Full-Wave Based Modal Analysis for Through Silicon Vias in Layered Media

Zhonghai Guo[1], Guangwen (George) Pan[1], and Chris Pan[2]

[1] Department of Electrical Engineering, Arizona State University, USA
[2] Quallcom Co., San Diego, CA, USA

With increasing demand of integrated circuits in higher density, faster clock rate and further miniaturization, the analysis of propagation for large number of through silicon vias (TSV) has attracted more attentions in the present high-performance packaging system design. Higher density, faster operating speed and routing complexity have introduced unwanted coupling among vias in the naturally formed parallel plate waveguide environment. All of the new features render the capacitance and inductance based quasi-static approach less accurate (G. Pan, et al., IEEE Transactions on CPMT, **18**(3), 521-531, 1995). Consequently, the full wave solution is absolutely necessary. Full wave characterizations of vias are carried out by numerical, analytical and semi-analytical methods. For large number of vias, analytical method is preferred due to its fast computational speed and high precision. Based on Foldy-Lax equations in vector cylindrical waves, a general-purpose analytical method was presented (L. Tsang, et al., MOTL **31**(3), 201-208,2001).

In this paper, we develop a full-wave solution to the propagation characteristics of multiple vias in a much simplified and more understandable manner. The equations are derived based on the traditional concept in the method of moments (MoM). The waveguide modes are decoupled through discrete Fourier transform so that the solution can be evaluated for each waveguide mode separately. The proposed method takes advantage of cylindrical symmetry, employing Bessel's functions and the addition theorem to solve the Helmholtz equations without resorting numerical discretization. As a result, it is a full-wave solution with high accuracy. Since the algorithm does not rely on numerically generated meshes, its computational speed is much faster. Numerical examples demonstrate that the new method provides excellent agreement with the HFSS results, consuming only a fraction of the CUP time.