

Article

Contraction Integral Equation for Three-Dimensional Electromagnetic Inverse Scattering Problems

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Abstract: Inverse scattering problems (ISPs) stand at the center of many important imaging applications, such as geophysical explorations, industrial non-destructive testing, bio-medical imaging, etc. Recently, a new type of contraction integral equation for inversion (CIE-I) has been proposed to tackle the two-dimensional electromagnetic ISPs, in which the usually employed Lippmann–Schwinger integral equation (LSIE) is transformed into a new form with a modified medium contrast via a contraction mapping. With the CIE-I, the multiple scattering effects, i.e., the physical reason for the nonlinearity in the ISPs, is substantially suppressed in estimating the modified contrast, without compromising physical modeling. In this paper, we firstly propose to implement this new CIE-I for the three-dimensional ISPs. With the help of the FFT type twofold subspace-based optimization method (TSOM), when handling the highly nonlinear problems with strong scatterers, those with higher contrast and/or larger dimensions (in terms of wavelengths), the performance of the inversions with CIE-I is much better than the ones with the LSIE, wherein inversions usually converge to local minima that may be far away from the solution. In addition, when handling the moderate scatterers (those the LSIE modeling can still handle), the convergence speed of the proposed method with CIE-I is much faster than the one with the LSIE. Secondly, we propose to relax the contraction mapping condition, i.e., different contraction mappings are used in updating contrast sources and contrast, and we find that the convergence can be further accelerated. Several numerical tests illustrate the aforementioned interests.

Keywords: inverse scattering; nonlinear problem; contraction integral equation for inversion (CIE-I); imaging

1. Introduction

Inverse scattering problems (ISPs) in electromagnetics and acoustics are of great interest in industries due to important imaging applications in various areas, such as geophysical survey, non-destructive testing, ground-penetrating radar, bio-medical imaging, etc., as solving the ISPs provides rich information about the unknown targets, such as locations, shapes, and material distributions within some structures [1–4]. For instance, microwave imaging has been used to inspect the abnormalities in human bodies like bleeding in the head and tumours in breasts. On the other hand, they are also quite important due to the representative difficulties in solving a large group of inverse problems concerning waves and fields, and thus researchers in mathematics, physics, and engineering societies have devoted great efforts to improving efficiencies and accuracies of the numerical solvers [5]. As shown in Figure 1, solving ISPs is to determine the unknown scatterers within a domain, when the domain is illuminated by several different incidences and we can measure

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