

Modeling and Optimization of the Microwave PCB Interconnects Using Macromodel Techniques

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## Abstract

Due to the operating frequency and signal bandwidth of communication and information applications, the electromagnetic simulation and modeling of modern electronic systems are essential. This is particularly problematic when attempting to solve problems that involve computationally expensive analysis (e.g., full-wave simulations) and parametric optimization. To address these problems, the use of fast and accurate surrogate models appears to be effective.

To this end, this study is divided into two parts. First, instead of attempting to characterize the entire system using Maxwell's equations, the overall system (such as a multilayer printed circuit board) is first divided into substructures (such as coupled line interconnects, vias, connectors, etc.), each of which is then further characterized using the standard *macromodels* (i.e., reduced-complexity behavioral models). As a result, the electrical interconnects at the board level and circuit components are effectively analyzed by using corresponding macromodels requiring limited computing resources.

Focusing on the black-box macromodeling approach, a rational approximation based on the integral operator is proposed. By integrating the data on several different intervals, a system of equations is formed, then the pole/residue values of the rational function are obtained by the conventional least-squares method. Finally, the stability of the model is guaranteed by using a closed-loop control technique and considering a controller coefficient. Also, using this parameter, the designer can increase the stability margin of a system with poor stability conditions. The introduced method has the potential to be used for a wide range of practical applications since there is no specific restriction on the use of this method. The only requirement that should be considered is the *Dirichlet condition* for the original data, which is usually the case for physical systems. The performance evaluation of the proposed method has been investigated in comparison with the well-known vector fitting (VF) method.

Also, the results show that the performance of the proposed method is less affected by input noise, and this is an important point because in most cases the measurement data is noisy.

In the second part, a new non-iterative optimization method based on the inverse modeling technique and its applications in the design and optimization of microwave components is presented. The proposed inverse model accepts the high-dimensional S-parameters computed at many frequency points as the input and estimates the optimal geometrical/physical parameters of the microwave component as its output. The Least-Square Support Vector Machine regression is combined with the Principal Component Analysis to simultaneously overcome both the high-dimensional input space and ill-posed challenges of the inverse modeling. We also propose a new empirical method to find the optimum number of principal components (i.e., compression level) for each example, in an automated way. This makes our proposed model general and easy to use compared with the existing data-driven inverse modeling techniques. The inverse model is trained by a set of scattering parameters computed via a 2D/3D electromagnetic solver for a few configurations of the geometrical parameters. The feasibility and the accuracy of the proposed optimization scheme are investigated by comparing its predictions with the corresponding optimal configuration estimated via a commercial solver.