# THERMAL PROCESSING OF WOOD. NUMERICAL MODELLING

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***Abstract***
*The present work is focused on the microwave treatment of oak wood and its numerical modeling. Drying wood in the microwave field represents an important tool for the industry due to the many advantages that it offers in front of the conventional methods.*

**Keywords:** heat treatment, dielectric properties, microwave drying, numerical modeling

## INTRODUCTION

Microwaves are high frequency electromagnetic waves composed of an magnetic and electric field. The electric field, noted (E) and magnetic field- (H) components are perpendicular to each other. The frequency range of microwaves is from 300MHz to 300GHz, equivalent to wavelengths of 1mm to 1m (Metaxas and Driscoll, 1974), (Metaxas and Meredith, 1983)

Microwaves represent an important tool with many applications in the industry like: in agricultural for drying crops, food processing- granola baking, drying of coatings, snack food processing, pharmaceutical processing, ceramic filter drying, ceramic sintering, rubber vulcanization, chemical vapor deposition, mold drying, and chemical waste processing (Koubaa et al, 2008).

The process of drying wood in the microwave field began in the 1950's and 1960's, when Egner, Jagfeld and Resch showed the advantages that the new technology had. The authors also underlined the problems regarding the distribution of field in the dielectric material. Barnes, Galperin, Perre and Turner also developed studies concerning microwave processed wood, later, in 1999, Antti published his research to show the possibility to dry single boards with a high quality in a few hours. During their studies Hanson and Antti started designing a special applicator that would solve the uneven field distribution (Leiker, Aurich and Adamska, 2004).

Research that combines the microwaves with vacuum were carried out by Seyfarth and Cividini, who demonstrated that this method would short the time of drying (Leiker et al, 2004).

**MATERIAL AND METHODS**

The knowledge of dielectric properties of materials and their development during microwave field processing is essential in all industrial applications, for better design of the applicator in which is going to be treated the dielectric material (Seyfarth, Leiker, Mollekopf, 2003). It is being focused on the behavior study of non homogenous dielectrics and a mixture of these kinds of dielectrics (Lucaci Codruta et al, 2011).

The wood in a living tree contains large quantities of water. After the tree is harvested, the weight of water in the wood is often greater than the weight of the wood itself (Simpson W., Anton TenWolde, 1999). This water must be removed to some degree to make the wood usable. The process of water removal is called drying. The dried wood is then said to be seasoned (Reeb, 1997). Water is found in wood in three forms. Free water is found in its liquid state in the cell cavities or lumens of wood. Water vapor may also be present in the air within cell lumens. Bound water is found as a part of the cell wall materials (Reeb, 1997).

The wood cells are known as tracheids in softwood and in hardwoods as tracheids, fibres and vessels. While the growing season wood's structure modifies differently at different times.

The layer between bark and pitch named cambium can be divided on kinds of functions for the wood. The sapwood is located adjacent to the cambium and handles the transport of sap and water. Furthermore, heartwood consists, in contrast to sapwood, of inactive cells without functions in either water conduction or sustenance storage (see Fig. 1) (Hansson, 2007).

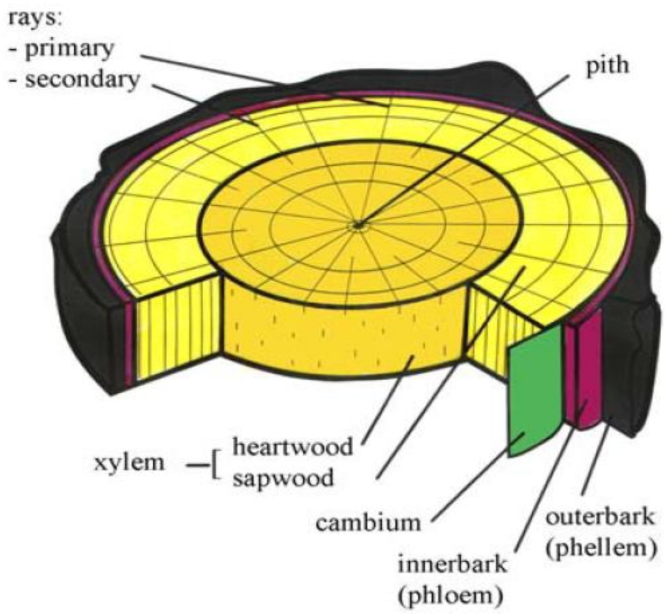


Figure 1. Cross Section of Wood (Lars Hansson, 2007)

The electromagnetic field inside the microwave oven can be represented by Maxwell's equations (Metaxas and Meredith, 1983):

$$rot\boldsymbol{E} = -\frac{\partial \boldsymbol{B}}{\partial t} \quad (1)$$

$$\boldsymbol{rotH} = \boldsymbol{J} + \frac{\partial \boldsymbol{D}}{\partial \boldsymbol{t}} \quad (2)$$

$$\boldsymbol{D} = \varepsilon \boldsymbol{E} \quad (3) \qquad \boldsymbol{B} = \mu \boldsymbol{H} \quad (4)$$

$$\boldsymbol{J} = \sigma \boldsymbol{E} \quad (5)$$

Where: ***E***- Electric Field Strength; ***B***- Magnetic Induction; ***J-*** Density of the Source Current; ***H-*** Magnetic Field Strength; ***D*** = Electric Induction; $\mu$=Magnetic Permeability; $\sigma$=Electrical Conductivity; $\varepsilon$=Electrical Permittivity.

For dielectric materials, heating is done by electric field primarily through interaction with water and ions. The complex permittivity $\underline{\underline{\varepsilon}}$ is given by (Hathazi and Maghiar, 2003):

$$\underline{\underline{\varepsilon}} = \varepsilon' - j\varepsilon'' \quad (6)$$

The tangent of the loss angle is the relation between the dielectric loss factor and the dielectric constant:

$$\tan\delta = \frac{\varepsilon''}{\varepsilon'} \quad (7)$$

The most important factors that affect the dielectric properties of materials are the moisture content, the bulk density, the temperature and the frequency (Hansson and Antti, 2003).

Measurement of dielectric properties involves measurements of the complex relative permittivity ($\varepsilon_r$) and complex relative permeability ($\mu_r$) of the materials. The permittivity of a dielectric is important to study in microwave drying processes because of its relation with process variables, described in the previous paragraph (Arun, 2006). A complex dielectric permittivity consists of a real part and an imaginary part. The real part of the complex permittivity, also known as dielectric constant is a measure of the amount of energy from an external electrical field stored in the material (Nelson, 1995), (Datta, 2001).

## RESULTS AND DISCUSSIONS

To determine the electromagnetic field we used the Ansoft HFSS 11.0 programme to study the heating of oak wood, of parallelepiped shape, situated in a multimode applicator, excited with energy through a wave guide (Bandici and Molnar, 2007), (Molnar et al, 2008).

ANSYS HFSS software is the industry-standard simulation tool for 3-D full-wave electromagnetic field simulation and is essential for the design of high-frequency and high-speed component design. HFSS offers multiple state-of the-art solver technologies based on either the proven finite element method or the well established integral equation method.

The main problem which appears is represented by the homogeneity of the field and implicitly of the temperature in the seeds bed.

During the research we followed two drying situations: one using a frequency of 1 GHz and one using 2.45 GHz. We studied the distribution of E field and also H field for each of the cases.

In figure 2 is being presented the distribution of electric field (at a frequency of 1 GHz) in a piece of oak wood, with a humidity of 20%. Figure 3 presents the distribution of magnetic field through the oak wood at a frequency of 1 GHz.

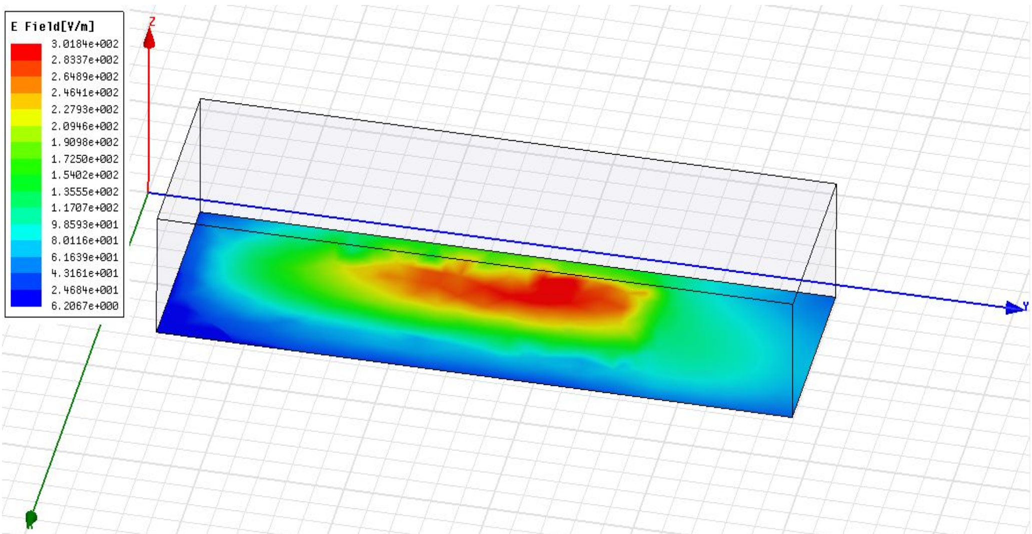


Figure 2 Electric Field Distribution

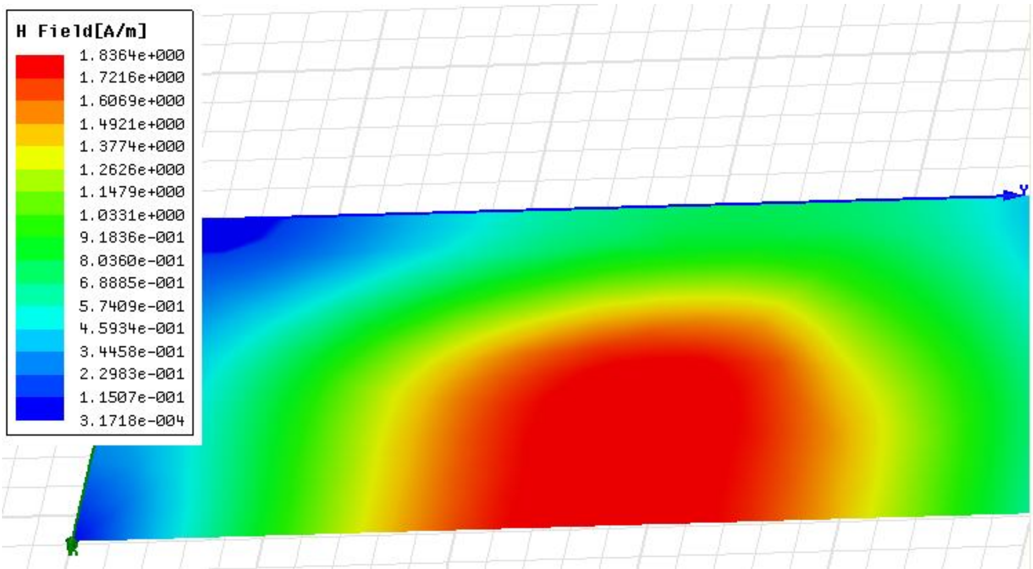


Figure 3 Magnetic Field Distribution

In figure 5 is being presented the distribution of electric field (at a frequency of 2.45 GHz) in a piece of oak wood, with a humidity of 20%. Figure 6 presents the distribution of magnetic field through the oak wood at a frequency of 2.45 GHz. Figure 4 presents the distribution of the electric field at a frequency of 2.45 GHz through the waveguide.

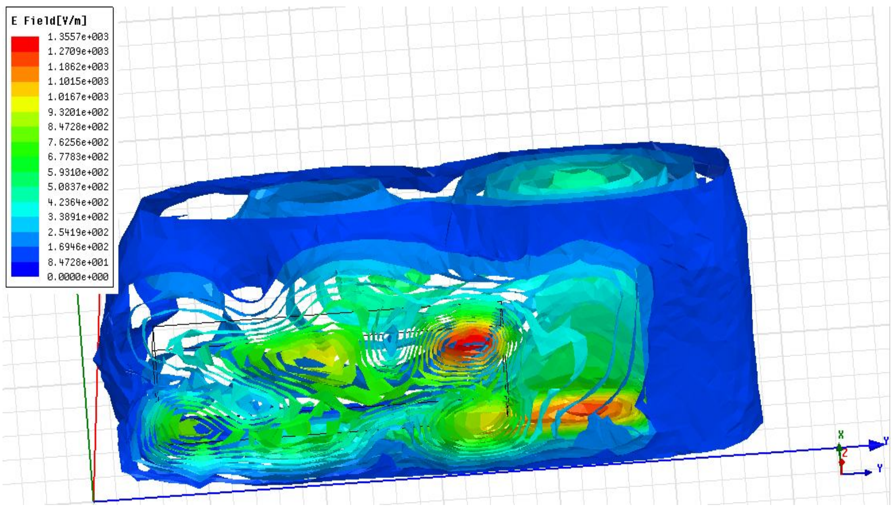


Fig.4 Electric Field Distribution Through the Waveguide

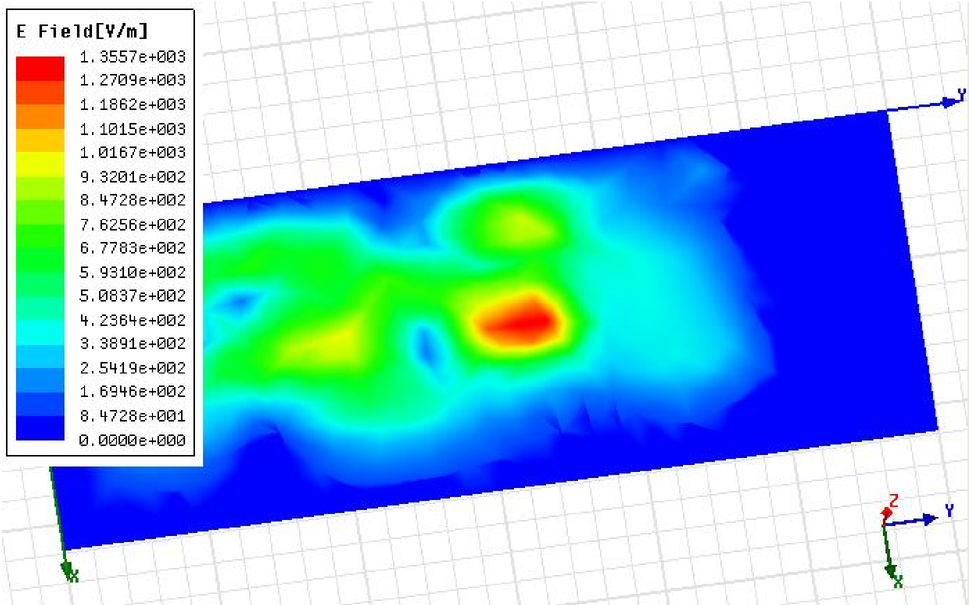


Figure 5 Electric Field Distribution

Comparing the above studies we can see that the distribution of field when using a frequency of 1GHz is more homogenous than when using a frequency of 2.45GHz.

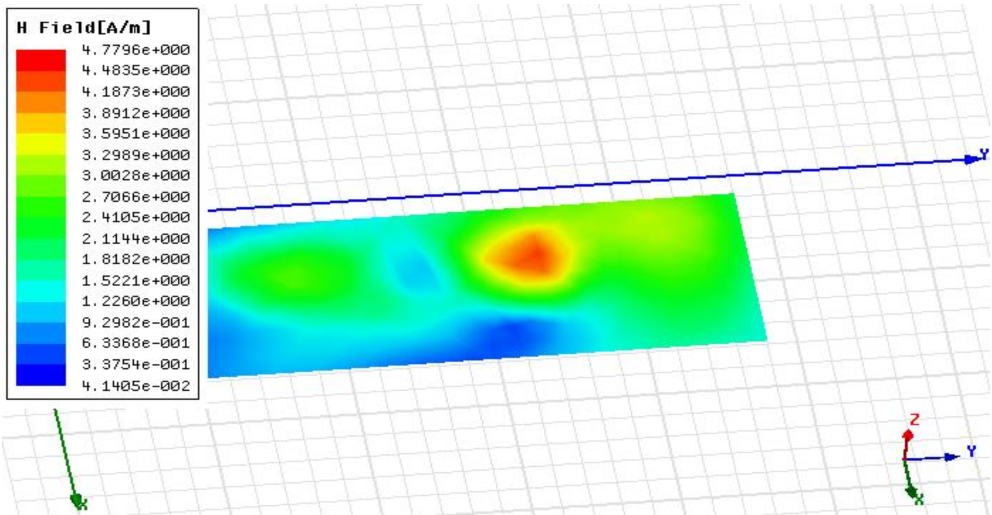


Figure 6 Magnetic Field Distribution

**Acknowledgements**
This work was partially supported by the strategic grant POSDRU/88/1.5/S/50783, Project ID50783 (2009), co-financed by the European Social Fund – Investing in People, within the Sectoral Operational Programme Human Resources Development 2007-2013.

**CONCLUSIONS**

We observe from the numerical modelling that the electric field on the wood surface is not homogenous; in some areas it has greater values than in other, that leading to high temperature areas that can destroy the wood.

With the help of simulation software's we can model cavities and study the distribution of the field before creating the installation. Structural changes, such as shrinkage and pit aspiration, take place during drying which makes wood behavior even harder to simulate.

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