

Time-Domain Scattering Analysis Using the Method of Auxiliary Sources (MAS) for Cylindrical Objects with Finite Conductivity

Minas Kouroublakis⁽¹⁾, Nikolaos L. Tsitsas⁽¹⁾, and Yehuda Leviatan⁽²⁾

⁽¹⁾ School of Informatics, Aristotle University of Thessaloniki, Thessaloniki, Greece

⁽²⁾ Department of Electrical and Computer Engineering, Technion, Haifa, Israel

Time-domain electromagnetic (EM) simulations are critical for studying transient wave interactions in applications such as radar, wireless communications, and materials characterization. This work develops a computational framework leveraging the Method of Auxiliary Sources (MAS), also known as Source Model Technique (SMT), to model the time-domain scattering of transient electromagnetic waves by cylindrical objects with finite conductivity. The proposed solution, shown in Fig. 1a, adapts the frequency-domain MAS, known for its efficiency in time-harmonic wave scattering analysis, to enable direct time-domain analysis of transient scattering. Following the scheme in (A. Ludwig and Y. Leviatan, “Towards a Stable Two-Dimensional Time-Domain Source-Model Solution by Use of a Combined Source Formulation,” *IEEE Transactions on Antennas and Propagation*, vol. 54, no. 10, pp. 3010-3021, Oct. 2006), the scatterer is replaced by a discrete set of spatially impulsive filamentary sources with time-dependent electric currents, located on a mathematical surface inside the cylinder. These sources radiate in free space, and their analytically known fields represent the transient scattered field outside the cylinder. The temporal behavior of the currents is expressed using pulse expansion functions with unknown amplitudes, which are determined by enforcing the Standard Impedance Boundary Condition (SIBC) at specific time instances and testing points on the cylinder’s surface. The SIBC is expressed by

$$\mathbf{E}_{\text{tan}}(\rho, t) = \int_0^t z(t - \tau) [\hat{\mathbf{n}} \times \mathbf{H}_{\text{tan}}(\rho, \tau)] d\tau, \quad (1)$$

where $z(t)$ is the inverse Fourier transform of the frequency-dependent surface impedance Z_s , $\mathbf{E}_{\text{tan}}$ is the total (incident plus scattered) tangential electric field on the boundary, and $\mathbf{H}_{\text{tan}}$ is the total tangential magnetic field on the boundary.

Key results include transient scattering patterns for cylinders with high conductivity ($\sigma \gg \omega\epsilon$) and intermediate conductivity materials such as semiconductors e.g., germanium (Ge) with $\sigma = 2.224 \text{ S/m}$, $\epsilon_r = 16$. Comparisons between materials with finite conductivity and perfect electric conductors (PEC) reveal notable differences, underscoring the impact of material properties on transient scattering. The results have been validated using those obtained from an analytic frequency-domain solver combined with an Inverse Fast Fourier Transform, demonstrating excellent agreement as shown in Fig. 1b.

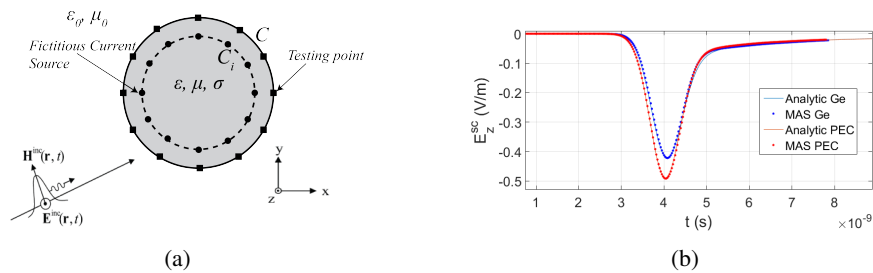


Figure 1: (a) The MAS equivalence for the case of a transient plane wave with Gaussian temporal variation impinging on a conductive cylindrical object. (b) The electric field backscattered by a cylinder composed by germanium (Ge). The field scattered by a PEC cylinder is also shown for comparison.