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Abstract

A reconstruction of the ultrasonic scattered fields in the zone near the scatter constitutes an image of the scatterer or flaw. In a real case the reconstruction zone may contain more than one distinct scatterer and accordingly the entire group form the image. At a remote location the scattered fields form a complicated diffraction pattern which will yield the image if operated on by a suitable set of mathematical operations. The measurement of the remote fields is of major interest as it affects the image quality. Unlike phased array systems, the transducer spacing, hence measurement sampling density, is determined by the spatial frequencies of the diffraction pattern and sampling theory. This paper will describe the implementation of a 64 x 64 2D array and the results obtained in imaging the phase and magnitude of source and scattered fields.

Keywords

Nondestructive Evaluation

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ACOUSTIC IMAGING BY WAVEFRONT RECONSTRUCTION

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ABSTRACT

A reconstruction of the ultrasonic scattered fields in the zone near the scatterer constitutes an image of the scatterer or flaw. In a real case the reconstruction zone may contain more than one distinct scatterer and accordingly the entire group form the image. At a remote location the scattered fields form a complicated diffraction pattern which will yield the image if operated on by a suitable set of mathematical operations. The measurement of the remote fields is of major interest as it affects the image quality. Unlike phased array systems, the transducer spacing, hence measurement sampling density, is determined by the spatial frequencies of the diffraction pattern and sampling theory. This paper will describe the implementation of a 64 x 64 2D array and the results obtained in imaging the phase and magnitude of source and scattered fields.

I. INTRODUCTION

Implementation of the coherent wavefront reconstruction imaging system discussed here involved the physical construction of a two dimensional transducer array and associated electronics. Last year we reported on the basic theory and detailed the 64 x 64 transducer array and multiplexer electronics (1). In the interim the receiver circuitry was improved in order to allow coherent phase sensitivity detection with I and Q channel pulse outputs proportional to the real and imaginary parts of the scattered tone burst waveform. Here we will briefly review the important features of the imaging system and then discuss the experimental results that have been obtained to date.

In the most general sense the imaging system is a means of sampling the spatial distribution of waves scattered from an object, Fig. 1. The basic assumption is that the nature of the object is indirectly revealed by the diffraction pattern and directly obtained by a suitable technique which reconstructs fields at the scatterer. The current form of reconstruction requires that the complex form of the scattered fields be measured and processed. Normally this would imply a CW system

with a high degree of temporal coherence. However, a CW system would be unusable in a real NDE system because of standing wave effects.

The system being implemented is coherent to the extent that tone burst excitation is employed at frequencies of interest. The length of tone burst must be sufficient to assure complete illumination of the object region so that waves vectorially sum at the measurement plane. Upper bounds on pulse length are determined by stray signal paths and the desire for fast data through-put.

In a time domain echo system two objects might be resolved by using short pulses that require large bandwidths. In a coherent imaging system the spatial bandwidth of the scattered field and sampling system is used to obtain the desired resolution. Since tone burst waveforms are relatively narrow bandwidth, higher signal-to-noise ratios may be obtained using narrow bandwidth amplifiers and coherent detection schemes.

The finite spatial sampling of the scattered fields has some important implications regarding resolution and image quality. Since discrete Fourier transforms are employed in the small angle reconstruction, the image is necessarily periodic in the image plane (1,2), Figs. 1,2. The system resolution is given simply by,

$$\Delta x \approx \lambda \frac{R}{W}$$

$$\text{or} \quad = \frac{\lambda}{2} \frac{1}{\tan \theta}$$

where λ is the acoustic wavelength and θ the half angle, Fig. 2. Note in particular that the resolution is independent of sampling densities in the measurement plane. However, the image width is given by

$$F = R/\Delta U.$$

Thus coarse sampling gives rise to narrow image fields that may result in aliasing. In general, only the object region should be illuminated if other distortion or ghost effects are to be avoided. These effects may be largely eliminated by simple image processing techniques which increase image width and display resolution.

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II. EXPERIMENTAL RESULTS

The coherent imaging technique has been tested with synthetic aperture data as well as with data taken from the 2D array. In the former case the data has higher signal-to-noise ratio, due to the more efficient transducer used for scanning, and does not have to be normalized. Here we report only on data that has been taken with the 2D array.

In using the 2D array it is necessary to first obtain a calibration matrix which is composed of individual transfer functions of the array elements. The transfer function, as used in this report, is obtained by translating the array such that a given element is located a fixed distance away from a conventional transducer in a water tank and then recorded the complex wave signal. After each array element has been positioned and measured the transfer function matrix is normalized to the largest signal. A grey scale display of the magnitude and phase of a typical calibration matrix is shown in Figs. 3a,b. Since the 2D array was built as four separate sections the slight lack of parallelism is apparent in the phase display. Note that the scan plane itself was not parallel to the transducer plane as indicated by the tilt in the phase characteristics. The slight tilt has no measurable influence on the amplitude of the transfer function.

In the amplitude part of the transfer function matrix it is clear that some array elements or multiplexing chips are inoperative. Isolated zeros in the measured scattered data, due to an inoperative element, do not cause significant errors in the reconstructed image because it appears as a small but uniform amplitude shift after the Fourier transform operation. A small number of zeros in the transfer function may be corrected by a nearest neighbor spatial averaging of the scattered field data assuming a high enough sampling density.

The first case of data measured by the array, and reported here, is the radiated beam from a 0.5" dia (42λ dia in water) focused transducer having a 2" focal length. The array was located 16" from the transducer in a water tank environment. Although the measured data is stored in real and imaginary form, the amplitude is shown in Fig. 4 for convenience. Since the computer could handle only part of the 64×64 data array, only the even elements are shown. Thus the display density is one half the true sampling density. In Fig. 4 it is clear that useful diffraction data exists well out into the edges of the measurement field. A close up view of the central 32×32 measured data is shown in Fig. 5 with the true sampling density.

The 64×64 focused transducer data was then reconstructed at several planes; Fig. 6a at the apparent focal point, Fig. 6b slightly closer to the transducer, and Fig. 6c at the plane of the transducer.

The second case considered was the scattering from a through-drilled hole in an aluminum block,

Fig. 7. In this case the measured field consisted of the main transducer pattern after reflection minus that part due to the hole in the block. The reconstructed image is shown in Fig. 8. An image more characteristic of the hole would have been obtained by positioning the array out of the main reflected beam.

III. SUMMARY AND CONCLUSION

Implementation of a 2D acoustic transducer array in a coherent imaging system has been carried out using both source and scattered fields. The finite sampling caused by the array and the periodic nature of discrete Fourier transforms places some constraints on the image field and may give rise to aliasing or ghost effects. However, when the data is oversampled image processing techniques may be employed to improve the image display quality.

IV. ACKNOWLEDGEMENTS

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V. REFERENCES

1. K. M. Lakin, W. R. Sheppard and K. Tam, "Wavefront Reconstruction Acoustic Imaging Using Two Dimensional Arrays", 1979 Ultrasonics Symposium Proceedings IEEE, Cat. # 79ch1482-9SU.
2. K. Lakin and A. Fedotowsky, IEEE Transactions Sonics and Ultrasonics, SU-23, 317 (1976).

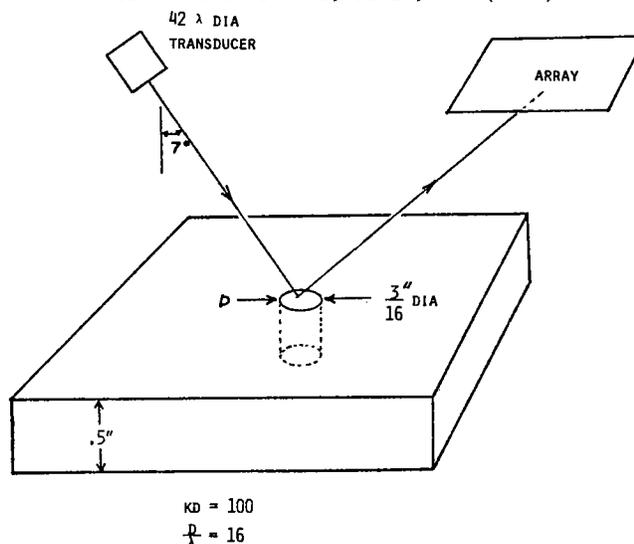


Figure 1. Configuration of Imaging System

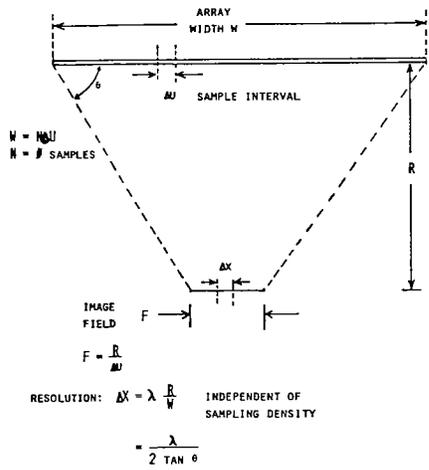


Figure 2. Effect of finite sampling in relation to array and object

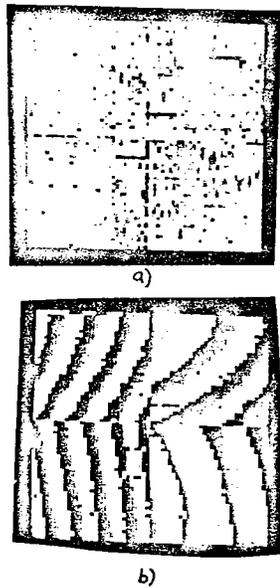


Figure 3. Array transfer function a) amplitude b) phase

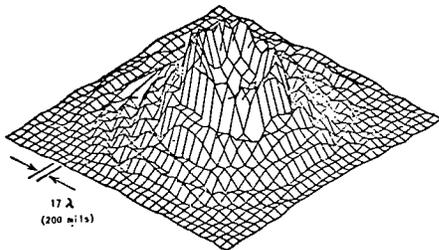


Figure 4. Measured data 0.5" dia focused transducer

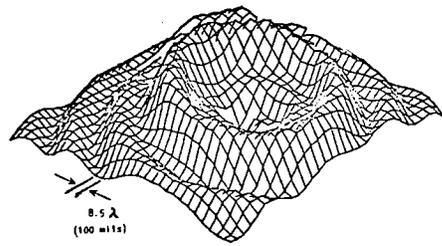


Figure 5. Expanded view of Figure 4 data

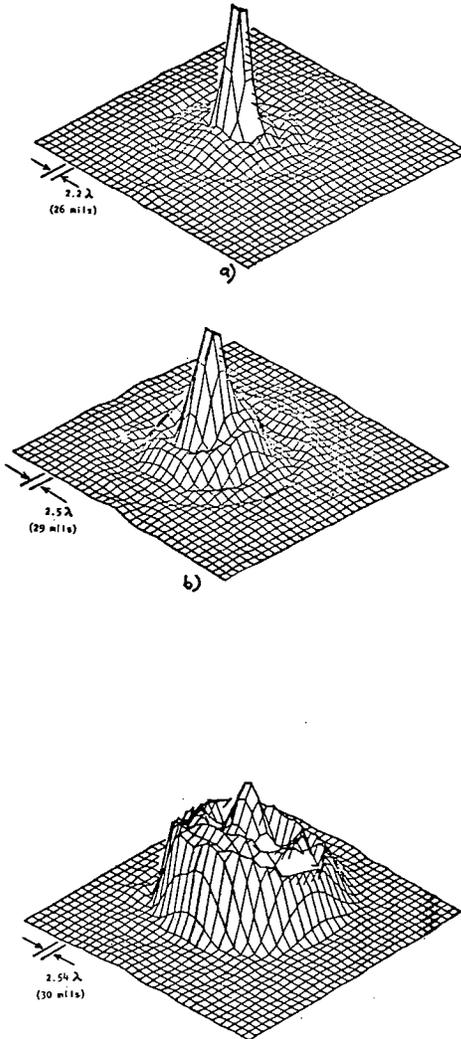


Figure 6. Reconstruction of focused transducer data a) at focal point b) near focal point c) at the transducer

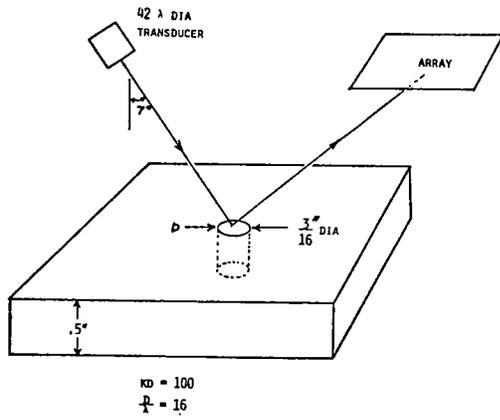


Figure 7. Configuration for scattering data from drilled hole

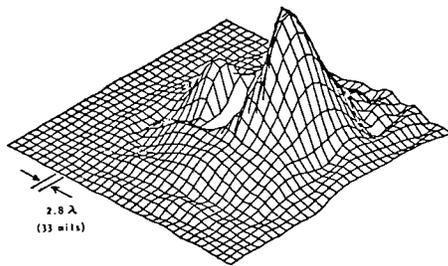


Figure 8. Image of fields at the drilled hole top surfaces