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A PDP-8 Fortran Program for Near-Field Array Testing

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ABSTRACT

A FORTRAN program has been developed for a small digital computer (PDP-8) to investigate theoretically the effect of irregularities in the positions of transducer elements in an acoustic "near-field" array. Details of the program are discussed and representative computer runs are presented.

PROBLEM STATUS

This is an interim report on the problem.

PROBLEM AUTHORIZATION

NRL Problem S02-30

Project RF 101-03-47-4471

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A PDP-8 FORTRAN PROGRAM FOR NEAR-FIELD ARRAY TESTING

INTRODUCTION

The design of near-field arrays for measurement applications is a subject of strong current interest in underwater acoustics [1]. One of the practical problems that arises in assembling such an array is the tolerance that must be maintained in positioning the individual elements. This problem has been investigated by simulation with a small digital computer. The basic approach has been to evaluate the performance of the array by computing:

(a) The sound field at selected field points when the array elements are positioned exactly.

(b) The sound field for the same field points, but with the positions of the elements subjected to some selectable perturbation.

The FORTRAN program is directed to solving the following problem:

(a) Accept the constants of the near-field array (number of elements, distance between elements, shading coefficient for each element, operating frequency, etc.).

(b) Accept a description of the number and position for the field points of interest in a particular computer run.

(c) Allow an operating option for specifying the positions of the elements as theoretically exact, or for accepting a description of a position-perturbing scheme for the elements.

(d) Perform the computations in terms of the information accepted in steps (a), (b), and (c).

DERIVATION OF THE PROGRAM

In this particular program, the acoustical near-field array has 2500 elements arranged as a 50x50 square array. Minor modifications to this program would adapt it to arrays of other dimensions. Because there is an even number (50) of rows and columns, there is no central row and no central column. For the same reason, the 50 rows and columns are numbered from -49 to +49 in steps of 2. In the FORTRAN program, the numbering variable for the rows is tagged KV, and for the columns the tag is KH; these are treated as integers, which may be positive or negative.

The computations are made with reference to a Cartesian system of coordinates with the origin at the center of the array. The plane of the

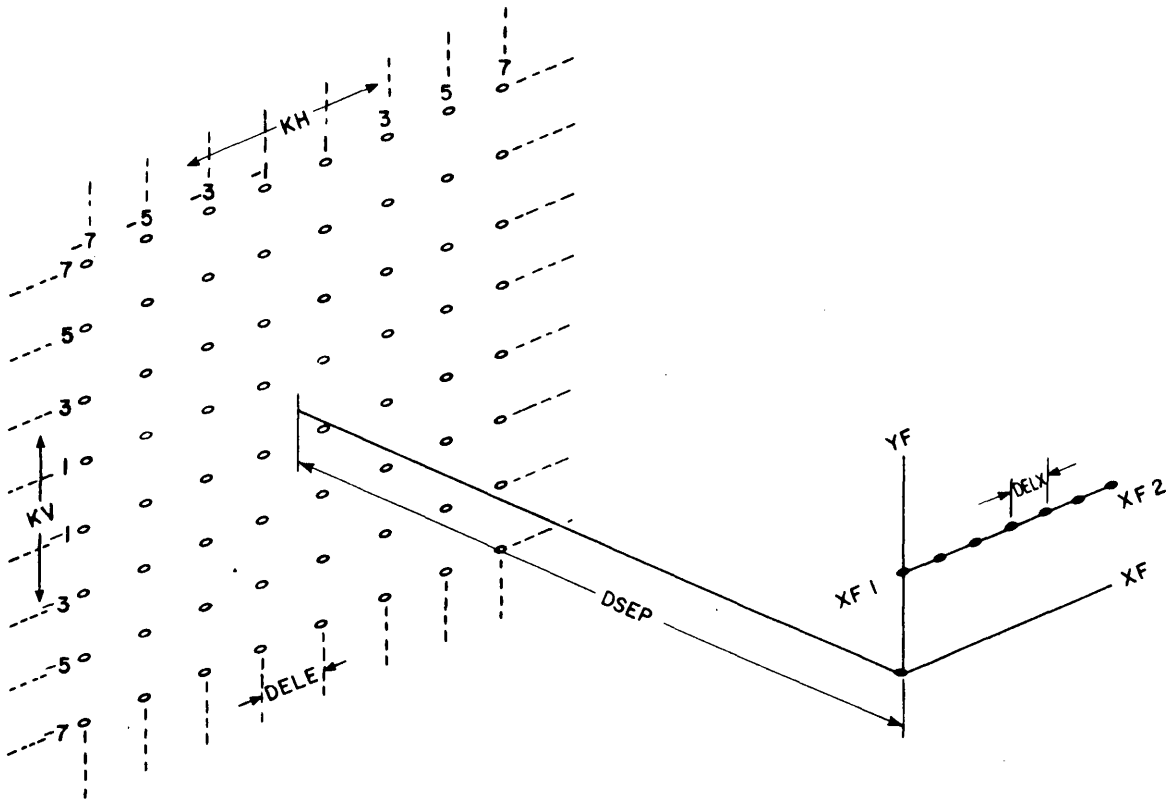


Fig. 1. Coordinate System

array lies in the xy plane. As shown by Fig. 1, KH is measured along the x axis and KV along the y axis. The sound field is computed for a number of points along a line parallel to the x axis in a plane that is parallel to that of the array. The separation distance between these two planes is tagged DSEP (see Fig. 1); it is a line segment along the z axis. At each field point of interest (x_f, y_f, z_f) the sound pressure is evaluated for each of the array elements according to the basic propagation equation for a point source

$$dp \text{ at } (x_f, y_f, z_f) = AW_i[\exp(-jkr_i)]/r_i, \tag{1}$$

so that, by superposition, the total pressure is

$$p \text{ at } (x_f, y_f, z_f) = A \sum_{i=1}^{N} W_i[\exp(-jkr_i)]/r_i. \tag{2}$$

In these equations, A is a proportionality constant that need not be evaluated, inasmuch as the computed values are to be examined on a relative basis only; W_i is the shading coefficient for the i-th element; N is the total number of array elements; r_i is the distance from the i-th element to the field point, a variable for each element; and k is the

wavenumber $2\pi f/c$, where f is the frequency and c is the speed of sound in the water. For distances measured in inches, k has the value $0.106966(10^{-3})f$. Each value computed by Eq. (2) will be a complex number representing the magnitude and phase angle of the sound pressure at the particular point.

The type of shading used in this program has been called circular by Trott [1]. The shading for a particular element is taken as the product of the shading due to its row number times the shading due to its column. For shading purposes, the row and column numbers are positive consecutive integers that run from 1 to 25, or, more correctly, from 25 down to 1 and then from 1 up to 25. These latter row and column numbers are used as the subscripts J and I, respectively, for the subscripted variable SHAD that is the FORTRAN tag for the array of shading coefficients. The shading coefficients are introduced into each computer run as entries at the Teletype keyboard (or preferably as a section of perforated paper tape that is read on the paper tape reader) in response to the program's first request: READ SHADING TAPE.

For the computations, Eq. (2) is separated into its real and imaginary parts:

$$\mathrm{Re}(p) \text{ at } (x_f, y_f, z_f) = A \sum_{i=1}^{N} W_i (\cos kr_i)/r_i \tag{3a}$$

$$\mathrm{Im}(p) \text{ at } (x_f, y_f, z_f) = -A \sum_{i=1}^{N} W_i (\sin kr_i)/r_i . \tag{3b}$$

Subsequently, the magnitude of the sound pressure and its phase angle are determined by

$$|p| = [\mathrm{Re}(p)]^2 + [\mathrm{Im}(p)]^2, \tag{4a}$$

$$\phi = \tan^{-1} [\mathrm{Im}(p)/\mathrm{Re}(p)]. \tag{4b}$$

The rest of the FORTRAN program is largely self-explanatory; special features are discussed in Appendix A. The program itself is given in Appendix B.

A second version of the FORTRAN program was developed and used to compute sound pressures at points on a line normal to the plane of the array. In the second version (but <u>not</u> in the first), each computed phase angle is normalized by adding the angle kz, where -kz is the phase angle due to an equivalent plane wave. The result is that final phase angles computed by the second program represent the variation from a plane wave. This normalization is introduced in the FORTRAN program by the statement 30; PHSE = PHSE + WNUM*Z.

RESULTS OF THE COMPUTATIONS

The direct result of the computations was, of course, a listing of numbers that showed the relative magnitude and phase angle of the sound pressure at the selected field points. In a companion program, a modification of PDP-5 PLOT program [2], the Teletype machine was used as a plotter for graphical presentation of the results. The Teletype plots to the accuracy of one character space (0.1 inch) only; for detailed and more precise analysis it is necessary to examine the numerical listings.

Table 1a. SUMMARY OF DATA PRESENTED. Sound pressure on a line in a plane parallel to the plane of the array (all distances in inches).

Fig. No. Table No.	Kind of Array	Horiz. Pertur-bation	Vert. Pertur-bation	x range and Increment	Separation between Planes
2	uniform, normal	none	none	0--240 (10)	30
3	shaded, normal	none	none	0--240 (10)	30
4	shaded, perturbed	.125 15	.125 7	0--240 (10)	30
5	shaded, perturbed	none	.125 -50	0--240 (10)	30
6	shaded, normal	none	none	0--240 (10)	35.874*
7	shaded, perturbed	.125 15	.125 7	0--240 (10)	35.874
8	shaded, perturbed	none	.125 -50	0--240 (10)	35.874

*35.874 inches is equivalent to 30 inches plus a half wavelength.

Table 1b. SUMMARY OF DATA PRESENTED. Sound pressure on a line normal to the plane of the array (all distances in inches)

Fig. No. Table No.	Kind of Array	Horiz. Pertur-bation	Vert. Pertur-bation	z range and Increment	Paraxial Line x,y
9	uniform, normal	none	none	10--400 (10)	(0,0)
10	shaded, normal	none	none	20--800 (20)	(0,0)
11	shaded, perturbed	.125 15	.125 7	20--800 (20)	(0,0)
12	shaded, perturbed	none	.125 -50	20--800 (20)	(0,0)

A summary of the data presented is given in Tables 1a and 1b. Typical results are shown in Tables 2-12 and Figs. 2A-12B. Plots in which X is used as the symbol are amplitude plots in dB; those in which ϕ appears are phase plots in degrees. The corresponding tabulations as well as the constants for each computational run are shown in the tables. In these tables, the three columnar tabulations are, respectively:

(1) x_f, the x coordinate of the field points.

(2) The relative magnitude (in dB) of the sound pressure as a function of x_f.

(3) The relative phase angle (in degrees) of the sound pressure as a function of x_f.

Above these tabulations on each Table are the constants that are used for the particular run as typed in by the operator in response to the computer's requests. These requests are explained below and identified as (a) through (g):

(a) READ SHADING TAPE
(b) 1 IS NORMAL, 2 IS PERTURBED
(c) HOR-PERT & START COLUMN:
(d) VER-PERT & START ROW:
(e) FREQ & DELE:
(f) DSEP & FIELD-Y:
(g) X-RANGE & INCR:

The numbers following request (a) are the 25 shading coefficients. The number following request (b) selects the mode of computation--"normal" or "perturbed"; when 1 is typed, the program skips requests (c) and (d).

Request (c) asks the operator to introduce the selected perturbation of the element positions. Two numbers are expected here by the program. First, the incremental shift (entered as a fraction of the half-distance between elements) in the positioning of the columns; second, the column number beyond which the perturbation begins to take effect. The effect on the geometry of the simulated array is that the first perturbed column of the array is shifted to the right by the specified incremental distance For subsequent columns in the array, the selected increment between the affected columns alternately changes sign.

The total result of request (c) is that up to and including a selected column number (remenber that they are numbered -49 to +49 in steps of 2), the columns are evenly spaced; beyond the selected column, half of the remaining columns are shifted to the <u>right</u> (along the positive x axis) by a given amount, the other half are shifted to the <u>left</u> (along the negative x direction). For example, when ".125 15" is typed by the operator in response to request (c), the program will treat columns -49 through 15 as positioned exactly, column 17 will be shifted $\frac{1}{2}$ inch to the right (0.125 times half the 8-inch separation between elements), column 19 will be shifted $\frac{1}{2}$ inch to the left, and so forth for the rest of the columns.

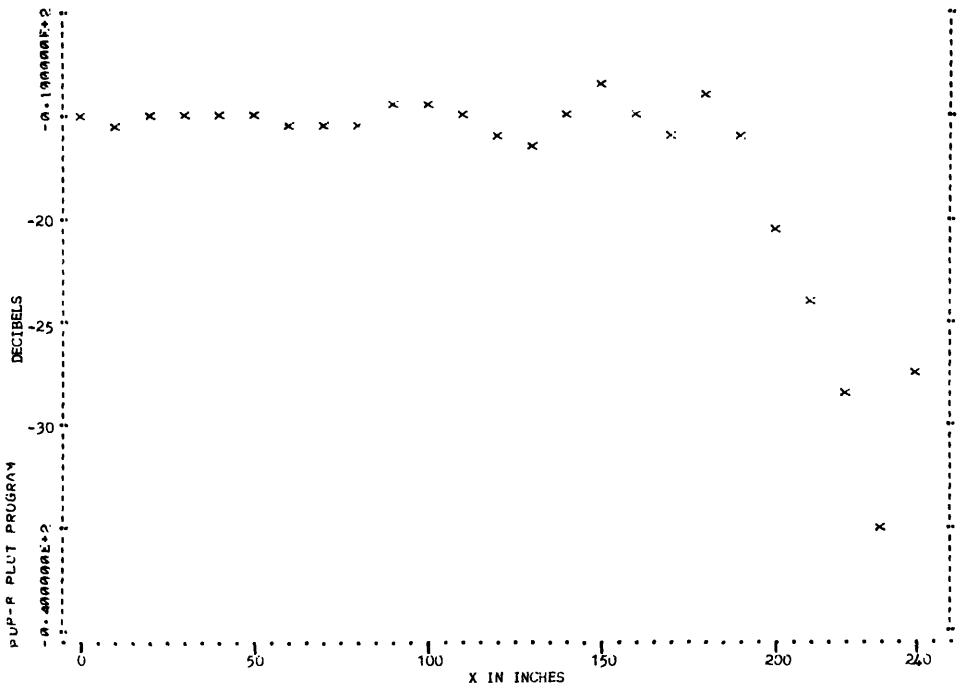
Request (d) performs the same function for the array rows that request (c) performs for the columns.

Request (e) asks for two numbers--the frequency in hertz and the separation distance in inches between elements.

TABLE 2

```
READ SHADING TAPE
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 IS NORMAL, 2 IS PERTURBED
1
FREQ & DELE:  5000  8
DSEP & FIELD-Y:  30  0
X-RANGE & INCR:  0  TO  240  10

+0.000000E+0     -0.147541E+2     +0.493496E+2
+0.100000E+2     -0.150629E+2     +0.527567E+2
+0.200000E+2     -0.149167E+2     +0.645115E+2
+0.300000E+2     -0.146585E+2     +0.705676E+2
+0.400000E+2     -0.147919E+2     +0.670708E+2
+0.500000E+2     -0.146408E+2     +0.560121E+2
+0.600000E+2     -0.151095E+2     +0.492223E+2
+0.700000E+2     -0.152681E+2     +0.500726E+2
+0.800000E+2     -0.151619E+2     +0.628972E+2
+0.900000E+2     -0.144049E+2     +0.696715E+2
+0.100000E+3     -0.140632E+2     +0.672114E+2
+0.110000E+3     -0.148176E+2     +0.555134E+2
+0.120000E+3     -0.157048E+2     +0.476979E+2
+0.130000E+3     -0.162261E+2     +0.572938E+2
+0.140000E+3     -0.145654E+2     +0.662946E+2
+0.150000E+3     -0.132306E+2     +0.597028E+2
+0.160000E+3     -0.149630E+2     +0.528374E+2
+0.170000E+3     -0.159043E+2     +0.721862E+2
+0.180000E+3     -0.137329E+2     +0.548439E+2
+0.190000E+3     -0.155589E+2     +0.762412E+2
+0.200000E+3     -0.203940E+2     +0.534651E+2
+0.210000E+3     -0.236242E+2     -0.834214E+1
+0.220000E+3     -0.283565E+2     -0.155395E+3
+0.230000E+3     -0.349285E+2     +0.130078E+2
+0.240000E+3     -0.274438E+2     +0.155142E+3
```



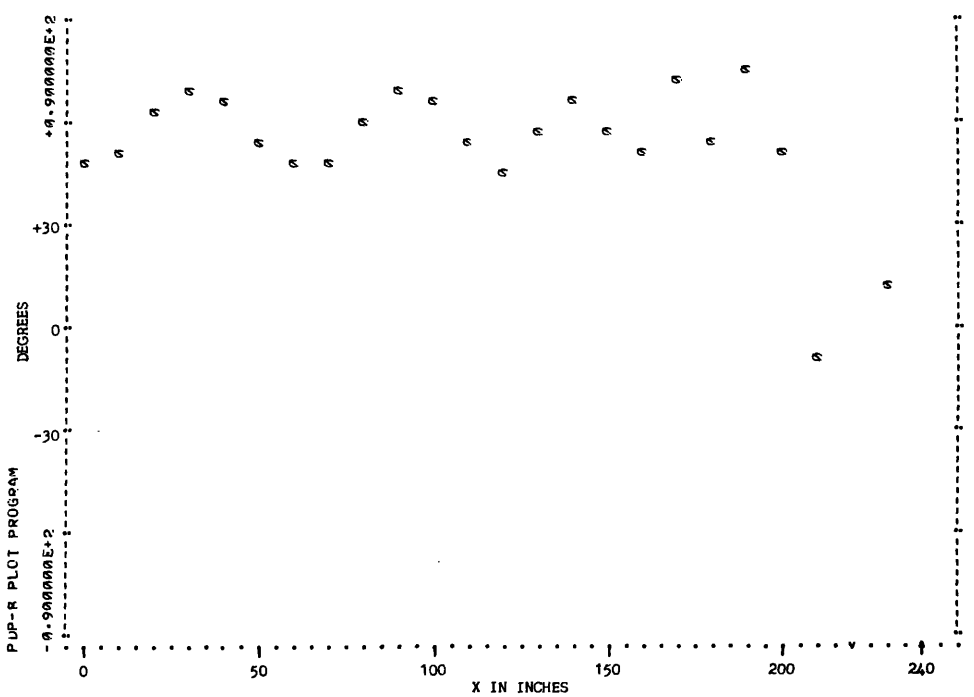
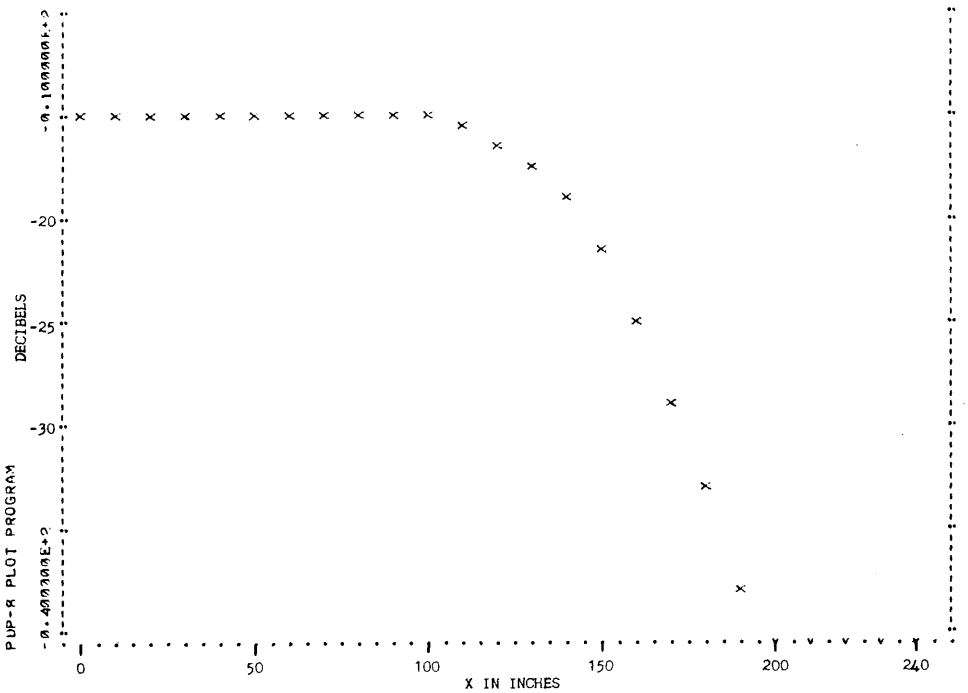


Fig. 2A (top). Sound pressure plot.
Fig. 2B (bottom). Phase plot.

TABLE 3

```
READ SHADING TAPE
1  1  1  1  1  1  1  1  1  .995  .989  .978  .957  .924  .874  .804  .716  .612  .500
.388  .248  .196  .126  .076  .042
1  IS NORMAL, 2 IS PERTURBED
1
FREQ & DELE:   5000   8
DSEP & FIELD-Y:  30   0
X-RANGE & INCR:   0   TO   240   10

+0.000000E+0     -0.145517E+2     +0.701485E+2
+0.100000E+2     -0.145944E+2     +0.702386E+2
+0.200000E+2     -0.146818E+2     +0.704778E+2
+0.300000E+2     -0.147319E+2     +0.707448E+2
+0.400000E+2     -0.146803E+2     +0.707854E+2
+0.500000E+2     -0.145904E+2     +0.703657E+2
+0.600000E+2     -0.145446E+2     +0.700096E+2
+0.700000E+2     -0.146309E+2     +0.699964E+2
+0.800000E+2     -0.147649E+2     +0.705807E+2
+0.900000E+2     -0.148732E+2     +0.714440E+2
+0.100000E+3     -0.149630E+2     +0.713086E+2
+0.110000E+3     -0.153483E+2     +0.702337E+2
+0.120000E+3     -0.162251E+2     +0.699480E+2
+0.130000E+3     -0.173162E+2     +0.719319E+2
+0.140000E+3     -0.186709E+2     +0.707052E+2
+0.150000E+3     -0.212634E+2     +0.719717E+2
+0.160000E+3     -0.246088E+2     +0.674359E+2
+0.170000E+3     -0.287724E+2     +0.667098E+2
+0.180000E+3     -0.326200E+2     +0.693453E+2
+0.190000E+3     -0.375833E+2     +0.572064E+2
+0.200000E+3     -0.455086E+2     +0.785888E+2
+0.210000E+3     -0.526335E+2     -0.781294E+2
+0.220000E+3     -0.607339E+2     -0.728488E+2
+0.230000E+3     -0.551479E+2     +0.479349E+2
+0.240000E+3     -0.535223E+2     +0.155098E+3
```



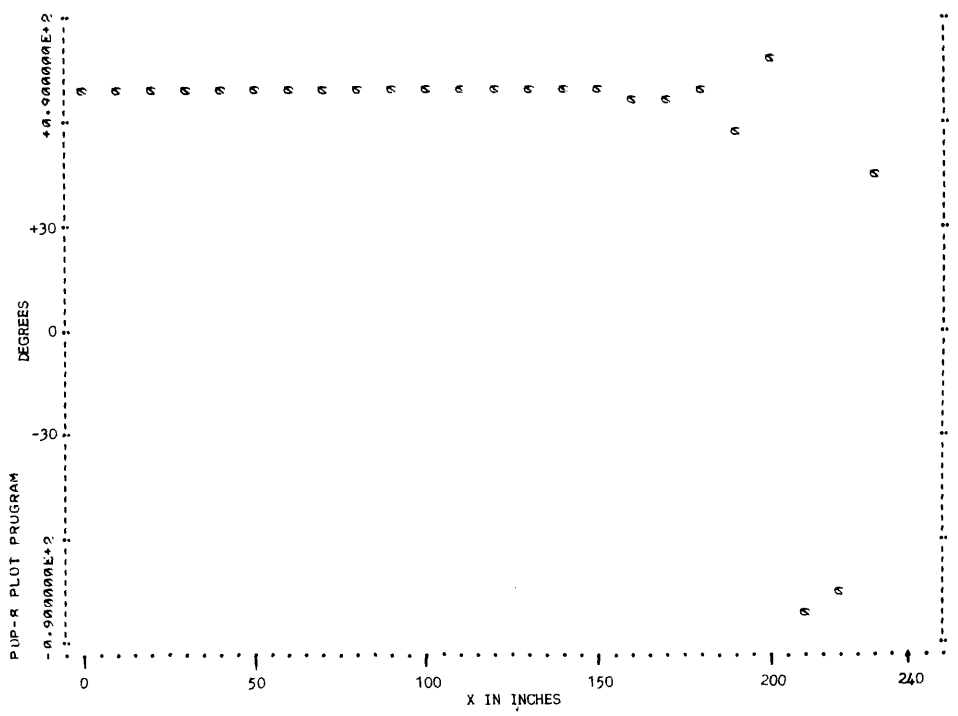
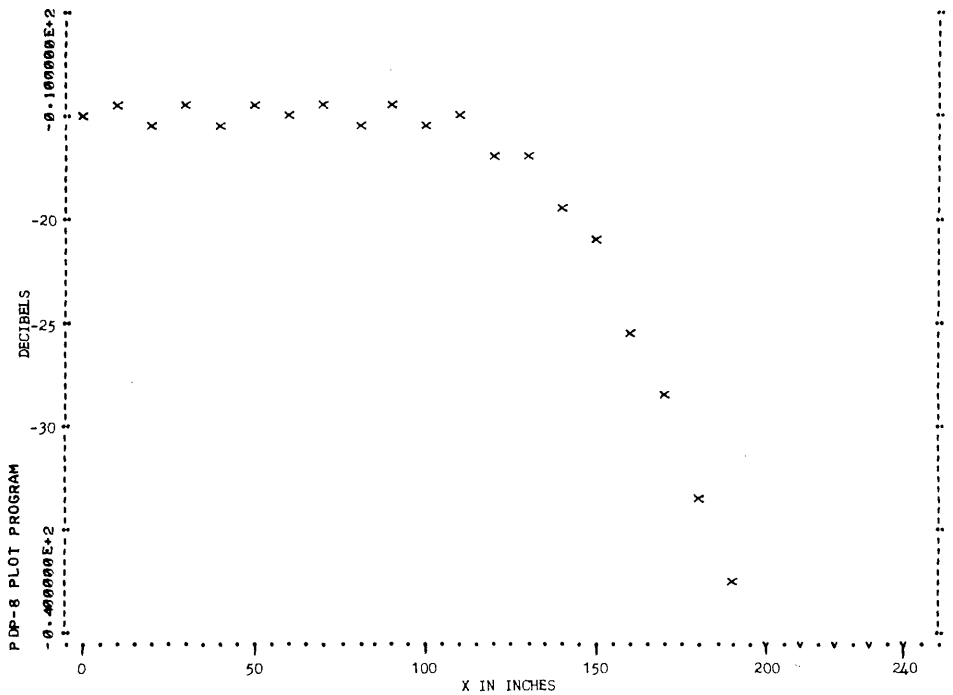


Fig. 3A (top). Sound pressure plot.
Fig. 3B (bottom). Phase plot.

TABLE 4

```
READ SHADING TAPE
1 1 1 1 1 1 1 1 1 .995 .989 .978 .957 .924 .874 .804 .716 .612 .500
.388 .248 .196 .126 .076 .042
1 IS NORMAL, 2 IS PERTURBED  2
HOR-PERT & START COLUMN: .125  15
VER-PERT & START ROW: .125 7
FREQ & DELE:  5000  8
DSEP & FIELD-Y:  30  0
X-RANGE & INCR:  0  240  10
+0.000000E+0     -0.148613E+2     +0.797552E+2
+0.100000E+2     -0.140613E+2     +0.613845E+2
+0.200000E+2     -0.150115E+2     +0.804902E+2
+0.300000E+2     -0.141170E+2     +0.623705E+2
+0.400000E+2     -0.150025E+2     +0.809032E+2
+0.500000E+2     -0.140386E+2     +0.624309E+2
+0.600000E+2     -0.149717E+2     +0.799343E+2
+0.700000E+2     -0.141101E+2     +0.615727E+2
+0.800000E+2     -0.151730E+2     +0.801103E+2
+0.900000E+2     -0.143257E+2     +0.628489E+2
+0.100000E+3     -0.153255E+2     +0.810487E+2
+0.110000E+3     -0.148031E+2     +0.617475E+2
+0.120000E+3     -0.165337E+2     +0.800802E+2
+0.130000E+3     -0.167860E+2     +0.637543E+2
+0.140000E+3     -0.190070E+2     +0.800260E+2
+0.150000E+3     -0.207995E+2     +0.624202E+2
+0.160000E+3     -0.250033E+2     +0.754100E+2
+0.170000E+3     -0.283843E+2     +0.586033E+2
+0.180000E+3     -0.330631E+2     +0.805385E+2
+0.190000E+3     -0.372597E+2     +0.550096E+2
+0.200000E+3     -0.455703E+2     +0.849087E+2
+0.210000E+3     -0.533874E+2     -0.431437E+2
+0.220000E+3     -0.583470E+2     -0.123779E+2
+0.230000E+3     -0.503232E+2     +0.529350E+2
+0.240000E+3     -0.497647E+2     +0.145765E+3
```



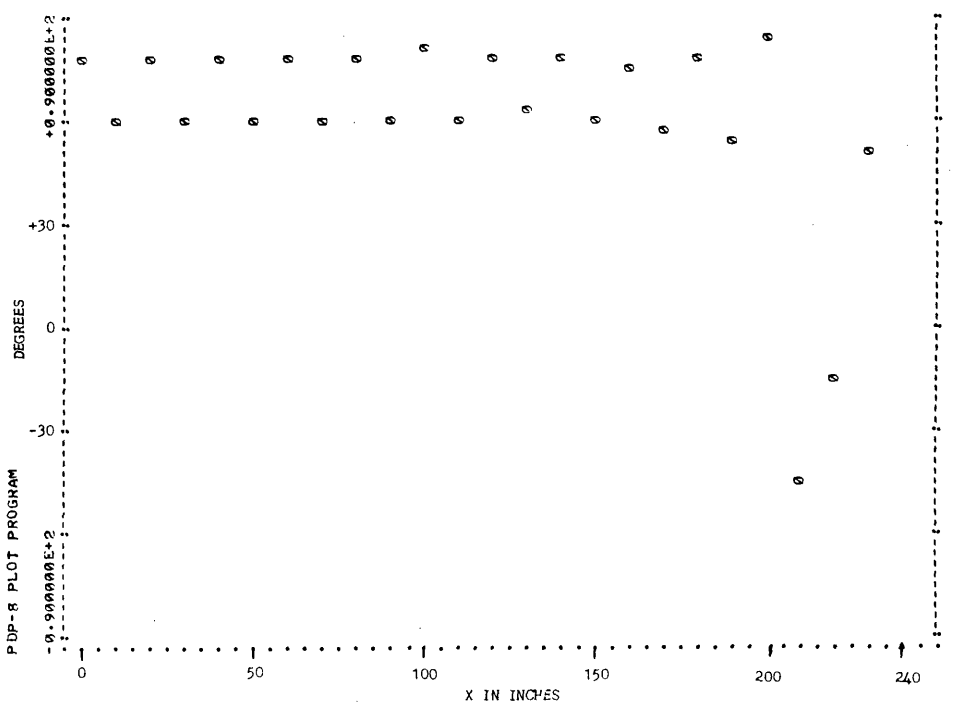


Fig. 4A (top). Sound pressure plot.
Fig. 4B (bottom). Phase plot.

TABLE 5

```
READ SHADING TAPE
1 1 1 1 1 1 1 1 1 .995 .989 .978 .957 .924 .874 .804 .716 .612 .500
.388 .248 .196 .126 .076 .042
1 IS NORMAL, 2 IS PERTURBED
2
HOR-PERT & START COLUMN: 0  0
VER-PERT & START ROW: .125  -50
FREQ & DELE:  5000  8
DSEP & FIELD-Y:  30  0
X-RANGE & INCR:  0  TO  240  10

+0.000000E+0     -0.120095E+2     +0.481547E+2
+0.100000E+2     -0.120265E+2     +0.481535E+2
+0.200000E+2     -0.121069E+2     +0.481167E+2
+0.300000E+2     -0.121521E+2     +0.482784E+2
+0.400000E+2     -0.121089E+2     +0.483170E+2
+0.500000E+2     -0.120509E+2     +0.482567E+2
+0.600000E+2     -0.119656E+2     +0.480849E+2
+0.700000E+2     -0.120737E+2     +0.479230E+2
+0.800000E+2     -0.121510E+2     +0.482901E+2
+0.900000E+2     -0.123443E+2     +0.487026E+2
+0.100000E+3     -0.123995E+2     +0.492253E+2
+0.110000E+3     -0.127944E+2     +0.481710E+2
+0.120000E+3     -0.135411E+2     +0.482560E+2
+0.130000E+3     -0.148099E+2     +0.490401E+2
+0.140000E+3     -0.160857E+2     +0.491341E+2
+0.150000E+3     -0.188044E+2     +0.494009E+2
+0.160000E+3     -0.219419E+2     +0.451351E+2
+0.170000E+3     -0.262080E+2     +0.428453E+2
+0.180000E+3     -0.301561E+2     +0.478479E+2
+0.190000E+3     -0.345892E+2     +0.391228E+2
+0.200000E+3     -0.471472E+2     +0.507705E+2
+0.210000E+3     -0.516438E+2     -0.664466E+2
+0.220000E+3     -0.541503E+2     -0.110726E+3
+0.230000E+3     -0.500673E+2     +0.542536E+2
+0.240000E+3     -0.521346E+2     -0.173770E+3
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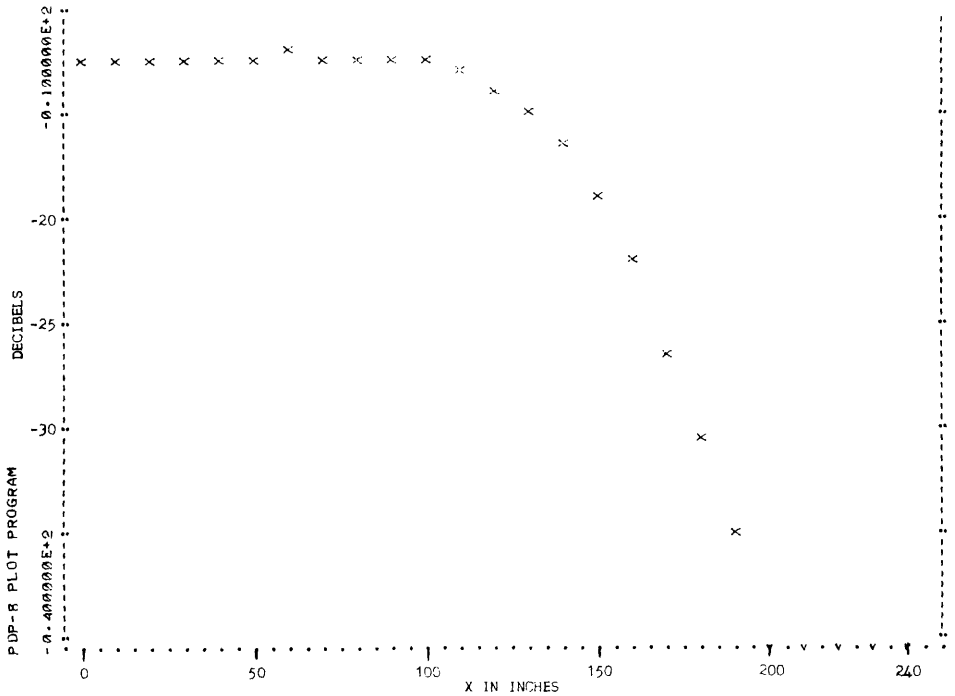


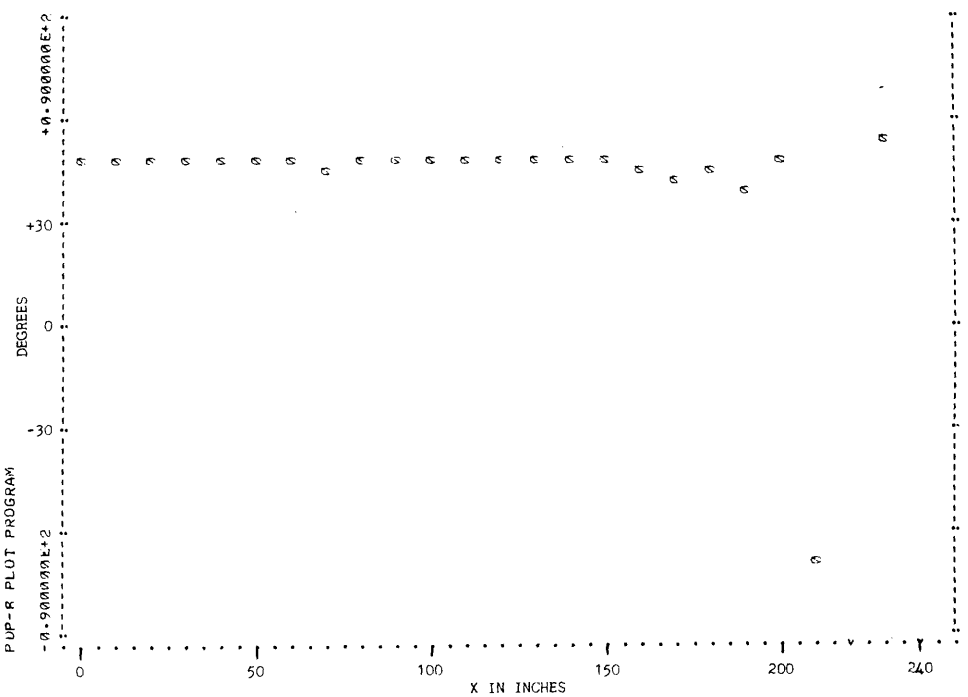
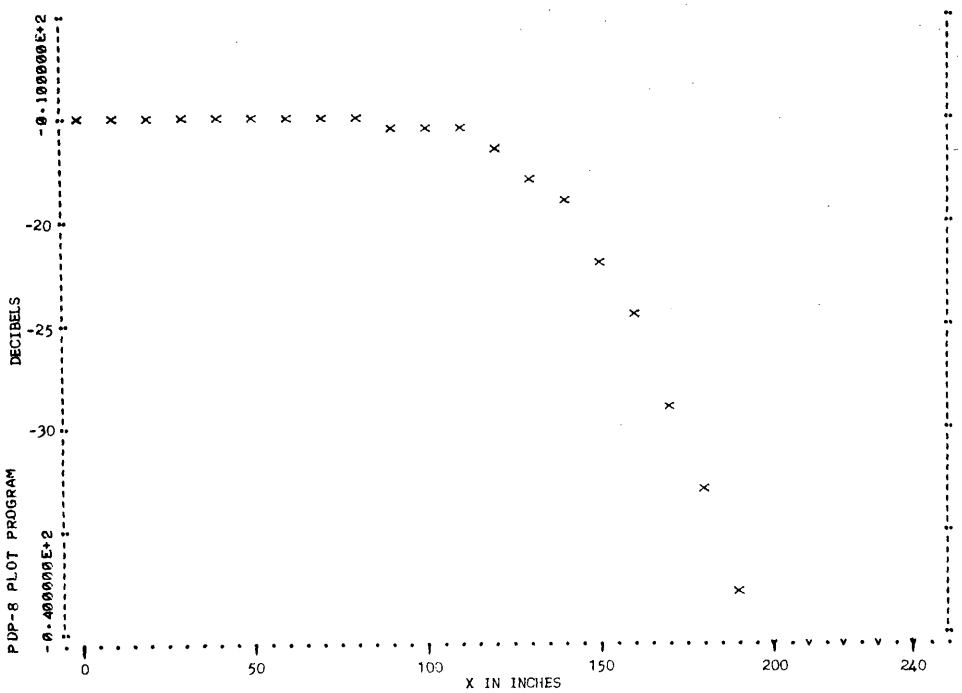


Fig. 5A (top). Sound pressure plot.
Fig. 5B (bottom). Phase plot.

TABLE 6

```
READ SHADING TAPE
1 1 1 1 1 1 1 1 1 .995 .989 .978 .957 .924 .874 .804 .716 .612 .500
.388 .248 .196 .126 .076 .042
1 IS NORMAL, 2 IS PERTURBED
1
FREQ & DELE:  5000  8
DSEP & FIELD-Y:  35.874  0
X-RANGE & INCR:  0  TO  240  10

+0.000000E+0     -0.148330E+2     -0.108071E+3
+0.100000E+2     -0.147972E+2     -0.108355E+3
+0.200000E+2     -0.147389E+2     -0.108981E+3
+0.300000E+2     -0.147333E+2     -0.109385E+3
+0.400000E+2     -0.147855E+2     -0.109056E+3
+0.500000E+2     -0.148196E+2     -0.108345E+3
+0.600000E+2     -0.147900E+2     -0.107842E+3
+0.700000E+2     -0.147474E+2     -0.108318E+3
+0.800000E+2     -0.148031E+2     -0.109248E+3
+0.900000E+2     -0.150125E+2     -0.109273E+3
+0.100000E+3     -0.152178E+2     -0.107980E+3
+0.110000E+3     -0.154604E+2     -0.107264E+3
+0.120000E+3     -0.161711E+2     -0.108472E+3
+0.130000E+3     -0.175903E+2     -0.107945E+3
+0.140000E+3     -0.189699E+2     -0.108220E+3
+0.150000E+3     -0.215079E+2     -0.107836E+3
+0.160000E+3     -0.244243E+2     -0.112485E+3
+0.170000E+3     -0.285730E+2     -0.113131E+3
+0.180000E+3     -0.326473E+2     -0.106798E+3
+0.190000E+3     -0.377274E+2     -0.113332E+3
+0.200000E+3     -0.550012E+2     -0.100292E+3
+0.210000E+3     -0.471247E+2     +0.149106E+3
+0.220000E+3     -0.591369E+2     -0.103984E+3
+0.230000E+3     -0.557833E+2     -0.619374E+2
+0.240000E+3     -0.546844E+2     +0.491484E+2
```



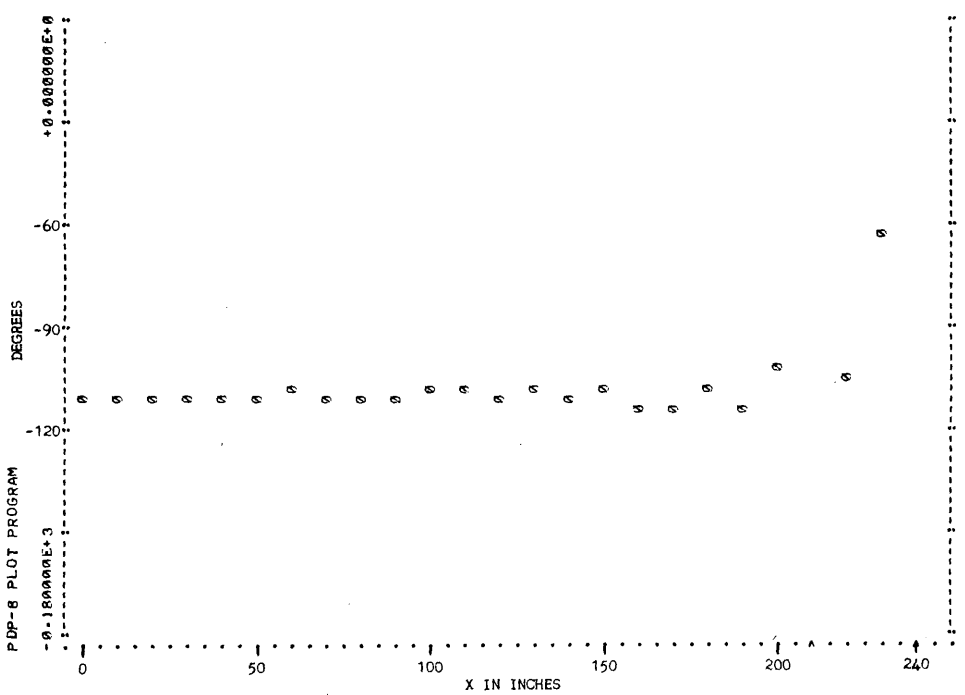
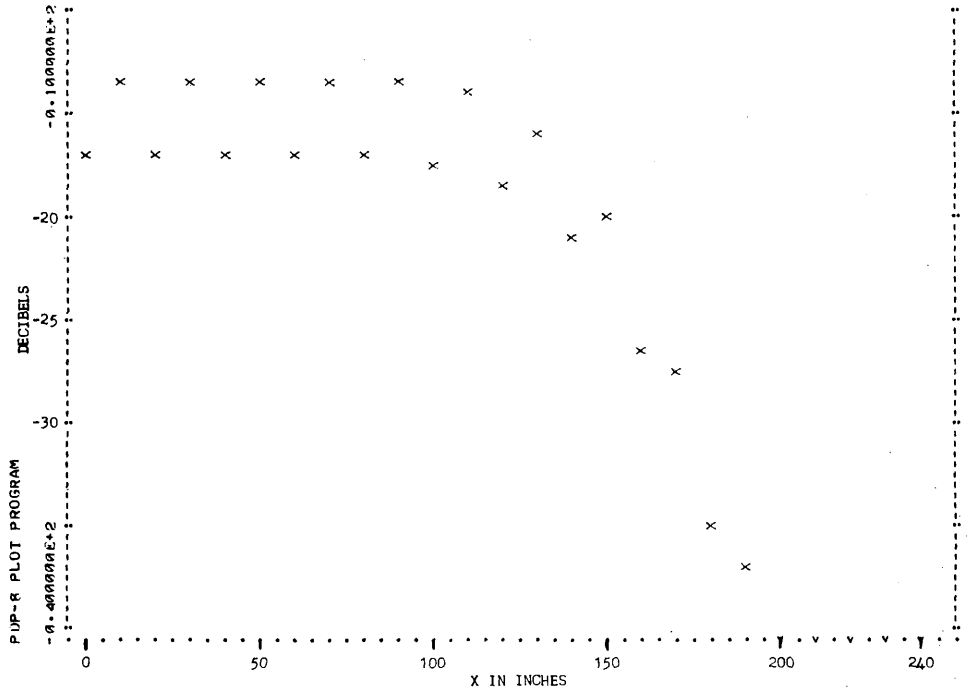


Fig. 6A (top). Sound pressure plot.
Fig. 6B (bottom). Phase plot.

TABLE 7

```
READ SHADING TAPE
1 1 1 1 1 1 1 1 1 .995 .989 .978 .957 .924 .874 .804 .716 .612 .500
.388 .248 .196 .126 .076 .042
1 IS NORMAL, 2 IS PERTURBED  2
HOR-PERT & START COLUMN: .125  15
VER-PERT & START ROW: .125  7
FREQ & DELE:  5000  8
DSEP & FIELD-Y:  35.874  0
X-RANGE & INCR:  0  TO  240  10

+0.000000E+0     -0.168566E+2     -0.106481E+3
+0.100000E+2     -0.131311E+2     -0.109154E+3
+0.200000E+2     -0.167682E+2     -0.107701E+3
+0.300000E+2     -0.131426E+2     -0.109567E+3
+0.400000E+2     -0.168478E+2     -0.107829E+3
+0.500000E+2     -0.132418E+2     -0.109085E+3
+0.600000E+2     -0.168091E+2     -0.106807E+3
+0.700000E+2     -0.131319E+2     -0.109335E+3
+0.800000E+2     -0.167488E+2     -0.108363E+3
+0.900000E+2     -0.133532E+2     -0.109733E+3
+0.100000E+3     -0.172410E+2     -0.106675E+3
+0.110000E+3     -0.138331E+2     -0.108141E+3
+0.120000E+3     -0.181941E+2     -0.106961E+3
+0.130000E+3     -0.159714E+2     -0.108651E+3
+0.140000E+3     -0.209419E+2     -0.106997E+3
+0.150000E+3     -0.197305E+2     -0.108775E+3
+0.160000E+3     -0.261667E+2     -0.110964E+3
+0.170000E+3     -0.270327E+2     -0.115663E+3
+0.180000E+3     -0.349183E+2     -0.106311E+3
+0.190000E+3     -0.366406E+2     -0.116521E+3
+0.200000E+3     -0.534565E+2     -0.688356E+2
+0.210000E+3     -0.496044E+2     +0.143055E+3
+0.220000E+3     -0.546578E+2     -0.690924E+2
+0.230000E+3     -0.531970E+2     -0.328913E+2
+0.240000E+3     -0.517380E+2     +0.643165E+2
```



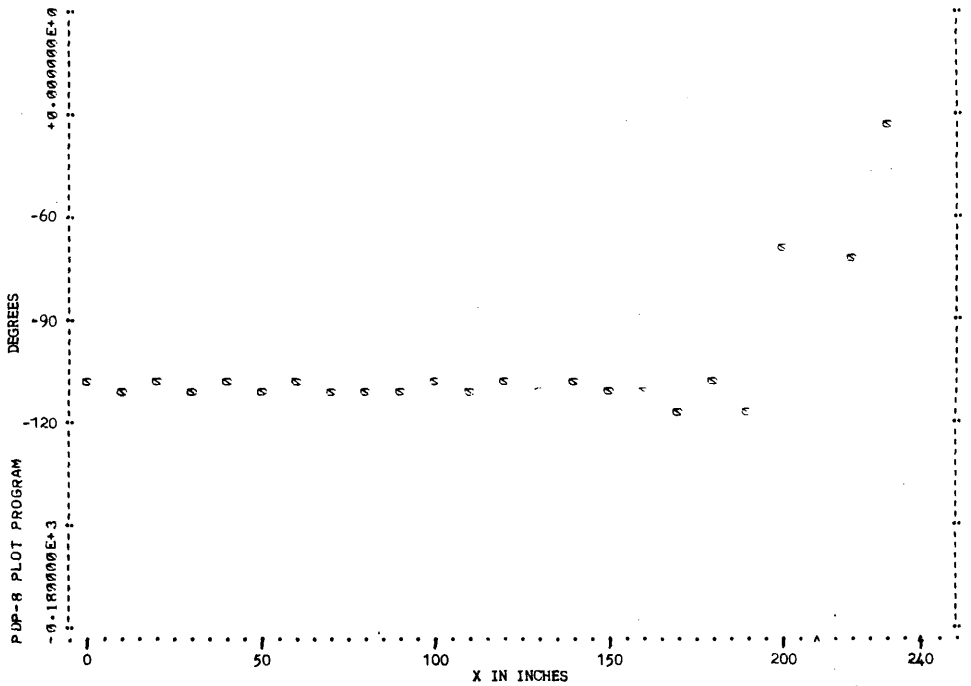
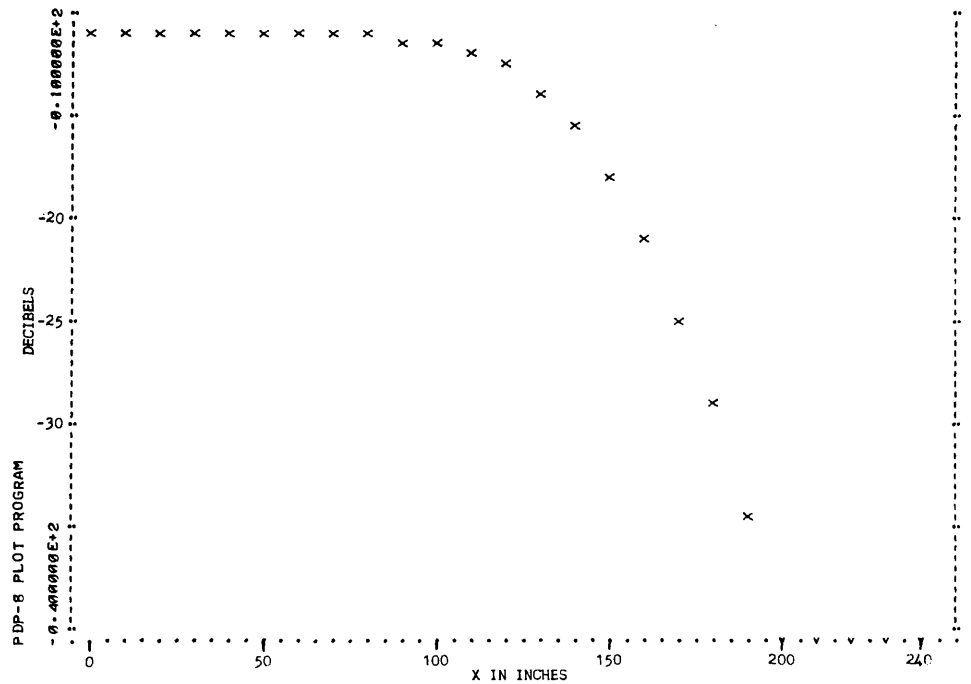


Fig. 7A (top). Sound pressure plot.
Fig. 7B (bottom). Phase plot.

TABLE 8

```
READ SHADING TAPE
1 1 1 1 1 1 1 1 1 .995 .989 .978 .957 .924 .874 .804 .716 .612 .500
.388 .248 .196 .126 .076 .042
1 IS NORMAL, 2 IS PERTURBED
2
HOR-PERT & START COLUMN: 0  0
VER-PERT & START ROW: .125  -50
FREQ & DELE:  5000  8
DSEP & FIELD-Y:  35.874  0
X-RANGE & INCR:  0  TO  240  10
```

+0.000000E+0	-0.108733E+2	-0.111316E+3
+0.100000E+2	-0.108582E+2	-0.111428E+3
+0.200000E+2	-0.108101E+2	-0.111838E+3
+0.300000E+2	-0.108100E+2	-0.112124E+3
+0.400000E+2	-0.108444E+2	-0.111836E+3
+0.500000E+2	-0.108618E+2	-0.111546E+3
+0.600000E+2	-0.108603E+2	-0.111001E+3
+0.700000E+2	-0.108118E+2	-0.111487E+3
+0.800000E+2	-0.108921E+2	-0.111847E+3
+0.900000E+2	-0.110167E+2	-0.112029E+3
+0.100000E+3	-0.112862E+2	-0.110895E+3
+0.110000E+3	-0.115255E+2	-0.110545E+3
+0.120000E+3	-0.123056E+2	-0.110948E+3
+0.130000E+3	-0.135441E+2	-0.111156E+3
+0.140000E+3	-0.150548E+2	-0.110727E+3
+0.150000E+3	-0.175518E+2	-0.111208E+3
+0.160000E+3	-0.205454E+2	-0.114996E+3
+0.170000E+3	-0.245672E+2	-0.117098E+3
+0.180000E+3	-0.289663E+2	-0.111292E+3
+0.190000E+3	-0.340144E+2	-0.114682E+3
+0.200000E+3	-0.471429E+2	-0.141069E+3
+0.210000E+3	-0.464917E+2	+0.146524E+3
+0.220000E+3	-0.587383E+2	-0.153246E+3
+0.230000E+3	-0.517225E+2	-0.378155E+2
+0.240000E+3	-0.579728E+2	+0.928054E+2



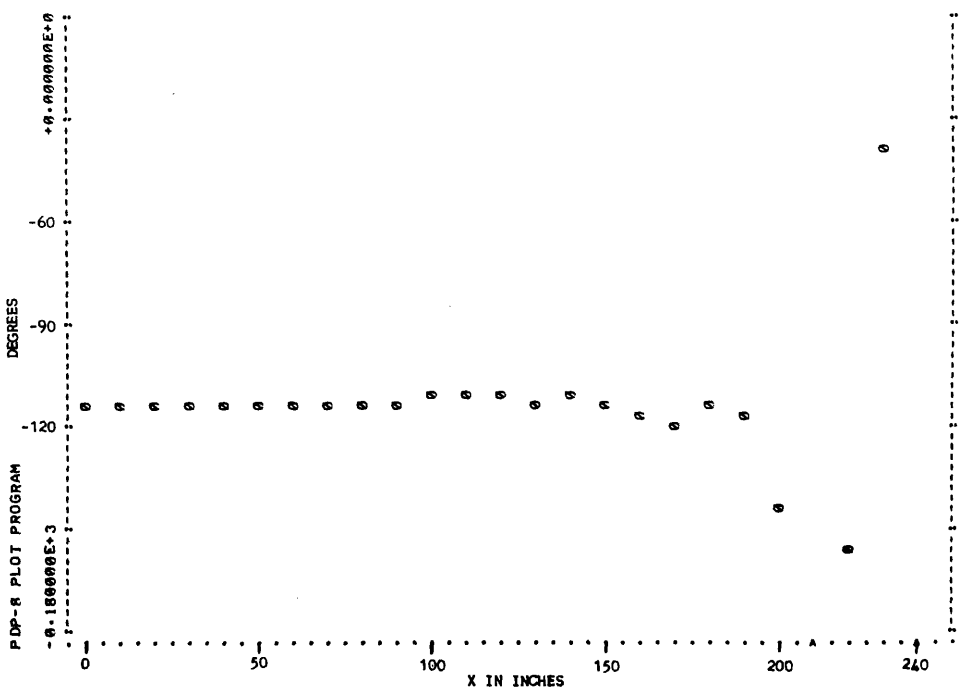
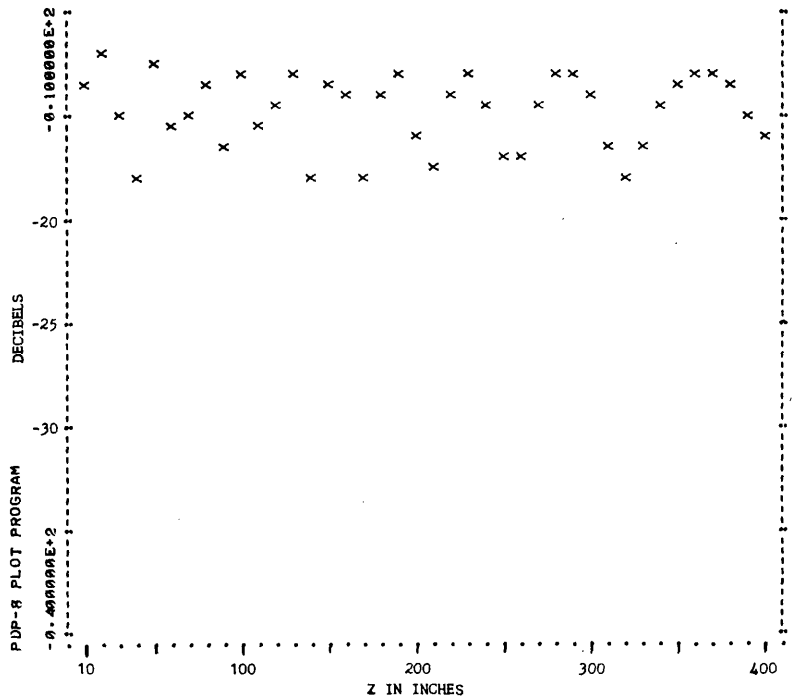


Fig. 8A (top). Sound pressure plot.
Fig. 8B (bottom). Phase plot.

TABLE 9

```
READ SHADING TAPE
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 IS NORMAL, 2 IS PERTURBED  1
FREQ & DELE:  5000  8
PARAXIAL LINE X,Y:  0  0
Z-RANGE & INCR:  10  TO  400  10

+1     -0.132228E+2     -0.731391E+2
+2     -0.119713E+2     -0.925440E+2
+3     -0.147541E+2     -0.111345E+3
+4     -0.177935E+2     -0.759598E+2
+5     -0.123324E+2     -0.822662E+2
+6     -0.150307E+2     -0.110149E+3
+7     -0.149798E+2     -0.701149E+2
+8     -0.130046E+2     -0.103631E+3
+9     -0.163860E+2     -0.712409E+2
+10    -0.129171E+2     -0.103225E+3
+11    -0.153179E+2     -0.700021E+2
+12    -0.144168E+2     -0.108724E+3
+13    -0.129954E+2     -0.781161E+2
+14    -0.177651E+2     -0.932915E+2
+15    -0.130605E+2     -0.998572E+2
+16    -0.136882E+2     -0.767908E+2
+17    -0.175386E+2     -0.894587E+2
+18    -0.139229E+2     -0.104674E+3
+19    -0.126038E+2     -0.851766E+2
+20    -0.155521E+2     -0.730803E+2
+21    -0.172440E+2     -0.997087E+2
+22    -0.137026E+2     -0.103611E+3
+23    -0.126801E+2     -0.884848E+2
+24    -0.140716E+2     -0.765460E+2
+25    -0.166060E+2     -0.799486E+2
+26    -0.167899E+2     -0.989305E+2
+27    -0.144615E+2     -0.104672E+3
+28    -0.128726E+2     -0.966749E+2
+29    -0.127308E+2     -0.846940E+2
+30    -0.139963E+2     -0.752136E+2
+31    -0.162433E+2     -0.754863E+2
+32    -0.175304E+2     -0.904152E+2
+33    -0.162173E+2     -0.103592E+3
+34    -0.144147E+2     -0.104543E+3
+35    -0.132792E+2     -0.993222E+2
+36    -0.128222E+2     -0.922546E+2
+37    -0.129185E+2     -0.852081E+2
+38    -0.134970E+2     -0.791373E+2
+39    -0.145266E+2     -0.752485E+2
+40    -0.159027E+2     -0.753954E+2
```



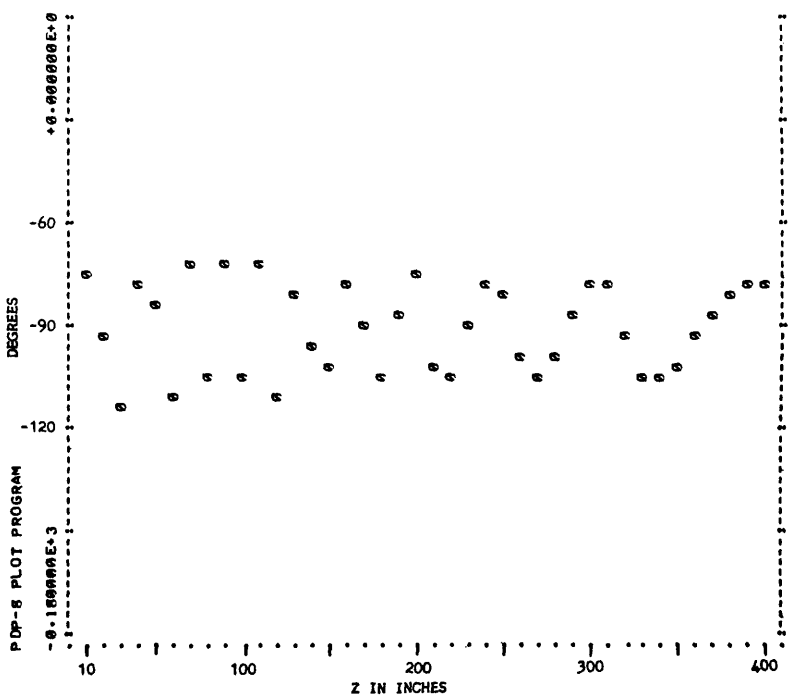
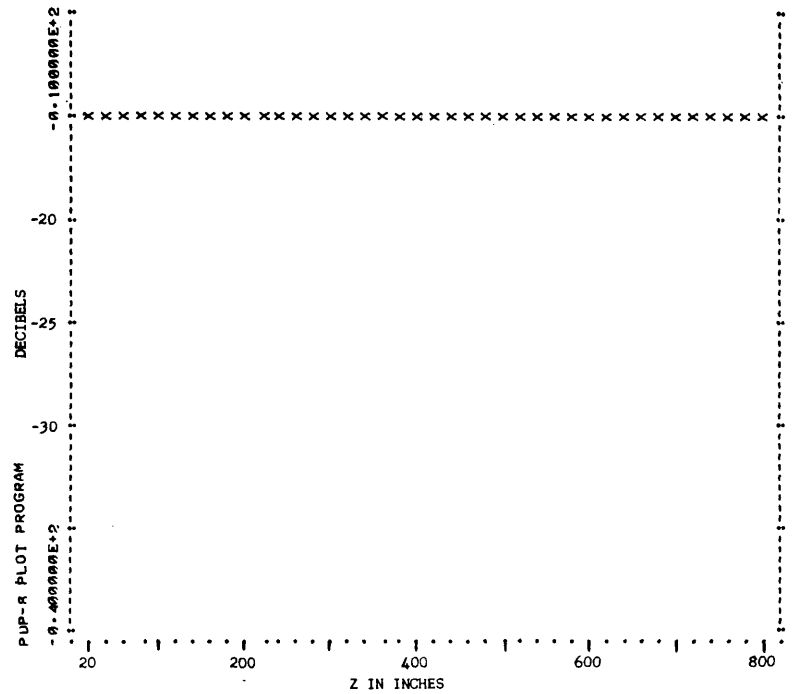


Fig. 9A (top). Sound pressure plot.
Fig. 9B (bottom). Phase plot.

TABLE 10

```
READ SHADING TAPE
1 1 1 1 1 1 1 1 1 .995 .989 .978 .957 .924 .874 .804 .716 .612 .500
.388 .248 .196 .126 .076 .042
1 IS NORMAL, 2 IS PERTURBED
1
FREQ & DELE:  5000  8
PARAXIAL LINE X,Y:  0  0
Z-RANGE & INCR:  20  TO 800  20

+0.200000E+2    -0.146599E+2    -0.889143E+2
+0.400000E+2    -0.149065E+2    -0.909756E+2
+0.600000E+2    -0.146141E+2    -0.916488E+2
+0.800000E+2    -0.145002E+2    -0.913463E+2
+0.100000E+3    -0.146423E+2    -0.917773E+2
+0.120000E+3    -0.149483E+2    -0.909223E+2
+0.140000E+3    -0.147121E+2    -0.888957E+2
+0.160000E+3    -0.146884E+2    -0.908453E+2
+0.180000E+3    -0.146657E+2    -0.891248E+2
+0.200000E+3    -0.148837E+2    -0.904624E+2
+0.220000E+3    -0.145308E+2    -0.904152E+2
+0.240000E+3    -0.147863E+2    -0.884638E+2
+0.260000E+3    -0.149272E+2    -0.908838E+2
+0.280000E+3    -0.145894E+2    -0.910761E+2
+0.300000E+3    -0.145891E+2    -0.892366E+2
+0.320000E+3    -0.148031E+2    -0.890863E+2
+0.340000E+3    -0.148633E+2    -0.901144E+2
+0.360000E+3    -0.147899E+2    -0.906355E+2
+0.380000E+3    -0.147200E+2    -0.906110E+2
+0.400000E+3    -0.146797E+2    -0.904886E+2
+0.420000E+3    -0.146512E+2    -0.903068E+2
+0.440000E+3    -0.146285E+2    -0.899570E+2
+0.460000E+3    -0.146399E+2    -0.895164E+2
+0.480000E+3    -0.147035E+2    -0.891983E+2
+0.500000E+3    -0.147867E+2    -0.891353E+2
+0.520000E+3    -0.148585E+2    -0.894220E+2
+0.540000E+3    -0.148980E+2    -0.899326E+2
+0.560000E+3    -0.148937E+2    -0.904781E+2
+0.580000E+3    -0.148440E+2    -0.908838E+2
+0.600000E+3    -0.147734E+2    -0.911006E+2
+0.620000E+3    -0.147085E+2    -0.910377E+2
+0.640000E+3    -0.146545E+2    -0.907928E+2
+0.660000E+3    -0.146192E+2    -0.904222E+2
+0.680000E+3    -0.146185E+2    -0.900305E+2
+0.700000E+3    -0.146432E+2    -0.896248E+2
+0.720000E+3    -0.146826E+2    -0.892961E+2
+0.740000E+3    -0.147383E+2    -0.891073E+2
+0.760000E+3    -0.148062E+2    -0.890234E+2
+0.780000E+3    -0.148736E+2    -0.890234E+2
+0.800000E+3    -0.149344E+2    -0.891842E+2
```



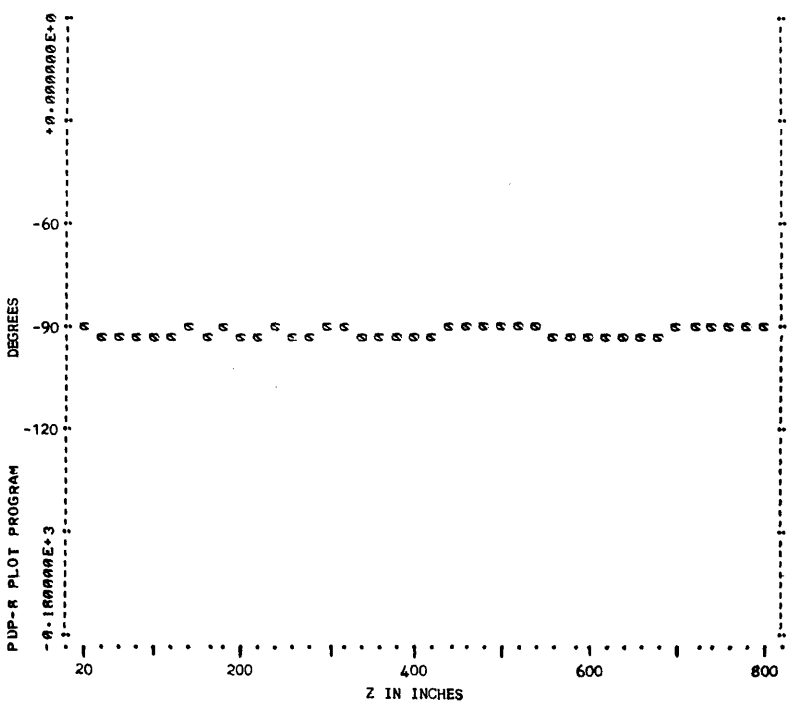
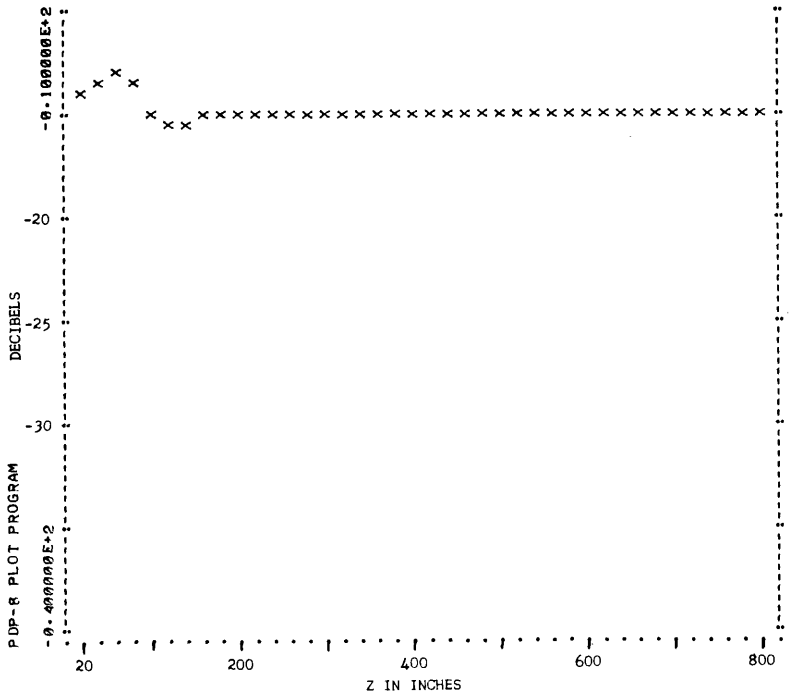


Fig. 10A (top). Sound pressure plot.
Fig. 10B (bottom). Phase plot.

TABLE 11

```
READ SHADING TAPE
1 1 1 1 1 1 1 1 1 .995 .989 .978 .957 .924 .874 .804 .716 .612 .500
.388 .248 .196 .126 .076 .042
1 IS NORMAL, 2 IS PERTURBED
2
HOR-PERT & START COLUMN: .125  15
VER-PERT & START ROW: .125  7
FREQ & DELE:  5000  8
PARAXIAL LINE X,Y:  0  0
Z-RANGE & INCR:  20  800  20
```

+0.200000E+2	-0.137528E+2	-0.923613E+2
+0.400000E+2	-0.134667E+2	-0.832436E+2
+0.600000E+2	-0.129980E+2	-0.797615E+2
+0.800000E+2	-0.133782E+2	-0.781712E+2
+0.100000E+3	-0.145590E+2	-0.766124E+2
+0.120000E+3	-0.153646E+2	-0.793209E+2
+0.140000E+3	-0.152703E+2	-0.825066E+2
+0.160000E+3	-0.149369E+2	-0.871787E+2
+0.180000E+3	-0.147563E+2	-0.874602E+2
+0.200000E+3	-0.148416E+2	-0.893906E+2
+0.220000E+3	-0.145020E+2	-0.903260E+2
+0.240000E+3	-0.147569E+2	-0.883309E+2
+0.260000E+3	-0.149222E+2	-0.910552E+2
+0.280000E+3	-0.145828E+2	-0.909957E+2
+0.300000E+3	-0.145941E+2	-0.894045E+2
+0.320000E+3	-0.148097E+2	-0.889709E+2
+0.340000E+3	-0.148569E+2	-0.901634E+2
+0.360000E+3	-0.147842E+2	-0.905900E+2
+0.380000E+3	-0.147243E+2	-0.906915E+2
+0.400000E+3	-0.146784E+2	-0.903802E+2
+0.420000E+3	-0.146463E+2	-0.903943E+2
+0.440000E+3	-0.146329E+2	-0.898871E+2
+0.460000E+3	-0.146352E+2	-0.895619E+2
+0.480000E+3	-0.147053E+2	-0.891562E+2
+0.500000E+3	-0.147840E+2	-0.891772E+2
+0.520000E+3	-0.148583E+2	-0.893801E+2
+0.540000E+3	-0.148954E+2	-0.899675E+2
+0.560000E+3	-0.148936E+2	-0.904362E+2
+0.580000E+3	-0.148423E+2	-0.909187E+2
+0.600000E+3	-0.147740E+2	-0.910586E+2
+0.620000E+3	-0.147079E+2	-0.910656E+2
+0.640000E+3	-0.146548E+2	-0.907509E+2
+0.660000E+3	-0.146186E+2	-0.904571E+2
+0.680000E+3	-0.146193E+2	-0.899885E+2
+0.700000E+3	-0.146417E+2	-0.896598E+2
+0.720000E+3	-0.146834E+2	-0.892542E+2
+0.740000E+3	-0.147363E+2	-0.891423E+2
+0.760000E+3	-0.148087E+2	-0.889814E+2
+0.780000E+3	-0.148709E+2	-0.890583E+2
+0.800000E+3	-0.149372E+2	-0.891493E+2



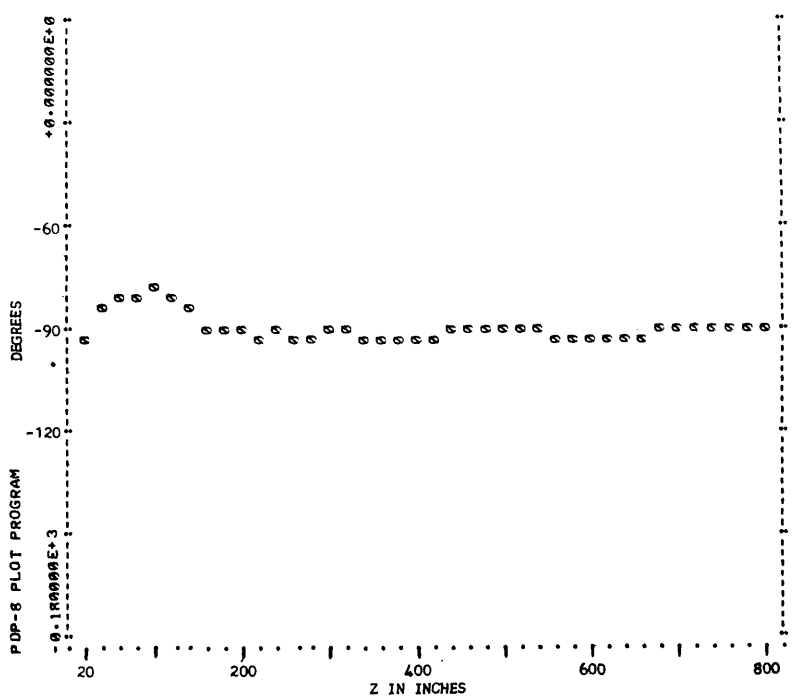
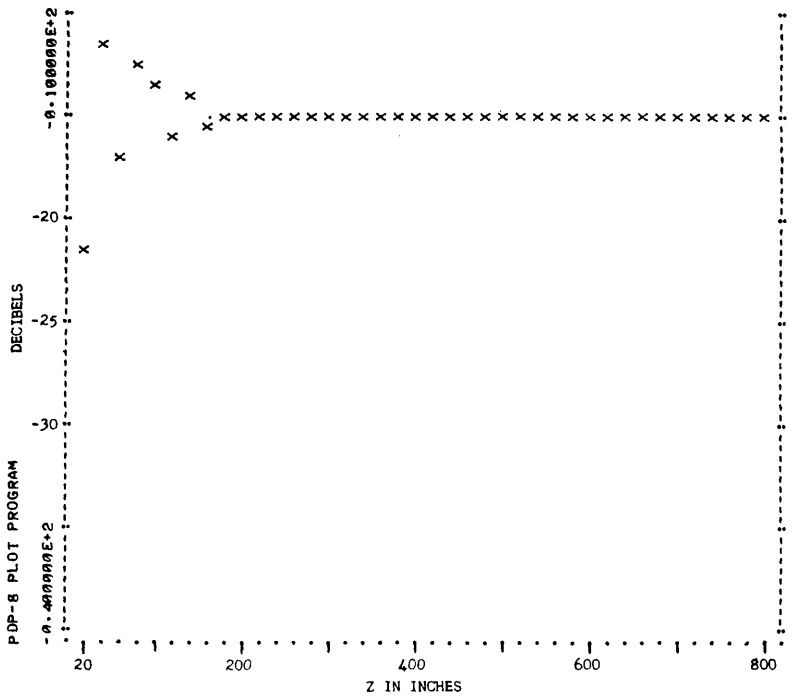


Fig. 11A (top). Sound pressure plot.
Fig. 11B (bottom). Phase plot.

TABLE 12

```
READ SHADING TAPE
1 1 1 1 1 1 1 1 1 .995 .989 .978 .957 .924 .874 .804 .716 .612 .500
.388 .248 .196 .126 .076 .042
1 IS NORMAL, 2 IS PERTURBED
2
HOR-PERT & START COLUMN: 0  0
VER-PERT & START ROW: .125  -50
FREQ & DELE:  5000  8
PARAXIAL LINE X,Y:  0  0
Z-RANGE & INCR:  20  TO  800  20
```

+0.200000E+2	-0.211760E+2	-0.108314E+3
+0.400000E+2	-0.112331E+2	-0.783693E+2
+0.600000E+2	-0.166902E+2	-0.126041E+3
+0.800000E+2	-0.121959E+2	-0.668626E+2
+0.100000E+3	-0.133593E+2	-0.118538E+3
+0.120000E+3	-0.156236E+2	-0.669797E+2
+0.140000E+3	-0.135307E+2	-0.995443E+2
+0.160000E+3	-0.152342E+2	-0.838652E+2
+0.180000E+3	-0.145112E+2	-0.926847E+2
+0.200000E+3	-0.148254E+2	-0.887243E+2
+0.220000E+3	-0.146166E+2	-0.909170E+2
+0.240000E+3	-0.147399E+2	-0.884743E+2
+0.260000E+3	-0.149436E+2	-0.908174E+2
+0.280000E+3	-0.145818E+2	-0.911460E+2
+0.300000E+3	-0.145823E+2	-0.891493E+2
+0.320000E+3	-0.148200E+2	-0.890408E+2
+0.340000E+3	-0.148717E+2	-0.902158E+2
+0.360000E+3	-0.147794E+2	-0.907159E+2
+0.380000E+3	-0.147071E+2	-0.905900E+2
+0.400000E+3	-0.146766E+2	-0.904222E+2
+0.420000E+3	-0.146556E+2	-0.902543E+2
+0.440000E+3	-0.146359E+2	-0.899501E+2
+0.460000E+3	-0.146451E+2	-0.895374E+2
+0.480000E+3	-0.147052E+2	-0.892332E+2
+0.500000E+3	-0.147867E+2	-0.891632E+2
+0.520000E+3	-0.148558E+2	-0.894360E+2
+0.540000E+3	-0.148961E+2	-0.899396E+2
+0.560000E+3	-0.148912E+2	-0.904781E+2
+0.580000E+3	-0.148441E+2	-0.908908E+2
+0.600000E+3	-0.147721E+2	-0.911076E+2
+0.620000E+3	-0.147071E+2	-0.910447E+2
+0.640000E+3	-0.146516E+2	-0.907928E+2
+0.660000E+3	-0.146171E+2	-0.904152E+2
+0.680000E+3	-0.146166E+2	-0.900166E+2
+0.700000E+3	-0.146413E+2	-0.896039E+2
+0.720000E+3	-0.146811E+2	-0.892821E+2
+0.740000E+3	-0.147393E+2	-0.890863E+2
+0.760000E+3	-0.148080E+2	-0.889954E+2
+0.780000E+3	-0.148758E+2	-0.890093E+2
+0.800000E+3	-0.149372E+2	-0.891703E+2



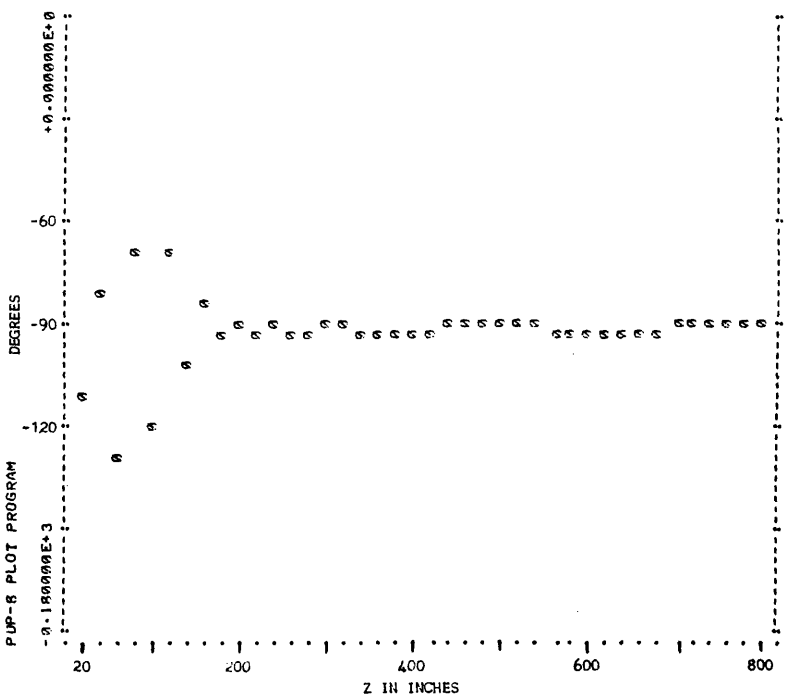


Fig. 12A (top). Sound pressure plot.
Fig. 12B (bottom). Phase plot.

The numbers after request (f) are the separation distance between the plane of the array and the plane of the sound field, and the y coordinate for the horizontal line where the sound field is being computed.

The final request (g) expects three numbers from the operator; these are the range of x and its increment in the sound field line. It is this request that defines to the program the number of points to be computed.

In the second version of the program, requests (f) and (g) differ from those in the first version. Recall that the second version computes the sound pressure at points on a line normal to the plane of the array--that is, on a line parallel to the z axis of coordinates. Request (f) asks for the x,y coordinates of the intersection of the paraxial line of interest with the plane of the array, and request (g) asks for the z range and increment for this line.

All numbers that are entered into the program to represent distances are in inches. All measurements were made for the frequency 5000 Hz and for 8-inch normal separation between array elements.

The data shown in the figures and tables are representative of the results obtained from many computer runs.

CONCLUSIONS

Examination of the Tables and Figures shows the following:

1. The theoretically predicated plane wave in the near field is indeed achieved by the simulated array specified according to Trott's theory [1]. Compare Figs. 2 and 9 for a uniform array with Figs. 3, 6, and 10 for the shaded array.

2. The effect of perturbation is shown by Figs. 4, 5, 7, 8, 11, and 12. Typically, these perturbations brought about amplitude variations of $1\frac{1}{2}$ to 3 dB and 3 to 20 degrees phase variation. Figure 4 (and Table 4) shows about $1\frac{1}{2}$ dB amplitude variation and about 20 degrees variation in phase. Figure 7 (and Table 7), which is for the same conditions as Fig. 4 except that the distance to the array has been increased by a half wavelength, shows 3 dB variation in amplitude and about 3 degrees phase variation.

3. Figures 11 and 12 show that the effect of the perturbation is more pronounced at short distances in front of the array.

ACKNOWLEDGMENT

The author acknowledges the suggestion by Mr. Claude C. Sims that the near-field perturbation problem be investigated on the USRD PDP-8 computer.

References

[1] W. James Trott, "Underwater Sound Transducer Calibration from Near-Field Data," J. Acoust. Soc. Am. 36, 1557-1568 (1964).

[2] R. Hilton, S. Fich, W. Welkowitz, "Digital Computer Techniques for Testing a Tapered Transmission Line Model of the Human Aorta," DECUS Proceedings, Spring 1966, pp. 21-33.

Appendix A

COMMENTS ON THE FORTRAN PROGRAM

The PDP-8 FORTRAN language symbolic listings are shown separately in Appendix B. Also shown in Appendix B are the MEMORY MAPS (called SYMBOL PRINT in PDP-8 terminology) for the two programs that show the memory location of the variables in the program.

The PDP-8 computer takes about 6 minutes to compute each point, so that typically each run has taken $2\frac{1}{2}$ to 3 hours. The computed values of sound pressure amplitude and phase angle are retained in memory until the end of the run, at which time the program halts. Then the Teletype machine of the PDP-8 is activated and the program is continued so that it types out all the computed numbers for the run. Many of the runs were performed after regular hours with the computer left unattended. A time clock shut off all electric power to the computer after the 3 hours required for the computation. The computed results were obtained in the morning after power was restored to the PDP-8.

An interesting feature available in PDP-8 FORTRAN is illustrated by the PAUSE 4078 statement near the middle of the program. Using this special feature causes the computer to exit from FORTRAN and execute the machine language program that it finds at the location (decimal) whose number is shown after PAUSE. In this case, the program at 7756 (octal equivalent of decimal 4078) is a very short program to display for a few seconds (on the accumulator lights) the number of the field point being computed. Use of this feature allowed monitoring of the long computer runs to verify that the PDP-8 was operating properly.

An investigation into the computer's use of about 6 minutes for each field point of interest shows that most of the time (87%) is spent in computing the 2500 square roots, sines, and cosines required at each field point. It is estimated that the computing time for other arrays would be proportional to the number of array elements at the rate of about 140 milliseconds per field point per array element.

Appendix B

PDP-8 FORTRAN PROGRAMS

The symbolic programs written in PDP-8 FORTRAN language are shown for both versions of the program on the following pages. On the first page of each program appears the corresponding MEMORY MAP (known as SYMBOL PRINT in PDP-8 usage). Also shown is the actual octal coding of the very brief machine language program that is called by the FORTRAN statement PAUSE 4078 for the purpose that has been described in Appendix A.

```
C   ;NEAR-FIELD ARRAY TESTER,SABIN,14 JUNE 1967
C   ;SOUND FIELD ALONG A HORIZONTAL LINE
C   ;ENTER FREQUENCY IN HERTZ, DISTANCE IN INCHES
     DIMENSION SHAD(25),P(50),PH(50)
    TYPE 1
    DO 1000 I=1,25
    ACCEPT 5, SHAD(I)
1000;CONTINUE
    ;LO=-49
500;TYPE 101
    ;ACCEPT 3, KASE
    ;IF(KASE-1) 220,220,240
240;TYPE 102
    ;ACCEPT 15, EPSH,KHER
    ;TYPE 103
    ;ACCEPT 15, EPSV,KVER
    ;GO TO 550
220;KHER=KVER=0
    ;EPSH=EPSV=0.
550;TYPE 104
    ;ACCEPT 5, FREQ,DELE
    ;DELE=DELE/2.
    ;TYPE 105
    ;ACCEPT 5,DSEP,YF
    ;TYPE 106
    ;ACCEPT 5, XF1,XF2,DELX
C   ;WNUM BELOW IS FOR INCH DISTANCES
    ;WNUM=0.106966E-3*FREQ
    ;RD=57.2958
    ;INDX=0
    ;JX1=XF1/DELX
    ;JX2=XF2/DELX
    ;DO 100 JH=JX1,JX2
     PAUSE 4078
C   ;FOR ACCUMULATOR DISPLAY OF CURRENT VALUE OF JH
    ;EJH=JH
    ;RP=QP=0.
    ;DO 120 KV=LO,49,2
C;J IS AN ARTIFICIAL INDEX, ALWAYS POSITIVE (FOR SUBSCRIPTED VARIABLES)
    ;J=KV
    ;IF(KV)  401,401,403
401;J=-J
403;J=(J+1)/2
    ;EKV=KV
    ;IF(KV-KVER) 260,260,250
250;EKV=EKV+EPSV
    ;EPSV=-EPSV
260;DO 120 KH=LO,49,2
C   ;I IS ANOTHER ARTIFICIAL INDEX
    ;I=KH
```

```
PAUSE 4078

7756 /0000
7757 /7440
7760 /7402
7761 /1375
7762 /3374
7763 /1772
7764 /2373
7765 /5364
7766 /2374
7767 /5364
7770 /7200
7771 /5756
7772 /6714 <-->
7773 /0000
7774 /0000
7775 /7000
```

MEMORY MAP

SHAD	7464
P	7236
PH	7010
I	7007
LO	7004
KASE	7002
EPSH	6776
KHER	6775
EPSV	6772
KVER	6771
FREQ	6762
DELE	6757
DSEP	6751
YF	6746
XF1	6743
XF2	6740
DELX	6735
WNUM	6732
RD	6724
INDX	6720
JX1	6716
JX2	6715
JH	6714
EJH	6711
RP	6706
QP	6703
KV	6677
J	6674
EKV	6667
KH	6666
EKH	6657
R1	6654
R2	6651
DST	6646
PI	6643
PHSE	6631
D	6625
6502	6624

```
    ;IF(KH)  301,301,303
301;I=-I
303;I=(I+1)/2
    ;EKH=KH
    ;IF(KH-KHER)  360,360,350
350;EKH=EKH+EPSH
    ;EPSH=-EPSH
360;R1=EKH*DELE-EJH*DELX
    ;R2=EKV*DELE-YF
    ;DST=SQTF(R1*R1+R2*R2+DSEP*DSEP)
    ;RP=RP+SHAD(I)*SHAD(J)*COSF(WNUM*DST)/DST
    ;QP=QP-SHAD(I)*SHAD(J)*SINF(WNUM*DST)/DST
120;CONTINUE
    ;PI=3.14159
    ;INDX=INDX+1
    ;P(INDX)=4.343*LOGF(RP*RP+QP*QP)
    ;PHSE=ATNF(QP/RP)
    ;IF(RP) 25,30,30
 25;IF(PHSE) 27,26,26
 26;PI=-PI
 27;PHSE=PHSE+PI
 30;PH(INDX)=PHSE*RD
100;CONTINUE
    ;PAUSE
    ;INDX=0
    ;DO 60 JH=JX1,JX2
    ;EJH=JH
    ;D=EJH*DELX
    ;INDX=INDX+1
    ;TYPE 5, D , P(INDX), PH(INDX)
    ;TYPE 121
 60;CONTINUE
    ;GO TO 500
  3;FORMAT(I)
  5;FORMAT(E)
 15;FORMAT(E,I)
  1;FORMAT(/,"READ SHADING TAPE",/)
101;FORMAT(/,"1 IS NORMAL, 2 IS PERTURBED  ")
102;FORMAT(/,"HOR-PERT & START COLUMN: ")
103;FORMAT(/,"VER-PERT & START ROW: ")
104;FORMAT(/,"FREQ & DELE:  ")
105;FORMAT(/,"DSEP & FIELD-Y:  ")
106;FORMAT(/,"X-RANGE & INCR:  ")
121;FORMAT(/)
  END
```

```
C   ;NEAR-FIELD ARRAY TESTER,SABIN,31 OCTOBER, 1967
C   ;SOUND FIELD ALONG A LINE NORMAL TO THE ARRAY PLANE
C;   COORDINATE ALONG SUCH LINE IS Z
C;   ARRAY IS IN XY-PLANE
C   ;ENTER FREQUENCY IN HERTZ, DISTANCE IN INCHES
     DIMENSION SHAD(25),P(50),PH(50)
    TYPE 1
    DO 1000 I=1,25
    ACCEPT 5, SHAD(I)
1000;CONTINUE
    ;LO=-49
500;TYPE 101
    ;ACCEPT 3, KASE
    ;IF(KASE-1) 220,220,240
240;TYPE 102
    ;ACCEPT 15, EPSH,KHER
    ;TYPE 103
    ;ACCEPT 15, EPSV,KVER
    ;GO TO 550
220;KHER=KVER=0
    ;EPSH=EPSV=0.
550;TYPE 104
    ;ACCEPT 5, FREQ,DELE
    ;DELE=DELE/2.
    ;TYPE 105
     ACCEPT 5,X,Y
    ;TYPE 106
     ACCEPT 5, Z1,Z2,DELZ
C   ;WNUM BELOW IS FOR INCH DISTANCES
    ;WNUM=0.106966E-3*FREQ
    ;RD=57.2958
    ;INDX=0
     JZ1 = Z1/DELZ
     JZ2 = Z2/DELZ
     DO 100 JZ=JZ1,JZ2
     PAUSE 4078
C   ;FOR ACCUMULATOR DISPLAY OF CURRENT VALUE OF JZ
     EJZ = JZ
     Z = EJZ*DELZ
    ;RP=QP=0.
    ;DO 120 KV=LO,49,2
C;J IS AN ARTIFICIAL INDEX, ALWAYS POSITIVE (FOR SUBSCRIPTED VARIABLES)
    ;J=KV
    ;IF(KV)  401,401,403
401;J=-J
403;J=(J+1)/2
    ;EKV=KV
    ;IF(KV-KVER) 260,260,250
250;EKV=EKV+EPSV
    ;EPSV=-EPSV
260;DO 120 KH=LO,49,2
C   ;I IS ANOTHER ARTIFICIAL INDEX
```

```
PAUSE 4078

7756 /0000
7757 /7440
7760 /7402
7761 /1375
7762 /3374
7763 /1772
7764 /2373
7765 /5364
7766 /2374
7767 /5364
7770 /7200
7771 /5756
7772 /6714 <-> JZ
7773 /0000
7774 /0000
7775 /7000
```

MEMORY MAP

SHAD	7464
P	7236
PH	7010
I	7007
LO	7004
KASE	7002
EPSH	6776
KHER	6775
EPSV	6772
KVER	6771
FREQ	6762
DELE	6757
X	6751
Y	6746
Z1	6743
Z2	6740
DELZ	6735
WNUM	6732
RD	6724
INDX	6720
JZ1	6716
JZ2	6715
JZ	6714
EJZ	6711
Z	6706
RP	6703
QP	6700
KV	6674
J	6671
EKV	6664
KH	6663
EKH	6654
R1	6651
R2	6646
DST	6643
PI	6640
PHSE	6626
6556	6621

```
   ;I=KH
   ;IF(KH)  301,301,303
301;I=-I
303;I=(I+1)/2
   ;EKH=KH
   ;IF(KH-KHER)  360,360,350
350;EKH=EKH+EPSH
   ;EPSH=-EPSH
360;R1=EKH*DELE-X
   ;R2=EKV*DELE-Y
   ;DST=SQTF(R1*R1+R2*R2+Z*Z)
   ;RP=RP+SHAD(I)*SHAD(J)*COSF(WNUM*DST)/DST
   ;QP=QP-SHAD(I)*SHAD(J)*SINF(WNUM*DST)/DST
120;CONTINUE
   ;PI=3.14159
   ;INDX=INDX+1
   ;P(INDX)=4.343*LOGF(RP*RP+QP*QP)
   ;PHSE=ATNF(QP/RP)
   ;IF(RP) 25,30,30
 25;IF(PHSE) 27,26,26
 26;PI=-PI
 27;PHSE=PHSE+PI
    PI = 3.14159
 30;PHSE = PHSE+WNUM*Z
 50;IF(PHSE-PI) 54,54,52
 52;PHSE = PHSE-PI-PI
    GO TO 50
 54;PH(INDX) = PHSE*RD
100;CONTINUE
   ;PAUSE
   ;INDX=0
    DO 60 JZ = JZ1,JZ2
    EJZ=JZ
    Z = EJZ*DELZ
   ;INDX=INDX+1
    TYPE 5, Z , P(INDX), PH(INDX)
   ;TYPE 121
 60;CONTINUE
   ;GO TO 500
  3;FORMAT(I)
  5;FORMAT(E)
 15;FORMAT(E,I)
  1;FORMAT(/,"READ SHADING TAPE",/)
101;FORMAT(/,"1 IS NORMAL, 2 IS PERTURBED  ")
102;FORMAT(/,"HOR-PERT & START COLUMN: ")
103;FORMAT(/,"VER-PERT & START ROW: ")
104;FORMAT(/,"FREQ & DELE:  ")
105;FORMAT(/,"PARAXIAL LINE X,Y:  ")
106;FORMAT(/,"Z-RANGE & INCR:  ")
121;FORMAT(/)
  END
```

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ABSTRACT

A FORTRAN program has been developed for a small digital computer (PDP-8) to investigate theoretically the effect of irregularities in the positions of transducer elements in an acoustic "near-field" array. Details of the program are discussed and representative computer runs are presented.

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