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NAVAL UNDERWATER SYSTEMS CENTER
NEW LONDON LABORATORY
NEW LONDON, CT 06320

TECHNICAL MEMORANDUM

Automatic Directivity Index Calculation Program

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ABSTRACT

A computer program was written for the HP 9845 and the HP 9816 to calculate the directivity index directly from the beam pattern. A graphics tablet and stylus is used to digitize data points used to compute the directivity index. Graphical output is produced on a printer and plotter.

INTRODUCTION

This program was developed to enable the user to digitally input beam pattern data points into a computer and calculate the directivity index from this data. It eliminates the slow and monotonous task of visually determining the polar coordinates of the data points and manually keying them into the computer for processing.

Prior to the creation of this program, two methods were used to find the directivity index of a beam pattern. The first method involved extracting data from the beam pattern by reading a data point at specific, regular intervals. This method was slow and less accurate due to the fact that the operator introduced error when approximating the position of the data points. The second method required the beam pattern, which was plotted in a polar coordinate system, to be re-plotted in a rectangular coordinate system. This operation was performed by the user. Once this conversion had been completed, a mechanical device called a planimeter was used to calculate the directivity index. Obviously, this method was extremely slow. Therefore, this program greatly reduces the time and effort required to calculate the directivity index of a beam pattern. It also produces a more accurate result.

The program requires an HP 9845 computer, an HP 9111A graphics tablet and an HP 9872A plotter. In addition, it requires that the Structured Programming ROM be resident in the HP 9845 computer. Without it, certain BASIC statements cannot be executed.

A slightly modified version of this program is available for the HP 9816 computer. It provides the same capabilities as the HP 9845 version but utilizes an HP 7470 plotter instead of an HP 9872A plotter. The HP 9816 version also requires that the BASIC extensions version 2.1 be present.

DESCRIPTION OF PROGRAM

The "CALCDI" program is responsible for converting a polar plot representing a beam pattern data into a finite number of polar coordinate data points. It is from these data points that the directivity index is computed.

The program is divided into subprograms which perform the functions of initializing the graphics tablet, digitizing a directivity pattern, calculating the directivity index, and producing a hard copy output. Subprograms are also employed to perform conversions between rectangular and polar coordinate systems and perform functions not found in HP BASIC. These programming techniques result in a program that is easy to understand and modify. Subprogram modules can also be used to create new programs.

PROBLEM DEFINITION AND SOLUTION

As stated in the introduction, this program's purpose is to allow the operator to digitize a finite number of data points from a directional response pattern. The number of data points collected is dependent upon the incremental angle specified by the operator. After collecting the data, the beam pattern's directivity index calculation is performed and the result is displayed. The beam pattern is plotted on the CRT to allow the operator to verify that no errors have occurred during the data entry process.

Looking at the program from an overall view, it can be divided into 3 distinct steps. The first step involves digitizing a beam pattern using the graphics tablet. This requires converting the rectangular coordinates from the graphics tablet to the polar coordinates required by the directivity index formula. The second step is to use the polar coordinate data points to compute the directivity index. This entails changing the formula for calculating the directivity index into a procedure able to be executed by the computer. The directivity index formula, an integral, is translated into a summation. Since the original rectangular coordinate data points are not saved, the polar coordinate data points must be converted back to the rectangular system to enable them to be displayed on the CRT, printer or plotter.

STEP 1

DIGITIZING A DIRECTIONAL RESPONSE PATTERN

A beam, or directional response, pattern is digitized by placing it on the surface of the graphics tablet and tracing it with the stylus. Although the beam pattern is printed on polar coordinate paper, X and Y coordinates are entered into the computer as the digitizing process occurs. These X and Y coordinates must be converted to polar form for use by the directivity index formula.

Polar coordinate points are in the form (Rho, Theta) with Rho equalling the distance from the origin and Theta equalling an angle in the range 0-360 degrees. Rho and Theta must be derived from the X and Y coordinates. This conversion process is accomplished by the following subprograms: "Displacement," "Calculateradius," "Calcarctangent," "Determinequad," and Convertto360." Each of these subprograms is well commented. The procedure for the conversion is also presented in algorithmic form.

STEP 2

CALCULATE THE DIRECTIVITY INDEX

The directivity index calculation is the most important segment of the program. From the polar coordinate data, we are able to determine the directivity index. This computation is performed by the subprogram called "Calcdirindex."

The directivity index is equal to ten times the common logarithm of the directivity factor. The directivity factor is defined as the ratio of the intensity in a reference direction, usually the axis, to the intensity average over all directions.

The directivity factor is calculated using the formula as presented by Bobber in Underwater Electroacoustic Measurements (Washington D.C., NRL, 1970, p. 84)

From Bobber,

$$\text{directivity factor} = \frac{2}{\Delta\theta \cdot \sum_{i=0}^{n} A_i} \qquad (1)$$

where $\Delta\theta$ equals the degrees resolution per angular interval, n equals the number of sampling points per 180 degrees, and

$$A_i = \left[\frac{p_{(\theta_i)}}{p_o}\right]^2 \cdot \sin\theta_i \qquad (2)$$

In equation 2, θ_i is the angular measure in degrees of the polar coordinate data point. Also,

$$\left[\frac{p_{(\theta_i)}}{p_o}\right]^2 = 10^{-(\text{db down}/10)} \qquad (3)$$

where db down equals the difference of the maximum response axis and the radius of the polar coordinate data point. The formula for sampling the directivity pattern through 360 degrees becomes,

$$\text{directivity factor} = \frac{4}{\Delta\theta \sum_{i=0}^{2n} A_i} \qquad (4)$$

Consider the case of $\Delta\theta = 5$ degrees, the default value for the resolution in "Calcdirindex." Converting $\Delta\theta$ to radians,

$$\text{directivity factor} = \frac{4}{\Delta\theta \cdot \frac{\pi}{180} \sum_{i=0}^{72} |A_i|} \tag{5}$$

Simplifying,

$$\text{directivity factor} = \frac{229.2}{\Delta\theta \cdot \sum_{i=0}^{72} |A_i|} \tag{6}$$

The directivity factor formula of Equation 6 is transformed into a sequence of BASIC statments. "Calcdirindex" simulates the summation process by utilizing an iterative loop. The variable "resolution" corresponds to $\Delta\theta$ and 229.2 is a numeric constant.

If a directivity pattern has symmetry about the equator of the measuring sphere, then it is only necessary to use one half of the pattern in the computation. However, some patterns are nearly rotationally symmetric, but not exactly. For these "near symmetric patterns," it is desirable to average the two directivity factors as calculated for the two halves of the pattern. Therefore, it must be noted that this program assumes all beam patterns are nearly rotationally symmetric and thus performs the summation over the full 360 degrees.

STEP 3

DISPLAY THE DIRECTIVITY PATTERN ON THE OUTPUT DEVICE

The polar coordinate data is converted to X and Y coordinates so that it may be output to the CRT, printer, and plotter. This is accomplished by the subprograms called "Displaypattern," "Printcopy," and "Plotcopy."

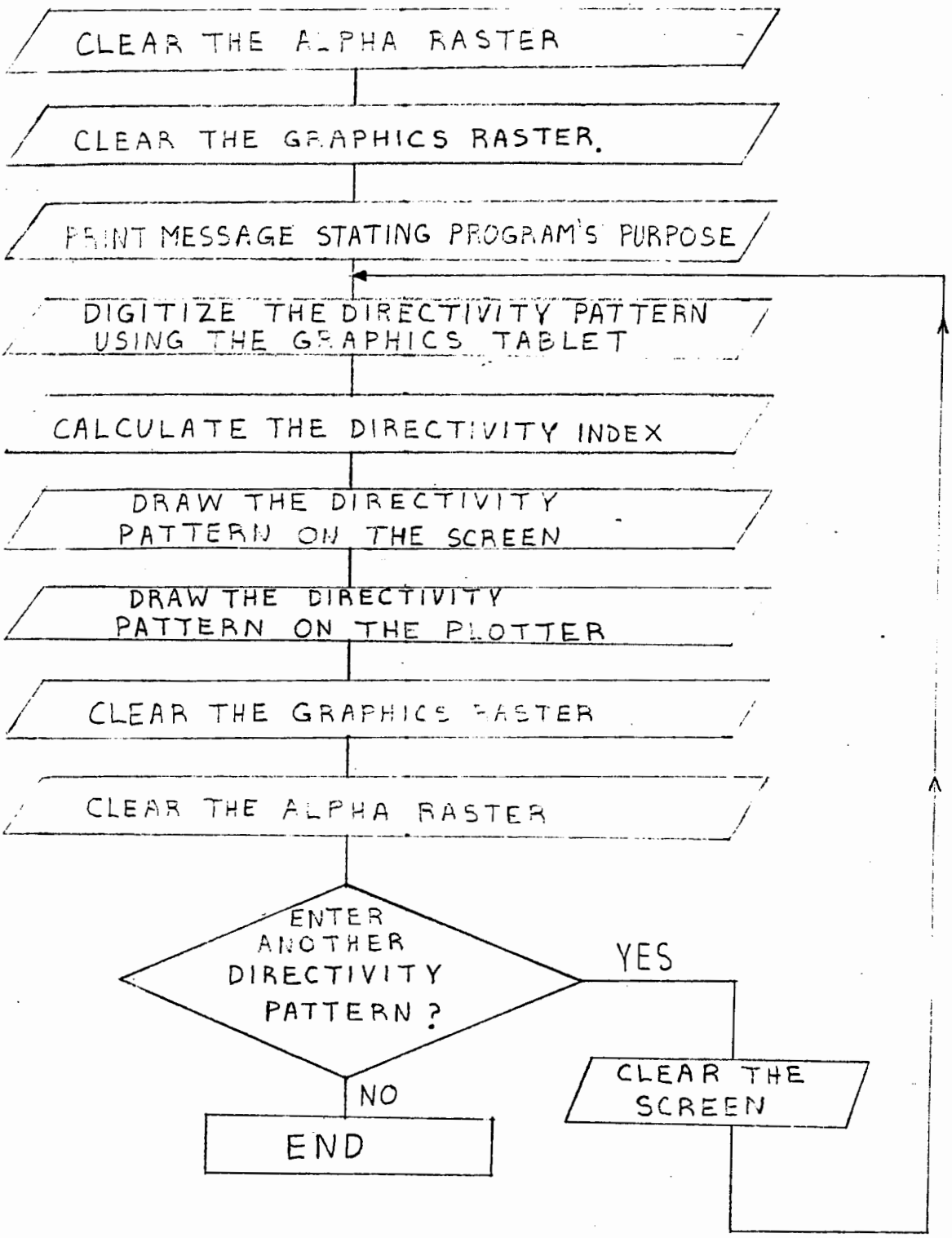
Pseudo-code

Main Program

1. Clear the CRT
   a. Clear the alphanumeric raster
   b. Clear the graphics raster
2. Print Identifying message
3. Wait for person to read message
   a. Continue when operator hits "Continue" key
4. Digitize the directivity pattern using the 9111A Graphics Tablet
5. Calculate the directivity index from the polar coordinate values entered from the graphics tablet
6. Draw the directivity pattern on the CRT and print the directivity index
7. Output directivity pattern to printer with option of suppressing output
8. Output directivity pattern to plotter with option of suppressing output
9. Clear the CRT
   a. Clear the alphanumeric raster
   b. Clear graphics raster
10. See if operator has more directivity patterns to digitize

```
If choice = yes then
     Repeat procedure from step 4
Else
     End of program
End if
```

MAIN PROGRAM FLOWCHART



Pseudo Code

Algorithm to Convert from the Rectangular to the Polar Coordinate System

1. Input the X and Y coordinates
2. Determine its X and Y displacements from the origin in user units
3. Calculate Rho (Radius) using the X and Y displacements with Rho being measured in user units
4. Compute the principle angle given the X and Y displacements from the origin
5. Determine which quadrant the point lies in based upon its relative position to the origin
6. Given the principle angle and the quadrant, produce an angle in the range 0-360 degrees

VARIABLES

originx - the x-coordinate of the origin of the directivity pattern in digitizing units.

originy - the y-coordinate of the origin of the directivity pattern in digitizing units.

zerodegfsx - the x-coordinate of the point representing zero degrees full scale on the directivity pattern. It is measured in digitizing units.

zerodegfsy - the y-coordinate of the point representing zero degrees full scale on the directivity pattern. It is measured in digitizing units.

mrax - the x-coordinate of the point representing the maximum response axis. It is measured in digitizing units.

mray - the y-coordinate of the point representing the maximum response axis. It is measured in digitizing units.

gtabuperdb - number of digitizing units (graphic tablet units) per decibel. This is used as a scaling or conversion factor.

dbfullscale - number of decibels from the origin to zero degrees full scale.

radiusvalues (*) - an array representing the radii of the polar coordinate data points.

angle (*) - an array representing the angles of the polar coordinate data points.

mra - the maximum response axis value.

resolution - the incremental angle, which determines the number of data points gathered.

dirindex - the value of the directivity index.

skew - an offset angle to compensate for directivity patterns positioned crookedly on the graphics tablet digitizing area.

```
10    ! ************************************************************************
20    ! *                                                                      *
30    ! *            AUTOMATIC DIRECTIVITY INDEX CALCULATION PROGRAM           *
40    ! *                              by JEHU ROOKARD                         *
50    ! *                                                                      *
60    ! *                            Created 2 AUG 1984                        *
70    ! *                                                                      *
80    ! ************************************************************************
90    !
100   ! THIS PROGRAM DIGITIZES A DIRECTIVITY PATTERN AND CALCULATES THE
110   ! DIRECTIVITY INDEX
120   !
130   !
140 Main:       ! MAIN DIRECTIVITY PATTERN PROGRAM
150   OPTION BASE 0
160   COM Originx,Originy,Zerodegfsx,Zerodegfsy,Mrax,Mray
170   COM Gtabuperdb,Dbfullscale
180   COM Radiusvalues(360),Angle(360)
190   COM Mra
200   COM Resolution
210   COM Dirindex
220   COM Skew
230   CALL Clearscreen
240   PLOTTER IS 13,"GRAPHICS"    ! ACTIVATE CRT GRAPHICS RASTER
250   GRAPHICS
260   GCLEAR                      ! CLEAR THE GRAPHICS RASTER
270   PLOTTER 13 IS OFF           ! DEACTIVATE CRT GRAPHICS RASTER
280   PRINT "THIS PROGRAM ENTERS A DIRECTIVITY PATTERN FROM THE GRAPHICS"
290   PRINT "TABLET AND CALCULATES THE DIRECTIVITY INDEX"
300   INPUT "PRESS 'CONT' WHEN READY TO PROCEED",Cont$
310   CALL Enterapattern          ! ENTER A DIRECTIVITY PATTERN USING THE 9111A
320                               ! GRAPHICS TABLET
330   CALL Calcdirindex           ! CALCULATE THE DIRECTIVITY INDEX
340   CALL Displaypattern         ! DRAW THE DIRECTIVITY PATTERN ON THE CRT
350   CALL Printcopy              ! MAKE HARD COPY ON PRINTER
360   CALL Plotcopy               ! MAKE HARD COPY ON PLOTTER
370   PLOTTER IS 13,"GRAPHICS"    ! CLEAR THE GRAPHICS RASTER
380   GCLEAR
390   EXIT GRAPHICS
400   PLOTTER 13 IS OFF           ! DEACTIVATE CRT GRAPHICS RASTER
410   CALL Clearscreen
420   Yesno$="Y"
430   INPUT "ENTER ANOTHER PATTERN - Y/N. DEFAULT IS 'Y'",Yesno$
440   IF Yesno$="Y" THEN
450   PLOTTER IS 13,"GRAPHICS"    ! CLEAR THE GRAPHICS RASTER
460   GCLEAR
470   PLOTTER 13 IS OFF           ! DEACTIVATE THE CRT GRAPHICS RASTER
480   GOTO 310
490   ELSE
500   END
510   !
520   !
530   !
540 Enterapattern:    ! PROCEDURE TO ENTER A DIRECTIVITY PATTERN FROM THE 9111A
550                   ! GRAPHICS TABLET
560   SUB Enterapattern
570   CALL Clearscreen        ! CLEAR THE ALPHA RASTER
580   PLOTTER IS 7,6,"9872A"  ! THE 9111A GRAPHICS TABLET CAN ONLY BE ACCESSED
590                           ! THROUGH THE GRAPHICS ROM. ALTHOUGH IT IS A
600                           ! GRAPHICS TABLET, THE COMPUTER TREATS IT AS A
610                           ! PLOTTER
620   OUTPUT 706;"IN"         ! INITIALIZE THE 9111A GRAPHICS TABLET
630   CALL Setupaxes          ! GET THE NECESSARY POINTS TO PROPERLY SCALE
640                           ! THE DIGITIZING AREA AND ALL POINTS ENTERED
650                           ! FROM IT
```

```
660   CALL Entercurve          ! DIGITIZE THE ACTUAL DIRECTIVITY PATTERN
670   SUBEND
680   !
690   !
700   !
710 Setupaxes:        ! ENTER THE NECESSARY SCALING VALUES FROM THE GRAPHICS
720                   ! TABLET SO THAT A BASIS FOR ENTERING ALL SUCCEEDING
730                   ! POINTS IS ESTABLISHED
740                   ! A METHOD (SCALE) FOR CONVERTING BETWEEN DIGITIZING UNITS
750                   ! AND USER UNITS IS SET UP
760   SUB Setupaxes
770   OPTION BASE 0
780   COM Originx,Originy,Zerodegfsx,Zerodegfsy,Mrax,Mray
790   COM Gtabuperdb,Dbfullscale
800   COM Radiusvalues(360),Angle(360)
810   COM Mra
820   COM Resolution
830   COM Dirindex
840   COM Skew
850   Dbfullscale=50
860   INPUT "ENTER NO. OF db'S FROM ORIGIN TO ZERO DEGREES FULL SCALE. DEFAULT I
S 50",Dbfullscale
870   IF Dbfullscale>50 THEN
880   PRINT "NO VALUES GREATER THAN 50 ALLOWED. PLEASE RE-ENTER"
890   GOTO 850
900   ELSE
910   END IF
920   !
930   Resolution=5
940   INPUT "ENTER INCREMENTAL ANGLE. DEFAULT IS 5 DEGREES",Resolution
950   Resolution=INT(Resolution)
960   IF Resolution<1 THEN
970   PRINT "INCREMENTAL ANGLE MUST BE GREATER THAN OR EQUAL TO 1"
980   GOTO 930
990   ELSE
1000  END IF
1010  !
1020  DISP "DIGITIZE ORIGIN"
1030  OUTPUT 706;"SG"              ! SET TO SINGLE POINT MODE
1040  CALL Status                  ! WAIT UNTIL GRAPHICS TABLET IS READY
1050  OUTPUT 706;"OD"              ! INSTRUCT GRAPHICS TABLET TO TRANSMIT POINT
1060  ENTER 706;Originx,Originy    ! GET THE POINT FROM THE GRAPHICS TABLET
1070  OUTPUT 706;"BP24,125,4"      ! INTRUCT GRAPHICS TABLET TO BEEP
1080  !
1090  DISP "DIGITIZE ZERO DEGREE FULL SCALE"
1100  CALL Status
1110  OUTPUT 706;"OD"
1120  ENTER 706;Zerodegfsx,Zerodegfsy
1130  OUTPUT 706;"BP"
1140  !
1150  DISP "DIGITIZE MAXIMUM RESPONSE AXIS"
1160  CALL Status
1170  OUTPUT 706;"OD"
1180  ENTER 706;Mrax,Mray
1190  OUTPUT 706;"BP"
1200  !
1210  ! CALCULATE THE NUMBER OF DIGITIZING UNITS PER DECIBEL BY DIVIDING
1220  ! THE RADIUS (Rho) AT FULL SCALE BY THE NUMBER OF DECIBELS FULL SCALE
1230  Differencex=ABS(Zerodegfsx-Originx)
1240  Differencey=ABS(Zerodegfsy-Originy)
1250  CALL Calculateradius(Differencex,Differencey,Rho_zerodegfs)
1260  Gtabuperdb=Rho_zerodegfs/Dbfullscale
1270  !
1280  ! CALCULATE THE MAXIMUM RESPONSE AXIS VALUE BY DIVIDING THE VALUE FOR
1290  ! THE MAXIMUM RESPONSE AXIS IN DIGITIZING UNITS BY THE NUMBER OF
1300  ! DIGITIZING UNITS PER DECIBEL
```

```
1310  ! ( ie. CONVERT FROM DIGITIZING UNITS TO USER UNITS )
1320  Differencex=ABS(Mrax-Originx)
1330  Differencey=ABS(Mray-Originy)
1340  CALL Calculateradius(Differencex,Differencey,Mra)
1350  Mra=Mra/Gtabuperdb
1360  !
1370  ! DETERMINE THE "SKEW ANGLE" TO CORRECT FOR ERRORS THAT WILL RESULT FROM
1380  ! THE ORIGINAL DIRECTIVITY PATTERN BEING POSITIONED CROOKED OR SKEWED ON
1390  ! THE GRAPHICS TABLET. THIS CORRECTION FACTOR ALLOWS THE USER TO PLACE THE
1400  ! ORIGINAL DIRECTIVITY PATTERN IN any POSITION inside THE GRAPHICS TABLET
1410  ! DIGITIZING AREA AND STILL GATHER ACCURATE DATA. IT ALSO RESULTS IN A
1420  ! TRUE POLAR CO-ORDINATE SYSTEM
1430  CALL Displacement(Zerodegfsx,Zerodegfsy,Xvalue,Yvalue)
1440  CALL Calcarctangent(Xvalue,Yvalue,Relativeangle)
1450  CALL Determinequad(Zerodegfsx,Zerodegfsy,Quadrant)
1460  CALL Convertto360(Relativeangle,Quadrant,Absoluteangle)
1470  Skew=Absoluteangle
1480  PLOTTER 7,6 IS OFF          ! DEACTIVATE GRAPHICS TABLET
1490                              ! ( ie. DON'T SEND GRAPHICS COMMANDS TO IT )
1500  SUBEND
1510  !
1520  !
1530  !
1540 Entercurve:    ! ENTER A DIRECTIVITY PATTERN USING THE 9111A GRAPHICS TABLET
1550                ! THE USER MUST START DIGITIZING FROM ZERO DEFREES AND
1560                ! CONTINUE UNTIL HE REACHES 360 DEGREES. 'Resolution'
1570                ! DETERMINES THE NUMBER OF DATA POINTS ACCEPTED.
1580                ! 360/'Resolution' SECTORS ARE CREATED AND A DATA POINT
1590                ! IS ENTERED FOR EACH SECTOR AND STORED IN ITS RESPECTIVE
1600                ! ARRAY ELEMENT
1610  SUB Entercurve
1620  OPTION BASE 0
1630  COM Originx,Originy,Zerodegfsx,Zerodegfsy,Mrax,Mray
1640  COM Gtabuperdb,Dbfullscale
1650  COM Radiusvalues(360),Angle(360)
1660  COM Mra
1670  COM Resolution
1680  COM Dirindex
1690  COM Skew
1700  DEG                         ! DEGREES MODE (NOT RADIANS)
1710  !
1720  ! "ENTERCURVE" EXPECTS TO HAVE A "COMMUNICATIONS CHANNEL" WITH THE
1730  ! GRAPHICS TABLET ALREADY ESTABLISHED. IT ALSO EXPECTS THE GRAPHICS
1740  ! TABLET TO HAVE BEEN INITIALIZED. ( AS IN "SETUPAXES" )
1750  ! "ENTERCURVE WILL RE-ACTIVATE THE GRAPHICS TABLET IF IT HAS PREVIOUSLY
1760  ! BEEN DEACTIVATED
1770  !
1780  PLOTTER 7,6 IS ON
1790  OUTPUT 706;"CN"             ! SET GRAPHICS TABLET TO CONTINUOUS
1800                              ! SAMPLING MODE
1810  DISP "START DIGITIZING FROM ZERO DEGREES AND PROCEED COUNTER-CLOCKWISE"
1820  FOR Anglecounter=0 TO 360-Resolution STEP Resolution
1830  CALL Status                 ! WAIT UNTIL GRAPHICS TABLET IS READY
1840  OUTPUT 706;"OD"
1850  ENTER 706;Beamformx,Beamformy    ! GET DATA POINT
1860  !
1870  ! CONVERT THE X AND Y COORDINATES TO POLAR COORDINATES BY CALLING THE
1880  ! FOLLOWING SUBPROGRAMS IN THE PROPER SEQUENCE
1890  !
1900  CALL Displacement(Beamformx,Beamformy,Xdisplacement,Ydisplacement)
1910  CALL Calculateradius(Xdisplacement,Ydisplacement,Radius)
1920  CALL Calcarctangent(Xdisplacement,Ydisplacement,Relativeangle)
1930  CALL Determinequad(Beamformx,Beamformy,Quadrant)
1940  CALL Convertto360(Relativeangle,Quadrant,Absoluteangle)
1950  !
1960  ! TEST TO SEE IF THE POINT LIES WITHIN THE SECTOR. IF IT DOES, THEN STORE
```

```
1970  ! IT IN ITS RESPECTIVE ARRAY ELEMENT. REMEMBER TO CORRECT FOR ANY "SKEW"
1980  ! ERRORS THAT MAY EXIST
1990  !
2000  IF (Absoluteangle-Skew>Anglecounter) AND (Absoluteangle-Skew<Anglecounter+
Resolution) THEN
2010  ELSE
2020  !
2030  ! IF 'Skew' IS NEGATIVE THEN PERFORM THE TEST BUT WITH 360 DEGREES ADDED
2040  ! TO MAKE THE ANGLE POSITIVE
2050  !
2060  IF (Absoluteangle+360-Skew>Anglecounter) AND (Absoluteangle+360-Skew<Angle
counter+Resolution) THEN
2070  Absoluteangle=Absoluteangle+360
2080  ELSE
2090  GOTO 1830
2100  END IF
2110  END IF
2120  DISP "ANGLE =";Absoluteangle-Skew,"db DOWN =";Mra-Radius
2130  Radiusvalues(Anglecounter)=Radius
2140  Angle(Anglecounter)=Absoluteangle-Skew
2150  BEEP
2160  NEXT Anglecounter
2170  !
2180  PLOTTER 7,6 IS OFF          ! DEACTIVATE GRAPHICS TABLET
2190  SUBEND
2200  !
2210  !
2220  !
2230 Displacement:     ! GIVEN A POINT'S X AND Y CO-ORDINATES, DETERMINE IT'S
2240                   ! RELATIVE X AND Y DISPLACEMENTS FROM THE ORIGIN
2250                   ! 'Xvalue' IS THE X-CO-ORDINATE OF THE POINT IN GRAPHIC
2260                   ! TABLET UNITS.
2270                   ! 'Yvalue' IS THE Y-CO-ORDINATE OF THE POINT IN GRAPHIC
2280                   ! TABLET UNITS
2290                   ! 'Xdisplacement' IS THE RELATIVE X-DISPLACEMENT FROM THE
2300                   ! ORIGIN IN USER DEFINED UNITS
2310                   ! 'Ydisplacement' IS THE RELATIVE Y-DISPLACEMENT FROM THE
2320                   ! ORIGIN IN USER DEFINED UNITS
2330  SUB Displacement(Xvalue,Yvalue,Xdisplacement,Ydisplacement)
2340  COM Originx,Originy,Zerodegfsx,Zerodegfsy,Mrax,Mray
2350  COM Gtabuperdb,Dbfullscale
2360  Xdisplacement=(Xvalue-Originx)/Gtabuperdb
2370  Ydisplacement=(Yvalue-Originy)/Gtabuperdb
2380  SUBEND
2390  !
2400  !
2410  !
2420 Calculateradius:     ! CALCULATE THE RADIUS USING THE PYTHAGAREAN THEOREM
2430                      ! (DISTANCE FORMULA)
2440  SUB Calculateradius(X,Y,R)
2450  R=SQR(X^2+Y^2)
2460  SUBEND
2470  !
2480  !
2490  !
2500 Calcarctangent:  ! CALCULATE THE VALUE OF THE ARCTANGENT GIVEN 'X' AND 'Y'
2510                  ! ALSO RESOLVE ANY INVALID INPUT PARAMETERS TO THE
2520                  ! ARCTANGENT FUNCTION BY SUBSTITUTING THE CORRECT VALUE
2530  SUB Calcarctangent(X,Y,Angle)
2540  DEG             ! DEGREES MODE (NOT RADIANS)
2550  ON ERROR GOTO Recovery
2560  Angle=ATN(Y/X)
2570  SUBEXIT
2580 Recovery:  !   ROUTINE TO RECOVER INVALID INPUT PARAMETERS TO
2590            !   ARCTANGENT FUNCTION. (ie. DENOMINATOR CAN'T EQUAL
2600            !   ZERO)
```

```
2610            !   ANGLE=ATN(Y/X) ; ASSUMES X DOES NOT 0
2620  IF ERRN=31 THEN  ! IF DIVISION BY ZERO ERROR THEN CORRECT THE ERROR
2630                   !   BY ASSIGNING THE CORRECT VALUE OR SOME ARBITRARY
2640                   !   VALUE TO 'ANGLE'
2650  SELECT SGN(Y)    ! A NUMBER IS EITHER +,-,  OR ZERO, SO DETERMINE THE
2660                   ! CORRECT VALUE FOR THE 3 CASES OF 'Y'
2670  CASE 1         ! IF 'Y' IS POSITIVE THEN THE CORRECT ANSWER IS 90 DEGREES
2680                 ! (ie. THE POINT LIES SOMEWHERE ON THE Y-AXIS, BUT ABOVE
2690                 ! THE X-AXIS)
2700  Angle=0        ! 0 PRODUCES A VALUE OF 90 DEGREES AFTER BEING PROCESSED
2710                 ! BY "CONVERTTO360"
2720  CASE 0         ! IF 'Y' IS ZERO THEN THE POINT IS AT THE ORIGIN, SO
2730                 ! ARBITRARILY ASSIGN AN ANGLE OF ZERO DEGREES. THE VALUE
2740                 ! OF THE RHO (RADIUS) WILL BE CALCULATED AS ZERO AND IT WILL
2750                 ! BE OBVIOUS TO THE USER THAT THE POINT WAS AT THE ORIGIN
2760  Angle=451      ! 451 PRODUCES A VERY LARGE VALUE AFTER BEING PROCESSED BY
2770                 ! "CONVERTTO360". THIS RESULTS IN "ENTERCURVE" REJECTING
2780                 ! ANY POINTS THAT LIE AT THE ORIGIN BECAUSE THEY WILL BE
2790                 ! OUT OF RANGE
2800  CASE -1        ! IF 'Y' IS NEGATIVE THEN THE CORRECT ANSWER IS 270 DEGREES
2810                 ! (ie. THE POINT LIES SOMEWHERE ON THE Y-AXIS, BUT BELOW THE
2820                 ! X-AXIS)
2830  Angle=0        ! 0 PRODUCES A VALUE OF 270 DEGREES AFTER BEING PROCESSED
2840                 ! BY "CONVERTTO360"
2850  END SELECT     ! NO NEED FOR A 'CASE ELSE' STATEMENT AS A NUMBER IF EITHER
2860                 ! +,- OR ZERO
2870  SUBEXIT        ! END OF ERROR HANDLER ROUTINE
2880  ELSE           ! IF THIS ISN'T A DIVISION BY ZERO ERROR, THEN DISPLAY THE
2890                 ! ERROR MESSAGE AND PAUSE PROGRAM EXECUTION
2900  DISP ERRM$
2910  PAUSE
2920  END IF
2930  SUBEND
2940  !
2950  !
2960  !
2970 Determinequad:  ! DETERMINE WHICH QUADRANT THE POINT LIES IN BASED UPON
2980                 ! WHETHER THE POINT LIES TO THE LEFT OR RIGHT OF THE
2990                 ! Y-AXIS AND ABOVE OR BELOW THE X-AXIS
3000  SUB Determinequad(Xvalue,Yvalue,Quadrant)
3010  COM Originx,Originy,Zerodegfsx,Zerodegfsy,Mrax,Mray
3020  IF Xvalue>Originx THEN            ! IN QUADRANT 1 OR 4 THEN
3030  IF Yvalue>=Originy THEN           ! IN QUADRANT 1
3040  Quadrant=1
3050  ELSE
3060  Quadrant=4
3070  END IF
3080  ELSE                              ! IN QUADRANT 2 OR 3 OR ON Y-AXIS THEN
3090  IF Yvalue>Originy THEN            ! IN QUADRANT 2
3100  Quadrant=2
3110  ELSE
3120  IF Xvalue=Originx THEN            !IN QUADRANT 4 ( ON Y-AXIS )
3130  Quadrant=4
3140  ELSE
3150  Quadrant=3
3160  END IF
3170  END IF
3180  END IF
3190  SUBEND
3200  !
3210  !
3220  !
3230 Convertto360:   ! GIVEN THE PRINCIPAL ANGLE AND THE QUADRANT PRODUCE
3240                 ! AN ANGULAR VALUE IN THE RANGE 0 TO 360 DEGREES
3250                 ! 'Relativeangle' IS THE PRINCIPAL ANGLE
3260                 ! 'Quadrant' IS IN THE RANGE 1-4 ( FROM CARTESIAN
```

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3270                  ! CO-ORDINATE SYSTEM )
3280                  ! 'Absoluteangle' IS THE RESULTANT ANGULAR VALUE IN
3290                  ! THE RANGE 0-360 DEGREES
3300  SUB Convertto360(Relativeangle,Quadrant,Absoluteangle)
3310  SELECT Quadrant
3320  CASE 1          ! FIRST QUADRANT    0 <= Relativeangle < 90
3330  Absoluteangle=Relativeangle+270
3340  CASE 2          ! SECOND QUADRANT  90 <= Relativeangle < 180
3350  Absoluteangle=Relativeangle+90
3360  CASE 3          ! THIRD QUADRANT  180 <= Relativeangle < 270
3370  Absoluteangle=Relativeangle+90
3380  CASE 4          ! FOURTH QUADRANT 270 <= Relativeangle < 360
3390  Absoluteangle=Relativeangle+270
3400  END SELECT
3410  SUBEND
3420  !
3430  !
3440  !
3450 Clearscreen:  ! CLEAR THE ALPHA RASTER BY PRINTING 24 BLANK LINES
3460  SUB Clearscreen
3470  FOR Line=1 TO 24
3480  PRINT
3490  NEXT Line
3500  SUBEND
3510  !
3520  !
3530  !
3540 Displaypattern:    ! DRAW THE DIRECTIVITY PATTERN ON THE GRAPHICS RASTER
3550                    ! AND LABEL THE DIRECTIVITY INDEX
3560  SUB Displaypattern
3570  OPTION BASE 0
3580  COM Originx,Originy,Zerodegfsx,Zerodegfsy,Mrax,Mray
3590  COM Gtabuperdb,Dbfullscale
3600  COM Radiusvalues(360),Angle(360)
3610  COM Mra
3620  COM Resolution
3630  COM Dirindex
3640  DEG                           ! DEGREES MODE ( NOT RADIANS )
3650  PLOTTER IS 13,"GRAPHICS"      ! ACTIVATE THE CRT GRAPHICS RASTER
3660  GRAPHICS                      ! ENABLE GRAPHICS
3670  GCLEAR                        ! CLEAR GRAPHICS RASTER
3680  LOCATE 20,95,0,100
3690  MOVE 37,2
3700  CSIZE 3.2
3710  LABEL "Directivity index =";DROUND(Dirindex,6)
3720  SCALE -Dbfullscale*.75,Dbfullscale*.75,-Dbfullscale,Dbfullscale
3730  FRAME
3740  AXES 10,10,0,0,1,1
3750  FOR Anglecounter=0 TO 360-Resolution STEP Resolution
3760  X=Radiusvalues(Anglecounter)*COS(Angle(Anglecounter)+90)
3770  Y=Radiusvalues(Anglecounter)*SIN(Angle(Anglecounter)+90)
3780  IF Anglecounter=0 THEN
3790  MOVE X,Y
3800  ELSE
3810  DRAW X,Y
3820  END IF
3830  NEXT Anglecounter
3840  ! COMPLETE THE DIRECTIVITY PATTERN PLOT BY DRAWING A LINE FROM THE
3850  ! LAST POINT TO THE FIRST POINT.
3860  DRAW Radiusvalues(0)*COS(Angle(0)+90),Radiusvalues(0)*SIN(Angle(0)+90)
3870  PLOTTER 13 IS OFF             ! DEACTIVATE THE CRT GRAPHICS RASTER
3880  SUBEND
3890  !
3900  !
3910  !
3920 Calcdirindex:    ! CALCULATE THE DIRECTIVITY INDEX GIVEN THE RADIUS (Rho)
```

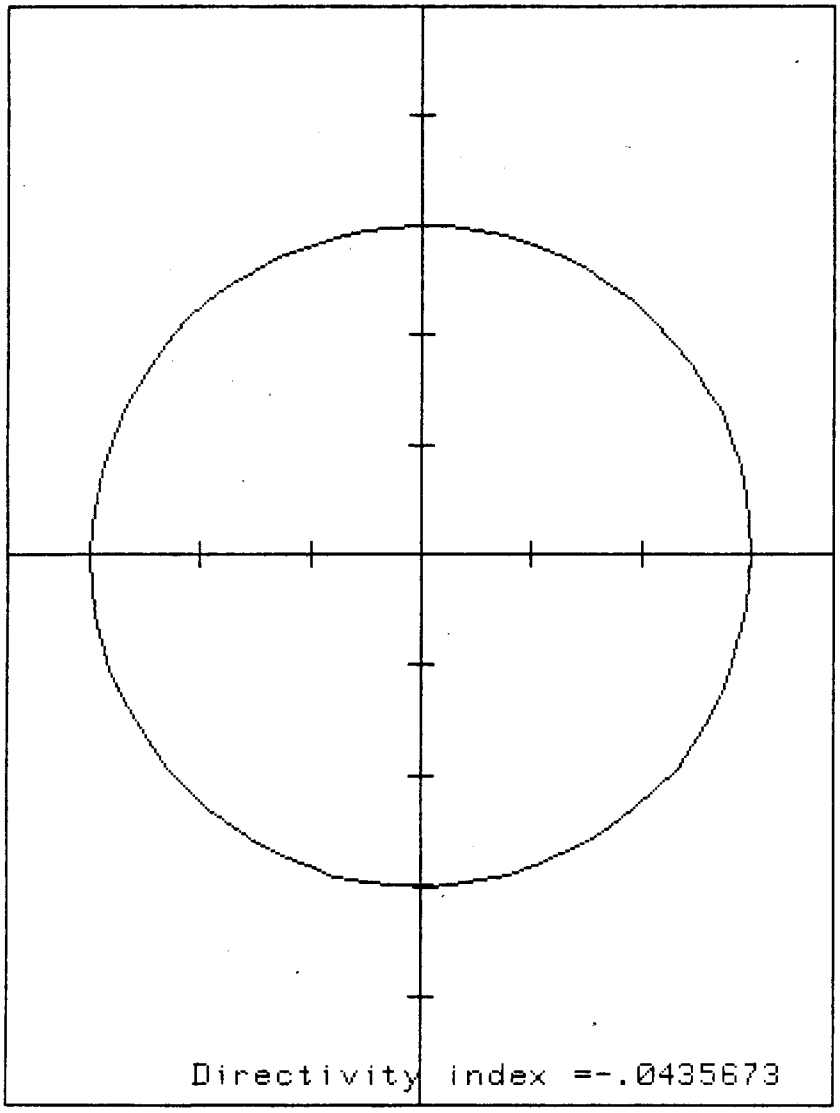
```
3930                  ! AND THE ANGLE ( 0-360 DEGREES )
3940  SUB Calcdirindex
3950  OPTION BASE 0
3960  COM Originx,Originy,Zerodegfsx,Zerodegfsy,Mrax,Mray
3970  COM Gtabuperdb,Dbfullscale
3980  COM Radiusvalues(360),Angle(360)
3990  COM Mra
4000  COM Resolution
4010  COM Dirindex
4020  DEG          ! DEGREES MODE, NOT RADIANS
4030  Sum=0
4040  Anglecounter=0
4050  FOR Anglecounter=0 TO 360-Resolution STEP Resolution
4060  Temp=ABS(SIN(Angle(Anglecounter)))*10^(-(Mra-Radiusvalues(Anglecounter))/1
0)
4070  Sum=Temp+Sum
4080  NEXT Anglecounter
4090  Dirfactor=229.2/(Resolution*Sum)
4100  Dirindex=10*LGT(Dirfactor)
4110  SUBEND
4120  !
4130  !
4140  !
4150 Printcopy:    ! DUMP THE CONTENTS OF THE GRAPHICS RASTER TO THE PRINTER
4160               ! ONLY THE DIRECTIVITY PATTERN AND ITS RESPECTIVE LABELS WILL
4170               ! APPEAR ON THE PRINTER OUTPUT
4180  SUB Printcopy
4190  Yesno$="N"
4200  INPUT "DUMP DIRECTIVITY PATTERN TO PRINTER - Y/N. DEFAULT IS 'N'",Yesno$
4210  IF Yesno$="Y" THEN
4220  PLOTTER 13 IS ON
4230  PRINTER IS 0                    ! OUTPUT DEVICE = PRINTER
4240  DUMP GRAPHICS
4250  PRINT CHR$(12)                  ! ADVANCE TO TOP OF NEXT SHEET OF PAPER
4260  PRINTER IS 16                   ! OUTPUT DEVICE = CRT
4270  PLOTTER 13 IS OFF
4280  ELSE
4290  END IF
4300  SUBEND
4310  !
4320  !
4330  !
4340 Status:    ! INTERROGATE THE 9111A GRAPHICS TABLET TO SEE IF IT'S READY
4350            ! READ THE STATUS WORD AND TEST BIT 2. THE GRAPHICS TABLET IS
4360            ! READY WHEN BIT 2 = 1
4370  SUB Status
4380  STATUS 7,6;S
4390  IF BIT(S,2)=0 THEN 4380
4400  SUBEND
4410  !
4420  !
4430  !
4440 Plotcopy:    ! PLOT THE DIRECTIVITY PATTERN ON THE PLOTTER AND LABEL THE
4450              ! DIRECTIVITY INDEX
4460  SUB Plotcopy
4470  OPTION BASE 0
4480  COM Originx,Originy,Zerodegfsx,Zerodegfsy,Mrax,Mray
4490  COM Gtabuperdb,Dbfullscale
4500  COM Radiusvalues(360),Angle(360)
4510  COM Mra
4520  COM Resolution
4530  COM Dirindex
4540  DEG          ! DEGREES MODE (NOT RADIANS)
4550  Yesno$="N"
4560  Dimflag=0
4570  INPUT "DUMP DIRECTIVITY PATTERN TO PLOTTER - Y/N. DEFAULT IS 'N'",Yesno$
```

```
4580  IF Yesno$="Y" THEN
4590  IF Dimflag=1 THEN 4630
4600  DIM Temp$(2)[35]
4610  Dimflag=1
4620  PLOTTER IS 7,5,"9872A"
4630  Temp$(0)=" "
4640  Temp$(1)=" "
4650  Temp$(2)=" "
4660  INPUT "ENTER LABEL FOR FIRST LINE",Temp$(0)
4670  INPUT "ENTER LABEL FOR SECOND LINE",Temp$(1)
4680  INPUT "ENTER DATE (OPTIONAL)",Temp$(2)
4690  LOCATE 0,RATIO*100,0,100
4700  FRAME
4710  LORG 2
4720  LDIR 90
4730  CSIZE 2.6
4740  MOVE 120,4            ! DRAW LABEL 1
4750  LABEL Temp$(0)
4760  MOVE 125,4            ! DRAW LABEL 2
4770  LABEL Temp$(1)
4780  MOVE 130,4            ! DRAW LABEL 3
4790  LABEL Temp$(2)
4800  MOVE 130,53           ! LABEL DIRECTIVITY INDEX
4810  LABEL "Directivity index =";DROUND(Dirindex,6)
4820  LDIR 0
4830  ! SCALE PLOTTING AREA TO USER DEFINED UNITS
4840  SCALE -Dbfullscale,Dbfullscale,-Dbfullscale*.75,Dbfullscale*.75
4850  ! DRAW AXES WITH TICK MARKS EVERY 10 db
4860  AXES 10,10,0,0,1,1
4870  ! DRAW DIRECTIVITY PATTERN
4880  FOR Anglecounter=0 TO 360-Resolution STEP Resolution
4890  X=Radiusvalues(Anglecounter)*COS(Angle(Anglecounter)+180)
4900  Y=Radiusvalues(Anglecounter)*SIN(Angle(Anglecounter)+180)
4910  IF Anglecounter=0 THEN
4920  MOVE X,Y
4930  ELSE
4940  DRAW X,Y
4950  END IF
4960  NEXT Anglecounter
4970  ! COMPLETE THE DIRECTIVITY PATTERN PLOT BY DRAWING A LINE FROM THE
4980  ! LAST POINT TO THE FIRST POINT.
4990  DRAW Radiusvalues(0)*COS(Angle(0)+180),Radiusvalues(0)*SIN(Angle(0)+180)
5000  PEN 0
5010  Yesno$="N"
5020  INPUT "MAKE ANOTHER PLOT - Y/N. DEFAULT IS (N)O",Yesno$
5030  IF Yesno$="Y" THEN 4570
5040  PLOTTER 7,5 IS OFF
5050  SUBEXIT
5060  ELSE
5070  SUBEXIT
5080  END IF
5090  SUBEND
```

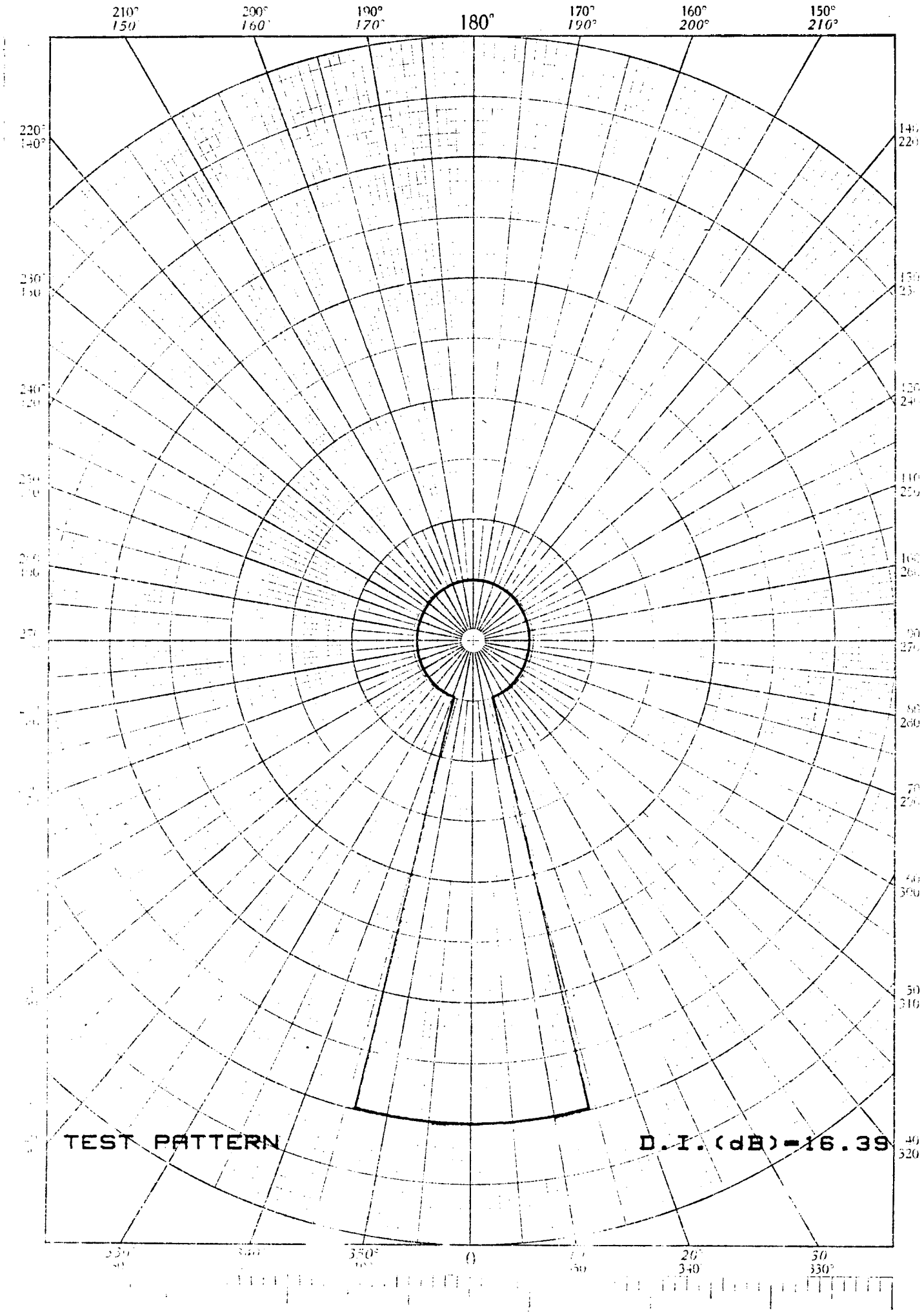
USING THE PROGRAM

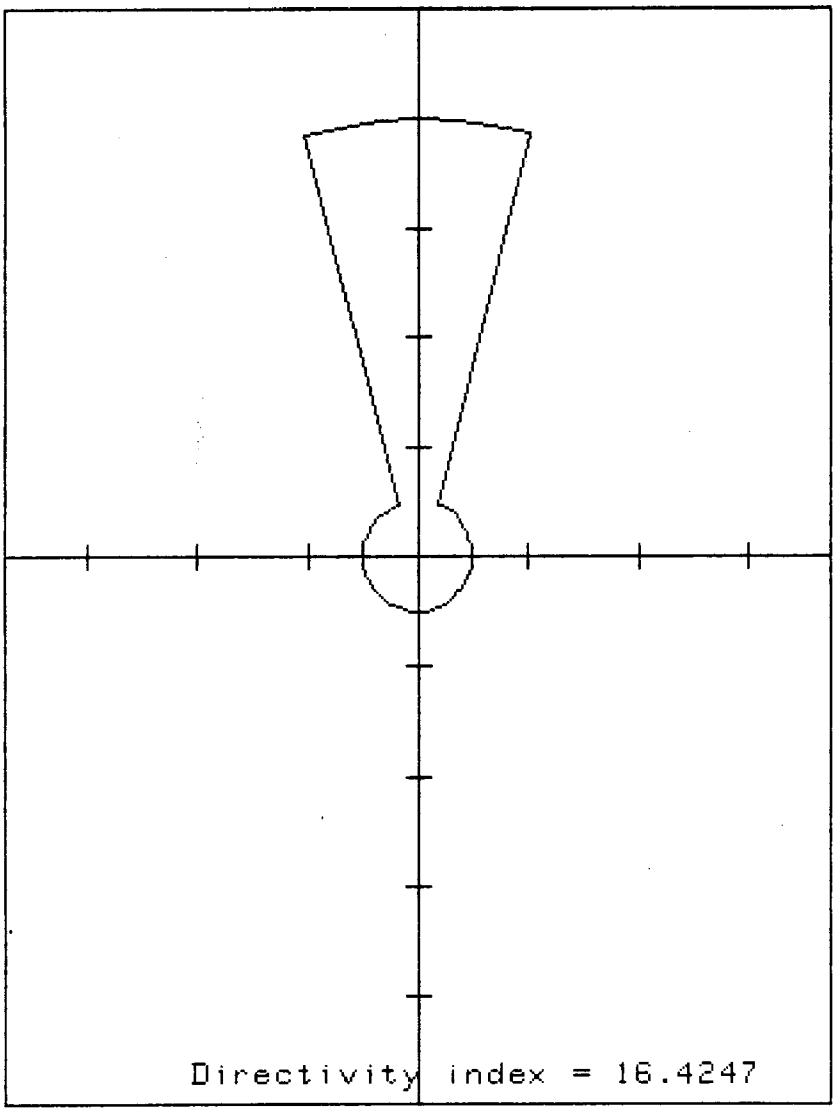
This program is very easy to use. Most input responses require simple "yes" or "no" answers. The process of digitizing a directivity pattern consumes the most time, and this process uses the stylus of the graphics tablet for input. To execute the program, the operator must complete the following simple steps:

1. Turn on the HP 9845 computer
2. Turn on the HP 9872A plotter
3. Turn on the HP 9111A graphics tablet
4. Load "CALCDI" from the proper mass storage device
5. Press the "RUN" key
6. Respond accordingly to computer generated questions



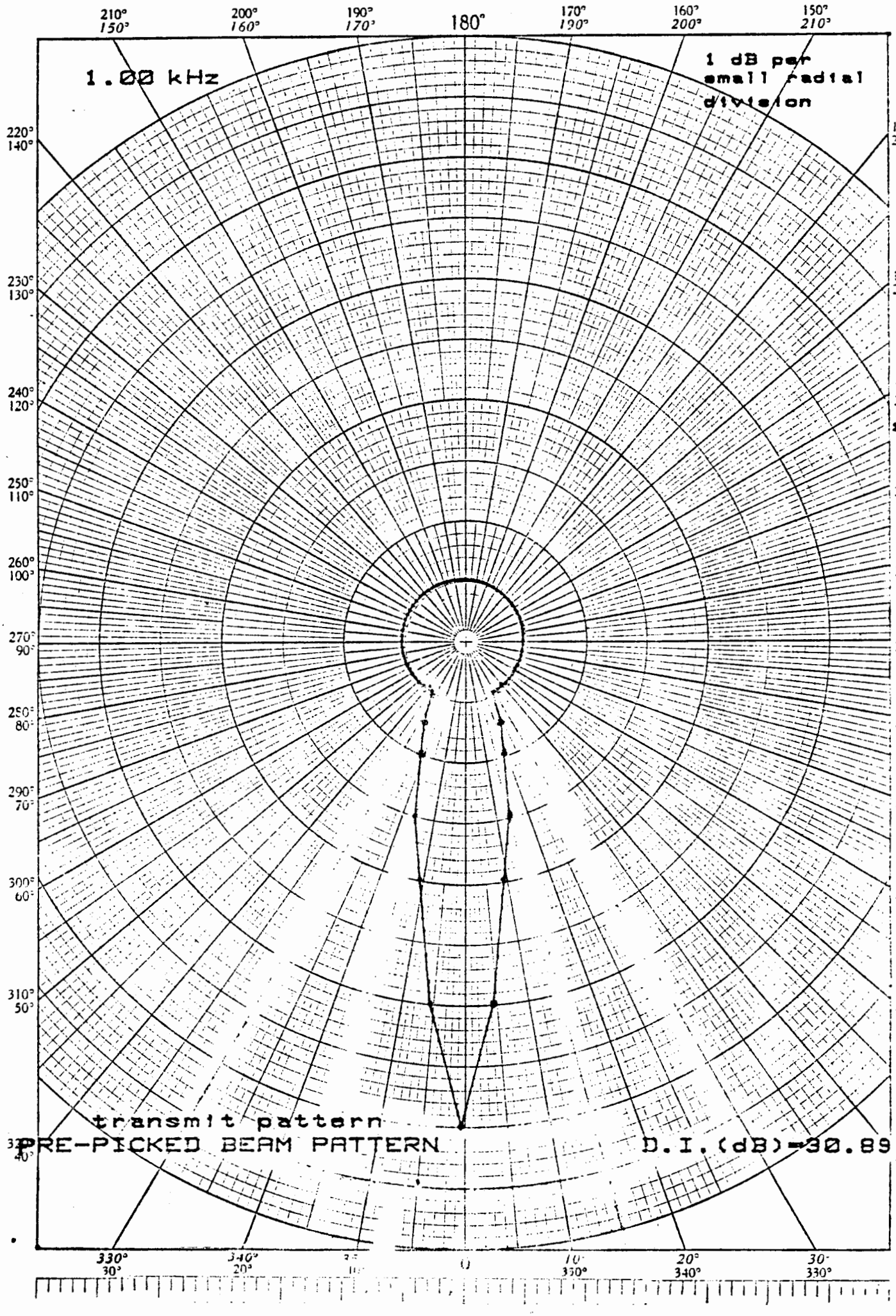
Sample circle pattern

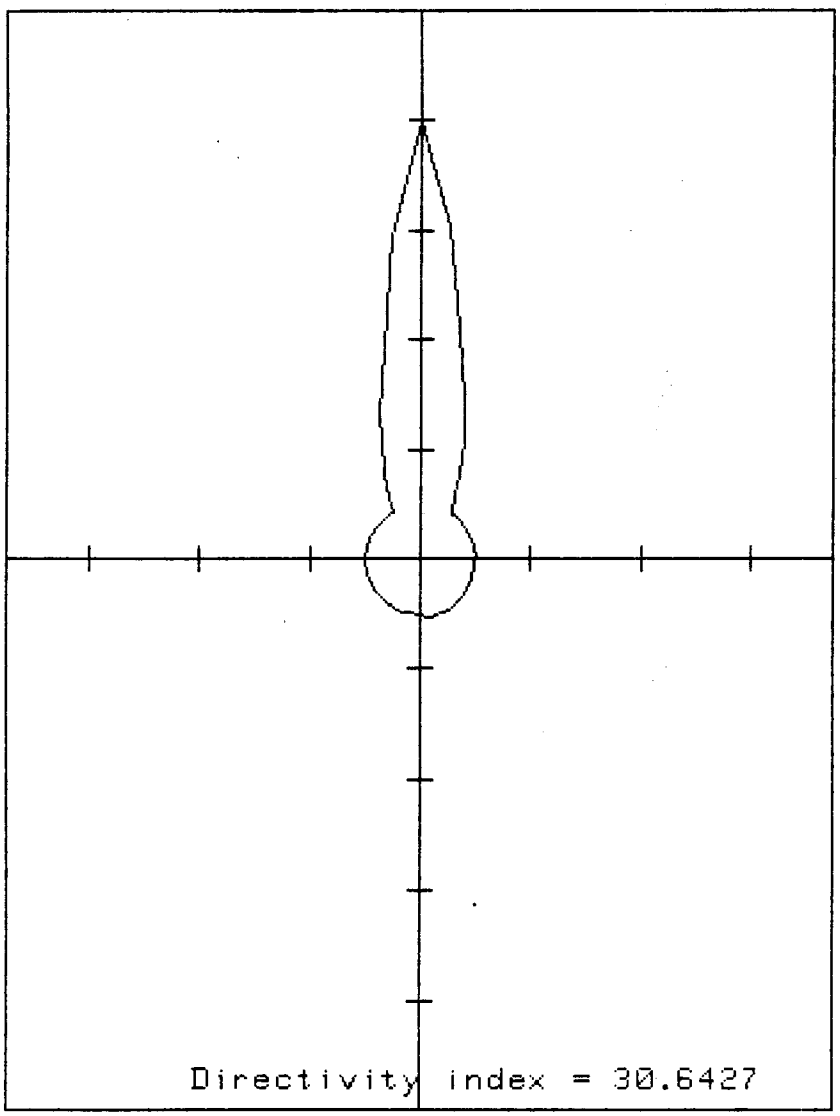

210°
150
200°
160°
190°
170°
180°
170°
190°
160°
200°
150°
210°
220°
140°
230°
130°
240°
120°
250°
110°
260°
100°
270°
90°
280°
80°
290°
70°
300°
60°
310°
50°
320°
40°
330°
30°
340°
20°
350°
10°
0
TEST PATTERN
D.I.(dB)=16.39



Sample wedge pattern generated from

previous page


1.00 kHz
1 dB per small radial division
210° 150°
200° 160°
190° 170°
180°
170° 190°
160° 200°
150° 210°
220° 140°
230° 130°
240° 120°
250° 110°
260° 100°
270° 90°
280° 80°
290° 70°
300° 60°
310° 50°
320° 40°
330° 30°
340° 20°
0
10° 350°
20° 340°
30° 330°
transmit pattern
PRE-PICKED BEAM PATTERN
D.I.(dB)=30.89



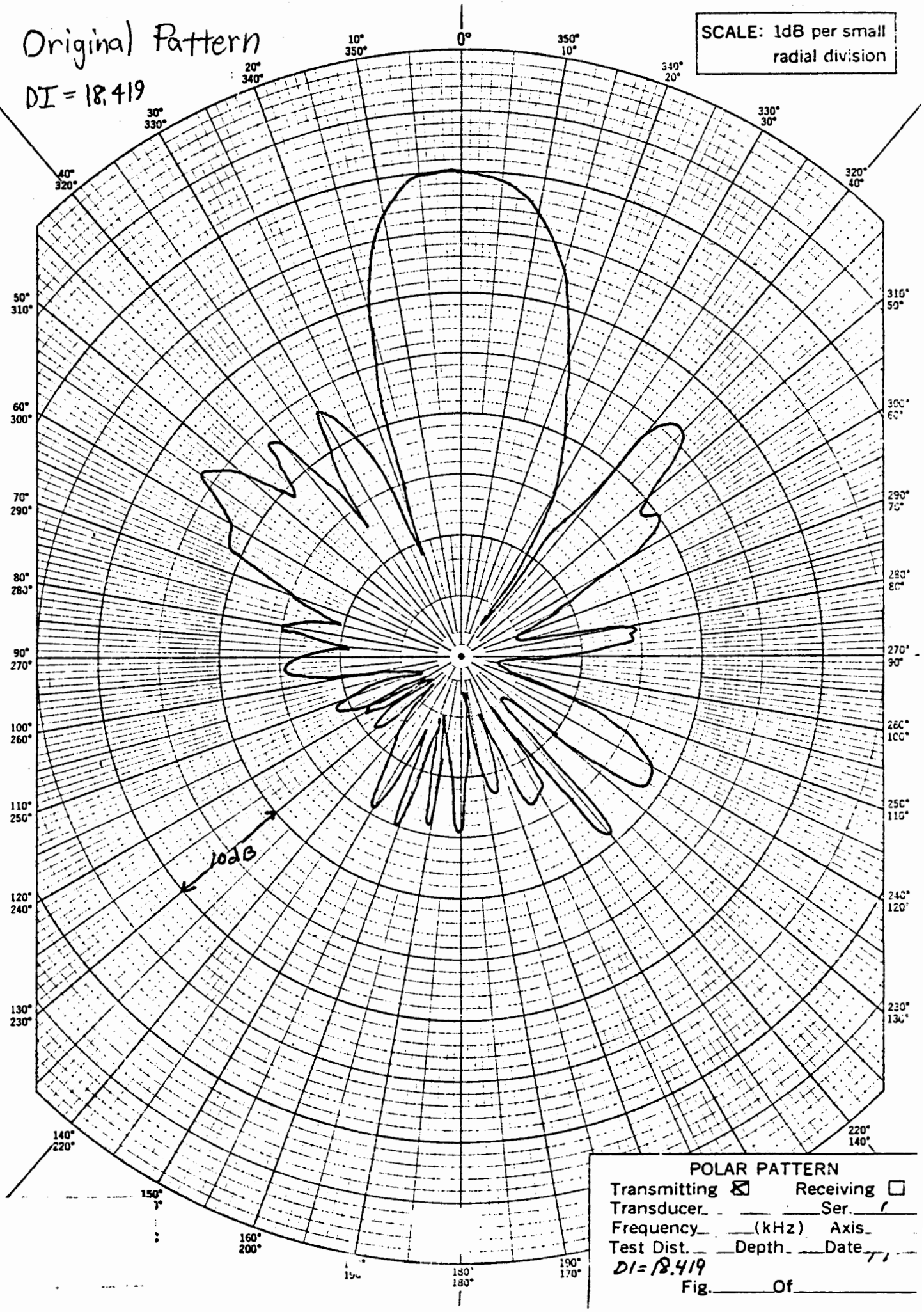
Sample spike pattern generated from

previous page

Original Pattern

DI = 18.419

SCALE: 1dB per small radial division



POLAR PATTERN

Transmitting ☒ Receiving ☐

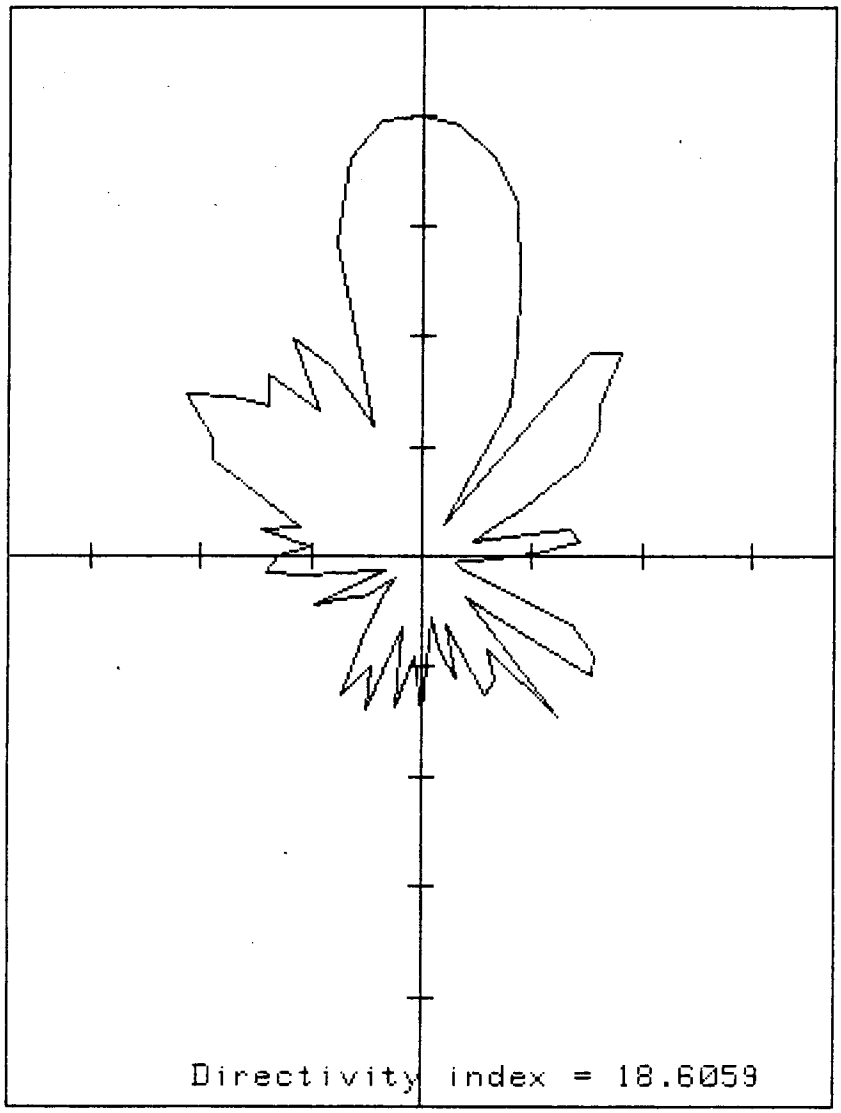
Transducer ____ Ser. ____

Frequency ____ (kHz) Axis ____

Test Dist. ____ Depth ____ Date ____

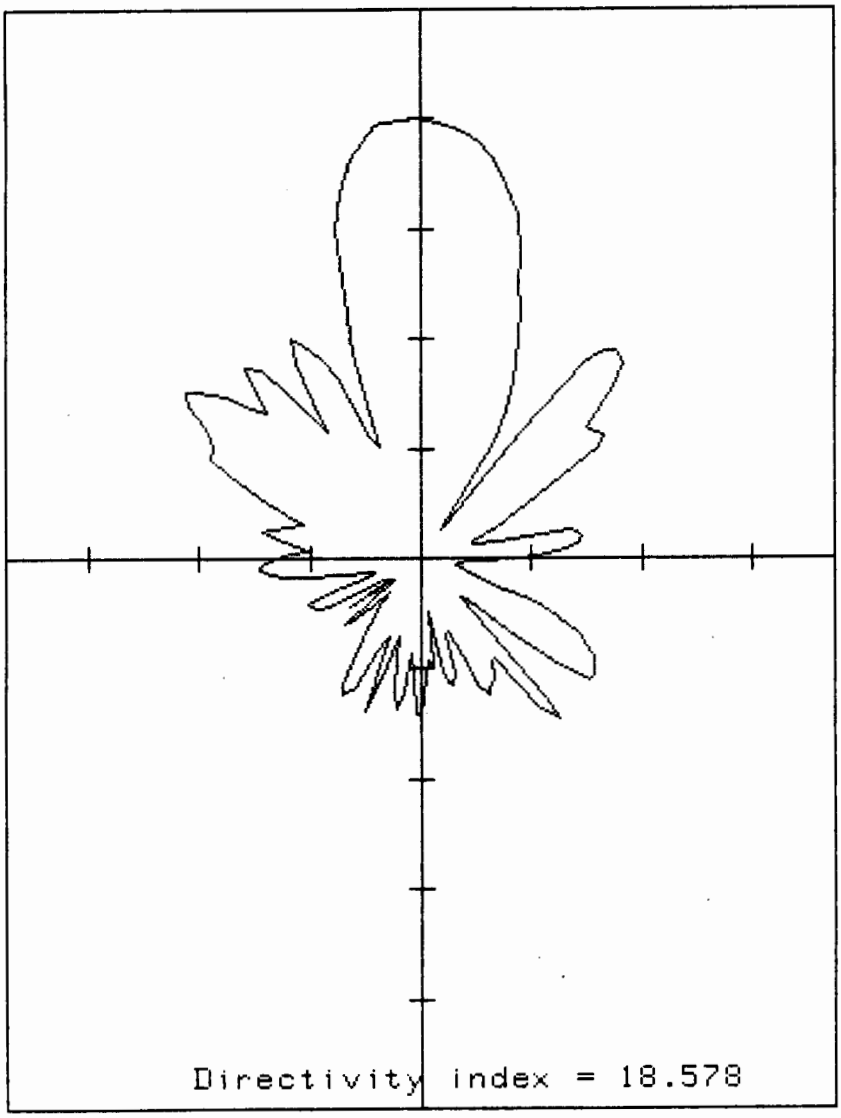
DI = 18.419

Fig. ____ Of ____



Sample of typical pattern generated

from previous page using 5° resolution



Sample of typical pattern generated

from previous page using 2° resolution