Electromagnetic Field Coupling to Thick Wires

Jürgen Nitsch and Sergey Tkachenko*
Otto-von-Guericke-University Magdeburg, IGET, Universitätsplatz 2,
39106 Magdeburg, GERMANY, http://www.uni-magdeburg.de/iget/

The investigation of electromagnetic field coupling to linear structures, which constitute an essential part of electronic and electric circuits, is one of the main issues in electromagnetic compatibility. Nowadays, the characteristic frequencies for the used signals, as well as for the interferences increase up to several GHz. Then the usually used classical transmission line (TL) theory as well as the thin wire approximation are no longer applicable for thick cables or cable-bundles.

One of the approaches to generalize the classical TL theory was suggested in (J. Nitsch and S.Tkachenko, Interaction Notes, Note 592). In this method for thin wires the electric field integral equations for the induced total (axial) current and the scalar potential along the wire are represented as an infinite set of multiconductor transmission line–like equations for each spatial Fourier mode. The coefficients in these equations-so called modal transmission line parameters (inductance and capacitance)-are connected with the Fourier representations of corresponding kernels of the integral equations. For finite wires these parameters are infinite dimensional matrices. They are complex-valued, depend on the used gauge and are connected with the radiation of the system. The solution for an arbitrary wire can be formally derived from these modal parameters. For high-symmetry cases: straight wire, circle, helix and their various combinations with each other and the grounding plane, conserving the symmetries, the corresponding matrices of the modal parameters become diagonal (J.Nitsch, S.Tkachenko, IEEE Trans. Electromagn. Compat., Vol. 47, Aug. 2004; J. Nitsch, S.Tkachenko, 8^{th} Int. Conf. on Electromagnetics in Advanced Applications (ICEAA 03), Sep., 2003 - Torino, Italy, 401-404.).

The method of modal parameters is generalized for the practically important case of the excitation of a thick straight cylindrical wire above ground. In this case, we have shown, that a thick wire formally can be described by multiconductor TL equations, however, the modal representation of the mixed potential form of EFIE generally includes an additional equation for the azimuthal component of the induced current. The inductance per unit length and the capacitance per unit length become matrices of (in general) infinite dimensions. Besides the "axial" inductance matrix we also obtain an "azimuthal" one. The three coupled telegrapher equations for the axial component of the current, the azimuthal component of the current and the scalar potential can be reduced to (the usual) two equations.

We have shown that the obtained system of general form allows an additional simplification for TM or TE waves: For each such polarization the system decouples into a system of two matrix equations. Moreover, the solution of the corresponding homogeneous system coincides with the solution for the axial current distribution for a TEM wave propagating along a thick cylindrical wire, which was obtained at the beginning of the twentieth century (A. Sommerfeld, "Electrodynamics", Lectures on Theoretical Physics, Vol.III, Academic Press, New York, 1952).

In the conclusion, we shortly discuss the application of the modal method to the general case of a curved thick "cylindrical" wire.