NEAR-FIELD AND FAR-FIELD IMAGE RECONSTRUCTION FOR AN IMPERFECTLY CONDUCTING CYLINDER

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ABSTRACT

Comparison of image reconstruction by using near-field and far-field data for an imperfectly conducting cylinder is investigated. A conducting cylinder of unknown shape and conductivity scatters the incident wave in free space and the scattered near and far fields are measured. By using measured fields, the imaging problem is reformulated into an optimization problem and solved by the genetic algorithm. Numerical results show that the convergence speed and final reconstructed results by using near-field data are better than those obtained by using far-field data. Finally, it is worth noting that the present work provides not only comparative information but also quantitative information.

INTRODUCTION

The electromagnetic inverse scattering problem of conductors has been a subject of considerable importance in remote sensing and noninvasive measurement. In the past twenty years, many rigorous methods have been developed to solve the exact equation. However, inverse problem of this type are difficult to solve because they are ill-posed and nonlinear. As a result, many inverse problems are reformulated as optimization problems. General speaking, two main kinds of approaches have been developed. The first is based on gradient search approach such as the Newton-Kantorovitch method [1], [2], the Levenberg-Marguart algorithm [3]. Since these approaches apply the gradient search method to find the extreme of the cost function. This method is highly dependent on the initial guess and tends to get trapped in a local extreme. In contrast, the second approach is based on the genetic algorithm [4], [5]. The genetic algorithm is a well known algorithm that uses the stochastic random choice to search through a coding of a parameter space. Compared to gradient search optimization techniques, the genetic algorithm is less prone to convergence to a local minimum, which in turn renders it an ideal candidate for global optimization.

In this paper, comparison of image reconstruction by using near-field and far-field data for an imperfectly conducting cylinder is presented. The genetic algorithm is used to reconstruct the shape and conductivity of a scatterer.

THEORETICAL FORMULATION

Let us consider an imperfectly conducting cylinder with cross section described in polar coordinates in the xy plane by the equation $\rho = F(\theta)$ located in free space. An incident plane wave whose electric field vector is parallel to the z axis is illuminated upon the metallic cylinder. By using the induced current concept, the scattered field can be expressed as the integral of the two-dimensional Green functions multiply the induced surface current density, which is proportional to the normal derivative of the electric field on the conductor surface [2], [4]. Besides, for an imperfectly conducting scatterer with finite conductivity, the boundary condition can be approximated by assuming that the total tangential electric field on the scatterer surface is related to surface current density through a surface impedance [2]. As a result, for the direct problem, given the shape and the conductivity of the object, we can use the boundary condition to solve the surface current density, then calculate the scattered field by using the Green function. Let us consider the following inverse problem: given the scattered field, determine the shape and the conductivity of the object. The genetic algorithm is used to minimize the root mean square error of the measured scattered field and the calculated scattered field, through three genetic operators: reproduction, crossover and mutation. When the root mean square error changes by less than 1% in two successive generations, the genetic algorithm will be terminated and a solution is then obtained, i.e., the shape and the conductivity is obtained.

NUMERICAL RESULTS

By a numerical simulation we compare the image reconstruction by using near-field and far-field data. Let us consider an imperfectly conducting cylinder in free space and a plane wave of unit amplitude incident upon the object. The frequency of the incident wave is chosen to be 3 GHz. In our calculation three examples are considered. To reconstruct the shape and conductivity of the cylinder, the object is illuminated by four incident waves with incident angles $\phi = 0^\circ$, 90°, 180°, and 270°, and eight measurement points is taken on a circle of radius R' at equal spacing. In our cases, R' is chosen much smaller than or larger than $2D'^2/\lambda$, corresponding to the near-field or far-field measurement, where D' is the largest dimension of the scatterer. Here R'=0.06m for near-field measurement and R'=7m for far-field measurement. The number of unknowns is set to 10, to save computing time. The population size is chosen as 300. The search range for unknown coefficient of the shape function is chosen to be from 0 to 0.1. The search range for unknown conductivity is chosen from 3×10^7 to 7×10^7. The extreme value of the coefficient of the shape function and conductivity can be determined by the prior knowledge of the objects. The crossover probability and mutation probability are set to be 0.8 and 0.04 respectively.

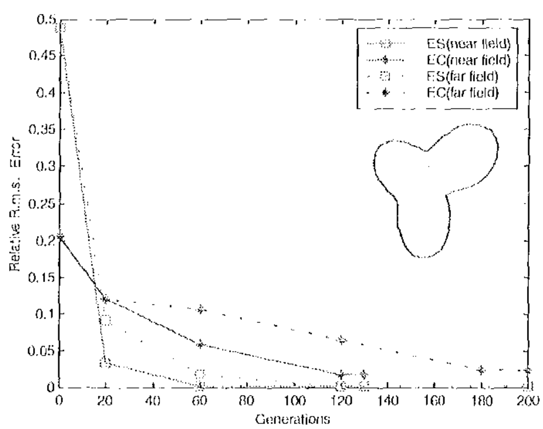

Fig. 1 Shape function errors and conductivity errors for example 1 in each generation by using near-field and far-field data

In the first example, the shape function is chosen to be $F(\theta) = (0.02 + 0.004 \sin 2\theta + 0.008 \sin 3\theta)$ m with copper material ($\sigma = 5.8\times10^7$ s/m). The reconstructed relative root mean square error for the shape and conductivity (ES and EC) by using the near-field and far-field data are plotted in Fig. 1. Here the shape function is also plotted for reference. From Fig. 1, it is clear the convergence speed and final rms error by using the near-field data are better than those obtained by using far-field data. The final rms errors for conductivity by using the near-field and far-field data are 1.7×10^{-2} and 2.4×10^{-2} respectively. Note that the convergence is achieved at the 130th generation by near-field measurement. However, for far-field measurement, the convergence is not achieved until the generation is 200. This is due to the fact that the kernel of integral for far-field measurement is more smooth (less singular) than that for near-field measurement. As a result, the near-field measurement is less illposed than the far-field measurement.

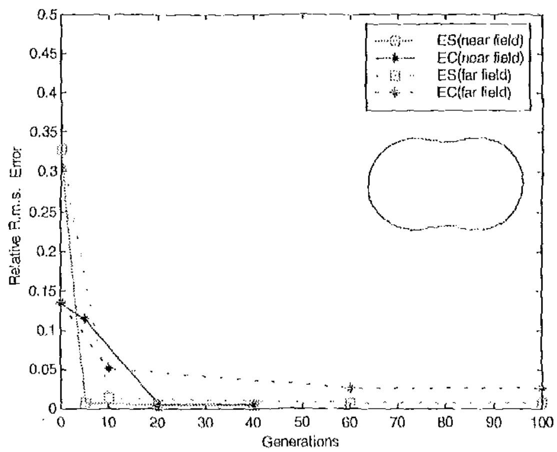

Fig. 2 Shape function errors and conductivity errors for the example 2 in each generation by using near-field and far-field data

In the second example, we selected the peanut shape function $F(\theta)=(0.026+0.009\cos2\theta)$ m with silver material ($\sigma=6.17\times10^{7}$ s/m). The purpose of this example is to show that different shape and conductivity has similar results. Reconstructed results are shown in Fig. 2.

CONCLUSIONS

We have compared the image reconstruction results for an imperfectly conducting cylinder by using near-field and far-field data. It is found that the reconstructed results for near-field measurement are better than those obtained by the far-field measurement. The can be explained by the fact that the near-field measurement is less illposed than the far field measurement. Finally, it is worth noting that in these cases the present work provides not only comparative information but also quantitative information.

REFERENCES

[1] A. Roger, "Newton-Kantorovitch algorithm applied to an electromagnetic inverse problem," IEEE Trans. Antennas Propagat., vol. 29, pp. 232-238, 1981.

[2] C. C. Chiu and Y. W. Kiang, "Electromagnetic imaging for an imperfectly conducting cylinders," IEEE Trans. Microwave Theory Tech., vol. 39, pp. 1632-1639, Sept. 1991.

[3] F. Hettlich, "Two methods for solving an inverse conductive scattering problem," Inverse Problems, vol. 10, pp. 375-385, 1994.

[4] C. C. Chiu and P. T. Liu, "Image reconstruction of a perfectly conducting cylinder by the genetic algorithm," IEE Proc.-Micro. Antennas Propagat., vol. 143, pp.249-253, June 1996.

[5] Z. Q. Meng, T. Takenaka and T. Tanaka, "Image reconstruction of two-dimensional impenetrable objects using genetic algorithm," Journal of Electromagnetic Waves and Application, vol. 13, pp. 95- 118, 1999.