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**Accurate and Efficient Modeling of Interconnects in Lossy Layered Media**

**Abstract:**
Semiconductor-based integrated circuits have become the mainstream for very-large-scale integration (VLSI) systems such as high-speed digital circuits, radio-frequency integrated circuits (RFIC), and even monolithic microwave integrated circuits (MMIC). The shrinking feature size and increasing frequency promote high integration density and interconnection complexity that demand high accuracy modeling techniques. The current design paradigm has shifted from the transistor-driven design to the interconnect-driven design. Thus the accurate and efficient modeling of on-chip interconnect becomes critical for the computer-aided design tools to analyze the overall system performance.

In this research, we focus on implementing the full wave spectral domain approach (SDA) for accurate modeling of shielded microstrip interconnects. Two new techniques, the mid-point summation (MPS) and the super convergent series (SCS) approach have been developed to accelerate the SDA by nearly five to six orders of magnitude. It involves the leading term extraction of the Green's function and the Bessel's function and using the above two methods to accelerate the summation of slowly convergent infinite spectral series.

An accelerated SDA has been developed using two superconvergent series to handle the more general case of multilayered shielded microstrip interconnects in which the signal strip can be displaced from the center. In addition to this, closed form expressions have been developed to dynamically choose the number of terms and the value of the parameters as a function of the argument, to adaptively obtain the best convergence of the second type of superconvergent series for a given accuracy and argument.

The accelerated spectral domain formulation using two super convergent series was extended to handle multiple metal lines on the same interface and very accurate results have been obtained for the propagation constant using a few terms of the infinite summation.

Also an equivalent model for a lossy shielded microstrip line on layered media is constructed by replacing the layered media with a single effective medium and a detailed analysis of its validity at different frequencies and different range of dimensions has been presented for application to on chip interconnects. The relative permittivity for a single layer microstrip which results in the same propagation constant for the dominant mode as the layered one at a given frequency is considered to be the equivalent. The results show that this model is frequency independent for layered structures when the given frequency and frequency of operation are less than the transition frequency (i.e. the frequency at which there is a significant change in the equivalent dielectric constant $\varepsilon_{req}$. For frequencies higher than the transition frequency the equivalent model is not frequency independent but it gives good results for the higher order mode although it is derived using the dominant mode. Also it is seen that at low frequency $\varepsilon_{req}$ depends on the layers near to the signal metal but at higher frequencies it depends on the layer with the highest value of $\varepsilon_{ri}$ irrespective of its location w.r.t to the metal strip. For the case, when some of the layers have a finite conductivity we see two transition frequencies. The first transition frequency just depends on the layer with the highest $\sigma_{ri}$ /$\varepsilon_{ri}$ ratio and the second transition frequency is the same as that for the lossless case and occurs when the thickness of the layer with the highest value of $\varepsilon_{ri}$ becomes comparable to the wavelength.

The Spectral Domain Immitance Approach (SDIA) was extended to handle multiple metal lines in different layers. Also, several techniques to account for the finite thickness and conductivity of the metal lines have been studied. The pulse-triangle and the triangle-triangle basis functions were developed so as to include this effect into the SDA. This, is because entire domain basis functions such as Chebyshev polynomials will lead to non-convergent infinite series summation while calculating the elements of the Method of Moment matrix.