

# Hybrid Modeling Approaches for Microwave Heating System Design

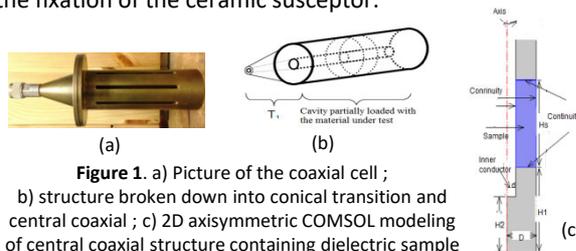
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**INTRODUCTION:** The advantages of microwave heating of dielectric material is the direct transfer of electromagnetic energy to the core of the dielectric through interactions between electromagnetic waves and the dielectric [1]. For an industrial application, the appropriate design of a specific applicator is essential [2]. This usually goes through the following steps:

**a)** Choice of generator and its working frequency. **b)** Identification of the electrical properties of the dielectric to be heated. **c)** Design of an applicator ensuring a good impedance matching.

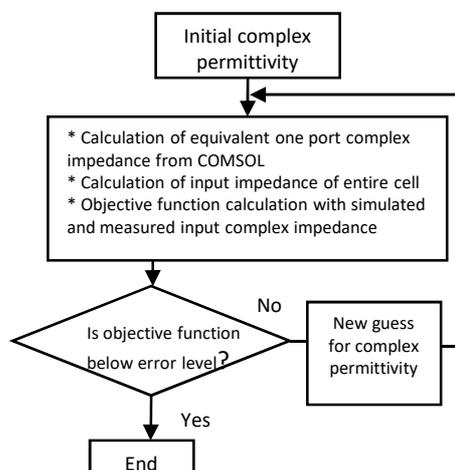
The applicator design work is based on a coaxial cell (Figure. 1a). This later will be used both as a measurement cell for complex permittivity of a dielectric having fairly good susceptibility to microwave power, and as part of the microwave applicator, ensuring the supply of electromagnetic energy in the form of a Transverse ElectroMagnetic (TEM) wave and the fixation of the ceramic susceptor.



**Figure 1.** a) Picture of the coaxial cell ; b) structure broken down into conical transition and central coaxial ; c) 2D axisymmetric COMSOL modeling of central coaxial structure containing dielectric sample

## Complex permittivity extraction by inverse modeling :

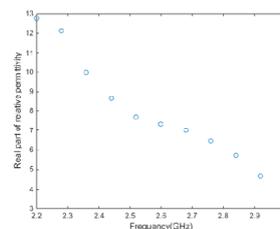
For the need of microwave heating, the size of the dielectric element, used as susceptor, is much greater than that of a conventional radiofrequency connector. A conical transition ensures the connection between the input N connector and the coaxial structure, as shown in Figure.1(a). The realization of the conical transition does not allow a good mathematical description of its profile and its 3D modeling. Therefore, a calibration method has been developed to get its two-port model with results of S parameter measurements by a vector network analyzer [3].



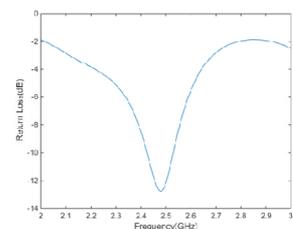
**Figure 2.** Flow chart of permittivity extraction under LiveLink™ MATLAB

The measurement based model will be hybridized with a model resulting from a 2D axisymmetric modeling of the central part of this cell with COMSOL Multiphysics software (Figure.1(c)). The dielectric sample will be fixed around the inner conductor of the coaxial structure in the 2D axisymmetric model. The electromagnetic wave propagates inside is of TEM type introduced from the top end. The complex permittivity extraction procedure based on these models is described in the flow chart for each investigated frequency, and implemented in LiveLink™ for MATLAB environment (Figure.2).

For the intended application at 2.45GHz, the two-port model of the conical transition was firstly performed with a calibration on the frequency band between 2.2GHz and 3GHz as described in [3]. The extraction procedure was then applied to a hollow cylindrical ceramic sample, with inner radius of 8mm and outer radius of 18mm and height of 30mm. The extraction results are shown in Figure. 3.



**Figure 3.** Extracted relative permittivity



**Figure 4.** Measured return loss of coaxial applicator

## Optimization design of a coaxial microwave heating applicator :

The design of a microwave coaxial applicator is conducted in COMSOL with a 120mm height section of ceramic measured above. A movable short-circuit plate is proposed on the other end of the RF generator. By varying the positions of the sample and the short circuit, the lowest reflection coefficient is obtained.

A procedure for optimization design has been implemented under the LiveLink MATLAB environment, leading to the identification of an optimum solution. Corresponding experimental set-up was carried out. S parameter measurements were taken and the return loss shown in Figure. 4 confirm the good quality of the design work.

**CONCLUSIONS:** A modeling technique associating two-port and one port models from both experimental determination and simulation by using COMSOL Multiphysics Software is shown. The use of LiveLink™ MATLAB module allows the inverse modeling for dielectric permittivity extraction, and the optimum design of a microwave coaxial applicator for 2.45GHz heating.

## REFERENCES:

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4. *Introduction to LiveLink™ for MATLAB*, Version 4.1, COMSOL.