SIMULATION OF WAVE PROPAGATION ON ELECTRIC LINES

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An interactive integrated package for the simulation of wave propagation on electric lines, operating under Scilab, is presented. The package is designed as an educational tool to be used as a laboratory application to specialized courses.

INTRODUCTION

The explosive development of communication made this area a subject of increased interest in the large electric engineering community. It also imposed an increased interest in improved educational methods and techniques targeted on electrical engineering students, dealing with such matters. Along with a good courseware, laboratory applications are an extremely useful educational tool, and the development of such educational material is very important.

In the framework of a developing educational curriculum, the design of a computer supported educational package for communication related disciplines is to be associated with an adequate computational package. The Scilab programming medium, which emulates at no cost the much more known Matlab package, was chosen for the development of an integrated interactive educational program for the simulation of wave propagation on electric lines [1].

SCOPE OF THE PROGRAMME

A two–conductor transmission line is considered as illustrative for the propagation of voltage and current waves as the simplest case of wave propagation [2,3,4,5,6]. Distracting aspects related to nonuniformity and nonlinearity are avoided, and the propagation is illustrated by use of an animation program supported by the Scilab package [7,8].

The propagation phenomena on a transmission line are strongly influenced by the propagation characteristics of the line. Three common cases of transmission lines – coaxial, parallel wire, and plane–parallel lines – are therefore considered, for which the propagation parameters are computed [9,10], depending on the constitutive parameters of the employed materials and the geometric structure of the line.

Phenomena associated with conditions at the limit, i.e., at the line ends, are approached as well. The essential phenomenon of wave reflection on an unmatched line load is illustrated by the example of the simplest voltage/current step wave incident at the load end of the line. For the sake of simplicity, the load is taken as a circuit of order zero or one, with the possibility of choosing the values of the lumped parameters of the load. A similar approach is taken for the illustration of the reflection/transmission phenomena at the connecting point of two transmission lines. Apart from the choice of different propagation parameters of the connected lines, the connection has to account for the presence of parasitic series or parallel connected circuits of order zero or one at the junction.

The propagation is simulated in the approximation of a lossless transmission line as the simplest case where distortion is eliminated and the evolution of the propagating wave is easily observed. In fact, operation above a sufficiently large frequency is supposed, so that Joule's losses can be neglected for adequately short transmission lines.

Finally, the very idea of direct and inverse waves propagating along a transmission line from a starting point is illustrated by the preliminary presentation of such direct and inverse components at the load end, which are afterward identified in the evolution of the voltage/current along the line.

STRUCTURE OF THE PROGRAMME

The programme is structured as an interactive package with choices offered to the user regarding the conditions of simulations and the visualisation of the voltage/current wave propagation, as suggested below :

0. *Choice of problem* :
reflection at line load end;
reflection/transmission at line junction;

1. *Choice of transmission line with choice of geometry and constitutive parameters* :
plane–parallel / conductor thickness, conductor width, distance between conductors;
coaxial / radius of internal conductor, inner and outer radii of external conductor;
two–conductor / conductor radius, distance between conductors;
Constitutive parameters: insulator permittivity, permeability, conductivity / conductor permeability, resistivity;

NOTE 1 : The choice is repeated for each line in the case of a reflection/transmission problem ;

NOTE 2 : The option of preset values is also offered ;

2. *Choice of operating frequency* ;

NOTE : The option of a preset value is also offered ;

3. *Display* of : values of line parameters on unit length, check of lossless operating condition $(\omega L_l/R_l >> 1\ ,\ \omega C_l/G_l >> 1)$, values of line propagation parameters (characteristic impedance and propagation velocity);

4. *Choice of load with choice of characteristic values for components* :
one lumped element / $R\ \langle\Omega\rangle$, $L\ \langle\mu\mathrm{H}\rangle$, $C\ \langle\mathrm{pF}\rangle$;
two lumped elements / series *RL* , parallel *RL* $\langle\Omega/\mu\mathrm{F}\rangle$, series *RC* , parallel *RC* $\langle\Omega/\mathrm{pF}\rangle$;

NOTE : The option of preset values is also offered ;

5. *Display* of: time constant and amplitude of the step voltage wave ;

6. *Choice of maximum duration of the propagation simulation* (maximum 5 time constants) ;

7. *Display* of inverse voltage / current wave at the load (reflection problem) ;
Display of inverse voltage / current wave at the junction (reflection on first line) and display of direct voltage / current wave at the junction (transmission on second line) ;

8. *Animated display* of (total) voltage / current propagation on the line (reflection problem), as it is suggested in fig. 1 for reflection on a *RC* parallel load;
Animated display of (total) voltage / current propagation on both lines (reflection / transmission problem), as it is suggested in fig. 2 for a parallel *C* line connection.

The successive steps of the programme allow a discussion of different options and comments regarding the influence of line type, geometry and constitutive parameters on line and propagation parameters, or the influence of these last parameters in connection with the load type and parameters on the resulted waveforms. Such an interactive use of the programme facilitates the understanding of wave propagation on transmission lines.

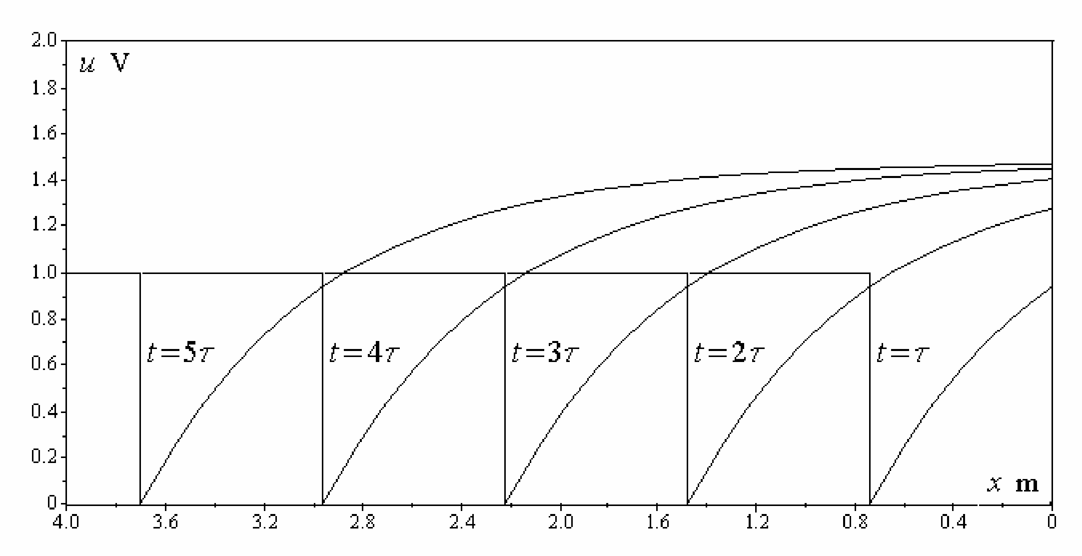

Fig. 1. Sample display for a reflection problem

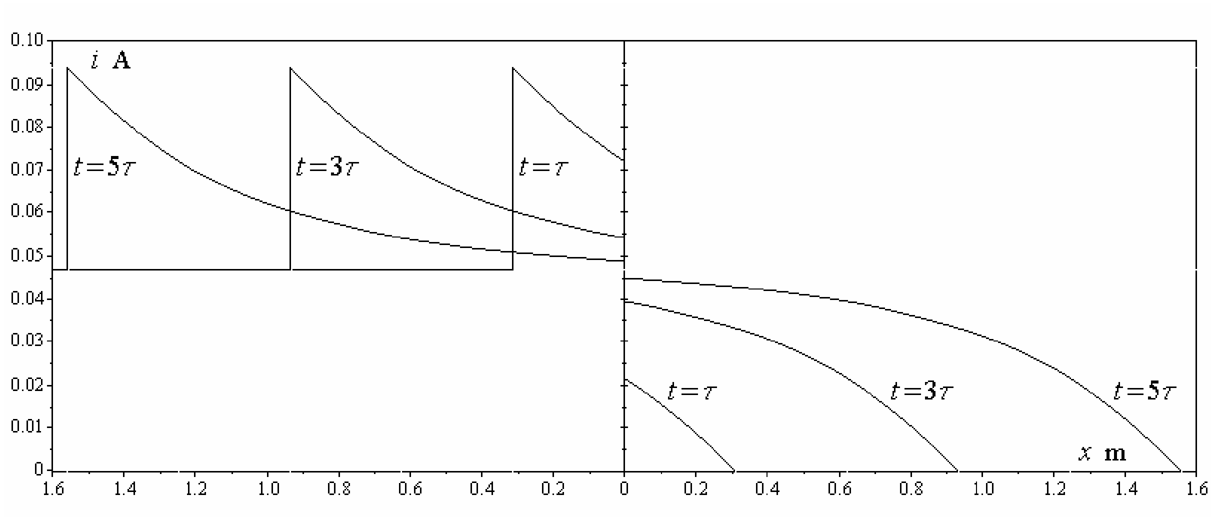

Fig. 2. Sample display for a reflection/transmission problem

CONCLUSIONS

A general programme was constructed for the simulation of voltage/current wave propagation on transmission lines, to be used as a laboratory educational material. The package is supported by a Scilab programming medium, which has the advantage of a great versatility and free downloading from the Internet.

The programme allows multiple choices – and accompanying discussion and comments – regarding wave reflection at the load end or wave reflection/transmission at the junction between two lines in connection with line type, geometry, constitutive and operating parameters, load/junction configuration and characteristic values of components, visualisation of voltage or current waves at the load/junction, and it offers visualisation of animated wave propagation along the line(s). The simulation package is thus a very useful educational tool to be used in laboratory applications for specialized disciplines.

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