Function-based material-field approach for modeling food loads in 3D RF simulations of industrial microwave ovens

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Introduction and goals

Industrial microwave heating models become computationally demanding when the food load consists of hundreds of individual products.

In this work, an RF model of an industrial microwave oven containing many cylindrical potato chips placed on a PTFE belt is developed using an implicit material representation. Instead of explicitly creating and meshing each cylinder, the load is represented by a single domain in which spatial functions assign

the complex dielectric properties of potatoes or air according to position. This approach strongly reduces the number of geometric domains, boundaries, and mesh elements while preserving the spatial distribution of the dielectric load. The resulting model enables the analysis of the electric field, power dissipation density, coupling efficiency, and heating uniformity with a computational cost compatible with full-scale industrial simulations. The proposed strategy provides a flexible and scalable alternative for modelling complex food loads in COMSOL Multiphysics®.

Methodology

Explicitly modeling hundreds of food slices would create many geometric domains and interfaces, making meshing and full-cavity RF solving impractical. Instead, the load is represented by a single thin parallelepiped domain. Spatial functions define where product and air gaps are located and are combined into a complex permittivity field. During the simulation, the solver distinguishes food from air through the local material value rather than through explicit CAD boundaries.

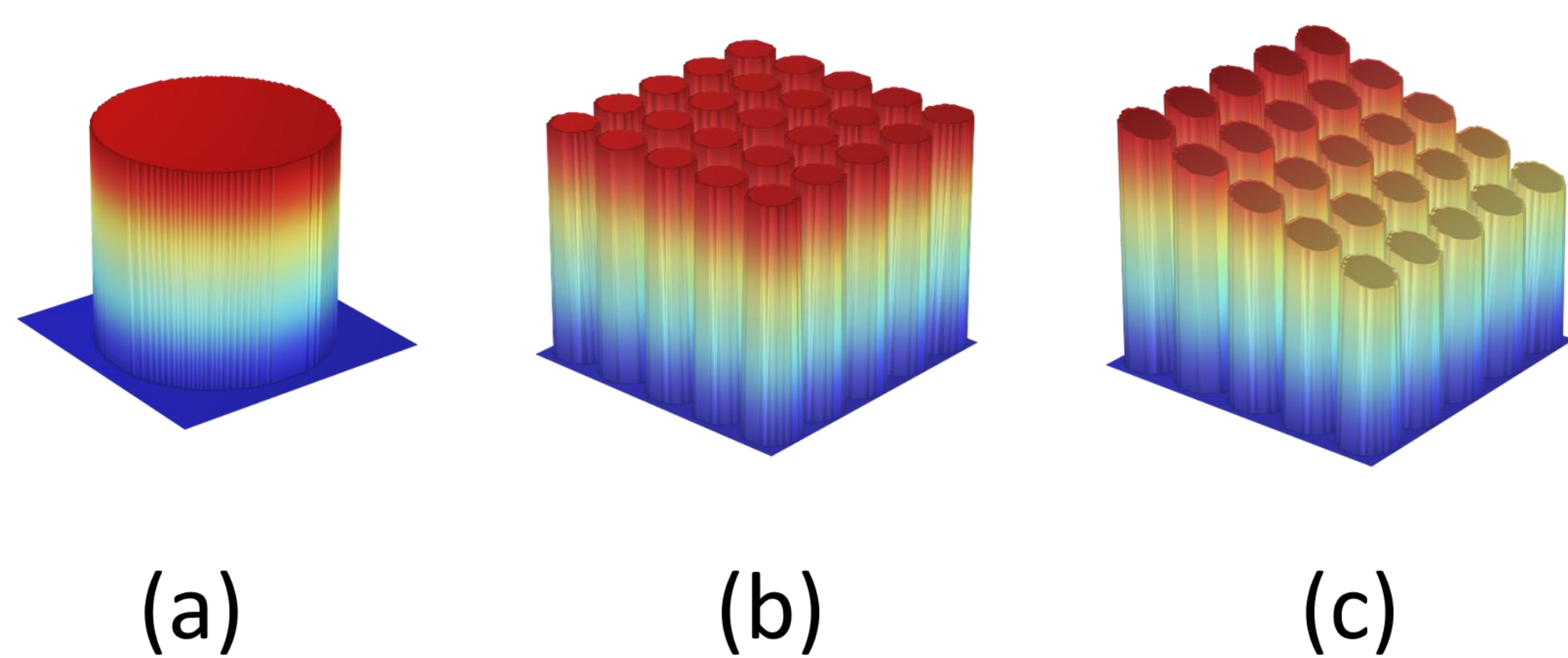


FIGURE 1. Explicit food geometries are replaced by spatial functions (a,b) that define slice location and generate the final complex permittivity field (c) inside a single equivalent domain.

$$\varepsilon_r(x, y, z) = \varepsilon_{air} + (\varepsilon_{food}(x, y, z) - \varepsilon_{air})M(x, y, z)$$

where $M = 1$ in the regions occupied by slices and $M = 0$ in the air gaps.

Results

The implicit material-field model reproduced the results of the explicit geometric model with deviations generally within 5–7%. This agreement confirms that the spatial permittivity approach can preserve the relevant electromagnetic behavior while significantly reducing geometrical complexity and computational time.

The remaining differences are mainly governed by the mesh resolution, since the mesh determines where the permittivity functions are evaluated and therefore how accurately the position and dielectric properties of the food slices are reconstructed.

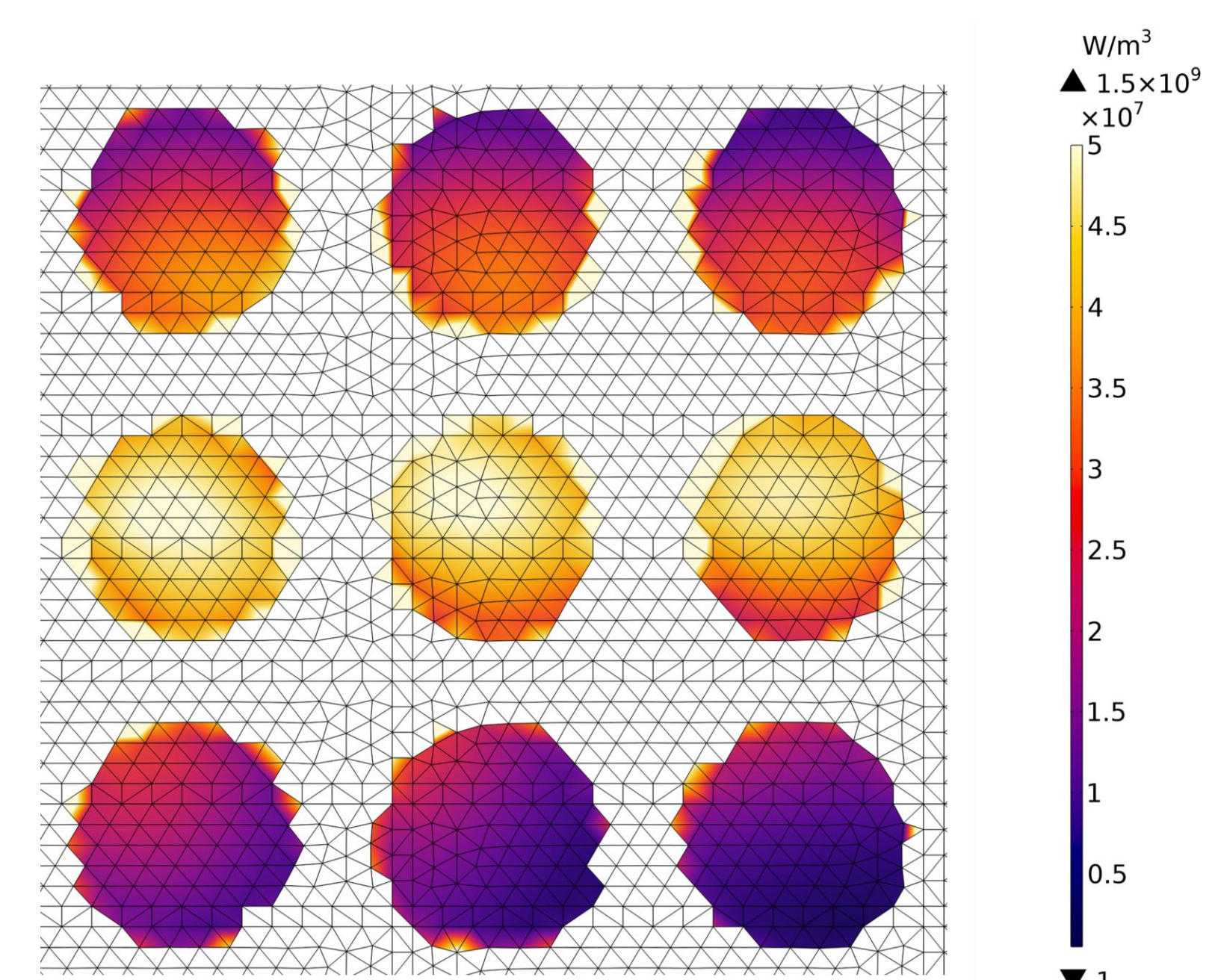


FIGURE 2. Slices electromagnetic power density: the mesh-based permittivity field reconstructs the food slices and distinguishes product regions from air gaps during the RF computation.

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