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# INTERIM TECHNICAL REPORT (U)

*January 1971*

*Research Sponsored By:*

*Office of Naval Research*
*Washington, D.C.*

*Contract N000 14-68-C-0338*
*NR 261-170/6-25-70(466)*

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*The Bendix Corporation*
*Research Laboratories*
*Southfield, Michigan 48075*

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## TABLE OF CONTENTS

Page

ABSTRACT

INTRODUCTION

# FIGURE CAPTIONS

## ABSTRACT

A summary of the work accomplished during calender 1970 is presented in this report. Accomplishments include completion of the design and construction of the experimental underwater viewing system and initial experiments to evaluate its performance. Demonstrations of the system were made for ONR, Naval Ships, and NUWC personnel. Progress in the development of the coherent light area modulator, to be used for reconstruction of acoustic holograms, is also reported.

# INTRODUCTION

A feasibility study and prototype system development for underwater viewing based on acoustic holographic principles was initiated at Bendix Research Laboratories in 1968 under Contract #N00014-C-68-0338. The objective was to study various receiving array configurations and construct a modular prototype system to evaluate the capabilities of holographic concepts. In parallel, the development of a system for real-time optical reconstruction of sampled holograms was initiated.

This report presents a summary of the activities during calender year 1970. Accomplishments include completion of the design and construction of the underwater viewing system (consisting of acoustic projector, receiving array, and processing electronics), preliminary testing of the system including reconstruction of the acoustic holograms, synthetic aperture analysis, and progress in the development of the real-time reconstruction system. These activities are discussed in the following sections.

## SECTION 1

## UNDERWATER VIEWING SYSTEM

The design and assembly of the underwater viewing system was completed in June, 1970. The system consists of an acoustic projector and a 20 x 20 piezoelectric detector array with individual signal processing channels for each element to generate the holographic data at that point. A simplified block diagram is shown in Fig. 1-1.

The underwater viewing system was demonstrated in July, 1970 for representatives of the Department of Naval Research, Naval Ships, and NUWC. This demonstration employed a three-disc target as well as an active target. Additional testing of the viewing system was performed at Bendix, Electrodynamics Division, by Bendix and NUWC personnel; and data was gathered for reconstruction purposes.

After several months of operation, the system performance was somewhat degraded due to the failure of connectors associated with the twenty signal processing boards. These connectors are presently being replaced with high reliability military type connectors and should no longer present a problem.

An operations handbook containing a detailed system description and schematics was prepared and submitted to the Department of Naval Research for approval in November, 1970. This handbook is presently being finalized for publication.

A brief description of the design and operation of the underwater viewing system is given below.

### 1.1 ACOUSTIC PROJECTOR

The acoustic projector (transmitter) consists of a small spherical shell of piezoelectric ceramic vibrating in a radiated mode. The spherical configuration was chosen to give the maximum transmitting surface area and radiation resistance. The high radiation resistance and relatively low stiffness of the shell give a low mechanical "Q" which in turn gives good bandwidth, good transient response, and for the case of project arrays, easier equalization of the projector elements response.

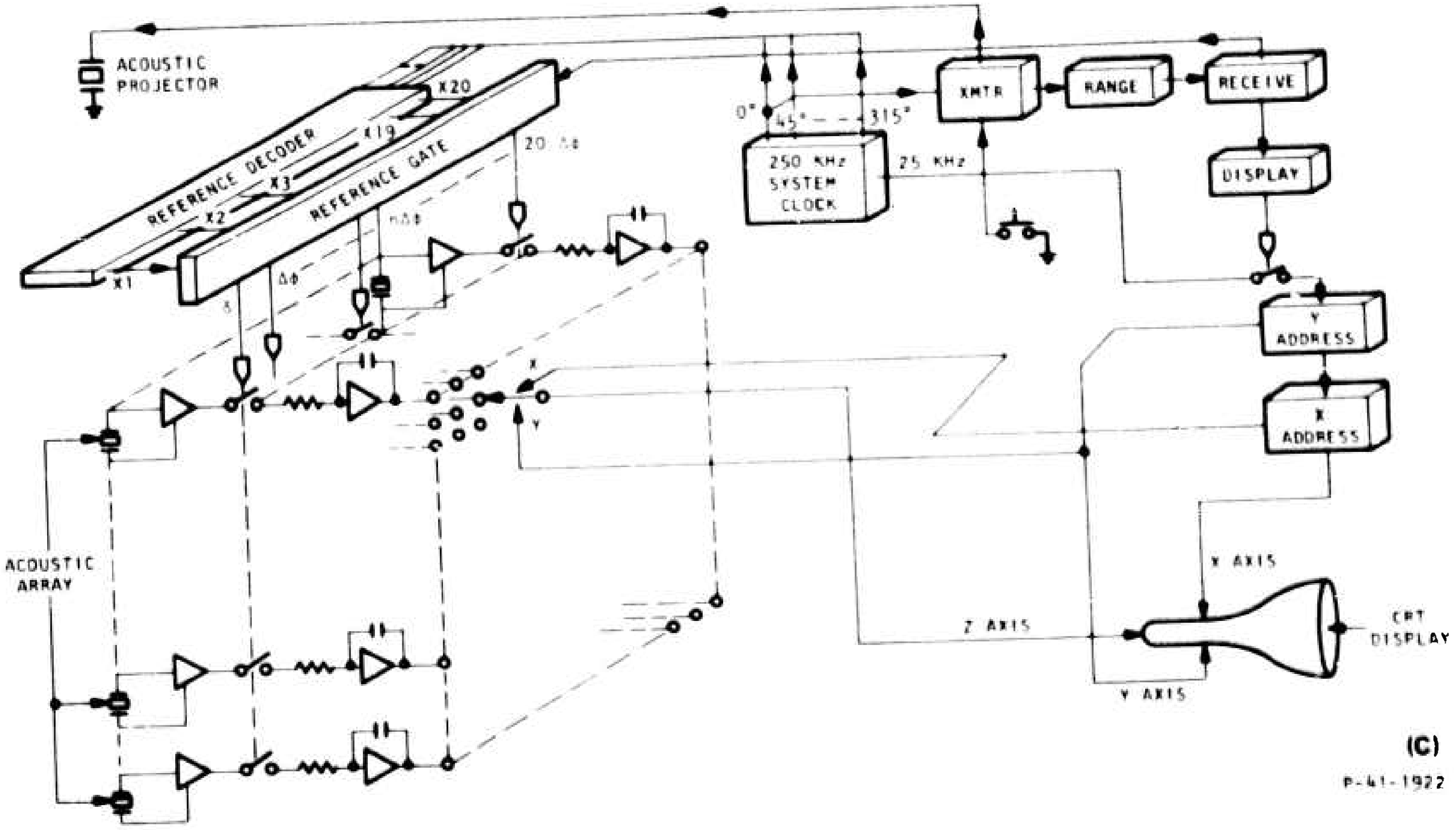

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Figure 1-1 - Block diagram of underwater viewing system

**The piezoelectric material is a barium titanate composition, CH300. It has a high sound velocity; thus the resonant sphere has a large enough diameter so that it can be manufactured without special tooling and high cost. In this particular application, a mechanical "Q" of 6 has been realized with maximum power limited by cavitation (5 Watts in the pulsed mode).**

**The uniaxial radiation pattern for a single sphere is shown in** Fig. 1-2.

## 1.2 RECEIVING ARRAY

The receiver is composed of 400 transducer slugs mounted to form a 20 x 20 planar square array in an acoustically soft baffle. The housing in back of the array contains the electronic boards that process the holographic signal.

Early in the program, it was realized that uniformity of element response (amplitude and phase) is of considerable importance. For this reason, 6-8 db of sensitivity was sacrificed so that nonresonant elements could be used. The detector elements chosen for this design are of lead zirconium titanate ceramic (Gulton G1512) with a resonant frequency slightly above the operating frequency.

It was considered important to provide a good acoustic baffle for each detector element, so that each would remain as close to an isotropic radiator as possible, and a lead-corprene baffled system was finally chosen. The diameter of each element was made close to a wavelength, for high sensitivity, and they were spaced 1.5 wavelengths apart to provide a viewing angle of approximately 40°. Their sensitivity at the operating frequency was better than -105 db ref 1V/μbar. The measured detectability pattern (equivalent to the radiation pattern) of the array is plotted in Fig. 1-3. It is observed that the acoustic response is constant within 3 db over the designed field of view.

## 1.3 PROCESSING ELECTRONICS AND SYSTEM OPERATION

The design and a detailed description of the electronics required to process the received holographic information is given in the Operations Handbook presently being prepared for publication and will not be repeated here. A brief description of the system operation is presented below.

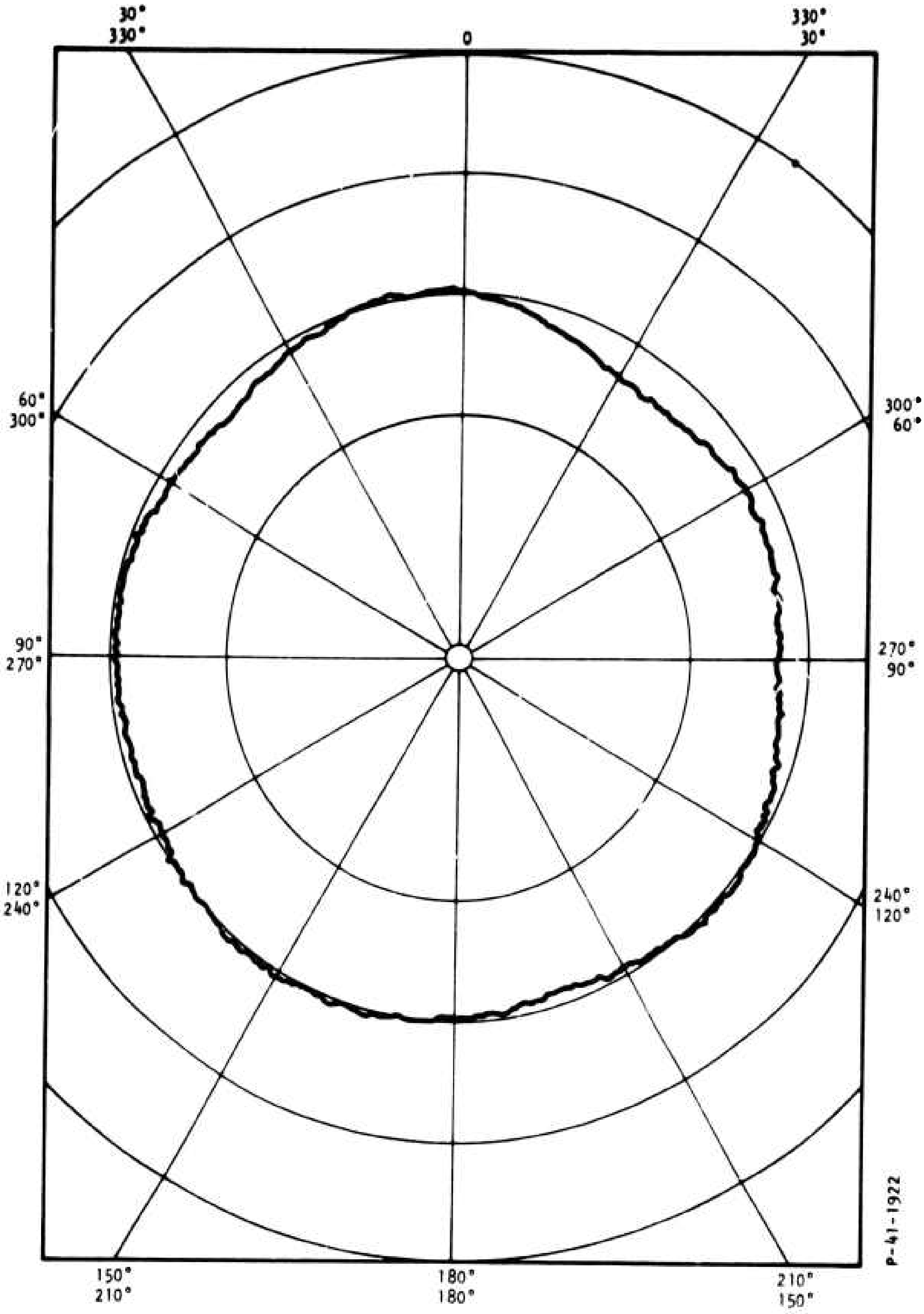

Figure 1-2 - Radiation pattern of acoustic projector

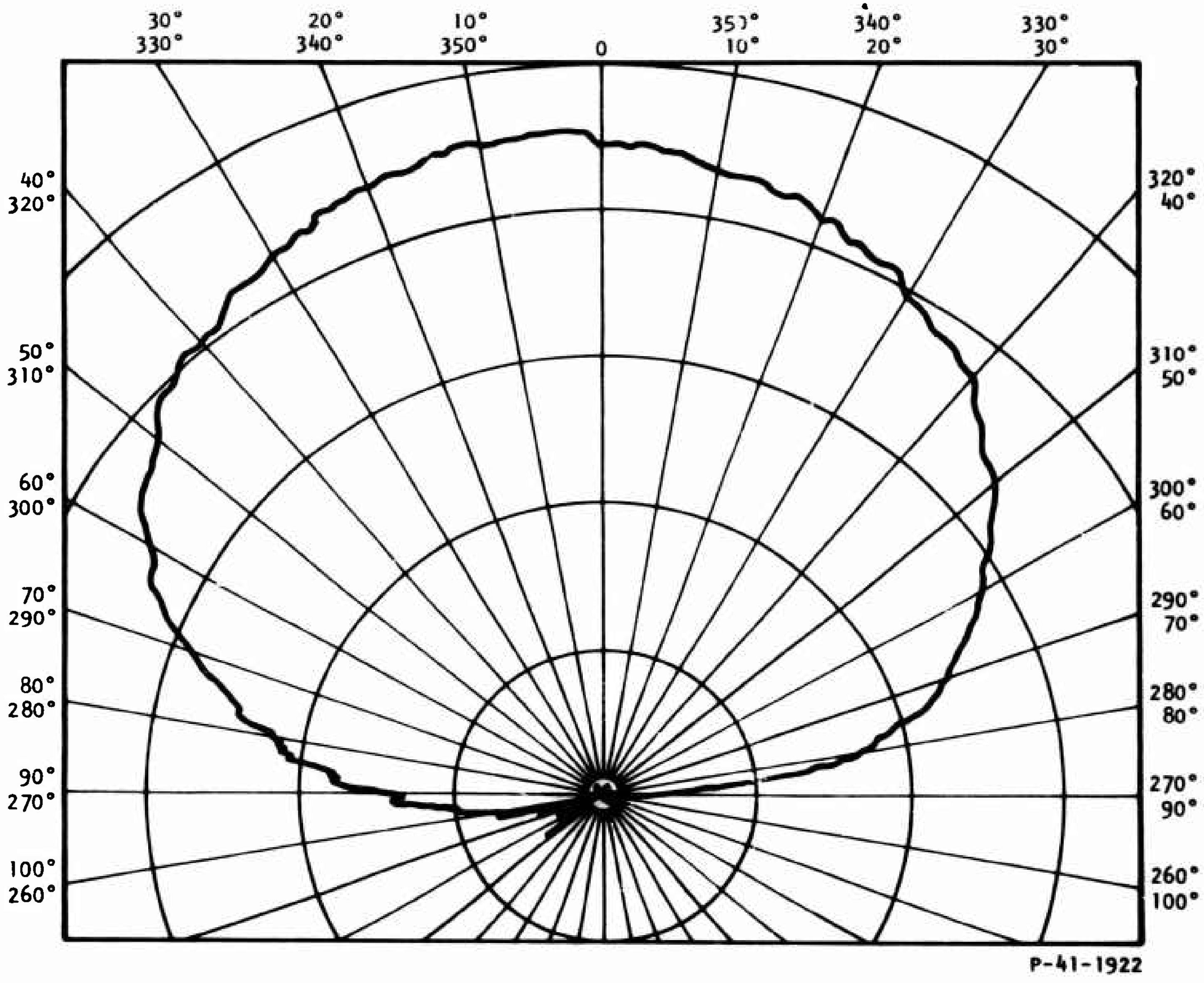

Figure 1-3 - Detectability pattern of receive array

The signal is received from each linear element of an acoustic array, mixed with a reference signal, averaged (integrated) for a predetermined length of time, and finally stored as a constant (D.C.) level. This constant level, proportional to both the amplitude and the cosine of the phase of the detected signal, represents the local holographic information which, when displayed for all points, makes up a complete hologram.

The reference signal, when considered for all points of the receive array, simulates a plane wave whose angle of incidence with the array is variable. This inclined reference plane wave is simulated using several reference signals applied to different parts of the array, each of which is shifted in phase from the previous signal by a fixed amount. During the Receive mode of operation, each column of signal processing channels receives a reference signal that is incremented in phase with respect to the previous column. Thus the reference plane wave is simulated, with an apparent angle of incidence determined by the phase increment between adjacent columns.

The sequence of events for a single system cycle is initiated by depressing the SINGLE TRANSMIT button. This triggers the transmit multivibrator which gates the drive signal to the transmitter. The range multivibrator, which provides a system delay equal to the two-way propagation of the transmitted wavefront, is also triggered at this time.

After the range delay, the system goes into a receive mode. In this mode, the simulated reference is gated to the signal processing circuitry where it is multiplied with the incoming signal. For each element, the product of this multiplication is integrated and stored as a D.C. level.

The receive mode is followed by a display mode, during which the system sequentially samples the stored D.C. levels and displays the information in the form of a dot matrix on a cathode ray tube. Through the use of a common clock, the readout address and the display address are synchronized to ensure that the CRT display has the same X-Y address as the information being sampled. The intensity of each dot corresponds to the value of the sampled D.C. level; since each D.C. level is proportional to the local holographic information, the display of the 400 D.C. levels is the desired hologram.

# SECTION 2

## HOLOGRAM RECONSTRUCTIONS

Holograms in the form of photographs of the interference pattern on the CRT display unit were taken under the conditions described in the above section and reconstructed. Two setups used to carry out the reconstructions are shown in Fig. 2-1. In Fig. 2-1(a), the reconstruction is carried out directly by the coherent illumination of the hologram obtained by photographing the display. Because the dimensions of these holograms are very large, the reconstructed image is very small and a microscope was used to obtain the necessary magnification. An alternative procedure was subsequently used, because (a) the microscope optics tends to introduce a relatively large number of reflecting surfaces and (b) the angle between the d.c. and image beams is very small because of the large hologram size. This approach, shown in Fig. 2-1(b), involves reproduction of a demagnified hologram by photographic means so that the d.c. and image information can more readily be separated. In addition, the (reduced) magnification necessary was achieved by using a long path, in order to avoid the use of a microscope.

A low-magnification example of the reconstruction obtained as in Fig. 2-1(b) is shown in Fig. 2-2. In the center of the photograph, the bright zero-order light can be seen; this consists of a d.c. spot and a convolution term, both of which are out of focus at the plane in which the image information is in focus. A similar reconstruction is shown in Fig. 2-3 in which most of the zero-order light was removed by a central stop. The zero-order position is denoted by a cross. At a distance of 36 mm to both the right and left of the zero-order light is a repeat of the zero-order pattern at lower intensity*; the repetition is due to the discrete nature of the underwater array. In the present case, the repetition serves a useful purpose since it directly gives the scale of the reconstruction. The dimensions of the array are known, and thus the angular position of its first lobe; hence, the angular position in the experimental setup corresponding to any point in the reconstruction is immediately known. The element separation in the array is $3\lambda/2$ and the angle $\theta$ of the first lobe of the array is therefore (see Fig. 2-4) given by

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*Other, even weaker, repetitions are visible above and below the zero-order position, especially in Fig. 2-2.

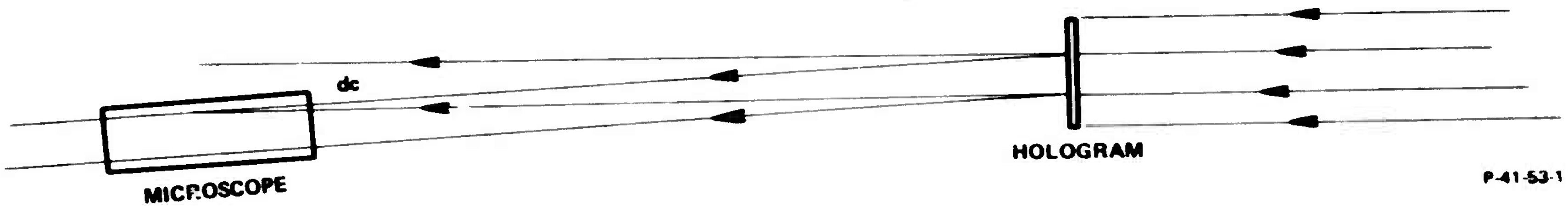

Figure 2-1(a) - Hologram reconstruction method A

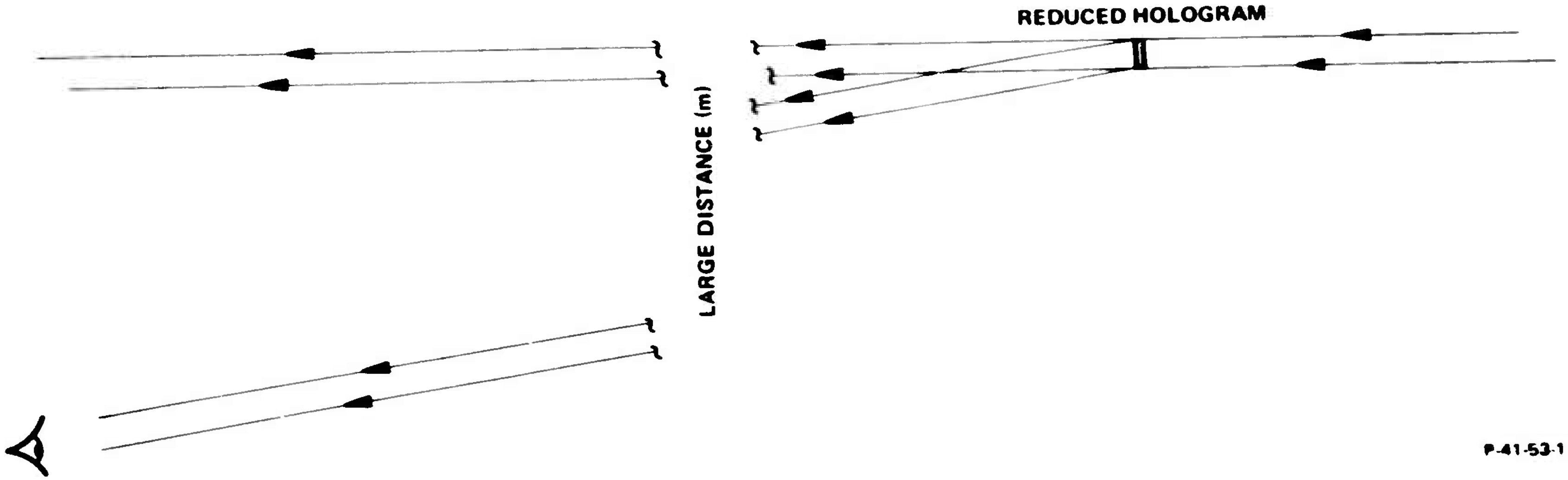

Figure 2-1(b) - Hologram reconstruction method B

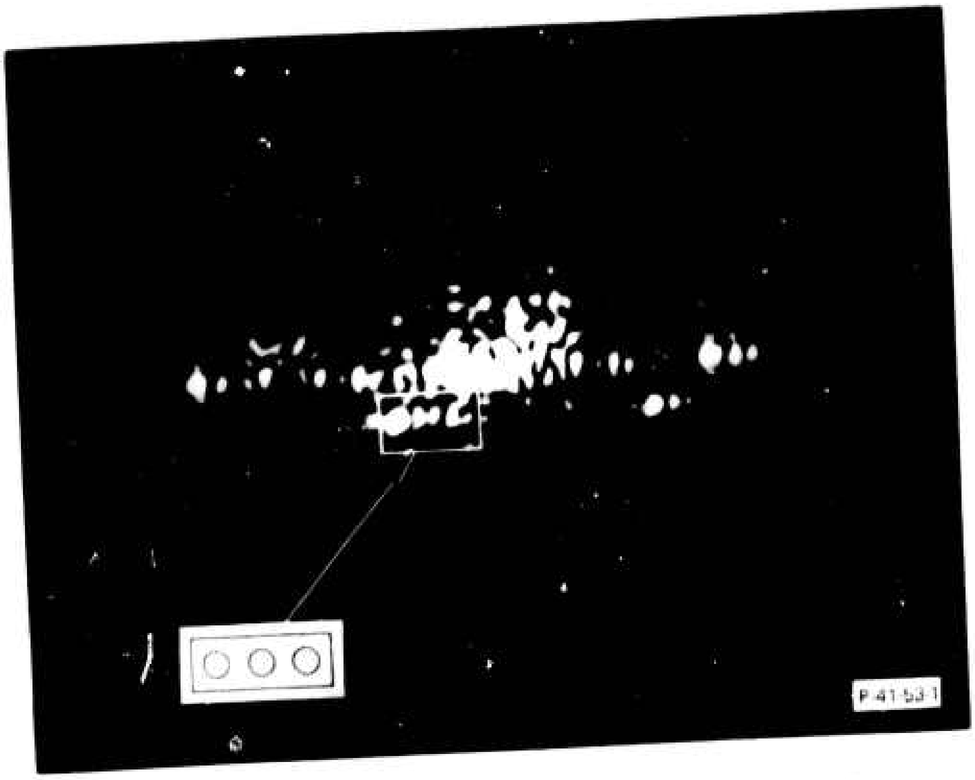

Figure 2-2 - Reconstruction of a 3-Disc Target

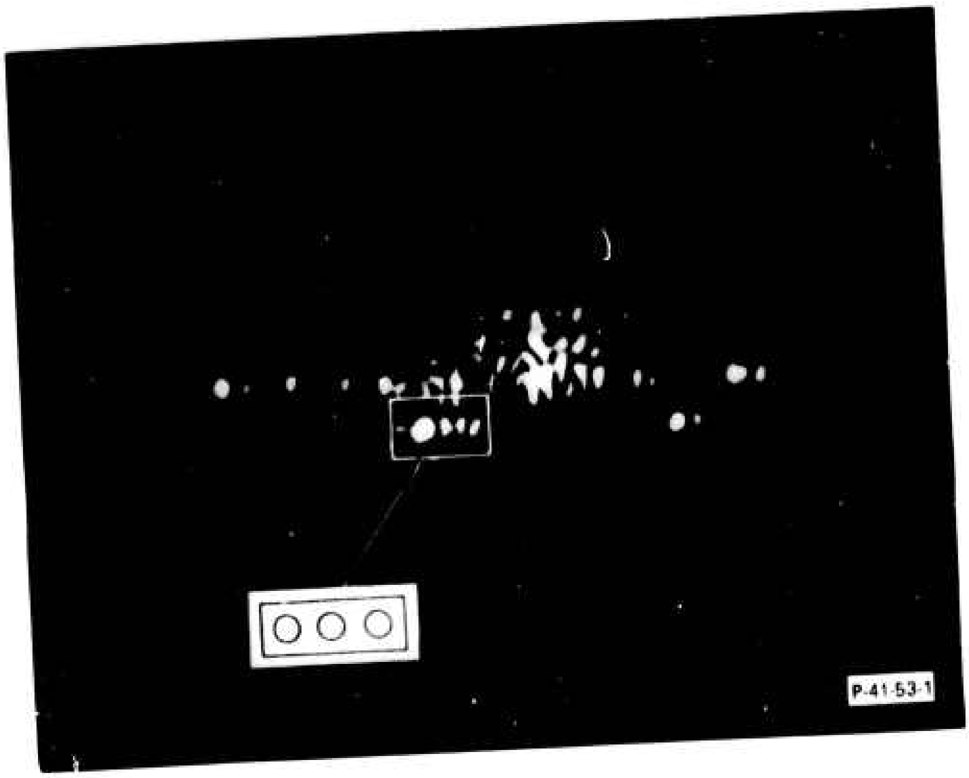

Figure 2-3 - Reconstruction of a 3-Disc Target - DC Removed

$$\sin\theta = 2/3, \quad \theta \gtrsim 42^\circ$$

The distance in the tank between object and array was 59" and thus the scale relationship between distances in Fig. 2-3 and distances in the object plane in the tank is

$$3.6 \text{ cm in photo} \equiv 59 \times (\tan\theta) \text{ in. in object plane}$$

$$\text{i.e., } 1 \text{ cm} \equiv \frac{1}{3.6} \times 59 \times \frac{2}{5} = 14.5 \text{ in.}$$

The object which was to be detected consisted of three discs which were 3" in diameter and placed with their centers 9" apart along a horizontal line. The overall separation of the centers of 18" is equivalent to 12.4 mm in the photographs shown in Figs. 2-2 and 2-3. With the expected resolution of the array (discussed below), the discs are expected to appear to be about 5" diameter ($\equiv$ 3.5 mm). The expected scale of the image of the three discs is shown in the inset of Figs. 2-2 and 2-3.

In the underwater experiment, the object was more or less on the axis of the array in the horizontal direction and was raised and lowered to give interference fringes on the CRT display, the fringes oriented at roughly $45^\circ$ to the array sides in the hologram. These fringes are due to interference between the internal reference and the object wave, and is reconstructed as the bright spot which appears on Fig. 2-3 about 11 mm. away from (above and to the right of) the central zero-order position (the cross). Because of the changes on the fringes obtained by moving the three-disc object bodily in the tank, this is clearly one of the discs. The apparent angle between the axis of the array and the reference for this experiment is $\tan^{-1}(1/6) \gtrsim 9\frac{1}{2}^\circ$. This is equivalent to a distance of $\sim$7 mm in Fig. 2-3 and thus we expect the image of the central disc to be around 7 mm to the right of the cross. Thus, since the bright disc is further from the cross than this, it is interpreted as the outer of the three discs. The three discs are represented by dotted lines on Fig. 2-5, an enlargement of the image information in Fig. 2-3.

Some of the other spots could perhaps be interpreted as diffraction from the central disc. However, they can be equally readily interpreted as "speckle" from the laser. The reason why the other two discs do not

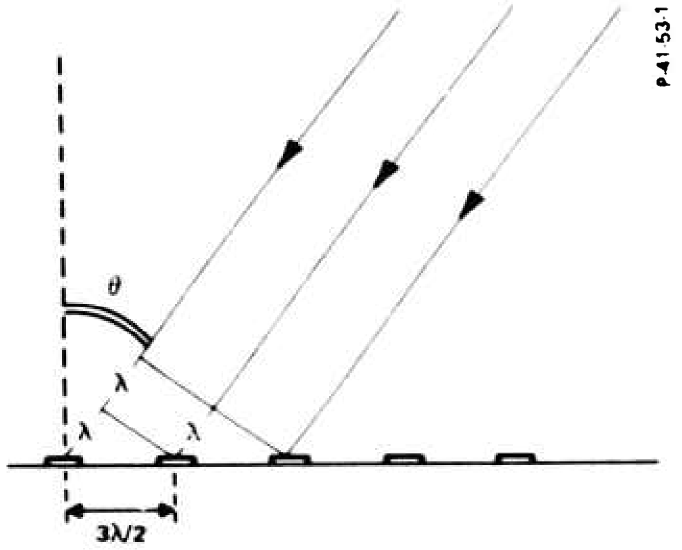

Figure 2-4 - Determination of Angle $\theta$ at Which First Lobe of Array Appears

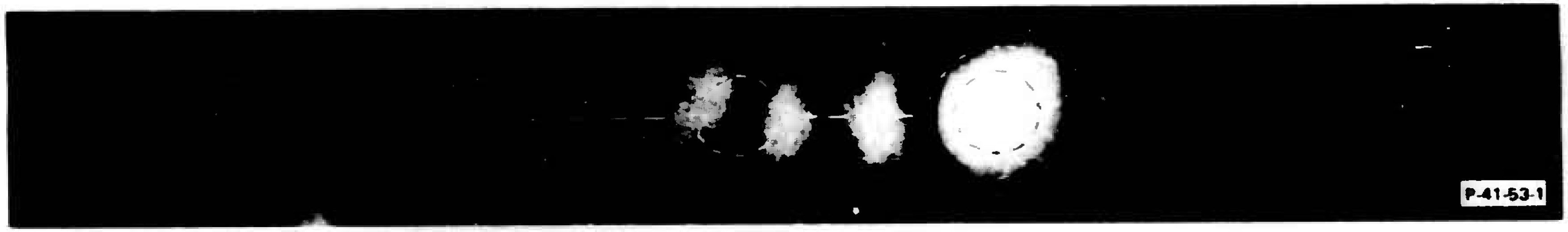

Figure 2-5 - Magnified Reconstructed Image of 3-Disc Target (from Fig. 2-3) give a specular return like that from one of the outer ones is fairly obvious when we examine Fig. 2-6, drawn to scale. When the object is set so that one disc gives a specular return, the specular returns from the other two discs are incident on the array.

The resolution expected for this experiment is very close to that observed experimentally, and shown in Fig. 2-5. The aperture function (MTF) for a square array is, in one of the dimensions,

$$A \; \frac{\sin\,(\pi a/\lambda\ \sin\phi)}{(\pi a/\lambda)\ \sin\phi}^{2}$$

where a is the array side (18 cm) and $\phi$ is the incident angle from the center. This function falls to 1/e when $(\pi a/\lambda)\ \sin \simeq \pi/2$. In the present experiment $a/\lambda = 30$ and thus $\phi = \sin^{-1}(1/60)$ is the theoretical angular resolution. At an object distance of 60" this represents an apparent widening of the object by 1" each side. Thus, we expect the image of the disc to be approximately 5" in diameter and only slightly distorted in shape. Such a disc is shown in Fig. 2-5 as the larger of the two concentric dotted circles. The observed resolution is seen to be very close to the theoretical resolution.

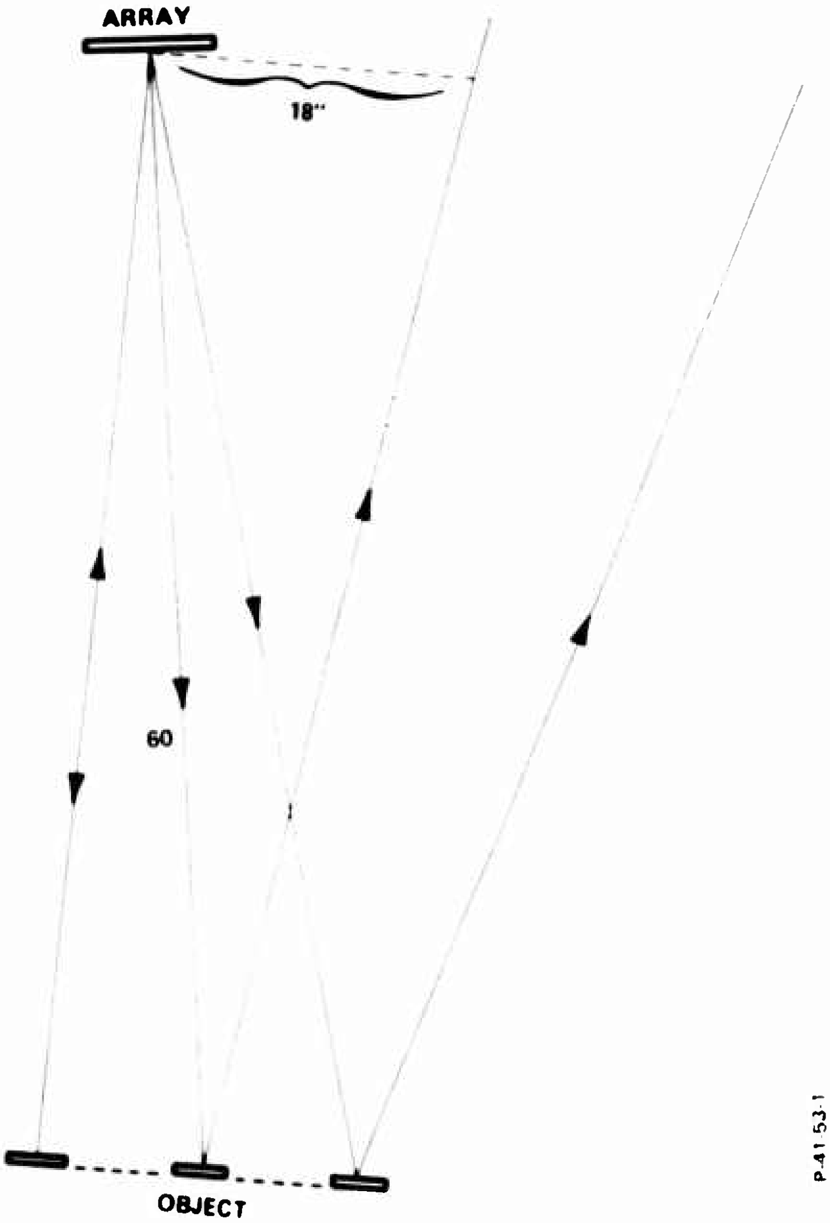

Figure 2-6 - Experimental arrangement to record hologram of 3-disc target

# SECTION 3

## SYNTHETIC APERTURE ANALYSIS

Several workers have shown that essentially equivalent holograms are obtained if the receiving element is scanned and the transmitting one is stationary or vice versa. A scanned system assumes, of course, that the target is quasi-stationary so that a phase instability of no more than $\pm\pi/4$ occurs during a scanning period.

The aperture area could be scanned by a single transducer; alternatively, it could be composed of a transducer array which can be operated in parallel (if identical electronic processing channels are provided for each transducer) or in sequence (if the target is stationary). High resolution image capability requires large apertures and thus a large number of elements. Scanning a large area in sequence is time-consuming and the requirement of stability does not always permit it. A compromise can be reached in which a relatively small array is operated in parallel and then scanned in its entirety. However, since it is seldom physically possible to displace a large array rapidly and accurately, we can consider displacing the transmitter an equal distance to the detection aperture.

Consider the duality of these alternatives. Let an object $f(u,v)$ be located at a distance D from the receiving array whose coordinates are $(x,y)$. Let the source be located in the same plane but at a point $(x_0,y_0)$, also a distance D from the object. The signal $g(x,y)$ scattered from the object $f(u,v)$ is:

$$g(x,y) = e^{i\frac{\pi}{\lambda D}} (u-x_0)^2 + (v-y_0)^2 \quad f(u,v)\, e^{i\frac{\pi}{\lambda D}} (x-u)^2 + (y-v)^2 \quad du\, dv. \qquad (1)$$

Rearranging terms yields

$$g(x,y) = e^{i\frac{\pi}{\lambda D}(x^2+y^2+x_0{}^2+y_0{}^2)} f(u,v)\, e^{i\frac{2\pi}{\lambda D}(u^2+v^2)} \qquad (2)$$

$$e^{-i\frac{2\pi}{\lambda D}} u(x_0+x) + v(y+y_0) \quad du\, dv.$$

One can easily see that scanning either the receiver (x,y) or the transmitter ($x_o$,$y_o$) will provide identical results since the integrand is symmetric in both x,$x_o$ and y,$y_o$.

Let us now investigate the case when the scanning is split between both transmitter and receiver (Fig. 3-1). Let the transmit array be composed of 5 x 5 elements located in the center of the coordinates:

$$\begin{array}{lcll} x_o = mA & & m & \\ & \text{with} & & = -2, -1, 0, 1, 2 \\ y_o = \bar{m}A & & \bar{m} & \end{array}$$

while the receive array is off axis with a spacing d between two consecutive rows or columns of detectors.

$$\begin{array}{lll} x = nd & n & \\ & & = -10, -9, \ldots 8, 9, 10 \\ y = -L + \bar{n}d & \bar{n} & \end{array}$$

and L is the offset of the center of the receive array from the center of the transmit array. If we were to use conventional scanning, we would have to scan only one of the elements; let us choose the source. A measure of comparison would be to determine how close the split-scanning arrangement comes to the single scanned element for which

$$\begin{array}{lcl} x_o = mA + nd & & x = 0 \\ & \text{and} & \\ y_o = \bar{m}A + \bar{n}d & & y = -L \end{array}$$

where m, m, n and n are as defined earlier. The phase term in the integrand will determine the similarity of the two approaches. Thus the phase difference $\phi$ is given by

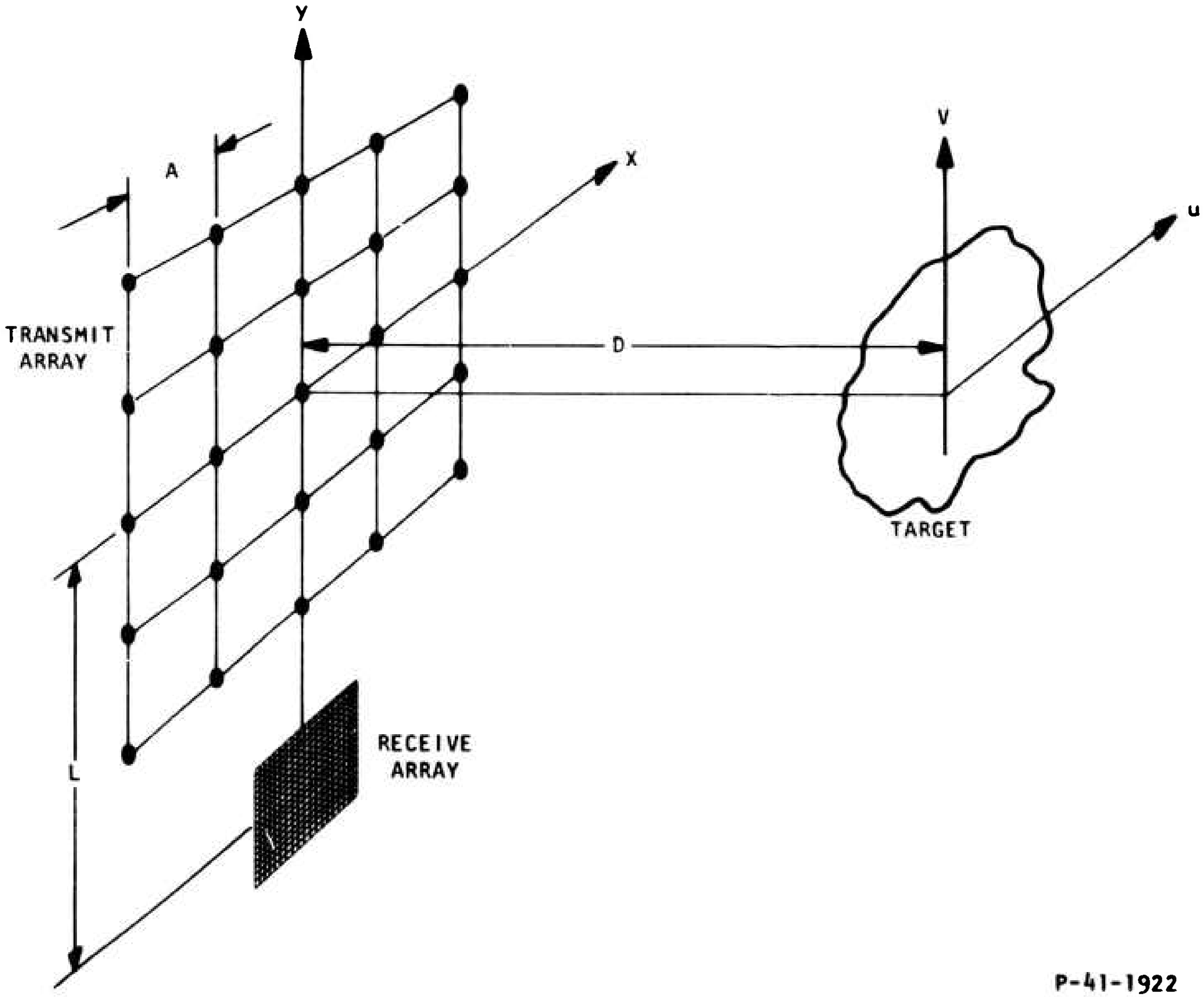

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Figure 3-1 - Source and receive arrays configuration

$$\frac{\lambda D}{\pi} = (u-mA-nd)^2 + (v-\bar{m}A=\bar{n}d)^2 + u^2 + (L+v)^2 \qquad (3)$$

$$- (u-mA)^2 + (v-\bar{m}A)^2 + (nd-u)^2 + (L+v-\bar{n}d)^2$$

which, upon reduction, becomes

$$\frac{\lambda D}{\pi}\phi = 2dA\,(nm + \overline{nm}) + 2\bar{n}dL. \qquad (4)$$

We thus see that within each "box" corresponding to a given activiated element $(m,\bar{m})$ of the transmit array, there is a correction to be added to the phase which is range dependent and linear in $n,\bar{n}$. This correction could be introduced during the recording of the hologram or during the reconstruction process.

Careful analysis of expression (4) indicates that:

- The slope of the linear function $\phi$ depends on the position of the source given by $(m,\bar{m})$. Thus, the constant lines are horizontal for all points along the y axis ($n=0$), and vertical for all points along the x axis ($\bar{n}=0$). Along the diagonal elements ($n=\bar{n}$) the lines run at an inclination of $45^\circ$.
- The phase changes more rapidly for points distanced further away from the origin.

Expression (4) reminds one of a zone plate, [illegible] differences being that the zones are linearized, and there is a lack of phase continuity when crossing the bos limits. For instance, at a crossing along a line parallel to the y axis, $\bar{n}$ and $\bar{m}$ are constant but m changes by a unit while n changes from +10 to -10.

If we choose to make the correction for this effect in the recording process, the electronic programming for the reference beam should allow the choice of various phase rates along the scanned coordinate. We do not anticipate the need to quantize the phase anymore than $45^\circ$ ($\pi/4$). On the other hand, if we computerize the electronic reconstruction system, the linear nonuniform phase correction can be introduced externally. An analog correction for these phase changes is also possible, i.e., by having a correction filter, composed of linear fringes of proper spacing and orientation or a 5 x 5 set of prisms, in contact and registration with the hologram.

The system in operation will require the activation of the source transducers in sequence. A full holographic recording is performed after each source activation. Thus, by the time that all the elements are activated, the complete $10^4$ sampled points in the aperture plane have been detected and displayed.

The receive-transmit array combination represents a nontrivial extension of synthetic aperture technology. The analysis performed makes it possible to predict and account for the position dependent phase corrections that are necessary for exact aperture synthesis.

# SECTION 4

# COHERENT LIGHT AREA MODULATOR

In the past year, large advances have been made toward the goal of obtaining real-time reconstructions from ultrasonic holograms. A number of approaches have been examined but the use of deuterated $KH_2PO_4$ (DKDP) to electro-optically modulate coherent light is the most promising and has received the most effort. In this approach, light is transmitted through a thin (0.5 mm) DKDP crystal and phase-modulated with holographic information placed on the crystal in the form of a charge pattern. Most of the work with the DKDP display tube has been of two types:

(1) Demonstrating that the required resolution (both at the crystal and in the image), contrast, and speed can be achieved; and obtaining actual reconstructed images.

(2) Increasing the reliability and expected life of the device.

In the first area of activity, all of the goals have been realized. A resolution on the crystal of over 270 lines has been demonstrated for crystals near the Curie temperature (100 lines required, 200 lines goal). Measurements of the temperature dependence of the crystal resolution show that well over 400 lines could be resolved at $T-T_C = 1^\circ C$ if a higher resolution electron gun was used. Even with room temperature operation, 100-line resolution can be achieved.

In earlier work, the quality in the image was severely limited by the flatness of the DKDP crystal. However, crystals that are less than $\lambda/2$ from flat have subsequently been obtained. Aperture-limited image quality can be achieved in the transmitted-light mode with mounting cement having the proper index of refraction. Operation with reflected light (which has several advantages) would require flatter crystals ($\approx \lambda/8$) for aperture-limited image quality.

The contrast between reconstructed images and the background noise is frequently poor in the case of ultrasonic holograms and careful filtering is often needed. Almost all of the background is scattered DC or zero-order light. It has been demonstrated both theoretically and experimentally that, with the KDP-type electro-optical modulation, it is possible to automatically filter out most of the DC light while passing almost all the image light. This is not possible with any of the other methods of real time holographic display that have been proposed.

The speed of the display tube is primarily determined by the current in the electron beam. Measurements have determined that a beam current of 2μA is required for real time operation at 16 frames/sec. While this can easily be achieved with a new electron-gun cathode, there are outgassing and dissociation products from the DKDP assembly which causes it to decrease its emission. Consequently, cathode life is a concern and will be discussed later. Actual real-time operation has not yet been demonstrated because of the limitations of the available electronics. The design and construction of new electronics which will permit real time operation are in progress.

Actual holographic reconstructions have been successfully obtained with the display tube. Several types of holograms have been tried, with computer generated binary holograms producing the best results. This is primarily because a TV camera was used to convert the holographic information on a photographic print to electrical signals which control the electron gun. The sensitivity of the camera varies at least 40% over the field of view so that the reconstructions from holograms with most of the information in the gray scale are severely degraded. Reconstructions were also obtained with an ultrasonic hologram from a 20 x 20 receiver array. They were very similar to those obtained with a transparency and the DC noise was less of a problem. All of the above results leave no question as to the feasibility of obtaining real time reconstructions from ultrasonic holograms with a DKDP display tube.

More recently, most of the effort has been concerned with the reliability and life of the display tube. Cracking of the DKDP crystals when cooled and operated near the Curie temperature was considered of prime importance. This cracking appears to be caused by a combination of piezoelectric and mechanical stresses. It is believed that this problem has been solved by changing the construction of the DKDP assembly to reduce mechanical stresses and by restricting the voltage when near the Curie temperature to limit the piezoelectric stresses. Further testing is needed to establish that the problem has been solved for operation near the Curie temperature ($T-T_C = 1^\circ C$), but there is little doubt that operating $5^\circ C$ or more above the Curie temperature is now quite safe.

The next most serious problem has been the life of the electron gun cathode. It has been reported that it is impossible to maintain an active oxide cathode in the presence of a KDP crystal. While serious cathode poisoning has been experienced with the display tube there were several other causes even more important than the DKDP. Elimination of several of them has significantly improved both cathode emission and life. No long-term life test have yet been conducted, but beam currents over 8μA have been obtained after over 500 hours of test operation with no evidence of cathode failure.

Another possible limitation on the life of the display tube is damage to the DKDP as a result of the electron bombardment. This damage can take at least four forms:

(1) Dissociation of the DKDP

(2) Decay of the secondary emission ratio ($\delta$)

(3) Production of color centers in the DKDP

(4) Ion migration through the DKDP

Films of $BaF_2$ or $CaF_2$ have been used as protective coatings on the DKDP, which also increase $\delta$. However, there will always be voids in these films so that damage to the DKDP as well as the protective coating must be considered.

Until recently, dissociation had been the major concern because of the expected harmful effects on the electron gun cathode. Recent tests suggest that as long as there is sufficient pumping on the tube this is not as serious a problem and may not be the final limit on tube life. Accelerated tests using high beam currents indicate that the decay in $\delta$ or the production of color centers could be more important limitations. These tests suggest the operating life of a DKDP crystal as limited by color center darkening would be at least 1600 hours. However, the decrease in $\delta$ would result in shorter life.

Accelerated tests with $CaF_2$ indicate that there is much less of a problem with decreases in $\delta$ but color centers may limit the life to under 1500 hours. These results are only preliminary, but they do indicate that a protective coating is desirable. However, further study is needed to find a coating that is much less prone to color center darkening and still has good secondary emission characteristics.

Ion migration is a potential problem near roon temperature operation. Damaging reactions with the conducting film has been reported as a result of ion migration during room temperature operation with a continuous field through the crystal. Also, ion migration would eventually cause sufficient stress to crack the crystal. This problem can be greatly reduced in two ways. Cooling the crystal to several tens of degrees below room temperature will greatly reduce the ion mobility and operating with the time average of the field in the crystal near zero (i.e., charge to a positive potential when writing and to a negative potential when erasing) will greatly reduce the net drift.

Efforts to improve the life and reliability of the display tube need to continue and more life test must be conducted. However, the present evidence leaves little doubt that a DKDP display tube can be constructed which can be kept operational by part replacements at reasonable intervals.

**For completeness, the results of the investigation of two other approaches to real time holographic display should be briefly covered. Both appear to have the potential of resulting in a simple reliable device. The first involves the use of a thin film membrane supported over an optically flat surface with many small holes or depressions in it. The membrane is deflected by electrostatic forces between it and the bottom or sides of the depressions. A scanning electron gun writes a charge pattern which determines the local forces and, consequently, deflection of the membrane. Light reflected from the membrane is modulated by the deflection pattern. This approach received considerable effort but work on it has been suspended. With present techniques, it does not appear likely that thin film membranes can be reliably mounted with the flatness required ($\gtrsim \lambda/8$) for holographic applications.**

The second approach involves the use of cathodochromic or photochromic materials. These materials are darkened directly by electron bombardment (cathodochromic) or indirectly (photochromic) through the use of a light emitting phosphor. The available data on many of these materials was examined and a number of the more promising cathodochromic materials were experimentally studied. The conclusion was that all materials of this type presently available either bleach too slowly for real time operation or have insufficient contrast. The physical requirements for fast bleaching and good contrast are in conflict. Therefore, an extensive materials research program would be required to develop materials with the desired characteristics with no guarantee of success. Consequently, efforts on this approach have also been suspended.

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13. ABSTRACT

A summary of the work accomplished during calender 1970 is presented in this report. Accomplishments include completion of the design and construction of the experimental underwater viewing system and initial experiments to evaluate its performance. Demonstrations of the system were made for ONR, Naval Ships, and NUWC personnel. Progress in the development of the coherent light area modulator, to be used for reconstruction of acoustic holograms, is also reported.

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