THE DEPOLARIZING TERM IN VECTOR (POLARIZATION) DIFFRACTION TOMOGRAPHY

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ABSTRACT

We wish to investigate the effects of depolarization in diffraction tomography. Thus, for the inverse problem of image formation, oblique incidence on a lossless dielectric circular cylindrical scatterer is considered. Because the radiation wavelength is comparable to the size of the object inhomogeneities in diffraction tomography, we must consider the wave nature of the scattering problem and solve the inverse problem correspondingly. By considering the problem in its wave nature, we can account for phenomena such as reflection, refraction, diffraction, and depolarization, all of which occur in diffraction tomography. Solving the inverse problem, however, becomes very complicated, and thus we will use the Born approximation to simplify the problem.

1. INTRODUCTION

Here, we have chosen to use the Born approximation as opposed to the Rytov [1], but either one would serve our purpose. Although the Born approximation is a good model for most of the wave phenomena listed above [2] (for a certain class of objects), it does not account for depolarization. Thus, we are interested primarily in the following question: Is it important to account for the depolarization phenomenon, and what are the effects of neglecting depolarization on the quality of the image reconstruction? To aid us in answering these questions, we have chosen the case of the scattering from a circular cylinder at oblique incidence [5]. In this problem, the scattered field is known exactly and is depolarized due to oblique incidence. The cross-section of the cylinder which we wish to reconstruct will lie in a plane (called the imaging plane) whose normal is at an angle ϕ_m with respect to the cylinder's axis of symmetry, as shown in Figure 1. In this plane, the shape of the reconstructed image will be elliptical [4].

The incident field vector $\hat{k}$ will be rotated in increments through 360 degrees in the imaging plane, and corresponding scattered field data will be collected for each direction of $\hat{k}$. This information will then be used to reconstruct an image of the two-dimensional cross-section of the object shown in Figure 1.

As the angle of the imaging plane ϕ_m increases, the plane wave becomes more obliquely incident, and hence increasingly stronger depolarization is present. Thus, we can examine reconstructions corresponding to different angles ϕ_m, and determine the effects of depolarization. In addition, apparent depolarization is present in the near field of the object, and becomes important for applications which require the scattered field to be measured very close to the object. Thus, we can again examine reconstructions corresponding to scattered field data measured in the near field and far field, to aid us in assessing the effects of this type of apparent depolarization.

2. MODEL SIMULATIONS AND INTERPRETATION OF RESULTS

The derivation of the inversion algorithm is a long procedure and will not be given here for brevity, but can be found in [3] and [4]. The resulting solution relates the (one-dimensional) Fourier transform of the scattered field $g(\sigma)$ to the (two-dimensional) Fourier transform domain of the object $F(\bar{\mu})$, as shown below.

$$F(\bar{\mu}) = -\frac{2\gamma}{\pi j}\exp(+j2\pi\Gamma\gamma)\ g(\sigma) \qquad \text{for all } \bar{\mu} \text{ s.t. } \bar{\mu} = (\gamma - \alpha)\hat{k} + \sigma\bar{k} \tag{5}$$

We will use the above relationship and the scattered field from a circular cylinder to determine the effects of depolarization on the image reconstructions. As the angle of the imaging plane ϕ_m increases, depolarization increases. To get a measure (a value or a number) of the degree of depolarization, we will refer to the polarization ratio, which is the ratio of the cross-polarized component to the co-polarized component of the scattered field. The co-polarized component of the scattered field is measured by arranging the receiving antenna parallel to the incident electric field, while the cross-polarized component is measured by arranging the receiving antenna perpendicular to the incident electric field and parallel to the plane of polarization. The plane of polarization is defined as that plane whose normal is $\hat{k}$.

As depolarization increases, more energy will be transferred from the co-polarized component to the cross-polarized component, so this polarization ratio is a measure of the degree of depolarization. Thus, to assess the effects of increasingly stronger depolarization on the reconstructions, we will reconstruct the object at four values of ϕ_m. Figure 2 shows these four reconstructions for ϕ_m equal to 5, 10, 15, and 25 degrees, and the results show that as depolarization increases, the quality of the image reconstruction decreases.

In addition we note that due to the near field effect, the polarization ratio increases as we move closer to the object, due to apparent depolarization. In this study, we chose to measure the scattered field for two distances, at $\Gamma = 25$ and $\Gamma = 75$. For each value of Γ, we will reconstruct the object using the co- and cross-polarized components of the scattered field.

The results of the simulations are shown in Figure 3. First, consider the reconstructions corresponding to the larger value of Γ: Although the cross-polarized reconstruction is not exactly like its co-polarized image, some information is contained in the cross-polarized image, and it appears to be of a partly circular and partly elliptic shape. Second, consider the cross-polarized images for the two values of Γ: The image for the smaller value of Γ contains more information than does the image for the larger value. Again, although this image cannot be related exactly to its co-polarized image, some observable effects are present and thus polarization information should not be neglected.

3. CONCLUSIONS

The results of this first order polarization study show that depolarization effects should not be neglected in the formulation of microwave (vector) diffraction tomography [1]. Although these results are only qualitative and subjective, they show that incorporating depolarization effects into the reconstruction algorithm could very well improve the image. The next step in this research is to acquire results which are more quantitative and conclusive. One way of doing so, would be to include the depolarizing term in the wave equation, and thereby account for depolarization in the reconstruction algorithm.

4. ACKNOWLEDGMENTS

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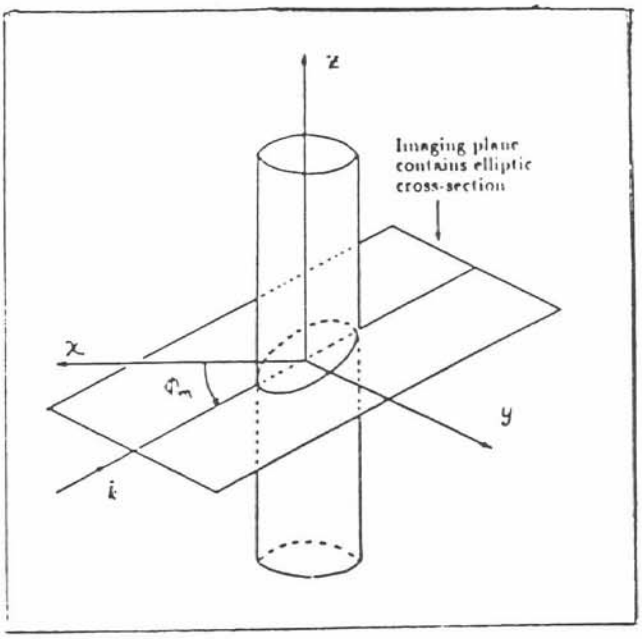
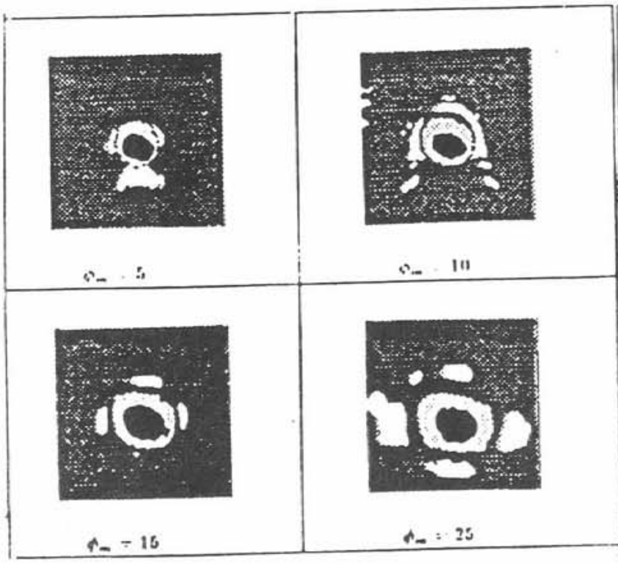


Figure 1: Imaging plane contains the shape of an ellipse.



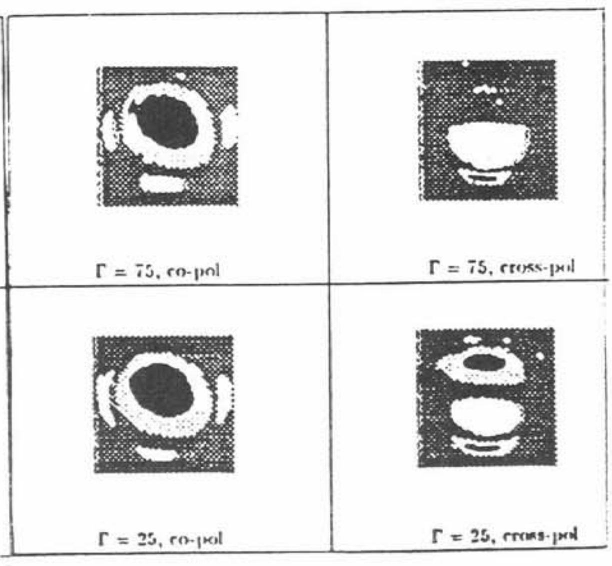


Figure 2:
Reconstructions for different ϕ_m. Image quality degrades with increasing degree of depolarization.

Figure 3:
Images of co- and cross-polarized components for two values of Γ. Some information is contained in the cross-polarized images.