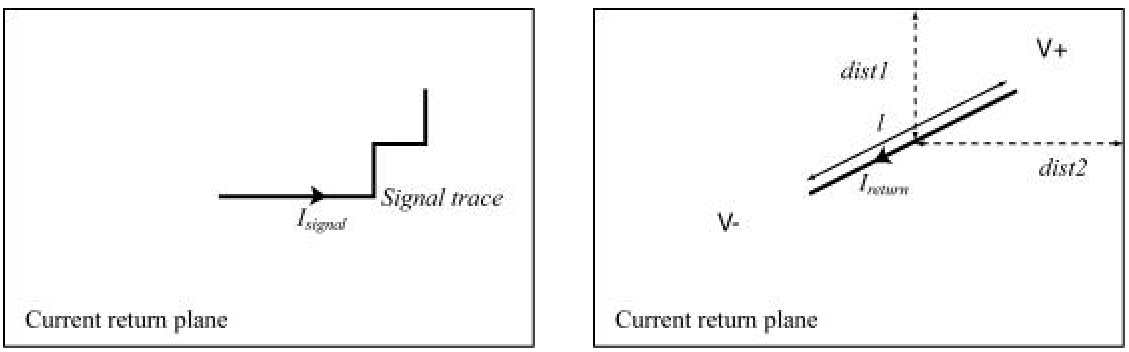
Grid Point Voltage Algorithm

Purpose of Algorithm

To estimate the common-mode voltage variations on the return plane of a printed circuit board due to current on microstrip traces.

Basic Description of Algorithm

The common-mode voltage difference on a return plane drives EMI antennas such as cables, heat sinks, and even the board itself [1, 2]. The voltage drops are created by magnetic fields that wrap around return plane. The expert system estimates the voltage difference by approximating the branch inductance of the current return path. The return path of a trace need only be identified by its end points, since the calculation is independent of the exact path of the trace.



(a) A signal trace over a return plane

(b) Simplified return path and voltage difference

Fig. 1. Configuration for partial inductance of a return plane

The branch inductance associated with the magnetic field created by return current is given as [3]

$$L_p = (4/\pi^2) \times \frac{\mu_o l h}{dist1 + dist2} \tag{1}$$

where, *h* is the height of the trace over the return plane. The voltage difference created by the return current is calculated as

$$V_d = \omega L_p I_{return} . \tag{2}$$

The return plane is divided into two regions by the virtual lines, dist1 and dist2, that are the two shortest distances to the boundary of the board from the mid point of the return path. The voltage difference is applied between any two points in different regions.

Assumptions

- The magnitude of the current is constant along the return path. (The length is electrically short or the termination is matched.)
- There are no significant holes or discontinuities in the return plane. (i.e. trace is not routed over a gap in the plane.)
- The internal inductance and resistance of the plane are much smaller the external inductance.

- The relative phase differences between signal traces are not taken into account. Currently, differential signals are ignored (i.e. perfect phase cancellation is assumed) and single-ended signal contributions are root-mean-square added.

Implementation Details

The algorithm first generates an array of points that are located over a solid return plane. The points are spaced by 1 cm in both horizontal and vertical directions. The voltage variation is represented using these discrete points. The value for each point, first, is initialized as zero.

Then, the algorithm goes through every net for which the return path is identified as a return plane. If the net is identified as HIGH or MEDIUM utilization and is longer than 1 cm, the algorithm is applied to the net. Otherwise, it is neglected.

For each voltage grid point, the overall voltage is obtained by taking a root mean square sum of the values created by traces as

$$V_{total} = \sqrt{V_{trace1}^2 + V_{trace\,2}^2 + \cdots + V_{trace\,N}^2} \quad \text{for each grid point and frequency} \qquad (2)$$

References

[1] D. M. Hockanson, J. L. Drewniak, T. H. Hubing, T. P. Van Doren, F. Sha, and M. Wilhelm, "Investigation of Fundamental EMI Source Mechanisms Driving Common-Mode Radiation from Printed Circuit Boards with Attached Cables," *IEEE Trans. on Electromag. Comp.*, vol. 38, no. 4, Nov. 1996, pp. 557-566

[2] D. M. Hockanson, J. L. Drewniak, T. H. Hubing, T. P. Van Doren, F. Sha, C. W. Lam, and L. Rubin, “Quantifying EMI Resulting from Finite-Impedance Reference Planes,” *IEEE Trans. on Electromag. Comp.*, vol. 39, no. 4, Nov. 1997, pp.286-297.

[3] Navin Kashyap, *An Expert System Application in Electromagnetic Compatibility*, M.S. Thesis, University of Missouri-Rolla, 1997.