DETERMINING COUPLING FOR SHIELDED CABLES USING A TLM APPROACH

Alexandros Gavrilakis*, Muhammed Al-Asadi*, Alistair P. Duffy*, Kenneth G.Hodge^, Arthur J.Willis^

*** De Montfort University, UK**
^ Brand-Rex Ltd., Fife, UK

Abstract

This paper presents the coupling mechanism for a geometry consisting of two parallel conductors located symmetrically inside a braided shield and grounded at both ends. The coupling is represented by voltage and current sources and is implemented using the Transmission Line Matrix (TLM) Method. Frequency domain analysis for both shield and inner conductor excitations is presented and compared against an existing, lossless, SPICE model.

Introduction

The subject of crosstalk between multiconductor lines and incident fields is discussed thoroughly in literature e.g.[1-3]. These analyses have been based on using a variety of modelling methods, like SPICE [1], TLM [2] etc. However, in most cases the excitation of the lines is due to incident fields directly applied on the lines. In this paper, the excitation is applied on a braid shield so the resulting excitation present on the parallel conductors depends mainly on the quality of the shield. The coupling between the parallel lines has been included and has been based on the same principles for the coupling between the shield and an inner conductor.

Coupling mechanism

The analysis for the circuit in Figure 1 is based, initially, on developing equivalent circuits for the system as in Figure 2 and then converting them into their Thevenin circuits, Figure 3. Then, TLM theory described by Christopoulos [4] is used to obtain the near and far end voltages of the line.

The coupling takes the form of induced voltage and current sources distributed along each conductor.

For example, the coupling into conductor 1 is,

$$VT_1 = I_2 \cdot ZTT \pm Is \cdot ZT \qquad (1)$$

$$IT_1 = V_2 \cdot YTT \pm Vs \cdot YT \qquad (2)$$

where,

$$ZTT = \left| R_2 + j\omega L_{12} \right| \qquad (3)$$

$$YTT = \left| G_2 + j\omega C_{12} \right| \qquad (4)$$

and *ZT* is the transfer impedance of the braid, *YT* is the transfer admittance of the braid, *ZTT* is the “transfer impedance” between the parallel conductors and *YTT* is the “transfer admittance” between the parallel conductors. Subsequently, L_{12} and C_{12} are the mutual inductance and capacitance of the parallel inner conductors and R_2 and G_2 the resistance and conductance of conductor 2. The transfer impedance *ZT* can be determined using [5,6], and the transfer admittance as,

$$YT = \left| j\omega Cxx \right| \qquad (5)$$

where *Cxx* is the transfer capacitance, described in Benson et. al. [7].

Lastly, *Is* represents the current on the surface of the shield, *Vs* the voltage between the shield and the external environment, and V_2 and I_2 the voltage and the current on conductor 2 respectively.

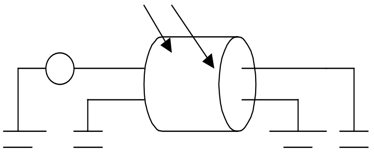

Figure 1: Shielded pair geometry

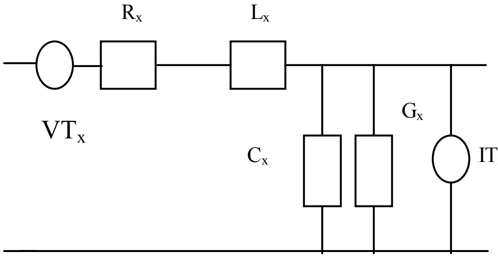

Figure 2: Equivalent circuit characterizing the shield and each of conductors.

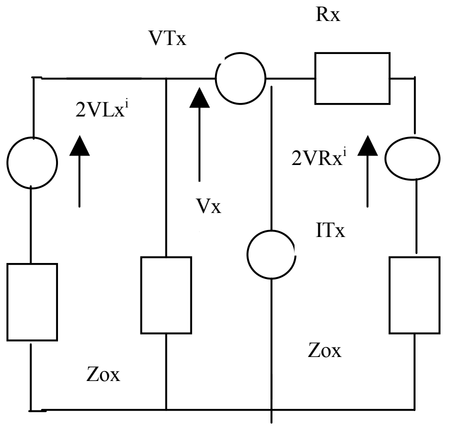

Figure 3: Thevenin equivalent of node n

Due to the symmetry of the line, the formulation for conductor 2 is derived in a similar way. The coupling from the conductor to the shield can be formulated using the same approach.

TLM

The TLM implementation involves the segmentation of the length of the cable in a number of nodes. Three different TLM models are required and their time synchronization is by using when needed extra stubs [4].

Applying theory in [4] on a node n of the shield (or any of the inner conductors), the voltage on the left end of node is,

$$ {}_kVx_n = \frac{{}_kITx \cdot Zox \cdot (Zox + Rx)}{2 \cdot Zox + Rx} + \frac{\dfrac{2\,{}_kVLx^i{}_n}{Zox} + \dfrac{2\,{}_kVRx^i{}_n - {}_kVTx_n}{Rx + Zox}}{\dfrac{1}{Zox} + \dfrac{1}{Rx + Zox} + \dfrac{1}{Gx}} \qquad (6) $$

for x=1,2 or 3 (shield & two conductors)
where Zox is the characteristic impedance, Rx is the conductor resistance, Gx the conductance and VLx^i and VRx^i is the incident voltages left and right of node n respectively.

A Fourier transform is then used to convert the data to the frequency domain. Notice that the time step has to be small to take into account the reflections present.

Discussion

In the above model the excitation can have two different sources. In one case, Figure 4, the grounded shield is supposed to be removed, so a 1V dc voltage source is applied to one of the inner conductors. In the second case, Figure 5, the only excitation is applied on the grounded shield so the inner conductors share the same induced excitation from the shield. As it can be seen on the results the effect of standing waves etc. is present. Comparison with a SPICE program, with a lossless transmission line method described by Paul [8] is good and the reflections extracted by the SPICE program are present in the TLM one.

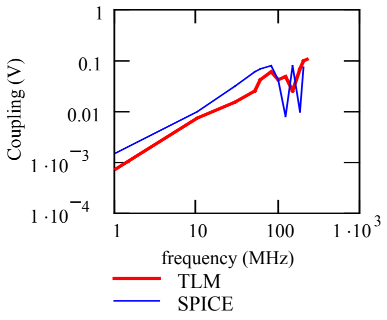

Figure 4. DC excitation on inner conductor 1

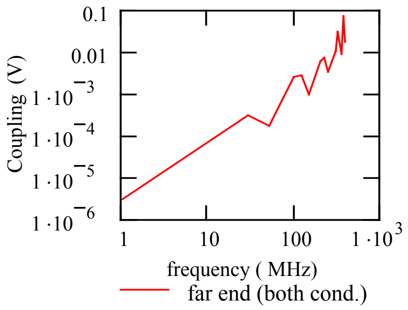

Figure 5. Pulse excitation on the shield

References

1. Paul, C.R., 1981,IEEe Trans.EMC, 23, (4), 352-358.
2. Christopoulos C, Naylor P.,1988, Int. J. of Num. Mod.,1,31-43
3. Tesche F.M,EMC Expo 1987, 19-21.
4. Christopoulos C., The Transmission Line Modelling Method –TLM, IEEE Press, New York 1995.
5. Tyni.M,1976, EMC Symp.Wroclaw,410-418.
6. Vance E.F, 1975, IEEE Trans. EMC, 17, (2), 71-77.
7. Benson F.A, Cudd P.A and Tealby J.M, 1992,IEE Proc-A, 139,(6),285-303.
8. Paul C.R, 1992, Introduction to electromagnetic compatibility, Wiley, New York