Analytic Methods for Coupling to Cables with Large Numbers of Component Wires

James L. Gilbert
Metatech Corporation, Goleta, CA, 93117

In this presentation, we discuss an analytic method for calculating coupling to the wires in a cable containing a large number of individual wires. We first examine the situation where the wire insulator thickness is small compared to the wire radius, so that the capacitance matrix is dominated by nearest neighbor interactions. In this case, it can be shown that the capacitance matrix is proportional to the transverse Laplacian operator

$$C = -6b^2 C_{od} \nabla_\perp^2$$

where C_{od} is the capacitance per unit length between nearest neighbor wires in a hexagonal array, and $2b$ is the spacing between nearest neighbor wires. The equation for forward propagating modes along the line is, ignoring backwards propagating modes,

$$\frac{\partial F}{\partial z} = 3vb^2 RC_{od} \nabla_\perp^2 F$$

where R is the resistance of an individual line, v is the propagation velocity in the dielectric (which is assumed to be uniform) and $F=I+vQ$, where I is the wire current and Q is the charge per unit length on the wire. This is a simple parabolic diffusion equation and easily solvable for many geometric configurations of interest. It can be used to calculate how an incident electric field diffuses into the interior of the cable bundle as well as used to calculate the impedance looking back into a single line or group of lines.

We will give examples of the use of this technique as well as modifications to the technique to include situations where the wires further away than the nearest neighbors contribute substantially to the capacitance matrix. We will also show numerical examples of the calculation of the capacitance matrix including non-nearest neighbors by successive over-relaxation and compare them to the asymptotic form that results when small wire diameters are assumed.