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USE OF BBC MICROCOMPUTER FOR SYNTHETIC APERTURE MEASUREMENTS

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INTRODUCTION

Consider a transmitter comprising an array of transducers across an aperture. If we are given the distribution of both the amplitude and phase of the transmitted signal across the array and if we ignore attenuation, it is possible to calculate the resulting field at a given point simply by applying Huygens principle. (We make the assumption that the point is sufficiently far enough from the array so that it is not necessary to take into account evanescent waves).

Referring to Fig. 1, the field at a point y is given by

$$F(y) = \int_{\text{aperture}} G(x) \cdot \frac{1}{R} \cdot e^{-j\frac{2\pi R}{\lambda}} \cdot dx \qquad \ldots\ldots\ldots\ldots\ldots (1)$$

where G(x) is a complex function representing the amplitude and phase at each point in the aperture. The 1/R term allows for spherical spreading.

Conversely if we measure a distribution G(x) along an aperture we can estimate the field from which this signal could have arisen. The solution is however not unique unless we have some other knowledge about the source which has given rise to the field, e.g. if we know there is a single source in the far field we can make an estimate of the direction of the source relative to the array provided the size of the array is sufficient and the signal/noise ratio is reasonable.

This paper will concentrate on line arrays but the methods are easily extendable to planar arrays or for that matter arrays of other geometries.

If a source is located at a point y on a line d metres from the plane of the aperture, as in Fig. 1, the aperture distribution which would result is:-

$$G(x) = \frac{1}{R} \cdot e^{-j\frac{2\pi R}{\lambda}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where R is defined as before

Fig. 2 shows a graph of the magnitude and phase of G(x). It should be noticed that the factor 1/R has only a very small effect on the amplitude unless x and y are comparable with d. If we take a finite length of the distribution G(x) and use equation 1 to reconstruct the field we get the picture in Fig. 3. Given the assumption that we know G(x) has arisen from a point source we can make an estimate of its position, but it can be seen that although the accuracy of location in bearing is reasonable that in range is very poor.

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However, we can normally obtain information about the range of the source by other means, typically by measuring the time of flight. Normally the 'sources' are targets which reflect a pulsed signal transmitted from the region of the receiving array - sometimes using the same transducer. The incoming signals measured at the array are gated in range so that the aperture distribution for each range gate can be processed separately. The duration of the range gate has, of course, to be sufficient to allow the measurement of the amplitude and phase of the signal.

The larger the aperture in terms of wavelengths the better is the resolution in angle but this can mean large and costly arrays, and in addition would require rapid processing of the data received at each element of the array. An alternative approach is to use a small transducer which is moved relatively slowly across the aperture while measurements are taken at each point of the amplitude and phase of the signal being received. This assumes the target is effectively stationary over the period during which the measurements take place. The technique, which enables very large apertures to be achieved with a relatively simple system, is by no means new. It was used first in Radio Astronomy by Sir Martin Ryle (Ref. 1). One of the authors of this paper used the principle in an experiment on acoustic holography about ten years ago (Ref. 2) and Synthetic Aperture Radars (SAR) have been under development for many years (Ref. 3). Recently systems mounted in satellites have been producing some very remarkable results. The recent rise in interest can be partly attributed to the remarkable change in processing power which has resulted from the very rapid developments in computer technology offering the possibility of real time or near real time reconstruction.

EXPERIMENTAL SYSTEM

We have been looking at various methods to achieve high resolution underwater acoustic images to classify targets and this paper describes the measuring system for the synthetic aperture work. The tank in which the experiments have been carried out is about 10 metres long, 5 metres wide and about 2 metres deep. A trolley carrying the transducer is driven by two stepper motors along an accurate track mounted on two RSJ's across the top of the tank. The stepper motors are controlled by a BBC computer and the same computer samples the amplitude and phase of the signal being received by the transducer. This information is stored on a disc and can be processed later by the BBC or can be down loaded directly from the BBC - using the BBC as a terminal emulator - to one of the main University computers.

The overall block diagram is shown in Fig. 4.

RESULTS

The work is in an early stage at the moment and it is possible to show only a few simple results.

A reconstruction based on a simulated aperture distribution from two sources is shown in Fig. 5. The frequency of operation is 150kHz, (i.e. the wavelength is 1 cm) and hence the aperture of 1.25m is equivalent to 125 wavelengths. The targets were spaced 11 cms apart. Fig. 6 shows a reconstruction based on measured data and it can be seen that the result is very similar to the simulation result. There are, however, some small differences: the structure seems much finer in the simulated case and there are some additional targets appearing in the reconstruction based on real measurements. It is possible that these are real echoes since there are many mechanisms in the practical situation from which such echoes could arise.

CONCLUSIONS

A simple acoustic synthetic aperture system has been constructed using a BBC microcomputer to control the movement of the receiving transducer and to process the received signal. Early results obtained with the system are very promising.

REFERENCES

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2. M. J-M. Clément & J.W.R. Griffiths, 'A Study of Translated-Circular Scanning for Acoustic Holography', Non-Destructive Testing, Aug. 1973, Vol. 6, No. 4, pp 195-199.

3. R.O. Harger, 'Synthetic Aperture Radar Systems', Academic Press 1970.

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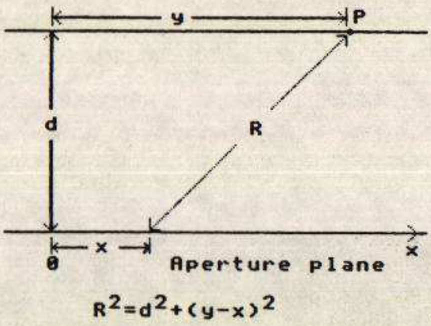

Fig. 1 Geometry

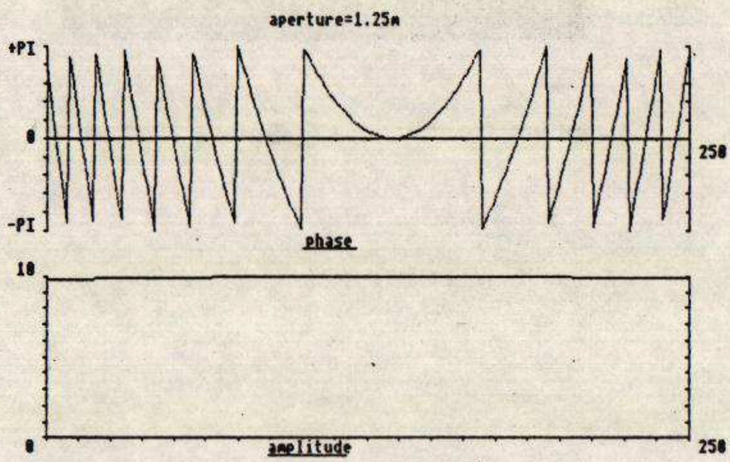

Fig. 2. Simulation of aperture distribution for a single source.

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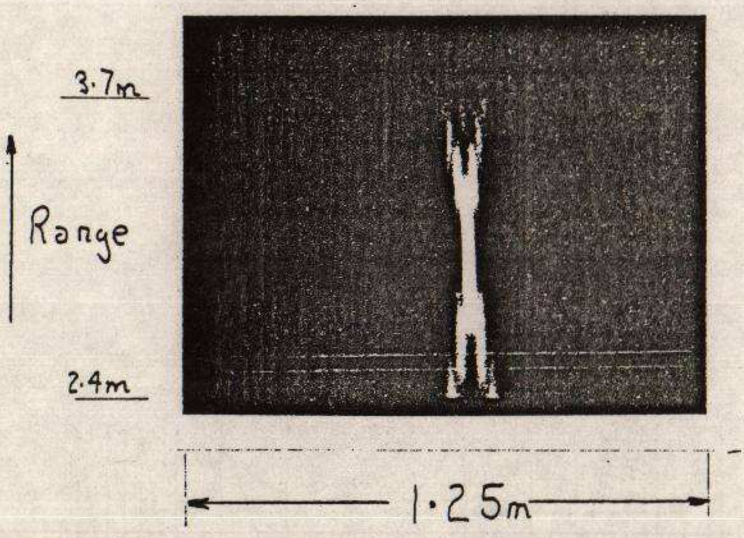

Fig. 3. Reconstruction for distribution in Fig. 2.

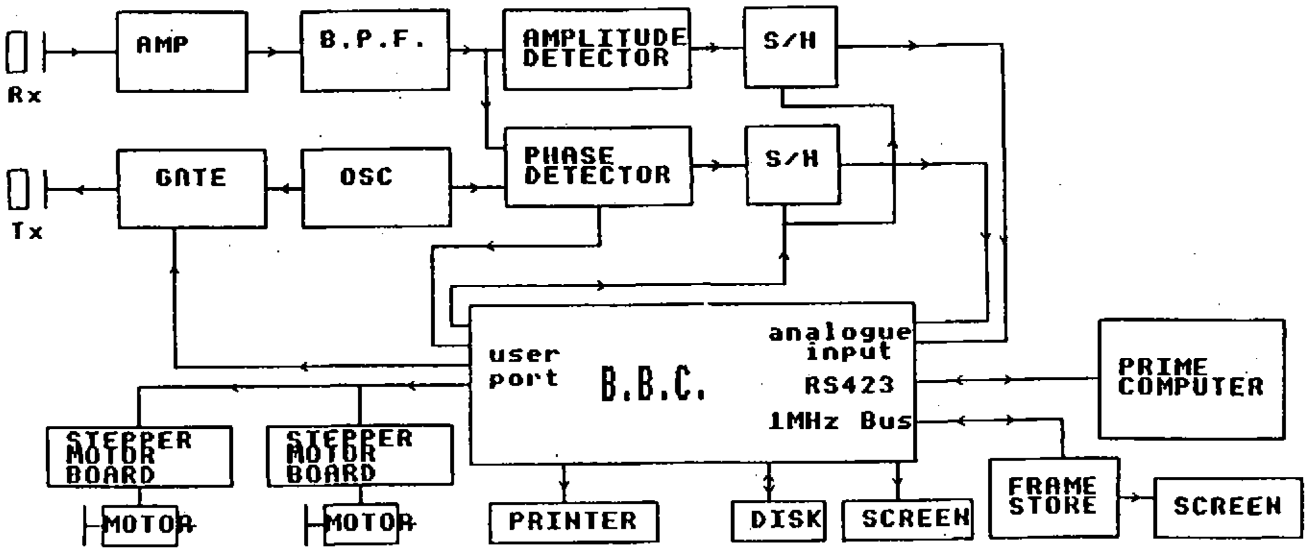

Fig. 4. Block Diagram of System

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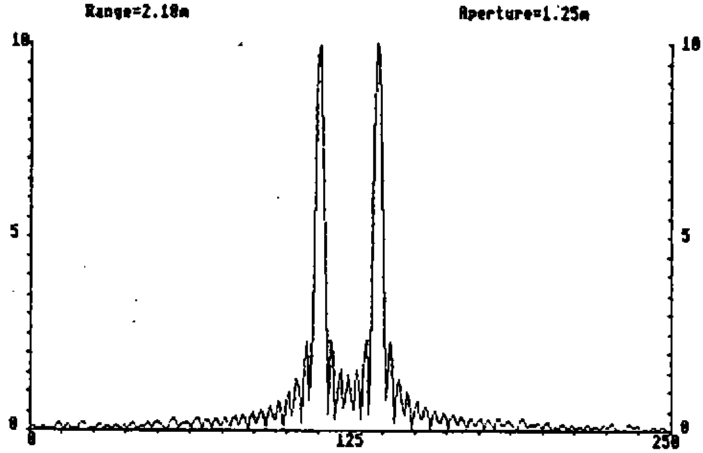

Fig. 5. Simulation reconstruction for two sources

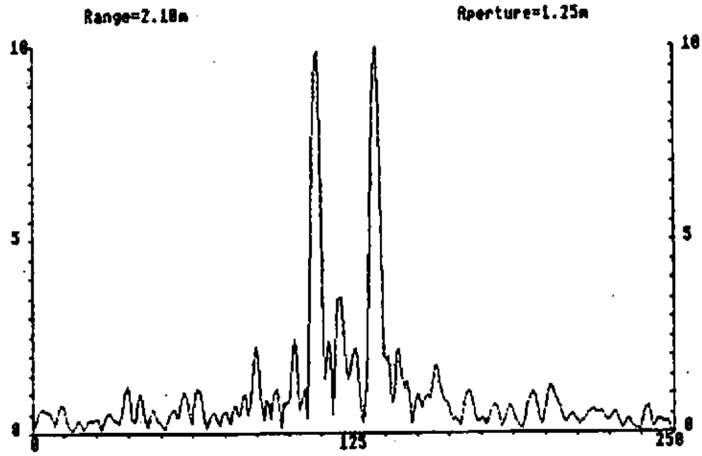

Fig. 6. Reconstruction based on measured data