High-Frequency Electrical Characterization of Printed Circuit Boards

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Printed circuit boards are increasingly being employed in high-frequency applications. In order for microwave engineers to successfully design transmission lines and other devices, knowledge of the printed circuit board's dielectric properties is critical. In particular, design engineers need to know the relative permittivity $\epsilon_r^{'}$ and loss tangent $\tan\delta$. Unfortunately, dielectric measurement of printed circuit boards is complicated by the fact that the board's relative permittivity and loss tangent may be a function of frequency, temperature, and humidity. In addition, depending on the material type and construction, the printed circuit board may also be anisotropic.

In an effort to develop new IPC standard test methods, we compare five candidate techniques for measuring the relative permittivity and loss tangent of printed-circuit boards over a frequency range of 1 to 20 GHz. The first three methods we investigate are resonant techniques: split-post resonator, split-cylinder resonator, and re-entrant cavity. Although resonant techniques only provide dielectric measurement data at discrete frequencies, the measurement uncertainties for both relative permittivity and loss tangent are low relative to transmission-line techniques.

The remaining two methods we examine employ planar transmission lines that are etched on the printed circuit board. We consider two different transmission-line geometries: microstrip and coplanar waveguide. The electric field orientation is nearly perpendicular to the board for microstrip and nearly parallel in the case of coplanar waveguide. In this way, we can examine any effects of the board's anisotropy. Although these transmission-line techniques allow for the broadband measurement of the board's dielectric properties, the measurement uncertainties are relatively high when compared to measurements performed in resonators.