An Incremental Inductance Approach to Proximity Effect Calculations of Differential Striplines

S. Asgari and M. Tsuk
Ansoft Corporation, USA

The performance of the high-speed digital integrated circuits depends on how well the signal waveforms are controlled on the coupled interconnecting transmission lines whether on-chip or off-chip. Hence, to preserve the signal integrity of the transmitted waveforms traveling with high speed through interconnecting lines requires the designer to analyze a broad band of frequencies.

Meanwhile in many applications, for example the printed circuit board (PCB) layout designs, the differential traces are pushed close to one another. This is done so as to save board space. As a result, the differential impedance will go down for closely spaced lines. Also, the effect of tight coupling decreases the effective trace width causing skin effect loss. This will result in intense concentration of magnetic flux near the corners of the traces, inducing substantial peaking of the current density at the corners. The proximity effect illustrates itself as the concentration of current around the periphery of the signal conductors and the reference planes. The proximity effect increases especially at the very high frequencies.

While usually different 2D and 3D field solvers such as Ansoft's SI2d and HFSS are used to do a more elaborate surface resistance calculation, no closed form equations that we know of are available to do an adequate approximation of the proximity effect even for the simpler case of symmetric differential striplines. In this paper, we derive closed form equations for the effective surface resistance matrix of symmetric edge-coupled differential stripline based on Wheeler's incremental inductance rule while incorporating the proximity effects of the lines. This methodology can be generalized to non-symmetric as well as multi-coupled lines.

The paper is organized as follows. In section II, we review Wheeler's incremental inductance rule and set up the general formulas needed to solve for the resistance matrix. In section III, we present the closed form equations for the resistance matrix and summarize the equations for the case of differential stripline. In section IV, we show few examples and simulation results which demonstrate the usefulness of our approach as compared to that of Ansoft's SI2d as well as Moments method (MOM) calculations. Finally we end the paper with concluding remarks and future extension of the work.