Electromagnetic Scattering Analysis Using a Model of Dipoles Located in Complex Space

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Abstract—Fictitious current-models have been applied extensively in recent years to a variety of time-harmonic electromagnetic wave scattering problems. This paper is introducing an extension of the current-model technique which facilitates the solution to problems subsuming metallic scatterers whose periphery contains a variety of length-scales features. This extension is in tune with the current-model technique philosophy of using simple current sources the fields of which are analytically derivable. It amounts to letting the coordinates of part of the source centers assume complex values. Positioned in complex space, the simple current sources radiate beam-type fields which are more localized and are better approximations of the scattering by the smooth expanses of the structure. The coordinates of the other source centers can retain their conventional real values or have only a relatively small imaginary constituent. These latter current sources are used to approximate the fields in the vicinity of the more rapidly varying regions of the structure. The new approach is applied to analyze electromagnetic scattering by a perfectly conducting oblate spheroid. It is found to render the solution computationally more effective at the expense of only a slight increase in its complexity.

I. INTRODUCTION

In recent years, the use of models of fictitious currents has proven to be an efficient computational technique for analyzing a variety of three-dimensional time-harmonic electromagnetic scattering problems [1], [2]. Such as in the related generalized multipole technique (GMT) [3], [4], the problem in the current-model technique is formulated not in terms of equivalent current distributions applying standard formulations, but in terms of fictitious simple sources—simple in the sense that their fields are analytically derivable in the region of interest. This kind of approach offers a few attractive features. First, the intensive field calculations involved are made simple by avoiding surface integrations. Second, the freedom in the choice of source locations permits fitting of the actual fields on the boundaries as per requirement by means of smooth field functions. Third, the inaccuracies in the approximate boundary field tend to be globally correlated, and an application of the boundary conditions in the simple point-matching sense is sufficient. In the current-model solution presented in [1], the simple sources are Hertzian dipoles located on suitably chosen mathematical surfaces which are displaced from the physical ones, while in the various GMT solutions discussed in [4] these sources are multipoles centered at multiple origins. In some other current-model solutions there have been preferences for other sources. Specifically, in the case of periodic structures, spatially diffused sources with analytically derivable fields have been used [5], [6].

This paper takes a step forward in extending the current-model technique to handle problems of electromagnetic scattering by objects that contain a variety of length-scales ranging from a subwavelength to several wavelengths. To solve problems of this kind, one can of course combine the current-model technique with other numerical and asymptotic methods to form a hybrid method which possesses the required flexibility. In such a hybrid method, the effect of the rapidly changing small-scale features can be accounted for by using the current-model technique, while the smoothly varying large-scale features can be analyzed by a high-frequency asymptotic technique such as the geometrical theory of diffraction. However, in this paper we further investigate the more promising way of accommodating large-scale variations, which has been applied recently by the authors to analyze three-dimensional acoustic [7] and electromagnetic [8] wave scattering by a structure comprising two adjacent spheres of different size. The basic principle is in tune with the current-model technique’s general idea of using simple sources the fields of which are analytically derivable. It amounts to letting the originally real coordinates of some of the source centers be analytically continued to complex values [9]–[11]. A similar approach has also been applied successfully in a GMT solution with the multipole sources assuming multiple origins in complex space [12]. Positioned in complex space, the simple current sources produce in the real space beam-type fields that are nearly Gaussian but have equivalent aperture distributions of finite extent. Hence, these fields can more effectively approximate the scattering from the smooth expanses of the object rendering the solution accurate with a reasonable number of unknowns. Note that although the concept of complex source points has been known for some time, the idea advocated in our works is new. In the earlier works with complex sources the emphasis was put on obtaining approximate representations for the complex source fields in terms of Gaussian beams, while in our works we use the exact fields of the complex sources as basis functions for expanding the scattered field, taking a clue on the way of choosing the coordinates of the complex sources from the earlier studies. The centers of the other current sources can be at real coordinates or have only a relatively small imaginary constituent, and the fields of these sources can be used to approximate the electromagnetic field.

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