Using COMSOL to Solve for Currents along a Thin-Wire Antenna Excited by a Lumped Source

A. Shoory[1], A. Smorgonskiy[1], and F. Vega[1]
[1]Swiss Federal Institute of technology, Lausanne (EPFL)
*Corresponding author: EPFL-SCI-STI-FR, Station 11, 1015 Lausanne, Switzerland, Email: abdolhamid.shoory@epfl.ch

Abstract: In this paper, we will present simulation results obtained using COMSOL RF module for the current along a wire antenna in both frequency and time domains. The structure is excited through a lumped (voltage or current) source at its center. For the frequency domain simulations we compare the results with the Numerical Electromagnetics Code (NEC-4) and for the time domain results we compare them with the prediction of the thin wire time domain (TWTD) code. Both codes are based on the method of moments (MoM) solutions of the governing electric field integral equation (EFIE). It will be shown that excellent agreement is found between current distributions along the wire antenna obtained using COMSOL in the frequency domain with NEC and in the time domain with TWTD. We will further discuss the effect of different excitation sources and some numerical issues necessary in COMSOL for obtaining the expected results. The objective of this paper is essentially to show the importance of such calibration mechanisms in order to be able to trust the results for more complicated structures.

Keywords: thin-wire, electric field integral equation (EFIE), method of moments (MoM), finite element method (FEM), current distribution.

1. Introduction

Accurate evaluation of currents along thin wire structures in both frequency and time domains plays an important role in lightning transient studies [1-5]. Significance of such a problem is revealed when we notice that characteristics of currents propagating along e.g., towers struck by lightning and along the lightning channel from both attenuation and dispersion points of view can affect considerably near and far electromagnetic fields [6]. Especially, for conical structures, it has been shown that while current pulses does not attenuate while propagating form cone apex to its base, they suffer significant attenuation in the reverse direction [3, 5]. It was further revealed that the definition of the source can affect current propagating waves even for the sources which are electromagnetically equivalent. In an effort to make these issues clear, this paper reports on the simulations carried out using COMSOL Multiphysics RF module. We compare the results with other softwares based on other techniques and we will show that by choosing appropriate conditions for simulation environment one can obtain similar results for standard cases. The objective of this paper is therefore, to show that before handling any simulation it is worthy to calibrate them using other techniques to make sure that the results are reliable e.g., from the definition of the source point of view.

2. Description of the Problem

The 2D geometry of the problem is shown in Fig. 1. It is a wire antenna of radius *a* and length *L*. The length of source region is *dL*. We aim at obtaining current distribution along the antenna in the frequency domain due to a voltage source at different frequencies and in the time domain due to a current source at different heights along the antenna.

3. Frequency Domain Simulations

According to Fig. 1, consider a dipole antenna of length L = 0.47 m and radius a = 0.005 m. The antenna is excited through a voltage source of 1000 V amplitude at its center. The magnitude of the induced current distribution along the wire for frequencies of f = 150 MHz, f = 300 MHz, and f = 600 MHz are shown in Fig. 2. In simulations using COMSOL a 2D axially symmetric problem is used. Simulation domain is truncated using scattering boundary conditions and the thin wire is represented using perfectly conducting surfaces.

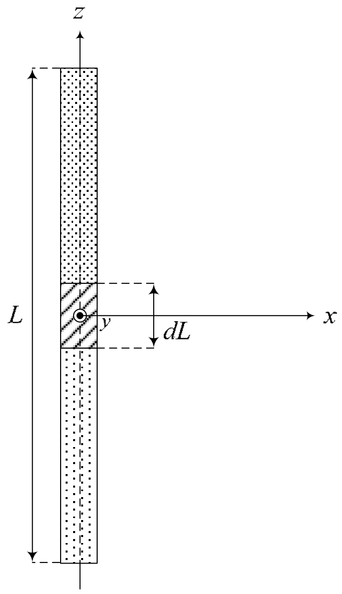

Fig. 1 Schematic of a dipole antenna of length L and radius a in free space (a = 0.005 m).

In the frequency domain solution using the COMSOL 2D axial symmetry module, we used the electric field on a boundary as the source. The current is obtained as $2\pi a H_\varphi$ where H_φ is the circumferential component of the magnetic field on wire surface. The length of excitation segment in COMSOL is assumed to be dL = 0.006 m.

Along with the curves obtained using COMSOL, we have included the curves obtained using Numerical Electromagnetic Code (NEC-4) [7] for comparison. It solves the electric field integral equations (EFIE) in the frequency domain using the method of moments (MoM) [8]. For the simulation using NEC we used 79 segments and the delta-gap voltage source excitation at wire center. With this number of segments, NEC provides a convergent behavior based on the number of segments along the wire.

It is seen that both softwares predict almost the same results. The differences in the curves of COMSOL and NEC are related to the different definition of the source implemented in NEC and COMSOL. It is therefore clear that source definition is a critical issue especially when currents along the structure are concerned. Considerable differences in the whole wire length in Fig. 2 (b) is however due to the resonant behavior of the half-wavelength at f = 300 MHz

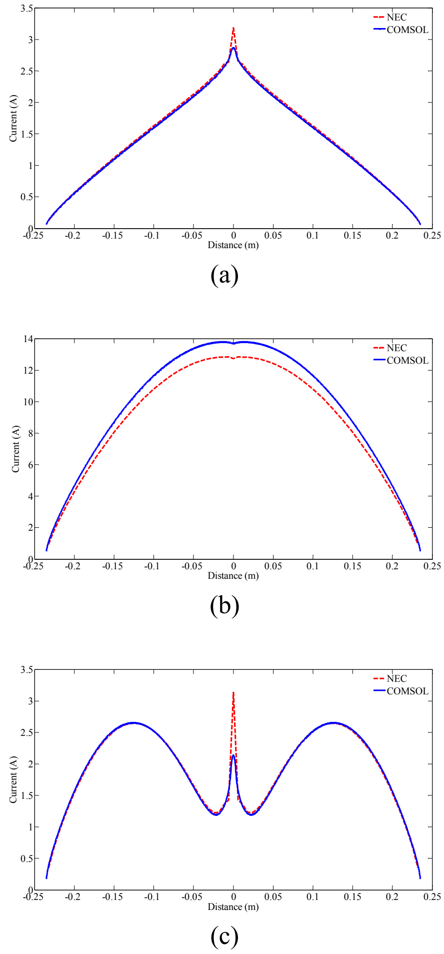

Fig. 2 The magnitude of the induced current along the wire obtained using COMSOL and NEC (a) f = 150 MHz, (b) f = 300 MHz, and (c) f = 600 MHz.

4. Time Domain Simulations

Let's consider a dipole antenna of length L = 30 m and radius a = 0.005 m as shown in Fig. 1 for time domain simulations. We assume that the antenna is excited through a current source at it its center using a Gaussian shape transient current given by

$$i(0,t) = A_m e^{-\pi^2 f_0^2 (t-T)^2} \quad (1)$$

where A_m = 4, f_0 = 50 MHz, and T = 20 ns.

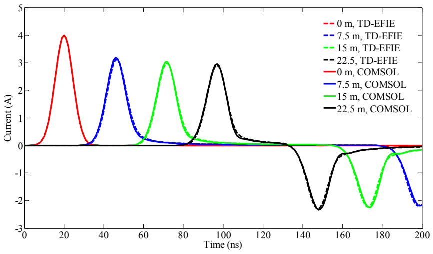

Fig. 3 Current distributions at different heights along the wire antenna obtained using TD-EFIE and COMSOL.

The spatial-temporal revolutions of the currents at different heights along the antenna are shown in Fig. 3. Also shown in this figure are the curves obtained using the MoM solution of the time domain electric field integral equation (TD-EFIE). As it is seen in this figure, the agreement between the predictions of the two codes is very well.

For the simulation of this part using the COMSOL we used the surface current excitation of length dL = 0.006 m (see Fig. 1) at the antenna center available in the 2D-axial symmetry module. The currents at different points along the antenna are obtained again as $2\pi a H_\varphi$. The time stepping of the solver is assumed to be dt = 1 ns. The Courant–Friedrichs–Lewy (CFL) condition [9] was chosen to be 0.2 with $N = 4$ number of elements at each wavelength ($dt = \mathrm{CFL}\times dh/c$) where dh is the element maximum length in COMSOL and c is the speed of light in free space. For the simulations using the TD-EFIE code we used 300 number of segments and time step is assumed to be $dt = 1$ ns.

5. Conclusions

We reported the simulation results for current along wire antennas in free space in both and frequency domains obtained using COMSOL RF Module. The results in the frequency domain were compared with NEC and in the time domain with the TD-EFIE code. It was shown that, using the same simulations parameters in the frequency domain between COMSOL and NEC, there are some differences between the predictions of the two techniques. The discrepancies were related to the definition of the source in the two softwares and also to the resonant behavior of the simulated structure. The results in the time domain obtained using COMSOL have however shown excellent agreement with the TD-EFIE technique.

6. References

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