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Original article

Residual correction techniques for the efficient solution of inverse scattering problems

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Abstract

We consider the scattering of time-harmonic electromagnetic waves by penetrable inhomogeneous obstacles. In particular, we study the numerical solution of an inverse scattering problem, where the refractive index of the obstacle is computed from some knowledge of the scattered waves, generated by the obstacle itself, and known incident waves. This problem can be formulated by a pair of non-linear integral equations, and its numerical solution is usually a time-consuming computation. We propose an efficient solution of this problem by taking into account a linearization of the integral equation under consideration. The proposed method is tested by a numerical experiment, where the inverse scattering problem is numerically solved for different obstacles.

1991 MSC: 65R32; 65R20; 78A46

Keywords: Numerical approximation; Integral equation; Inverse scattering

1. Introduction

We introduce the notation. Let $\mathbb{R}$, $\mathbb{C}$ be the set of real numbers, and complex numbers, respectively. Let $\mathbb{R}^N$, $\mathbb{C}^N$ be the N-dimensional real Euclidean space, and the N-dimensional complex Euclidean space, respectively. Let $\underline{x}, \underline{y} \in \mathbb{R}^N$, we denote with $\underline{x}^\top \cdot \underline{y}$ the Euclidean scalar product of $\underline{x}$ and $\underline{y}$, the superscript $\top$ means transposed, and $||\underline{x}||$ denotes the Euclidean norm of $\underline{x}$. Let $\mathbb{S} = \{\underline{x} \in \mathbb{R}^2 : \ ||\underline{x}|| = 1\}$. Let $z \in \mathbb{C}$, we denote with $\bar{z}$ the complex conjugate of z, with $Re(z)$, $Im(z)$ the real and the imaginary part of z respectively. We denote with $\imath$ the imaginary unit. We denote with $\mathbb{C}^{M\times N}$ the space of complex matrices having M rows and N columns.

We consider a two-dimensional inhomogeneous isotropic medium. The inhomogeneity of the medium is contained in a compact set $D \subset \mathbb{R}^2$. Let $n : \mathbb{R}^2 \to \mathbb{C}$ be the refractive index of the medium, so that $n(\underline{x}) = 1$ for $\underline{x} \in \mathbb{R}^2 \setminus D$, and $Re(n(\underline{x})) \geq 1$, $Im(n(\underline{x})) \geq 0$ for $\underline{x} \in D$.

We consider an electromagnetic wave propagating on this medium. We suppose that this is a time-harmonic plane wave, so that the space-variables dependent part is given by

$$u^i(\underline{x}, \underline{d}, k) = e^{\imath k \underline{d}^\top \cdot \underline{x}}, \ \underline{x} \in \mathbb{R}^2, \tag{1}$$

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