# A novel method for the determination of the complex constitutive parameters of multilayer dielectric structures based on S-parameters measurements

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**Abstract**

A novel method for the determination of the complex constitutive parameters of multilayer dielectric structures using X-band S-parameter measurements obtained using an HP-8510 Network Analyzer is presented here. It is assumed that the region of the section of the waveguide containing the sample consists of n-planar layers of uniform cross-sectional dimensions of the waveguide (X-band). Assuming only the dominate $TE_{10}$ mode propagates, the formulation of the scattering parameters for non-magnetic materials in terms of the unknown complex permittivities and geometric dimensions of the layered dielectric is done using the Method of Moments (MOM) yielding S-parameters (S = function($\epsilon$,geometry). Determination of the complex permittivities for each region is accomplished via a solution to an inverse problem where an error function (objective function) between predicted and measured values of the scattering parameters is minimized using a least squares error approach where the objective function error is defined by the equation ($error = s_{m,n(measured)} - s_{m,n(formulated)}$). Several alternative instrumentation and numerical approaches are also discussed in the presentation.

The resulting complex permittivities provide a 'best fit' to the input S-parameter measurements. Sensitivity of the method to both computational and measured errors was thoroughly investigated. The results indicate that the total error in the layered samples' complex permittivity value is primarily dependant on accuracy in sample construction (e.g., uniformity of layer thicknesses and cross-sectional dimensions). The results of the analyses of five representative multilayered samples are presented. Excellent agreement was found in a comparison of the predicated and known values of each layer's complex permittivity. In all cases considered, the overall accuracy of this technique is found to excellent ($error \sim 3 - 7\,\%$).

Previous work in this area relied on standard algorithms for determining the effective or "bulk" constitutive parameters of the entire layered material and neglected the possibility of parameter variations within the sample. If the permittivity of specific dielectric layers was required, the sample was typically physically dissected into several smaller samples where the material properties are assumed relatively constant and each subsection analyzed separately. Information obtained in this manner placed severe limitations on the usefulness of this technique. Samples are required to be of sufficient thickness so that material loss and damage during preparation can be minimized. However, many materials currently used are relatively thin and are intentionally fabricated with graded or layered electrical properties for specific purposes.

The results of this study have shown a highly accurate alternative solution of the problem where accuracy is due to errors in the sample fabrication process thus allowing individual layers to be characterized.

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