Differential-Mode Radiation Algorithm

Purpose of Algorithm

To estimate the radiation due to differential currents flowing on printed circuit board traces.

Basic Description of Algorithm

Signal trace segments and their corresponding return trace segments are modeled as differential pairs. The effects of common-mode currents are modeled by other algorithms. Fig. 1 illustrates a differential pair.

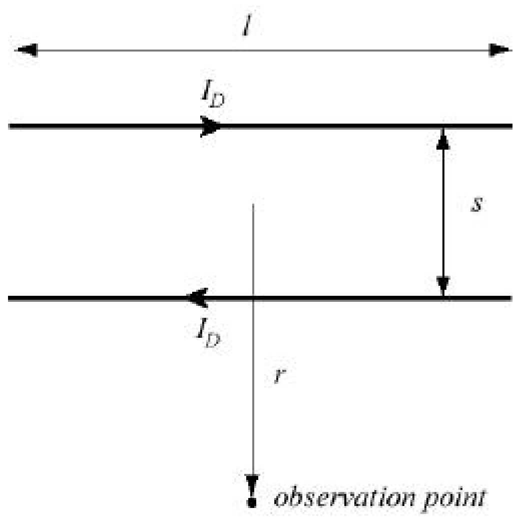

Fig. 1. A simple differential mode current radiation source

The maximum electric field is given as [1]

$$|E|_{\max} = 1.316\times10^{-14} \left. \frac{|I_D|\, f^2 l\, s}{r} \right|_{r=3m} = 4.4\times10^{-15} |I_D|\, f^2 l\, s \qquad (1)$$

where, f is frequency [Hz]. According to most EMI regulations, emissions are measured over a conducting plane. This condition increases radiation by factor of two.

$$\begin{aligned} |E|_{\max} &= 4.4\times10^{-15} |I_D|\, f^2\, l\, s \times 2 \\ &\approx 10^{-14} |I_D|\, f^2\, l\, s \end{aligned} \qquad (2)$$

This calculation is performed by the subroutine *field_from_traces_no_enclosure()*.

Assumptions

- All dimensions are small compared to the wavelength of interest
- Segments are thin relative to their spacing and length
- Currents on both wires are equal and opposite

- When the return path is actually in a plane, the image of the signal trace is used. This assumes that the plane is large relative to the length of the trace segment and the height of the segment above the plane.
- No phase information is included. Estimate may be high, since actual radiation from many wire segments may not add in phase.
- Polarity of radiated field is not considered. Estimate may be high, since actual radiation from many wire segments may not have the same polarity.

Implementation Details

The length, *l*, of segment is obtained from layout data file. The distance, *s*, between trace and return path and the magnitude of differential current, I_D, are determined by the subroutines in the net-classification stage.

Each segment of every net on the board is passed to this algorithm. The routine first checks if the net is a digital net with appropriate utilization or an analog net with a narrow-band signal. If this condition is satisfied, the routine calculates the E-field using Equation (2) at each frequency. Contributions from each segment are summed linearly to obtain the total E-field radiated by a net. The differential emission estimate for the entire board is obtained by taking a root mean square sum of the fields due to each net,

$$\left|\boldsymbol{E}\right|_{total} = \sqrt{\boldsymbol{E}_{net.1}^{2} + \boldsymbol{E}_{net.2}^{2} + \cdots + \boldsymbol{E}_{net.N}^{2}} \quad \text{for each frequency} \qquad (3)$$

References

[1] C. Paul, *Introduction to Electromagnetic Compatibility*, New York: Wiley, 1992.