Ultrasonic Diffraction Tomography: The Experimental Result

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ABSTRACT

Diffraction tomography is a technique for imaging with acoustic fields. It takes advantage of the linearization process of the non-linear wave equation describing wave propagation in heterogeneous media. When the scattering effect is weak, one can invoke the Born or Rytov approximation and thus derive the generalized Fourier Slice Theorem to reconstruct the cross-section of the insonified object. Although diffraction tomography is a promising technology for medical application as it provides a quantitative ultrasonic image, its realization toward medical use is still far-to-go, this may be due to the complexity of the hardware involved. In this research we investigate a potential use of diffraction tomography for medical application by using a delicate-designed ultrasonic computerized tomographic system. The result of experiment investigation of diffraction tomography is very promising.

Keywords

ultrasound, tomography, diffraction.

1. INTRODUCTION

Ultrasound has potentially many important technological applications. These include medical imaging [Jof90a], nondestructive testing [Bol89a], and robotic vision [Bol89a]. The advantages of ultrasound imaging offered over more conventional imaging are numerous. They include the relatively low health hazard of non-ionizing, low power of sources, its ability to image physiological properties of a tissue or organ, and the likely cost competitiveness of the imaging equipment. The difficulty with ultrasound imaging is associated problem with performing object reconstruction. Because ultrasound imaging experience significant attenuation, scattering problem and diffraction, standard tomographic reconstruction schemes are not readily applicable and are of only limited usefulness. In an attempt to overcome this problem, many approaches to ultrasound imaging has been investigated in the recent past[Kak88a]. Ultrasonic Diffraction tomography is a technique for inverting the differential wave equation governing interaction between the insonifying field and the scattering medium. This paper investigate the experimental result of ultrasonic diffraction tomography.

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2. ULTRASONIC DIFFRACTION TOMOGRAPHY

When an object is insonified with a plane wave and the detector is located at y = l_0. as shown in Fig. 1, the propagation of acoustic waves and the detected scatter field can be modeled with the Helmholtz's wave equation.[sla95a]

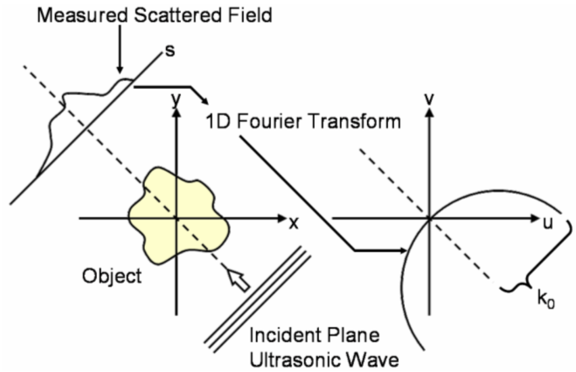

Figure 1. Fourier Diffraction Theorem.

which finally leads to the generalized Fourier slice theory defined by :

$$\Phi_s(\omega, l_0) = \frac{j}{2\sqrt{k_o^2 - \alpha^2}} e^{j\sqrt{k_0^2-\alpha^2} l_o} \cdot$$

$$O(\alpha, \sqrt{k_o^2 - \alpha^2} - k_0) \qquad (1)$$

where

$\Phi_S(\omega, l_0)$ is the Fourier transform of the scatter field detected by the detector.

$O(\alpha, \sqrt{k_o^2 - \alpha^2} - k_0)$ is fourier transform of the object evaluated along the circular arc of radius $k_0 = 2\pi/\lambda$, which is the wave number.

By illuminating an object in many different directions and measuring the diffracted projection data, one can fill up the Fourier space with the samples of the Fourier transform of the object over ensemble of circular arcs and then reconstruct the object by Fourier inversion.

3. EXPERIMENTAL RESULTS

The scattered field is measured by placing the specimen on the rotating platform and insonifying the object with ultrasonic plane-wave transducer. The needle-shaped ultrasonic receiver is linearly scanned to pick up the transmitted pulse. After one complete linear scan, the specimen is rotated to the next angle and the process is repeated. Figure 8 shows phantoms and the reconstruction results. The phantoms are made from the gelatin with different refractive index.

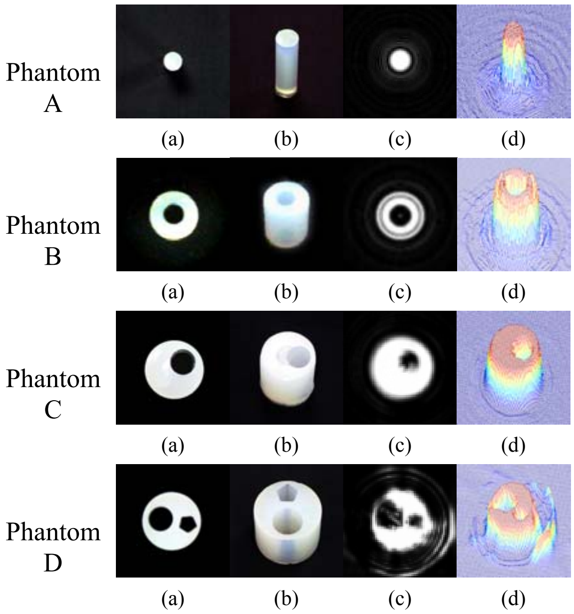

Figure 2. Phantom and Reconstructed Results

(a) Top view (b) side view (c) Reconstructed Results. (d) mesh of (c). (Number of projection: 8, scanning interval: 1mm. Refractive index of phantom A: 1.055 diameter: 1 cm. MSE : 13.81, B: 1.033 diameter: 3.5 cm. MSE : 11.09, C: 1.012 diameter: 3.5 cm. MSE : 13.29, D: 1.017 diameter: 3.5 cm. MSE : 26.64)

4. DISCUSSION AND CONCLUSION

We investigated the quantitative ultrasonic imaging using the diffraction tomography. The experiment results indicate that the diffraction tomography method provides quantitatively accurate imaging. Despites its promising technique, diffraction tomography is subjected to various limitations, which include artifacts due to diffraction effects in strong inhomogenous media.

5. REFERENCES

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