# Application of Singularity Expansion Method (SEM) to Long Transmission Lines

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***Abstract*—This work deals with the calculation of the first layer SEM poles of a long finite transmission line above a conducting ground excited by high frequency electromagnetic fields. This set of poles yields the main contribution to the susceptibility of the transmission line to external excitations. For canonical cases of an open-circuit wire and a horizontal wire short-circuited by vertical risers, SEM poles are obtained in explicit form. The comparison of the results of the SEM approach with those of numerical simulation gives a good agreement.**

***Keywords- SEM; transmission lines; time domain; pulse response***

## I. Introduction

Transmission lines play an important role in EMC. They serve for the transmission of desired signals between electronic devices of different kinds. On the other hand, they can be subject to different kinds of electromagnetic interferences. Induced overvoltages are often the reason for the failure of electronic devices. Different numerical methods (such as MoM, FDTD, etc.) can be adopted to calculate induced currents and voltages but they are not very helpful to gain insight into the physics of the coupling phenomena, especially when they are calculated in time domain.

In contrast, the analytical Singularity Expansion Method (SEM) [1] represents the scattering object as a set of oscillators, helpful to understand the underlying physics of the coupling phenomena, both, in the frequency domain and in the time domain. Recently, this method has attracted an increased interest [2, 3] in connection with the definition of the complex eigen frequencies of a finite straight wire for target identification.

In a recent paper [4], SEM was applied to the analysis of loaded transmission lines above a conducting ground, using classical Transmission Line (TL) theory. In particular, it was shown that as a result of the action of a finite sinus-like pulse, transients in the system can greatly exceed the steady-state oscillations, and this effect can cause failures of the electronic components in the early stages of such an exposure. Of course, TL approximation does not describe radiation effects, which can be important for high frequencies, when the wavelength is comparable with the height of the line.

## II. Description of obtained results

In this work, we consider a long loaded line above a perfect conducting ground with arbitrary terminals illuminated by an incident high frequency plane wave [5, 6]. To obtain the frequency domain solution for the induced current in the main, central part of the wire, the co-called asymptotic approach [7] is used. The zeros of the denominator of this expression yield the SEM poles of the first layer. This set of poles yields the main contribution to the susceptibility of the transmission line to an external pulse excitation in time domain. Furthermore, SEM poles are obtained in an explicit form for two canonical cases: (i) an open-circuit wire, and (ii) a horizontal wire short-circuited by vertical risers. The obtained results using the proposed SEM approach are compared with those obtained using NEC (Numerical Electromagnetics Code) simulations and a good agreement is found.

Using the SEM poles, the time response function can be expressed in an explicit form, which has shown to be in good agreement with the results of numerical simulations obtained by an inverse Fourier transformation of NEC results. Two interesting physical effects were observed: radiation damping of the induced current and the domination of transient oscillation for a high-frequency sinusoidal excitation.

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