

An experimental test for the validation of time domain codes for the analysis of transient field coupling to transmission line networks

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1. INTRODUCTION

The progress achieved during the last years in modelling the field-to-transmission line interaction allows today an accurate prediction of the response of multiconductor lines to external electromagnetic excitation.

The paper first describes two computer codes developed by the University of Bologna and by the Swiss Federal Institute of Technology in cooperation with CESI and EdF respectively, which allow the computation of the voltages and currents along a complex transmission line network induced by an external transient electromagnetic excitation [1,2,3,4]. The external electromagnetic field could be either due to a nearby lightning discharge, a plane wave, or a measured field. First, the interaction of the external field to each transmission line forming the network is modelled using the Agrawal et al. [5] coupling equations and solved in time domain using the finite difference method (FDTD). Then, the junctions to other lines and the terminal conditions are taken into account using an interface with the EMTP (Electromagnetic Transient Program). Such an interface allows for the use of a wide range of existing models for electrical components.

Then the paper presents the comparison of the theoretical calculations with the experimental results that have been recently obtained by means of an experimental network illuminated by the Swiss Defence Procurement Agency EMP simulator (VERIFY).

2. DESCRIPTION OF THE CODES

2.1 - The structure of the computer code developed by the Swiss Federal Institute of Technology in cooperation with EdF is schematically represented in Fig. 1a [2]. First, the incident electromagnetic field, generated either by an indirect lightning discharge, a plane wave, or determined experimentally is evaluated. In the second step, the coupling to each individual line forming the network is computed for matched terminations. The induced currents are computed using the Agrawal et al. [5] coupling model, appropriately extended to take into account the presence of a lossy ground plane [6]. The equations are solved using the finite-difference time-domain (FDTD) method. Finally the coupling to the whole network is taken into account by introducing the induced currents previously computed, as current generators, into the EMTP (Electromagnetic Transient Program) [2].

2.2 - The structure of the computer code developed by the University of Bologna in cooperation with CESI is represented in Fig. 1b [3,4]. This code allows the computation of the voltages and currents along a complex distribution line network by means of a real time link, realized at each line termination, between the EMTP and each illuminated line ('LIOV line'). Each 'LIOV line' implements the Agrawal et al. [5] coupling model between the line and the external electromagnetic field, also in this case, appropriately extended to take into account the presence of a lossy ground plane [6]. The EMTP is used to solve the boundary condition at each line termination. EMTP and 'LIOV lines' exchange currents and voltages

at each time step. This particular kind of interface allows the evaluation of systems in which non-linear phenomena, such as corona, occur.

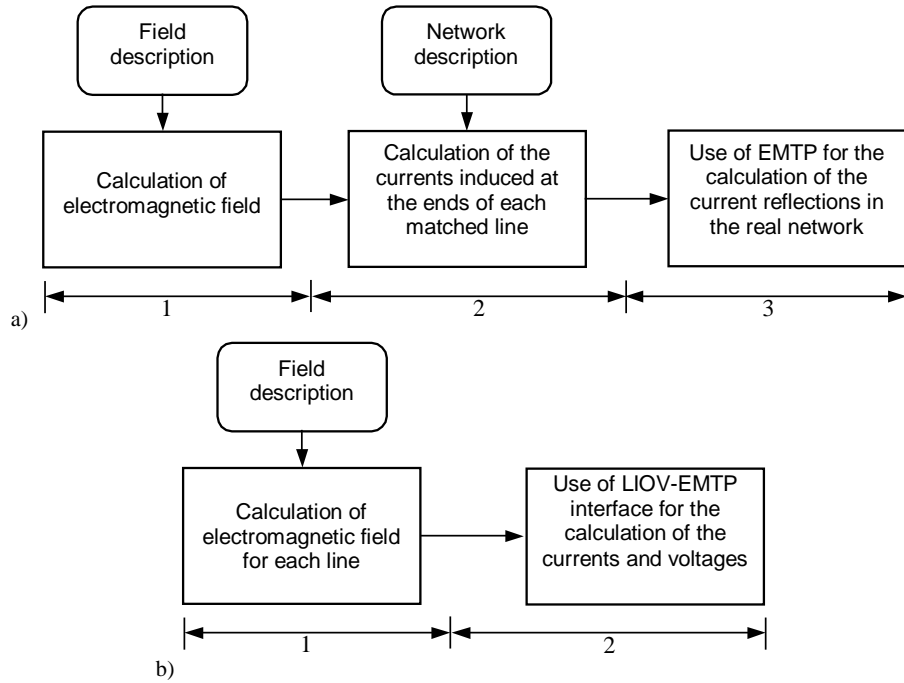


Fig. 1 Presentation of the method of calculation of the field-to-network coupling: a) Eiffel code, b) LIOV_EMTPM39 code

3. EXPERIMENTAL VALIDATION

For the experimental validation of time domain codes for the analysis of transient field coupling to transmission line networks an experimental network (see Fig. 2) illuminated by the Swiss Defence Procurement Agency EMP simulator (VERIFY) was used. The network is actually represents a simple model for a car cable harness (see companion paper [7]), flattened on the ground plane.

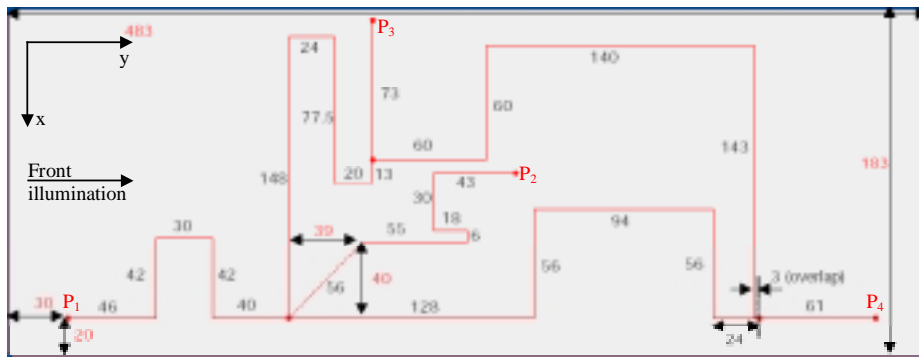


Fig. 2. Experimental network on ground plane (drawing to scale, all dimensions in cm) for EMP measurements and simulations.

The wire used to construct the harness has a stranded multiconductor core with an insulating sheath. The diameter of the conductor for the wire is approximately 1 mm, while that for the insulation is 2.5 mm. The height of the wire over the ground plane was 20 mm. VERIFY generates a vertically polarized electric field with a rise time of 0.9 ns and a FWHM of 24 ns. The E-field amplitude is about 60 kV/m.

The harness was terminated in different ways (open circuit, short circuit, terminated with nominal 50Ω loads).

Fig. 3 presents comparisons between experimental data and the computation for different load configurations. It can be seen that the numerical simulations are in good agreement with measurements.

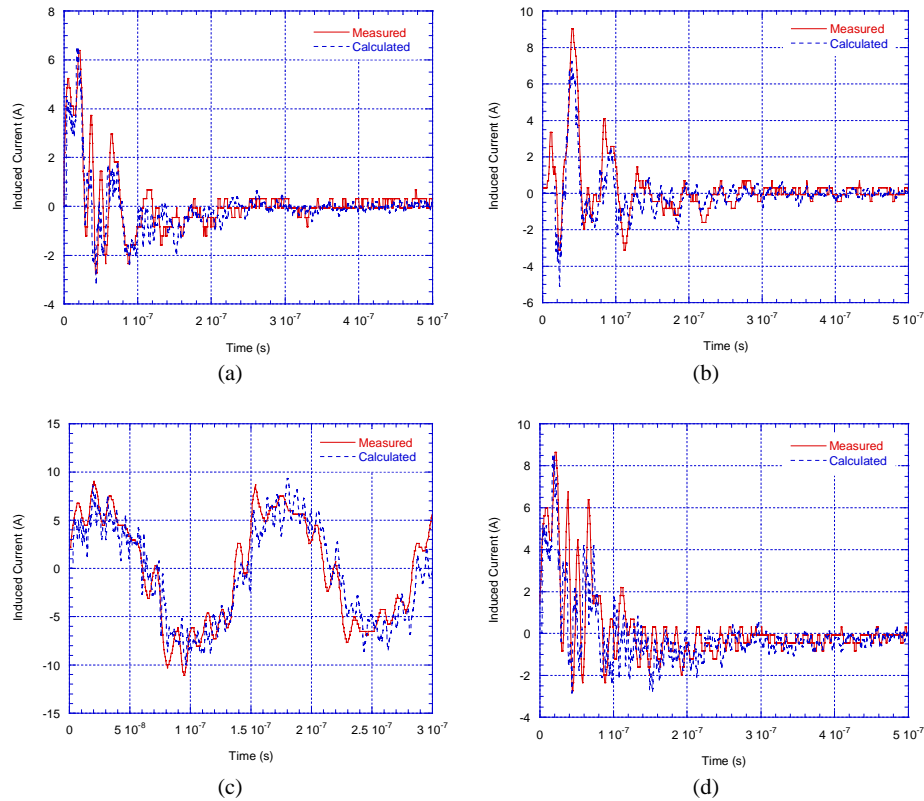


Fig. 3. Induced current for different load conditions. Comparison between calculations and measurements.

- (a) Induced current in P1 (P1, P2, P3, P4 = 50Ω)
- (b) Induced current in P4 (P1, P2, P3, P4 = 50Ω)
- (c) Induced current in P1 (P1 = short-circuited; P2, P3, P4 = open circuit)
- (d) Induced current in P1 (P1 = short-circuited; P2, P3, P4 = 50Ω)

4. CONCLUSION

Time-domain computer codes simulating the interaction of an external electromagnetic field with a complex electrical network were presented. The codes are interfaced with EMTP, allowing the use of a wide range of existing models for electrical components. Numerical simulations were compared with experimental results obtained by means of an experimental network illuminated by the Swiss Defence Procurement Agency EMP simulator (*VERIFY*) and a very good agreement was found.

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