Data-driven Parametrized Model Order Reduction using Multivariate Orthonormal Vector Fitting technique

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Nowadays, full-wave electromagnetic (EM) methods [1],[2],[3] are widely used to simulate a variety of complex electromagnetic systems and are considered to be essential for efficient design. The use of these methods usually results in the computation of a huge number of field (E,H) or circuit (i,v) unknowns, in the frequency domain (FD) or time domain (TD), although users are usually only interested in a few of them at the input and output ports. These methods provide high accuracy, often at a significant cost in terms of memory storage and computing time. Therefore, Model Order Reduction (MOR) techniques are crucial to reduce the complexity of the model defined by the full-wave numerical method and the computational cost required by simulations, while retaining the important physical features of the original system [4],[5].

Efficient real-time design space exploration, design optimization and sensitivity analysis require the development of accurate parametric broadband macromodels that approximate the dynamic behavior of a system characterized by several design parameters, such as geometrical layout or substrate characteristics, in addition to time or frequency. These applications call for Parametrized Model Order Reduction (PMOR) techniques.

Multivariate Orthonormal Vector Fitting (MOVF) [6],[7] is a recently developed algorithm able to compute accurate rational parametric macromodels, based on parametrized frequency responses with a highly dynamic behavior. This technique can be seen as a *data-driven* PMOR method. Instead of reducing the size of the matrices of a parametrized state-space model directly (*model-based* PMOR), MOVF builds rational parametric macromodels with a reduced model complexity based on a set of input-output data samples. The goal of the macromodeling algorithm is to find a multivariate rational function which approximates a large set of $K+1$ data samples $\{(s,\vec{g})_k, H(s,\vec{g})_k\}_{k=0}^{K}$ in a least-squares sense. These data samples depend on the complex frequency $s=j\omega$ and several additional parameters $\vec{g}=(g^{(n)})_{n=1}^{N}$ as design variables which describe e.g. the metallizations in an EM circuit (lengths, widths,...) or the substrate features (thickness, dielectric constant, losses, ...). The proposed approach results in accurate and compact rational parametric macromodels of complex electromagnetic systems.

References

[1] R. F. Harrington, Field Computation by Moment Methods. NewYork: Macmillan, 1968.
[2] A. E. Ruehli and P. A. Brennan, "Efficient Capacitance Calculations for Three-Dimensional Multiconductor Systems", *IEEE Trans. on Microwave Theory and Techniques*, vol. 21, no. 2, pp. 76-82, February 1973.
[3] J. M. Jin, The Finite Element Method in Electromagnetics, 2nd ed. New York: Wiley, 2002.
[4] B. Gustavsen and A. Semlyen, "Rational Approximation of Frequency Domain Responses by Vector Fitting", *IEEE Trans. on Power Delivery*, vol. 14, no. 3, pp. 1052-1061, July 1999.
[5] D. Deschrijver, B. Haegeman and T. Dhaene, "Orthonormal Vector Fitting: A Robust Macromodeling Tool for Rational Approximation of Frequency Domain Responses", *IEEE Trans. on Advanced Packaging*, vol. 30, no. 2, pp. 216-225, May 2007.
[6] D. Deschrijver, T. Dhaene and D. De Zutter, "Robust Parametric Macromodeling using Multivariate Orthonormal Vector Fitting", *IEEE Trans. on Microwave Theory and Techniques*, vol. 56, no. 7, pp. 1661-1667, July 2008.
[7] F. Ferranti, D. Deschrijver, L. Knockaert and T. Dhaene, "Fast Parametric Macromodeling of frequency responses using parameter derivatives", *IEEE Microwave and Wireless Components Letters*, submitted for publication, May 30th 2008.