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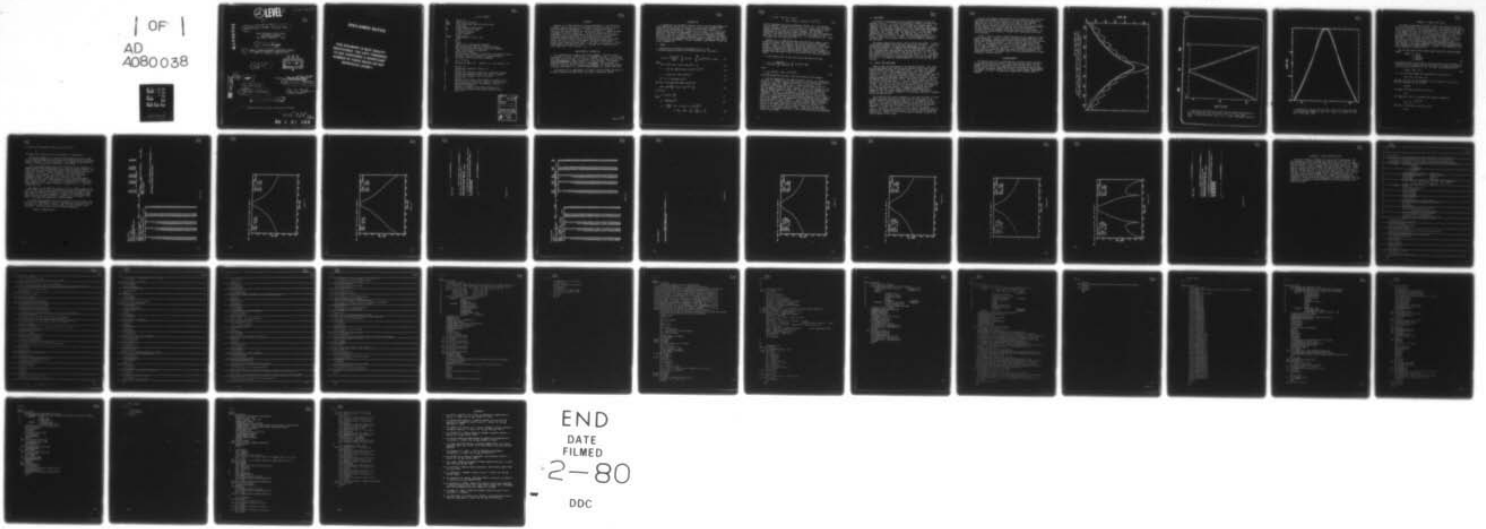
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CONVOL: A COMPUTER PROGRAM FOR PARAMETRIC SOURCE NEARFIELD AND --ETC(U)  
JUL 79 M B MOFFETT, R H MELLEN

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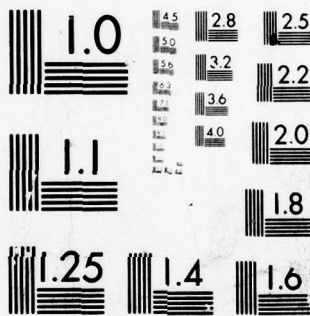
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NAVAL UNDERWATER SYSTEMS CENTER  
NEW LONDON LABORATORY  
NEW LONDON, CONNECTICUT 06320

⑨ Technical Memorandum

⑥ CONVOL: A COMPUTER PROGRAM FOR PARAMETRIC SOURCE  
NEARFIELD AND FARFIELD BEAM PATTERNS.

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⑪ Date: 17 Jul 1979

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LIST OF SYMBOLS

$B^2$	See Eq. (5)
BDG	bearing deviation gain
BDGAP	aperture-corrected bearing deviation gain
$c$	sound speed
$D_0$	primary-pressure beam pattern
$DI_0$	primary directivity index
$f$	difference frequency
$f_0$	primary frequency
$I$	see Eq. (3)
ISHAPE	shape parameter, see Eq. (A1)
$j$	$(-1)^{1/2}$
$k$	$2\pi f/c$
$k_0$	$2\pi f_0/c$
$N$	aspect ratio of rectangular projector
$P$	peak pressure amplitude of difference frequency
$P_0$	peak face pressure amplitude, one primary component
$r$	range (from projector to observer)
$r'$	source point distance
$R_0$	Rayleigh length, projector area/primary wavelength for piston projectors, projector length/ $\pi$ for endfire projector
$SL_0$	rms source level of one primary component
$SL_0^*$	$SL_0 + 20 \log f_0$
$SL_1^*$	$20 \log(\rho c^3 / 2\pi \sqrt{2B}) + 60$ dB// $\mu$ Pa - m - kHz (see Ref. 14)
$U$	see Eq. (6)
$y$	variable of integration, see Eq. (3)
$z$	see Eq. (4)
$\alpha$	primary wave absorption coefficient (nepers/unit length)
$\bar{\alpha}$	primary wave absorption coefficient (dB/unit length)
$\beta$	nonlinearity parameter ( $\approx 3.5$ for water)
$\eta$	see Eq. (9)
$\theta$	observer's polar angle (with respect to projector axis)
$\theta'$	source-point polar angle (with respect to projector axis)
$\nu$	angle between source point and observer, see Eq. (2)
$\rho$	ambient fluid density
$\phi$	observer's azimuthal angle (about projector axis)
$\phi'$	source point azimuthal angle (about projector axis)
$x$	see Eq. (8)

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ABSTRACT

Because it is often impractical to make measurements in the farfield of parametric acoustic sources, it is desirable to be able to predict the far field from nearfield measurements. A nearfield beam pattern theory, previously outlined [J. Acoust. Soc. Am. 63, 1622-1624 (L) (1978)], has been programmed for digital computation. The results compare favorably with experimental data from an absorption-limited source involving substantial difference-frequency generation in the primary farfield and from a saturation-limited source with most of the generation taking place in the primary nearfield. In the first example, the nearfield beam pattern is broader and the apparent source level is lower than in the farfield. In the second example, the nearfield pattern is narrower and the apparent source level higher than in the farfield.

ADMINISTRATIVE INFORMATION

This memorandum was prepared under project A70921, "Nonlinear Sensor Development," Principal Investigator, R.L. Schmidt (Code 3631). The Guidance and Control Block Principal is C. Ackerman (ARL/PSU), Navy subproject and task number SF 33-341-491, Project Manager, E. Liszka (SEA 034). The research described herein was performed under Project A61400, "Nearfield Model for Parametric Acoustic Sources," Principal Investigator, M.B. Moffett (Code 313); Associate Investigator, R.H. Metten; Program Manager, J.H. Probus (MAT 08T1).

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## INTRODUCTION

In experiments with parametric acoustic sources, farfield measurements are often impractical, because the farfield (the region where secondary signal generation has ceased) may be as remote as  $5/\alpha$  from the projector ( $\alpha =$  primary absorption coefficient in nepers per unit length). To allow farfield prediction from nearfield measurements, a nearfield theory must be employed. Reference 2 describes a nearfield model and outlines a computation procedure. We can now report on the computer implementation of this procedure and some of the results that have been obtained from the computer program. A user's guide to the program (called CONVOL) is given in Appendix A and FORTRAN listings are given in Appendix B.

### I. THEORY

The details of the theory are presented in Ref. 2. The difference-frequency pressure at the field point  $(r, \theta, \phi)$  is given by

$$p(r, \theta, \phi) = \frac{\beta(P_0 R_0 k)^2}{4\pi\rho c^2} \int_0^\pi d\theta' \sin\theta' \int_0^{2\pi} d\phi' D_0^2(\theta', \phi') I(\cos v), \quad (1)$$

where

$$\cos v \equiv \cos\theta' \cos\theta + \sin\theta' \sin\theta \cos(\phi' - \phi), \quad (2)$$

$$I = \exp(-jkr) \int_0^\infty dy \exp(-y) U(\xi)(z^2 + B^2)^{-1/2}, \quad (3)$$

$$z \equiv y - 2\alpha r \cos v + j2kr \sin^2(v/2), \quad (4)$$

$$B^2 \equiv (1 + jk/\alpha)(2\alpha r \sin v)^2, \quad (5)$$

and  $U(\xi)$  is the saturation taper function,<sup>3,4</sup>

$$U(\xi) = (2\xi^{-2}) \left[ (1 + \xi)(1 + 2\xi)^{-1/2} - 1 \right]. \quad (6)$$

In Eq. (6),

$$\xi \equiv 3(\chi/\pi)^2 \eta^2 \quad (7)$$

where

$$\chi \equiv 2\pi\beta P_0 R_0 f_0 / \rho c^3 \quad (8)$$

$$\eta \equiv \ln \left\{ \left[ 1 + (N-1)(r'/R_0) + (r'/R_0)^2 \right]^{1/2} + (r'/R_0) + \frac{1}{2}(N-1) \right\} - \ln \left\{ \frac{1}{2}(N+1) \right\}, \quad (9)$$

$$r = r \cos v + (2\alpha)^{-1}(1 + jk/\alpha)^{-1} \times \left[ (1 + jk/2\alpha)z - (jk/2\alpha)(z^2 + B^2)^{1/2} \right], \quad (10)$$

and N is the aspect ratio of a rectangular projector (N = 1 for square or circular shapes). The quantities I, z, B<sup>2</sup>, U, ξ, η, and r' are all complex, because the integral of Eq. (3) is the result of a transformation in the complex plane<sup>5</sup> of a highly oscillatory integrand. Thus the method substitutes the complications of complex arithmetic for the slow convergence inherent in the use of the oscillatory function. For example, at high amplitudes, the singularity introduced at ξ = -1/2 must be dealt with. (There is no pole at ξ = 0, since U(0) = 1.)

Equation (1) is a generalized form of the convolution integral used by Blue<sup>6</sup> and by Berktaf and Leahy<sup>7</sup> for the farfield of absorption-limited parametric sources. The integrand involves the product of an endfire beam pattern, I(cos v), and the square of the primary beam pattern, D<sub>0</sub>(θ', φ'). No aperture factor<sup>8</sup> results from the theory, because the primary beam is assumed to be spherically spreading from the projector face. Therefore the program makes beam pattern plots with and without a multiplicative aperture factor.

In the farfield, Eqs. (3) and (10) can be simplified as follows:

$$I \xrightarrow{r \rightarrow \infty} \frac{\exp(-jkr)}{2\alpha r + j2kr \sin^2(v/2)} \int_0^{\infty} dy \exp(-y) U(\xi), \quad (11)$$

where

$$r' \xrightarrow{r \rightarrow \infty} y/2\alpha \left[ 1 + (jk/\alpha) \sin^2(v/2) \right], \quad (12)$$

and these expressions are used in the farfield option of the program.

Since the computation of the endfire pattern, I(cos v), is a lengthy one and since I is a smooth function, 225 values are first computed and stored in a table for values of v ranging from 10<sup>-4</sup> rad to 3.14 rad. In the subsequent integrations over φ' and θ', linear interpolation is used to evaluate I(cos v) between the tabular values. (For v < 10<sup>-4</sup> rad and v > 3.14 rad, the endpoint values are used.) The tabular values are computed with an adaptive Simpson quadrature routine,<sup>9,10</sup> in which the step size for the integration variable, y, is determined by the degree of success at local convergence. The integrations over the azimuthal angle, φ', and the polar angle, θ', are each performed by 48-point Gaussian quadrature over a number of subintervals depending on the beamwidths of the endfire and primary patterns and on the observer's polar angle, θ. Typical running times to generate a beam pattern for a square, circular or endfire projector range from about 1 minute for easy cases (absorption-limited sources with large αR<sub>0</sub>, i.e., sources of the Westervelt<sup>11</sup> type) to about 5 minutes for difficult cases (saturation-limited sources with small αR<sub>0</sub>). These times are approximately doubled for a rectangular projector, in which case beam patterns are generated in each of two planes.

## II. EXPERIMENTS

The results of experiments with two different parametric sources are reported in Sec. III. The first was rectangular in shape, with active face dimensions of 0.53 m (horizontal) x 0.44 m (vertical), a mean primary frequency of 24 kHz, and a source level of 233.5 dB/ $\mu$ Pa-m at each primary component. The difference frequency was 2.5 kHz. Beam pattern measurements were made in the horizontal plane at a depth of 49 m in a fresh water lake (Seneca Lake, NY) in March, 1979. The range was 42.8 m and the water temperature was approximately 10°C. The Rayleigh length,  $R_0$ , was 4.0 m,  $\alpha R_0 \approx 0.001$  dB, and  $20 \log \chi \approx -19$  dB. This source generated much of the secondary signal in the primary farfield, since the absorption parameter,  $\alpha R_0$ , was small.

The second projector was circular, with an active face diameter of 0.91 m, a mean primary frequency of 65 kHz, and a source level of 244.5 dB/ $\mu$ Pa-m at each primary component. The beam pattern measurement was made at NUSC's Millstone Quarry facility in January, 1975 at a difference-frequency of 3.5 kHz. The measurement range was 82.6 m, and the depth was 15 m, where the water temperature was approximately 15°C and the salinity 3.0‰. This source was saturation-limited ( $\chi \approx 1.0$ ) in the primary nearfield, i.e., substantial generation of the difference frequency took place within the Rayleigh length,  $R_0$  of 28.4 m. The amount of primary absorption in the nearfield,  $\alpha R_0$ , was 0.51 dB.

## III. RESULTS AND CONCLUSIONS

Figure 1 shows the beam pattern of the rectangular source. The circles are the experimental data, and they may be seen to lie fairly well on the computed pattern (indicated by the solid curve). Also shown (as a dashed curve) in the figure is the computed farfield pattern. For the actual observation of such a pattern, measurement ranges in excess of 5000 m would be required.<sup>1</sup> It may be seen that considerable change in the beam is to be expected between the measurement range of 42.8 m and the farfield, with the 3 dB beamwidth decreasing from 6° to 4.5°. The farfield pattern is shown at the correct relative amplitude, i.e., about 14 dB more source level is to be expected in the farfield, and the skirts of the pattern will grow about 4 dB in level. The ripples on the skirts of the farfield pattern are related to the square of the primary pattern, characteristic of sources with small  $\alpha R_0$ .<sup>4</sup> The amplitude of the ripples is somewhat exaggerated by the assumption that both primary frequencies have identical beam patterns, whereas, in fact, the outer sidelobes will not coincide, resulting in smoother skirts than depicted here.

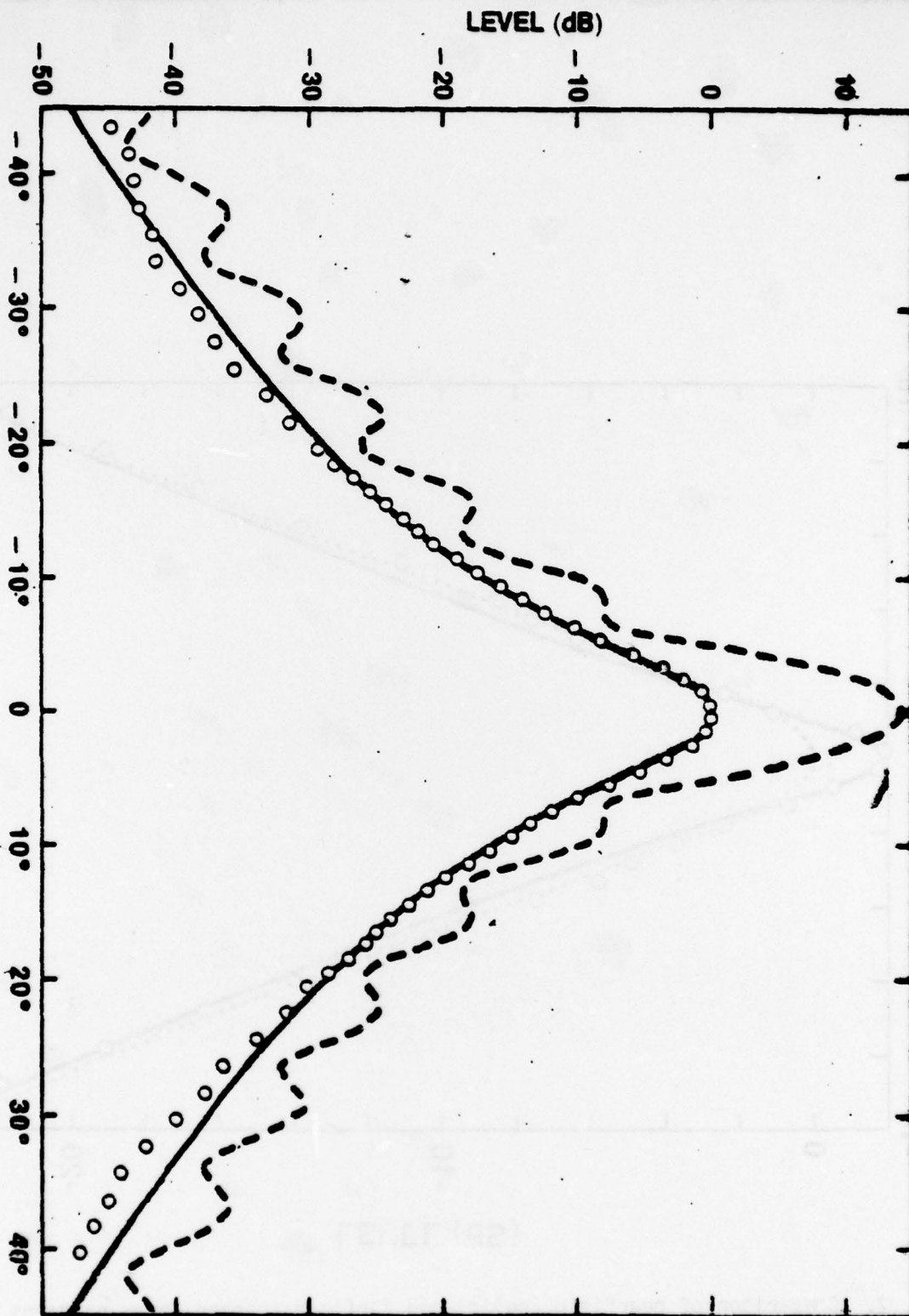
The results with the circular projector in salt water are shown in Figure 2. Again, the data are shown as circles, while the solid curve is the computed nearfield pattern and the dashed curve is the computed farfield pattern. In this case of moderately high  $\alpha R_0$ , the nearfield source level is 2 dB higher than that which would obtain in the farfield and the nearfield beamwidth is narrower than its farfield value (2.5° and 4°, respectively). The skirts of the patterns coincide, however, because the farfield conditions are reached much more quickly on the skirts than on the maximum response axis. Ranges in excess of 700 m would be required to observe the farfield pattern in this case.

The fact that nearfield beam patterns can be narrower than their farfield counterparts for parametric sources with large  $\alpha R_0$  has been recognized for some time,<sup>12,13</sup> but only more recently has it come to light that the apparent source level can be larger than the farfield value.<sup>1,14</sup> It is now obvious from our computer studies that the source level and beamwidth effects are tied together. For cases of large  $\alpha R_0$ , the nearfield pattern is narrower and of higher apparent source level than the farfield pattern. For small  $\alpha R_0$ , the nearfield pattern is broader and of lower source level than in the farfield.

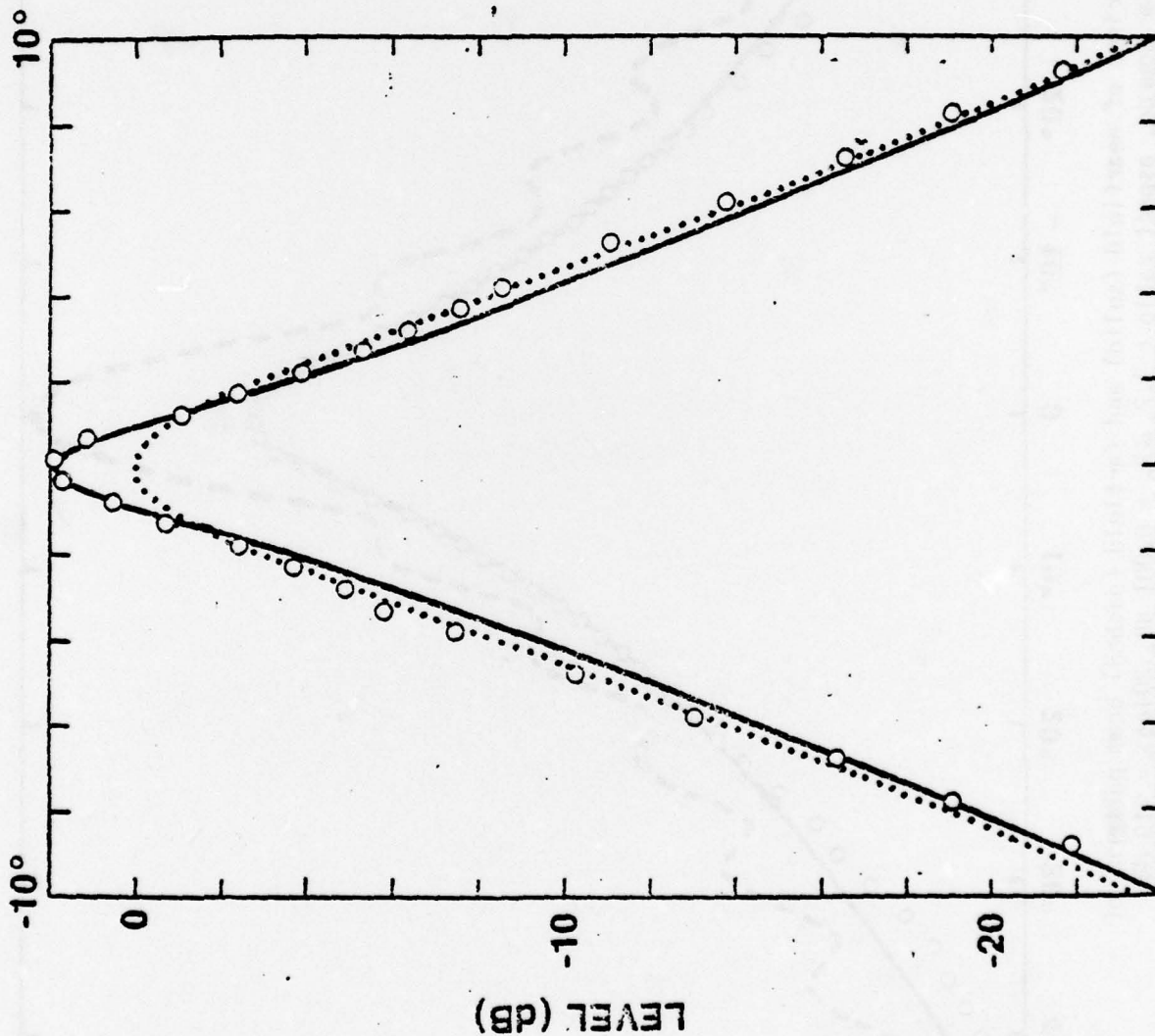
In Refs. 3 and 4, a simple, closed-form expression was suggested for beam pattern estimation. Figure 3 provides a comparison between that simplified model, shown dashed, and the present theory, shown as the solid curve, for the farfield of the 65 kHz projector. It may be seen that the simple formula predicts a 3 dB beamwidth ( $5.5^\circ$ ) which is too broad (computed value =  $4^\circ$ ) but provides a reasonable fit to the skirts of the pattern. As discussed in Ref. 3, some error near the 3 dB points is to be expected in the use of the simple formula, because the formula was constructed from knowledge of the large-angle behavior. The present theory is to be preferred for all but rough estimates of the beam behavior.

#### ACKNOWLEDGEMENTS

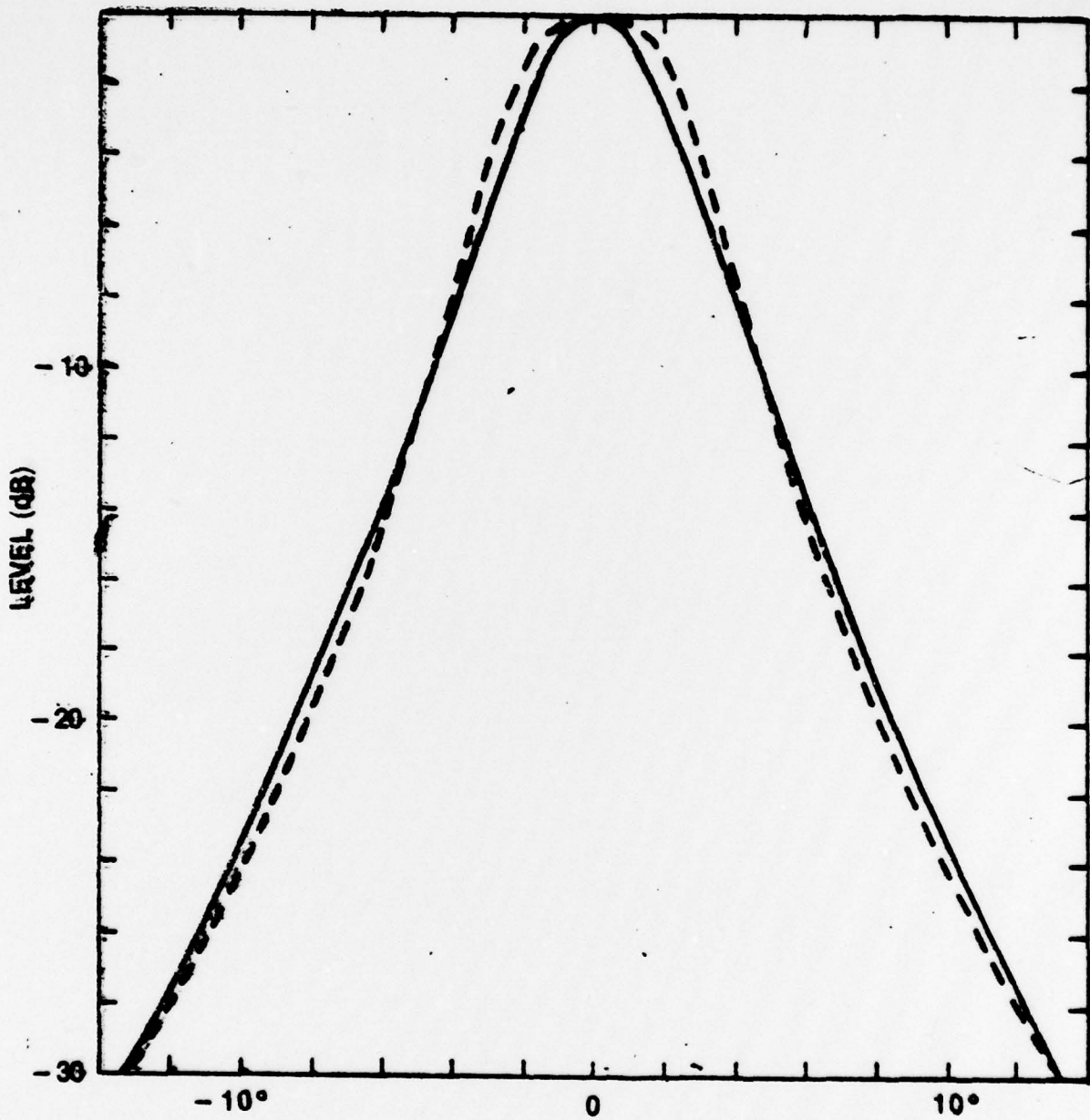
The authors would like to acknowledge the assistance of Marvin Goldstein, who provided the adaptive-Simpson's rule program and Peter Miner, who programmed the plotting routine. Experimental data were provided by William Konrad and Lynn Carlton. Assistance during various phases of the programming was obtained from George Botseas, David Potter, Joseph Auwood, Thomas Wheeler and Edmund J. Sullivan. The project was supported by the Naval Material Command.



1. Comparison of nearfield (solid) and farfield (dashed) beam patterns of rectangular source, aspect ratio = 1.2,  $\bar{\alpha}R_0 = 0.001$  dB,  $20 \log x = -19$  dB,  $f_0/f = 9.6$ ,  $k_0R_0 = 430$ . For nearfield pattern,  $r/R_0 = 10.7$ . Circles: experimental nearfield data



2. Comparison of nearfield (solid) and farfield (dashed) beam patterns of circular source,  $\bar{\alpha}R_0 = 0.51$  dB,  $20\log x = 0$  dB,  $f_0/f = 18.6$ ,  $k_0R_0 = 7740$ . For nearfield pattern,  $r/R_0 = 2.91$ . Circles: experimental nearfield data.



3. Comparison of present farfield theory (solid) with closed-form beam pattern expression (dashed) of Refs. 3,4.  $20\log x = 0$  dB,  $\bar{\alpha}R_0 = 0.51$  dB,  $f_0/f = 18.6$ ,  $k_0R_0 = 7740$ .

APPENDIX A. CONVOL USER'S GUIDE

The CONVOL program computes parametric source beam patterns out to 45° for plane piston projectors of circular, square, and rectangular shape and for endfire line projectors. The program generates a table and plots the negative of the bearing deviation loss, denoted BDG, as well as aperture-corrected values, BDGAP, as a function of the polar observation angle,  $\theta$ , with respect to the maximum response axis. For a rectangular projector, plots are generated for each of the two principal observation planes at  $\phi = 0$  and  $\phi = 90^\circ$ , where  $\phi$  is the azimuthal observation angle. In addition to the beam patterns, the program computes the on-axis apparent parametric gain,  $20\log(rP/R_0P_0)$ , i.e., the difference between the apparent secondary source level and that of one primary component. Since the apparent parametric gain can be regarded as a complex quantity,<sup>4</sup> its phase is also computed and the result tabulated as a function of  $\theta$ .

The user must specify the projector shape through the integer parameter ISHAPE:

ISHAPE = 0: circle  
           1: square  
           2: rectangle  
           3: endfire. (A1)

The parameter ISHAPE is also used to indicate the end of the input data file. A negative value of ISHAPE causes the plot tape to be properly terminated so that plots can be generated off line. The other input parameters are:<sup>4</sup>

$$20\log x = SL_0^* - SL_1, \quad (A2)$$

i.e., the difference between the "scaled" primary source level,<sup>15</sup>

$$SL_0^* \equiv SL_0 + 20 \log f_0 \text{ (kHz)}$$

and the value,  $SL_1^*$ , which corresponds to shock formation at  $R_0$  ( $SL_1^* \approx 281 \text{ dB//1 } \mu\text{Pa-m-kHz}$  for sea water<sup>15</sup>),

$$\alpha R_0 \text{ (dB),}$$

the amount of primary absorption loss at  $R_0$ ,

$$f_0/f,$$

the "downshift" ratio of the primary and secondary frequencies,

$$k_0 R_0 = \frac{1}{2} \times 10^{(DI_0/10)},$$

where  $DI_0$  is the primary directivity index,

$$r/R_0,$$

the ratio of the observation range to  $R_0$ , and finally,<sup>3</sup>

$N$ ,

the aspect ratio (required only if the projector is rectangular).

The Rayleigh length,  $R_0$ , is defined as the projector face area divided by the primary wavelength for the plane piston projectors and as the projector length divided by  $\pi$  for endfire projectors. The program has been tested for  $20 \log \chi \leq 10$  dB,  $\bar{\alpha}R_0 \geq 0.001$  dB, and  $-100 < r/R_0 < +100$ .

Typical runstream examples are given in Figures A1-A11 for operation of CONVOL on NUSC's Univac 1108 computer from a Tektronix graphics terminal. The first input data card specifies the projector type according to the value of ISHAPE in an I5 format. ISHAPE = 1(square) in the first example and 2(rectangle) in the second. The second data card provides the source parameters,  $20 \log \chi$  (dB),  $\bar{\alpha}R_0$  (dB),  $f_0/f$ ,  $k_0R_0$ , and  $r/R_0$  in five 15-character fields. (The negative value of  $r/R_0$  in the second example specifies infinite range.) The decimal points may be placed anywhere within their respective fields. If the projector is rectangular, as in the second example another card is needed to specify the aspect ratio,  $N$ , in the first 15-character field.

Each example is concluded with a negative value of ISHAPE to generate the plotting tape. Actually, both examples could have been run together in this case, i.e., the tabulation from the first example could have been followed with ISHAPE = 2, for the next example. If there is any doubt about whether there is sufficient time to complete all examples of a run, however, it is safer to terminate each example with a negative ISHAPE.

In each of these examples, plots were displayed first on the terminal CRT with the @ XQT D.TEKTRONIX instruction. They were then transmitted for later printing to a 1 inch = 10 dB, 1 inch = 10 deg scale with the @ XQT D.FR80 instruction. Note that these instructions were preceded with

@USE D.,DISSPLA\*DISSPLA.



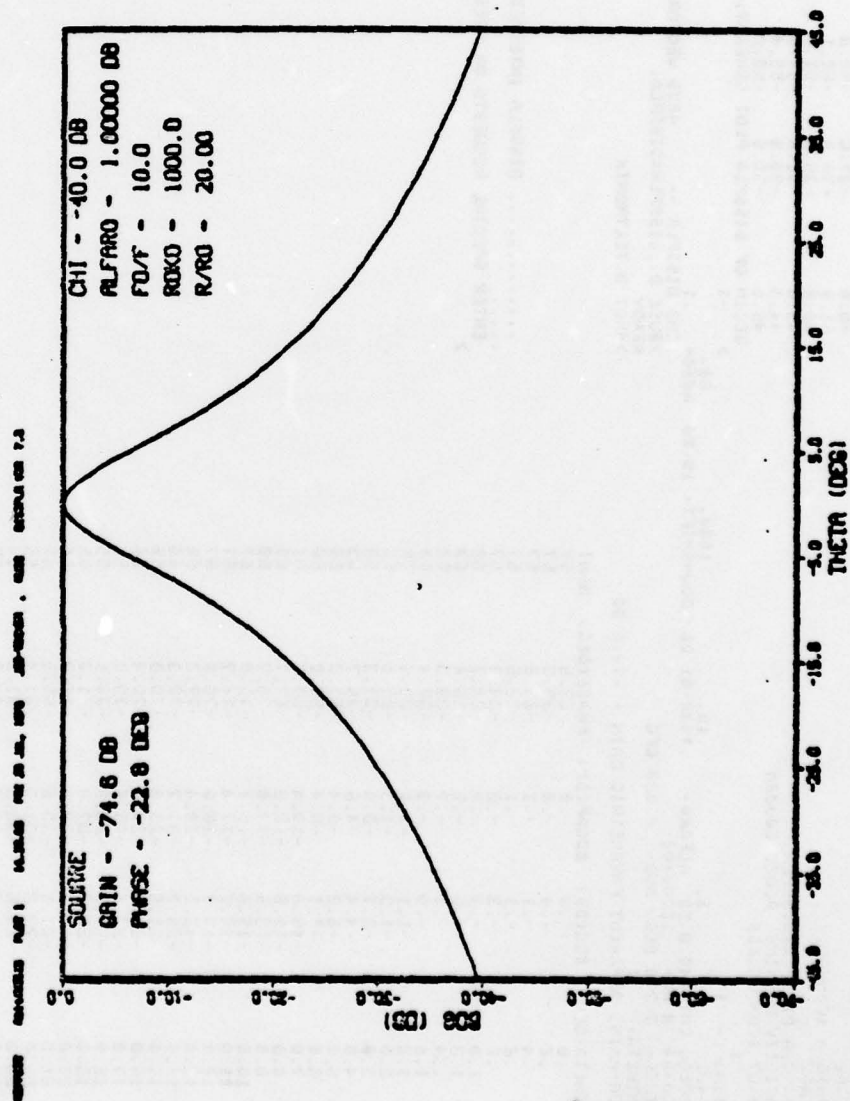


Figure A-2

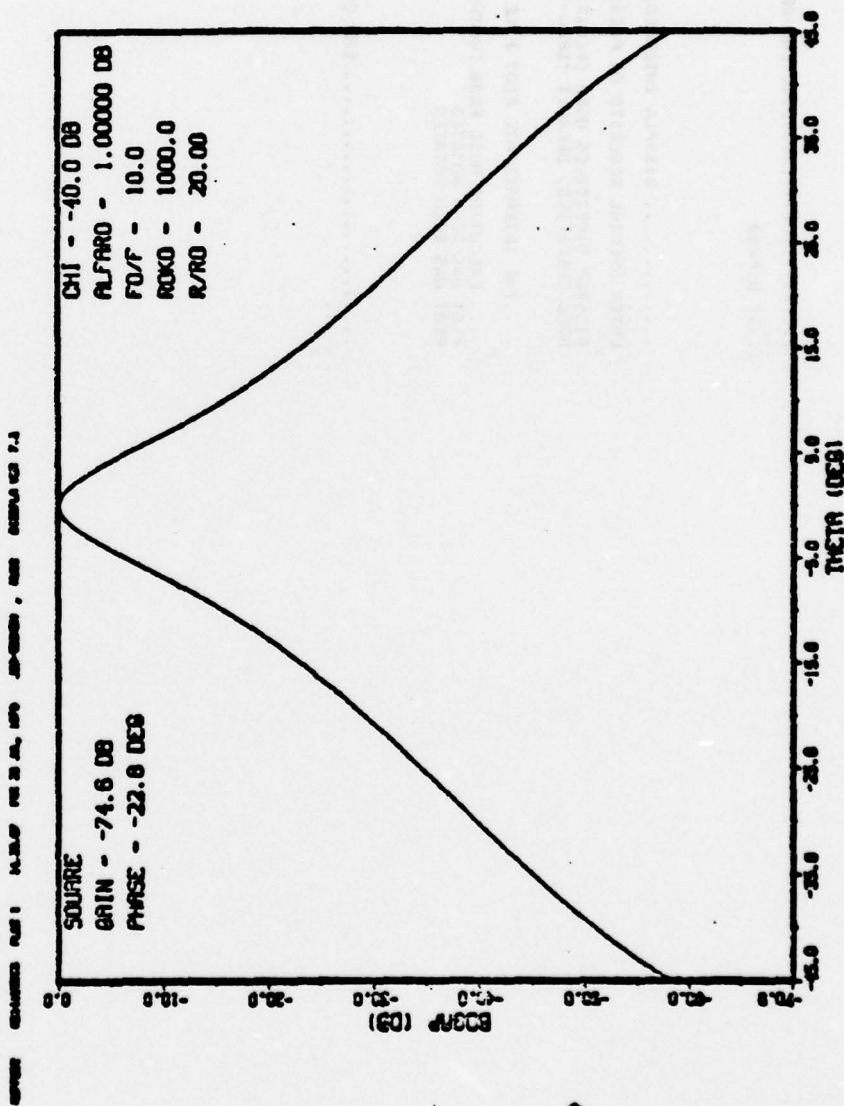


Figure A-3

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>EXIT D.FR80  
  
..... DISPLA INTERMEDIATE PLOT FILE POSTPROCESSOR .....  
>ENTER SPECIAL REQUESTS OR PRESS -RETURN-  
DISSTOP DIRECTIVES USER SPECIFIED-  
NONE SPECIFIED, DEFAULT 'DRAW-1-END' ASSUMED  
  
9 .....THE INTERMEDIATE PLOT FILE WAS GENERATED AT 142801 ON 07/28/7  
..... EXECUTING NJSC FR80 POSTPROCESSOR FOR HARDCOPY CAMERA .....  
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Figure A-4

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91.0 91.0 .0 .0 .0
92.0 92.0 .0 .0 .0
93.0 93.0 .0 .0 .0
94.0 94.0 .0 .0 .0
95.0 95.0 .0 .0 .0
96.0 96.0 .0 .0 .0
97.0 97.0 .0 .0 .0
98.0 98.0 .0 .0 .0
99.0 99.0 .0 .0 .0
100.0 100.0 .0 .0 .0

```

Figure A-5

EXIT D. TEKTRONIX

.....: DISPLA INTERMEDIATE PLOT FILE POSTPROCESSOR .....  
, ENTER SPECIAL REQUESTS OR PRESS -RETURN-

Figure A-6

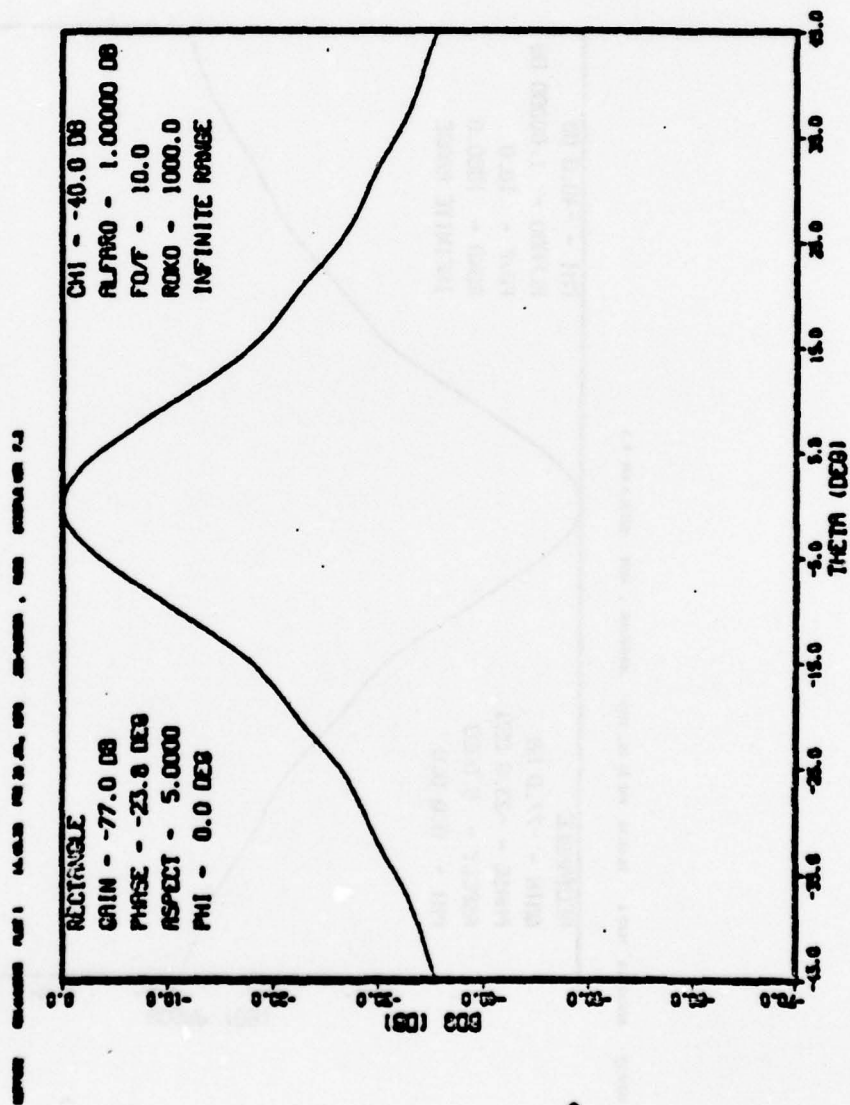


Figure A-7

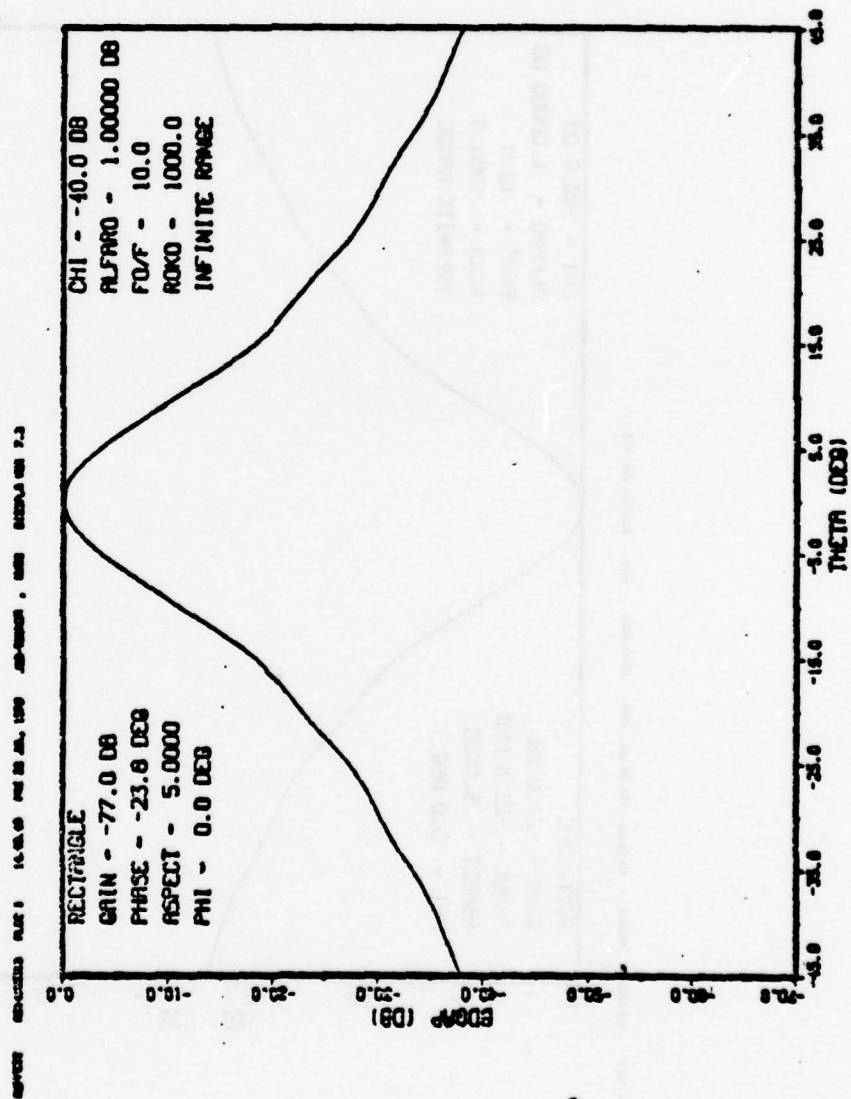


Figure A-8

020111 79111323 PAGE 1 14.04.20 001 20.00 1000 20-00000 , 000 00000000 7.3

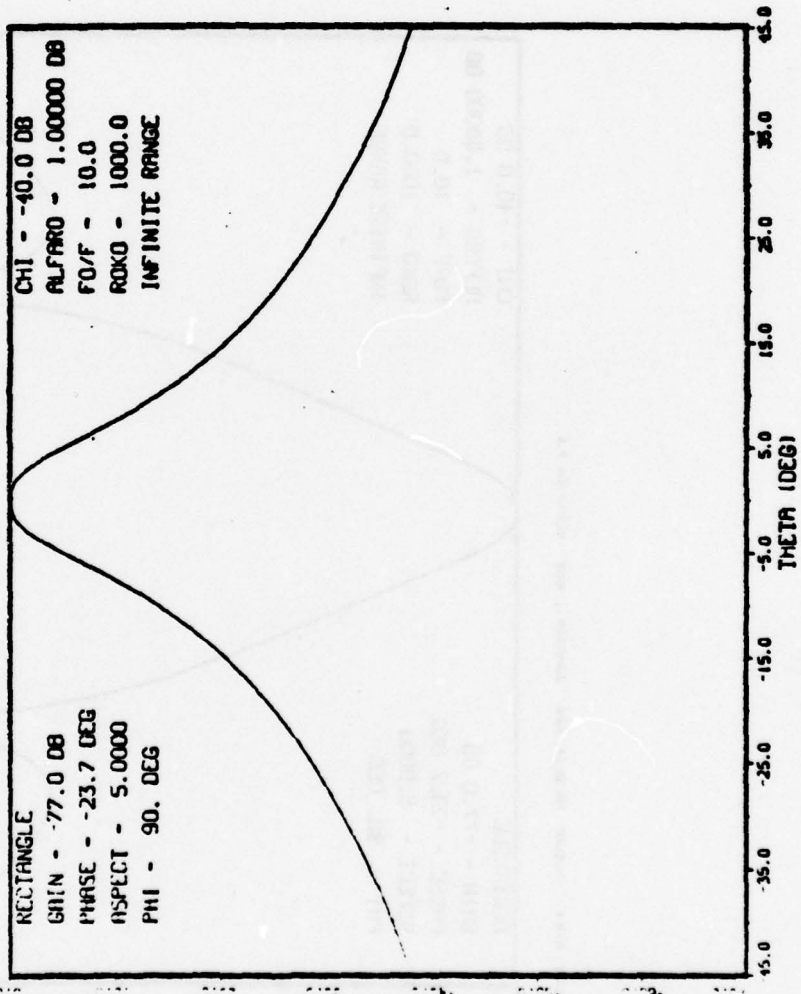


Figure A-9

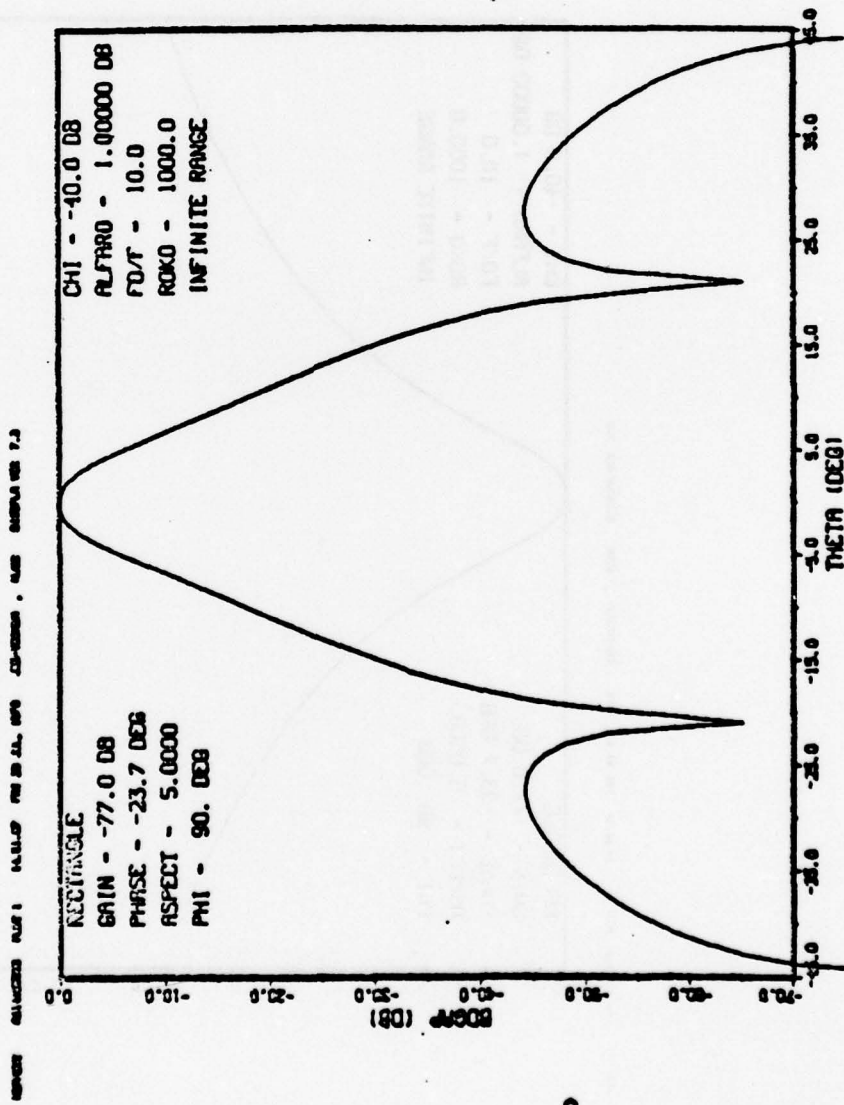


Figure A-10

AIP

```

..... END OF POSTPROCESSOR .....
>XGT D.FR80

..... DISPLA INTERMEDIATE PLOT FILE POSTPROCESSOR .....
>ENTER SPECIAL REQUESTS OR PRESS -RETURN-
>DISPOP DIRECTIVES USER SPECIFIED-
  NONE SPECIFIED, DEFAULT 'DRAW-1-END' ASSUMED

.....THE INTERMEDIATE PLOT FILE WAS GENERATED AT 144833 ON 07/20/7
9
>... EXECUTING MUSC FR80 POSTPROCESSOR FOR HARDCOPY CAMERA ....
  PLOT HAS BEEN ROTATED
  PLOT HAS BEEN ROTATED
  PLOT HAS BEEN ROTATED

..... END OF POSTPROCESSOR .....
>

```

Figure A-11

## APPENDIX B. CONVOL FORTRAN LISTING

The various elements of CONVOL are listed on the following pages. The main program calls subroutine QGM48, which generates coefficients for the Gaussian quadrature, and subroutine TABLE, which stores the real and imaginary values of  $\exp(jkr) I(\cos v)$  in arrays VALUE1 and VALUE2, respectively. TABLE does this by calling function ADPSBC, the adaptive Simpson's routine. ADPSBC requires integrand evaluations from the function FNC, which in turn, calls UEVAL for the evaluation of U, the saturation taper function. When TABLE has completed its job, the main program performs the integration over  $\theta'$ , using the coefficients generated by QGM48. The  $\theta'$  integrand evaluations and integrations over  $\phi'$  are done by subroutine FCTPHI, which evaluates the  $\phi'$  integrand by interpolation of the table stored in VALUE1 and VALUE2. The beam pattern data is stored by subroutine MMSTOR and plotting instructions are generated by MMPLLOT.

```

C-08:21:14-(C,)
C THIS PROGRAM COMPUTES THE NEARFIELD PARAMETRIC GAIN RP/ROPO AS A
C FUNCTION OF OBSERVATION ANGLE THETA. MAX RUN TIME = 20 MIN.
C (RC=PROJECTOR AREA/PRIMARY WAVELENGTH FOR CIRCULAR,SQUARE, AND
C RECTANGULAR PROJECTORS. RC=PROJECTOR LENGTH/PI FOR ENDFIRE CASE.)
C INPUTS ISHAPE=0 CIRCLE
C          1 SQUARE
C          2 RECTANGLE
C          3 ENDFIRE
C          .LT.C STOP
C          CHIDB=2*LOG10(CHI)(DB) MAX=10 DB
C          ALFAR0=ALPHA*RC(DEG) MIN=0.001 DB
C          DOWNSR=FT/F MIN=2.0
C          ROK0=K0*P0 MIN=1.4
C          RANGE=R/RC (IF RANGE.LT.0, FARFIELD GAIN COMPUTED)
C          -100 .LE. RANGE .LE. 100 (NE. ZERO)
C          ASPECT (IFF ISHAPE=2) MIN=1.0
C OUTPUTS RK=KR
C          CONST3=3*(CHI/PI)**2
C          TWCALF=2*ALPHA*R
C          PI=3.14159265
C          PHIR=PHI(RAD)
C          CTH=COS(THETA)
C          STH=SIN(THETA)
C          THETA(DEG)
C          BDG(DB)=BEARING DEVIATION GAIN
C          BDGAP(DB)=BDG+2*LOG(APERTURE FACTOR)
C          GAIN(DB)
C          PHASE(DEG)
C          PHASE(DEG)=AXIAL VALUE OF PHASE
C          NAPFAC=0 NO APERTURE FACTOR
C          1 APERTURE FACTOR INCLUDED
C          BWEFR(RAD)=WESTERVELT BEAMWIDTH
C          BWER(RAD)=PRIMARY BEAMWIDTH
C          NTHETA=NO. OF THETA PRIME POINTS / 48
C          NPHI=NO. OF PHI PRIME POINTS / 48
C DIMENSION IC(2)
C COMMON/ELK/UD,VD,TWCALF,RK
C COMMON/TAN/RANGE
C COMMON/BLUE/ASPECT,ISHAPE
C COMMON/YELLOW/CONST3
C COMMON/PURPLE/ NPOINT
C COMMON/ODRAB/ CHIDB,ALFAR0,DOWNSR,GAIN,PHASE,NAPFAC
C COMMON/WHT/C(24),w(24)
C COMMON/GREY/BWEFR,BWER,ICOUNT,STH,CTH,PI
C COMMON/PINK/ROK0,PHIR
C CALL COMPRS
C CALL FIRST
C ICCK='08200.'
C PI=3.14159265
C E=EXP(1.0)
C DEGRAD=PI/180.
C CALL QGM48
C JUST READ (5,15) ISHAPE
C 15 FORMAT(I5)
C IF(ISHAPE.LT.0) GO TO 500

```

```

PRINT 10 ISHAPE
10 FORMAT(1X, 'ISHAPE=', I3)
READ (7,11) CHIDB,ALFARD,DOWNSR,RK0,RANGE
11 FORMAT(5E15.5)
PRINT 12 CHIDB,ALFARD,DOWNSR,RK0,RANGE
12 FORMAT(1X, '2CLOG CHI=', F5.1, 1X, 'DB', 2X, 'ALFARD=', E11.4, 1X, 'DB', 2X
, 'DOWNSHIFT=', F5.2, 1X, 'RK0=', E11.4, 2X, 'R/R'=', E11.4)
IF(ISHAPE.EQ.2) GO TO 1003
ASPECT=1.0
GO TO 1004
1003 READ (3,17) ASPECT
17 FORMAT(E15.5)
PRINT 13 ASPECT
18 FORMAT(1X, 'ASPECT=', F10.4)
1004 IF(ISHAPE.GT.3) GO TO 1007
IF(ALFARD.LE.0.0) GO TO 1007
IF(DOWNSR.LE.0.0) GO TO 1007
IF(RK0.LT.1.4) GO TO 1007
IF(RANGE.EQ.0.0) GO TO 1007
IF(ASPECT.LT.1.0) GO TO 1007
BWEF=4.0*ASIN(SQRT(ALFARD*DOWNSR/(20.*DLOG10(E)*RK0)))
BWEF=BWEF/DEGRAD
IF(ISHAPE.EQ.0) BWOR=2.0*ASIN(SQRT(1.31/RK0))
IF(ISHAPE.EQ.1) BWOR=2.0*ASIN(SQRT(1.25/RK0))
IF(ISHAPE.EQ.2) BWOR=2.0*ASIN(SQRT(1.25/(RK0)*ASPECT)))
IF(ISHAPE.EQ.3) BWOR=4.0*ASIN(SQRT(0.442/RK0))
BWO=BWOR/DEGRAD
PRINT 27 BWEF,BWO
27 FORMAT(1X, 'BWEF=', F7.3, ' DEG', 2X, 'BWO=', F7.3, ' DEG')
NTHETA=1+INT(1.0/BWO)
ENN=FLOAT(NTHETA)
PRINT 26 NTHETA
26 FORMAT(1X, 'NTHETA=', I5)
CHI=10.**(.05*CHIDB)
PK=RK0*RANGE/DOWNSR
CONST3=3.0*(CHI/PI)**2
THALF=.1*ALFARD*RANGE/ALOG10(E)
COEFF=CHI*RANGE*RK0/(4.0*PI*DOWNSR*DOWNSR)
CALL TABLE
PHIR=0.0
GO TO 1005
1005 PHIR=PI*0.5
START OF POINT GENERATION
1006 NPOINT=0
DO 1041 N=1,54
IF(N.LE.10) THETA=FLOAT(N-1)*.2
IF(N.GT.10) THETA=FLOAT(N-9)
THETAR=THETA*DEGRAD
CTH=COS(THETAR)
STH=SIN(THETAR)
ANS1=0.0
ANS2=0.0
ANS3=0.0
ANS4=0.0
PHI=0
IF(BWEF.GT.BWO) GO TO 1030
IF(THETA.LT.0.5*BWEF) GO TO 1031

```

```

IF (THETA,LT.90).-G.5*BWEF) GO TO 1032
GO TO 1033
C INTEGRAL FROM 0 TO PI/2:
1030 B=(0.5*PI/ENN
BHALF=0.5*B
A=0.5*PI-BHALF
DO 1022 J=1,NTHETA
CALL PROCC1
A=A-B
1022 CONTINUE
ANS1=ANS3*B
ANS2=ANS4*B
GO TO 1034
C INTEGRAL FROM BWEFR TO PI/2:
1031 B=(0.5*PI-BWEFR)/ENN
BHALF=C.5*B
A=0.5*PI-BHALF
DO 1027 J=1,NTHETA
CALL PROCC1
A=A-B
1027 CONTINUE
ANS1=ANS3*B
ANS2=ANS4*B
C INTEGRAL FROM C TO BWEFR:
ANS3=0.0
ANS4=0.0
B=BWEFR
BHALF=C.5*B
A=BHALF
CALL PROCC1
ANS3=ANS3*B
ANS4=ANS4*B
C ACCUMULATION FOR TOTAL INTEGRAL:
ANS1=ANS1+ANS3
ANS2=ANS2+ANS4
GO TO 1034
1032 K=(NTHETA+1)/2
L=NTHETA-K
IF (L.EQ.0) L=1
DKAY=FLOAT(K)
DELL=FLOAT(L)
C INTEGRAL FROM (THETAR+BWEFR/2) TO PI/2:
B=(0.5*(PI-BWEFR)-THETAR)/DELL
BHALF=C.5*B
A=0.5*PI-BHALF
DO 1035 J=1,L
CALL PROCC1
A=A-B
1035 CONTINUE
ANS1=ANS3*B
ANS2=ANS4*B
C INTEGRAL FROM 0 TO (THETAR-BWEFR/2):
ANS3=0.0
ANS4=0.0
B=(THETAR-0.5*BWEFR)/DKAY
BHALF=C.5*B
A=THETAR-0.5*BWEFR-BHALF

```

1044

```

1037 J=1,K
CALL PROCC1
A=A-B
1037 CONTINUE
ANS3=ANS3*B
ANS4=ANS4*B
5 ACCUMULATION:
ANS1=ANS1+ANS3
ANS2=ANS2+ANS4
C INTEGRAL FROM (THETAR-BWEFR/2) TO (THETAR+BWEFR/2):
ANS3=0.0
ANS4=0.0
B=BWEFR
CHALF=0.5*B
A=THETAR
CALL PROCC1
ANS3=ANS3*B
ANS4=ANS4*B
5 ACCUMULATION FOR TOTAL INTEGRAL:
ANS1=ANS1+ANS3
ANS2=ANS2+ANS4
GO TO 1034
C INTEGRAL FROM 0 TO (PI/2-BWEFR):
1033 B=(0.5*PI-BWEFR)/ENN
BHALF=0.5*B
A=0.5*PI-BWEFR-BHALF
DO 1040 J=1,NTHETA
CALL PROCC1
A=A-B
1040 CONTINUE
ANS1=ANS3*B
ANS2=ANS4*B
C INTEGRAL FROM (PI/2-BWEFR) TO PI/2:
ANS3=0.0
ANS4=0.0
B=BWEFR
BHALF=0.5*B
A=0.5*PI-BHALF
CALL PROCC1
ANS3=ANS3*B
ANS4=ANS4*B
C ACCUMULATION FOR TOTAL INTEGRAL:
ANS1=ANS1+ANS3
ANS2=ANS2+ANS4
1034 PHASE=ATAN2(ANS2,ANS1)
PHASE=PHASE/DEGRAD
IF(.,GT.1) GO TO 1020
RGAIN=10.*ALOG10(ANS1*ANS1+ANS2*ANS2)
PHASE=PHASE
GAIN=RGAIN+10.*ALOG10(COEFF*COEFF)
PRINT 19 GAIN
19 FORMAT(1X,'ON-AXIS, APPARENT PARAMETRIC GAIN =',F6.1,1X,'DB')
PRINT 13
13 FORMAT(1HD,'THETA( DEG)',2X,'BDG(DB)',2X,'BDGAP(DB)',2X,'PHASE( DEG)
',2X,'NPHI')
1020 BDG=10.*ALOG10(ANS1*ANS1+ANS2*ANS2)-RGAIN
IF(N.EG.1) GO TO 1017

```

```

IF(ISHAPE.EQ.0.OR.ISHAPE.EQ.3) GO TO 1014
ARG11=SQRT(0.5*R0K0*PI)*STH/DOWNSR
IF(ISHAPE.EQ.1) GO TO 1015
RTAS=SQRT(ASPECT)
IF(PHIR.EQ.0.0) GO TO 1016
ARG11=ARG11*RTAS
GO TO 1015
1015 ARG11=ARG11/RTAS
1015 DAP=SIN(ARG11)/ARG11
GO TO 1013
1014 ARG11=SQRT(2.0*R0K0)*STH/DOWNSR
DAP=2.0*SSS(ARG11,3)/ARG11
ARG11=0.5*PI*R0K0*(1.0-CTH)/DOWNSR
IF(7.LE.11) ARG11=0.25*PI*R0K0*(THETAR**2)/DOWNSR
IF(ISHAPE.EQ.3) DAP=SIN(ARG11)/ARG11
1013 DAPSQ=DAP**2
IF(DAPSQ.EQ.0.0) DAPSQ=1.0E-09
BDGAP=BDG*10.*ALOG10(DAPSQ)
GO TO 1019
1017 BDGAP=0.0
1019 PRINT 14 THETA,BDG,BDGAP,PHASE,NPHI
14 FORMAT(1X,F6.1,7X,F6.1,3X,F6.1,5X,F6.1,6X,I4)
CALL MMSTOR(THETA,BDG,BDGAP)
1041 CONTINUE
NAPFAC=0
CALL MMPL0T
NAPFAC=1
CALL MMPL0T
IF(PHIR.EQ.0.0) GO TO 1002
GO TO 1021
1002 IF(ISHAPE.EQ.2) GO TO 1005
1021 CALL SECOND(IC)
C DON'T START ANY BEAM PATTERNS AFTER 900 SEC HAS ELAPSED.
IF(IC(1).GE.ICCK) GO TO 900
GO TO 1001
900 CALL DONEPL
STOP DONE
1007 PRINT 21
21 FORMAT(1X,"BAD INPUT. NEXT CASE.")
GO TO 1001
C PROCEDURE PROCO1
SUBROUTINE PROCO1
GO TO23 I=1,24
CALL FCT(A+BHALF*C(I),ARG1,ARG2)
NPHI=NPHI+ICOUNT
ARG3=ARG1
ARG4=ARG2
CALL FCT(A-BHALF*C(I),ARG1,ARG2)
NPHI=NPHI+ICOUNT
ANS3=ANS3+W(I)*(ARG3+ARG1)*0.5
1023 ANS4=ANS4+W(I)*(ARG4+ARG2)*0.5
RETURN
END

```

BLE

23-08:53:48-(0,)

SUBROUTINE TABLE

```

C THIS SUBPROGRAM TABULATES EXP(JKR)*I(COSNU) FOR 0.0001.LE.GNU.LE.
C 3.14, WITH REAL PARTS STORED IN VALUE1(N) AND IMAGINARY PARTS
C STORED IN VALUE2(N). THE INDEX N IS RELATED TO GNU BY
C GNU = FLOAT(N)/10000 1.LE.N.LE. 10
C FLOAT(N-9)/1000 10.LE.N.LE. 19
C FLOAT(N-18)/100 19.LE.N.LE. 118
C FLOAT(N-68)/50 118.LE.N.LE. 225
C COSNU IS NEGATIVE FOR GNU.GT.PI/2.
C INPUTS T=OALF=2*ALPHA*R
C RK=KR
C RANGE=R/RQ
C OUTPUTS UC=TWOALF*COSNU
C VC=KR*(1-COSNU)
C CONST1=COSNU*R/RQ
C VALUE1(225)
C VALUE2(225)
C AKOTAL=ALPHA/(2*K)
C BSQ=B**2 (COMPLEX)

```

EXTERNAL FNC

COMPLEX BSQ

COMMON/BLK/UC,VC,TWOALF,RK

COMMON/TAN/RANGE

COMMON/RED/VALUE1(240),VALUE2(240)

COMMON/BROWN/CONST1,AKOTAL

COMMON/GRN/X(23),V(23)

COMMON/FUCIA/BSQ

YMAX=20.

EPSI=0.5E-02

DO 201 N=1,225

IF(N-10) 203,203,204

203 GNU=FLOAT(N)\*1.0E-04

GO TO 205

204 IF(N-19) 208,208,209

208 GNU=FLOAT(N-9)\*1.0E-03

GO TO 205

209 IF(N-118) 212,212,213

212 GNU=FLOAT(N-18)\*0.01

GO TO 205

213 GNU=FLOAT(N-68)\*0.02

205 COSNU=COS(GNU)

UC=TWOALF\*COSNU

VC=RK\*(1.0-COSNU)

IF(N.LT.19) VC=RK\*((GNU\*\*6)/720.-(GNU\*\*4)/24.\*0.5\*(GNU\*\*2))

CONST1=COSNU\*RANGE

AKOTAL=RK/TWOALF

BSQ=CMPLX(1.0,2.0\*AKOTAL)\*(TWOALF\*\*2)\*((SIN(GNU))\*\*2)

A=0.0

B=YMAX

E=EPSI

VALUE1(N)=ADPSB C(A,B,FNC,1,E,NP1)

A=0.0

B=YMAX

E=EPSI

VALUE2(N)=ADPSB C(A,B,FNC,2,E,NP2)

TM No.  
791132

BIN ..

```
IF(RANGE.ST.D.C) 50 TO 201  
VEE=V0/TWCALF  
DEN=-1./(TWCALF*(1.+VEE**2))  
V1=VALUE1(N)  
V2=VALUE2(N)  
VALUE1(N)=(V1+VEE*V2)*DEN  
VALUE2(N)=(V2-VEE*V1)*DEN  
201 CONTINUE  
RETURN  
END
```

1 5 IN 44

ADPSBC

7/23-08:54:07-(0,)

```

FUNCTION ADPSBC(A,B,FNC,INDEX,EPS,NP)
C*****PROGRAMMED BY M. J. GOLDBSTEIN*****
C*****
C*****THIS SINGLE PRECISION SUBPROGRAM APPROXIMATES THE*****
C*****INTEGRAL FROM A TO B OF THE FUNCTION FNC(X,INDEX)*****
C*****TO WITHIN A RELATIVE ERROR EPS BY ADAPTIVE SIMPSON*****
C*****QUADRATURE AND RETURNS THE APPROXIMATION IN ADPSBC.***
C*****THE FUNCTION FNC(X,INDEX) IS A SINGLE PRECISION *****
C*****EXTERNAL FUNCTION SUBPROGRAM WHICH EVALUATES THE *****
C*****FUNCTION AT POINT X. INDEX IS A POINTER TO ONE OF *****
C*****SEVERAL INTEGRANDS CONTAINED IN THE CODE OF *****
C*****FNC(X,INDEX). NP IS RETURNED TO THE CALLING PRU- *****
C*****GRAM AS ONE LESS THAN THE NUMBER OF INTEGRAND EVAL- **
C*****UATIONS USED TO OBTAIN THE RESULT ADPSBC. *****
C*****
DIMENSION EPSP(30),F2(30),F3(30),FMP(30),XM(30),F3P(30),DX(30),
*X2(30),X3(30),EST2(30),ITRN(30),PVAL(30,2)
LOGICAL TEST
CORR = 0.0
NP = 0
EPS = .15*EPS
LVL = 0
ABSA = 1.0
EST = 1.0
DA = B - A
FA = FNC(A,INDEX)
FM = 4.0*FNC((A + B)*.5,INDEX)
FB = FNC(B,INDEX)
NP = 2
ASSIGN 20001 TO PROC01
GO TO 30001
20001 CONTINUE
20002 CONTINUE
IF(.NOT.(TEST)) GO TO 20003
LVL = LVL + 1
ICOL = ITRN(LVL)
PVAL(LVL,ICOL) = SUM
ASSIGN 20005 TO PROC02
GO TO 30002
20005 CONTINUE
GO TO 20004
20003 CONTINUE
ITRN(LVL) = 1
DA = DX(LVL)
FM = F2(LVL)
FB = FMP(LVL)
EPS = EPSP(LVL)*.5
EST = EST1  & SAVE 3 POINT APPROX. ON (A, A+DA)
ASSIGN 20006 TO PROC01
GO TO 30001
20006 CONTINUE
20004 CONTINUE
IF(.NOT.(LVL.EQ.1)) GO TO 20002
ADPSBC = SUM - CORR/15.0
RETURN

```

C  
C  
C  
C  
C

PROCEDURE RECUR

30001 CONTINUE

LVL = LVL + 1

DX(LVL) = DA\*0.5

SX = DX(LVL)/6.0

XM(LVL) = A + DX(LVL)

X2(LVL) = A+DX(LVL)\*0.5

F2(LVL) = 4.0\*FNC(X2(LVL),INDEX)

X3(LVL) = X2(LVL) + DX(LVL)

F3(LVL) = 4.0\*FNC(X3(LVL),INDEX)

EPSP(LVL) = EPS

C TOLERANCE MUST BE .GT. 15/(2\*\*27) TO AVOID NOISE PROBLEMS:

C IN NEXT STATEMENT, LVLMAX IS SUCH THAT

C (2\*\*LVLMAX) .LT. (30\*E07\*EPSI)

IF(LVL.GT.20) EPSP(LVL)=1.0E-07

FMP(LVL) = FM\*0.25

EST1 = (FA + F2(LVL) + FMP(LVL))\*SX

FBP(LVL) = FB

EST2(LVL) = (FMP(LVL) + F3(LVL) + FBP)\*SX

SUM = EST1 + EST2(LVL)

§ STORE 5 POINT APPROX. IN SUM

ABSA = ABSA - ABS(EST) + ABS(EST1) + ABS(EST2(LVL))

CI = EST - SUM

TEST = ABS(CI).LE.EPSP(LVL)\*ABSA

§ SET COMPARISON TEST

TEST = TEST.AND.(EST.NE.1.0)

TEST = TEST.OR.LVL.GE.30

IF(TEST)CORR = CORR + CI

NP = NP + 2

GO TO PROC01

C  
C  
C  
C

PROCEDURE CAS

30002 CONTINUE

GO TO(20007,20008), ICOL

20007 CONTINUE

ITRN(LVL) = 2

DA = DX(LVL)

FA = FMP(LVL)

FM = F3(LVL)

FB = FBP(LVL)

EPS = EPSP(LVL)\*0.5

A = XM(LVL)

EST = EST2(LVL)

ASSIGN 20010 TO PROC01

GO TO 30001

20010 CONTINUE

GO TO 20009

20008 CONTINUE

SUM = PVAL(LVL,1) + PVAL(LVL,2)

20009 CONTINUE

GO TO PROC01

END

```

C
23-08:54:25-(0,)
FUNCTION FNC(Y, INDEX)
C THIS SUBPROGRAM COMPUTES THE INTEGRAND
C U=EXP(-Y)/SQRT(Z**2+B**2) IF RANGE.GT.0.
C U=EXP(-Y) IF RANGE.LT.0
C INPUTS Y
C INDEX=1 OR 2
C UO=TWOALF*COSNU
C VJ=KR*(1-COSNU)
C RANGE
C BSQ=B**2 (COMPLEX)
C OUTPUTS RT=SQRT(Z**2+B**2) (COMPLEX)
C FNC(Y,1)=REAL PART
C FNC(Y,2)=IMAGINARY PART
COMPLEX RT,Z,U,Y3,BSQ
COMMON/BLX/UO,VC,TWOALF,RK
COMMON/TAN/RANGE
COMMON/DRANGE/RT
COMMON/FUCIA/BSQ
IF(RANGE.(.0.0) GO TO 401
Z=CMPLX(Y+UO,-VC)
RT=CSQRT(Z**2+BSQ)
CALL UEVAL(Y,Z,U)
Y3=U*CMPLX(EXP(-Y),0.)
IF(INDEX.EQ.1) FNC=REAL(Y3)
IF(INDEX.EQ.2) FNC=AIMAG(Y3)
RETURN
401 Z=CMPLX(Y-UO,VC)
RT=CSQRT(Z**2+BSQ)
CALL UEVAL(Y,Z,U)
Y3=U*CMPLX(EXP(-Y),0.)/RT
IF(INDEX.EQ.1) FNC=REAL(Y3)
IF(INDEX.EQ.2) FNC=AIMAG(Y3)
RETURN
END

```

```

VAL
23-08:54:37-(0,0)
SUBROUTINE LEVAL(Y,Z,U)
C THIS SUBPROGRAM COMPUTES THE SATURATION-TAPER U(R*/RO).
C INPUTS Y (USED ONLY IF RANGE.LT.ZERO)
C V0 (USED ONLY IF RANGE.LT.ZERO)
C Z (COMPLEX)
C CONST1=COSNU*RANGE
C CONST3=3*(CHI/PI)**2
C RT=SQRT(2**2+B**2) (COMPLEX)
C TWOALF=2*ALPHA*R
C RANGE
C ASPECT
C AKOTAL=ALPHA/(2*K)
C ISHAPE=0,1,2,OR 3
C BSG=B**2 (COMPLEX)
C U (COMPLEX)
COMMON/BLK/UC,V0,TWOALF,RK
COMMON/TAN/RANGE
COMMON/BLUE/ASPECT,ISHAPE
COMMON/YELLOW/CONST3
COMMON/BROWN/CONST1,AKOTAL
COMMON/ORANGE/RT
COMMON/FUCIA/BSG
C IF CHIOB.LE.-35, SET U=(1.0,0.0)
IF(CONST3.LT.1.0E-04) GO TO 101
ZTEST=CABS(Z-RT)/CABS(Z)
RPRIME=CMPLX(1.,AKOTAL)*Z-CMPLX(0.,AKOTAL)*RT
IF(ZTEST.LE.0.01) RPRIME=Z*((1.,0.)-CMPLX(0.,.5+AKOTAL)*
*(BSG/Z**2)-(0.25,0.)*(BSG/Z**2)**2)+(0.125,0.)*(BSG/Z**2)**3))
RPRIME=RPRIME+CMPLX((RANGE/TWOALF),0.)/CMPLX(1.,2.*AKOTAL)
IF(RANGE.LT.0.0) RPRIME=CMPLX(RANGE*Y,U.)/CMPLX(TWOALF,V0)
IF(RANGE.GT.0.0) RPRIME=RPRIME+CMPLX(CONST1,0.)
IF(ISHAPE.NE.2) BB=RPRIME+CSQRT((1.,0.)+RPRIME**2)
IF(ISHAPE.EQ.2) BB=((2.,0.)+RPRIME-CMPLX(ASPECT-1.,0.)+(2.,0.)
*CSQRT((1.,0.)+CMPLX(ASPECT-1.,0.)*RPRIME+RPRIME**2))
*/CMPLX(1.,+ASPECT,0.)
XI=CMPLX(CONST3,0.)*(CLOG(BB)**2)
IF(CABS(RPRIME).LT.0.1.AND.ISHAPE.NE.2) XI=CMPLX(CONST3,0.)*
*((0.075,0.)*(RPRIME**5)-CMPLX(1./6.,0.)*(RPRIME**3)+RPRIME)**2
IF(ISHAPE.NE.2) GO TO 103
DELTA=CMPLX(0.5*(ASPECT-1.0),0.0)
IF(CABS(RPRIME).LT.0.1.AND.CABS(DELTA).LT.0.02) XI=
*CMPLX(CONST3,0.)*(CMPLX(ALOG(2./(1.+ASPECT)),0.)+DELTA+RPRIME
*(0.5,0.)*DELTA**2+(DELTA+RPRIME)*(DELTA**2-(2.,0.)*DELTA
**RPRIME-RPRIME**2)/(3.,0.)-(0.25,0.)*DELTA**4+(0.2,0.)*(DELTA
**RPRIME)*(DELTA**4-RPRIME+DELTA**3+(DELTA+RPRIME)**2+(1.5,0.)*
**DELTA+RPRIME**3+(0.375,0.)*RPRIME**4))**2
103 IF(CABS(XI).LT.0.02) GO TO 102
XITEST=CABS((1.,0.)+(2.,0.)*XI)
IF(XITEST.LT.1.0E-10) U=((1.,0.)+XI)*(1.0E09,0.)
IF(XITEST.GE.1.0E-10.AND.XITEST.LE.0.01) U=((1.,0.)+XI)/CSQRT
*(CMPLX(0.01/XITEST,0.)*(1.,0.)+(2.,0.)*XI)-(1.,0.)
IF(XITEST.GT.0.01) U=((1.,0.)+(1)/CSQRT((1.,0.)+(2.,0.)*XI)
*(1.,0.))
U=U*(2.,0.)/(XI**2)

```

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```
RETURN
102 U=(1.,0.)-(2.,0.)*XI+(3.75,0.)*(XI**2)-(7.,0.)*(XI**3)
RETURN
101 U=(1.,0.)
RETURN
END
```

BIN 44

M4s

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SUBROUTINE GGM4s

C THIS SUBPROGRAM COMPUTES WEIGHTING FACTORS FOR THE GAUSSIAN  
 C QUADRATURE.

COMMON/WHT/C(24),W(24)

C(1)=.99877101

C(2)=.99353017

C(3)=.98412458

C(4)=.97059159

C(5)=.95296770

C(6)=.93138669

C(7)=.90587914

C(8)=.87657202

C(9)=.84358626

C(10)=.80706620

C(11)=.76715903

C(12)=.72403413

C(13)=.67797233

C(14)=.62886740

C(15)=.57722473

C(16)=.52316097

C(17)=.46690290

C(18)=.40863648

C(19)=.34875559

C(20)=.28736249

C(21)=.22476379

C(22)=.16122236

C(23)=.97004699E-1

C(24)=.32380171E-1

W(1)=.31533461E-2

W(2)=.73275539E-2

W(3)=.11477235E-1

W(4)=.15579316E-1

W(5)=.19616150E-1

W(6)=.23570761E-1

W(7)=.27426510E-1

W(8)=.31167228E-1

W(9)=.34777223E-1

W(10)=.38241351E-1

W(11)=.41545083E-1

W(12)=.44674561E-1

W(13)=.47616653E-1

W(14)=.50357036E-1

W(15)=.52890189E-1

W(16)=.55199504E-1

W(17)=.57277292E-1

W(18)=.59114840E-1

W(19)=.60704439E-1

W(20)=.62039423E-1

W(21)=.63114192E-1

W(22)=.63924239E-1

W(23)=.64466164E-1

W(24)=.64737697E-1

RETURN

END

```

T
23-08:55:16-(0,)
SUBROUTINE FCT(ARG,ARG1,ARG2)
C   THIS SUBPROGRAM COMPUTES THE THETAPRIME INTEGRAND =
C   SIN(THETAPRIME)*00**2*(INTEGRAL OVER PHIPRIME).
C   INPUTS   STH=SIN(THETA)
C             CTH=COS(THETA)
C             ARG=THETAPRIME
C             PHIR=PHI(RAD)
C             ASPECT
C             ISHAPE=0,1,2,OR 3
C             ROKO
C             C(24)
C             W(24)
C   OUTPUTS  ARG1=REAL PART
C             ARG2=IMAGINARY PART
C             ICOUNT=NO.OF PHIPRIME POINTS / 48
COMMON/BLUE/ASPECT,ISHAPE
COMMON/WHT/C(24),W(24)
COMMON/GREY/BWFR,BWGR,ICOUNT,STH,CTH,PI
COMMON/PINK/ROK0,PHIR
S=SIN(ARG)
C=COS(ARG)
CCTH=C0*CTH
SSTH=S*STH
N=1+INT(PI*S/(1.0+BWGR))
NNNN=N
ARG1=0.0
ARG2=0.0
ARG11=0.0
ARG12=0.0
ICOUNT=0
IF(ISHAPE.EQ.0.OR.ISHAPE.EQ.3) GO TO 604
IF(ISHAPE.EQ.1) GO TO 605
ARG3=SQRT(0.5*PI*ROK0/ASPECT)*S
IF(PHIR.EQ.0.0) GO TO 606
ARG3=ARG3*ASPECT
GO TO 606
604 IF(ISHAPE.EQ.0) ARG3=SQRT(2.0*ROK0)*S
IF(ISHAPE.EQ.3) ARG3=0.5*PI*ROK0*(1.0-C0)
IF(ISHAPE.EQ.3.AND.S.LE.0.01) ARG3=0.25*PI*ROK0*(ARG**2)
N=1
GO TO 606
605 ARG3=SQRT(PI*ROK0*0.5)*S
606 ENN=FLOAT(N)
IF(N.EQ.1) GO TO 622
IF(BWFR.GE.BWGR/S) GO TO 623
622 IF(BWFR.GE.1.0) GO TO 623
IF(DABS(S-STH).LT.BWFR) GO TO 618
623 9=PI/ENN
A=PI-0.5*B
L=1
GO TO 625
618 B=(PI-BWFR)/ENN
A=PI-0.5*B
L=2
625 DO 626 J=1,NNNN

```

```

619 DO 603 I=1,24
DO 617 K=1,2
OKAY=FLOAT(K)
PHIPRI=A+B*C(I)=(1.5-OKAY)
COSNU=COCTH+SSTH=COS(PHIPRI)
CALL FCTPHI(COSNU,VAL1,VAL2)
IF(ISHAPE.EQ.0.OR.ISHAPE.EQ.3) GO TO 607
CPRI=COS(PHIPRI)
SPRI=SIN(PHIPRI)
ARG4=ARG3*CPRI
ARG5=ARG3*SPRI
IF(ISHAPE.EQ.1) GO TO 612
IF(PHIR.EQ.0.0) GO TO 616
ARG5=ARG5/ASPECT
GO TO 612
616 ARG5=ARG5*ASPECT
612 IF(ARG4.EQ.0.0) GO TO 608
DO=SIN(ARG4)/ARG4
GO TO 609
608 DO=1.0
609 IF(ARG5.EQ.0.0) GO TO 610
DO=DO*SIN(ARG5)/ARG5
610 FAC=(DO**2)**(I)
GO TO 614
607 FAC=(I)
614 ARG1=ARG1+FAC*VAL1
617 ARG2=ARG2+FAC*VAL2
603 CONTINUE
ICOUNT=ICOUNT+1
IF(L.EQ.3) GO TO 621
A=A-B
626 CONTINUE
FAC=B*S
IF(L.EQ.1) GO TO 626
L=3
ARG11=ARG1*FAC
ARG12=ARG2*FAC
ARG1=0.0
ARG2=0.0
B=B*WEFR
A=0.5*B
NNNN=1
GO TO 625
621 FAC=B*S
ARG1=ARG1*FAC+ARG11
ARG2=ARG2*FAC+ARG12
GO TO 629
626 ARG1=ARG1*FAC
ARG2=ARG2*FAC
629 IF(ISHAPE.EQ.1.OR.ISHAPE.EQ.2) GO TO 613
IF(ARG3.EQ.0.0) GO TO 601
IF(ISHAPE.EQ.0) DO=2.0*BSSL(ARG3,3)/ARG3
IF(ISHAPE.EQ.3) DO=SIN(ARG3)/ARG3
DO=DO**2
GO TO 602
601 DO=1.0
602 CONTINUE

```

TPHI

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```
      SUBROUTINE FCTPHI(COSNU,VAL1,VAL2)
C     THIS SUBPROGRAM COMPUTES THE PHIPRIME INTEGRAND, EXP(JKR)*I(COSNU).
C     INPUTS      COSNU
C                VALUE1(225)
C                VALUE2(225)
C     OUTPUTS    VAL1=REAL PART
C                VAL2=IMAGINARY PART
      COMMON/RED/VALUE1(240),VALUE2(240)
      GNU=ACOS(COSNU)
      C=1.0E04*GNU
      I=INT(C)
      IF(I.GT.0).GO TO 500
      VAL1=VALUE1(1)
      VAL2=VALUE2(1)
      RETURN
500  IF(I.LT.10) GO TO 502
      IF(I.GE.100) GO TO 501
      C=1000.*GNU+9.
      GO TO 506
501  IF(I.GE.10000) GO TO 504
      C=100.*GNU+18.
      GO TO 506
504  IF(I.GE.31400) GO TO 507
      C=50.*GNU+68.
      GO TO 506
507  VAL1=VALUE1(225)
      VAL2=VALUE2(225)
      RETURN
506  I=INT(C)
502  CII=C-FLOAT(I)
      VAL1=VALUE1(I)
      VAL1=VAL1+(VALUE1(I+1)-VAL1)*(CII)
      VAL2=VALUE2(I)
      VAL2=VAL2+(VALUE2(I+1)-VAL2)*(CII)
      RETURN
      END
```

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ARG1=ARG1=00  
ARG2=ARG2=00  
013 RETURN  
END

ORPLOT

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```

SUBROUTINE MMSTCR(THETA,BDG,BDGAP)
PARAMETER MPTS=200
C PETER R MINER APR 1977
COMMON/TAN/RANGE
COMMON/BLUE/ASPECT,ISHAPE
COMMON/PURPLE/ NPOINT,XARRAY(MPTS),YARRAY(MPTS),ZARRAY(MPTS)
COMMON/ODRAB/ CHIDB,ALFARO,DOWNSR,GAIN,FASE,NAPFAC
COMMON/PINK/RXCL,PHIR
NPOINT=NPOINT+1
IF(NPOINT.GT.MPTS) GO TO 50
XARRAY(NPOINT)=THETA
YARRAY(NPOINT)=BDG
ZARRAY(NPOINT)=BDGAP
RETURN
50 WRITE(4,2000)
2000 FORMAT(' PLOT STORAGE OVERFLOW')
NPOINT=MPTS
RETURN
C
C PLOT CURVE
ENTRY MMPLOT
CALL NOBRDR
IF(NAPFAC.EQ.0) GO TO 101
CALL TITLE(' ', -1, 'THETA (DEG)', 11, 'BDGAP (DB)', 10, 9., 7.)
GO TO 102
101 CALL TITLE(' ', -1, 'THETA (DEG)', 11, 'BDG (DB)', 8, 9., 7.)
102 CALL NOCHECK
CALL FRAME
CALL GRAF(-45., 10., 45., -70., 10., 0.)
CALL XTICKS(2)
CALL YTICKS(2)
C CALL DOT
C CALL GRID(2,1)
C CALL RESET('DOT')
IF(NAPFAC.EQ.0) GO TO 103
CALL CURVE(XARRAY,ZARRAY,NPOINT,0)
GO TO 104
103 CALL CURVE(XARRAY,YARRAY,NPOINT,0)
104 DO 100 I=1,NPOINT
XARRAY(I)=-XARRAY(I)
100 CONTINUE
IF(NAPFAC.EQ.0) GO TO 105
CALL CURVE(XARRAY,ZARRAY,NPOINT,0)
GO TO 106
105 CALL CURVE(XARRAY,YARRAY,NPOINT,0)
C
C PLOT VARIABLES
100 I=ISHAPE+1
GO TO (150,160,170,180), I
150 CALL MESSAG('CIRCLE',5,.5,6.2)
GO TO 200
160 CALL MESSAG('SQUARE',4,.5,6.3)
GO TO 200
170 CALL MESSAG('RECTANGLE',9,.5,6.8)
GO TO 200

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180 CALL MESSAG('ENDFIRE',7,.5,6.8)
200 CALL MESSAG('GAIN = ',7,.5,6.5)
    AVALUE=GAIN
    CALL REALNO(AVALUE,103,'ABUT',6.5)
    CALL MESSAG(' DB',3,'ABUT',6.5)
    CALL MESSAG('PHASE = ',3,.5,6.2)
    AVALUE=FASE
    CALL REALNO(AVALUE,103,'ABUT',6.2)
    CALL MESSAG(' DEG',4,'ABUT',5.2)
    IF(ISHAPE.NE.2) GO TO 250
    CALL MESSAG('ASPECT = ',9,.5,5.9)
    AVALUE=ASPECT
    CALL REALNO(AVALUE,105,'ABUT',5.9)
    CALL MESSAG('PHI = ',6,.5,5.6)
    IF(PHIR.EQ.0.) AVALUE=0.
    IF(PHIR.NE.0.) AVALUE=90.
    CALL REALNO(AVALUE,102,'ABUT',5.6)
    CALL MESSAG(' DEG',4,'ABUT',5.6)
C
C
250 PLOT VARIABLES, RIGHT SIDE
    CALL MESSAG('CHI = ',6,6.5,6.8)
    AVALUE=CHIDB
    CALL REALNO(AVALUE,103,'ABUT',6.8)
    CALL MESSAG(' DB',3,'ABUT',6.8)
    CALL MESSAG('ALFARO = ',9,5.5,6.5)
    AVALUE=ALFARO
    CALL REALNO(AVALUE,106,'ABUT',6.5)
    CALL MESSAG(' DB',3,'ABUT',6.5)
    CALL MESSAG('FD/F = ',7,6.5,6.2)
    AVALUE=DOWNSR
    CALL REALNO(AVALUE,103,'ABUT',6.2)
    CALL MESSAG('ROK0 = ',7,6.5,5.9)
    AVALUE=ROK0
    CALL REALNO(AVALUE,105,'ABUT',5.9)
    IF(RANGE.LT.0.000) GO TO 210
    CALL MESSAG('R/RO = ',7,6.5,5.6)
    AVALUE=RANGE
    CALL REALNO(AVALUE,104,'ABUT',5.6)
    GO TO 220
210 CALL MESSAG('INFINITE RANGE',14,6.5,5.6)
220 CALL ENOPL(-1)
    RETURN
    END
```

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