Microwave Characterization Using Partial Least Square Regression

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***Abstract*—Inverse problems for determination of dielectric materials properties (complex permittivity) are usually solved by iterative methods using numerically based forward model. These methods are computationally expensive. In this paper, we propose a fast inversion model based on partial least square regression (PLSR). The idea is to build a model able to predict in real time the properties of the sample under test using measurements of admittance or reflexion coefficient of the propagating electromagnetic micro wave along the coaxial line. Numerical solution of the direct problem is made using Finite Element Method (FEM).**

***Index Terms*— Microwave Characterization, PLSR, FEM.**

I. Introduction

Modeling the behavior of physical phenomena is rarely solved by analytical solution and numerical solutions are computationally expensive when used in an iterative procedure. In order to avoid the drawbacks of an iterative procedure, a more efficient approach is to use a parametric model (Artificial Neural Networks (ANN), Support Vector Machines (SVM), Fuzzy Neural Networks (FNN),...) trained thanks to a database constituted of examples of the relation linking the observations to the permittivity.

Inversion using ANN, SVM or FNN is a time consuming process, because they are time consuming methods since they need optimization of network architecture and large databases which leads to slow learning. In addition, creating thousands of examples is a very difficult task due to complex geometries. In this paper, we propose a new method for the evaluation of complex permittivity (ε'+iε'') from the admittance measured at the discontinuity plane of a coaxial open-ended probe which is connected to an impedance analyzer (Fig. 1). The FEM provides the data set to build the predictors matrix X and the response matrix Y. A data set is constituted of input (complex admittance $Y=G+iB$ and frequency) and output (ε',ε'') pairs.

II. PLSR For Inverse Problem Solving

PLS was initially developed by Wold [1,2]. It became popular in the field of chemometrics and it finds applications in other fields including physiology, marketing, geophysics, supervision... PLS provides simultaneously a dimension reduction by feature extraction and a regression model. The original variables, predictors and responses, are assumed to be both correctly described by a linear combination of a reduced number of new variables called latent variables. If we have a low number of internal parameters, of the relation linking the responses to the predictors. PLS decomposes X and Y into the following form:

$$X = T P' + E \quad (1)$$

$$Y = T Q' + F \quad (2)$$

Where P is the predictor loading matrix. The responses have their own loading Q matrix. T is the score matrix. E and F are the matrices of residuals for the predictors and the responses, respectively.

III. Results

Since the model correctly approximate the outputs contained in the checking set (cross validation), experimental measurements (Fig. 2) can be presented at the input.

Measurements have been carried out by using an impedance analyser Agilent 4291A on an ethanol sample whose dielectric characteristics are known. The coaxial guide is an APC7 standard (a=3.5mm, b=1.52mm). The measurement frequency band is from 1MHz to 1.8GHz. The tight coaxial window used to characterise liquids is made of plexiglas and hase a tickness of 0.82mm and a dielectric constant of 2.7. The tickness of the sample under test is 13.8mm.

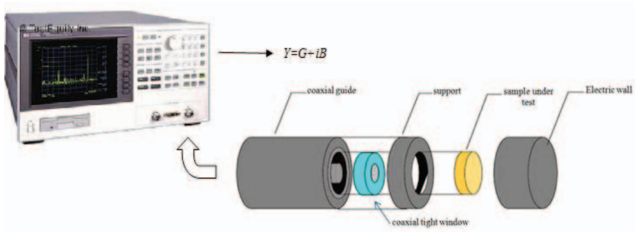

Fig. 1. Experimental setup

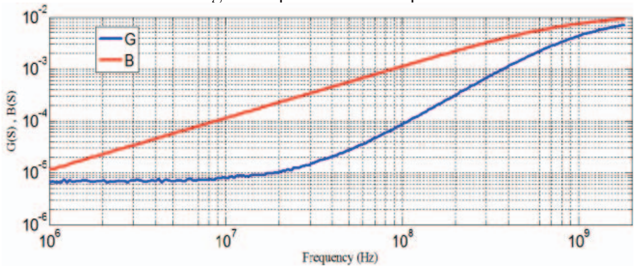

Fig. 2. Experimental measurements

IV. Conclusion

In this paper, PLSR has been investigated as an alternative inversion tool in broad-band microwave characterization of materials. Results on Ethanol confirm its suitability for regression problem solution.

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