Multidimensional Model-Based Parameter Estimation Method for Compact Modeling of High-Speed Interconnects

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ABSTRACT

A multivariate modeling technology is developed that allows engineers to define the frequency range, layout parameters, material properties and desired accuracy for automatic generation of simulation models of general passive electrical structures. It combines electromagnetic (EM) accuracy of parameterized passive models with the simulation speed of analytical models. The adaptive algorithm doesn't require any a priori knowledge of the dynamics of the system to select an appropriate sample distribution and an appropriate model complexity. With this technology, designers no longer must put up with legacy modeling techniques or invest resources in examining new ones.

Keywords: meta-modeling, surrogate modeling, reflective exploration, model-based parameter estimation.

1 ADAPTIVE MODELING AND SAMPLING TECHNIQUE

The proposed '*Multidimensional Adaptive Parameter Sampling*' (MAPS) technique [1]-[2] builds a global fitting model of the chosen parameters, handling frequency and geometrical dependencies separately. Multidimensional polynomial (or multinomial) fitting techniques are used to model the geometrical dependencies, while rational fitting techniques are used to handle frequency dependencies. The modeling process does not require any *a priori* knowledge of the circuit under study. Different adaptive algorithms are combined to efficiently generate a parameterized fitting model that meets the predefined accuracy. This includes the adaptive selection of an optimal number of data samples along the frequency axis and in the geometrical parameter space, and adaptive selection of the optimal order of the multinomial-fitting model.

The number of data points is selected to avoid oversampling and undersampling. The process of selecting data points and building models in an adaptive way is called *reflective exploration* [3]. Reflective exploration is useful when the process that provides the data is very costly, which is the case for full-wave EM simulators.

Reflective exploration requires *reflective functions* that are used to select new data points. For example, the difference between two fitting models can be used as a reflective function. Also, some physical rules, such as a passivity-check, can be used as a reflective function. The modeling process starts with an initial set of data points. New data points are selected near the maximum of the reflective function until the desired accuracy is reached.

The MAPS modeling technique follows four steps to adaptively build a model.

Step One: The frequency response of the circuit is calculated at a number of discrete sample points (using the Agilent Momentum full-wave EM simulator [4]). The Adaptive Frequency Sampling (AFS) algorithm [5] selects a set of frequencies and builds a rational model for the S-parameters over the desired frequency range (Figure 1).

Step Two: A multinomial is fitted to the S-parameter data at multiple discrete frequencies (Figure 2).

Step Three: This model is written as a weighted sum of orthonormal multinomials. The multinomials only depend on the layout parameters. The weighting coefficients preceding the orthonormal multinomials in the sum are only frequency dependent (Figure 3).

Step Four: Using the AFS models built in step one, the coefficients can be calculated over the whole frequency range (Figure 4). These coefficients, together with the orthonormal multinomials, are stored in a database for use during extraction afterwards.

The model complexity is automatically adapted to avoid overmodeling (overshoot or ringing) and undermodeling, and the model covers the whole parameter and frequency space and can easily be used for optimization purposes.

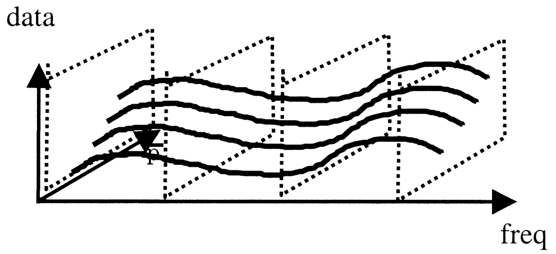

Figure 1: rational models over the desired frequency range, derived from full-wave EM simulation.

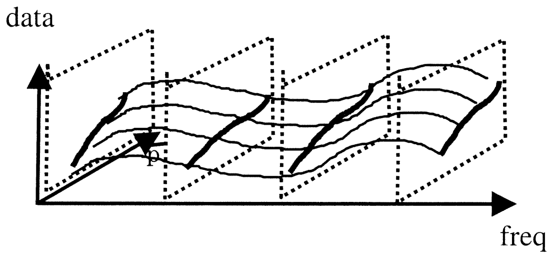

Figure 2: Multinomial models are created at discrete frequencies.

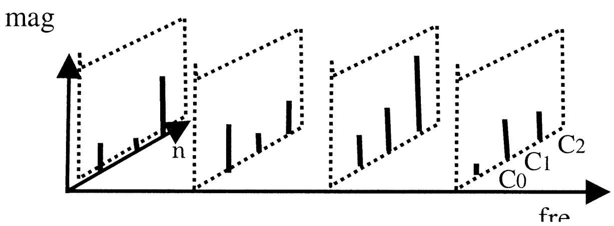

Figure 3: Creation of the coefficients of orthogonal multinomials at discrete frequencies.

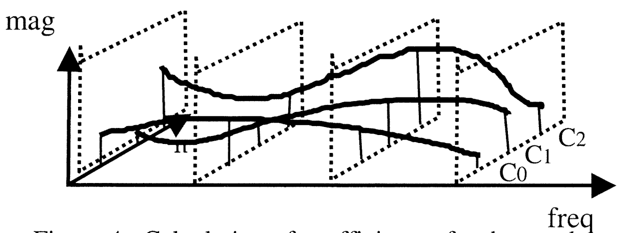

Figure 4: Calculation of coefficients of orthogonal multinomials over the entire frequency range.

2 CONCLUSIONS

An advanced modeling technique was presented for building parameterized models for general passive microwave and RF structures. The models are based on full-wave EM simulations, and have a user-defined accuracy. Once generated, the analytical models can be grouped in a library, and incorporated in an EDA tool where they can be used for simulation, design and optimization purposes.

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