Ultra-Fast Finite Element Simulation of Planar Electromagnetic Structures

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Microwave devices and antennas often form layered structures consisting of multiple dielectric and metallization layers with the metallization interconnected by vias. Typical examples of such structures are printed circuit boards, IC packages, MMICs and planar antennas. While the fields in such structures are three-dimensional, the geometry is mostly planar. This paper employs a mode decomposition approach to modeling such structures that greatly reduces simulation requirements. In particular, we decompose the fields in planar structures into two types of modes: (1) parallel plate cavity modes in which the electric field is assumed to be purely normal to the power and ground planes in the structure, and (2) TEM modes for propagation in the direction of the metallization traces between the power and ground planes. These two types of modes are orthogonal from an electromagnetic point of view but are coupled through voltage and current continuity constraints. The parallel plate cavity modes neglect fringing fields but are remarkably accurate provided that the power and ground planes are close together. While large cut-outs in power and ground planes must be modeled, small holes or perforations may be neglected with little loss in accuracy. The finite element method is used to solve both for the cavity modes and for the TEM modes. For the cavity modes, we solve the Helmholtz equation over the two-dimensional layout of the power/ground geometry for the normal component of the electric field. For the TEM mode of each unique trace/metallization geometry, we solve the complex Poisson equation for the skin effect and the electric and magnetic potentials. All of these computations are very fast and usually take only seconds. Electromagnetic models of vias are used to tie the two types of modes together. The procedure has been used to simulate a wide variety of planar electromagnetic components. A simple test example is presented in Figure 1. Examples involving many layers and complex metallization patterns with thousands of traces are solved accurately orders of magnitude faster than would be possible with full three-dimensional finite element solvers.

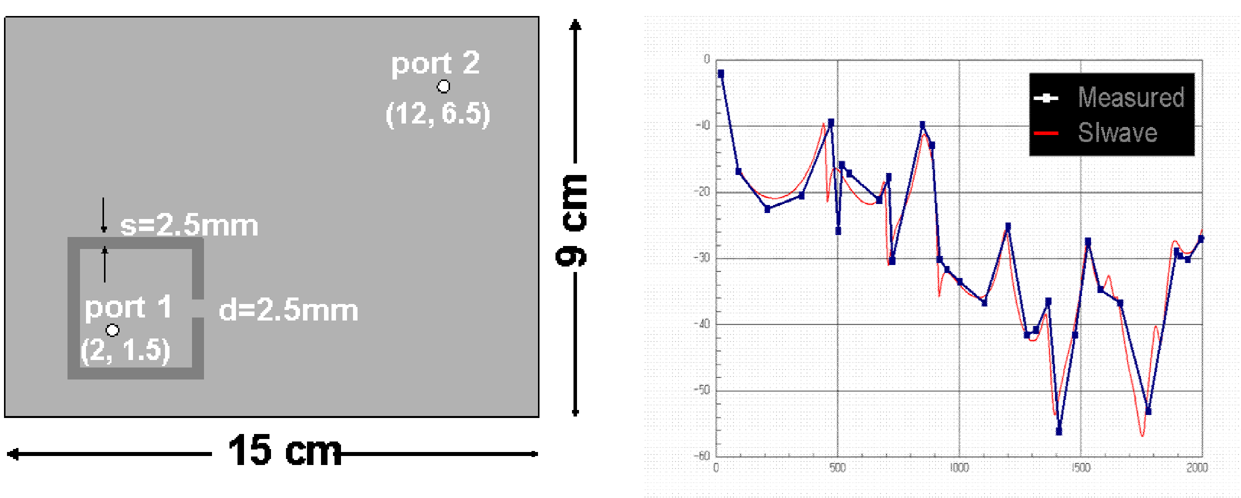

Figure 1. Power island with a PEC bridge (a) Layout (b) Measured and simulated S_{21} v frequency