Compact Macromodel for Lossy Coupled Transmission Lines

Roni Khazaka and Michel Nakhla

Dept. of Electrical Engineering, Carleton University, Canada, msn@doe.carleton.ca

Abstract

This paper describes a systematic algorithm for obtaining passive time domain reduced order transmission line macromodels. The proposed algorithm makes use of a new order reduction technique that removes the redundant poles obtained using conventional order reduction methods. The reduced macromodel is passive by construction.

I. Summary

At high frequencies interconnects are treated as multi-conductor transmission lines. While such distributed models provide the necessary accuracy for simulation, they are best described in the frequency domain. This presents a challenge for the time domain transient simulation of nonlinear circuits. Various discretization techniques for obtaining a time domain representation of distributed interconnects in the form of ordinary differential equations are available [1]. However, the difficulty with discretized transmission line models is that they are typically very large and result in a prohibitively high CPU cost. In order to solve this problem, the use of order reduction techniques has been proposed in the literature.

Recently, passive order reduction techniques for general linear circuits based on Krylov subspace methods have been proposed [2]. Such techniques have proven to be very efficient for circuit simulation, and the concept was later used to obtain reduced order interconnect macromodels [3]. While this approach results in a significant reduction in size over the original discretized transmission models, the reduced macromodel still contains many redundant poles. Some attempts have been made to remove the unnecessary poles using the Truncated Balance Realization (TBR) [4], but this approach does not guarantee the passivity of the model. The approach used in [5] preserves the passivity of the reduced order model for general linear circuits. In this paper a method for obtaining reduced order passive macromodels for lossy coupled transmission lines is presented. Using the proposed approach, redundant poles are eliminated while preserving the passivity of the transmission line model. The reduction is done in two steps. The first step of reduction is done by projecting the original system onto an orthonormal basis of the Krylov subspace. The reduced system is guaranteed passive but still contains many unnecessary poles. This severely reduces the efficiency of standard time domain simulators such as SPICE. This problem is addressed using a second step of reduction. In this step, the unnecessary poles in are removed by projection onto an orthonormal basis of the eigenspace of the dominant poles. Pole selection is done based on their contribution to the response in the frequency range of interest. The resulting interconnect macromodel has two main properties: 1) it is passive by construction, and 2) it conserves the dominant poles of the original system. Several practical interconnects were considered and significant reduction in the size of the macromodel and CPU cost were obtained. Some of the results are shown in the table below. As can be seen, the proposed approach produces significantly smaller macromodels than conventional Krylov based reduction.

References

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	Krylov Macromodel [2,3]		Proposed Macromodel		
	Size	CPU Cost (sec)	Size	CPU Cost (sec)	Speed-up
Example 1, two coupled lines	80	11.98	34	3.21	3.7
Example 2, nine coupled lines	398	1268	211	339	3.74

TABLE I. Summary of computational results