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Improvement of direct sampling method in transverse electric polarization

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Abstract

Recently, the mathematical structure of the direct sampling method (DSM) was investigated in transverse-electric (TE) polarization, and the reason why the exact locations of small inhomogeneities cannot be retrieved through traditional DSM has been revealed. In this paper, we present an improved DSM for identifying the exact locations of small inhomogeneities in TE polarization. Furthermore, we investigate a multi-frequency indicator function to obtain a better result. Corresponding mathematical analysis and simulations are performed to show the feasibilities of the proposed improvement techniques.

Key words: Direct sampling method, Transverse Electric (TE) polarization, Bessel function, Simulation results

1. Introduction

Identifying the locations or shapes of unknown targets from a set of measured scattered fields or far-field patterns is an important and interesting inverse scattering problem; this problem arises in physics, engineering, medical imaging, non-destructive evaluation, and in applied mathematics, and it is highly related to many issues in modern human life [1, 2, 3, 4, 5, 6, 7]. In order to solve this problem, various reconstruction techniques have been developed. These include a Newton-type iterative scheme [8, 9, 10], a level-set method [11, 12, 13], MUltiple Signal Classification (MUSIC) algorithm [14, 15, 16], subspace migration [17, 18, 19], topological derivatives [20, 21, 22], and linear-sampling method [23, 24, 25]. A number of studies have confirmed the robustness and effectiveness of these techniques; however, these techniques still require a significant amount of incident-field and corresponding scattered-field (or far-field-pattern) data to guarantee a good reconstruction.

The direct sampling method (DSM) is a promising technique for identifying inhomogeneities from a set of measured data in various inverse problems [26, 27, 28, 29, 30, 31, 32]. In contrast to the previous techniques, incident-field data with one or a small number of propagation directions is needed to perform DSM. Nevertheless, DSM is very stable, effective, and computationally cheap. However, most research on DSM has focused on transverse-magnetic (TM) polarization-detection of targets whose permittivities differ from that of the background. Concerning transverse-electric (TE) polarization, little research has been performed. Recently, DSM in TE polarization has been considered, and the mathematical structure of the indicator function of DSM has been explored by determining a relationship with the Bessel function of order one [33]. This relationship reveals that the exact locations of inhomogeneities cannot be retrieved through traditional DSM in TE polarization; therefore, an improved DSM is needed to identify exact locations.

In this study, we design an alternative DSM by modifying traditional indicator functions to identify the exact locations of small inhomogeneities in TE polarization. By constructing a relationship with the Bessel function of order zero, we investigate as to how the exact locations of inhomogeneities can be identified via the designed DSM. Furthermore, to obtain a better imaging/detection performance, we design a multi-frequency DSM and form a relation between Bessel and Struve functions of integer order. This is based

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