Analytical Approach of Multiconductor Non-uniform Transmission Lines

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A determination of the time domain response of multi-conductor transmission lines is of great importance in the analysis of crosstalk in fast digital circuit interconnections. When the signal speed is high and the transmission line is nonuniform, delay, cross talk, and the distortion of signals are especially troublesome. Although time domain analysis of these lines has been of interest for many years, there is no general time domain analytical solution applicable to both the TEM line and quasi-TEM line. A time domain analytical solution for a single homogeneous transmission line has been introduced (R. Nevels and J. Miller, "A Simple Equation for Analysis of Nonuniform Transmission Lines," *IEEE Trans. Microwave Theory Tech.*, vol. 49, No.4, pp. 721-724, April, 2001). It was shown that a numerical version of the time domain propagator solution to the Telegrapher's equations coupled in terms of current and voltage can be used to obtain accurate results for several types of single conductor nonuniform transmission lines. A particularly useful feature of the explicit numerical method developed to evaluate the propagator solution is that it is not subject to numerical dispersion.

As an extension of the analytical and numerical methods described above, in this paper we present a time domain solution method based upon the N-mode condition for multiconductor transmission lines. First the eigenvalues and eigenvectors of the N x N coupling capacitance matrix for an N-conductor coupled line is used to find the N-mode inductance and capacitance vectors in air and in the dielectric medium of the substrate. This step is an expansion of an equivalent procedure for obtaining the even and odd modes from the eigenvalues and eigenvectors of the 2 x 2 capacitance matrix for a 2-conductor line. Next, the corresponding characteristic impedance and phase velocity for each mode can be calculated from the N-mode capacitances. The mode phase velocities and characteristic impedances are in turn used to find the propagator method eigenvalues and eigenvectors. Finally a 2N x 2N propagator matrix is found and an explicit numerical algorithm is developed. It is noted that the analytical process presented here is valid for any type of lossless and symmetrical transmission line. Moreover, this method can be applied to symmetrical and non-symmetrical multiconductor TEM transmission lines, such as coupled striplines. We will present time domain results for coupled nonuniform striplines and microstrip lines solved by the propagator method described here and compared with the results obtained with the ADS commercial tool.