A Hybrid FEM/Analytic Method for the design of Substrate Integrated Waveguide Circuits

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Substrate Integrated Waveguide (SIW) circuits are very common in many applications due to its compact size and ease of fabrication. Current numerical methods for analyzing SIW circuits are based on the Method of Moments (MoM) combined with other formulations, such as Mode Matching (MM). Analytical formulations, combined with MM, can also be used to study SIW circuits. All of these methods have limitations when a complex, multilayer SIW circuit with interconnections between layers has to be designed.

We have developed a new hybrid formulation that combines the Finite Element Method (FEM) and an analytical scattering method based on addition theorems of cylindrical modes. Using our formulation, a multilayer SIW circuit can be studied as a coupled set of cylinders. Each cylinder can include a via hole, a resonator, a feeding port (coaxial connector), etc. Arbitrary slots for connecting several layers can also be included in a cylinder. Then, a multimode Generalized Scattering Matrix (GSM) of each cylinder is obtained with FEM, based on radial waveguide modes. The position of each cylinder and its rotation is taken into account analytically in the formulation of the scattering method in terms of addition theorems.

Additionally, we have extended an existing formulation for fast frequency sweep based on a Reduced Basis Method for radial waveguide modes. This is not evident, since the frequency dependence for the z and φ component of the electric field is not the same in the case of radial waveguide modes. We have solved the problem taking advantage of the GSM structure obtained with our FEM.

We have analyzed several SIW circuits to show the performance of the method. Comparisons with published experimental results and full-wave simulations show an excellent agreement.