Fast Passivity Enforcement Technique for Common-Pole S-Parameter Multiport Systems *

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Abstract

This paper applies a reliable and efficient algorithm for passivity enforcement of common-pole multiport S-parameter macromodels. It ensures that the maximum passivity violation decreases monotonically in each iteration step, and convergence to a uniformly passive macromodel is guaranteed.

1 Introduction

The synthesis of accurate broadband macromodels from tabulated S-parameter data is very important for the design of passive microwave systems and devices. Although standard identification techniques are available to extract the model coefficients accurately, the resulting macromodel is stable but possibly non-passive [1]. This paper applies a new iterative algorithm [2] that is able to enforce passivity by means of a fast pole perturbation scheme. By perturbing only the poles of the macromodel, it is possible to deal with large multiport systems that share a common set of poles in a very efficient way.

Although the idea of pole perturbation has been considered before [3], the method in [2] is substantially different. This approach perturbs the poles of the model while preserving the zeros, whereas [3] perturbs the poles of the model while preserving the residues. By considering the pole-zero form instead of the pole-residue form, it is possible to derive some analytic conditions which guarantee that the maximum passivity violation is monotonically decreasing in each iteration step.

2 Passivity Assessment

The passivity enforcement method considers a stable, but potentially non-passive multiport system in state-space form

$$j\omega X(j\omega) = AX(j\omega) + BU(j\omega) \quad (1)$$

$$Y(j\omega) = CX(j\omega) + DU(j\omega). \quad (2)$$

A stable realization is obtained by applying the fast Vector Fitting procedure to some tabulated S-parameters, while enforcing a common pole set for each matrix element [4]. The exact definition of passivity stipulates that the transfer matrix $S(j\omega)$

$$S(j\omega) = C(j\omega I - A)^{-1}B + D \quad (3)$$

must be unitary bounded for all frequencies such that

$$\max_{\omega}(\sigma(j\omega)) \leq 1, \forall\sigma(S(j\omega)) \quad (4)$$

The eigenvalues of an associated Hamiltonian matrix can be used to assess model passivity [5]. An overview and comparison of existing work is given in [6], and the references therein.

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3 Passivity Enforcement

If the macromodel is found to be non-passive, then the passivity enforcement algorithm in [2] is applied. It converts the state-space model to a pole-zero form and perturbs the common poles until all singular value curves (4) are unitary bounded. During this process, it is ensured that the perturbation does not introduce new violations at other frequencies. Therefore some additional constraints are imposed, which guarantee that the size of the largest passivity violation decreases monotonically in each iteration step. These conditions allow the algorithm to pinpoint exactly the region in which a perturbed pole can be located without introducing new passivity violations.

The iterative compensation algorithm consists of 3 steps. First, it calculates the frequency that corresponds to the largest passivity violation, based on the eigenvalues of the Hamiltonian. Then, it selects the pole of the model for which the contribution to the largest passivity violation is maximal. Finally, it perturbs the pole in such a way that the passivity violation becomes smaller, without introducing new violations. At the same time, the model deviation is minimized by error control.

These steps are repeated iteratively until the macromodel is passive. The details about this procedure are reported in [2].

4 Example : 48-Port BGA Package

In this example, the presented approach is used to compute a passive macromodel of a 48-port ball grid array package [3]. The scattering parameters of the structure are simulated from DC up to 10 GHz, and Vector Fitting is used to approximate the response by a 6-pole proper transfer function using 100 data samples. It is seen from Fig. 1 that the macromodel has several non-negligle passivity violations, both inside and outside the frequency range of interest. The proposed passivity enforcement procedure is applied to compensate the violations, and converges to a passive macromodel in only 18 seconds on a Dual Core 2.4 GHz laptop computer. Figs. 2 and 3 show that the accuracy of the overall macromodel is well preserved, both in terms of the magnitude and the phase angle respectively. The worst case error over all matrix elements is -43 dB, which is quite small given the size of the maximum violation ($\sigma_{\max} = 1.0069$). The RMS deviation that was introduced by the perturbations corresponds to 3×10^{-2}. It is seen from Fig. 4 that the maximum singular value of the scattering matrix decreases monotonically in each iteration step. The algorithm converges in 10 iterations to a guaranteed passive macromodel.

Conclusions

A robust passivity enforcement algorithm is applied to compensate the non-passive behavior of a large common-pole state-space model (BGA package). The maximum singular value of the scattering matrix decreases monotonically in each iteration

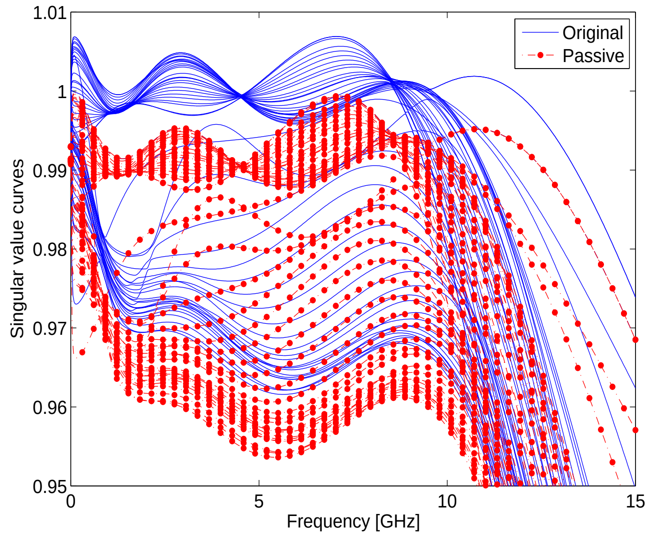

Figure 1: Singular values of scattering matrix.

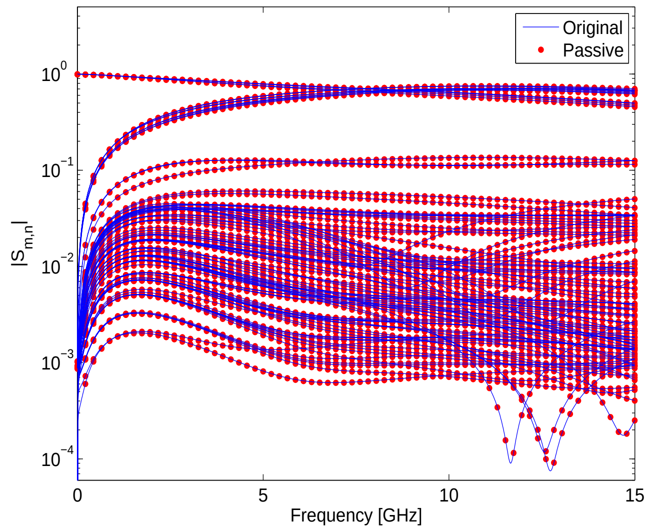

Figure 2: Magnitude of matrix elements (subset).

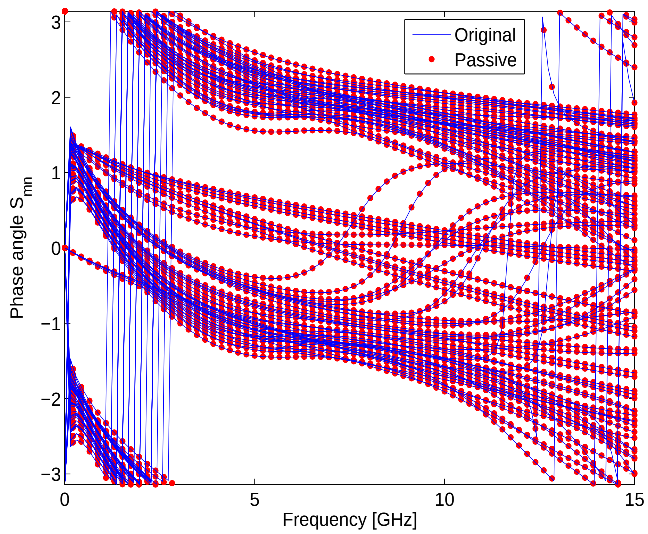

Figure 3: Phase angle of matrix elements (subset).

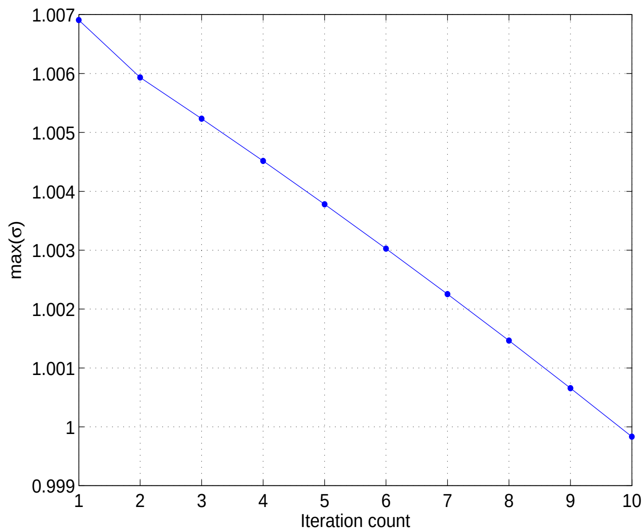

Figure 4: Maximum singular value in each iteration step.

step, and convergence to a passive macromodel is guaranteed.

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