



A time-domain method of auxiliary sources for efficient analysis of transient electromagnetic scattering by moderately conductive cylinders

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ABSTRACT

This paper presents a time-domain implementation of the Method of Auxiliary Sources (MAS) combined with the Standard Impedance Boundary Condition (SIBC) for electromagnetic scattering problems involving cylindrical scatterers with finite but moderate conductivity. The proposed approach focuses on solving the two-dimensional problem using a first-order SIBC, which is valid when the conductivity is sufficiently higher than the maximum spectral frequency times the dielectric permittivity of the scatterer. This regime includes moderately conductive materials — such as carbon-based composites, conductive polymers, and doped dielectrics — that are increasingly used in real-world radio-frequency applications, including wearable electronics, electromagnetic interference shielding, and biomedical sensors. Under the above validity conditions, the interaction between the incident wave and the scatterer is dominated by surface effects, allowing for an efficient and accurate modeling strategy without the need to compute internal fields. The theoretical formulation of the time-domain MAS-SIBC method is developed, followed by extensive numerical testing on various geometries whose cross section is a closed curve. Such geometries include circular, elliptical, super-circular, rounded-triangular, and inverted-elliptical scatterers. A planar geometry is also tested. All results are validated against analytical solutions and commercial frequency-domain solvers, demonstrating the accuracy and practical potential of the proposed method. The findings suggest that time-domain MAS-SIBC offers a promising and computationally efficient approach for modeling scattering from materials even with moderate conductivity.

1. Introduction

Time-domain electromagnetic scattering has become increasingly important thanks to its wide range of applications, spanning from radars [1,2], geophysical exploration [3,4], and non-destructive testing [5] to electromagnetic shielding studies [6,7] and biomedical imaging [8]. Unlike frequency-domain approaches, which focus on how a system responds at specific frequencies, time-domain methods use short electromagnetic pulses to probe a much broader range of frequencies at once. The width of the temporal pulse determines how wide this frequency range is—the shorter the pulse, the broader the spectrum it covers. This ability to capture rich, broadband information makes time-domain techniques a powerful tool for studying complex materials and structures, detecting hidden objects, exploring the subsurface, and ensuring electronic systems perform reliably in fast-changing environments.

Several numerical methods have been developed over the years to tackle time-domain electromagnetic scattering problems [9]. Among

them, the Finite-Difference Time-Domain (FDTD) method is by far the most widely used, thanks to its flexibility and straightforward implementation [10,11]. A Time Domain-Finite Element Method (TD-FEM) has also been implemented and used in commercial software such as COMSOL Multiphysics [12]. Galerkin time domain methods have been developed through the years [13,14]. Surface- and volume-integral-equation based methods are other popular choices [15,16]. All these techniques rely on meshing either the volume or the surface of the scatterer. On the other hand, the Method of Auxiliary Sources (MAS) [17], also known as the Method of Fundamental Solutions (MFS) [18–20], and the Source Model Technique (SMT) [21,22], offers a meshless alternative together with other methods [23] related to the Generalized Multipole Technique [24]. MAS has already shown solid results in certain time domain two-dimensional scattering problems [25–28] and is considered a promising approach for more complex scenarios, due to its efficiency and potential to handle intricate geometries without the need for traditional meshing.

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