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Technical Report RK-CR-73-9

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LASER RESONATOR MODEL-FINITE DIFFERENCE METHOD

User's Manual - 1 June 1973 through 21 November 1973

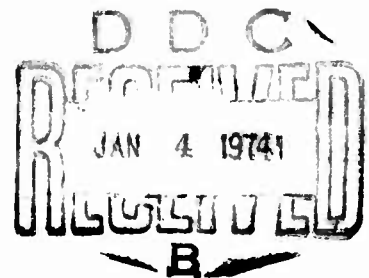
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November 1973

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Prepared for

**Propulsion Directorate, U S Army Missile Research
Development And Engineering Laboratory**

U S Army Missile Command, Redstone Arsenal, Alabama 35809

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13. ABSTRACT Three computer programs are described which allow the study of optical properties of two dimensional laser resonators. Two of the programs treat the propagation of an electric field inside an optical resonator (there are two methods for propagating an arbitrary electric field), and couple the propagating fields to a specified laser medium which may be nonuniform, transversely flowing, saturable, and inhomogeneous. The propagation technique includes diffraction effects throughout the laser medium. Both programs provide output beam characteristics and output power. The third program calculates far field beam characteristics for the laser output. Some of the features offered the user are a restart facility for long runs, arbitrary location of the medium in the resonator cavity, and capacity for mirror tilt on either or both mirrors.		

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FOREWORD

This manual describes three computer programs designed to study the optical properties of laser resonators. The first two are both Step-by-Step Computer Programs, termed SSCP and SSCP(ECS), where the latter is based on an Expanding Coordinate System. Both programs simulate the propagation of one or more waves between mirrors in a laser cavity, differing primarily in the coordinate system used to describe the propagation. Experience has shown the SSCP(ECS) program to be more efficient in most cases, requiring less computer time and memory to solve equivalent problems, and for this reason only the SSCP(ECS) is fully documented. The SSCP package is documented only in Section I and Appendix C.

The third program is designed to take an output waveform from the laser cavity (computed by one of the two programs above) and propagate it to the far field to determine the resulting intensity distribution. Appendix B contains a complete description of the program, including its mathematical basis and a description of the required input.

This report represents the second of two user's manuals which have been prepared under Contract DAAH01-73-C-0298. The first was a user's guide for laser resonator modeling using the Fresnel integral technique. This work was monitored by William Martin of the Propulsion Directorate.

NOMENCLATURE

<u>Symbol</u>	
AA	Defined by eq. (14)
ASR	π for cylindrical resonators, 4 for square resonators, 0 for 2-dimensional calculations
c	Speed of light
DIA1, DIA2	Diameter of mirror 1 (output mirror) or mirror 2
DXMIR1, DXMIR2	Mesh spacing at mirror 1 or 2 for x coordinate
G_j	Small-signal gain at j^{th} mesh point
g_1	Resonator parameters defined by eq. (16)
g_2	Resonator parameter defined by eq. (16)
GZERO	Small-signal gain for analytical gain subroutine
I_{2d}	Local flux density for two-dimensional resonator
I_{3d}	Local flux density for pseudo-three-dimensional resonator
K_o	Wave number ($2\pi/\lambda$)
M	Geometric magnification of unstable resonator
NX	Number of propagating field points in x direction
NZ	Number of propagation steps between mirrors
OMEGA1, OMEGA2	1/e truncation distance for mirror edges
RCURV1, RCURV2	Radius of curvature for mirror 1 and mirror 2

<u>Symbol</u>	
REFL1, REFL2	Mirror reflectivity
TLOSS1	Transmission loss for mirror 1
$\underline{U}$	Electric field vector
$\hat{U}$	Phasor for electric field $\underline{U}$
$U_{j,m}$	Free-space electric field at $x = j\Delta x$ and $z = m\Delta z$
U_{2d}	Electric field in two-dimensional resonator
VR1, VR2	Defined in eq. (15)
x	Transverse coordinate for electric field
XIZERO	Saturation parameter for analytical gain subroutine
XWIDTH	Extent of x dimension at start of each roundtrip
ZLEN	Distance between mirrors
ZLENMD	Gain medium length
ZMDLOC	Distance from mirror 1 to center of gain medium
<u>Greek</u>	
ϵ	$n^2 - 1$
ΔP_{2d}	Power contained in strip of Δx width
Δx	Incremental step size in x coordinate
Δz	Incremental step size in z coordinate
Δn	$n - 1$
Δn_j	$n_j - 1$, where $n \equiv$ refractive index at j^{th} field point
δx	Defined in eq. (7)
λ	Wavelength

Greek

∇^2

Laplacian operator in rectangular coordinates

∇^2_x

Laplacian operator for x coordinate only

ϕ

Angular coordinate for cylindrical resonators

ω

Optical frequency

I. SYSTEM DESCRIPTION

A. Introduction

The purpose of the Step-by-Step Computer Program (SSCP) is to study the optical properties of laser resonators. The optical properties of a laser system are dependent upon many factors which are interrelated in a complicated manner. This makes it impossible for an experimenter to determine the best choice of medium and resonator parameters for producing an optimum output beam without an expensive experimental trial and error analysis or without conducting a realistic analytical study. The SSCP is useful to the experimenter because it can greatly narrow the range of parameters from which he has to choose. By modeling the laser medium and the optical resonator for the device under analysis, he can vary the model parameters which represent physical variables and choose a range of parameters that give the best beam quality.

The experimenter has the choice of making his analytical analysis using the Step-by-Step Computer Program (SSCP) described in this user's manual or the Fresnel Integral Computer Program (FICP) described in the user's manual for the Two-Dimensional Fresnel Integral Computer Program.¹ The choice is dependent upon the size of the resonator's Fresnel Number and the homogeneity of the laser medium. The SSCP must be used for laser resonators with Fresnel numbers larger than sixty, for a transverse flowing medium, when the medium is highly gain saturated, or when significant density variations exist.

The SSCP is a very versatile tool for the experimenter to use in the analysis of large Fresnel number, inhomogeneous laser devices. Once he has optimized the nonoptical parameters to obtain the largest

¹ Two-Dimensional Fresnel Integral Computer Program, User's Manual, Hughes Research Laboratories, Contract No. DAAH01-73-C-0298, May 1973.

amount of energy in the medium, he must select an optical resonator which will optimize the far field intensity distribution (in most instances this means obtaining the largest far field flux density). The SSCP will allow the experimenter to couple up to 6 laser waves to a particular laser medium (except for empty cavity calculations the SSCP must be furnished with a kinetics subroutine). The medium subroutine can represent a single line laser system such as a CO_2 laser or a multiline laser such as an HF laser and it must supply saturated gain and refractive index for each local propagating field point. It will accurately account for diffraction of each propagating wave as they propagate through the laser medium. By examining each wave and their composite (obtained from their averaged intensities) the user can determine if the laser will be single or multimode, the total roundtrip loss or gain for each wave, the output power of the laser, the intensity and phase distribution for each wave in both the near and far field, and an averaged intensity distribution for both the near and far field if the laser is operating multimode. All the above information can be both printed and plotted after each roundtrip pass through the resonator (the operator has the option to print and plot after any given roundtrip pass). Furthermore, the user has the option of including mirror tilt, selecting the axial location of the medium inside the resonator, and selecting mirror reflectivity and mirror transmission loss.

The accuracy of the optimization results using the SSCP depends upon how realistically the medium and resonator models describe the actual laser device. Since any model must make certain approximations, the optical properties as predicted by the SSCP will never be in exact agreement with measured results. Therefore, it is important for anyone using the SSCP to understand the techniques used in the analysis and its limitations. In the remainder of this section the techniques used to analyze laser resonators, the type of information available from the SSCP, the limitations of the computer program, and the factors governing input data to the program will be described.

B. Step-by-Step Technique

The approach that is taken to solve for the transverse modes of a laser resonator is one which closely resembles the actual development of the modes from the laser's spontaneous emission. An arbitrary input wave (the SSCP has a choice of a wave with uniform or gaussian amplitude distribution) is propagated back and forth between two resonator mirrors. As the wave traverses between the mirrors it interacts with the laser medium. As it interacts, its amplitude and phase are adjusted according to the gain and refractive index of the medium. This iterative procedure is repeated until a stable solution is obtained. The wave represented by the stable solution is the steady state transverse mode or modes of the laser. A measure of the beam quality is obtained by transforming the steady state solution (near field of the laser) into the far field and comparing it with the resulting far-field distribution for a uniform near-field distribution.

1. Approximate Solution to the Wave Equation

Confining our attention to the case in which orthogonal field polarizations are not mixed by the laser medium, the electric field vector $\underline{U}$ within the resonator may be represented by

$$\underline{U}(x, z, t) = \underline{i} \operatorname{Re}[\hat{U}(x, z) \exp (iK_0 z - i\omega t)], \quad (1)$$

where $\underline{i}$ is a unit polarization vector, K_0 is the free-space wave number ($K_0 = 2\pi/\lambda$), ω is the optical frequency in rad/sec ($\omega = cK_0$), and the phasor $\hat{U}$ is a complex number depending on the position coordinates x, z . In a laser resonator, $\hat{U}(x, z)$ satisfies the wave equation.

$$(\nabla^2 + K_0^2 n^2) \hat{U}(x, z) = 0 \quad (2)$$

where ∇^2 is the Laplacian in rectangular coordinates, and n is the refractive index (contains both real and imaginary terms). By converting the above differential equation into an integral equation and

using the Green's function for the Helmholtz equation, we can obtain the following equation:

$$\hat{U}(x, z + \Delta z) = \hat{U}_0(x, z + \Delta z) \exp \left(i K_0 \Delta n \Delta z + O(\epsilon \Delta z^2 / \rho^2) \right) \quad (3)$$

where $\hat{U}_0(x, z + \Delta z)$ is the resulting electric field after propagating $\hat{U}(x, z)$ through free-space for a distance Δz , $\epsilon = n^2 - 1$, ρ is the shortest characteristic length in the z direction over which the field amplitude or phase changes, and $O(\epsilon \Delta z^2 / \rho^2)$ is a truncation error term. In other words, if we know both the electric field $\hat{U}$ and the local refractive index of the medium (assumed to be constant for a distance Δz) in the z plane, and if we know what the free-space electric field $\hat{U}_0$ is in the $z + \Delta z$ plane, we can determine the electric field $\hat{U}$ in the $z + \Delta z$ plane.

In a laser resonator model, the medium as well as the initial propagating field is assumed to be known. Therefore, what remains to be solved is how to determine the free-space electric field at $z + \Delta z$ from a known electric field $\hat{U}$ at z .

2. Propagation Algorithm (Two-Dimensional)

The two-dimensional free-space wave equation assuming constant K_0 is written as

$$\left(i2K_0 \frac{\partial}{\partial z} + \nabla_t^2 \right) \hat{U}_0(x, z) = 0 \quad (4)$$

where $\nabla_t^2 = \partial^2 / \partial x^2$. Using the following difference equations of DuFort and Frankel (Ref. 2)

²R. D. Richtmyer and K. W. Morton, Difference Methods for Initial-Value Problems, Interscience Publishers, Second Edition, 1967.

$$\frac{\partial \hat{U}_o}{\partial z} = \frac{1}{2\Delta z} (U_j^{m+1} - U_j^{m-1}) \quad (5a)$$

$$\frac{\partial^2 \hat{U}_o}{\partial x^2} = \frac{1}{\Delta x^2} (U_{j+1}^m - U_j^{m+1} - U_j^{m-1} + U_{j-1}^m) \quad (5b)$$

where

$$\begin{aligned} x &= j\Delta x & 1 \leq j \leq NX \\ z &= m\Delta z & 1 \leq m \leq NZ \end{aligned} \quad (6)$$

[Eq. (5) includes both the real and imaginary terms of $\hat{U}_o$.] We obtain after substituting eq. (5) into eq. (4) the following propagation algorithm:

$$\begin{aligned} \hat{U}_j^{m+1} &= \frac{1}{1 + \delta x^2} \left[\hat{U}_j^{m-1} + i\delta x \left(\hat{U}_{j+1}^m - 2\hat{U}_j^{m-1} + \hat{U}_{j-1}^m \right) \right. \\ &\quad \left. + \delta x^2 \left(\hat{U}_{j+1}^m - \hat{U}_j^{m-1} + \hat{U}_{j-1}^m \right) \right] \\ &\quad + \text{Truncation Terms} \end{aligned} \quad (7)$$

where $\delta x = \Delta z / (K_o(\Delta x)^2)$. Equation (7) allows the field at $z + \Delta z$ to be computed from known field values at z and $z - \Delta z$.

The difference method of DuFort and Frankel is explicit and is unconditionally stable (solution always converges independent of δx , and Δz) in unbounded regimes. From experience and an examination of the truncation terms, it has been determined that if $\Delta z \leq 0.5K_o(\Delta x)^2$, and Δx and Δz are less than the smallest characteristic length in the x and z directions, respectively, eq. (7) will accurately propagate an arbitrary field through free space with a gain or loss of less than 1 or 2% for each roundtrip pass (the user should note that these errors do not accumulate from pass to pass).

3. Calculation Procedure

The calculation technique for analyzing laser resonators using the step-by-step propagation algorithm given in eq. (7) is very similar to the technique described in Ref. 1; the main difference is the propagation algorithm [Ref. 1 uses a Fresnel integral to propagate the electric field back and forth in the resonator, while here propagation is accomplished using the numerical difference technique in eq. (7)].

The approach taken is to consider a propagating wave or waves reflecting back and forth between two cavity mirrors. It will be assumed for the moment that there is no laser medium present. (This condition gives the empty cavity or nonperturbed mode.) The following calculation sequence is used:

Empty Cavity

1. Reflect input wave or waves (a maximum of six waves can be used) from mirror 1. This step corrects the field amplitude for mirror reflectivity and mirror size and corrects the phase of the field for mirror curvature and angular mirror tilt. (For perfectly aligned resonators, mirror tilt is zero.)
2. Propagate one step to $z = \Delta z$ using the following initial propagation algorithm

$$\hat{U}_j^1 = \hat{U}_j^0 + i \delta x \left(\hat{U}_{j-1}^0 - 2\hat{U}_j^0 + \hat{U}_{j+1}^0 \right) \quad (8)$$

3. Propagate to mirror 2 (see Fig. 1) using eq. (7) repeatedly for $NZ - 1$ steps.
4. Reflect from mirror 2. This step corrects the amplitude and phase of the field for the effects of mirror 2.
5. Propagate one step using eq. (8).
6. Propagate to mirror 1 using eq. (7) repeatedly for $(NZ - 1)$ steps.

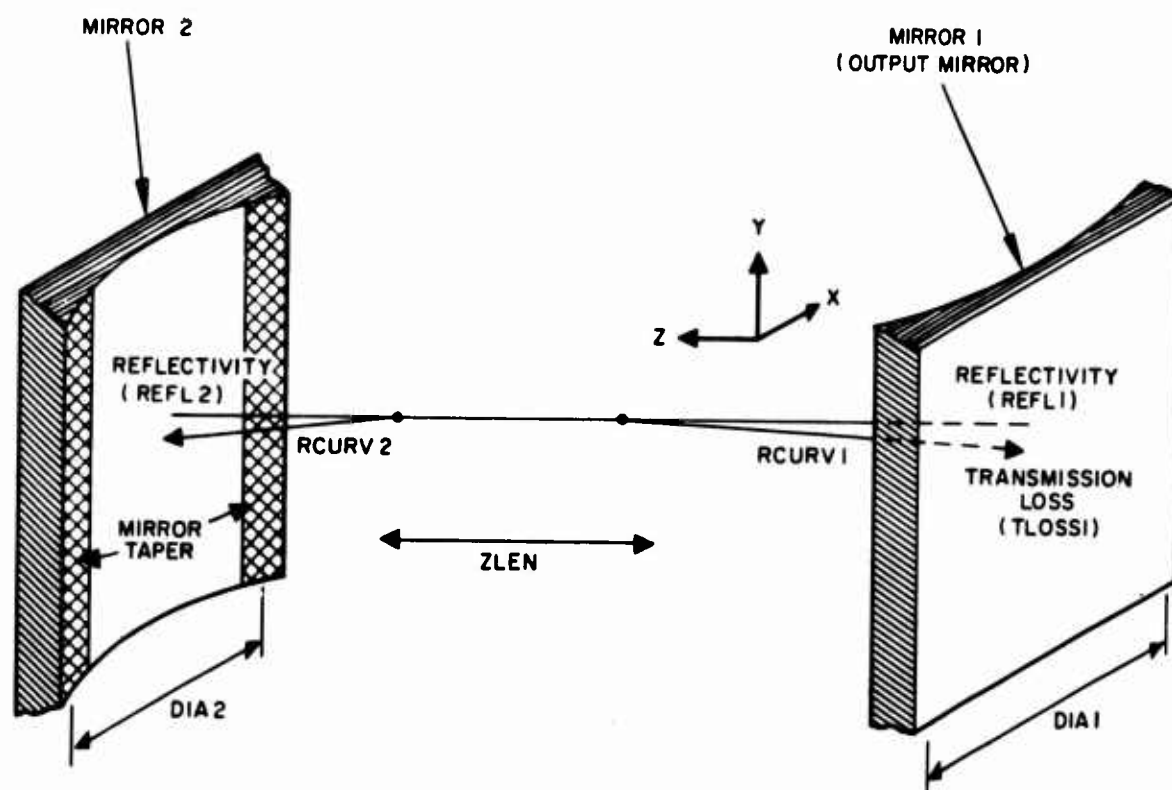


Fig. 1. Resonator geometry for step-by-step computer program.

7. Store real and imaginary terms of $\hat{U}_j$ on a RSTART tape. These values will be used later in a FAR FIELD PROGRAM to compute the far field intensity distribution.
8. Renormalize field amplitude at mirror 1. This step multiplies the field at mirror 1 by a constant so that at this location the area under the distribution curve remains fixed from pass to pass.
9. Repeat steps 1 through 8 for NPASS passes.

By following steps 1 through 9, the many modes that went into defining the input wave will reduce to a single mode, and this mode will be the lowest loss transverse mode of the resonator. This mode is also the lowest loss mode for three-dimensional square mirror geometry and should be interpreted as applying to a cross section through a resonator having square mirrors with spherical surfaces. It should be noted that when a saturable gain medium exists, this equivalence is no longer true.

Figure 2 shows the active laser medium inserted into the calculation procedure. Unlike the FICP, the SSCP is not restricted to low Fresnel number calculations and therefore can treat diffraction in the gain medium. The total gain length of the medium is ZLENMD, where ZLENMD can be equal to or less than ZLEN. The location of the center of the laser medium is located ZMDLOC distance from the mirror 1.

When propagating through the laser medium, the phase and amplitude of the field is adjusted after each propagation step according to eq. (3). Rewriting eq. (3) in terms of the local power gain G_j and the local index of refraction Δn_j , results in the following:

$$\hat{U}(j\Delta x, z + \Delta z) = \hat{U}_0(j\Delta x, z + \Delta z) \exp \left[\left(\frac{G_j}{2} + i K_0 \Delta n_j \right) \Delta z \right] \quad (9)$$

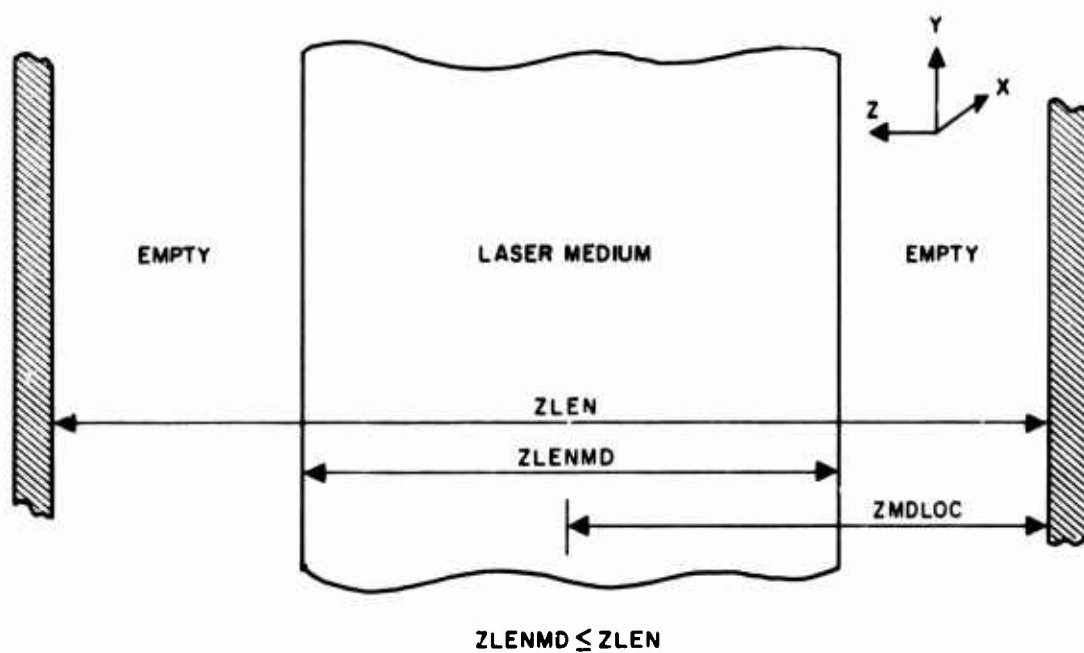


Fig. 2. Resonator geometry with laser medium.

(G_j can be positive or negative depending on whether the medium has gain or loss). Δz is the step size in the gain medium and is equal to $ZLEN/NZ$ and Δn_j is the local refractive index difference. The local power gain G_j can be supplied by a separate gain subroutine such as the Lockheed 2-D, DF-CO₂ (Ref. 3) mixing program or by a built-in gain subroutine GAINA which assumes the gain to be uniform and homogeneously broadened. The latter gain routine is expressed as

$$G_j = \frac{GZERO}{1 + \frac{|U_T(j\Delta x)|^2}{XZERO}} \quad (10)$$

where GZERO is the small-signal gain, XZERO is the saturation flux density, and $U_T(j\Delta x)$ is total field amplitude (forward plus backward traveling wave). If the medium is assumed to have uniform density, then $\Delta n_j = 0$. Since this type of gain medium cannot couple laser transitions, GZERO and XZERO are the same for each propagating wave.

The calculation procedure when the two-dimensional laser medium is included is as follows:

Medium Included:

1. Reflect input wave or waves from mirror 1.
2. Propagate to edge of laser medium using eqs. (7) and (8).
3. Sum present field intensity with field intensity from previous pass traveling in opposite direction (stimulated emission depends on total local intensity).
4. Call gain subroutine. This routine furnishes gain and refractive index values for each field point.
5. Propagate one step in the z direction using eq. (7).
6. Adjust the U_j field points for gain and density variations according to eq. (9).

³ Chemical Laser Analysis Development Program, Two-Dimensional Fresnel Integral Laser and Mixing Program User's Guide, Vol. II, Lockheed Missile and Space Company, Contract DAAH01-73-C-0232, Technical Report RK-CR-73-2, October 1973.

7. Store the intensity ($|U_j|^2$) for each field point. (The total number of times the intensities are stored in the z direction is limited to 21. If the number of propagation steps in the medium exceeds 21, the program automatically skips storing every step in order not to exceed this number.)
8. Repeat steps 5 and 6 for total of IGSKIP times. The parameter IGSKIP requires that IGSKIP propagation steps be made before the gain subroutine is called.
9. Repeat steps 3 through 8 until far side of laser medium is reached.
10. Propagate to mirror 2 using eq. (7).
11. Reflect from mirror 2.
12. Repeat steps 2 through 9.
13. Propagate to mirror 1 using eq. (7).
14. Store amplitude and phase of field points on the RSTART tape. (This data is used in the FAR FIELD PROGRAM to compute the far field intensity distributions.)
15. Repeat steps 1 through 14 for NPASS passes.

Laser power can be coupled out of the laser at either or both ends of the resonator if the beam spills past the edges of the resonator mirrors. The power lost in this way can be determined by taking the beam power before and just after the beam hits a mirror and taking their difference (mirror reflectivity is assumed to be 1). Useful laser power is assumed to occur at mirror 1 and this can be from both spillage and transmission through the mirror ($REFL1 < 1$). It is this combined beam that is used to determine the far field.

4. Mirror Edge Tapering

The truncation error terms in eq. (7) contain the following partial derivatives.

$$\begin{aligned} \text{Truncation Error} = & \frac{i}{K_o} \left[\left(\frac{\partial^2 \hat{U}}{\partial z^2} \right) \left(\frac{\Delta z}{\Delta x} \right)^2 \right] + \frac{1}{3} \frac{\partial^3 \hat{U}}{\partial z^3} \Delta z^2 \\ & - \frac{i}{12K_o} \left[\frac{\partial^4 U}{\partial x^4} \Delta x^2 \right] + \dots \end{aligned} \quad (11)$$

Because of the partial derivatives with respect to x , we cannot accurately treat infinitely steep field gradients that occur at sharp mirror edges; therefore, it is necessary to use edge-tapering. In our step-by-step resonator model, the mirror reflectivity at the edge of the mirror is given by the following gaussian function:

$$\text{Mirror Reflectivity} = \text{REFL} \exp \left(-(x - x_o)^2 / \text{OMEGA}^2 \right), \text{ for } |x| \geq x_o \quad (12)$$

where REFL is the power reflectivity of the mirror, $2x_o$ is the mirror width describing the region of uniform reflectivity, $x = 0$ at mirror center, and OMEGA describes the distance of truncation. (When the operator sets DIA1 or DIA2, the program automatically computes x_o such that $x_o = \text{DIA}/2 - \sqrt{0.7 \cdot \text{OMEGA}}$. This fixes the effective mirror diameter between the half power points in the taper region.)

C. Step-by-Step Technique (Expanding Coordinates)

The discussion up to this point has outlined the technique for solving for the transverse modes of a laser resonator using the step-by-step propagation technique. As stated in the introduction the step-by-step technique is best suited for large Fresnel number waves. Thus, the step-by-step model should be best suited for studying large Fresnel number resonators. However, this is not the case. Larger Fresnel numbers require increasingly larger numbers of mesh points and therefore more computer time. This is due to the beam curvature

which is introduced into the wave every time the beam bounces off a resonator mirror. For example, in a confocal unstable resonator using a convex and concave mirror (laser output is obtained at the convex mirror), the beam that is reflected from the output mirror has a radius of curvature equal to that of the mirror and thus its effective Fresnel number is much lower than the Fresnel number of the resonator. However, by using an expanding coordinate system, we can remove the dependence of the mirror curvature on the number of mesh points required to accurately propagate the beam. We can propagate the beam back and forth inside the resonator, assuming it is nearly a plane wave, and then by using a suitable coordinate transformation determine the actual beam distribution including phase information.

The SSCP can treat diffraction within the laser medium, but it is limited to studying resonators with Fresnel numbers of approximately 60 or less. However, by going to an expanding coordinate system the Step-by-Step Computer Program (Expanding Coordinate System) SSCP(ECS) does not have an upper limit on the Fresnel number. Because of the importance of large Fresnel numbers in high power laser systems, this user's manual will be mainly devoted to the SSCP(ECS). Features which are explicitly different in the SSCP will be described in Appendix C.

1. Propagation Algorithm (Two-Dimensional)

The propagation algorithm for the expanding coordinate system is similar to the algorithm given in eq. (7) and is expressed as follows.⁴

⁴ Chemical Laser Mode Control Program, Semiannual Technical Report, Hughes Research Laboratories, Contract No. DAAH01-73-C-0290, 13 November 1972 through 12 May 1973.

$$\begin{aligned}\hat{U}_j^{m+1} = & \frac{AA}{1 + \delta x^2} \left[\hat{U}_j^{m-1} \cdot AA + i \delta x \left(\hat{U}_{j+1}^m - 2\hat{U}_j^{m-1} \cdot AA + \hat{U}_{j-1}^m \right) \right. \\ & \left. + \delta x^2 \left(\hat{U}_{j+1}^m - \hat{U}_j^{m-1} \cdot AA + \hat{U}_{j-1}^m \right) \right] \\ & + \text{Truncation Terms}\end{aligned}\quad (13)$$

where AA is a variable which is a function of z. AA is defined as

$$AA = \left(1 - \frac{\Delta z}{2(z + VR)} \right) \quad (14)$$

where VR is shown in Fig. 3 as the virtual image source distance with z measured from the mirror as the beam propagates away from it. The virtual source distance VR is a function of the physical parameters of the resonator and is given as⁵:

$$VR_{1,2} = \left[\frac{\sqrt{1 - (g_1 g_2)^{-1}} - 1 + (g_{1,2})^{-1}}{2 - (g_1)^{-1} - (g_2)^{-1}} \right] \cdot ZLEN \quad (15)$$

where $g_{1,2}$ are the resonator g parameters defined as

$$g_{1,2} = 1 - \frac{ZLEN}{RCURV_{1,2}} \quad (16)$$

Because of the expanding coordinate system δx is no longer a constant since Δx is a function of z. Δx is expressed as follows.

⁵A. E. Siegman, "Unstable Optical Resonators for Laser Applications," Proceedings IEEE, 53, 277-287, March 1965.

2785-3

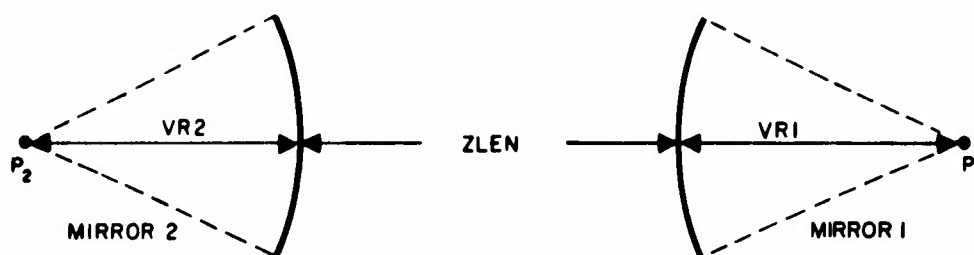


Fig. 3. Geometry showing location of virtual image sources P_1 and P_2 .

$$\Delta x = DXMIR1 \left(1 + \frac{z}{VR1} \right) \text{ propagating from mirror 1 to mirror 2}$$

$$\Delta x = DXMIR2 \left(1 + \frac{z}{VR2} \right) \text{ propagating from mirror 2 to mirror 1}$$

(17)

where DXMIR1 and DXMIR2 are the values for Δx at mirror 1 and mirror 2, respectively, and z is again measured from the mirror that the beam is propagating away from.

As a result of the coordinate transformation the SSCP(ECS) differs from the SSCP in that beam expansion or contraction is controlled by the increase or decrease of Δx in eq. (17) and not by the phase curvature placed on the beam upon reflection from a mirror as is the case for the SSCP. In the SSCP(ECS), the transformed mirrors are flat (infinite radius of curvature). The operator, when inputting the mirror radii of curvature, must supply the physical curvatures to the program (these are used to compute the virtual image distances in eq. 15), but the program treats the mirrors as if they were flat when the beam reflects off their surfaces. The divergence or convergence that would be caused by the actual curvature of the mirrors is treated by the coordinate transformation. The operator can supply any mirror curvature to the program as long as all virtual image sources are located outside the resonator. The coordinate transformation cannot treat internal focal points. It should be pointed out that in the SSCP(ECS), the maximum distance traversed in the x -direction depends on the maximum value for Δx .

2. Calculation Procedure

The calculation procedure for the empty cavity configuration is as follows (see Fig. 4).

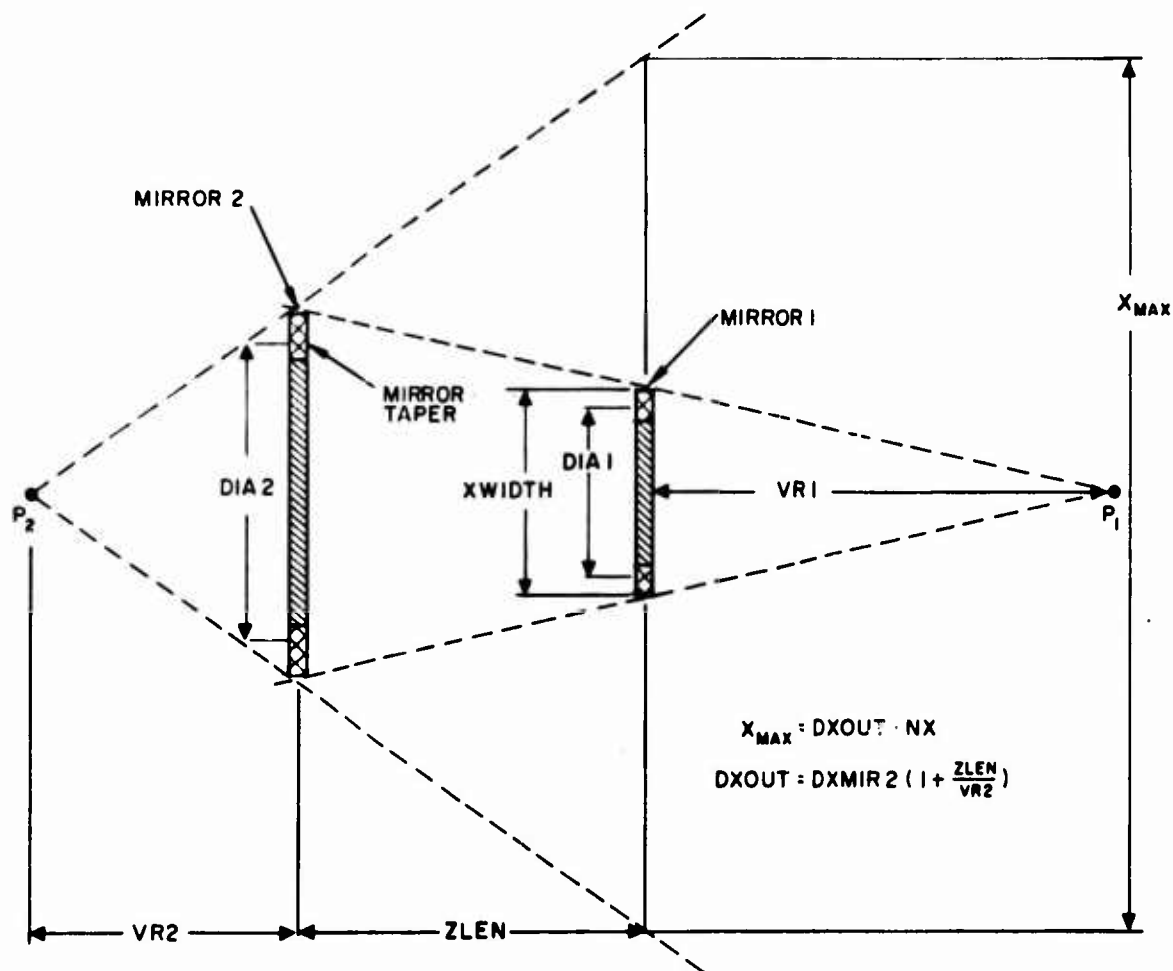


Fig. 4. Resonator geometry for step-by-step propagation with expanding coordinate system.

Empty Cavity

1. Compute VR1 and VR2 and VR2 using eq. (15).
2. Reflect input wave or waves from mirror 1.
(Maximum of six waves can be specified.)
Mirror 1 and mirror 2 are treated as if they have infinite radius of curvature (flat mirrors), therefore only the spatial properties of the input wave are changed.
3. Compute Δx using eq. (17). ($DXMIR1 = XWIDTH/NX$, where $XWIDTH$ is an input parameter).
4. Propagate one step to $z = \Delta z$ using eq. (8).
5. Compute Δx using eq. (17).
6. Propagate one step in the z direction using eq. (13).
7. Repeat steps 5 and 6 until mirror 2 is reached.
8. Reflect from mirror 2.
9. Repeat steps 3 through 6 until mirror 1 is reached.
10. Store field points on RSTART tape for use in the FAR FIELD PROGRAM.
11. Renormalize field amplitude. This step multiplies the field at mirror 1 by a constant so that at this location the area under the distribution remains fixed from pass to pass.
12. Reduce the maximum spatial extent of the beam from x_{max} to $XWIDTH$. This step takes the NX field points which have amplitude and phase information for the beam spaced every $DXOUT$ and replaces every field point with beam information spaced $DXMIR1$ apart.
13. Repeat steps 2 through 13 for NPASS passes.

For the empty cavity configuration, the operator can determine the total roundtrip losses for the resonator by summing the losses that

occur at each mirror. The loss at mirror 1 is determined by taking the area under the intensity distribution after completing step 11 and subtracting from it the area after step 2. The loss at mirror 2 is the difference in areas after completing steps 7 and 8 [the area after each of the indicated steps is printed as output by both the SSCP and the SSCP(ECS)].

The phase distribution obtained with the expanding coordinate system is normalized to the geometric phase for the output beam. In other words, if there are no perturbations in the resonator, the output phase will be essentially flat (all geometric curvature removed).

To include the laser medium effects in the SSCP(ECS) an additional step, other than the steps outlined for the SSCP, is required to compute the local intensities needed for the gain subroutine. Note in Fig. 4 that propagating from mirror 1 to mirror 2 the total extent of the beam in the x-direction is smaller than for the opposite traveling beam. Since the field points of the two opposite traveling waves do not necessarily coincide, the total local intensity (which is needed for the gain subroutine) must be obtained by interpolation. In addition the matrix containing the local intensities $S\phi T\phi T$ and GAIN must be expanded to include field points covering the entire beam of the previous pass when propagating from mirror 1 to mirror 2 at the current z location.

D. Pseudo Three-Dimensional Calculations

In high power laser devices with transverse medium flow, the spatial homogeneity of the near field intensity distribution depends upon the output coupling of the resonator. Since the coupling loss for two- and three-dimensional resonators are not equal [for two-dimensional confocal unstable resonators the loss $(1 - 1/M)$ is considerably less than the three-dimensional loss $(1 - 1/M^2)$], a realistic near-field distribution cannot be obtained with a two-dimensional resonator calculation. Furthermore, three-dimensional calculations are

necessary to determine output power since this quantity also depends upon coupling loss. The SSCP and the SSCP(ECS) contain an option to perform a pseudo-three-dimensional calculation. A description of the calculation technique is given below.

1. Calculation Technique

The three-dimensional cylindrical resonator is divided into two halves about a line running from the top to the bottom of the resonator. The same propagation algorithms used for the two-dimensional resonators can be used if it is assumed that for the right half (downstream half) of the resonator the field amplitude in the resonator is

$$\underline{U}_{3d}(r, \phi) = \underline{U}_{3d}(r)e^{j\phi} = \underline{U}_{2d}(x) , \quad (18)$$

for

$$-\frac{\pi}{2} < \phi \leq \frac{\pi}{2} ,$$

$$0 < x \leq \frac{DIA2}{2}$$

and for the left half (upstream half) of the resonator for field amplitude is

$$\underline{U}_{3d}(r, \phi) = \underline{U}_{3d}(r)e^{j\phi} = \underline{U}_{2d}(x) , \quad (19)$$

for

$$\frac{\pi}{2} < \phi \leq \frac{3\pi}{2} ,$$

and

$$\frac{-DIA2}{2} \leq x \leq 0$$

Thus, for the upstream half of the resonator, the mode distribution is independent of ϕ , and a similar assumption is made about the downstream portion. Next the flux density that the gain medium senses must be adjusted in order to account for the differences in coupling loss. To find this adjustment factor, note that the power contained in a thin strip Δx wide and $DIA/2$ high in a two-dimensional resonator is

$$\Delta p_{2d} = I_{2d} \cdot DIA/2 \cdot \Delta x, \quad (20)$$

where $I = |U_j|^2$. The power contained in a thin strip Δr wide and covering half a three-dimensional resonator (either the upstream or downstream half) is

$$\Delta p_{3d} = ASR \cdot I_{3d} \cdot r \Delta r = ASR \cdot I_{3d} \cdot x \Delta x$$

$$ASR = \pi \text{ (cylindrical resonator)} \quad (21)$$

$$ASR = 4 \text{ (square resonator)}$$

$$ASR = 0 \text{ (two-dimensional calculation)}$$

where the center of the resonator mirror is assumed to be located at $x = 0$, and I is the flux density in the laser cavity. Because of the imposed angular requirements (cylindrical resonator) on I_{3d} in the cavity, the three-dimensional cavity flux density can be set equal to the two-dimensional cavity flux density. Thus

$$\Delta p_{3d} = \frac{ASR}{DIA/2} \cdot x \cdot \Delta p_{2d} \quad (22)$$

However, in order to satisfy eq. (22) the flux density that the medium senses I^P (I^P is the flux density used to calculate the gain which in this case is different from the cavity flux I) must be adjusted as follows

$$I_{3d}^p = \frac{ASR}{DIA^2} \cdot x \cdot I_{2d} \quad (23)$$

2. Calculation Procedure

The procedure for computing the pseudo-three-dimensional near-field in the presence of a laser medium is similar to the two-dimensional procedure described for the SSCP and the SSCP(ECS). The three-dimensional procedure requires two additional steps. First, since eqs. (7) and (13) conserve the two-dimensional area the field amplitude at each propagation step must be renormalized in order to conserve the three-dimensional area. Each field point is multiplied by the following constant:

RATIO = Renormalization Constant (3-d)

$$= \left(\frac{\sum_i |U_i^m|^2 |x_i - x_c| \Delta x}{\sum_i |U_i^{m+1}|^2 |x_i - x_c| \Delta x} \right)^{1/2} \quad (24)$$

where x_c is the x-dimension for the center of the resonator. The accumulative ratio RCUM3D is the NZ products of RATIO for each propagation step ($RATIO_1 \cdot RATIO_2 \cdots RATIO_{NZ}$). Second, the total local intensities must be adjusted according to eq. (23) before computing the local gain. It should be pointed out that the local intensities are not permanently changed by this adjustment; they retain their original values once the local gain has been computed.

Both programs, the SSCP and the SSCP(ECS) are set up so that when $ASR = 0$, two-dimensional calculations are made.

E. Program Uses

The Step-by-Step Computer Program (SSCP) and the Step-by-Step Computer Program with Expanding Coordinate System

[SSCP(ECS)], when used to analyze empty cavity resonators, will solve for the amplitude and phase of the lowest loss transverse mode, the total roundtrip loss per pass, the output coupling fraction, the amplitude and phase of the far-field distribution, and the far-field normalized area distribution. This latter distribution gives the total area, or power, under the far-field distribution for a given far-field angle. Both near- and far-field information is provided regardless of the resonator configuration. The resonator may be stable or unstable, perfectly aligned or misaligned as a result of mirror tilt, or have partially transmitting mirrors.

The empty cavity analysis is important because it gives the program user the nonperturbed intensity distributions for any two-dimensional resonator configuration. It also permits the user to determine the effects of mirror misalignment and coupling on the intensity distributions.

With an active medium present, additional information can be obtained from the SSCP and SSCP(ECS). Using the uniformly saturable gain routine contained in the two programs, the user can determine how the intensity distributions are perturbed when saturable gain is present. Furthermore, he can determine if a given small signal gain will cause multimoding in the resonator. For gain routines such as the Lockheed 2-D, DF-CO₂ mixing program,³ effects from flow, multi-wavelengths, and refractive index gradients can be studied. In addition, of course, parametric studies involving concentration, temperature, and mixing of gas species can be performed in order to determine their effect on the output beam.

F. Limitations

The two-dimensional Step-by-Step Computer Program (SSCP) has three basic limitations. The first limitation is that the analysis is limited to slit or two-dimensional resonators; this restrains the laser medium from varying in the y direction. Therefore, lasers which have

³ Chemical Laser Analysis Development Program, Two-Dimensional Fresnel Integral Laser and Mixing Program User's Guide, Vol. II, Lockheed Missile and Space Company, Contract DAAH01-73-C-0232, Technical Report RF-CR-73-2, October 1973.

free expansion nozzles, shock waves, etc., cannot be accurately analyzed with a two-dimensional analysis. The pseudo-three-dimensional calculation procedure discussed in Subsection D permits the user to eliminate the difference in coupling loss between the two- and three-dimensional resonators; however, the procedure still requires medium uniformity in the y direction.

The second limitation of the SSCP is the size of the Fresnel number of the resonator which can be analyzed. For efficient calculations the number of field points NX should be less than approximately 300. From past experience this requires Fresnel numbers of 60 or less. The Step-by-Step Computer Program with Expanding Coordinate System [SSCP(ECS)] removes this limitation. However, in removing the Fresnel number limit it adds a constraint that no internal focal points can exist inside the resonator (all virtual image sources must be outside the resonator).

The third limitation is the inability to treat infinitely sharp mirror edges. Since the mirror edges must be gradually tapered, the fine structure in the near-field intensity distribution is eliminated. However, the overall structure is not degraded by the tapering of the mirror edges and the net result is an averaging of the fine structure to produce a smooth varying intensity distribution for the transverse modes.

G. Input Data Considerations

Several input variables to the program are not set by the physical dimensions of the laser device being analyzed. A list of these along with a brief description follows:

<u>Variable</u>	<u>Description</u>
NX	Number of field points
NZ	Number of propagation steps between mirrors

<u>Variable</u>	<u>Description</u>
IGSKIP	Number of propagation steps between GAIN calls
AMPINT	Amplitude of input wave (uniform or gaussian ($\sqrt{W}/L$))
WOMEGA	1/e radius of input wave (L)
OMEGA 1, 2	Truncation distance for mirror edges (L)
XWIDTH	Maximum spatial extent of input wave (L)

NX must be chosen such that there are at least two field sample points within the smallest length in the x direction over which the amplitude or phase of the beam changes. The smallest length may be OMEGA or the size of a density variation such as a shock wave. For single mode lasers, NX will be determined primarily by the truncation distance of the mirror edges (see discussion at end of this section).

NZ is determined from the following equation:

$$\Delta z \leq \frac{K_o}{2} \cdot \Delta x^2 \quad (25)$$

where

$$\Delta x = \frac{XWIDTH}{NX} \quad \text{and} \quad \Delta z = \frac{ZLEN}{NZ}.$$

Under most conditions, eq. (25) is sufficient to determine Δz ; however, if a laser medium is present such that the amplitude or phase of the beam changes by more than 5 or 10%, then Δz must be reduced in order not to exceed this limit.

IGSKIP should be set so that the GAIN subroutine is called whenever the beam amplitude changes by 5 or 10%

The amplitude of the input waves (uniform or gaussian distribution) is set by AMPINT. For empty cavity conditions the field distribution is normalized every pass in order to make the average intensity at mirror 1 equal to 1.0; therefore, AMPINT has no meaning in this

case. For gain filled resonators the distribution is not normalized. Since the final mode distribution must be independent of the input wave, the value for AMPINT is arbitrary. For values less than the saturation levels of the medium, the SSCP and SSCP(ECS) require several passes through the resonator before the medium saturates (gain equals loss). By setting $(AMPINT)^2$ approximately equal to the saturation flux density of the medium, the SSCP and SSCP(ECS) require the fewest number of iterations for a solution.

WOMEGA is the $1/e$ radius for the input wave or waves. The amplitude distribution for the input is as follows:

$$|U|_{\text{input}} = AMPINT \exp\left(-(x - x_c)^2 / WOMEGA^2\right). \quad (26)$$

For uniform distributions, $WOMEGA \rightarrow \infty$.

The truncation distance for the mirror edges is given by OMEGA 1 and OMEGA2. The values for OMEGA should be such that $2 \cdot OMEGA \leq 0.07 \cdot DIA$. For example, if $DIA2 = 10$ cm then $OMEGA 2 \leq 0.35$ cm. The purpose of the upper limit on OMEGA is to insure that the taper region does not contribute to a significant portion of the mirror surface. There is an additional consideration that must be made when setting a value for OMEGA. Significant truncation error terms in the propagation algorithm can develop if there are not sufficient sample field points in the taper region; therefore, the operator must be sure that $DXMIR \leq OMEGA/3$. Decreasing OMEGA means that DXMIR must be decreased proportionately. However, DXMIR can only be decreased by increasing NX, which means more computer storage and computation time to analyze the resonator. Therefore the operator must compromise between the sharpness of the mirror edge and computational efficiency.

Since the step-by-step propagation algorithm is a numerical difference method, the first and last field points in the propagation algorithm must always contain zero. Therefore in the SSCP and the

SSCP(ECS), XWIDTH must be large enough to ensure that throughout the entire cavity, significant truncation errors are not introduced by setting the end points to zero (in both programs, the value assigned to the end points are always zero). In the SSCP (where there is no expansion of the coordinate system), XWIDTH must be large enough to include both geometric and diffraction spreading of the beam. For example, on the first pass when the initial beam is reflected from mirror 1 and propagated toward mirror 2, XWIDTH (which is equal to $NX \cdot \Delta x$) must be larger than the beam when it arrives at mirror 2 (the beam size at mirror 2 will depend on both the radius of curvature of mirror 1 and diffraction spreading). In the SSCP(ECS), geometric spreading is accounted for by the expanding coordinate system. Therefore, XWIDTH which sets the width of the initial input beam does not have to be made large enough to include geometric spreading, but only large enough to include diffraction. This is the advantage of the expanding coordinate system. When using the SSCP(ECS), XWIDTH usually is slightly larger than DIA1, while in the SSCP, XWIDTH usually is larger than the largest cavity mirror.

II. PROGRAM DESCRIPTION

A. Summary of the SSCP(ECS)

The Step-by-Step Computer Program with Expanding Coordinate System, or SSCP(ECS), is composed of a variety of FORTRAN sub-routines and functions. For simplicity, they can be grouped into four divisions based on function: primary, satellite, utility, and input/output routines. The boundaries between divisions are arbitrary; but in general reflect the importance or difficulty of implementation of a subprogram.

Primary routines are generally the longest and most logically complex of a system of routines. In addition, they usually contain the fundamental mathematical concepts and techniques upon which the program was based. The SSCP(ECS) system consists of three such routines.

PR51	Main program, defines input, contains overall logic
P50SBS	Propagates one or more waves through free space
P50MED	Propagates one or more waves one way through a medium

Satellite routines are generally self-contained routines which accomplish some smaller portion (often repetitive) of the overall solution. Four of these routines are incorporated in the SSCP(ECS).

P50GAI	Returns a set of gain values at a particular location in the medium
GAINA	Computes the gain for each element of each wave for some location in the medium
MIRROR	Reflects one or more waveforms from a particular mirror
SETMIR	Sets up a mirror vector

The GAINA routine is described as a satellite routine only because of its mathematical simplicity and its short length. A program such as the Lockheed DF-CO₂ mixing program³ would obviously be a primary routine when substituted for GAINA.

Utility routines generally have little to do with the calculation that the program system is performing, but accomplish some necessary function instead. The four routines of SSCP(ECS) in this category are:

P50GET	Retrieves one intensity value from the last-pass intensities matrix by a triple linear interpolation
P50INT	Reduces the output wave(s) from fully expanded form to compacted form for start of next pass by linear interpolation
NORM2D	Two-dimensional area conservation (renormalization routine)
RAT3DA	Three-dimensional area conservation routine

Input/output routines are normally special purpose routines designed to manipulate a particular type of input or output in a particular way, and hence are self-explanatory and highly inflexible. Three routines of this class are:

AREA21	Computes and prints the area under a curve
PWROUT	Computes and prints the near field power and power transmitted for one or more waves positioned before the output mirror
RSTART	Restarts a previous run by reading a magnetic tape

The fourth routine in this category, ALLOUT, is in reality a package of routines designed to allow the programmer to describe the type, frequency, and quantity of output he desires while retaining flexibility. Since these routines have nothing to do with the problems

³ Chemical Laser Analysis Development Program, Two-Dimensional Fresnel Integral Laser and Mixing Program User's Guide, Vol. II, Lockheed Missile and Space Company, Contract DAAH01-73-C-0232, Technical Report RK-CR-73-2, October 1973.

which the SSCP(ECS) was designed to handle, their description will be given in Appendix A.

B. Main Program and Key Subprogram Descriptions

1. PR51 (Main Program)

The main program, PR51, defines all input parameters and controls all output either directly (by calling the output package) or indirectly (by supplying an output file code to routines which use the output package). In addition, PR51 controls job flow by initializing certain parameters before each case begins, defining certain vectors (such as the mirror vectors), and defining the manner of execution of the primary routines P50MED and P50SBS.

All important arrays are declared in PR51 and supplied to subprograms through the argument list or by labeled COMMON. This feature permits the user to alter the size of certain arrays as desired to minimize the storage requirement. All arrays dimensioned in PR51 are indexed by one or more of five quantities: (1) the maximum number of propagating points in the x-direction, (2) the maximum number of last-pass intensity values stored in the z-direction, (3) the largest number of propagating waves, (4) the largest number of passes that PR51 can handle, and (5) the largest number of gain values that PR51 can handle. These five values are assigned to variables NXDIM, NZDIM, NWDIM, NPDIM, and NGDIM, respectively, and appear in a DATA statement at sequence number 1820. Table I describes the relationship between each subscript of each array and the approximate quantity involved. The abbreviations used in the table are

X $\equiv$ NXDIM

Z $\equiv$ NZDIM

W $\equiv$ NWDIM

P $\equiv$ NPDIM

G $\equiv$ NGDIM

TABLE 1. PR51 ARRAY SUBSCRIPT REFERENCES

Array Name	Array Type	Subscript Reference No.		
		1	2	3
T	Complex	X	W	-
U	Complex	X	W	-
V	Complex	X	-	-
XMIR1	Complex	X	-	-
XMIR2	Complex	X	-	-
GAIN	Complex	G	W	-
SO	Real	X	Z	W
SONEW	Real	X	W	-
SOTOT	Real	G	W	-
XLAMDA	Real	W	-	-
XKZERO	Real	W	-	-
AMPINT	Real	W	-	-
INFOUT	Real	P	-	-
WOMEGA	Real	W	-	-
X	Real	X	-	-
OUT1	Real	X	-	-
OUT2	Real	X	-	-
OUT3	Real	X	-	-
OUT4	Real	X	-	-
OUT5	Real	X	-	-
OUT6	Real	X	-	-
OUT7	Real	X	-	-

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Should the user need to change one or more of the dimensions of PR51, he should first identify which arrays are affected (by Table I) and then change each array declaration in PR51 to reflect the changed dimension. Last, he should change the appropriate value in the DATA statement at sequence number 1820 so that all subprograms will automatically handle the change.

2. Selected Subprogram Descriptions

Flowcharts and listings are provided in Appendix E for each primary routine and the more complex satellite and utility routines. Other routines, including the output package (GPOP), have only listings. Documentation describing the purpose of each routine and the nature of the arguments supplied are provided in the listings themselves with the exception of three GPOP routines. The description of GPOP usage appears in Appendix A. The information provided by the listings (and, if present, the flowchart) is generally sufficient to adequately describe the subprogram. However, three routines warrant further mention.

P50GAI

The critical feature of P50GAI is the storage and retrieval of the last-pass intensities prior to the call to the gain routine. Since a major portion of dimensioned storage lies in the SO (last-pass intensity) matrix, a facility exists by which the user can avoid storing intensities at every medium propagation step. When retrieving intensity values from the matrix, therefore, a linear interpolation procedure is used to derive an approximate intensity value for each field point. As the propagation proceeds along the z-direction, current intensity values are stored in place of last-pass intensities which are no longer needed so that the wave re-entering the medium during the next P50GAI call will contain new values. The SO index in the z-direction increments when propagating toward the back mirror, and decrements when propagating toward the output mirror.

SETMIR

The mirror setup routine, SETMIR, computes three components for each location of the mirror matrix. The first, reflectivity, is supplied directly to the routine as an input parameter but may be locally adjusted by SETMIR to accommodate edge tapering (see Section I. B. 4). The second component, mirror curvature, is defined as

$$\text{CURV}_i = \exp[-jK_o(x_i - x_c)^2 / \text{RCURV}] , \quad i = 1, 2, \dots, \text{NX}$$

where

x_c is the x-value at the mirror center

RCURV is the mirror radius of curvature.

The third component, mirror tilt, is defined as

$$\text{TILT}_i = e^{j[2K_o\beta(x_i - x_c)]} , \quad i = 1, 2, \dots, \text{NX}$$

where

β = mirror tilt angle (radians).

GAINA

The gain routine returns an array defining the power gain and refractive index variation of the medium for each wave and each field point at a desired z-location. The gain matrix is complex, with the real part containing the local power gain, g_j , and the imaginary part containing the refractive index variation, $\Delta\eta_j K_o$. The GAINA routine supplied with the SSCP and SSCP(ECS) only returns a power gain.

C. Input Description

PR51 is the only routine in the SSCP(ECS) package requiring input to be prepared by the user. All such input is entered on data cards by the FORTRAN NAMELIST convention, with which the reader is assumed to be familiar. (A complete description can be found in the FORTRAN reference manual.) In general, a NAMELIST data record consists of a "\$" in column 2 of the data card followed immediately by the particular NAMELIST name for this record, followed by one or more blanks or a comma, followed by the list of variables and corresponding values (in the form of assignment statements separated by commas), and finally terminated by a "\$".

Two NAMELIST group names are used by PR51, the first, CASENO, used to define the number of cases to be analyzed during the run, and the remaining one used for each case to describe all run conditions, geometry, and constraints. The data deck for a run will always have as its first NAMELIST record a card of the form

\$CASENO NCASES = 5\$

to describe the number of cases to be analyzed (here set to "5" for illustration). Following this card will be NCASES groups of cards, each group having a first card starting "\$INPUT..." and a last card ending with a "\$" following the last data value defined.

The parameters which must be defined in the case description block named "INPUT" are:

(Title)

CASE	Real number in format XXX.XX to be displayed for titling purposes on output as case number
------	--

(Run option descriptions)

NPASS	The number of passes which the starting wave is to be propagated (no upper limit)
IFILE	The FORTRAN file code on which all normal output will appear (normally = 6)
IRCODE	FORTTRAN file code for restarting a previous run, if >0 (must match the file code assigned to a magnetic tape on a system control card)
IRTAG	Pass number from which restart information is desired from file code IRCODE, if IRCODE > 0
IROUT	FORTTRAN file code for generating a tape for later restart or far field analysis, if >0 (must match the file code assigned to a magnetic tape on a system control card)

(Cavity description)

NX	Number of propagating field points (see Section I-G and II-B-1)
XWIDTH	Minimum spatial extent in x of the beam (see Fig. 4), L^*
NZ	Number of propagation steps to be taken between mirrors (see Section I-G and II-B-1)
ZLEN	Distance between mirrors, L
XCENTR	Relative location along x of mirror axis centerline, L
ASR	Pseudo-three-dimensional parameter (see Section I-D-1)

*Unit of length is arbitrary but must be consistent for a data case.

(Medium description)

ZMDLOC Location of the center of the medium
relative to the output mirror, L (see
Fig. 2)

ZLENMD Length of the medium, L (see Fig. 2)

(Gain routine description)

IGSKIP Skip parameter for call to GAINA, where
IGSKIP = 3 would call the gain routine
every third propagation step (see Sec-
tion I-G)

GZERO g_0 , the small signal gain used by
GAINA, L^{-1}

XIZERO I_0 , the saturation flux density used by
GAINA, watts/ L^2

(Input wave description)

NWAVES The number of propagating waves

XLAMDA λ , or wavelength for each wave; array of
NWAVES, L

AMPINT Initial amplitude for each wave (see Sec-
tion I-G); array of NWAVES, (watts) $^{1/2}/L$

WOMEGA ω for each gaussian input wave, if > 0 (see
Section I-G); array of NWAVES, L

(Mirror descriptions)

DIA1 Diameter of output mirror, L

DIA2 Diameter of back mirror, L

REFL1 Power reflectivity of output mirror*

REFL2 Power reflectivity of back mirror*

RCURV1 Radius of curvature of output mirror, L

RCURV2 Radius of curvature of back mirror, L

*Fraction with values between 0 and 1.

OMEGA1	1/e truncation distance for output mirror edges (see Section I-G), L
OMEGA2	1/e truncation distance for back mirror edges (see Section I-G), L
TILT1	Tilt angle of output mirror, radians
TILT2	Tilt angle of back mirror, radians
TLOSS1	Power loss of output mirror*
(Output option selection)	
INFOUT	Near field print options (a "zero" stored in the <i>i</i> th location of this vector will suppress the output for the matching pass number; a "one" will produce the normal output); array of NPASS

D. Restart Facility

PR51 controls the generation of a restart tape if a certain option is supplied, while RSTART controls the search of a restart tape to find and read a desired waveform if two other parameters are supplied. The user will normally not be concerned with the format of the data on the tape since the program handles the information solely on the basis of three input variables during case definition (IRCODE, IRTAG, and IROUT). Should it be necessary to know the format of the data on the restart tape, the following information should be sufficient.

The information on the restart tape is written by FORTRAN unformatted (binary) WRITE statements. The first record consists of five words regarded as titling information only. The second record consists of 20 words used for describing the quantity of information to be read from the tape. The first word of the integer array is NX, the second is NZ, and the third is IWAVE, where these variables represent the number of propagating field points in the x-direction, the number of SO matrix locations used for storage in the z-dimension,

*Fraction with values between 0 and 1.

and the number of propagating waves (NWAVES in data input section), respectively.

The remaining logical records on the tape occur in groups of three, each group representing the results of a different round-trip pass.

<u>Record</u>	<u>Information Contained</u>
1	The pass number for this set of information. (This number is searched for if a restart is requested.)
2	The near-field pattern for each propagating wave, written and read by ([U(I, J), I=1, NX], J=1, IWAVE)
3	The last-pass intensities matrix, so that propagation can be continued; written and read as ([(SO(I, J, K), I=1, NX], J=1, NZ), K=1, IWAVE)]

Groups of three logical records are read at a time in the event of a restart until the pass number read from the tape matches the restart number supplied by input variable IRTAG.

E. Gain Routine Replacement

GAINA, the gain routine provided with SSCP(ECS) is designed to be replaced with a more sophisticated routine whenever desired. A replacement of this nature will be simplest if the new routine uses the same name and calling arguments as does the present GAINA routine. If additional arguments (such as g_o and I_o in GAINA) are required, provision for their initialization can be made by including a labeled COMMON block in both PR51 and the gain subroutine and initializing the parameters by a READ statement, an initialization subroutine, or by a BLOCK DATA subprogram. Modification of the argument list required for the gain routine is not recommended since at least the P50GAI routine would have to be changed, and possibly P50MED, to assure that the arguments are passed successfully to the gain routine.

III. MACHINE UTILIZATION

The SSCP(ECS) package is written in FORTRAN IV. The program was originally written for a GE635 computer operating under the GECOS III operating system, though this manual reflects changes made allowing the program to run on a CDC 6600 computer operating with the SCOPE monitor (Version 3.4). This requires about 34K (decimal) or 103K (octal) words of memory, of which

$$\begin{aligned} &NXDIM[(NZDIM + 7)NWDIM + 12] + NWDIM(3 \cdot NGDIM + 6) \\ &+ NPDIM + NZDIM \end{aligned}$$

resides in dimensioned arrays in the main program. For the current dimensioning parameters

$$NXDIM = 101$$

$$NZDIM = 21$$

$$NWDIM = 2$$

$$NPDIM = 101$$

$$NGDIM = 1001$$

the total storage required for dimensioned variable storage is 13,000 words (decimal) or 31,300 words (octal).

Processor time depends on too many parameters and option settings to be accurately estimated, but the longest case analyzed so far consumed about two minutes on the CDC 6600 and about 15 minutes on the GE635.

REFERENCES

1. Two-Dimensional Fresnel Integral Computer Program, User's Manual, Hughes Research Laboratories, Contract No. DAAH01-73-C-0298, May 1973.
2. R. D. Richtmyer and K. W. Morton, Difference Methods for Initial-Value Problems, Interscience Publishers, second edition, 1967.
3. Chemical Laser Analyses Development Program, Two-Dimensional Fresnel Integral Laser and Mixing Program User's Guide, Vol. II, Lockheed Missile and Space Company, Contract DAAH01-73-C-0232, Technical Report RK-CR-73-2, October 1973.
4. Chemical Laser Mode Control Program, Semiannual Technical Report, Hughes Research Laboratories, Contract No. DAAH01-73-C-0290, 13 November 1972 through 12 May 1973.
5. A. E. Siegman, "Unstable Optical Resonators for Laser Applications," Proceedings IEEE, Vol 53, pp. 277-287, March 1965.

APPENDIX A

GENERAL PURPOSE OUTPUT PACKAGE (GPOP) DESCRIPTION

The GPOP package was written to eliminate the need for specialized output routines (and to eliminate the inevitable errors incurred during their development) while still retaining enough flexibility that output could be tailored to a program's needs. The routine is able to handle real or complex vectors and perform various normalization operations on the data to be displayed. Tables and/or printer plots can be specified for any vector as can a skip parameter in case the data need not be tabled in their entirety. Pages are titled and data are headed by the appropriate user-supplied column heading. Up to seven vectors of information can be handled at once. Since all such output is fully specified by providing the appropriate information in a FORTRAN subroutine CALL statement, the possibility of user error is virtually eliminated.

Usage

CALL ALLOUT (IFILE, NPTS, ISKIP, NMAT, NCHAR, LABEL,

 ITYPE₁, IOPT₁, NCHAR₁, LBL₁, AMAT₁, DUMMY₁,

.

.

.

 ITYPE_n, IOPT_n, NCHAR_n, LBL_n, AMAT_n, DUMMY_n)

where $n \equiv NMAT$ and $1 \leq n \leq 7$.

Description of Parameters

IFILE	Output file code	
NPTS	Number of points in each user vector	
ISKIP	Skip parameter for vectors (i. e. , use every ISKIP th location)	
NMAT	Number of vectors supplied to ALLOUT, ≤ 7	
NCHAR	Number of characters in title	
LABEL	Title (either an array or a Hollerith literal)	
for each vector	ITYPE _i	Matrix type (1 = real, 2 = complex) for i th vector
	IOPT _i	Output option (described below) for i th vector
	NCHAR _i	Number of characters in label for i th vector
	LBL _i	Label for i th vector (array or Hollerith literal)
	AMAT _i	Name of user matrix to be displayed
	DUMMY _i	Dummy vector supplied by user (dimensioned at least NPTS)

The IOPT_i option is a seven-digit integer which completely describes the sort of output to be produced from the corresponding vector. Each digit has a specific meaning. For the description below, assume that the integer's digits are numbered from right to left (i. e. , 7654321), and that numbers shorter than seven digits will have zeroes assumed for the leftmost digits.

Digit Number

Options

1

Value type to be taken from
vector

- 0 number is assumed
 real
- 1 real part of complex
 number
- 2 imaginary part of
 complex number
- 3 magnitude of complex
 number
- 4 intensity of complex
 number
- 5 phase (radians) of
 complex number
- 6 phase (degrees) of
 complex number

2

Option for tabular output

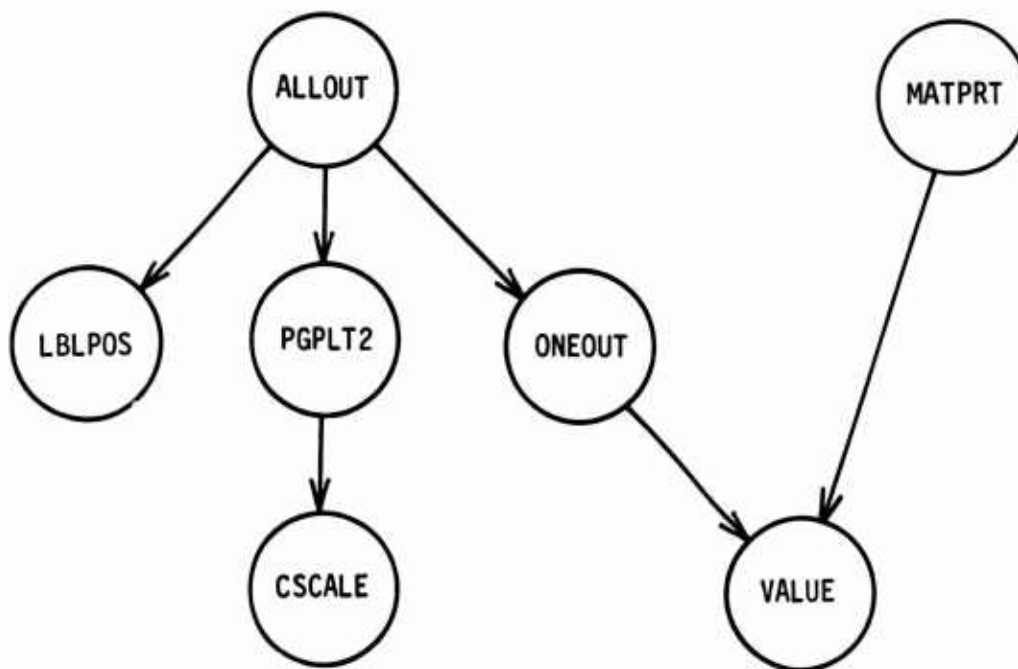
- 0 no tabular output for
 this vector
- 1 produce tabular output
 for this vector

3

Option for printer plot

- 0 no plot for this vector
- 1 plot vector versus
 AMAT₁, full page
 scaling
- 2 plot vector versus
 AMAT₁, plot scaled for
 "convenient" axis
 increments

<u>Digit Number</u>	<u>Options</u>
4	Not currently used
5	Option for normalization type 0 no normalization 1 vector normalized to one by division 2 vector normalized to zero by subtraction
6	Option for position of normalization 0 no normalization 1 center point is normalized to zero or one 2 highest value point normalized to zero or one 3 lowest value point normalized to zero or one
7	Option for normalized area plot 0 produce vector itself 1 use vector to produce normalized area plot



ALLOUT	main routine of the GPOP set; produces a complete set of listings and/or plots when referenced by a CALL statement
ONEOUT	prepares one vector to be listed and/or plotted; called once for every vector supplied to ALLOUT
VALUE	computes the value for one location in the vector to be listed and/or plotted; called for each location of every vector handled by ONEOUT
LBLPOS	positions alphanumeric column heading above each vector to be listed
PGPLT2	produces line printer plot
CSCALE	scales axes for PGPLT2

Fig. A1. GPOP subprogram references.

APPENDIX B

FAR FIELD PROGRAM DESCRIPTION

I. SYSTEM DESCRIPTION

A. Introduction

The purpose of the FAR FIELD PROGRAM (FFP) is to determine the far-field intensity distribution of the laser output beam, the total far-field power, and the incoherent average of the near- and far-field intensity distributions (averaging is only necessary if the laser is operating multimode).

The method used to determine the far-field intensity distribution is to take the near-field distribution that is transmitted by the output mirror and multiply each field point by a phase correction factor $\exp(i K_0 (x - x_c)^2 / (RCURV))$, where x_c is located at mirror center. This correction factor acts as if the output beam is reflected from a spherical mirror having a radius of curvature $RCURV$. This is referred to as a far-field mirror. The far field is by definition located in the focal plane of a spherical mirror, therefore propagating the beam reflected from the far-field mirror a distance $ZLENFF = RCURV/2$, the far-field intensity distribution is obtained for the output laser beam.

Incoherent averaging is used whenever the output beam is multimode or, in other words, whenever the transverse mode does not stabilize but continues to change from pass to pass. The averaging is performed by adding the intensities, at each field point, to each successive pass through the resonator and dividing by the number of passes averaged. For multimode lasers, both the averaged near- and far-field intensity distributions will converge to a stable solution after sufficient averaging.

B. Calculation Procedure (Empty Cavity)

For two-dimensional ($ASR = 0$) far-field distributions the computational procedure is straightforward. The near field amplitude and phase for the empty cavity is obtained from the RSTART tape. This distribution is multiplied by mirror 1 (output mirror) and the resulting distribution (e. g., the portion of the beam that spills past the edges of the mirror plus the portion transmitted by mirror 1) multiplied by the far-field mirror. Finally the beam is propagated to the focal plane of the mirror by a two-dimensional Fresnel integral (see Ref. 1 for a description of the Fresnel Integral). The user must choose RCURV so that the spatial extent of the far field distribution is similar to the spatial extent of the near field. For example, if RCURV is too small, the number of sample points containing significant information will be a small percentage of the total number of sample points NX.

When $ASR \neq 0$ or in other words when pseudo three-dimensional calculations are being made, the far-field calculation procedure is similar to that described above except the two-dimensional Fresnel integral must be replaced with a three-dimensional Fresnel integral. The following propagation algorithm is used to find the far-field distribution (in a transverse plane cutting through the focal point) for a cylindrical near-field distribution in Section I-D.

$$\begin{aligned}
 U(x) = & -\frac{iK_o}{2} \sum_{j=1}^{Nx/2} |x| e^{iK_o \frac{(x^2 + (j\Delta x)^2)}{RCURV}} \left(J_o \left(\frac{K_o x j \Delta x}{ZLENFF} \right) - i H_o \left(\frac{K_o x j \Delta x}{ZLENFF} \right) \right) \\
 & \cdot U(j\Delta x) \Delta x - \frac{iK_o}{2} \sum_{j=Nx/2}^{Nx} |x| e^{iK_o \frac{(x^2 + (j\Delta x)^2)}{RCURV}} \\
 & \cdot \left(J_o \left(\frac{K_o x j \Delta x}{ZLENFF} \right) + i H_o \left(\frac{K_o x j \Delta x}{ZLENFF} \right) \right) U(j\Delta x) \Delta x , \quad (1)
 \end{aligned}$$

for $x \leq 0$,

where x is measured in the far field plane with the center located at $x = 0$, $U(j\Delta x)$ is the output beam (includes both real and imaginary terms), and H_0 is the Struve function. For $x \geq 0$, the far field distribution is found by changing the sign in front of the Struve functions.

C. Calculation Procedure (Laser Medium Included)

Since the step-by-step propagation algorithm requires that mirror edges be tapered, the phase distribution for the near field transverse mode will change significantly for small changes in x in the region of the taper (note that this rapid phase change occurs in the taper region). This change is seen as an increase in the phase curvature as $|x|$ increases. In empty cavity resonators, the amplitude of the beam in the taper region falls rapidly and therefore the small amplitude combined with a rapidly changing phase does not significantly distort the far-field distribution. However, in transverse flow lasers where the upstream portion of the resonator can have considerably higher unsaturated gain (especially in the taper region), the amplitude of the beam in the taper region may no longer be insignificant and therefore there could be significant distortion in the far field due to the taper region. To correct for this effect which is introduced because of the necessity to taper the mirror edges, there is an option in the FAR FIELD PROGRAM to take the phase of the output beam from the gain filled resonator and subtract from it the phase of the empty cavity output beam (obtained from empty cavity RSTART tape). This removes the phase curvature due to the taper region, but does not affect any phase distortion introduced by the medium.

The use of the phase subtraction is an operator option. Experience has shown that the phase curvature in the taper region for the SSCP(ECS) is considerably smaller than for the SSCP and therefore phase subtraction has not been needed when the SSCP(ECS) was used. To better understand the phase subtraction, refer to Fig. B1. Figure B1(a) shows a typical near-field phase distribution for an empty

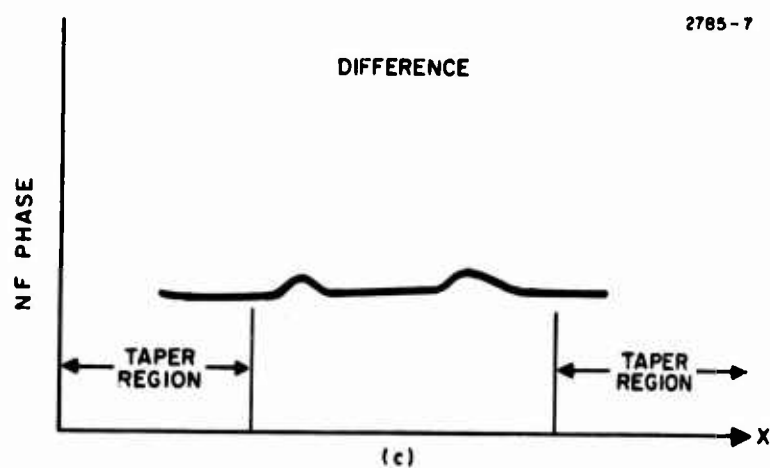
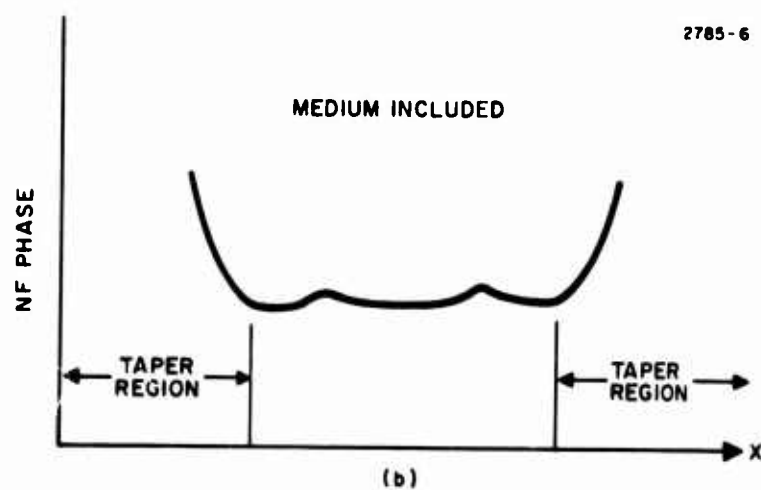
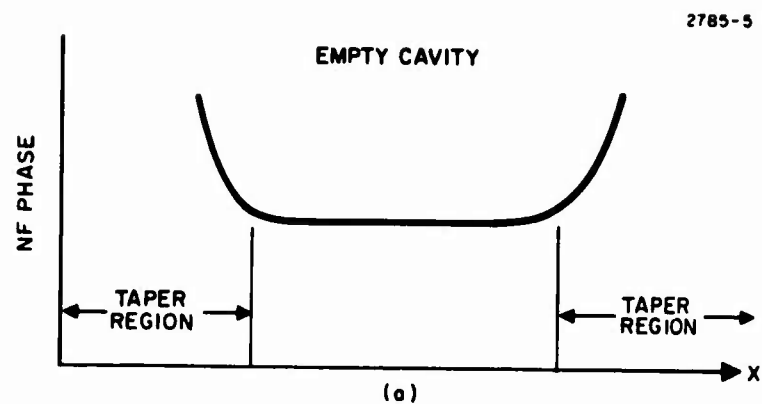


Fig. B1. Example of phase subtraction when computing far field intensity distributions in the far field program.

confocal unstable resonator. The phase is essentially flat in the center of the resonator and increases rapidly in the taper region. The phase distribution for the medium filled resonator looks essentially the same as the empty cavity distribution except for some distortion near the center. The difference in the two distributions is shown in Fig. B1(c) and is essentially flat everywhere except for the distortion caused by the medium. The far field distribution for the last two phase distributions (assuming some amplitude distribution) will be the same if the amplitude is small in the taper region. However, if the amplitude is not small in the taper region, the far-field distribution for the second phase distribution will appear distorted. Thus by using the third phase distribution, the rapidly varying phase in the taper region is eliminated.

II. PROGRAM DESCRIPTION

A. Summary of the FFP

The Far Field Program (FFP) is composed of primary, satellite, and input/output routines of the sort described earlier. The two primary routines are

FFLD	Main program, defines input, contains overall logic
FFLDAV	Propagates one or more waves to the far field; controls averaging; controls output of far field and averaging information

Four satellite routines are contained in the FFP.

PMAT30	Sets up a Fresnel integral vector for two-dimensional propagation to the far field
SETM01	Sets up the far field mirror vector
FFPRP2	Propagates a wave to the far field by three-dimensional propagation
STRUVE	Computes the Struve function by Taylor series approximation

The three input/output routines, RSTART, AREA21, and ALLOUT have been discussed in Section II-A of the SSCP(ECS) part of this manual and will not be further discussed here.

Four of the routines deserve further mention at this point.

FFLD

FFLD, the main program, controls the definition of the input near field wave prior to calling the far field/averaging routine (FFLDAV). The procedure in constructing the near field wave is to define both a "primary" and a "secondary" wave, where the latter may not be supplied for certain cases. When phase subtraction of the empty cavity waveform is desired, the secondary wave is restored

from the specified magnetic tape and the phase correction terms computed. As each primary wave is restored (from a different tape), it is phase-corrected by the secondary wave (if it has been supplied) to yield the desired near field waveform.

There is no functional difference between restart tapes generated by the SSCP and those generated by the SSCP(ECS) – both are fully compatible with the tape requirements of the FFP package. The difference has, in the past, been that an SSCP tape will also require the empty cavity secondary tape for phase subtraction while the SSCP(ECS) primary tape exhibits a sufficiently flat phase profile to not warrant the empty cavity tape. The latter situation is a significant advantage since the number of tapes should be minimized for faster job turnaround.

SETM01

The mirror setup routine, SETM01, computes three components for each location of the mirror matrix. The first is the transmission distribution. The distribution takes into account the size of the output mirror DIAL, the output mirror reflectivity REFL which is constant over the mirror surface, and the transmission loss TLOSS1 of the output mirror. This distribution when multiplied by the near field distribution taken from the RSTART tape, gives the field distribution incident on the far-field mirror. The second component, curvature, is defined as

$$\text{CURV}_i = \exp [-jK_o(x_i - x_c)^2 / \text{RCURV}], \quad i = 1, 2, \dots, \text{NX}$$

The third component, mirror tilt, is defined as

$$\text{TILT}_i = e^{j[2K_o \beta (x_i - x_c)]}, \quad i = 1, 2, \dots, \text{NX}$$

where

β = mirror tilt angle

x_c = x at the mirror center

RCURV = radius of curvature of the far-field mirror

PMAT30

PMAT30 generates the Fresnel Integral matrix by which diffraction propagation is performed. To simplify computation, the matrix is symmetrical around the $(2 \cdot NX - 1)$ point. In general, the i th value of the matrix is defined as

$$\Delta x \cdot \sqrt{\frac{1-j}{2L\lambda}} e^{jK_o [(i-1)\Delta x]^2 / 2L}$$

where

$L \equiv ZLENFF^*$, or far-field propagation distance

though the procedure in PMAT30 performs this computation in a different form than that shown.

FFLDAV

The concept of averaging is included in the FFLDAV routine along with the far-field propagation (which is straightforward). Averaging can be used independently on either the near-field or the far-field intensity distribution or both, and consists of a numerical average at each point of all the values of the intensity distribution over some set of passes.

B. Input Description

FFLD is the only routine in the FFP package requiring input to be prepared by the user. All such input is entered on data cards by the FORTRAN NAMELIST convention, with which the reader is assumed to be familiar. (A complete description can be found in the FORTRAN Reference Manual.) In general, a NAMELIST data record consists of a "\$" in column 2 of the data card followed immediately by the particular NAMELIST name for this record, followed by one or more blanks or a comma, followed by the list of variables and corresponding values (in the form of assignment statements separated by commas), and finally terminated by a "\$."

Two NAMELIST group names are used by FFLD, the first, CASENO, used to define the number of cases to be analyzed during the run, and the remaining one used for each case to describe all run conditions, geometry, and constraints. The data deck for a run will always have as its first NAMELIST record a card of the form

\$CASENO NCASES = 5\$

to describe the number of cases to be analyzed (here set to "5" for illustration).

Following this card will be NCASES groups of cards, each group having a first card starting "\$INITL. . ." and a last card ending with a "\$" following the last data value defined.

The parameters which must be defined in the case description block named "INITL" are:

ASR	Pseudo-three-dimensional parameter (see Section I-B in this appendix)
IPSTRT	Pass number at which to initially restore the primary wave (≥ 0)
IPFIN	Last desired pass for which a near field wave is to be constructed ($\leq$ NPASS of run generating tape)
ISTAG	The pass number of the wave to be design- ated the secondary wave ($\leq$ NPASS of run generating tape)
IPCODE	Primary wave's file code, > 0
ISCODE	Secondary wave's file code, if > 0
IFILE	The FORTRAN file code on which all normal output will appear (normally = 6), > 0
NWAVES	The number of waves to be taken from tape ($\leq$ NWDIM in FFLD)

ZLENFF	The far field propagation distance (normally half the far field radius of curvature)
RCURV	The far field radius of curvature (see Section I-B in this appendix)
XK0	The wave number ($2\pi/\lambda$) for each wave; array of NWAVES, L^{-1}
DX	The spacing between field points
NX	The number of field points ($\leq$ NXDIM in FFLD)
TLOSS	The power loss of the output mirror*
REFL	The power reflectivity of the output mirror*
BETA	Tilt angle of far field mirror, radians
DIA1	Diameter of output mirror, L^{**}
DIA2	Diameter of back mirror, L
VR2	Virtual source distance for the back mirror; (set to 1.E30 if SSCP(ECS) not used)
ZLEN	Distance between cavity mirrors, L
INFOUT	Near field print options; array of IPFIN (≤ 101)
	0 stored in the i^{th} location of this vector will suppress the near field output for the matching primary pass number
	1 stored in the i^{th} location of this vector will produce full near field output for the matching primary pass number

*Decimal percent between 0 and 1

**Units are arbitrary but must be consistent for a case.

IFFOPT

Far field propagation and near/far field averaging switch, where the i^{th} location in IFFOPT controls the matching primary pass number

- 0 Do not propagate to FF; do not average NF or FF
- 1 Propagate to FF; do not average NF or FF
- 2 Do not propagate to FF; average NF only
- 3 Propagate to FF; average NF only
- 4 Propagate to FF; average FF only
- 5 Propagate to FF; average both NF and FF

IFFOUT

Far field averaging output options, where the i^{th} location in IFFOUT controls the output for the matching primary pass number

- 0 Print neither set of results
- 1 Print FF results only
- 2 Print averaging results only
- 3 Print both FF and averaging results

C. Flowcharts and Listings

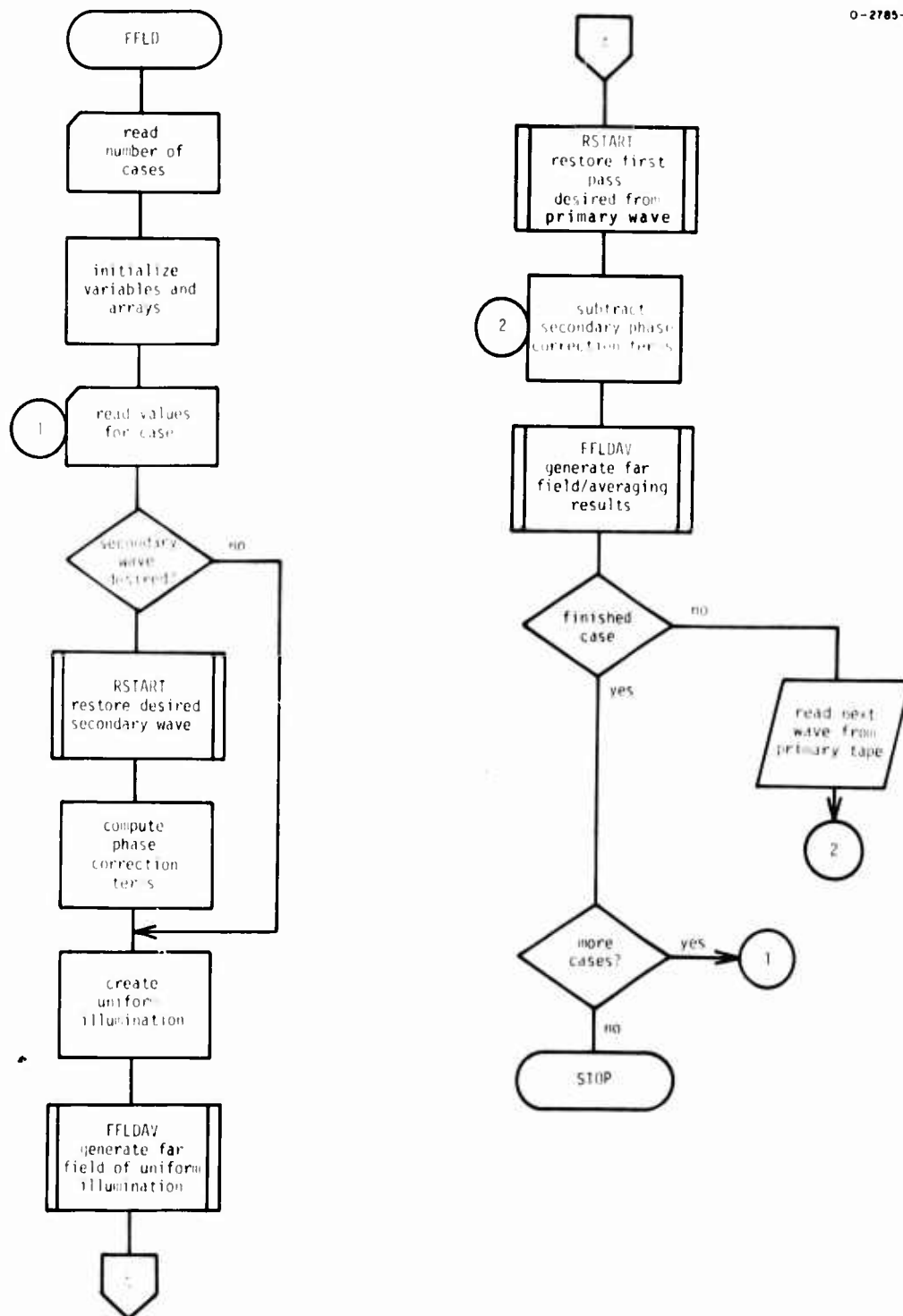


Fig. B2. FFLD logic flow diagram.

```

PROGRAM FFLD(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE10,TAPE11,
+ TAPE12)
C
C COMPLEX T(301,2),U(301,2),V(301,2),PHATFF(601),XMIR(301)
C
C DIMENSION INFOUT(101),IFFOPT(101),IFFOUT(101),STOTN=(301,2),
+ STOTFF(301,2),SO(301,2),XK0(2),XK0(2),SPHASE(301,2),K(301)
C
C COMMON /OT1/OUT1(301),OT2/OUT2(301),OT3/OUT3(301)
+ /OT4/OUT4(301),OT5/OUT5(301),OT6/OUT6(301),OT7/OUT7(301)
C COMMON /FFNZ/ NZ
C
C NAMELIST /CASENO/MCASES
C NAMELIST /INITL/ASR,IPSTRI,IPFIN,ISTAG,NWAVES,IPCODE,
+ ISCODE,IFILE,ZLENFF,XK0,DX,NK,INFOUT,IFFOPT,IFFOUT,
+ FLOSS,REFL,RCURV,BETA,DIAL,DIA2,VR2,ZLEN
C
C DATA NXDIM,NZDIM,NWDIM/301,21,2/
C
C BEGIN RUN
C
C READ(5,CASENO)
C DO 900 ICASE=1,NCASES
C
C INITIALIZE NECESSARY VARIABLES AND ARRAYS
C
C TOTMF=0.
C TOTFF=0.
C DO 30 I=1,101
C INFOUT(I)=0
C IFFOPT(I)=0
C IFFOUT(I)=0
C
C 30
C
C INITIALIZE INPUT VALUES FOR CASE
C
C READ(5,INITL)
C DO 20 JMAVE=1,NWAVES
C DO 20 I=1,NK
C STOTMF(I,JMAVE)=0.
C STOTFF(I,JMAVE)=0.
C CONTINUE
C
C 20
C
C NXC=DIAL/DX
C WRITE(5,INITL)
C IF(ASR.LE.0.) CALL PHAT30(NK,DX,ZLENFF,XK0,PHATFF)
C CALL SETM01(NK,NXC,XK0,0.,FLOSS,REFL,RCURV,BETA,DX,XMIR)
C
C PRINT INITIAL VALUES FOR MIRROR
C
C DO 45 I=1,NK
C X(I)=FLOAT(I-(NK+1)/2)*DX
C CALL ALLOUT(5,FILE,NK,1,3,10,10,MIRROR DESCRIPTION,
+ 1,10,1,INX,X,OUT1,
+ 2,116,9,9,INTENSITY,XMIR,OUT2,
+ 2,116,10,10,PHASE (DG),XMIR,OUT3)
C
C 45
C
C COMPUTE PHASE CORRECTION TERMS, IF REQUIRED
C
C 55
C

```



```

60      IF (ISCODE.GT.0) CALL RSTART(IFILE,ISCODE,ISTAG,NMAVES,
      *   NXDIM,NZDIM,U,S0)
      DO 75 JMAVE=1,NMAVES
      DO 50 I=1,NK
      SPHASE(I,JMAVE)=0.
      50      IF (ISCODE.GT.0 .AND. REAL(U(I,JMAVE)).NE.0. .AND.
      *   AIMAG(U(I,JMAVE)).NE.0.)
      *   SPHASE(I,JMAVE)=-ATAN2(AIMAG(U(I,JMAVE)),REAL(U(I,JMAVE)))
      65      IF (ISCODE.GT.0 .AND. NMAVES.GT.1) WRITE(IFILE,9010)JMAVE
      75      IF (ISCODE.GT.0) CALL ALLOUT(IFILE,NK,1,4,14,1+HSECONDARY WAVE,
      *   1,10,1,1HX,X,OUT1,
      *   2,114,9,9HINTENSITY,U(1,JMAVE),OUT2,
      *   2,115,11,11HMPHASE (RAD),U(1,JMAVE),OUT3,
      *   1,110,16,16HMPHASE CORRECTION,SPHASE(I,JMAVE),OUT4)
      C
      C   CREATE INITIAL WAVEFORM FOR UNIFORM ILLUMINATION
      C
      IF (VR2.GE.(1.E30)) DMAX=0IA2
      IF (VR2.LI.(1.E30)) DMAX=(VR2+ZLEN)*DIA2/VR2
      IPTAG=0
      DO 90 I=1,NK
      U(I,1)=0.
      80      IF (ABS(X(I)).LE.(DMAX/2.)) U(I,1)=1.
      CONTINUE
      GO TO 200
      C
      C   RESTORE PRIMARY WAVE
      C
      85      IPTAG=MAX0(IPTAG,1)
      CALL RSTART(IFILE,IPCODE,IPTAG,NMAVES,NXDIM,NZDIM,U,S0)
      C
      C   SUBTRACT SECONDARY WAVE PHASE CORRECTION
      C
      90      CONTINUE
      IF (IPTAG.LE.0) GO TO 200
      DO 150 JMAVE=1,NMAVES
      DO 150 I=1,NK
      95      U(I,JMAVE)=U(I,JMAVE)+CMPLX(COS(SPHASE(I,JMAVE)),SIN(
      *   SPHASE(I,JMAVE)))
      200      WRITE(IFILE,9000)IPTAG
      C
      C   PRINT INITIAL WAVE(S), IF DESIRED
      C
      100      IF (IPTAG.GT.0 .AND. INFOUT(IPTAG).LE.0) GO TO 500
      DO 300 JMAVE=1,NMAVES
      IF (IPTAG.LE.0 .AND. JMAVE.GT.1) GO TO 300
      IF (NMAVES.GT.1) WRITE(IFILE,9010) JMAVE
      CALL ALLOUT(IFILE,NK,1,3,15,15HNEAR FIELD WAVE,
      *   1,10,1,1HX,X,OUT1,
      *   2,114,9,9HINTENSITY,U(1,JMAVE),OUT2,
      *   2,116,10,10HMPHASE (DG),U(1,JMAVE),OUT3)
      300      CONTINUE
      500      CONTINUE
      C
      C   CALL FAR FIELD/AVERAGING SUBROUTINE
      C
      C   IOPT=1

```

```

115      IOUT=1
      NMS=1
      IF(IPTAG.GT.0) IOPT=IFFOPT(IPTAG)
      IF(IPTAG.GT.0) IOUT=IFFOUT(IPTAG)
      IF(IPTAG.GT.0) NMS=NMAVES
      CALL FFLDAV(IFILE,IOP,T,IOUT,NX,NXDIM,NMS,
      * ASR,ZLENF,TOTNF,TOTFF,KK0,DX,T,U,V,
      * XMIR,PHATFF,STOTNF,STOTFF)
      IF(IPTAG.GE.IPFIN) GO TO 800
      C
      C      IF DESIRED, RESTORE NEXT PRIMARY WAVE AND LOOP BACK
      C
      IF(IPTAG.LE.0) GO TO 95
      READ(IPCODE) ITAG
      READ(IPCODE) ((U(I,J),I=1,NX),J=1,NMAVES)
      READ(IPCODE) ((SO(I,J,K),I=1,NX),J=1,NZ),K=1,NMAVES)
      IPTAG=IPTAG+1
      GO TO 100
      C
      C      CASE ENDED
      C
      800 REMIND IPCODE
      IF(ISCODE.GT.0) REMIND ISCODE
      900 CONTINUE
      STOP
      9000 FORMAT(11M1,13HSTARTING PASS,IS)
      9010 FORMAT(11M1,11H WAVE NUMBER,IS)
      END
11704
11706
11708
11820
11840
11868
11880
11900
11920
11930
11940
11960
11980
11990
12000
12020
12040
12060
12070
12071
12080
12100
12110
12120
12120
12140

```

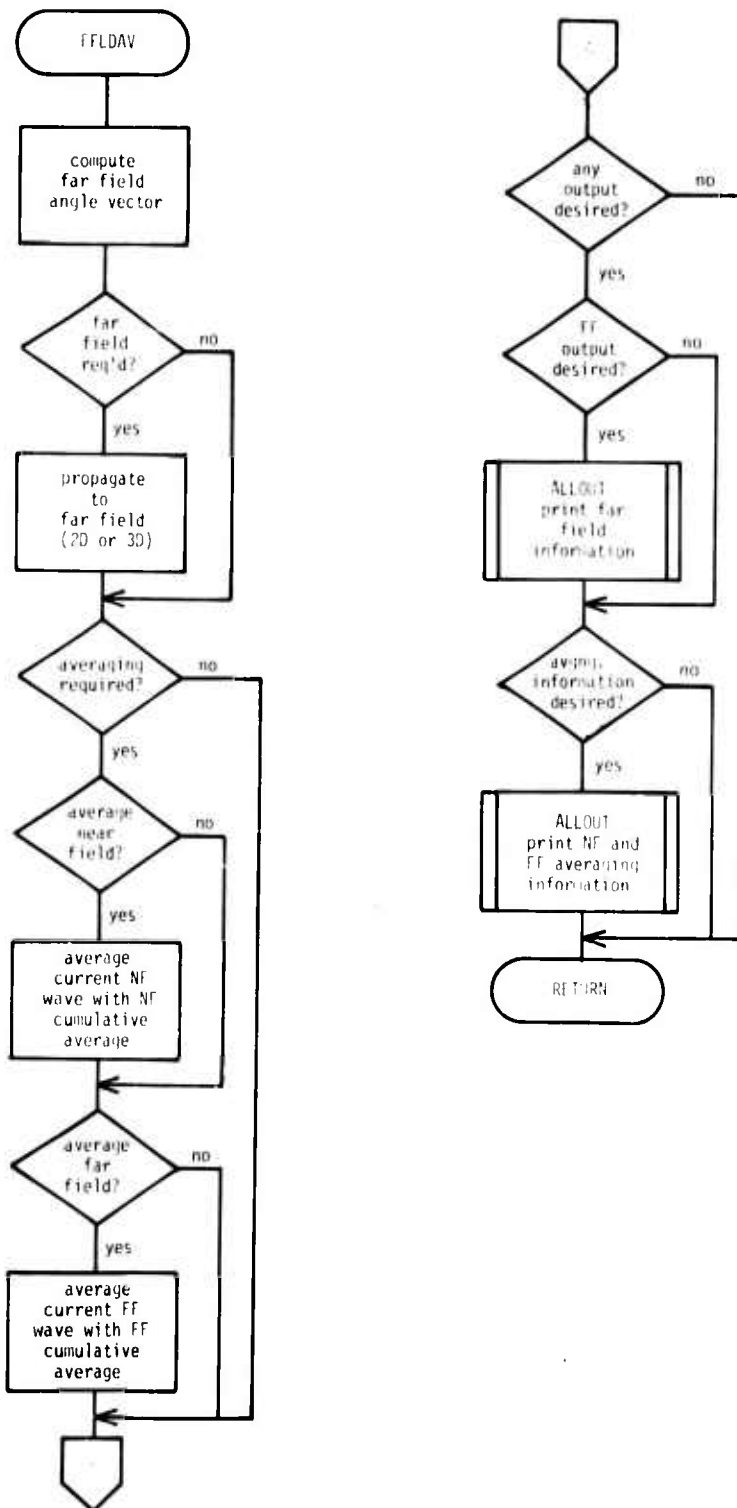


Fig. B3. FFLDAV logic flow diagram.

```

SUBROUTINE FFLDVA(IFILE,IFFOPT,IFFOUT,NX,NKDIM,
+  NWAVER,ASR,ZLENFF,TOTNF,TOTFF,XK0,DX,T,U,V,XMIRFF,PMATFF,
+  STOTNF,STOTFF)
  COMPLEX U(NKDIM,NWAVES),V(NKDIM,NWAVES),XMIRFF(NX),PMATFF(1),A
  COMPLEX T(NKDIM,NWAVES)
  DIMENSION XK0(NWAVES),STOTNF(NKDIM,NWAVES),STOTFF(NKDIM,NWAVES)
  COMMON /OT1/OUT1(1)/OT2/OUT2(1)/OT3/OUT3(1)/OT4/OUT4(1)
  COMMON /OT5/OUT5(1)/OT6/OUT6(1)/OT7/OUT7(1)
  XINTY(A)=REAL(A)**2+AIMAG(A)**2
  10 C
  C-----
  C FFLDVA FAR FIELD PROPAGATION, NF AND FF PROP AND AVERAGING,
  C FAR FIELD AND AVERAGING OUTPUT
  C-----
  15 C THE PARAMETERS ARE
  C-----
  C IFILE OUTPUT FILE CODE
  C IFFOPT FF PROP AND NF/FF AVERAGING OPTION
  C .LE. 0 DON'T PROP, DON'T AVERAGE
  C .EQ. 1 PROP, DON'T AVERAGE
  C .EQ. 2 DON'T PROP, AVERAGE NF ONLY
  C .EQ. 3 PROP, AVERAGE NF ONLY
  C .EQ. 4 PROP, AVERAGE FF ONLY
  C .EQ. 5 PROP, AVERAGE BOTH NF AND FF
  C IFFOUT FAR FIELD/AVERAGING OUTPUT OPTION
  C .EQ. 0 DON'T PRINT
  C .EQ. 1 PRINT ONLY FF INFORMATION
  C .EQ. 2 PRINT ONLY AVERAGING INFORMATION
  C .EQ. 3 PRINT BOTH FF AND AVERAGING INFORMATION
  C NX THE NUMBER OF PROPAGATING POINTS
  C NKDIM THE X-DIMENSION OF THE PRINCIPAL MATRICES
  C NWAVER THE NUMBER OF PROPAGATING WAVES
  C ASR 3D PROPAGATION SWITCH
  C ZLENFF THE FAR FIELD PROPAGATION DISTANCE
  C TOTNF THE CURRENT NUMBER OF NF AVERAGES TAKEN
  C TOTFF THE CURRENT NUMBER OF FF AVERAGES TAKEN
  C XK0 K=2*PI/LAMBDA, FOR EACH WAVE
  C DX DELTA-X
  C T A DUMMY MATRIX
  C U THE NF PROPAGATION MATRIX (SUPP.)
  C V A DUMMY MATRIX--RETURNS FF VALUES (RET.)
  C XMIRFF FF MIRROR VECTOR (SUPP.)
  C PMATFF FF FRESNEL PROPAGATION VECTOR (SUPP.)
  C STOTNF NF AVERAGED INTENSITY MATRIX (SUPP./RET.)
  C STOTFF FF AVERAGED INTENSITY MATRIX (SUPP./RET.)
  C
  C COMMON REQUIRED--OT1 THROUGH OT7 FOR OUTPUT PURPOSES
  C
  C SUBPROGRAMS REQUIRED--ALLOUT,AREA21,FFPRP2
  C
  C CREATED 4/10/73
  C CHANGED 4/18/73 (POWER OUTPUT ADDED)
  C CHANGED 9/6/73 3D OPTION ADDED
  C CHANGED 9/19/73 (ALL WAVES AVERAGED TOGETHER INCOMEENTLY)
  C-----
  55 C
  C
  12160
  12180
  12200
  12220
  12240
  12260
  12280
  12300
  12320
  12340
  12360
  12380
  12400
  12420
  12440
  12460
  12480
  12500
  12520
  12540
  12560
  12580
  12600
  12620
  12640
  12660
  12680
  12700
  12720
  12740
  12760
  12780
  12800
  12820
  12840
  12860
  12880
  12900
  12920
  12940
  12960
  12980
  13000
  13020
  13040
  13060
  13080
  13100
  13120
  13140
  13160
  13180
  13190
  13200
  13220
  13240

```

```

60      C      COMPUTE FAR FIELD ANGLE, IN MILLIRADIANS
      C
      NCENT=(NX+1)/2
      DO 1000 I=1,NX
      1000  OUT1(I)=FLOAT(I-NCENT)*DX/ZLENFF*1000.
      IF(IFFOPT.LE.0 .OR. IFFOPT.EQ.2) GO TO 3000

65      C      PROPAGATE TO FAR FIELD
      C
      C
      IF(ASR.GT.0.) GO TO 2500
      C-----2D FAR FIELD-----
      DO 2000 I=1,MWAVES
      DO 2000 J=1,NX
      V(J,I)=0.
      DO 2000 K=1,NX
      L=NX-J+K
      V(J,I)=V(J,I)+U(K,I)*XMIRFF(K)*PMATFF(L)
      2000  CONTINUE
      C-----3D FAR FIELD-----
      2500  DO 2700 J=1,MWAVES
      DO 2700 I=1,NX
      2700  T(I,J)=U(I,J)*XMIRFF(I)
      CALL FFRP2(NX,ZLENFF,DX,XK0,T,V)

80      C      ENSEMBLE AVERAGING, IF DESIRED
      C
      C
      3000  IF(IFFOPT.LE.1) GO TO 5000
      IF(IFFOPT.NE.4) TOTNF=TOTNF+1.
      IF(IFFOPT.GE.4) TOTFF=TOTFF+1.
      DO 4000 J=1,NX
      XTEMPU=0.
      XTEMPV=0.
      DO 3500 I=1,MWAVES
      XTEMPU=XTEMPU+XINTY(U(J,I))
      XTEMPV=XTEMPV+XINTY(V(J,I))
      3500  IF(IFFOPT.NE.4)
      * STOTNF(J,1)=(XTEMPU+STOTNF(J,1)*(TOTNF-1.))/TOTNF
      * STOTFF(J,1)=(XTEMPV+STOTFF(J,1)*(TOTFF-1.))/TOTFF
      4000  CONTINUE

90      C      OUTPUT, IF DESIRED
      C
      C
      5000  IF(IFFOUT.LE.0) GO TO 9999
      IF(IFFOUT.EQ.2) GO TO 7000
      C-----FAR FIELD PRINTOUT-----
      DO 6000 I=1,MWAVES
      IF(MWAVES.GT.1) WRITE(1,9020) I, IMAVE
      CALL ALLOUT(1,1,7,17,17,MFAR FIELD RESULTS ,
      * 1,10,12,12,THETA (MRAD) ,OUT1,OUT1,
      * 2,11,9,9,MAGNITUDE ,V(1,IMAVE),OUT2,
      * 2,11,9,9,INTENSITY ,V(1,IMAVE),OUT3,
      * 2,20,21,10,10,NORM. MAG. ,V(1,IMAVE),OUT4,
      * 2,20,21,10,10,NORM. INT. ,V(1,IMAVE),OUT5,
      * 2,11,0,21,11,11,NORM. PHASE ,V(1,IMAVE),OUT6,
      * 2,11,0,21,10,10,NORM. AREA ,V(1,IMAVE),OUT7)
      6000  IMAVE=1,MWAVES
      9999  CONTINUE
      7000  CONTINUE
      9020  CONTINUE

```

70

```

5      SUBROUTINE PMAT30(NX,DX,ZLEN,KX0,PMAT)
        COMPLEX PMAT(1)
        DATA PI/3.14159265/

10     C-----
        C PMAT30 FRESNEL PROPAGATION MATRIX GENERATOR (FOX AND LI
        C APPROXIMATION) FOR PR30 ROUTINES
        C-----
        C THE PARAMETERS ARE
        C
        C NX      THE NUMBER OF POINTS TO BE PROPAGATED
        C DX      DELTA X FOR PROPAGATION MATRIX
        C ZLEN    PROPAGATION LENGTH
        C KX0     WAVE NUMBER ( K = 2*PI/LAMBDA)
        C PMAT    PROPAGATION MATRIX TO BE FORMED (DIM. 2*NX-1)
        C
        C NO SUBPROGRAMS REQUIRED
        C
        C CREATED 2-5-73
        C-----
        C---DEFINE MULTIPLIER CONSTANTS (T1 AND T2)---
        T1=DX*SQRT(KX0/(PI*ZLEN))/2.
        T2=KX0*DX*DX/(12.*ZLEN)
        C---DEFINE PROPAGATION MATRIX---
        DO 100 I=1,NX
            T6=FLOAT((I-1)*(I-1))*T2
            T7=COS(T6)
            T8=SIN(T6)
            J1=NX+1-I
            J2=NX+I-1
            PMAT(J1)=T1*CMPLX(T7+T8,T8-T7)
            PMAT(J2)=PMAT(J1)
        100 RETURN
        END

```

```

5      SUBROUTINE FFPRP2(NN,XLEN,DR,XK0,U,V)
        COMPLEX U(1),COEF1,COEF2,V1,V2,COEF3,V(1),VC
        IC=(NN+1)/2
        JC=(NN-1)/2
        COEF1=-XK0/(2.*XLEN)*DR*(0.,1.)
        DO 100 JJ=1,JC
          J1=IC-JJ
          J2=IC+JJ
          R=DR*FLOAT(JJ)
          COEF2=CEXP((0.,1.)*XK0*R*R/(2.*XLEN))
          V1=U(I1C)
          V2=U(I1C)
          DO 50 II=1,JC
            I1=IC-II
            I2=IC+II
            RPRIME=DR*FLOAT(II)
            COEF3=RPRIIME*CEXP((0.,1.)*XK0*RPRIME*RPRIIME/(2.*XLEN))
            ARG=XK0*R*RPRIIME/XLEN
            CALL BESJ(ARG,0,TERMJ,1,E-4,IER)
            TERMN=STRUVE(ARG)
            V1=V1*(U(I1))*(TERMJ-(0.,1.)*TERMH)
            * +U(I2)*(TERMJ+(0.,1.)*TERMH))*COEF3
          V2=V2*(U(I1))*(TERMJ-(0.,1.)*TERMH)
            * +U(I2)*(TERMJ+(0.,1.)*TERMH))*COEF3
          V(J1)=COEF1*COEF2*V1
          V(J2)=COEF1*COEF2*V2
          VC=U(I1C)
          DO 300 II=1,JC
            RPRIME=DR*FLOAT(II)
            COEF3=RPRIIME*CEXP((0.,1.)*XK0*RPRIME*RPRIIME/(2.*XLEN))
            I1=IC-II
            I2=IC+II
            VC=VC*(U(I1)+U(I2))*COEF3
          V(I1C)=VC*COEF1
        RETURN
      END
35
15600
15700
15740
15780
15800
15820
15840
15860
15880
15900
15920
15940
15960
15980
16000
16020
16040
16060
16100
16120
16140
16160
16180
16200
16220
16240
16260
16280
16300
16320
16340
16360
16380
16400
16420
16440
16460

```


FUNCTION STRUVE 74/74 OPT=1 FTM 4.0+PI57 09/27/73 14.43.51. PAGE 1

```

5      FUNCTION STRUVE(Z)
        RATIO=1./Z
        STRUVE=0.
        DO 100 I=1,1000.2
          RATIO=RATIO*Z**2/FLOAT(I*I)
          TERM=(1.-I)**((I+1)/2+1)*RATIO
          STRUVE=STRUVE+TERM
          IF (ABS(TERM).LT.(1.E-8)) GO TO 500
        100 CONTINUE
        WRITE(6,1000)
        1000 FORMAT(1H0,33HSTRUVE FUNCTION DOES NOT CONVERGE)
        RETURN
        500 STRUVE=STRUVE*.63661977
        RETURN
        END
15
16480
16500
16520
16540
16560
16580
16600
16620
16640
16660
16680
16700
16720
16740
16760
16780

```

```

SUBROUTINE SETM01(NX,NXC,XK0,OMEGA,TLOSS,REFL,RCURV,BETA,DX,XM)
  COMPLEX XM(NX),CURV,TILT
  C-----
  C SETM01 SETS UP A MIRROR VECTOR
  C-----
  C THE PARAMETERS ARE
  C NX THE NUMBER OF POINTS TO BE SET UP
  C NXC THE NUMBER OF INTERVALS ACROSS THE MIRROR CENTER
  C .LT. 0 FAR FIELD MIRROR ASSUMED
  C .GT. 0 NEAR FIELD MIRROR ASSUMED
  C XK0 K = 2 PI / LAMBDA
  C OMEGA M.F. MIRROR EDGE FALLOFF PARAMETER
  C TLOSS F.F. MIRROR LOSS (POWER)
  C REFL MIRROR REFLECTIVITY (POWER)
  C RCURV MIRROR RADIUS OF CURVATURE
  C BETA MIRROR TILT ANGLE
  C DX DELTA-X
  C XM MIRROR VECTOR (COMPLEX, DIM. AT LST NX)
  C-----
  C SUBPROGRAMS REQUIRED--NONE
  C-----
  C CREATED 4-3-73 FROM SETMIR (PR20 ROUTINE)
  C CHANGED 4-9-73 (MIRROR EDGES REDEFINED, END POINTS ADDED)
  C CHANGED 9/6/73 DX USED INSTEAD OF X-ARRAY
  C-----
  ICENT=(NX+1)/2
  NXCP1=ICENT-(IABS(NXC)+1)/2
  NXCP2=ICENT+(IABS(NXC)+1)/2
  C-----
  C DEFINE MIRROR VALUE FOR EACH MATRIX LOCATION
  C-----
  DO 140 J=1,NX
    IF(RCURV.EQ.(1.E30)) CURV=1.
    IF(RCURV.LT.(1.E30)) CURV=
      + CEXP(1-NXC*(FLOAT(J-ICENT)*DX)**2*(0.,1.)/RCURV)
    C-----
    TILT=CEXP(12.*XK0*BETA*(FLOAT(J-ICENT)*DX)*(0.,1.))
    C-----
    DETERMINE NEAR FIELD MIRROR REFLECTIVITY COMPONENT-----
    IF(NXC.LT.0) GO TO 100
    RFLEC=0.
    IF(J.GE.NXCP1.AND.J.LE.NXCP2) RFLEC=1.
    IF(OMEGA.EQ.0. .AND. J.LT.NXCP1) RFLEC=
      + EXP(-(FLOAT(NXCP1-J)*DX/OMEGA)**2)
    IF(OMEGA.EQ.0. .AND. J.GT.NXCP2) RFLEC=
      + EXP(-(FLOAT(J-NXCP2)*DX/OMEGA)**2)
    RFLEC=SQRT(REFL)*RFLEC
    GO TO 130
  C-----
  DETERMINE FAR FIELD MIRROR REFLECTIVITY COMPONENT-----
  100 IF(J.LT.NXCP1 .OR. J.GT.NXCP2) RFLEC=1.
    IF(J.GE.NXCP1 .AND. J.LE.NXCP2) RFLEC=
      + SQRT(1.-REFL)*SQRT(1.-TLOSS)
  C-----
  COMPUTE MIRROR VECTOR VALUE-----
  130 XM(J)=RFLEC*CURV*TILT
  140 CONTINUE

```

SUBROUTINE SETM01 74/74 OPT=1 FTM 4.0+P357 09/27/73 14.43.55. PAGE 2

```

60      C-----REDEFINE MIRROR END POINTS TO HALF THEIR VALUE-----
          IF (MXC.GT.0) XM(MXCPI)=XM(MXCPI)/2.
          IF (MXC.GT.0) XM(MXCPI)=XM(MXCPI)/2.
          RETURN
          END
          17948
          17968
          17982
          18000
          18020

```

D. Sample Case for FFP

The case described by the input below is a far-field analysis of the waveforms computed during the sample case "8.45" described in Appendix D. A magnetic tape was generated and saved by that program and will be used for input to the FFP. The user is assumed to be familiar with the conventions adopted by his own computer center when referencing a previously saved magnetic tape.

The far-field analysis is to be two-dimensional ($ASR = 0.$) adhering to the same mode of analysis used in the SSCP(ECS) sample case 8.45. The tape is to be read from its beginning, rather than some intermediate pass number, and is to read no further than the 7th pass. One wave is to be taken from the tape at each pass (the tape could contain more waves). The file code for the primary wave is logical file code 10 (the user is assumed to have previously informed the computer system that file code 10 is to be associated with the SSCP restart tape). There is no secondary, or empty cavity, tape to furnish phase terms for subtraction from the primary waveforms. The file code for normal program output is logical file code 6. The far-field propagation distance is to be 6×10^4 cm. The wave number (XK0) can be found in the fifth NAMELIST group (WAVES) at the beginning of the normal output of the SSCP(ECS) for case 8.45 following the vector name XKZERO. The Δx mesh spacing can similarly be found in the second NAMELIST block (CAVITY) following the term DXOUT. The number of mesh points along the x direction is known (from the input to 8.45) to be 81. The first seven passes read from the restart tape are to have their near field values printed, to be propagated to the far field, and to have the far field values printed. No averaging is to be performed. The output mirror of the 8.45 cavity is 100% reflecting (the loss has no meaning in this instance since no light energy passes through the mirror). The radius of curvature of the far field mirror is twice the propagation length above, or 12×10^4 cm. The far-field mirror is not tilted. The diameters of the output mirror and back

mirror for the 8.45 cavity are 5.74 cm and 11.1 cm, respectively. The virtual radius of the back mirror is found in the second, or CAVITY, NAMELIST group of case 8.45 after the term VR2. The distance between mirrors in the cavity is 10,000 cm.

Sample Input Deck

(column 2)

↓
\$CASENO NCASES=1\$
\$INITL
ASR=0., IPSTRT=0, IPFIN=7, NWAVES=1,
IPCODE=10, ISCODE=0, ISTAG=0,
IFILE=6, ZLENFF=6. E4, XK0(1)=20944.,
DX=.225, NX=81,
INFOUT(1)=7*1, IFFOPT(1)=7*1, IFFOUT(1)=7*1,
TLOSS=0., REFL=1., RCURV=1.2E5, BETA=0.,
DIA1=5.74, DIA2=11.1, VR2=1. E30,
ZLEN=10000.\$

The output produced by the FFP consists of four major groups. The first is not optional and includes the following:

1. Repetition of the input data
2. Description of the far-field mirror matrix (intensity and phase listings and plots)
3. Restart summary of titling information contained on the secondary tape, followed by a listing and plot of the phase correction information (appears only if a secondary wave, or empty cavity, tape is used)
4. Description of the "ideal" uniformly illuminated aperture for this cavity configuration
5. Far field summary of the wave in 4.
6. Restart summary of titling information contained on the primary tape

The near-field summary (optional) lists and plots the intensity and phase information of a wave taken from a primary tape (after phase correction, if a secondary tape was specified).

The far-field summary (optional) lists and plots magnitude, intensity, normalized magnitude, normalized intensity, normalized phase, and normalized area of a near-field wave.

The averaging summary (optional) lists and plots the incoherent average of both near-field and far-field waveforms.

The following pages represent the output produced by the sample data case. All types of output except the secondary wave restart and averaging are represented.

MIRROR DESCRIPTION

I	X	INTENSITY	PHASE (DG)
1	0.90000000E 01	0.10000000E 01	-0.90002237E 02
2	0.87750000E 01	0.10000000E 01	-0.50008240E 02
3	0.85500000E 01	0.10000000E 01	-0.11026748E 02
4	0.83249999E 01	0.99999996E 00	0.26942243E 02
5	0.81000000E 01	0.99999996E 00	0.63898710E 02
6	0.78750000E 01	0.10000000E 01	0.99842085E 02
7	0.76500000E 01	0.10000000E 01	0.13477415E 03
8	0.74250000E 01	0.10000000E 01	0.16869311E 03
9	0.72000000E 01	0.10000000E 01	-0.18840182E 03
10	0.69750000E 01	0.10000000E 01	-0.12650787E 03
11	0.67500000E 01	0.10000000E 01	-0.95626431E 02
12	0.65250000E 01	0.99999998E 00	-0.65757497E 02
13	0.63000000E 01	0.99999998E 00	-0.36901669E 02
14	0.60750000E 01	0.99999999E 00	-0.90571454E 01
15	0.58500000E 01	0.10000000E 01	0.17774270E 02
16	0.56250000E 01	0.99999998E 00	0.43593178E 02
17	0.54000000E 01	0.99999999E 00	0.6A399585E 02
18	0.51750000E 01	0.99999999E 00	0.92193480E 02
19	0.49500000E 01	0.10000000E 01	0.11497487E 03
20	0.47250000E 01	0.10000000E 01	0.13674376E 03
21	0.45000000E 01	0.99999999E 00	0.18750013E 03
22	0.42750000E 01	0.10000000E 01	0.17724401E 03
23	0.40500000E 01	0.99999999E 00	-0.16402602E 03
24	0.38250000E 01	0.99999999E 00	-0.14630715E 03
25	0.36000000E 01	0.10000000E 01	-0.12960880E 03
26	0.33750000E 01	0.10000000E 01	-0.11390699E 03
27	0.31500000E 01	0.10000000E 01	-0.99225614E 02
28	0.29250000E 01	0.	-0.50000000E 00
29	0.27000000E 01	0.	-0.50000000E 00
30	0.24750000E 01	0.	-0.50000000E 00
31	0.22500000E 01	0.	-0.50000000E 00
32	0.20250000E 01	0.	-0.50000000E 00
33	0.18000000E 01	0.	-0.50000000E 00
34	0.15750000E 01	0.	-0.50000000E 00
35	0.13500000E 01	0.	-0.50000000E 00
36	0.11250000E 01	0.	-0.50000000E 00
37	0.90000000E 00	0.	-0.50000000E 00
38	0.67500000E 00	0.	-0.50000000E 00
39	0.45000000E 00	0.	-0.50000000E 00
40	0.22500000E 00	0.	-0.50000000E 00
41	0.	0.	-0.50000000E 00
42	0.22500000E 00	0.	-0.50000000E 00
43	0.45000000E 00	0.	-0.50000000E 00
44	0.67500000E 00	0.	-0.50000000E 00
45	0.90000000E 00	0.	-0.50000000E 00
46	0.11250000E 01	0.	-0.50000000E 00
47	0.13500000E 01	0.	-0.50000000E 00
48	0.15750000E 01	0.	-0.50000000E 00
49	0.18000000E 01	0.	-0.50000000E 00
50	0.20250000E 01	0.	-0.50000000E 00

MIRROR DESCRIPTION

I	X		INTENSITY	PHASE (DG)
51	0.22500000E 01	0.		0.50000000E 00
52	0.24750000E 01	0.		0.50000000E 00
53	0.27000000E 01	0.		0.50000000E 00
54	0.29250000E 01	0.		0.50000000E 00
55	0.31500000E 01	0.10000000E 01		0.99225814E 02
56	0.33750000E 01	0.10000000E 01		0.11390895E 03
57	0.36000000E 01	0.10000000E 01		0.12960080E 03
58	0.38250000E 01	0.99999999E 00		0.14630715E 03
59	0.40500000E 01	0.99999999E 00		0.16402602E 03
60	0.42750000E 01	0.10000000E 01		0.17724401E 03
61	0.45000000E 01	0.99999999E 00		0.19750013E 03
62	0.47250000E 01	0.10000000E 01		0.13674376E 03
63	0.49500000E 01	0.10000000E 01		0.11497487E 03
64	0.51750000E 01	0.99999999E 00		0.92193480E 02
65	0.54000000E 01	0.99999999E 00		0.68399585E 02
66	0.56250000E 01	0.99999998E 00		0.43593178E 02
67	0.58500000E 01	0.10000000E 01		0.17774270E 02
68	0.60750000E 01	0.99999999E 00		0.90571454E 01
69	0.63000000E 01	0.99999998E 00		0.36901869E 02
70	0.65250000E 01	0.99999998E 00		0.65757497E 02
71	0.67500000E 01	0.10000000E 01		0.95626431E 02
72	0.69750000E 01	0.10000000E 01		0.12650787E 03
73	0.72000000E 01	0.10000000E 01		0.15840182E 03
74	0.74250000E 01	0.10000000E 01		0.16869311E 03
75	0.76500000E 01	0.10000000E 01		0.13477415E 03
76	0.78750000E 01	0.10000000E 01		0.99842685E 02
77	0.81000000E 01	0.99999996E 00		0.63898710E 02
78	0.83250000E 01	0.99999996E 00		0.26942843E 02
79	0.85500000E 01	0.10000000E 01		0.11026748E 02
80	0.87750000E 01	0.10000000E 01		0.50008240E 02
81	0.90000000E 01	0.10000000E 01		0.90002237E 02

MIRROR DESCRIPTION
NUMBER OF POINTS= A1

Y INCREMENT= 0.16363636E 00

Y INCREMENT= 0.20000001E-01

INTENSITY

0.10000000E 01

0.90000004E 00

0.80000003E 00

0.70000003E 00

0.60000002E 00

0.50000002E 00

0.40000002E 00

0.30000001E 00

0.20000001E 00

0.10000000E 00

0.

0.90000000E 01
=0.73636364E 01
=0.97272727E 01
=0.40909091E 01
=0.24545455E 01
=0.81818182E 00
=0.81818182E 00
=0.40909091E 01
=0.40909091E 01
=0.57272727E 01
=0.73636364E 01

X

STARTING PASS 0

NEAR FIELD WAVE

I	X	INTENSITY	PHASE (DG)
1	-0.90000000E 01	0.	-0.50000000E 00
2	-0.87750000E 01	0.	-0.50000000E 00
3	-0.85500000E 01	0.	-0.50000000E 00
4	-0.83249999E 01	0.	-0.50000000E 00
5	-0.81000000E 01	0.	-0.50000000E 00
6	-0.78750000E 01	0.	-0.50000000E 00
7	-0.76500000E 01	0.	-0.50000000E 00
8	-0.74250000E 01	0.	-0.50000000E 00
9	-0.72000000E 01	0.	-0.50000000E 00
10	-0.69750000E 01	0.	-0.50000000E 00
11	-0.67500000E 01	0.	-0.50000000E 00
12	-0.65250000E 01	0.	-0.50000000E 00
13	-0.63000000E 01	0.	-0.50000000E 00
14	-0.60750000E 01	0.	-0.50000000E 00
15	-0.58500000E 01	0.	-0.50000000E 00
16	-0.56250000E 01	0.	-0.50000000E 00
17	-0.54000000E 01	0.10000000E 01	0.
18	-0.51750000E 01	0.10000000E 01	0.
19	-0.49500000E 01	0.10000000E 01	0.
20	-0.47250000E 01	0.10000000E 01	0.
21	-0.45000000E 01	0.10000000E 01	0.
22	-0.42750000E 01	0.10000000E 01	0.
23	-0.40500000E 01	0.10000000E 01	0.
24	-0.38250000E 01	0.10000000E 01	0.
25	-0.36000000E 01	0.10000000E 01	0.
26	-0.33750000E 01	0.10000000E 01	0.
27	-0.31500000E 01	0.10000000E 01	0.
28	-0.29250000E 01	0.10000000E 01	0.
29	-0.27000000E 01	0.10000000E 01	0.
30	-0.24750000E 01	0.10000000E 01	0.
31	-0.22500000E 01	0.10000000E 01	0.
32	-0.20250000E 01	0.10000000E 01	0.
33	-0.18000000E 01	0.10000000E 01	0.
34	-0.15750000E 01	0.10000000E 01	0.
35	-0.13500000E 01	0.10000000E 01	0.
36	-0.11250000E 01	0.10000000E 01	0.
37	-0.90000000E 00	0.10000000E 01	0.
38	-0.67500000E 00	0.10000000E 01	0.
39	-0.45000000E 00	0.10000000E 01	0.
40	-0.22500000E 00	0.10000000E 01	0.
41	0.	0.10000000E 01	0.
42	0.22500000E 00	0.10000000E 01	0.
43	0.45000000E 00	0.10000000E 01	0.
44	0.67500000E 00	0.10000000E 01	0.
45	0.90000000E 00	0.10000000E 01	0.
46	0.11250000E 01	0.10000000E 01	0.
47	0.13500000E 01	0.10000000E 01	0.
48	0.15750000E 01	0.10000000E 01	0.
49	0.18000000E 01	0.10000000E 01	0.
50	0.20250000E 01	0.10000000E 01	0.

NEAR FIELD WAVE

I	X	INTENSITY	PHASE (DG)
51	0,22500000E 01	0,10000000E 01	0,
52	0,24750000E 01	0,10000000E 01	0,
53	0,27000000E 01	0,10000000E 01	0,
54	0,29250000E 01	0,10000000E 01	0,
55	0,31500000E 01	0,10000000E 01	0,
56	0,33750000E 01	0,10000000E 01	0,
57	0,36000000E 01	0,10000000E 01	0,
58	0,38250000E 01	0,10000000E 01	0,
59	0,40500000E 01	0,10000000E 01	0,
60	0,42750000E 01	0,10000000E 01	0,
61	0,45000000E 01	0,10000000E 01	0,
62	0,47250000E 01	0,10000000E 01	0,
63	0,49500000E 01	0,10000000E 01	0,
64	0,51750000E 01	0,10000000E 01	0,
65	0,54000000E 01	0,10000000E 01	0,
66	0,56250000E 01	0,	0,50000000E 00
67	0,58500000E 01	0,	0,50000000E 00
68	0,60750000E 01	0,	0,50000000E 00
69	0,63000000E 01	0,	0,50000000E 00
70	0,65250000E 01	0,	0,50000000E 00
71	0,67500000E 01	0,	0,50000000E 00
72	0,69750000E 01	0,	0,50000000E 00
73	0,72000000E 01	0,	0,50000000E 00
74	0,74250000E 01	0,	0,50000000E 00
75	0,76500000E 01	0,	0,50000000E 00
76	0,78750000E 01	0,	0,50000000E 00
77	0,81000000E 01	0,	0,50000000E 00
78	0,83249999E 01	0,	0,50000000E 00
79	0,85500000E 01	0,	0,50000000E 00
80	0,87750000E 01	0,	0,50000000E 00
81	0,90000000E 01	0,	0,50000000E 00

NEAR FIELD HAVE NUMBER OF POINTS= 91	X INCREMENT= 0.163636E 00	Y INCREMENT= 0.1000000E-01
PHASE (DG)		
0.		
-0.5000000E-01		
-0.1000000E 00		
-0.1500000E 00		
-0.2000000E 00		
-0.2500000E 00		
-0.3000000E 00		
-0.3500000E 00		
-0.4000000E 00		
-0.4500000E 00		
-0.5000000E 00		
-0.9000000E 01	-0.818181E 01	-0.409090E 01
-0.736363E 01	-0.245454E 01	-0.572727E 01
	-0.818181E 00	0.736363E 01
	-0.409090E 01	0.900000E 01

FAR FIELD RESULTS

I	THETA (MRAD)	MAGNITUDE	INTENSITY	NORM. MAG.	NORM. I/P.T.	NORM. PHASE	NORM. AREA
1	-0.1500000E+00	0.13502147E+00	0.10249705E+01	0.11578605E+00	0.13406547E+01	-0.19707332E+01	0.99816729E+00
2	-0.1462500E+00	0.16388962E+00	0.26859507E+01	0.14046945E+00	0.19731677E+01	-0.12268787E+01	0.99551935E+00
3	-0.1425000E+00	0.16562559E+00	0.27431835E+01	0.14195735E+00	0.20151698E+01	0.33340452E+01	0.99270458E+00
4	-0.1387500E+00	0.14353220E+00	0.20601493E+01	0.13302119E+00	0.15134212E+01	0.26713339E+01	0.99074527E+00
5	-0.1350000E+00	0.11052784E+00	0.11083542E+01	0.97233921E+00	0.81421608E+02	0.20263540E+01	0.98964736E+00
6	-0.1312500E+00	0.61500767E+01	0.37823443E+02	0.57712193E+01	0.27875535E+02	0.13990157E+01	0.98927166E+00
7	-0.1275000E+00	0.23726006E+01	0.56292336E+03	0.23335916E+01	0.41353320E+03	0.78934871E+00	0.98921575E+00
8	-0.1237500E+00	0.20460411E+02	0.41862843E+05	0.17536981E+02	0.30753166E+05	-0.17351933E+00	0.98921575E+00
9	-0.1200000E+00	0.29687870E+02	0.88136962E+05	0.26445419E+02	0.64746931E+05	-0.37362282E+00	0.98921575E+00
10	-0.1162500E+00	0.27855416E+01	0.77592420E+03	0.23874825E+01	0.57006729E+03	-0.9362282E+00	0.98913739E+00
11	-0.1125000E+00	0.72269198E+01	0.52228369E+02	0.61941795E+01	0.38367860E+02	-0.14726033E+01	0.98861861E+00
12	-0.1087500E+00	0.12641162E+00	0.15979898E+01	0.10834717E+00	0.11739108E+01	-0.19939124E+01	0.98703136E+00
13	-0.1050000E+00	0.17683475E+00	0.31190834E+01	0.18139335E+00	0.22919935E+01	0.37856351E+01	0.98393232E+00
14	-0.1012500E+00	0.20782315E+00	0.43190460E+01	0.17812483E+00	0.31728456E+01	0.32996690E+01	0.97966429E+00
15	-0.0975000E+00	0.20627031E+00	0.42547440E+01	0.17679390E+00	0.31256082E+01	0.26313743E+01	0.97541612E+00
16	-0.0937500E+00	0.16256248E+00	0.26428561E+01	0.13933200E+00	0.19413407E+01	0.23807511E+01	0.97279120E+00
17	-0.0900000E+00	0.73950360E+01	0.5468557E+02	0.63382719E+01	0.40173687E+02	0.19477991E+01	0.97224801E+00
18	-0.0862500E+00	0.54254986E+01	0.29436036E+02	0.46501848E+01	0.2164219E+02	-0.16090739E+01	0.97195563E+00
19	-0.0825000E+00	0.20658594E+01	0.43508095E+01	0.17877865E+00	0.31961798E+01	-0.20066524E+01	0.96763404E+00
20	-0.0787500E+00	0.36874358E+00	0.13597183E+00	0.31600494E+00	0.99887248E+01	0.38965557E+01	0.95412818E+00
21	-0.0750000E+00	0.51023051E+00	0.2603518E+00	0.43731762E+00	0.19124671E+00	0.35342999E+01	0.92826949E+00
22	-0.0712500E+00	0.60794937E+00	0.36960243E+00	0.57017228E+00	0.27151632E+00	0.31897057E+01	0.89155747E+00
23	-0.0675000E+00	0.64024054E+00	0.40990795E+00	0.56874899E+00	0.30112544E+00	0.28627830E+01	0.85084196E+00
24	-0.0637500E+00	0.59272718E+00	0.35132551E+00	0.50802533E+00	0.25808977E+00	0.25535317E+01	0.81594536E+00
25	-0.0600000E+00	0.46132719E+00	0.21282378E+00	0.39540268E+00	0.15634328E+00	0.22619520E+01	0.79480601E+00
26	-0.0562500E+00	0.25389001E+00	0.6466138E+01	0.21760866E+00	0.47383528E+01	0.1988037E+01	0.76840329E+00
27	-0.0525000E+00	0.98951941E+02	0.97914864E+04	0.84811925E+02	0.71929946E+04	-0.14097865E+01	0.7839356E+00
28	-0.0487500E+00	0.30041629E+00	0.90249946E+01	0.29748625E+00	0.66289166E+01	-0.1648309E+01	0.77942917E+00
29	-0.0450000E+00	0.58169372E+00	0.3383758E+00	0.49856865E+00	0.24887065E+00	-0.16692447E+01	0.74581966E+00
30	-0.0412500E+00	0.81512231E+00	0.66605562E+00	0.69949692E+00	0.489593E+00	-0.20724669E+01	0.67966142E+00
31	-0.0375000E+00	0.96974169E+00	0.94039896E+00	0.83116381E+00	0.69083328E+00	-0.22580177E+01	0.58025308E+00
32	-0.0337500E+00	0.10172667E+01	0.10348316E+01	0.87189743E+00	0.76030512E+00	0.38572884E+01	0.48346489E+00
33	-0.0300000E+00	0.94611920E+00	0.89513396E+00	0.81091355E+00	0.65786883E+00	0.3707004E+01	0.39455266E+00
34	-0.0262500E+00	0.75879315E+00	0.57576705E+00	0.63036020E+00	0.42226839E+00	0.3374544E+01	0.33736263E+00
35	-0.0225000E+00	0.47322426E+00	0.2239120E+00	0.45559963E+00	0.16481106E+00	0.3456796E+01	0.31511891E+00
36	-0.0187500E+00	0.12070488E+00	0.14617989E+01	0.19362735E+00	0.10738627E+01	0.3624864E+01	0.31366692E+00
37	-0.0150000E+00	0.25691208E+00	0.66003815E+01	0.22019887E+00	0.48487540E+01	0.14137199E+00	0.30711087E+00
38	-0.0112500E+00	0.61450456E+00	0.37761585E+00	0.52669072E+00	0.27740311E+00	0.79521738E+01	0.28960288E+00
39	-0.0075000E+00	0.90771194E+00	0.82394096E+00	0.77799922E+00	0.60528122E+00	0.35342991E+01	0.18776214E+00
40	-0.0037500E+00	0.10998590E+01	0.12096899E+01	0.94268715E+00	0.88865905E+00	0.88357478E+02	0.67605552E+01
41	0.	0.11667275E+01	0.13611231E+01	0.10000000E+01	0.10000000E+01	0.	0.67605552E+01
42	0.0037500E+00	0.10998590E+01	0.12096899E+01	0.94268715E+00	0.88865905E+00	0.88357478E+02	0.67605552E+01
43	0.0075000E+00	0.90771195E+00	0.82394097E+00	0.77799922E+00	0.60528123E+00	0.35342991E+01	0.28960288E+00
44	0.0112500E+00	0.61450457E+00	0.37761586E+00	0.52669073E+00	0.27740312E+00	0.79521739E+01	0.30711087E+00
45	0.0150000E+00	0.25691208E+00	0.66003816E+01	0.22019887E+00	0.48487540E+01	0.14137199E+00	0.31366692E+00
46	0.0187500E+00	0.12070488E+00	0.14617991E+01	0.19362735E+00	0.10738628E+01	0.3624864E+01	0.31511891E+00
47	0.0225000E+00	0.47322426E+00	0.2239120E+00	0.45559963E+00	0.16481106E+00	0.3456796E+01	0.31366692E+00
48	0.0262500E+00	0.75879316E+00	0.57576706E+00	0.63036021E+00	0.42226840E+00	0.35342991E+01	0.18776214E+00
49	0.0300000E+00	0.94611918E+00	0.89513393E+00	0.81091355E+00	0.65786881E+00	0.3707006E+01	0.39455266E+00
50	0.0337500E+00	0.10172667E+01	0.10348316E+01	0.87189743E+00	0.76030510E+00	0.38572884E+01	0.48346489E+00

FAR FIELD RESULTS

I	THETA (HRAD)	MAGNITUDE	INTENSITY	NORM. MAG.	NORM. INT.	NORM. PHASE	NORM. AREA
51	0.3750000E-01	0.9677139E 00	0.9403989E 00	0.8311632E 00	0.6908332E 00	-0.22580177E 01	0.67966142E 00
52	0.4125000E-01	0.8161223E 00	0.6660556E 00	0.6994969E 00	0.4892959E 00	-0.2072466E 01	0.74581967E 00
53	0.4500000E-01	0.5816931E 00	0.33836757E 00	0.4985680E 00	0.2405706E 00	-0.18692447E 01	0.77942918E 00
54	0.4875000E-01	0.3004122E 00	0.9024994E-01	0.2974862E 00	0.6629916E-01	-0.16483509E 01	0.78839337E 00
55	0.5250000E-01	0.9855192E-02	0.97914837E-04	0.8481151E-02	0.71929928E-04	-0.14097866E 01	0.78840330E 00
56	0.5625000E-01	0.2538901E 00	0.64460139E-01	0.2176086E 00	0.47353528E-01	0.19880438E 01	0.79480602E 00
57	0.6000000E-01	0.4613271E 00	0.2128227E 00	0.3954028E 00	0.15834328E 00	0.22619520E 01	0.8159458E 00
58	0.6375000E-01	0.5927271E 00	0.35132551E 00	0.50802537E 00	0.25808977E 00	0.25535317E 01	0.85084196E 00
59	0.6750000E-01	0.6402405E 00	0.4090795E 00	0.5487489E 00	0.30112544E 00	0.28627830E 01	0.89159748E 00
60	0.7125000E-01	0.6079493E 00	0.36950242E 00	0.5210727E 00	0.27151631E 00	0.31897057E 01	0.92826951E 00
61	0.7500000E-01	0.5102305E 00	0.26033517E 00	0.4373176E 00	0.19124670E 00	0.35342999E 01	0.9541281E 00
62	0.7875000E-01	0.3687435E 00	0.13597183E 00	0.3160494E 00	0.9988724E-01	0.38965657E 01	0.96763405E 00
63	0.8250000E-01	0.2085899E 00	0.43508096E-01	0.1787783E 00	0.31961797E-01	-0.2006824E 01	0.97195563E 00
64	0.8625000E-01	0.54254981E-01	0.29436029E-02	0.4650183E-01	0.21324214E-02	-0.16090736E 01	0.97224801E 00
65	0.9000000E-01	0.7395035E-01	0.5468556E-02	0.8338271E-01	0.40173886E-02	-0.19477994E 01	0.97279119E 00
66	0.9375000E-01	0.1425624E 00	0.26426561E-01	0.1393320E 00	0.19413407E-01	0.23807511E 01	0.97541610E 00
67	0.9750000E-01	0.20627031E 00	0.42537440E-01	0.1767930E 00	0.31256082E-01	0.28313743E 01	0.97964228E 00
68	0.1012500E 00	0.2078231E 00	0.43150458E-01	0.1781248E 00	0.31288455E-01	0.32996690E 01	0.98393232E 00
69	0.1050000E 00	0.17663474E 00	0.31199833E-01	0.15139331E 00	0.22919935E-01	0.37858351E 01	0.98703136E 00
70	0.1067500E 00	0.1264116E 00	0.15979898E-01	0.10834717E 00	0.11739109E-01	-0.19939125E 01	0.98861863E 00
71	0.1125000E 00	0.72269197E-01	0.5228368E-02	0.14941795E-01	0.38867859E-02	-0.14720033E 01	0.98913740E 00
72	0.1162500E 00	0.27855416E-01	0.77592421E-03	0.29445412E-02	0.57000729E-03	-0.93362276E 00	0.98921446E 00
73	0.1200000E 00	0.29680786E-02	0.88136920E-05	0.29445412E-02	0.64746900E-05	-0.37697406E 00	0.98921534E 00
74	0.1237500E 00	0.20400410E-02	0.4182835E-05	0.17536379E-02	0.30753160E-05	0.19734923E 00	0.98921576E 00
75	0.1275000E 00	0.2372600E-01	0.5629233E-03	0.20339515E-01	0.41353318E-03	0.78934873E 00	0.98921768E 00
76	0.1312500E 00	0.61500076E-01	0.37823445E-02	0.52712195E-01	0.2785755E-02	0.13990157E 01	0.98964736E 00
77	0.1350000E 00	0.10527840E 00	0.11083542E-01	0.9823392E-01	0.81481607E-02	0.20265540E 01	0.99074828E 00
78	0.1387500E 00	0.14353221E 00	0.20601494E-01	0.12302119E 00	0.15134212E-01	0.26713639E 01	0.9927460E 00
79	0.1425000E 00	0.14562559E 00	0.27431835E-01	0.14195736E 00	0.20151898E-01	0.33340451E 01	0.99551935E 00
80	0.1462500E 00	0.16388962E 00	0.26859807E-01	0.1404699E 00	0.19731677E-01	-0.22687875E 01	0.99818728E 00
81	0.1500000E 00	0.13509147E 00	0.18249705E-01	0.18578665E 00	0.13406547E-01	-0.15707632E 01	0.1000000E 01

FAR FIELD RESULTS NUMBER OF POINTS= 91

MAGNITUDE
0.11667275E 01

0.10502594E 01

0.93379124E 00

0.81732309E 00

0.70085493E 00

0.58430679E 00

0.46791864E 00

0.35145049E 00

0.23490234E 00

0.11851419E 00

0.20460410E-02

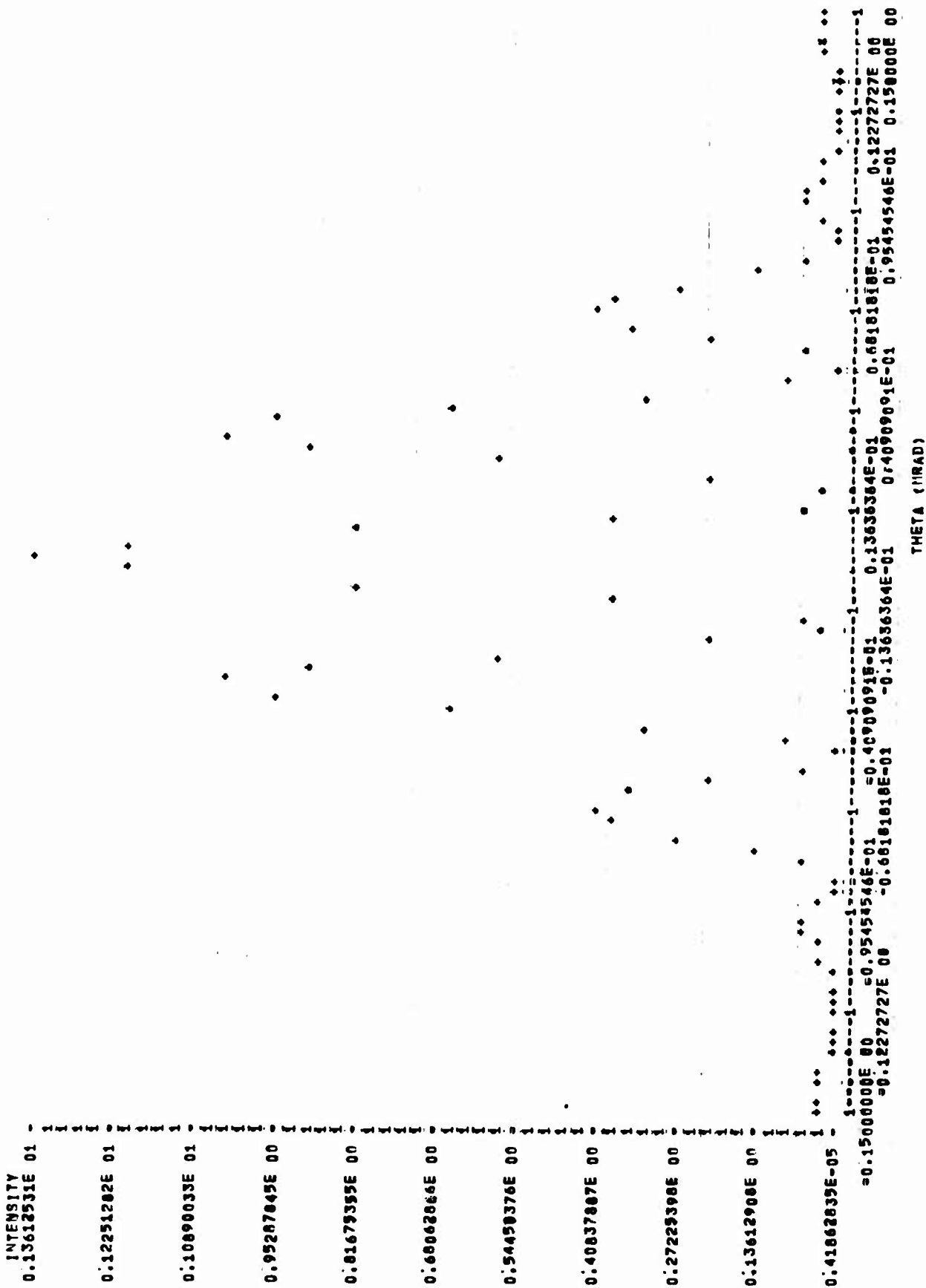
X INCREMENT= 0.27272727E-02

Y INCREMENT= 0.23293630E-01

0.1500000E 00
0.1227272E 00
-0.9545454E-01
-0.6818181E-01
-0.4090909E-01
-0.1363636E-01
0.1363636E-01
0.6818181E-01
0.4090909E-01
0.9545454E-01
0.1227272E 00
0.1500000E 00

THETA (MRAD)

FAR FIELD RESULTS
 NUMBER OF POINTS= 81
 X INCREMENT= 0.272727E-02
 Y INCREMENT= 0.27224979E-01



FAR FIELD RESULTS
 NUMBER OF POINTS: 41
 X INCREMENT: 0.4000000E-02
 Y INCREMENT: 0.2000000E-01

NORM. INT.

0.1000000E 01

0.9000000E 00

0.8000000E 00

0.7000000E 00

0.6000000E 00

0.5000000E 00

0.4000000E 00

0.3000000E 00

0.2000000E 00

0.1000000E 00

0.

0.1500000E 00
 -0.1100000E 00
 -0.7000000E 01
 -0.3000000E 01
 0.1000000E 01
 0.5000000E 01
 0.9000000E 01
 0.1300000E 00
 0.1700000E 00
 0.2100000E 00
 0.2500000E 00
 0.2900000E 00

THETA (MRAD)

FAR FIELD RESULTS
NUMBER OF POINTS: 81

X INCREMENT: 0.4000000E+02

Y INCREMENT: 0.2000000E+02

NORM. PHASE
0.7000000E 01

0.6000000E 01

0.5000000E 01

0.4000000E 01

0.3000000E 01

0.2000000E 01

0.1000000E 01

-0.1164153E+00

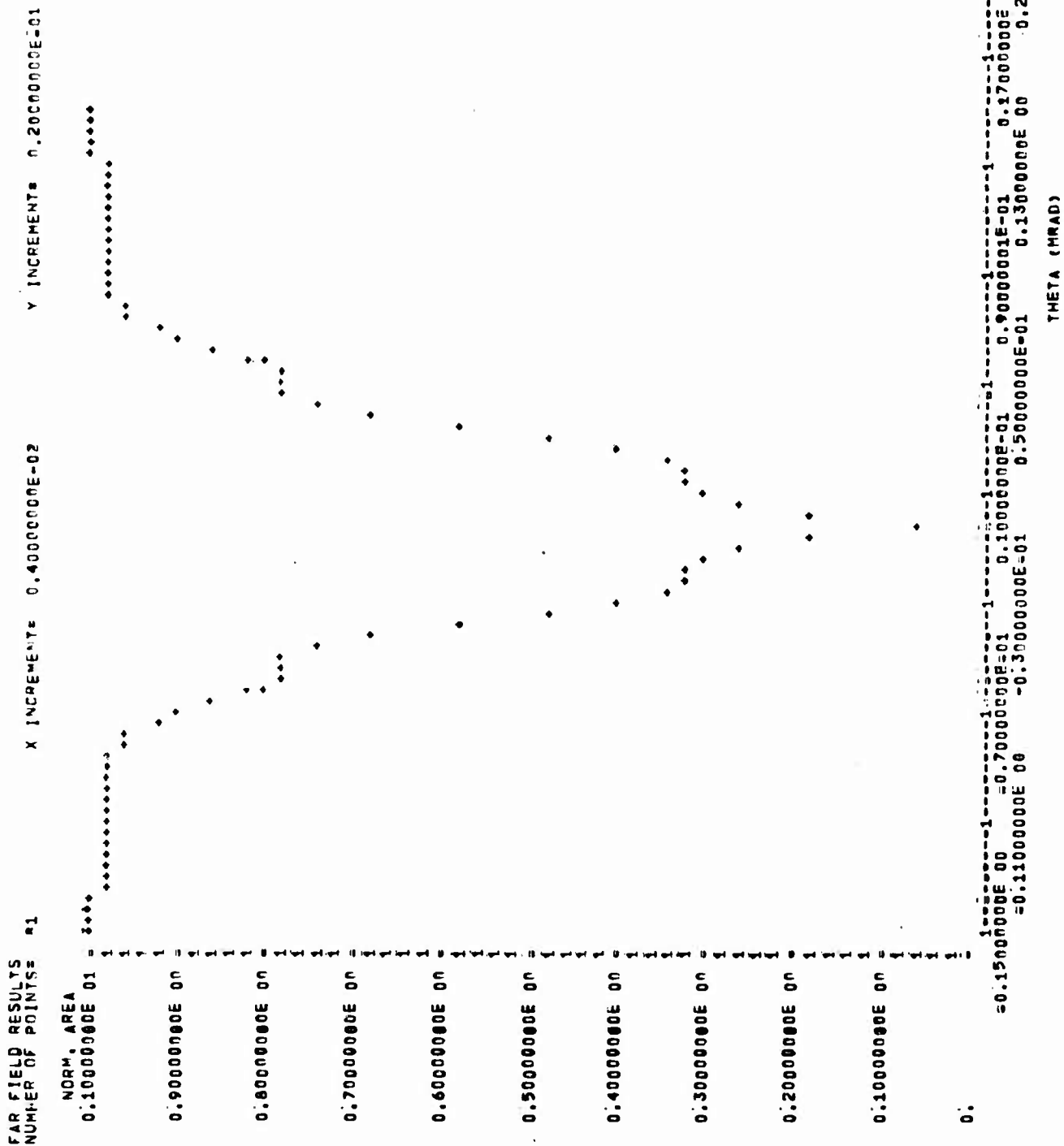
-0.1000000E 01

-0.2000000E 01

-0.3000000E 01

0.3500000E 00 0.7000000E+01 0.1000000E-01 0.9000000E-01 0.1700000E 00 0.2500000E 00
-0.1100000E 00 -0.3000000E+01 0.5000000E-01 0.1300000E 00 0.2100000E 00 0.2900000E 00

THETA (RAD)



FAR FIELD POWER
WAVE NUMBER 1

0.4930426E 01

USING RESTART TAPE, FILE CODE 10, TO MATCH 1

TAPE IDENTIFICATION

TIME 1728
DATE 110973
SNUMR MC496
PROGRAM PR51
CASE 8.5

GOVERNING PARAMETERS FOR TAPE INFORMATION

NX= 81
NZ= 18
IHAVE= 1
NWAVES= 1

STARTING PASS 1

NEAR FIELD WAVE

I	Y	INTENSITY	PHASE (DG)
1	-0.9000000E 01	0.	-0.5000000E 00
2	-0.8775000E 01	0.75674660E-05	-0.97506783E 02
3	-0.8550000E 01	0.41665491E-04	-0.16015575E 03
4	-0.8324999E 01	0.24518104E-03	0.13211626E 03
5	-0.8100000E 01	0.12512085E-02	0.66593365E 02
6	-0.7875000E 01	0.53955163E-02	0.22078894E 01
7	-0.7650000E 01	0.19177114E-01	-0.60500175E 02
8	-0.7425000E 01	0.54341917E-01	-0.12060474E 03
9	-0.7200000E 01	0.11943601E 00	-0.17637511E 03
10	-0.6975000E 01	0.20487260E 00	0.13504758E 03
11	-0.6750000E 01	0.30463679E 00	0.96663246E 02
12	-0.6525000E 01	0.47058502E 00	0.67128470E 02
13	-0.6300000E 01	0.75146557E 00	0.41738200E 02
14	-0.6075000E 01	0.11381766E 01	0.21065556E 02
15	-0.5850000E 01	0.17311248E 01	0.56140589E 01
16	-0.5625000E 01	0.26115426E 01	-0.63136734E 01
17	-0.5400000E 01	0.38408426E 01	-0.14382819E 02
18	-0.5175000E 01	0.55497097E 01	-0.19239547E 02
19	-0.4950000E 01	0.77306541E 01	-0.21249061E 02
20	-0.4725000E 01	0.10302654E 02	-0.20634401E 02
21	-0.4500000E 01	0.13012202E 02	-0.18087313E 02
22	-0.4275000E 01	0.15405082E 02	-0.13932439E 02
23	-0.4050000E 01	0.16915964E 02	-0.94520355E 01
24	-0.3825000E 01	0.17386950E 02	-0.51728818E 01
25	-0.3600000E 01	0.16899323E 02	-0.25051325E 01
26	-0.3375000E 01	0.16613077E 02	-0.14853200E 01
27	-0.3150000E 01	0.16824183E 02	0.47121676E 00
28	-0.2925000E 01	0.16351832E 02	0.30857758E 01
29	-0.2700000E 01	0.15078270E 02	0.44063043E 01
30	-0.2475000E 01	0.13803747E 02	0.41645935E 01
31	-0.2250000E 01	0.12890086E 02	0.27963634E 01
32	-0.2025000E 01	0.12502281E 02	0.77025557E 00
33	-0.1800000E 01	0.12717130E 02	-0.11165999E 01
34	-0.1575000E 01	0.13466974E 02	-0.21954015E 01
35	-0.1350000E 01	0.14306391E 02	-0.21524707E 01
36	-0.1125000E 01	0.14681104E 02	-0.11449752E 01
37	-0.9000000E 00	0.14606437E 02	0.55489418E 00
38	-0.6750000E 00	0.14365512E 02	0.16909650E 01
39	-0.4500000E 00	0.14048664E 02	0.99090094E 00
40	-0.2250000E 00	0.13641351E 02	-0.56461975E 00
41	0.	0.13414623E 02	-0.12733530E 01
42	0.2250000E 00	0.13641351E 02	-0.56461295E 00
43	0.4500000E 00	0.14048665E 02	0.99090175E 00
44	0.6750000E 00	0.14365513E 02	0.16909655E 01
45	0.9000000E 00	0.14606438E 02	0.55489293E 00
46	0.1125000E 01	0.14681105E 02	-0.11449748E 01
47	0.1350000E 01	0.14306392E 02	-0.21524732E 01
48	0.1575000E 01	0.13466972E 02	-0.21954028E 01
49	0.1800000E 01	0.12717129E 02	-0.11165989E 01
50	0.2025000E 01	0.12502280E 02	0.77025545E 00

NEAR FIELD WAVE

I	Y	INTENSITY	PHASE (DG)
51	0.22500000E 01	0.12890008E 02	0.27963623E 01
52	0.24750000E 01	0.13803747E 02	0.41645935E 01
53	0.27000000E 01	0.15078271E 02	0.44063469E 01
54	0.29250000E 01	0.16351832E 02	0.30857753E 01
55	0.31500000E 01	0.16624184E 02	0.47121233E 00
56	0.33750000E 01	0.16613077E 02	0.14853186E 01
57	0.36000000E 01	0.16899323E 02	0.25051346E 01
58	0.38250000E 01	0.17386949E 02	0.51728802E 01
59	0.40500000E 01	0.16915964E 02	0.94520372E 01
60	0.42750000E 01	0.15405081E 02	0.13932439E 02
61	0.45000000E 01	0.13012202E 02	0.18087312E 02
62	0.47250000E 01	0.10302654E 02	0.20634401E 02
63	0.49500000E 01	0.77306591E 01	0.21249058E 02
64	0.51750000E 01	0.55497094E 01	0.19239545E 02
65	0.54000000E 01	0.38408428E 01	0.14382815E 02
66	0.56250000E 01	0.26115426E 01	0.63136737E 01
67	0.58500000E 01	0.17311249E 01	0.56140631E 01
68	0.60750000E 01	0.11381765E 01	0.21065558E 02
69	0.63000000E 01	0.75140547E 00	0.41738199E 02
70	0.65250000E 01	0.47058503E 00	0.67128470E 02
71	0.67500000E 01	0.30463677E 00	0.96663245E 02
72	0.69750000E 01	0.20487262E 00	0.13504757E 03
73	0.72000000E 01	0.11943605E 00	0.17637511E 03
74	0.74250000E 01	0.54341938E-01	0.12060474E 03
75	0.76500000E 01	0.19177119E-01	0.60500164E 02
76	0.78750000E 01	0.53995167E-02	0.22079027E 01
77	0.81000000E 01	0.12512082E-02	0.66593578E 02
78	0.83250000E 01	0.24518096E-03	0.13211627E 03
79	0.85500000E 01	0.41665472E-04	0.16015974E 03
80	0.87750000E 01	0.75674633E-05	0.97506788E 02
81	0.90000000E 01	0.	0.50000000E 00

X INCREMENT= 0.1A36363AE 00

Y INCREMENT= 0.34773900F 00

NEAR FIELD WAVE
NUMBER OF POINTS= 81

INTENSITY
0.17386950E 02

0.15640255E 02

0.13909560E 02

0.12170965E 02

0.10432170E 02

0.86934750E 01

0.69547800E 01

0.52160950E 01

0.34773900E 01

0.17386950E 01

0.

0.90000000E 01
-0.73636364E 01
-0.57272727E 01
-0.40909091E 01
-0.24545455E 01
-0.08181818E 00
0.08181818E 00
0.24545455E 01
0.40909091E 01
0.57272727E 01
0.73636364E 01

X

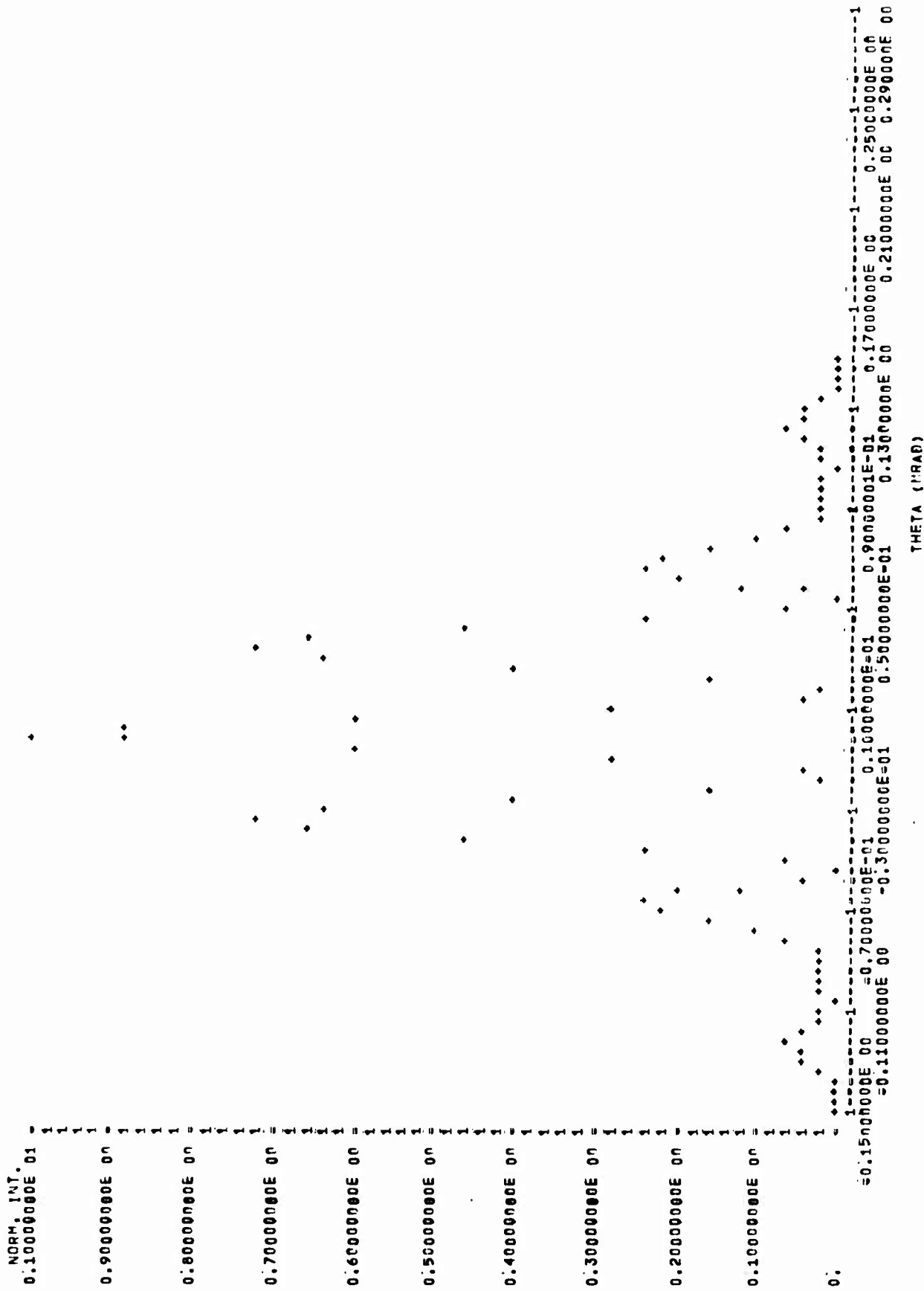
FAR FIELD RESULTS

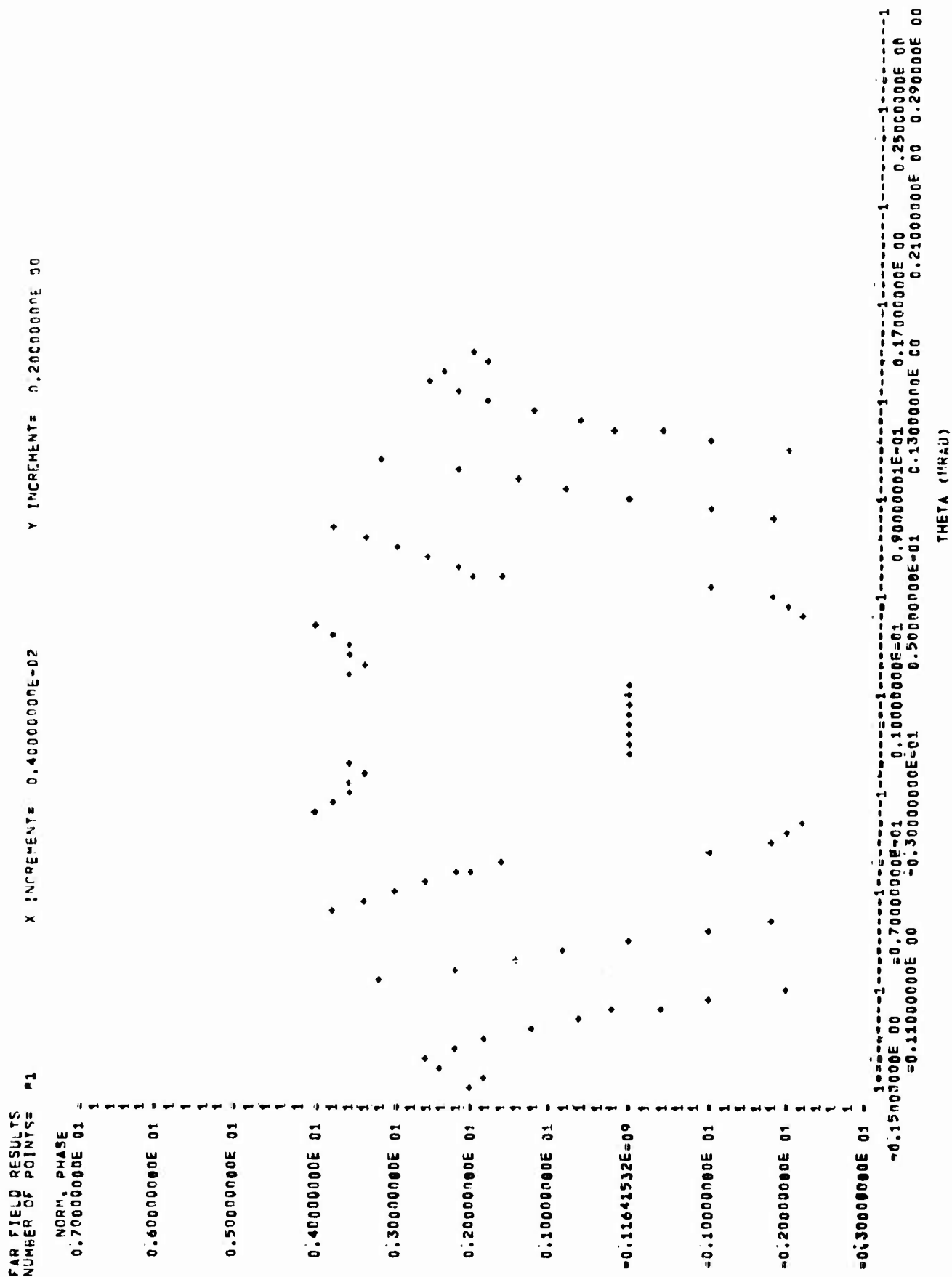
I	THETA (MRAD)	MAGNITUDE	INTENSITY	NORM. MAG.	NORM. I.P.T.	NORM. PHASE	NORM. AREA
1	-0.1500000E+00	0.33093774E+00	0.10951979E+00	0.74599164E+01	0.55630351E+02	0.19918697E+01	0.99922224E+00
2	-0.14625000E+00	0.19425066E+00	0.37733321E+01	0.43787903E+01	0.19173453E+02	0.17819739E+01	0.99922224E+00
3	-0.14250000E+00	0.16415078E+00	0.26945479E+01	0.37002461E+01	0.13651821E+02	0.24760834E+01	0.99922224E+00
4	-0.13875000E+00	0.13515538E+00	0.12359008E+00	0.29246386E+01	0.62799897E+02	0.25598625E+00	0.99922224E+00
5	-0.13500000E+00	0.10789982E+00	0.33523894E+00	0.17051633E+00	0.17034513E+01	0.21814877E+01	0.99922224E+00
6	-0.13125000E+00	0.78319605E+00	0.61339605E+00	0.17654611E+00	0.31168527E+01	0.17139000E+01	0.99922224E+00
7	-0.12750000E+00	0.92927430E+00	0.86335072E+00	0.28947479E+00	0.43879651E+01	0.12157485E+01	0.99922224E+00
8	-0.12375000E+00	0.99226984E+00	0.98455943E+00	0.23675901E+00	0.50035050E+01	0.69958422E+00	0.99922224E+00
9	-0.12000000E+00	0.95996507E+00	0.92153292E+00	0.21639294E+00	0.46825903E+01	0.16121528E+00	0.99922224E+00
10	-0.11625000E+00	0.83788673E+00	0.70205417E+00	0.18807431E+00	0.35673518E+01	0.41921838E+00	0.99922224E+00
11	-0.11250000E+00	0.85616505E+00	0.43052558E+00	0.17911105E+00	0.21877692E+01	0.10927435E+01	0.99922224E+00
12	-0.10875000E+00	0.48454692E+00	0.23478572E+00	0.19922536E+00	0.11930180E+01	0.19713447E+01	0.99922224E+00
13	-0.10500000E+00	0.43803785E+00	0.19187716E+00	0.97414011E+01	0.97498647E+02	0.31972328E+01	0.99922224E+00
14	-0.10125000E+00	0.53003725E+00	0.28093949E+00	0.11947988E+00	0.14253394E+01	0.22097101E+01	0.99922224E+00
15	-0.97500000E+01	0.63367350E+00	0.40154211E+00	0.17284111E+00	0.20493582E+01	0.14350327E+01	0.99922224E+00
16	-0.93750000E+01	0.67680921E+00	0.45807071E+00	0.13256465E+00	0.23275972E+01	0.71402658E+00	0.99922224E+00
17	-0.90000000E+01	0.67825697E+00	0.46003252E+00	0.12891001E+00	0.23375658E+01	0.82606845E+01	0.99922224E+00
18	-0.86250000E+01	0.74955662E+00	0.56183513E+00	0.18896319E+00	0.28548560E+01	0.26360567E+00	0.99922224E+00
19	-0.82500000E+01	0.99457898E+00	0.98918734E+00	0.32419552E+00	0.50263631E+01	0.18048123E+01	0.99922224E+00
20	-0.78750000E+01	0.13675032E+01	0.18706505E+01	0.38259172E+00	0.95023718E+01	0.38494788E+01	0.99922224E+00
21	-0.75000000E+01	0.17514218E+01	0.30674783E+01	0.39480114E+00	0.15586794E+00	0.33603359E+01	0.99922224E+00
22	-0.71250000E+01	0.20355103E+01	0.41330222E+01	0.49883967E+00	0.21053384E+00	0.29543424E+01	0.99922224E+00
23	-0.67500000E+01	0.21284361E+01	0.45303404E+01	0.49788675E+00	0.23019536E+00	0.26003437E+01	0.99922224E+00
24	-0.63750000E+01	0.19661412E+01	0.38657114E+01	0.43202076E+00	0.19642861E+00	0.22810405E+01	0.99922224E+00
25	-0.60000000E+01	0.15211123E+01	0.23137825E+01	0.33288935E+00	0.11797036E+00	0.19827520E+01	0.99922224E+00
26	-0.56250000E+01	0.80995850E+00	0.65603278E+00	0.13257881E+00	0.33335038E+01	0.16718065E+01	0.99922224E+00
27	-0.52500000E+01	0.14613750E+00	0.21351187E+01	0.39941966E+01	0.10851733E+01	0.94726054E+00	0.99922224E+00
28	-0.48750000E+01	0.11498705E+01	0.13220233E+01	0.29200961E+00	0.67165136E+01	0.37381988E+01	0.99922224E+00
29	-0.45000000E+01	0.16030337E+01	0.46669119E+01	0.48697028E+00	0.23714009E+00	0.39730338E+01	0.99922224E+00
30	-0.41250000E+01	0.30159408E+01	0.90959900E+01	0.67984588E+00	0.46259042E+00	0.21657516E+01	0.99922224E+00
31	-0.37500000E+01	0.35872828E+01	0.12863988E+02	0.88636337E+00	0.69389277E+00	0.39486472E+01	0.99922224E+00
32	-0.33750000E+01	0.37743265E+01	0.14245540E+02	0.89079929E+00	0.72385944E+00	0.37997386E+01	0.99922224E+00
33	-0.30000000E+01	0.35228268E+01	0.12410309E+02	0.79410885E+00	0.63080578E+00	0.36997046E+01	0.99922224E+00
34	-0.26250000E+01	0.28550933E+01	0.80373536E+01	0.69079676E+00	0.40842282E+00	0.35953768E+01	0.99922224E+00
35	-0.22500000E+01	0.17730789E+01	0.31435089E+01	0.39968304E+00	0.15974654E+00	0.34755690E+01	0.99922224E+00
36	-0.18750000E+01	0.45579103E+00	0.20774547E+00	0.14274332E+00	0.10596182E+01	0.35148049E+01	0.99922224E+00
37	-0.15000000E+01	0.97954626E+00	0.95951087E+00	0.25080888E+00	0.48755679E+01	0.81861813E+01	0.99922224E+00
38	-0.11250000E+01	0.23337833E+01	0.54465446E+01	0.29075631E+00	0.27675558E+00	0.53169636E+01	0.99922224E+00
39	-0.07500000E+01	0.34487619E+01	0.11893957E+02	0.77741127E+00	0.60436820E+00	0.29551416E+01	0.99922224E+00
40	-0.37500000E+02	0.18108444E+01	0.17481467E+02	0.94248965E+00	0.88826672E+00	0.65647960E+02	0.99922224E+00
41	0.	0.44362125E+01	0.19679980E+02	0.10000000E+01	0.10000000E+01	0.	0.99922224E+00
42	0.37500000E+02	0.41810845E+01	0.17481467E+02	0.94248966E+00	0.88826675E+00	0.65647960E+02	0.99922224E+00
43	0.75000000E+02	0.34487616E+01	0.11893957E+02	0.77741127E+00	0.60436820E+00	0.29551435E+01	0.99922224E+00
44	0.11250000E+01	0.23337833E+01	0.54465448E+01	0.29075646E+00	0.27675558E+00	0.53169636E+01	0.99922224E+00
45	0.15000000E+01	0.97954623E+00	0.95951083E+00	0.25080888E+00	0.48755676E+01	0.81861815E+01	0.99922224E+00
46	0.18750000E+01	0.45579103E+00	0.20774546E+00	0.14274332E+00	0.10596182E+01	0.35148050E+01	0.99922224E+00
47	0.22500000E+01	0.17730789E+01	0.31435088E+01	0.39968304E+00	0.15974653E+00	0.34755690E+01	0.99922224E+00
48	0.26250000E+01	0.28350933E+01	0.80373539E+01	0.69079688E+00	0.40842284E+00	0.35953768E+01	0.99922224E+00
49	0.30000000E+01	0.35228268E+01	0.12410309E+02	0.79410885E+00	0.63080571E+00	0.36997046E+01	0.99922224E+00
50	0.33750000E+01	0.37743265E+01	0.14245541E+02	0.89079938E+00	0.72385944E+00	0.37997386E+01	0.99922224E+00

FAR FIELD RESULTS

I	THETA (MRAU)	MAGNITUDE	INTENSITY	NORM. MAG.	NORM. I/I.T.	NORM. PHASE	NORM. AREA
51	0.3750000E-01	0.35872829E 01	0.12868399E 02	0.80583640E 00	0.6538282E 00	0.3948672E 01	0.6855455E 00
52	0.4125000E-01	0.30159409E 01	0.90958995E 01	0.67984590E 00	0.46219044E 00	-0.2165716E 01	0.7561400E 00
53	0.4500000E-01	0.21603037E 01	0.46669120E 01	0.48697028E 00	0.23744006E 00	-0.1973035E 01	0.7832822E 00
54	0.4875000E-01	0.11498706E 01	0.13222023E 01	0.25920096E 00	0.67185139E-01	-0.1738198E 01	0.7926718E 00
55	0.5250000E-01	0.14613754E 01	0.21356180E-01	0.32941961E-01	0.10891728E-02	-0.9472608E 00	0.7928235E 00
56	0.5625000E-01	0.80995851E 00	0.65603279E 00	0.14257483E 00	0.3335030E-01	-0.16718065E 01	0.7974823E 00
57	0.6000000E-01	0.15211123E 01	0.23137627E 01	0.34288335E 00	0.11737037E 00	0.19827120E 01	0.8139136E 00
58	0.6375000E-01	0.19661412E 01	0.38657113E 01	0.44320267E 00	0.19642860E 00	0.22810405E 01	0.8413600E 00
59	0.6750000E-01	0.21284362E 01	0.45302405E 01	0.47978679E 00	0.23019536E 00	0.26003437E 01	0.8735375E 00
60	0.7125000E-01	0.20355104E 01	0.41433024E 01	0.45883969E 00	0.21053386E 00	0.29543424E 01	0.9029612E 00
61	0.7500000E-01	0.17514219E 01	0.30674785E 01	0.39480116E 00	0.15580796E 00	0.33603359E 01	0.9247449E 00
62	0.7875000E-01	0.13675033E 01	0.1870052E 01	0.30825919E 00	0.95023726E-01	0.38494789E 01	0.9380252E 00
63	0.8250000E-01	0.99457898E 00	0.98918734E 00	0.22619952E 00	0.50263631E-01	-0.18048123E 01	0.9450499E 00
64	0.8625000E-01	0.74995663E 00	0.56183314E 00	0.16896319E 00	0.28548560E-01	-0.94360370E 00	0.9490398E 00
65	0.9000000E-01	0.67825697E 00	0.46003251E 00	0.15389100E 00	0.23375657E-01	-0.8260615E-01	0.9523067E 00
66	0.9375000E-01	0.67680920E 00	0.45807870E 00	0.15256465E 00	0.23275972E-01	0.7140260E 00	0.9555975E 00
67	0.9750000E-01	0.63367354E 00	0.40154216E 00	0.1428411E 00	0.20403584E-01	0.1435032E 01	0.9841131E 00
68	0.1012500E 00	0.53003728E 00	0.28093951E 00	0.11947969E 00	0.14275395E-01	0.22097101E 01	0.9904064E 00
69	0.1050000E 00	0.43803787E 00	0.1987718E 00	0.9474140E-01	0.97488656E-02	0.3197227E 01	0.9917690E 00
70	0.1087500E 00	0.48434697E 00	0.2347897E 00	0.18922937E 00	0.11930182E-01	-0.1971346E 01	0.9934363E 00
71	0.1125000E 00	0.65616511E 00	0.43055265E 00	0.1479111E 00	0.21877696E-01	-0.10927435E 01	0.9964039E 00
72	0.1162500E 00	0.83788680E 00	0.7020528E 00	0.1887436E 00	0.35675523E-01	-0.41921339E 00	0.9714795E 00
73	0.1200000E 00	0.95996511E 00	0.92153302E 00	0.21639299E 00	0.46823900E-01	0.16121331E 00	0.9780238E 00
74	0.1237500E 00	0.99226986E 00	0.98459948E 00	0.22367501E 00	0.50030508E-01	0.69958425E 00	0.9850159E 00
75	0.1275000E 00	0.992927429E 00	0.86359071E 00	0.20947470E 00	0.43899650E-01	0.12157485E 01	0.99114850E 00
76	0.1312500E 00	0.78319604E 00	0.61339603E 00	0.17654610E 00	0.31168527E-01	0.17139000E 01	0.9955045E 00
77	0.1350000E 00	0.57899821E 00	0.33523893E 00	0.13051634E 00	0.17036514E-01	0.21814678E 01	0.99788524E 00
78	0.1387500E 00	0.35195380E 00	0.12359007E 00	0.79246384E 00	0.62799893E-02	0.25555537E 01	0.99876291E 00
79	0.1425000E 00	0.16415078E 00	0.26945477E-01	0.37002460E-01	0.13691820E-02	0.24760833E 01	0.9989542E 00
80	0.1462500E 00	0.19425068E 00	0.37733328E-01	0.43787900E-01	0.19173457E-02	0.17819729E 01	0.99922224E 00
81	0.1500000E 00	0.33037776E 00	0.10951980E 00	0.74599166E-01	0.55650356E-02	0.19918698E 01	0.1000000E 01

FAR FIELD RESULTS
 NUMBER OF POINTS= 41
 X INCREMENT= 0.4000000E-02
 Y INCREMENT= 0.2000000E-01

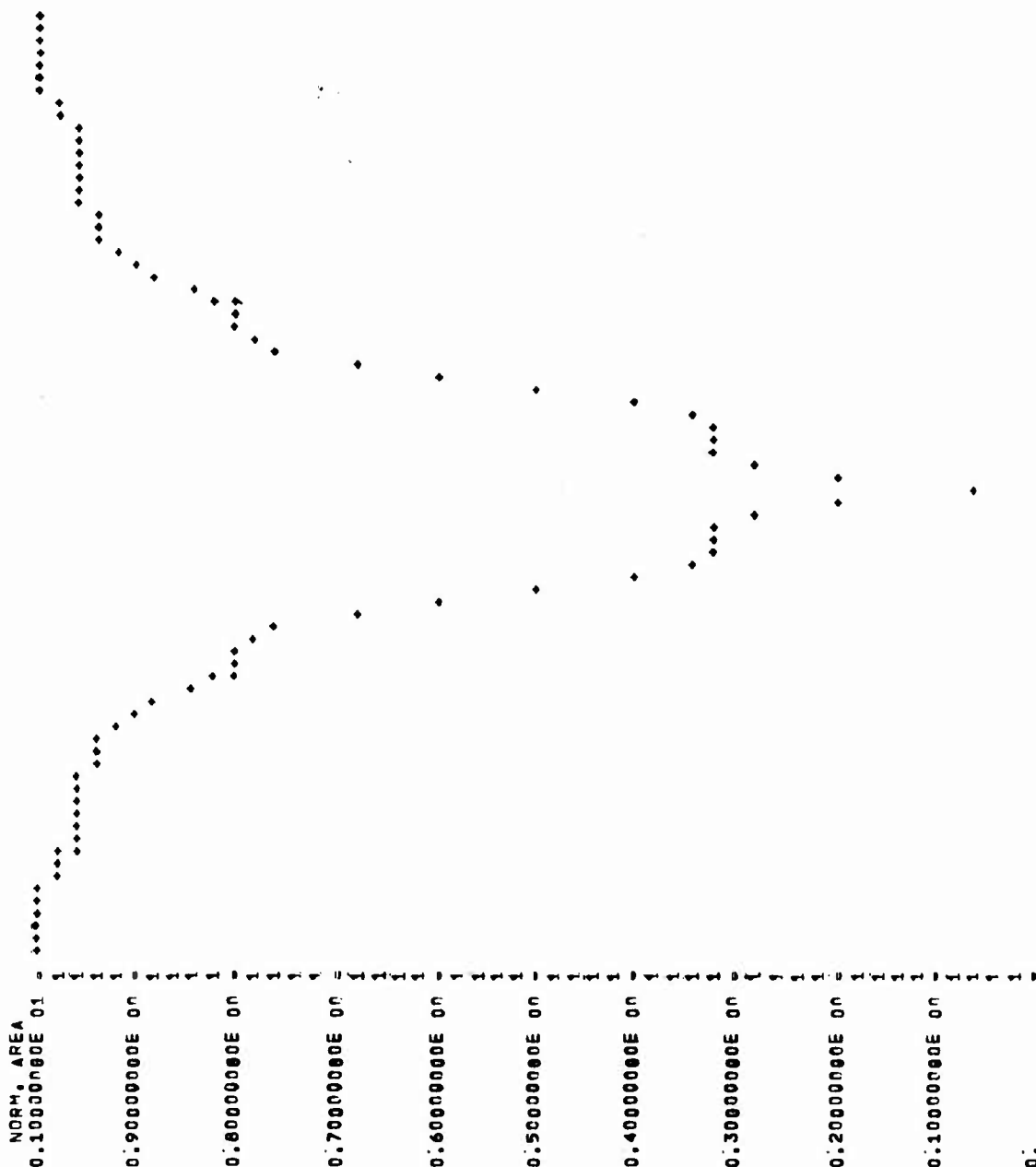




FAR FIELD RESULTS
NUMBER OF POINTS= 81

X INCREMENT= 0.40000000E-02

Y INCREMENT= 0.20000000E-01



THETA (MRAD)

FAR FIELD POWER
WAVE NUMBER 1 0,6336684E 02

STARTING PASS 2

APPENDIX C

SSCP DESCRIPTION AND USAGE

I. PROGRAM DESCRIPTION

A. Summary of the SSCP

The Step-by-Step Computer Program (SSCP) shares a number of attributes with the SSCP(ECS) program described earlier in this manual. As an illustration, three of four satellite routines, two of four utility routines, and all four input/output routines of the SSCP(ECS) program are used by both programs. The three routines which are not shared are peculiar to the SSCP(ECS) package and bear no equivalents in the SSCP solution. All three of the primary routines are different, as one might suspect from the definition of a primary routine, though their logic structure is strikingly similar.

The three primary routines used by the SSCP are

PR23	Main program, defines input, contains overall logic
PRPSBS	Propagates one or more waves through free space
PRPGAI	Propagates one or more waves one way through a medium

The three satellite routines shared with SSCP (ECS) are

GAINA	Returns a set of gain values at a particular location in the medium
MIRROR	Reflects one or more waveforms from a particular mirror
SETMIR	Sets up a mirror vector

The two utility routines shared with SSCP(ECS) are

NORM2D	Two-dimensional area conservation (renormalization) routine
RAT3DA	Three-dimensional area conservation routine

The input/output routines are exactly the same as in the SSCP(ECS), namely

AREA21	Computes and prints the area under a curve
PWROUT	Computes and prints the near field power and power transmitted for one or more waves positioned before the output mirror
RSTART	Restarts a previous run by reading a magnetic tape
ALLOUT	The general purpose master subroutine for the GPOP routines

B. Description of Primary Routines

1. PR23 (Main Program)

All important arrays are declared in PR23 and supplied to subprograms through the argument list or by labeled COMMON. This feature permits the user to alter the size of certain arrays as desired to minimize the storage requirement. All arrays dimensioned in PR23 are related to one or more of four quantities: (1) the maximum number of propagating points in the x-direction, (2) the maximum number of last-pass intensity values stored in the z-direction, (3) the largest number of propagation waves, and (4) the largest number of passes that PR23 can handle. These four values are assigned to variables NXDIM, NZDIM, NWDIM, and NPDIM, respectively, and appear in a DATA statement at sequence number 1860. Table 2 describes the relationship between each subscript of each array and the appropriate quantity involved. The abbreviations used in the table are

TABLE 2. PR23 ARRAY SUBSCRIPT REFERENCES

Array Name	Array Type	Subscript Reference No.		
		1	2	3
T	Complex	X	W	-
U	Complex	X	W	-
V	Complex	X	W	-
XMIR1	Complex	X	-	-
XMIR2	Complex	X	-	-
GAIN	Complex	X	W	-
SO	Real	X	Z	W
SONEW	Real	X	W	-
SOTOT	Real	X	W	-
XLAMDA	Real	W	-	-
XKZERO	Real	W	-	-
AMPINT	Real	W	-	-
INFOUT	Real	P	-	-
WOMEGA	Real	W	-	-
X	Real	X	-	-
SOASR	Real	X	-	-
OUT1	Real	X	-	-
OUT2	Real	X	-	-
OUT3	Real	X	-	-
OUT4	Real	X	-	-
OUT5	Real	X	-	-
OUT6	Real	X	-	-
OUT7	Real	X	-	-

T1100

X $\equiv$ NXDIM

Z $\equiv$ NZDIM

W $\equiv$ NWDIM

P $\equiv$ NPDIM

Should the user need to change one or more of the dimensions of PR23, he should first identify which arrays are affected (by Table II) and then change each array declaration in PR23 to reflect the changed dimension. Last, he should change the appropriate value in the DATA statement at sequence number 1860 so that all subprograms will automatically handle the change.

2. Primary Subprogram Descriptions

Only two subprograms are not shared with the SSCP(ECS), these being the primary subroutines responsible for propagation through free space and propagation through a medium. Their logic structure, however, is almost indistinguishable from their ECS counterparts, differing mainly in the different equations used in propagation. For this reason, no further description of these routines will follow other than a listing for each.

C. Input Description

The SSCP and SSCP(ECS) share exactly the same input method, with all but two variables, NX and XWIDTH, retaining their values independent of the program selected. The considerations to be made when determining values for these two variables are presented in Section I-G of the SSCP(ECS) User's Manual.

II. MACHINE UTILIZATION

The SSCP package is written in FORTRAN IV. The program was originally written for a GE635 computer operating under the GECOS III operating system, though this manual reflects changes made allowing the program to run on a CDC 6000 computer operating with the SCOPE monitor (Version 3.4). This requires about 41k (decimal) or 127K (octal) words of memory, of which

$$\text{NXDIM}[(\text{NZDIM}+8)\text{NWDIM}+13]+\text{NPDIM}+5\text{NWDIM}$$

resides in dimensioned arrays in the main program. For the current dimensioning parameters

$$\text{NXDIM} = 301$$

$$\text{NZDIM} = 21$$

$$\text{NWDIM} = 2$$

$$\text{NPDIM} = 101$$

the total storage required for dimensioned variable storage is 21,480 words (decimal) or 52,000 words (octal).

Processor time depends on too many parameters and option settings to be accurately estimated.

III. LISTINGS

PROGRAM PR23(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE10,TAPE11,
+ TAPE12)

*PR23 PR23--20 STEP-BY-STEP RESONATOR MODEL WITH RESTART

C NXDIM CHANGES REQUIRE 19 STRING REPLACEMENTS OF #3010

C NWAVER CHANGES REQUIRE 7 #.2)S AND 1 #.2.#

C EXTERNAL GAINA

C COMPLEX T(301,2),U(301,2),V(301,2),XMIR1(301),XMIR2(301)
COMPLEX GAIN(301,2)

C DIMENSION SO(301,21,2),SONEN(301,2),SOTOT(301,2)
DIMENSION XLAMDA(2),XKZERO(2),AMPINT(2),WOMEGA(2)
DIMENSION INFOUT(101)

C COMMON/RCUM/RCUM3D(2)
COMMON /XARRAY/X(301)
COMMON /ASPSO/ SOASR(301)
COMMON /OT1/OUT1(301)/OT2/OUT2(301)/OT3/OUT3(301)
COMMON /OT4/OUT4(301)/OT5/OUT5(301)/OT6/OUT6(301)
COMMON /OT7/OUT7(301)
COMMON /CGAINA/ GZERO,XZERO,TEMP(2)

C NAMELIST /CASENO/NCASES
NAMELIST/INPUT/CASE,NPASS,IFILE,IRCODE,ROUT,IRYAG,NX,XWIDTH,
+ NZ,ZLEN,XCENTR,ASR,ZMOLC,ZLENMD,IGSKIP,GZERO,XZERO,
+ NWAVER,XLAMDA,AMPINT,WOMEGA,DIA1,DIA2,REFL1,REFL2,
+ RCURV1,RCURV2,CMEGA2,TILT1,TILT2,TLOSS1,INFOUT
NAMELIST/RUMOPT/NPASS,IFILE,IRCODE,ROUT,IRYAG
NAMELIST/CAVITY/NX,XWIDTH,NZ,ZLEN,XCENTR,DX,DZ
NAMELIST/MEDIUM/ZMOLC,ZLENMD,IGSKIP,
+ NZMEO,NZOIV,NZSTPD,ZLEN1,ZLEN2
NAMELIST /GAINC/GZERO,XZERO

C NAMELIST/WAVES/NWAVER,XLAMDA,AMPINT,WOMEGA,XKZERO,STAB
NAMELIST/HIRRS/DIA1,DIA2,REFL1,REFL2,RCURV1,RCURV2,
+ OMEGA1,OMEGA2,TILT1,TILT2,TLOSS1,ASR,NXC1,NXC2
NAMELIST /NRFLD/INFOUT

C DATA PI/3.14159265/,PROG/4HPR23/
DATA NXDIM,NZOIM,NWDM,NPOIM/301,21,2,101/

C DATA TIME,DATE/1H .1H /
DATA SNMB/1M /

C READ NUMBER OF CASES TO BE ANALYZED AND
INITIALIZE MATRICES BEFORE EACH CASE

C READ(5,CASENO)
DO 999 ICASE=1,NCASES
DO 30 K=1,NWDM
DO 30 I=1,NXDIM
DO 30 J=1,NZOIM
SOTI,J,KI=0.
DO 40 I=1,NPOIM
INFOUT(I)=0

DEFINE INPUT PARAMETERS

1123
1140
1163
1183
1200
1220
1240
1260
1280
1300
1320
1340
1360
1380
1400
1420
1440
1460
1480
1500
1520
1540
1560
1580
1600
1620
1640
1660
1680
1700
1720
1740
1760
1780
1800
1820
1840
1860
1880

1940
1960
1980
2000
2020
2040
2060
2080
2100
2120
2140
2160
2180
2200


```

C-----READ TITLE AND RUN OPTIONS-----
C
60 READ(5, INPUT)
   WRITE (IFILE,9005) PROG,CASE
   WRITE (IFILE,RUNOPT)
C-----DEFINE CAVITY-----
65 DX=XWIDTH/FLOAT(NX-1)
   DZ=ZLEN/FLOAT(NZ-1)
   ICENT = (NX+1)/2
   DO 50 I=1,NX
     X(I)=ICENT+FLOAT(I-ICENT)*DX
50   WRITE (IFILE,CAVITY)
C-----DEFINE MEDIUM-----
70 NZMED=ZLENMD/DZ+.999
   NZSTPD=FLOAT(NZMED+1)/FLOAT(NZDIM)+.999
   IF (NZMED.NE.0) NZDIV=FLOAT(NZMED)/FLOAT(NZSTPD)+.999
   ZLEN1=ATN((2*NOLOC-ZLENMD/2.)/DZ)*DZ
   ZLEN2=ZLEN-ZLENMD-ZLEN1
   WRITE (IFILE,MEDIUM)
C-----DEFINE GAIN CONSTANTS-----
75   WRITE (IFILE,GAINC)
C-----DEFINE WAVE(S)-----
80   XKMAX=-1.E30
   ICENT=(NX+1)/2
   XZERO=X(ICENT)
   DO 110 IWAVE=1,NWAVES
     XKZERO(IWAVE)=2.*PI/XLAMD(IWAVE)
     XKMAX=AMAX1(XKMAX,XKZERO(IWAVE))
     DO 100 I=1,MX
       IF (WOMEGA(IWAVE).EQ.0.) U(I,IWAVE)=AMPINT(IWAVE)
       IF (WOMEGA(IWAVE).NE.0.) U(I,IWAVE)=
         * AMPINT(IWAVE)*EXP(-(X(I)-XZERO)/WOMEGA(IWAVE))**2)
100   CONTINUE
       U(1,IWAVE)=0.
       U(NX,IWAVE)=0.
110   CONTINUE
   STAB=.5*XKMAX*DX*DX
   IF (DZ.GT.STAB) WRITE (IFILE,9007) DZ,STAB
   IF (IRCODE.GT.1) CALL RSTART(IFILE,IRCODE,IRTAG,NWAVES,NXDIM,
     * NZDIM,U,S0)
   WRITE (IFILE,WAVES)
   IF (IRCODE.GT.0) REWIND IRCODE
C-----DEFINE MIRRORS-----
100   NXC1=(DIA1-1.17737*OMEGA1)/DX+.5
       IF (MOD(NXC1,2).NE.0) NXC1=NXC1-1
       NXC2=(DIA2-1.17737*OMEGA2)/DX+.5
       IF (MOD(NXC2,2).NE.0) NXC2=NXC2-1
       CALL SETHIR(NX,NXC1,DX,XKZERO,REFL1,RCURV1,OMEGA1,TILT1,XMIR1)
       CALL SETHIP(NX,NXC2,DX,XKZERO,REFL2,RCURV2,OMEGA2,TILT2,XMIR2)
       WRITE (IFILE,MIRRS)
C-----DEFINE NEAR FIELD PRINT OPTIONS-----
105   WRITE (IFILE,9008) (I,I=1,NPASS)
       WRITE (IFILE,9009) (INOUT(I),I=1,NPASS)
C
C     SETUP 3D CONVERSION MATRIX
C
C     XMAX=DX*FLOAT(NXC2)+2.*OMEGA2

```

```

115 DO 120 I=1,NX
120 SOASR(I)=ASR*ABS(X(I)-X(ICENT))/XMAX
C
C WRITE INPUT MATRICES
C-----MIRRORS-----
CALL ALLOUT(1,1,NX,1.5,19,19,MIRROR DESCRIPTIONS,
+ 1,10,1,1MX,X,OUT1,
+ 2,11,4,12,12,MIRROR 1 INT,XMIR1,OUT2,
+ 2,11,5,14,14,MIRROR 1 PHASE,XMIR1,OUT3,
+ 2,11,4,12,12,MIRROR 2 INT,XMIR2,OUT4,
+ 2,11,5,14,14,MIRROR 2 PHASE,XMIR2,OUT5)
C-----INPUT WAVE(S)-----
DO 140 IMAVE=1,NNAVES
CALL ALLOUT(1,1,NX,1.5,22,22,INPUT WAVE DESCRIPTION,
+ 1,10,1,1MX,X,OUT1,
+ 2,11,3,9,9,MAGNITUDE,U(1,1,IMAVE),OUT2,
+ 2,11,4,9,9,INTENSITY,U(1,1,IMAVE),OUT4,
+ 2,11,6,10,10,PHASE (DG),U(1,1,IMAVE),OUT5,
+ 2,10,0,11,4,9,9,NORM AREA,U(1,1,IMAVE),OUT3)
CALL PRROUT(1,1,NX,NX,1,ASR,DX,OMEGA1,TLOSS1,REFL1,
+ U(1,1,IMAVE),PWRNF,PHROT)
140 CONTINUE
C
C GENERATE RESTART TAPE LABEL
C
IF(IROUT.LE.0) GO TO 200
WRITE(IROUT)TIME,DATE,SNMB,PROG,CASE
NZGAIN=1
IF(NZMED.GT.0) NZGAIN=FLOAT(NZMED)/FLOAT(NZSTPD)+1.9999
WRITE(IROUT)NX,NZGAIN,NNAVES,(I,I=1,7),(X(I),I=1,10)
IPASS=0
WRITE(IROUT)IPASS
WRITE(IROUT) ((U(I,J),I=1,NX),J=1,NNAVES)
WRITE(IROUT) ((S(I,J,K),I=1,NX),J=1,NZGAIN),K=1,NNAVES)
200 CONTINUE
C
C BEGIN MAIN PROPAGATION LOOP
C
DO 900 IPASS=1,NPASS
WRITE(1,901) IPASS,CASE
C-----NORMALIZE PROPAGATION MATRIX, IF NECESSARY-----
IF ((ZLENHD.EQ.5.) .AND. (ASR.EQ.0.))
+ CALL NORM2D(1,1,NX,NX,1,NNAVES,OX,U)
CALL AREA21(1,1,NX,NX,1,NNAVES,2,
+ 24,24,AREA21) AT START OF PASS,DX,U,ASR,AREA20,AREA30)
DO 400 I=1,NNAVES
400 RCUM3D(I)=1.
C-----MAKE ROUND TRIP PASS-----
CALL MIRROR(NNAVES,NX,NX,1,NX,1,NNAVES,2,
CALL AREA21(1,1,NX,NX,1,NNAVES,2,
+ 19,19,AFTER OUTPUT MIRROR,DX,U,ASR,AREA20,AREA30)
CALL PRPSBS(NNAVES,NX,1,NX,1,NNAVES,2,
CALL AREA21(1,1,NX,NX,1,NNAVES,2,
+ 30,30,AFTER STEP-BY-STEP PROPAGATION,DX,U,ASR,AREA20,AREA30)
CALL PRPGA1(ZLEN1,NZSTPD,NZDIV,NX,1,NNAVES,+1,
+ DX,DX,ZLENHD,XKZERO,ASR,T,U,V,SO,SONEN,SOTOT,GAIN,GAINA)

```

```

175      CALL AREA21(1,FILE,NX,NXDIM,NWAVES,2,
+ 12,12,HAFTER MEDIUM,DX,U,ASR,AREA20,AREA3D)
+ CALL PRPSBS(NWAVES,NXDIM,NX,DX,DZ,ZLEN2,ZLEN1,ZLENMD,
+ KKZERO,ASR,T,U,V)
+ CALL AREA21(1,FILE,NX,NXDIM,NWAVES,2,
+ 30,30,HAFTER STEP-BY-STEP PROPAGATION,DX,U,ASR,AREA2D,AREA3D)
+ IF(ASR.GT.0.) WRITE(1,FILE,9090) (RCUM3D(I),I=1,NWAVES)
DO 500 I=1,NWAVES
180      RCUM3D(I)=1.
+ CALL MIRROR(NWAVES,NX,NXDIM,U,V,XMIR2)
+ CALL AREA21(1,FILE,NX,NXDIM,NWAVES,2,
+ 17,17,HAFTER BACK MIRROR,DX,U,ASR,AREA2D,AREA3D)
+ CALL PRPSBS(NWAVES,NXDIM,NX,DX,DZ,ZLEN2,0.,KKZERO,ASR,T,U,V)
+ CALL AREA21(1,FILE,NX,NXDIM,NWAVES,2,
+ 30,30,HAFTER STEP-BY-STEP PROPAGATION,DX,U,ASR,AREA2D,AREA3D)
+ CALL PRGAI(ZLEN2,NZSTPD,NZDIV,NXDIM,NXDIM,NX,ICKSKIP,NWAVES,-1,
+ DX,DZ,ZLENMD,KKZERO,ASR,T,U,V,SO,SONEM,SOTOT,GAIN,GAINA)
190      CALL AREA21(1,FILE,NX,NXDIM,NWAVES,2,
+ 12,12,HAFTER MEDIUM,DX,U,ASR,AREA2D,AREA3D)
+ CALL PRPSBS(NWAVES,NXDIM,NX,DX,DZ,ZLEN1,ZLEN2,ZLENMD,
+ KKZERO,ASR,T,U,V)
+ CALL AREA21(1,FILE,NX,NXDIM,NWAVES,2,
+ 30,30,HAFTER STEP-BY-STEP PROPAGATION,DX,U,ASR,AREA2D,AREA3D)
+ IF(ASR.GT.0.) WRITE(1,FILE,9090) (RCUM3D(I),I=1,NWAVES)
C-----OUTPUT FOR ROUND TRIP PASS-----
WRITE(1,FILE,9060) IPASS
DO 600 I=1,NWAVES
200      CALL PMROUT(1,FILE,NX,NXC1,ASR,DX,OMEGA1,TLOSS1,REFL1,
+ U(1,1,1,1),PHASE,PHROT)
+ IF(INFOUT(IPASS).GE.1)
+ CALL ALLOUT(1,FILE,NX,1,7,27,27,MN,F, RESULTS FOR ROUND TRIP,
+ 1,13,1,1,1,1,X,OUT1,
+ 2,113,9,9,MAGNITUDE,U(1,1,1,1),OUT2,
+ 2,114,9,9,INTENSITY,U(1,1,1,1),OUT3,
+ 2,220,113,10,10,NORM. MAG.,U(1,1,1,1),OUT4,
+ 2,220,114,10,10,NORM. INT.,U(1,1,1,1),OUT5,
+ 2,110,115,11,11,NORM. PHASE,U(1,1,1,1),OUT6,
+ 2,1000,114,10,10,NORM. AREA,U(1,1,1,1),OUT7)
210      CONTINUE
C-----WRITE INFORMATION ON RESTART TAPE-----
IF(1,OUT.GT.0) WRITE(1,OUT) IPASS
IF(1,OUT.GT.0) WRITE(1,OUT) ((U(1,1,1,1),I=1,NX),J=1,NWAVES)
IF(1,OUT.GT.0) WRITE(1,OUT) ((SO(I,1,1,1),I=1,NX),
+ J=1,NZGAIN),K=1,NWAVES)
C-----TERMINATION OF PROPAGATION LOOP-----
900 CONTINUE
C
C      PROGRAM TERMINATION
C
999 IF(1,OUT.GT.0) ENDFILE 1,OUT
STOP
C
C      FORMATS
C
9005 FORMAT(1M1,7MPROGRAM, 5X, A6/1X,4MCASE,8X,F6.2)
9007 FORMAT(1M1,25/(130(1H*)))/30X,7MDelta Z, E20.7,

```

PROGRAM PR23	74/74	OPT=1	FTN 4.0+P357	09/27/73	14.27.23.	PAGE	5
230			+ 2X.31MGREATER THAN STABILITY CRITERIA.E20.7.25(/133 (1H*))) 9008 FORMAT(1H0.11MPASS NUMBER/(1X.43I3)) 9009 FORMAT(1X.17MNF OUTPUT OPTIONS/(1X.40I3)) 9010 FORMAT(1H1.20MSTARTING PASS NUMBER,15,10H FOR CASE ,F6.2) 9060 FORMAT(1H0.20MFINISHED PASS NUMBER,15) 9090 FORMAT(1H0.5X.17MCUMULATIVE RATIOS/(5X.E15.7)) END				
235							

```

SUBROUTINE PRPGAI (ZSTART,NZSTPD,NZD,NXDIM,NZDIM,NX,IGSKIP,IMAVE,
+ IDIR,DX,DZ,ZLEN,XK0,ASR,T,U,V,SO,SOMEN,SOTOT,GAIN,GAINS)
  COMPLEX Y(NXDIM,IMAVE),U(NXDIM,IMAVE),VINXDIM,IMAVE),GY(10),A
  DIMENSION SOMEN(NXDIM,IMAVE),SOTOT(NXDIM,IMAVE),
+ SO(NXDIM,NZDIM,IMAVE)
  COMPLEX GAIN(NXDIM,IMAVE),CMX
  DIMENSION XK0(IMAVE),CEX(10),R(10)
  COMMON /ASR50/SOASR(1)
  -----ASF TO COMPUTE INTENSITY OF A COMPLEX NUMBER-----
  XINTY(A)=REAL(A)*2+AIMAG(A)*2

C-----
C
C-----PRPGAI---PROPAGATES (IMAVE) WAVEFORMS THROUGH A GAIN MEDIUM
C OF LENGTH (ZLEN) ASSUMING CONSTANT DX AND DZ
C-----
C THE PARAMETERS ARE
C
C ZSTART CURRENT DISTANCE FROM LAST MIRROR
C NZSTPD--NO. OF Z-STEPS/DIVISION
C NZD-----NUMBER OF Z-DIVISIONS
C NXDIM--THE X-DIMENSION OF THE SO MATRIX
C NZDIM--THE Z-DIMENSION OF THE SO MATRIX
C NX-----THE NUMBER OF X POINTS
C IGSKIP--SKIP PARAMETER FOR GAIN CALL
C IMAVE--NUMBER OF WAVES TO PROPAGATE
C IDIR--DIRECTION INDICATOR FOR SO ACCESS
C .EQ. 1 INCREASING Z
C .EQ. -1 DECREASING Z
C DX-----DELTA X FOR PROPAGATION MATRIX
C DZ-----DELTA Z FOR ONE PROPAGATION STEP (APPROXIMATE,
C ADJUSTED SLIGHTLY BY ROUTINE)
C ZLEN-----TOTAL PROPAGATION LENGTH
C XK0-----K = 2 PI/LAMBDA (DIM. AT LST IMAVE)
C ASR-----3D AREA ADJUSTMENT FACTOR (SWITCH FOR CALL TO RAT3DA)
C Y-----DUMMY MATRIX (COMPLEX, DIM. NXDIM BY IMAVE)
C U-----INPUT/ OUTPUT WAVE MATRIX (COMPLEX)
C V-----DUMMY MATRIX (COMPLEX)
C SO-----INTENSITY MATRIX (REAL, DIM. NXDIM BY NZDIM BY IMAVE)
C SOMEN--DUMMY MATRIX (DIM. NXDIM BY IMAVE)
C SOTOT--DUMMY MATRIX (DIM. NXDIM BY IMAVE)
C GAIN--GAIN MATRIX (REAL, DIMENSIONED NXDIM BY IMAVE)
C GAINS--GAIN ROUTINE NAME (TYPED EXTERNAL IN MAIN PROGRAM)
C
C SUBPROGRAMS NECESSARY--GAINS,RAT3DA
C
C CHANGED 1-25-73
C CHANGED 9/19/73 (ZSTART ADDED--SKIPS BPROP WHEN .GT. 0.)
C-----
C
  IGCNT=0
  NXM1=NX-1
  IF (ZLEN.LE.0.) GO TO 999
  -----COMPUTE PROPAGATION CONSTANTS-----
  DO 20 JMAVE=1,IMAVE
    EX=DZ/(XK0(JMAVE)*DX*DX)
    CEX(JMAVE)=EX*EX
  20 CONTINUE
  999

```

```

60      20      R(JWAVE)=1./((1.+CEX(JWAVE))
        C      GY(JWAVE)=EX*(0.,1.)
        C
        C      PROPAGATE OVER DISTANCE ZLEN USING NZD*NZSTPD STEPS
65      C-----COMPUTE SUM OF OLD AND NEW INTENSITIES-----
        DO 500 IZD=1,NZD
        DO 300 J=1,NZSTPD
        R1=FLOAT(J-1)/FLOAT(NZSTPD)
        DO 50 JWAVE=1,IMAVE
        DO 50 K=1,NX
        SK=XINTY(U(K,JWAVE))
        IF (IDIR.NE.(-1)) L=IZD
        IF (IDIR.EQ.(-1)) L=NZD+2-IZD
        IF (IDIR.NE.(-1)) L2=L+1
        IF (IDIR.EQ.(-1)) L2=L-1
        IF (J.NE.1) GO TO 40
        SOTOT(K,JWAVE)=SOTOT(K,L,JWAVE)
        SONEW(K,JWAVE)=SK
        GO TO 45
40      SOTOT(K,JWAVE)=SOTOT(K,L,JWAVE)+R1*(SOTOT(K,L2,JWAVE)-SOTOT(K,L,JWAVE))
45      SOTOT(K,JWAVE)=SOTOT(K,JWAVE)+SK
50      IF (ASR.NE.0.) SOTOT(K,JWAVE)=SOTOT(K,JWAVE)*SOASR(K)
        C-----COMPUTE GAIN FOR FOLLOWING PROPAGATION STEP-----
        IF (MOD(IGCNT,IGSKIP).EQ.0) CALL GAINS(NX,NXDIM,IMAVE,SOTOT,GAIN)
        IGCNT=IGCNT+1
        C-----PROPAGATE ONE STEP-----
        IF (ZSTART.GT.0. .OR. (IZD+J).GT.2) GO TO 200
        C----- (PROP STEP) -----
        DO 120 I=2,NXM1
        V(I,JWAVE)=U(I,JWAVE)+GY(JWAVE)/2.)*(U(I+1,JWAVE)-
        + 2.*U(I,JWAVE)+U(I-1,JWAVE))
        GO TO 280
        C----- (PROP STEP) -----
200      DO 250 JWAVE=1,IMAVE
        DO 250 I=2,NXM1
        V(I,JWAVE)=
        + R(JWAVE)*(U(I,JWAVE)+GY(JWAVE)*(U(I+1,JWAVE)-2.*U(I,JWAVE)+
        + U(I-1,JWAVE))
        + CEX(JWAVE)*(U(I+1,JWAVE)-T(I,JWAVE)+U(I-1,JWAVE)))
        IF (ASR.NE.0.) CALL RAT3DA(NX,NXDIM,IMAVE,OX,OX,V,U)
        C-----MOVE ARRAYS COMN AND APPLY GAIN-----
280      DO 290 JWAVE=1,IMAVE
        DO 290 I=2,NXM1
        GNX=CEXP(OZZ*CMPLX(1.5*REAL(GAIN(I,JWAVE)),AIMAG(GAIN(I,JWAVE))))
        T(I,JWAVE)=U(I,JWAVE)*GNX
        U(I,JWAVE)=V(I,JWAVE)*GNX
        C-----LOAD NEW LINE INTO PAST INTENSITIES MATRIX-----
300      CONTINUE
        DO 400 JWAVE=1,IMAVE
        DO 400 I=1,NX
        SO(I,L,JWAVE)=SONEW(I,JWAVE)
        C-----ADJUST V AND SO MATRICES AT Z=ZLEN-----
500      CONTINUE
        DO 600 JWAVE=1,IMAVE
        DO 600 I=1,NX

```

SUBROUTINE PRPSAI 74/74 OPT=1 FTN 4.C+P357 09/27/73 14.27.35. PAGE 3

```
115      V(I,JWAVE)=0(I,JWAVE)
      600  SO(I,L2,JWAVE)=XINTY(V(I,JWAVE))
      C-----PROPAGATION TC Z=ZLEN COMPLETE-----
      999  RETURN
          END
      8180
      8200
      8220
      8240
      8260
```

```

5      SUBROUTINE PRPSBS(IMAVE,NXDIM,NX,DX,DZ,ZLEN,ZSTART,XK0,ASR,T,U,V)
      COMPLEX I(NXDIM,IMAVE),U(NXDIM,IMAVE),V(NXDIM,IMAVE),GY(10)
      DIMENSION XK0(IMAVE),CEX(10),R(10)
      C-----
      C--PRPSBS---PROPAGATES A WAVEFORM OVER A DISTANCE ZLEN ASSUMING
      C      CONSTANT DX AND DZ
      C
      C      THE PARAMETERS ARE
      C
      C IMAVE---THE NUMBER OF PROPAGATING WAVES
      C NXDIM---THE X-DIMENSION OF THE PROPAGATION MATRIX
      C NX-----THE NUMBER OF X POINTS
      C DX-----DELTA X FOR PROPAGATION MATRIX
      C DZ-----DELTA Z FOR PROPAGATION STEP (APPROXIMATE--ADJUSTED
      C      SLIGHTLY BY ROUTINE)
      C ZLEN---TOTAL PROPAGATION LENGTH
      C ZSTART CURRENT DISTANCE FROM LAST MIRROR
      C XK0---K = 2 PI/LAMBDA (VECTOR, DIM AT LST IMAVE)
      C ASR---30 AREA ADJUSTMENT FACTOR (USED FOR SWITCH FOR RAT3DA)
      C T-----DUMMY MATRIX (COMPLEX, DIMENSIONED NXDIM BY IMAVE)
      C U-----INPUT WAVE/OUTPUT WAVE MATRIX (COMPLEX)--IS MODIFIED
      C V-----DUMMY VECTOR (COMPLEX)
      C
      C SUBPROGRAMS NECESSARY--RAT3DA (IF ASR .NE. 0.)
      C
      C CHANGED 9/19/73 (ZSTART ADDED--SKIPS 8PROP WHEN .GT. 0.)
      C-----
30      IF (ZLEN.LE.0.) GO TO 999
      NXMI=NX-1
      NSTEP=ZLEN/DZ+.9999
      DZ=ZLEN/FLOAT(NSTEP)
      C-----COMPUTE PROPAGATION CONSTANTS-----
      DO 50 JMAVE=1,IMAVE
      EX=DZ/(XK0(JMAVE)*DX*DX)
      CEX(JMAVE)=EX*EX
      R(JMAVE)=1./((1.+CEX(JMAVE))
      GY(JMAVE)=EX*(0.,1.)
      C-----TAKE ONE 8PROP STEP-----
      IF (ZSTART.GT.0.) GO TO 200
      DO 150 JMAVE=1,IMAVE
      DO 100 I=2,NXMI
      V(I,JMAVE)=U(I,JMAVE)+(GY(JMAVE)/2.)*
      + (U(I+1,JMAVE)-2.*U(I,JMAVE)+U(I-1,JMAVE))
      V(I+1,JMAVE)=0.
      V(NX,JMAVE)=0.
      DO 170 JMAVE=1,IMAVE
      DO 170 I=1,NX
      T(I,JMAVE)=U(I,JMAVE)
      U(I,JMAVE)=V(I,JMAVE)
      170 U(I,JMAVE)=V(I,JMAVE)
      IF (NSTEP.EQ.1) GO TO 999
      C-----TAKE (NSTEP-1) PROPAGATION STEPS-----
      200 CONTINUE
      DO 500 JMAVE=1,IMAVE
      DO 400 J=2,NSTEP

```



```

60      DO 300 I=2,NXM1
          V(I,JWAVE)=
          + R(JWAVE)*(T(I,JWAVE)+GY(JWAVE)*(U(I+1,JWAVE)-2.*T(I,JWAVE)+
          + U(I-1,JWAVE))+CEX(JWAVE)*(U(I+1,JWAVE)-T(I,JWAVE)+U(I-1,JWAVE)))
          300 CONTINUE
          IF(ASR.NE.0.) CALL RAT3DA(NX,NXDIM,IMAVE,OX,OX,V,U)
          DO 350 I=1,NX
            T(I,JWAVE)=U(I,JWAVE)
            U(I,JWAVE)=V(I,JWAVE)
          350 CONTINUE
          400 CONTINUE
          500 CONTINUE
          999 RETURN
          70      END
          9460
          9480
          9500
          9523
          9540
          9563
          9580
          9600
          9620
          9640
          9660
          9680
          9700

```

APPENDIX D

SAMPLE CASE FOR SSCP(ECS)

The case (named "8.45") described by the input data below involves 10 round-trip passes with restart information to be written on file code 10 (a control card must appear elsewhere in the deck assigning file code 10 to a new, or scratch, magnetic tape) and normal program output to be directed to file code 6. The input, or starting, waveform for this case is not to be taken from a restart tape but is, instead, to be generated by parameters described below. The number of mesh points along the x-axis (across the face of a mirror) is to be 81, and the minimum width over which these 81 points are to be defined is 9 cm (see Fig. 4). There are to be 101 mesh points (100 steps) between mirrors, where the mirrors are 10,000 cm apart. The x-value of the mirror centerline is to be 0. The analysis will be two-dimensional (ASR = 0.). The medium, whose center is located 5000 cm from the output mirror, is to be 5000 cm in width, thereby filling half the cavity. The gain routine, to be called at every propagation step in the Z-direction, is supplied two parameters - g_0 and I_0 , with values 3.5×10^{-4} and 100., respectively. One wave of wavelength 3×10^{-4} cm and uniform initial amplitude 1.0 is to be propagated. The initial wave does not have a gaussian structure. The output mirror has a diameter of 5.74 cm, 100% reflectivity, a radius of curvature of -2×10^4 cm, an edge taper of 0.45 cm, no tilt, and no loss in the mirror itself (meaningless in this case since the reflectivity was total). The back mirror has a diameter of 11.1 cm, 100% reflectivity, a radius of curvature of 4×10^4 cm, an edge taper of 0.6 cm, and no tilt. Normal output is desired for all 10 passes.

Sample Input Deck

(column 2)

```
$CASENO NCASES=1$
```

```
$INPUT
```

```
CASE=8.45, NPASS=10, IFILE=6, IRCODE=0, IROUT=10,  
IRTAG=0, NX=81, XWIDTH=9., NZ=101, ZLEN=10000.,  
XCENTR=0., ASR=0., ZMDLOC=5000., ZLENMD=5000.,  
IGSKIP=1, GZERO=3.5E-4, XIZERO=100., NWAVES=1,  
XLAMDA(1)=3.E-4, AMPINT(1)=1., WOMEGA(1)=0.,  
DIA1=5.74, REFL1=1.0, RCURV1=-2.E4, OMEGA1=.45,  
TILT1=0., TLOSS1=0., DIA2=11.1, REFL2=1.0, RCURV2=4.E4,  
OMEGA2=.6, TILT2=0., INFOUT(1)=10*1$
```

The output produced by either the SSCP or SSCP(ECS) for the data above consists of three major groups. The two that are not optional are the summation of the data input defining the case and the summary information printed during each round-trip propagation. The first includes the following information:

1. Repetition of the information read
2. Descriptions of both mirror matrices (intensity and phase listings and plots for each)
3. Description of each input wave (magnitude, intensity, phase, and normalized area listings and plots for each).

The round-trip summary information is self-explanatory, basically monitoring the area of the propagating wave as it proceeds through a round-trip pass.

The third type of output (optional) that can be produced summarizes the waveform itself at the conclusion of a round-trip pass. The magnitude, intensity, normalized magnitude, normalized intensity, normalized phase, and normalized area are listed and plotted versus their corresponding x-location.

The following pages represent the output produced by the sample data case. All three types of output are represented.

```

PROGRAM PR51
CASE 8.45

NAMELIST RUNOPT
NPASS 10 IFILE 6 IRCODE 0 IRCUT 10 IRTAG 0
END NAMELIST RUNOPT

NAMELIST CAVITY
NX 81
XWIDTH 0.9000000E 01
NZ 101
ZLEN 0.1000000E 05
ASP 0.
VR1 0.1000000E 05
ISHIFT 4 NG
END NAMELIST CAVITY

NAMELIST MEDIUM
ZNDLOC 0.9000000E 04
IGSKIP 1 NZHD
ZLEN1 0.2500000E 04
ZLEN2 0.2500000E 04
END NAMELIST MEDIUM

NAMELIST GAINC
GZERO 0.3500000E-03
END NAMELIST GAINC

NAMELIST WAVES 1
WAVES 1
XLAMDA11 0.3000000E-03 0.
AMPINT11 0.1000000E 01 0.
WOMEGA11 0.
XKZEBO11 0.
STAB 1 0.20943951E 03 0.
END NAMELIST WAVES

NAMELIST MIRRS
DIA1 0.5740000E 01
OMEGA1 0.4500000E 00
TLOSS1 0.
NXC1 46 NXC2 45 NXCOUT 23
END NAMELIST MIRRS

NAMELIST REFLECT
REFL1 0.1000000E 01
YILT1 0.
REFL2 0.1000000E 01
YILT2 0.
END NAMELIST REFLECT

NAMELIST CURV
RCURV1 0.2000000E 05
DXMIR1 0.1125000E 00
VR2 0.1000000E 31
RCURV2 0.4000000E 05
DXMIR2 0.2250000E 00
G1 0.6066666E 00
G2 0.2250000E 00
XCENTR 0.
DXOUT 0.2250000E 00
END NAMELIST CURV

NAMELIST XCENTR
XCENTR 0.
DXOUT 0.2250000E 00
G2 0.1333333E 01
END NAMELIST XCENTR

NAMELIST WZSTPD
WZSTPD 17
END NAMELIST WZSTPD

NAMELIST XZERO
XZERO 0.1000000E 03
END NAMELIST XZERO

NAMELIST PASS
PASS NUMBER 1 2 3 4 5 6 7 8 9 10
NF OUTPUT OPTIONS 1 1 1 1 1 1 1 1 1 1

```

MIRROR DESCRIPTIONS

I	MIRROR 1 X	MIRROR 1 INT	MIRROR 1 PHASE	MIRROR 2 X	MIRROR 2 INT	MIRROR 2 PHASE
1	0.4500000E 01	0.20469717E-15	0.	0.90000000E 01	0.50118913E-35	0.
2	0.43875000E 01	0.12664166E-13	0.	0.87750000E 01	0.53801461E-31	0.
3	0.42750000E 01	0.41019367E-12	0.	0.85500000E 01	0.32908078E-27	0.
4	0.41625000E 01	0.22897348E-10	0.	0.83249999E 01	0.11468766E-23	0.
5	0.40500000E 01	0.6615861E-09	0.	0.81000000E 01	0.22774057E-20	0.
6	0.39375000E 01	0.15229980E-07	0.	0.78750000E 01	0.25767571E-17	0.
7	0.38250000E 01	0.26995786E-06	0.	0.76500000E 01	0.16611770E-14	0.
8	0.37125000E 01	0.37266532E-05	0.	0.74250000E 01	0.61019381E-12	0.
9	0.36000000E 01	0.40065298E-04	0.	0.72000000E 01	0.12771116E-09	0.
10	0.34875000E 01	0.33546263E-03	0.	0.69750000E 01	0.15229980E-07	0.
11	0.33750000E 01	0.21874911E-02	0.	0.67500000E 01	0.10348542E-05	0.
12	0.32625000E 01	0.11108997E-01	0.	0.65250000E 01	0.40065298E-04	0.
13	0.31500000E 01	0.43336934E-01	0.	0.63000000E 01	0.86382636E-03	0.
14	0.30375000E 01	0.13533529E 00	0.	0.60750000E 01	0.11108997E-01	0.
15	0.29250000E 01	0.32465247E 00	0.	0.58500000E 01	0.79559509E-01	0.
16	0.28125000E 01	0.60653067E 00	0.	0.56250000E 01	0.32465247E 00	0.
17	0.27000000E 01	0.88249690E 00	0.	0.54000000E 01	0.75483961E 00	0.
18	0.25875000E 01	0.10000000E 01	0.	0.51750000E 01	0.10000000E 01	0.
19	0.24750000E 01	0.10000000E 01	0.	0.49500000E 01	0.10000000E 01	0.
20	0.23625000E 01	0.10000000E 01	0.	0.47250000E 01	0.10000000E 01	0.
21	0.22500000E 01	0.10000000E 01	0.	0.45000000E 01	0.10000000E 01	0.
22	0.21375000E 01	0.10000000E 01	0.	0.42750000E 01	0.10000000E 01	0.
23	0.20250000E 01	0.10000000E 01	0.	0.40500000E 01	0.10000000E 01	0.
24	0.19125000E 01	0.10000000E 01	0.	0.38250000E 01	0.10000000E 01	0.
25	0.18000000E 01	0.10000000E 01	0.	0.36000000E 01	0.10000000E 01	0.
26	0.16875000E 01	0.10000000E 01	0.	0.33750000E 01	0.10000000E 01	0.
27	0.15750000E 01	0.10000000E 01	0.	0.31500000E 01	0.10000000E 01	0.
28	0.14625000E 01	0.10000000E 01	0.	0.29250000E 01	0.10000000E 01	0.
29	0.13500000E 01	0.10000000E 01	0.	0.27000000E 01	0.10000000E 01	0.
30	0.12375000E 01	0.10000000E 01	0.	0.24750000E 01	0.10000000E 01	0.
31	0.11250000E 01	0.10000000E 01	0.	0.22500000E 01	0.10000000E 01	0.
32	0.10125000E 01	0.10000000E 01	0.	0.20250000E 01	0.10000000E 01	0.
33	0.90000000E 00	0.10000000E 01	0.	0.18000000E 01	0.10000000E 01	0.
34	0.78750000E 00	0.10000000E 01	0.	0.15750000E 01	0.10000000E 01	0.
35	0.67500000E 00	0.10000000E 01	0.	0.13500000E 01	0.10000000E 01	0.
36	0.56250000E 00	0.10000000E 01	0.	0.11250000E 01	0.10000000E 01	0.
37	0.45000000E 00	0.10000000E 01	0.	0.90000000E 00	0.10000000E 01	0.
38	0.33750000E 00	0.10000000E 01	0.	0.67500000E 00	0.10000000E 01	0.
39	0.22500000E 00	0.10000000E 01	0.	0.45000000E 00	0.10000000E 01	0.
40	0.11250000E 00	0.10000000E 01	0.	0.22500000E 00	0.10000000E 01	0.
41	0.	0.10000000E 01	0.	0.	0.10000000E 01	0.
42	0.11250000E 00	0.10000000E 01	0.	0.22500000E 00	0.10000000E 01	0.
43	0.22500000E 00	0.10000000E 01	0.	0.45000000E 00	0.10000000E 01	0.
44	0.33750000E 00	0.10000000E 01	0.	0.67500000E 00	0.10000000E 01	0.
45	0.45000000E 00	0.10000000E 01	0.	0.90000000E 00	0.10000000E 01	0.
46	0.56250000E 00	0.10000000E 01	0.	0.11250000E 01	0.10000000E 01	0.
47	0.67500000E 00	0.10000000E 01	0.	0.13500000E 01	0.10000000E 01	0.
48	0.78750000E 00	0.10000000E 01	0.	0.15750000E 01	0.10000000E 01	0.
49	0.90000000E 00	0.10000000E 01	0.	0.18000000E 01	0.10000000E 01	0.
50	0.10125000E 01	0.10000000E 01	0.	0.20250000E 01	0.10000000E 01	0.

MIRROR DESCRIPTIONS

I	MIRROR 1 X	MIRROR 1 INT	MIRROR 1 PHASE	MIRROR 2 X	MIRROR 2 INT	MIRROR 2 PHASE
51	0.1125000E 01	0.1000000E 01	0.	0.2250000E 01	0.1000000E 01	0.
52	0.1250000E 01	0.1000000E 01	0.	0.2475000E 01	0.1000000E 01	0.
53	0.1350000E 01	0.1000000E 01	0.	0.2700000E 01	0.1000000E 01	0.
54	0.1462500E 01	0.1000000E 01	0.	0.2925000E 01	0.1000000E 01	0.
55	0.1575000E 01	0.1000000E 01	0.	0.3150000E 01	0.1000000E 01	0.
56	0.1687500E 01	0.1000000E 01	0.	0.3375000E 01	0.1000000E 01	0.
57	0.1800000E 01	0.1000000E 01	0.	0.3600000E 01	0.1000000E 01	0.
58	0.1912500E 01	0.1000000E 01	0.	0.3825000E 01	0.1000000E 01	0.
59	0.2025000E 01	0.1000000E 01	0.	0.4050000E 01	0.1000000E 01	0.
60	0.2137500E 01	0.1000000E 01	0.	0.4275000E 01	0.1000000E 01	0.
61	0.2250000E 01	0.1000000E 01	0.	0.4500000E 01	0.1000000E 01	0.
62	0.2362500E 01	0.1000000E 01	0.	0.4725000E 01	0.1000000E 01	0.
63	0.2475000E 01	0.1000000E 01	0.	0.4950000E 01	0.1000000E 01	0.
64	0.2587500E 01	0.1000000E 01	0.	0.5175000E 01	0.1000000E 01	0.
65	0.2700000E 01	0.1000000E 01	0.	0.5400000E 01	0.1000000E 01	0.
66	0.2812500E 01	0.1000000E 01	0.	0.5625000E 01	0.1000000E 01	0.
67	0.2925000E 01	0.1000000E 01	0.	0.5850000E 01	0.1000000E 01	0.
68	0.3037500E 01	0.1000000E 01	0.	0.6075000E 01	0.1000000E 01	0.
69	0.3150000E 01	0.1000000E 01	0.	0.6300000E 01	0.1000000E 01	0.
70	0.3262500E 01	0.1000000E 01	0.	0.6525000E 01	0.1000000E 01	0.
71	0.3375000E 01	0.1000000E 01	0.	0.6750000E 01	0.1000000E 01	0.
72	0.3487500E 01	0.1000000E 01	0.	0.6975000E 01	0.1000000E 01	0.
73	0.3600000E 01	0.1000000E 01	0.	0.7200000E 01	0.1000000E 01	0.
74	0.3712500E 01	0.1000000E 01	0.	0.7425000E 01	0.1000000E 01	0.
75	0.3825000E 01	0.1000000E 01	0.	0.7650000E 01	0.1000000E 01	0.
76	0.3937500E 01	0.1000000E 01	0.	0.7875000E 01	0.1000000E 01	0.
77	0.4050000E 01	0.1000000E 01	0.	0.8100000E 01	0.1000000E 01	0.
78	0.4162500E 01	0.1000000E 01	0.	0.8324999E 01	0.1000000E 01	0.
79	0.4275000E 01	0.1000000E 01	0.	0.8550000E 01	0.1000000E 01	0.
80	0.4387500E 01	0.1000000E 01	0.	0.8775000E 01	0.1000000E 01	0.
81	0.4500000E 01	0.1000000E 01	0.	0.9000000E 01	0.1000000E 01	0.

MIRROR DESCRIPTIONS
NUMBER OF POINTS 01

X INCREMENT= 0.81818182E-01

Y INCREMENT= 0.20000000E-01

MIRROR 1 INT
0.10000000E 01

0.90000000E 00

0.80000000E 00

0.70000000E 00

0.60000000E 00

0.50000000E 00

0.40000000E 00

0.30000000E 00

0.20000000E 00

0.10000000E 00

0.20469717E-15

0.45000000E 01
0.28636364E 01
-0.36818182E 01
-0.20454545E 01
-0.40909091E 80
0.12272727E 01
0.20454545E 01
0.28636364E 01
0.36818182E 01
0.45000000E 01

MIRROR 1 X

MIRROR 1 X

(Note – page is empty because phase at each. point = 0)

MIRROR DESCRIPTIONS
NUMBER OF PRINTS= 81

X INCREMENT= 0.16363636E 00

Y INCREMENT= 0.

MIRROR 2 PHASE

0:

0:

0:

0:

0:

0:

0:

0:

0:

0:

0:

(Note — page is empty because phase at each point = 0)

0.9000000E 01 0.572727E 01 0.2454545E 01 0.818181E 00 0.4090909E 01 0.7363636E 01 0.572727E 01 0.2454545E 01 0.818181E 00 0.4090909E 01 0.7363636E 01 0.900000E 01

MIRROR 2 X

INPUT WAVE DESCRIPTION

	X	MAGNITUDE	INTENSITY	PHASE (DG)	NORM AREA
1					
2	=0.90000000E 01	0.	0.10000000E 01	=0.50000000E 00	0.10000000E 01
3	=0.87750000E 01	0.10000000E 01	0.10000000E 01	0.	0.97468355E 00
4	=0.85500000E 01	0.10000000E 01	0.10000000E 01	0.	0.94936709E 00
5	=0.83249999E 01	0.10000000E 01	0.10000000E 01	0.	0.92405064E 00
6	=0.81000000E 01	0.10000000E 01	0.10000000E 01	0.	0.89873417E 00
7	=0.78750000E 01	0.10000000E 01	0.10000000E 01	0.	0.87341772E 00
8	=0.76500000E 01	0.10000000E 01	0.10000000E 01	0.	0.84810127E 00
9	=0.74250000E 01	0.10000000E 01	0.10000000E 01	0.	0.82278481E 00
10	=0.72000000E 01	0.10000000E 01	0.10000000E 01	0.	0.79746836E 00
11	=0.69750000E 01	0.10000000E 01	0.10000000E 01	0.	0.77215190E 00
12	=0.67500000E 01	0.10000000E 01	0.10000000E 01	0.	0.74683544E 00
13	=0.65250000E 01	0.10000000E 01	0.10000000E 01	0.	0.72151899E 00
14	=0.63000000E 01	0.10000000E 01	0.10000000E 01	0.	0.69620253E 00
15	=0.60750000E 01	0.10000000E 01	0.10000000E 01	0.	0.67088608E 00
16	=0.58500000E 01	0.10000000E 01	0.10000000E 01	0.	0.64556962E 00
17	=0.56250000E 01	0.10000000E 01	0.10000000E 01	0.	0.62025317E 00
18	=0.54000000E 01	0.10000000E 01	0.10000000E 01	0.	0.59493671E 00
19	=0.51750000E 01	0.10000000E 01	0.10000000E 01	0.	0.56962029E 00
20	=0.49500000E 01	0.10000000E 01	0.10000000E 01	0.	0.54430380E 00
21	=0.47250000E 01	0.10000000E 01	0.10000000E 01	0.	0.51898734E 00
22	=0.45000000E 01	0.10000000E 01	0.10000000E 01	0.	0.49367088E 00
23	=0.42750000E 01	0.10000000E 01	0.10000000E 01	0.	0.46835443E 00
24	=0.40500000E 01	0.10000000E 01	0.10000000E 01	0.	0.44303798E 00
25	=0.38250000E 01	0.10000000E 01	0.10000000E 01	0.	0.41772152E 00
26	=0.36000000E 01	0.10000000E 01	0.10000000E 01	0.	0.39240506E 00
27	=0.33750000E 01	0.10000000E 01	0.10000000E 01	0.	0.36708861E 00
28	=0.31500000E 01	0.10000000E 01	0.10000000E 01	0.	0.34177215E 00
29	=0.29250000E 01	0.10000000E 01	0.10000000E 01	0.	0.31645570E 00
30	=0.27000000E 01	0.10000000E 01	0.10000000E 01	0.	0.29113924E 00
31	=0.24750000E 01	0.10000000E 01	0.10000000E 01	0.	0.26582278E 00
32	=0.22500000E 01	0.10000000E 01	0.10000000E 01	0.	0.24050633E 00
33	=0.20250000E 01	0.10000000E 01	0.10000000E 01	0.	0.21518987E 00
34	=0.18000000E 01	0.10000000E 01	0.10000000E 01	0.	0.18987342E 00
35	=0.15750000E 01	0.10000000E 01	0.10000000E 01	0.	0.16455696E 00
36	=0.13500000E 01	0.10000000E 01	0.10000000E 01	0.	0.13924051E 00
37	=0.11250000E 01	0.10000000E 01	0.10000000E 01	0.	0.11392405E 00
38	=0.90000000E 00	0.10000000E 01	0.10000000E 01	0.	0.88607595E-01
39	=0.67500000E 00	0.10000000E 01	0.10000000E 01	0.	0.63291139E-01
40	=0.45000000E 00	0.10000000E 01	0.10000000E 01	0.	0.37974684E-01
41	=0.22500000E 00	0.10000000E 01	0.10000000E 01	0.	0.12658228E-01
42	0.	0.10000000E 01	0.10000000E 01	0.	0.12658228E-01
43	=0.22500000E 00	0.10000000E 01	0.10000000E 01	0.	0.37974684E-01
44	=0.45000000E 00	0.10000000E 01	0.10000000E 01	0.	0.63291139E-01
45	=0.67500000E 00	0.10000000E 01	0.10000000E 01	0.	0.88607595E-01
46	=0.90000000E 00	0.10000000E 01	0.10000000E 01	0.	0.11392405E 00
47	=0.11250000E 01	0.10000000E 01	0.10000000E 01	0.	0.13924051E 00
48	=0.13500000E 01	0.10000000E 01	0.10000000E 01	0.	0.16455696E 00
49	=0.15750000E 01	0.10000000E 01	0.10000000E 01	0.	0.18987342E 00
50	=0.18000000E 01	0.10000000E 01	0.10000000E 01	0.	0.21518987E 00
	=0.20250000E 01	0.10000000E 01	0.10000000E 01	0.	0.24050633E 00

MIRROR DESCRIPTIONS	NUMBER OF POINTS
1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	8
9	9
10	10
11	11
12	12
13	13
14	14
15	15
16	16
17	17
18	18
19	19
20	20
21	21
22	22
23	23
24	24
25	25
26	26
27	27
28	28
29	29
30	30
31	31
32	32
33	33
34	34
35	35
36	36
37	37
38	38
39	39
40	40
41	41
42	42
43	43
44	44
45	45
46	46
47	47
48	48
49	49
50	50
51	51
52	52
53	53
54	54
55	55
56	56
57	57
58	58
59	59
60	60
61	61
62	62
63	63
64	64
65	65
66	66
67	67
68	68
69	69
70	70
71	71
72	72
73	73
74	74
75	75
76	76
77	77
78	78
79	79
80	80
81	81
82	82
83	83
84	84
85	85
86	86
87	87
88	88
89	89
90	90
91	91
92	92
93	93
94	94
95	95
96	96
97	97
98	98
99	99
100	100

X INCREMENT# 0.16363636E 00

Y INCREMENT = 0.

MIRRO 2 PHASE



9

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[illegible]

MIRROR 2 X

(Note -- page is empty because phase at each point = 0)

INPUT WAVE DESCRIPTION

I	X	MAGNITUDE	INTENSITY	PHASE (DG)	NORM AREA
51	0.22500000E 01	0.10000000E 01	0.10000000E 01	0.	0.26582278E 00
52	0.24750000E 01	0.10000000E 01	0.10000000E 01	0.	0.29113924E 00
53	0.27000000E 01	0.10000000E 01	0.10000000E 01	0.	0.31645570E 00
54	0.29250000E 01	0.10000000E 01	0.10000000E 01	0.	0.34177215E 00
55	0.31500000E 01	0.10000000E 01	0.10000000E 01	0.	0.36708861E 00
56	0.33750000E 01	0.10000000E 01	0.10000000E 01	0.	0.39240506E 00
57	0.36000000E 01	0.10000000E 01	0.10000000E 01	0.	0.41772152E 00
58	0.38250000E 01	0.10000000E 01	0.10000000E 01	0.	0.44303798E 00
59	0.40500000E 01	0.10000000E 01	0.10000000E 01	0.	0.46835443E 00
60	0.42750000E 01	0.10000000E 01	0.10000000E 01	0.	0.49367088E 00
61	0.45000000E 01	0.10000000E 01	0.10000000E 01	0.	0.51898734E 00
62	0.47250000E 01	0.10000000E 01	0.10000000E 01	0.	0.54430380E 00
63	0.49500000E 01	0.10000000E 01	0.10000000E 01	0.	0.56962029E 00
64	0.51750000E 01	0.10000000E 01	0.10000000E 01	0.	0.59493671E 00
65	0.54000000E 01	0.10000000E 01	0.10000000E 01	0.	0.62025317E 00
66	0.56250000E 01	0.10000000E 01	0.10000000E 01	0.	0.64556962E 00
67	0.58500000E 01	0.10000000E 01	0.10000000E 01	0.	0.67088608E 00
68	0.60750000E 01	0.10000000E 01	0.10000000E 01	0.	0.69620253E 00
69	0.63000000E 01	0.10000000E 01	0.10000000E 01	0.	0.72151899E 00
70	0.65250000E 01	0.10000000E 01	0.10000000E 01	0.	0.74683544E 00
71	0.67500000E 01	0.10000000E 01	0.10000000E 01	0.	0.77215190E 00
72	0.69750000E 01	0.10000000E 01	0.10000000E 01	0.	0.79746836E 00
73	0.72000000E 01	0.10000000E 01	0.10000000E 01	0.	0.82278481E 00
74	0.74250000E 01	0.10000000E 01	0.10000000E 01	0.	0.84810127E 00
75	0.76500000E 01	0.10000000E 01	0.10000000E 01	0.	0.87341772E 00
76	0.78750000E 01	0.10000000E 01	0.10000000E 01	0.	0.89873417E 00
77	0.81000000E 01	0.10000000E 01	0.10000000E 01	0.	0.92405064E 00
78	0.83249999E 01	0.10000000E 01	0.10000000E 01	0.	0.94936709E 00
79	0.85500000E 01	0.10000000E 01	0.10000000E 01	0.	0.97468355E 00
80	0.87750000E 01	0.10000000E 01	0.10000000E 01	0.	0.10000000E 01
81	0.90000000E 01	0.	0.	=0.50000000E 00	0.10000000E 01

[illegible][illegible]

Y INCREMENTS 0.2000000E+01

INTENSITY
0.1000000E 01 =

0.900000E+00

0:8000000000

0.7000000E 00

0.000000E+00

0.500000E 00

0:40000000E 00 1

0:3000030E 00

0:2000000E 00

0:10000000E 00

0

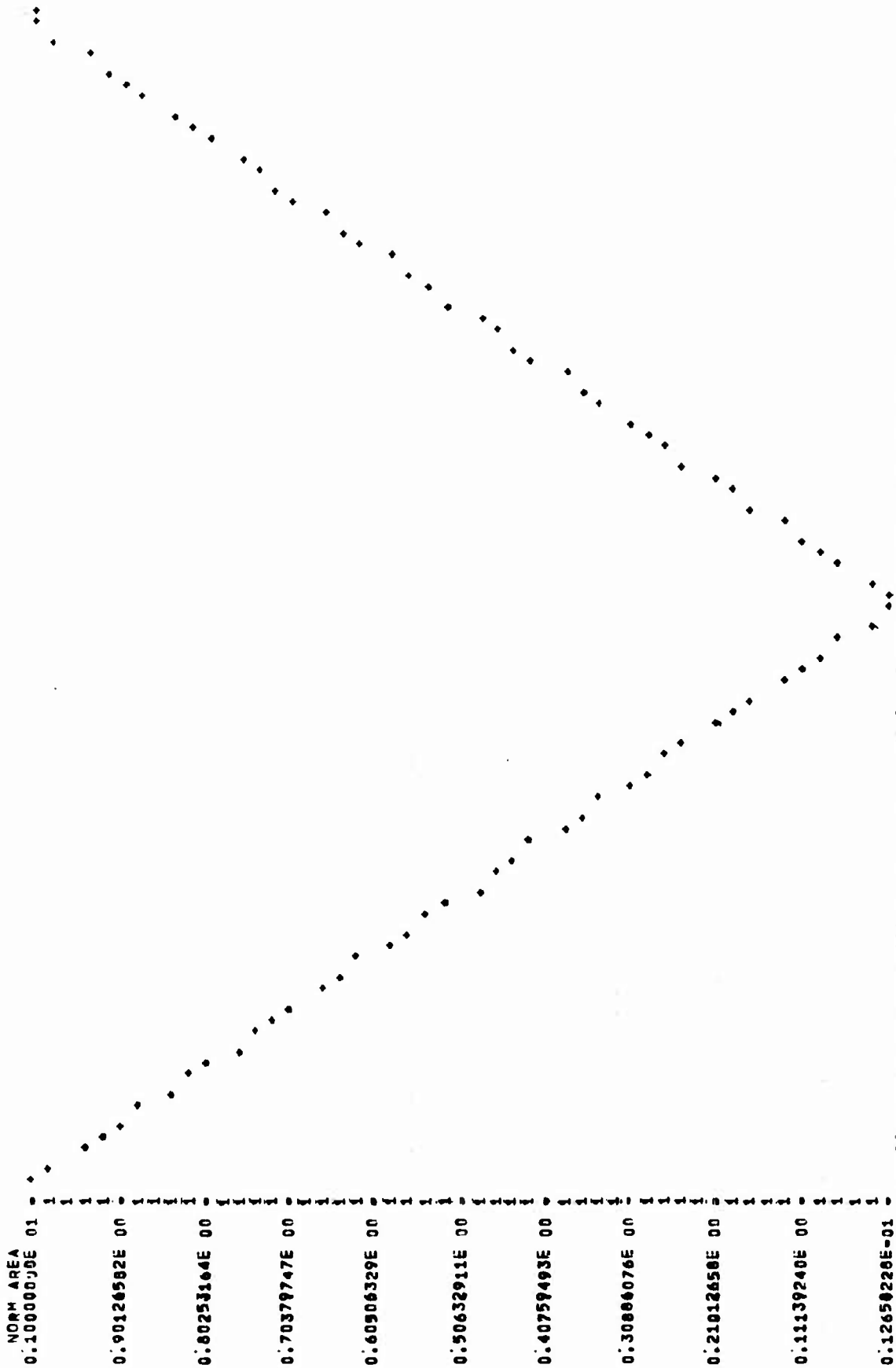
-	+
1	1
-0.900000E 01	=0.572727E 01
-0.736363E 01	-0.409090E 01
	-0.818181E 00
	-0.245455E 01
	0.818181E 00
	0.245455E 01
	0.409090E 01
	0.572727E 01
	0.736363E 01
	0.900000E 01

X

INPUT WAVE DESCRIPTION
NUMBER OF POINTS: 41

X INCREMENT: 0.16363636E 00

Y INCREMENT: 0.19746835E-01



0.9000000E 01 0.81810102E 00 0.73636364E 01 0.65454545E 01 0.57272727E 01 0.4909091E 01 0.40909091E 01 0.3272727E 01 0.2454545E 01 0.16363636E 00 0.08181818E 00

x

POWER

STARTING PASS NUMBER 1 FOR CASE 8.45
 AREA(S) AT START OF PASS
 2D AREA 0.1777500E 02
 AFTER INTERPOLATION
 2D AREA 0.9112500E 01
 AFTER OUTPUT MIRROR
 2D AREA 0.5738991E 01
 AFTER STEP-BY-STEP PROPAGATION
 2D AREA 0.5736809E 01
 AFTER MEDIUM
 2D AREA 0.3208506E 02
 AFTER STEP-BY-STEP PROPAGATION
 2D AREA 0.3207932E 02
 AFTER BACK MIRROR
 2D AREA 0.3014530E 02
 AFTER STEP-BY-STEP PROPAGATION
 2D AREA 0.3014541E 02
 AFTER MEDIUM
 2D AREA 0.1516768E 03
 AFTER STEP-BY-STEP PROPAGATION
 2D AREA 0.1516770E 03
 FINISHED PASS NUMBER 1
 POWER
 NEAR FIELD POWER= 0.1516770E 03
 OUTPUT POWER AFTER MIRROR= 0.6655180E 02
 POWER DIFFERENCE= 0.8512518E 02

NEAR FIELD POWER= 0.1777500E 02
OUTPUT POWER AFTER MIRROR= 0.6750800E 01
POWER DIFFERENCE= 0.1102500E 02

N.F. RESULTS FOR ROUND TRIP

I	X	MAGNITUDE	INTENSITY	NORM. MAG.	NORM. INT.	NORM. PHASE	JORN. APLA
1	0.90000000E 01	0.27509028E-02	0.75674660E-05	0.65972590E-03	0.43523824E-06	-0.4777588E 00	0.10000000E 01
2	-0.87750000E 01	0.64548012E-02	0.41665491E-04	0.15480199E-02	0.23963657E-05	-0.16785838E 01	0.99999998E 00
3	-0.64500000E 01	0.15658256E-01	0.24518104E-03	0.37551984E-02	0.14101441E-04	-0.27330102E 01	0.99999998E 00
4	-0.83249999E 01	0.35372425E-01	0.12512085E-02	0.84830171E-02	0.71962505E-04	0.23280790E 01	0.99999993E 00
5	-0.81000000E 01	0.73544179E-01	0.53955163E-02	0.17159999E-01	0.31031989E-03	0.11844966E 01	0.99999992E 00
6	-0.76500000E 01	0.13848446E 00	0.19177114E-01	0.33210845E-01	0.10209025E-02	-0.10339991E 01	0.99999999E 00
7	-0.74250000E 01	0.23311153E 00	0.54341917E-01	0.35905659E-01	0.31234427E-02	-0.2082176E 01	0.99976129E 00
8	-0.72000000E 01	0.3455916E 00	0.11943601E 00	0.82881184E-01	0.68692907E-02	-0.20560904E 01	0.99940694E 00
9	-0.69750000E 01	0.45262854E 00	0.20487260E 00	0.10855101E 00	0.11783121E-01	0.2379399E 01	0.99879912E 00
10	-0.67500000E 01	0.35193912E 01	0.30636692E 00	0.13236692E 00	0.17521002E-01	0.17093095E 01	0.99789532E 00
11	-0.65250000E 01	0.68599200E 00	0.47058502E 00	0.16451570E 00	0.27065415E-01	0.11933324E 01	0.99649917E 00
12	-0.63000000E 01	0.86683653E 00	0.75140557E 00	0.129788012E 00	0.43216641E-01	0.7569033E 00	0.99426987E 00
13	-0.60750000E 01	0.10668536E 01	0.11381766E 01	0.23585454E 00	0.65461545E-01	0.38988402E 00	0.99089310E 00
14	-0.58500000E 01	0.13157222E 01	0.17311248E 01	0.31553859E 00	0.98564604E-01	0.12020755E 00	0.98575714E 00
15	-0.56250000E 01	0.14160268E 01	0.26115426E 01	0.38755913E 00	0.15020131E 00	-0.87969847E-01	0.97800913E 00
16	-0.54000000E 01	0.19598068E 01	0.38408426E 01	0.47000400E 00	0.22090376E 00	-0.22880246E 00	0.96661400E 00
17	-0.51750000E 01	0.23597822E 01	0.5597097E 01	0.56496745E 00	0.31918823E 00	-0.31356803E 00	0.95014695E 00
18	-0.49500000E 01	0.27804054E 01	0.77306541E 01	0.86680127E 00	0.44462393E 00	-0.34866053E 00	0.92721341E 00
19	-0.47250000E 01	0.32097748E 01	0.10302654E 02	0.74977332E 00	0.59235096E 00	-0.33791273E 00	0.89666471E 00
20	-0.45000000E 01	0.36072430E 01	0.13012202E 02	0.84509479E 00	0.74838899E 00	-0.29345783E 00	0.85804219E 00
21	-0.42750000E 01	0.39249308E 01	0.15405882E 02	0.94128319E 00	0.88601404E 00	-0.2209188E 00	0.81233378E 00
22	-0.40500000E 01	0.41129022E 01	0.16915964E 02	0.98636278E 00	0.97291153E 00	-0.1274439E 00	0.76215106E 00
23	-0.38250000E 01	0.41697662E 01	0.17386950E 02	0.18000000E 01	0.10000000E 01	-0.68050354E-01	0.71056693E 00
24	-0.36000000E 01	0.41108785E 01	0.18099323E 02	0.98587747E 00	0.9195440F 00	-0.21498526E-01	0.68042949E 00
25	-0.33750000E 01	0.40759143E 01	0.16613077E 02	0.97749228E 00	0.95549117E 00	-0.236995076E-02	0.61114130E 00
26	-0.31500000E 01	0.41017292E 01	0.16824183E 02	0.94368372E 00	0.96763278E 00	0.30448369E-01	0.5612279E 00
27	-0.29250000E 01	0.40437399E 01	0.16351832E 02	0.96977918E 00	0.94046583E 00	0.7608058E-01	0.51271366E 00
28	-0.27000000E 01	0.38830748E 01	0.15078270E 02	0.93124321E 00	0.86721764E 00	0.99128339E-01	0.46797698E 00
29	-0.24750000E 01	0.37153394E 01	0.13803747E 02	0.89101864E 00	0.79391422E 00	0.9490007E-01	0.4270259E 00
30	-0.22500000E 01	0.35902276E 01	0.12890084E 02	0.86101889E 00	0.74136559E 00	0.71029679E-01	0.38878288E 00
31	-0.20250000E 01	0.35358564E 01	0.12502281E 02	0.84797475E 00	0.71906117E 00	0.35667561E-01	0.35169072E 00
32	-0.18000000E 01	0.35661085E 01	0.12171130E 02	0.85522284E 00	0.73141808E 00	0.31396115E 00	0.31396115E 00
33	-0.15750000E 01	0.36697375E 01	0.13466974E 02	0.88008333E 00	0.77454491E 00	-0.16099720E-01	0.27400091E 00
34	-0.13500000E 01	0.37823790E 01	0.14306391E 02	0.90709019E 00	0.82282356E 00	-0.15343439E-01	0.23256227E 00
35	-0.11250000E 01	0.38315929E 01	0.14681104E 02	0.91889373E 00	0.84437488E 00	0.22405061E-02	0.18800591E 00
36	-0.90000000E 00	0.38218168E 01	0.14606437E 02	0.91655563E 00	0.84008045E 00	0.3190810E-01	0.14467108E 00
37	-0.67500000E 00	0.37901663E 01	0.14365512E 02	0.90896853E 00	0.82622386E 00	0.51736911E-01	0.10205103E 00
38	-0.45000000E 00	0.37401548E 01	0.14048664E 02	0.89888448E 00	0.80800050E 00	0.39518535E-01	0.60371014E-01
39	-0.22500000E 00	0.36934300E 01	0.13641351E 02	0.88576189E 00	0.78497413E 00	0.12369751E-01	0.19899433E-01
40	-0.22500000E 00	0.36625979E 01	0.13514623E 02	0.87837010E 00	0.77153403E 00	0.12369751E-01	0.19899433E-01
41	-0.22500000E 00	0.36934399E 01	0.13641351E 02	0.88576189E 00	0.78497413E 00	0.12369751E-01	0.19899433E-01
42	-0.22500000E 00	0.37481548E 01	0.14048664E 02	0.89888448E 00	0.80800050E 00	0.39518535E-01	0.60371014E-01
43	-0.45000000E 00	0.37901663E 01	0.14365512E 02	0.90896853E 00	0.82622386E 00	0.51736911E-01	0.10205103E 00
44	-0.67500000E 00	0.38218168E 01	0.14606437E 02	0.91655563E 00	0.84008045E 00	0.3190810E-01	0.14467108E 00
45	-0.90000000E 00	0.38315929E 01	0.14681104E 02	0.91889373E 00	0.84437488E 00	0.22405061E-02	0.18800591E 00
46	-0.11250000E 01	0.37823790E 01	0.14306391E 02	0.90709019E 00	0.82282356E 00	-0.15343439E-01	0.23256227E 00
47	-0.13500000E 01	0.38315929E 01	0.14681104E 02	0.91889373E 00	0.84437488E 00	0.22405061E-02	0.18800591E 00
48	-0.15750000E 01	0.36697375E 01	0.13466974E 02	0.88008333E 00	0.77454491E 00	-0.16099720E-01	0.27400091E 00
49	-0.18000000E 01	0.35661085E 01	0.12171129E 02	0.85522284E 00	0.73141807E 00	0.31396115E-01	0.31396115E 00
50	-0.20250000E 01	0.35358564E 01	0.12502280E 02	0.84797474E 00	0.71906116E 00	0.35667559E-01	0.35169072E 00

N.F. RESULTS FOR ROUND TRIP

I	X	MAGNITUDE	INTENSITY	NORM. MAG.	NORM. INT.	NORM. PHASE	NORM. AREA
51	0.2500000E 01	0.35902766E 01	0.12890086E 02	0.86102888E 00	0.74136557E 00	0.71028657E-01	0.42702565E 00
52	0.24750000E 01	0.37153394E 01	0.13801364E 02	0.89101964E 00	0.79301423E 00	0.04909009E-01	0.46797903E 00
53	0.27000000E 01	0.38830749E 01	0.15078271E 02	0.93128523E 00	0.87021766E 00	0.09121383E-01	0.51271372E 00
54	0.29250000E 01	0.40437399E 01	0.16351832E 02	0.96777618E 00	0.94046583E 00	0.07608048E-01	0.56122083E 00
55	0.31500000E 01	0.41017293E 01	0.16824184E 02	0.98368330E 00	0.96763283E 00	0.03048029E-01	0.61114133E 00
56	0.33750000E 01	0.40755143E 01	0.16613077E 02	0.97749228E 00	0.95549117E 00	-0.03699483E-02	0.60042952E 00
57	0.36000000E 01	0.41108786E 01	0.16899323E 02	0.98587750E 00	0.97195445E 00	-0.02149856E-01	0.71056494E 00
58	0.38250000E 01	0.41697461E 01	0.17386949E 02	0.99999997E 00	0.99999999E 00	-0.06805327E-01	0.76215110E 00
59	0.40500000E 01	0.41129021E 01	0.16915964E 02	0.98636276E 00	0.97291153E 00	-0.01427444E 00	0.81233791E 00
60	0.42750000E 01	0.39249308E 01	0.15405087E 02	0.94128317E 00	0.88601403E 00	-0.02209418E 00	0.85804318E 00
61	0.45000000E 01	0.36072430E 01	0.13012202E 02	0.86509480E 00	0.74838903E 00	-0.02934578E 00	0.89664738E 00
62	0.47250000E 01	0.32097747E 01	0.10302654E 02	0.76977330E 00	0.59255093E 00	-0.03379127E 00	0.92721340E 00
63	0.49500000E 01	0.27804054E 01	0.77306541E 01	0.66680127E 00	0.44462394E 00	-0.03486404E 00	0.95014694E 00
64	0.51750000E 01	0.23557821E 01	0.55497094E 01	0.54493744E 00	0.31918823E 00	-0.03133680E 00	0.96661401E 00
65	0.54000000E 01	0.19596068E 01	0.38408428E 01	0.47009401E 00	0.22090377E 00	-0.02288024E 00	0.97800933E 00
66	0.56250000E 01	0.16160268E 01	0.26115426E 01	0.38755813E 00	0.15020131E 00	-0.02796985E-01	0.98575714E 00
67	0.58500000E 01	0.13157222E 01	0.17311247E 01	0.31553860E 00	0.09564610E-01	0.12020763E 00	0.99089310E 00
68	0.60750000E 01	0.10668536E 01	0.11381765E 01	0.25585452E 00	0.03461540E-01	0.38988604E 00	0.99426987E 00
69	0.63000000E 01	0.86683647E 00	0.75140547E 00	0.20788811E 00	0.43216635E-01	0.75069032E 00	0.99649916E 00
70	0.65250000E 01	0.68598201E 00	0.47058503E 00	0.1451570E 00	0.27065416E-01	0.11938324E 01	0.99780132E 00
71	0.67500000E 01	0.55193910E 00	0.30463677E 00	0.13236692E 00	0.17521001E-01	0.17093095E 01	0.99879912E 00
72	0.69750000E 01	0.45262857E 00	0.20487262E 00	0.10855011E 00	0.11783128E-01	0.23792398E 01	0.99940693E 00
73	0.72000000E 01	0.34559521E 00	0.11943808E 00	0.8288196E-01	0.88692928E-02	-0.03050904E 01	0.99976129E 00
74	0.74250000E 01	0.23211357E 00	0.54341938E 01	0.55905670E-01	0.31254440E-02	-0.02082175E 01	0.99992252E 00
75	0.76500000E 01	0.13848148E 00	0.19177112E 01	0.33210849E-01	0.11029603E-02	-0.10336989E 01	0.9999943E 00
76	0.78750000E 01	0.73454181E-01	0.53955167E-02	0.17618899E-01	0.31031991E-03	0.60759141E-01	0.99999914E 00
77	0.81000000E 01	0.35372422E-01	0.12512083E-02	0.84830709E-02	0.71962490E-04	0.11844968E 01	0.99999994E 00
78	0.83249999E 01	0.15658255E-01	0.24518094E-03	0.37551878E-02	0.14101435E-04	0.23280791E 01	0.99999997E 00
79	0.85500000E 01	0.64548797E-02	0.41665472E-04	0.15480196E-02	0.23963646E-05	-0.02773010E 01	0.99999998E 00
80	0.87750000E 01	0.27509023E-02	0.75674633E-05	0.65972579E-03	0.43523811E-06	-0.01679583E 01	0.10000000E 01
81	0.90000000E 01	0.	0.	0.	0.	-0.47777588E 00	0.10000000E 01

N.F. RESULTS FOR ROUND TRIP
NUMBER OF POINTS= 41

X INCREMENT= 0.1636363E 00 Y INCREMENT= 0.83395324E-01

MAGNITUDE

0.41697602E 01

0.37527896E 01

0.33358130E 01

0.29188363E 01

0.25018597E 01

0.20848831E 01

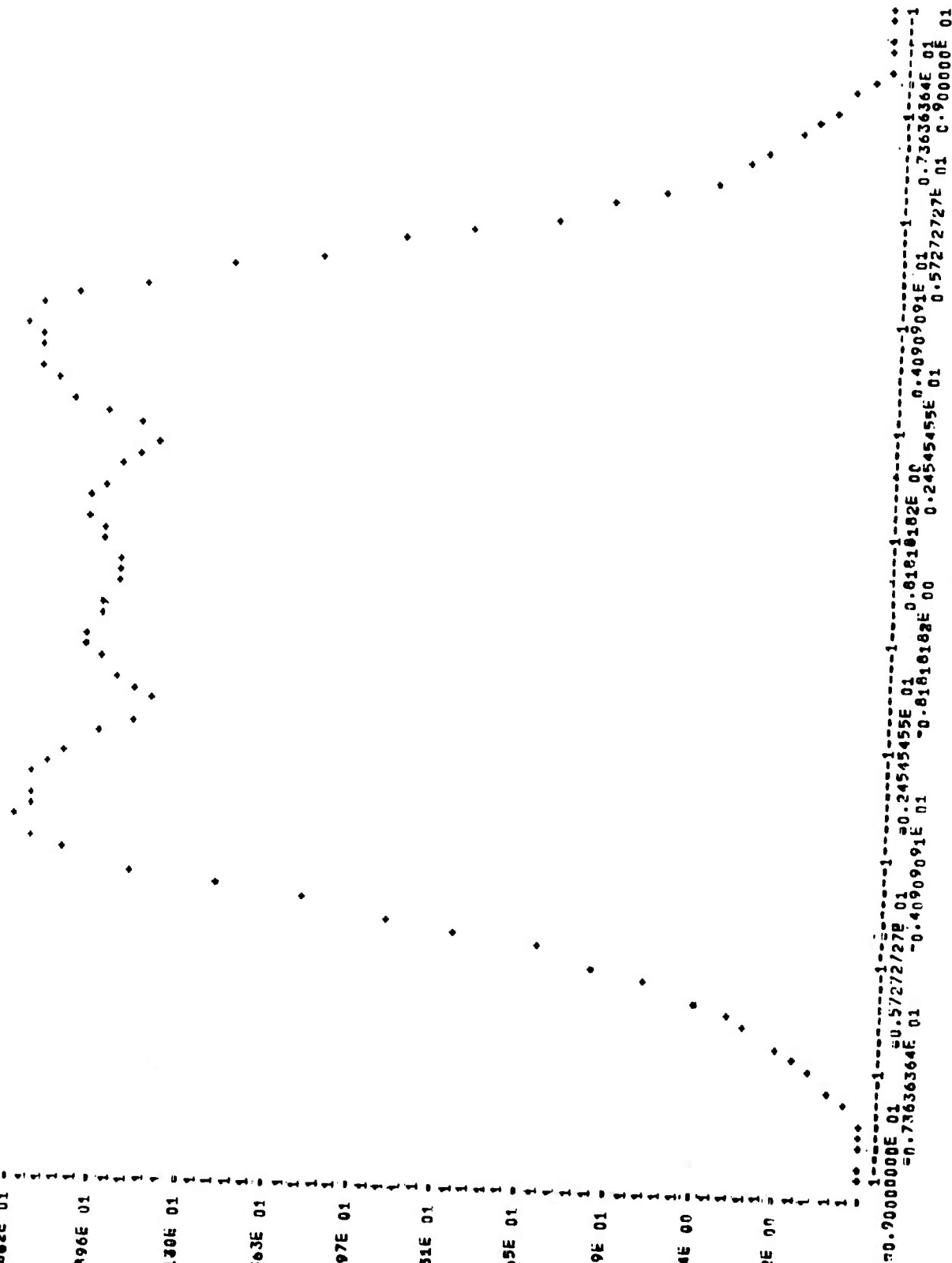
0.16679005E 01

0.12509299E 01

0.83395324E 00

0.41697602E 00

0:



X INCREMENT= 0.16363636E 00

INTENSITY
0-17380950E 02

0-17380950E 02

0115648235E 02

0.13909560E 02

0:12170865E 02

0:10432170E 02

0:06934750E 01

0.62547800E 01

0:52160830E 03

0:3477390DE 05

0:17386930E 0:1



	-0.736364E 01	-0.409091E 01	=0.727272E 01	-0.245455E 01	-0.818182E 00	0.818182E 00	0.409091E 01	0.736364E 01
	-0.900000E 01	-0.409091E 01	-0.727272E 01	-0.245455E 01	-0.818182E 00	0.818182E 00	0.409091E 01	0.900000E 01

X

Y INCREMENT= 0.2000000E+01

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=0.9000000E 01	-0.5727272E 01	=0.2454545E 01	-0.8181818E 00	0.4090909E 01	-0.5727272E 01
=0.7363636E 01	-0.4090909E 01	-0.8181818E 00	0.2454545E 01	0.5727272E 01	0.9000000E 01

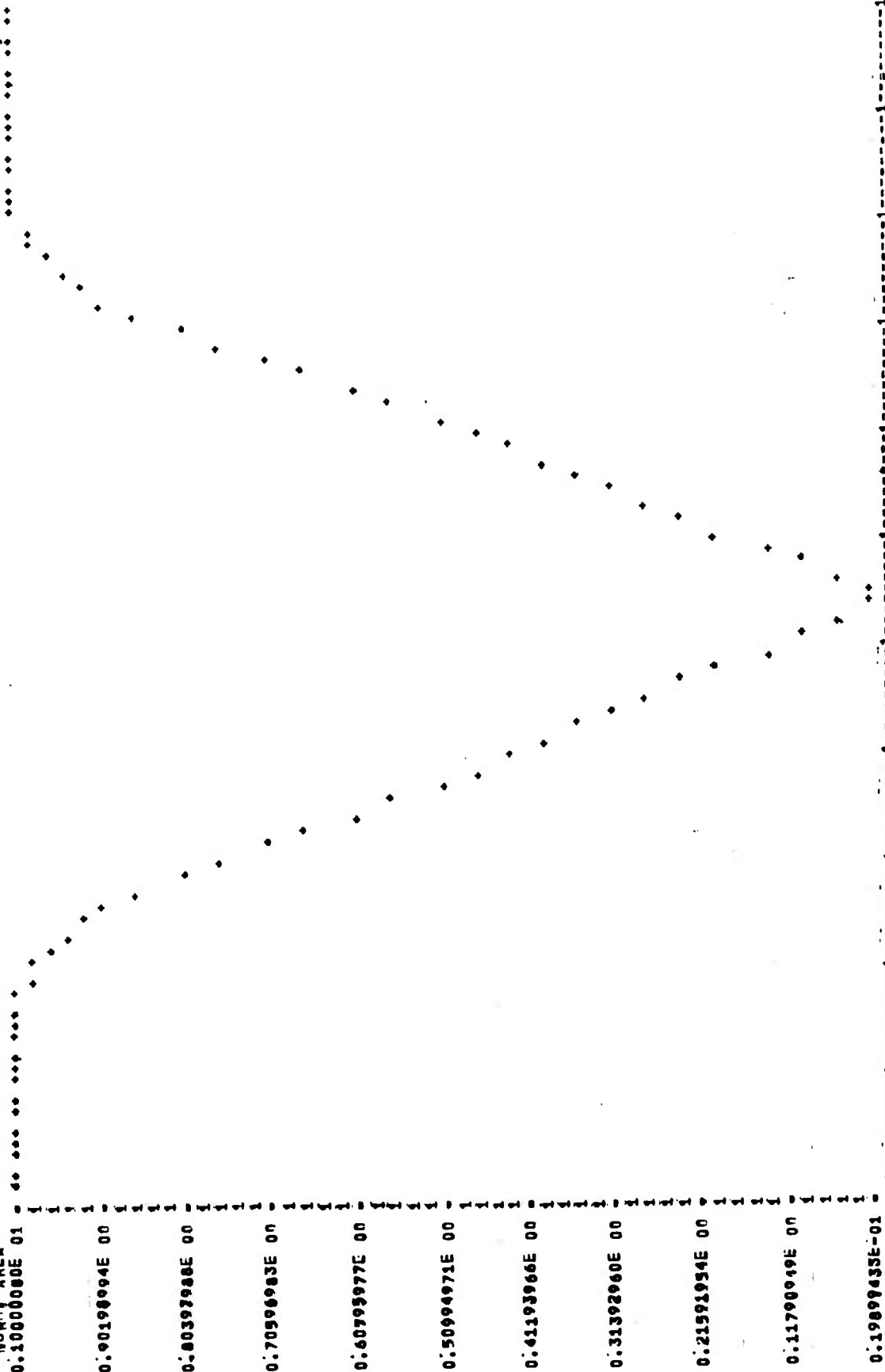
X

N.F. RESULTS FOR ROUND TRIP
NUMBER OF POINTS= 61

X INCREMENT= 0.163636E 00

Y INCREMENT= 0.1960201E-01

NORM. AREA



0.100000E 01
0.90198994E 00
0.80397988E 00
0.70596983E 00
0.60795977E 00
0.50994971E 00
0.41193966E 00
0.31392960E 00
0.21591954E 00
0.11790949E 00
0.19899435E-01
-0.9000000E 01
-0.5727272E 01
-0.4090909E 01
-0.2454545E 01
-0.8181818E 00
0.8181818E 00
0.2454545E 01
0.4090909E 01
0.5727272E 01
0.7363636E 01
0.7363636E 01
C.900000E 01

X

STARTING PASS NUMBER 2 FOR CASE 8.45
 AREA(S) AT START OF PASS
 2D AREA 0.1516770E 03
 AFTER INTERPOLATION
 2D AREA 0.1344971E 03
 AFTER OUTPUT MIRROR
 2D AREA 0.7974570E 02
 AFTER STEP-BY-STEP PROPAGATION
 2D AREA 0.7971669E 02
 AFTER MEDIUM
 2D AREA 0.3209774E 03
 AFTER STEP-BY-STEP PROPAGATION
 2D AREA 0.3209204E 03
 AFTER BACK MIRROR
 2D AREA 0.2973094E 03
 AFTER STEP-BY-STEP PROPAGATION
 2D AREA 0.2973098E 03
 AFTER MEDIUM
 2D AREA 0.6705350E 03
 AFTER STEP-BY-STEP PROPAGATION
 2D AREA 0.6705364E 03
 FINISHED PASS NUMBER 2
 POWER
 NEAR FIELD POWER= 0.8705364E 03
 OUTPUT POWER AFTER MIRROR= 0.3968980E 03
 POWER DIFFERENCE= 0.4736384E 03

APPENDIX E

LISTINGS AND FLOWCHARTS SSCP(ECS)

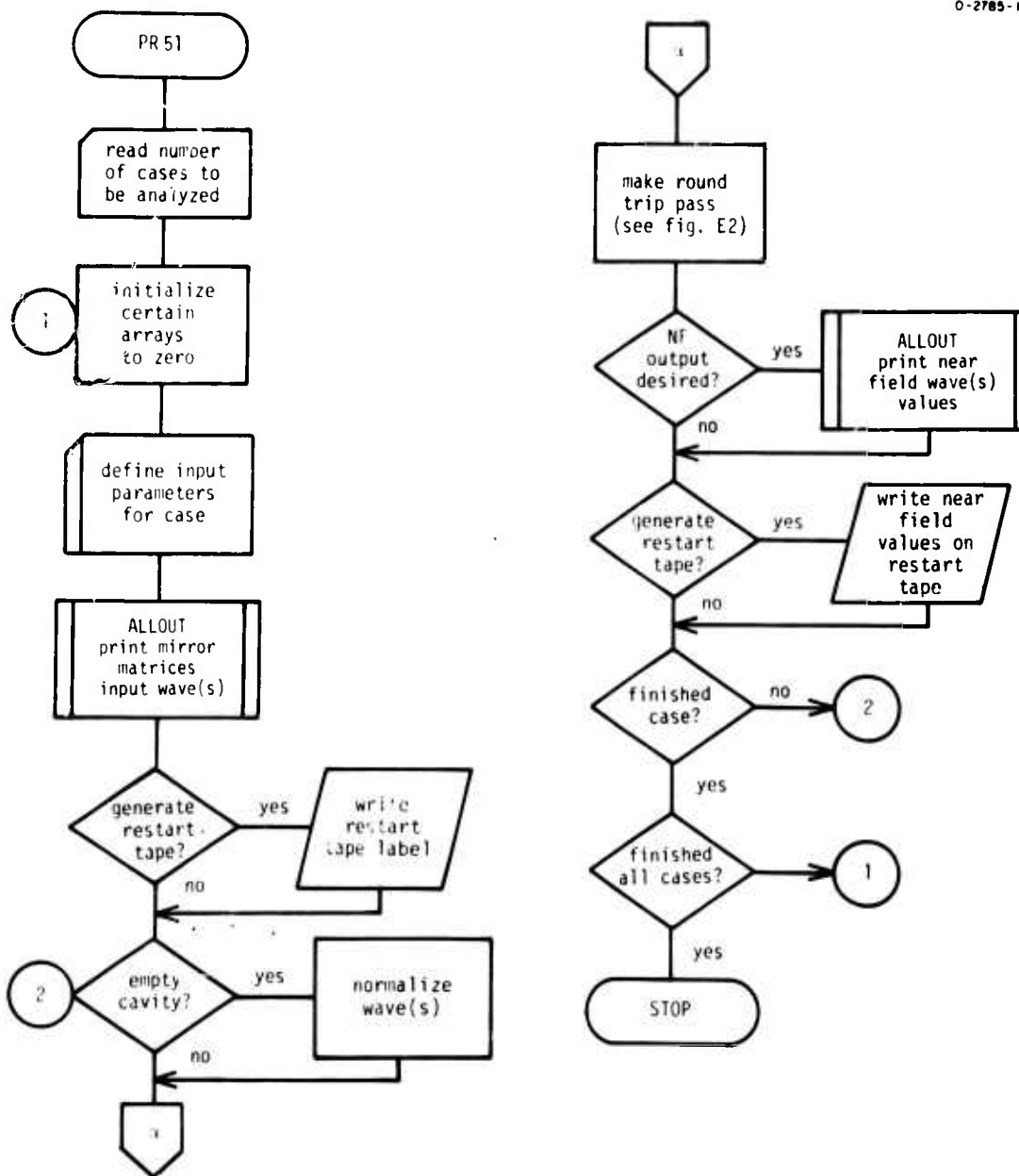


Fig. E1. PR51 logic flow diagram.

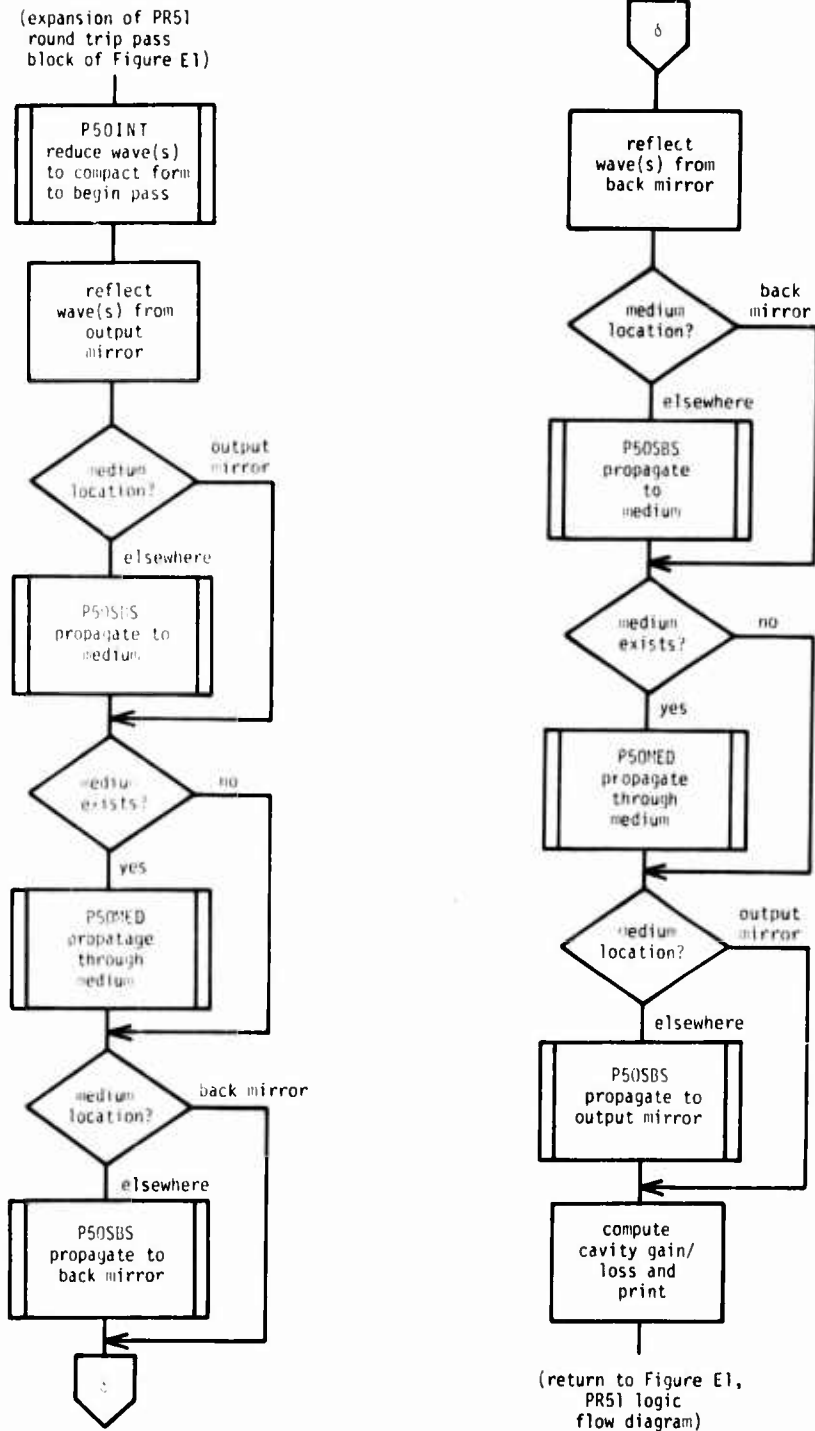


Fig. E2. Logic flow diagram for round trip section of PR51.

C9/27/73 14.08.46.

FTN 4.C+P357

PROGRAM PK51 74/74 OPT=1

```

60      READ(5,INPUT)
      WRITE (IFILE,9005) PROG,CASE
      WRITE (IFILE,RUNOPT)
      C-----DEFINE CAVITY-----
      G1=1./((1.-ZLEN/RCURV1)
      G2=1./((1.-ZLEN/RCURV2)
      DENOM=2.-G1-G2
      VR1=ABS(RCURV1/2.)
      VR2=1.E30
      IF (ABS(DENOM).LE. 1.E-3) GO TO 70
      XNUM=SQRT(1.-G1*G2)-1.
      VR1=(XNUM+G2)/DENOM
      VR2=(XNUM+G1)/DENOM
      70      CONTINUE
      OXMR1=XWIDTH/FLOAT(NX-1)
      OXMR2=OXMR1*(1.+ZLEN/VR1)
      OXOUT=OXMR2*(1.+ZLEN/VR2)
      ISHIFT=(OXOUT-OXMR1)*FLOAT((NX-1)/2)
      NG=NX+ISHIFT
      IF (NGDIM.GE.NG) GO TO 75
      WRITE (IFILE,9070) CASE,NG
      GO TO 999
      75      OZ=ZLEN/FLOAT(NZ-1)
      ICENT=(NX+1)/2
      DO 80 I=1,NX
      80      X(I)=XCENT+FLOAT(I-ICENT)*OXOUT
      WRITE (IFILE,CAVITY)
      C-----DEFINE MEDIUM-----
      NZMED=ZLENMD/DZ+.999
      NZSTPD=FLOAT(NZMED+1)/FLOAT(NZDIM)+.999
      IF (NZMED.NE.0) NZCTV=FLOAT(NZMED)/FLOAT(NZSTPD)+.999
      ZLEN1=INT((ZMOLCC-ZLENMD/2.)/OZ)*OZ
      ZLEN2=ZLEN-ZLENMD-ZLEN1
      IZD=NZDIV+1
      DO 90 I=1,IZD
      J=IZD+1-I
      ZCUR=ZLEN-ZLEN2+FLOAT(I-1)*DZ
      OXOLD(J)=OXMR2*(1.+ZCUR/VR2)
      OXMD1=OXMR1*(1.+ZLEN1/VR1)
      OXMD2=OXMR1*(1.+ZLEN1+ZLENMD)/VR1
      OXMD3=OXMR2*(1.+ZLEN2/VR2)
      OXMD4=OXMR2*(1.+ZLEN2+ZLENMD)/VR2
      WRITE (IFILE,MEDIUM)
      C-----DEFINE GAIN CONSTANTS-----
      WRITE (IFILE,GAINC)
      C-----DEFINE WAVE(S)-----
      XKMAX=-1.E30
      ICENT=(NX+1)/2
      XZERO=X(ICENT)
      DO 110 I=1,NWAVES
      XKZERO(I,WAVE)=2.*PI/XLAMD(I,WAVE)
      XKMAX=AMAX1(XKMAX,XKZERO(I,WAVE))
      DO 100 I=1,NX
      IF (WOMEGA(I,WAVE).EQ.0.) U(I,I,WAVE)=AMPINT(I,WAVE)
      IF (WOMEGA(I,WAVE).NE.0.) U(I,I,WAVE)=
      * AMPINT(I,WAVE)*EXP(-(X(I)-XZERO)/WOMEGA(I,WAVE))**2)
      100      CONTINUE

```

```

115      U(1,IMAVE)=1.
      U(NX,IMAVE)=0.
110      CONTINUE
      STAB=.5+XKMAX*DXMIR1*DXMIR1
      IF(OZ.GT.STAB) WRITE(IFILE,9007) OZ,STAB
      IF(IRCODE.GT.0) CALL RSTART(IFILE,IRCODE,IRTAG,NMAVES,NXOIM,
      + NZOIM,U,SO)
      WRITE(IFILE,NAVES)
      IF(IRCODE.GT.0) REWIND IRCODE
      C-----DEFINE MIRRORS-----
      NXCI=IOIA1-1.17737*OMEGA1/DXMIR1+.5
      NXCOU=(OIA1-1.17737*OMEGA1)/DXOUT+.5
      IF(MOD(NXCI,2).NE.0) NXCI=NXCI-1
      NXCI=IOIA2-1.17737*OMEGA2/DXMIR2+.5
      IF(MOD(NXCI,2).NE.0) NXCI=NXCI-1
      CALL SETMIR(NX,NXCI,DXMIR1,XKZERO,REFL1,1.E30,OMEGA1,TILT1,XMIR1)
      CALL SETMIR(NX,NXCI,DXMIR2,XKZERO,REFL2,1.E30,OMEGA2,TILT2,XMIR2)
      WRITE(IFILE,MIRRS)
      C-----DEFINE NEAR FIELD PRINT OPTIONS-----
      WRITE(IFILE,9008) (I,I=1,NPASS)
      WRITE(IFILE,9009) (INOUT(I),I=1,NPASS)
      C
      C      WRITE INPUT MATRICES
      C
      C-----MIRRORS-----
      DO 130 I=1,NX
      OUT1(I)=XCENIR+FLOAT(I-ICENT)*DXMIR1
      OUT6(I)=XCENIR+FLOAT(I-ICENT)*DXMIR2
      CALL ALLOUT(IFILE,NX,1,6,19,19,MIRROR DESCRIPTIONS,
      + 1,10,10,10,MIRRCR 1 X,OUT1,OUT1,
      + 2,11,12,12,MIRROR 1 INT,XMIR1,OUT2,
      + 2,11,14,14,MIRROR 1 PHASE,XMIR1,OUT3,
      + 1,10,10,10,MIRROR 2 X,OUT6,OUT6,
      + 2,14,12,12,MIRROR 2 INT,XMIR2,OUT4,
      + 2,15,14,14,MIRROR 2 PHASE,XMIR2,OUT5)
      CALL ALLOUT(IFILE,NX,1,3,19,19,MIRROR DESCRIPTIONS,
      + 1,0,10,13,MIRROR 2 X,OUT6,OUT6,
      + 1,10,12,12,MIRROR 2 INT,OUT4,OUT4,
      + 1,10,14,14,MIRROR 2 PHASE,OUT5,OUT5)
      C-----INPUT WAVE(S)-----
      DO 140 IMAVE=1,NMAVES
      CALL ALLOUT(IFILE,NX,1,5,22,22,INPUT WAVE DESCRIPTION,
      + 1,10,1,1MX,X,OUT1,
      + 2,11,9,9,MAGNITUDE,U(1,IMAVE),OUT2,
      + 2,11,9,9,INTENSITY,U(1,IMAVE),OUT4,
      + 2,11,10,10,PHASE (DG),U(1,IMAVE),OUT5,
      + 2,10,0,11,9,9,NORM AREA,U(1,IMAVE),OUT3)
      CALL PAROUT(IFILE,NX,NXCI,ASR,DXOUT,OMEGA1,TLOSS1,REFL1,
      + U(1,IMAVE),PMRNF,PMROT)
140      CONTINUE
      C
      C      GENERATE RESTART TAPE LABEL
      C
      IF(IROUT.LE.0) GO TO 200
      WRITE(IROUT) TIME,DATE,SNM8,PROS,CASE
      NZGAIN=1
      IF(NZMED.GT.0) NZGAIN=FLOAT(NZMED)/FLOAT(NZSTPD)+1.9999

```

```

175 WRITE(IROUT,NX,NZGAIN,NWAVES,(I,I=1,7),(X(1),I=1,10)
      IPASS=0
      WRITE(IROUT) IPASS
      WRITE(IROUT) ((U(I,J),I=1,NX),J=1,NWAVES)
      WRITE(IROUT) ((SC(I,J,K),I=1,NX),J=1,NZGAIN),K=1,NWAVES)
200 CONTINUE
      C
      C
      C BEGIN MAIN PROPAGATION LOOP
      C
      DO 900 IPASS=1,NPASS
      WRITE(IFILE,9010) IPASS,CASE
      C-----NORMALIZE PROPAGATION MATRIX, IF NECESSARY-----
      IF((ZLENH0.EQ.0.) .AND. (ASR.EQ.3.))
      * CALL NORM2D(IFILE,NX,NXDIM,NWAVES,DXOUT,U)
      * CALL AREA21(IFILE,NX,NXDIM,NWAVES,2,
      * 24,24,AREA13) AT START OF PASS,DXOUT,U,ASR,AREA20,AREA30)
      DO 400 I=1,NWAVES
      400 RCUM3D(I)=1.
      C-----MAKE ROUND TRIP PASS-----
      CALL PS0INT(NX,NXDIM,NWAVES,DXMIR1,DXOUT,U,V)
      CALL AREA21(IFILE,NX,NXDIM,NWAVES,2,
      * 19,19,HAFTER INTERPOLATION,DXMIR1,U,ASR,AREA20,AREA30)
      CALL MIRROR(NWAVES,NX,NXDIM,U,V,XMIR1)
      CALL AREA21(IFILE,NX,NXDIM,NWAVES,2,
      * 19,19,HAFTER OUTPUT MIRROR,DXMIR1,U,ASR,AREA20,AREA30)
      CALL PS0SBS(NWAVES,NX,NXDIM,KZERO,ASR,DXMIR1,VR1,DZ,
      * 0,ZLEN1,T,U,V)
      CALL AREA21(IFILE,NX,NXDIM,NWAVES,2,
      * 30,30,HAFTER STEP-BY-STEP PROPAGATION,DXMID1,U,ASR,AREA20,AREA30)
      CALL PS0MED(NX,NXDIM,NWAVES,NZDIM,NGDIM,IGSKIP,NZCIV,NZSTPD,1,
      * ZLEN1,ZLEN1+ZLENH0,ASR,DXMIR1,ZLEN,VR1,VR2,DIA2,
      * KZERO,DXOLD,SCNEW,SOTOT,SD,T,U,V,GAIN,GAINA)
      CALL AREA21(IFILE,NX,NXDIM,NWAVES,2,
      * 12,12,HAFTER MECIUM,DXMID2,U,ASR,AREA20,AREA30)
      CALL PS0SBS(NWAVES,NX,NXDIM,KZERO,ASR,DXMIR1,VR1,DZ,
      * ZLEN1+ZLENH0,ZLEN,T,U,V)
      CALL AREA21(IFILE,NX,NXDIM,NWAVES,2,
      * 30,30,HAFTER STEP-BY-STEP PROPAGATION,DXMIR2,U,ASR,AREA20,AREA30)
      IF(ASR.GT.0.) WRITE(IFILE,9090) (RCUM3D(I),I=1,NWAVES)
      DO 500 I=1,NWAVES
      500 RCUM3D(I)=1.
      CALL MIRROR(NWAVES,NX,NXDIM,U,V,XMIR2)
      CALL AREA21(IFILE,NX,NXDIM,NWAVES,2,
      * 17,17,HAFTER BACK MIRROR,DXMIR2,U,ASR,AREA20,AREA30)
      CALL PS0SBS(NWAVES,NX,NXDIM,KZERO,ASR,DXMIR2,VR2,DZ,
      * 6,ZLEN2,T,U,V)
      CALL AREA21(IFILE,NX,NXDIM,NWAVES,2,
      * 30,30,HAFTER STEP-BY-STEP PROPAGATION,DXMID3,U,ASR,AREA20,AREA30)
      CALL PS0MED(NX,NXDIM,NWAVES,NZDIM,NGDIM,IGSKIP,NZCIV,NZSTPD,-1,
      * ZLEN1+ZLENH0,ZLEN1,ASR,DXMIR1,ZLEN,VR1,VR2,DIA2,KZERO,
      * DXOLD,SOMEW,SOTOT,SD,T,U,V,GAIN,GAINA)
      CALL AREA21(IFILE,NX,NXDIM,NWAVES,2,
      * 12,12,HAFTER MECIUM,DXMID4,U,ASR,AREA20,AREA30)
      CALL PS0SBS(NWAVES,NX,NXDIM,KZERO,ASR,DXMIR2,VR2,DZ,
      * ZLEN2+ZLENH0,ZLEN,T,U,V)
      CALL AREA21(IFILE,NX,NXDIM,NWAVES,2,
      * 30,30,HAFTER STEP-BY-STEP PROPAGATION,DXOUT,U,ASR,AREA20,AREA30)

```

```

230 IF(IASR,GT.6.) WRITE(1,FILE,9090) (RCUM3D(I),I=1,NH WAVES)
C-----OUTPUT FOR ROUND TRIP PASS-----
WRITE(1,FILE,9063) IPASS
DO 600 IMAVE=1,NH WAVES
CALL PHROUT(1,FILE,NX,NXCOUT,ASR,DXOUT,OMEGA1,TLOSS1,REFL1,
+ U(1,IMAVE),PHRAF,PHROT)
IF (ENFOUT(IPASS).GE.1)
+ CALL ALLOUT(1,FILE,NX,1,7,27,27MN.F. RESULTS FOR ROUND TRIP,
+ 1,10,1,1HK,X,OUT1,
+ 2,113,9,9MAGNITUDE,U(1,IMAVE),OUT2,
+ 2,114,9,9INTENSITY,U(1,IMAVE),OUT3,
+ 2,223113,10,10HNORM. MAG,U(1,IMAVE),OUT4,
+ 2,223114,10,10HNORM. INT,U(1,IMAVE),OUT5,
+ 2,110115,11,11HNORM. PHASE,U(1,IMAVE),OUT6,
+ 2,1003114,10,10HNORM. AREA,U(1,IMAVE),OUT7)
600 CONTINUE
245 C-----WRITE INFORMATION ON RESTART TAPE-----
IF (IROUT,GT.0) WRITE (IROUT) IPASS
IF (IROUT,GT.0) WRITE (IROUT) ((UI,I),I=1,NX),J=1,NH WAVES)
IF (IROUT,GT.0) WRITE (IROUT) ((ISO(I),J,K),I=1,NX),
+ J=1,NZGAIN,K=1,NH WAVES)
C-----TERMINATION OF PROPAGATION LOOP-----
250 980 CONTINUE
C
C
C PROGRAM TERMINATION
255 IF (IROUT,GT.0) ENDFILE IROUT
999 CONTINUE
STOP
C
C FORMATS
260 9005 FORMAT(1H1,7HPROGRAM, 5X, A6/1X,4MCASE,0X,F6.2)
9007 FORMAT(1H1,25/(130(1H*))1/30X,7HDELTA Z, E20.7,
+ 2X,31HGREATER THAN STABILITY CRITERIA,E20.7,25/(130(1H*)))
9008 FORMAT(1H0,11HPASS NUMBER/(1X,4I3))
9009 FORMAT(1X,17HMF OUTPUT OPTIONS/(1X,40I3))
9010 FORMAT(1H1,20HSTARTING PASS NUMBER,I5,10H FOR CASE ,F6.2)
9063 FORMAT(1H0,20HFINISHED PASS NUMBER,I5)
9070 FORMAT(1H1,5HCASE ,F8.2,26HABORTED--INCREASE NGDIM TO,I10)
9090 FORMAT(1H0,5X,17HMCUMULATIVE RATIOS/(5X,E15.7))
END
270

```

```

SUBROUTINE P50GAI(NX,NXDIM,NWAVES,NZDIM,NGDIM,L,L2,
+ ASR,DXMIN,ZLEN,VR1,VR2,ZCUR,DXCUR,R1,DIA2,
+ U,SOTOT,SO,DXOLD,GAIN,GAINS)
  COMPLEX U(NXDIM,NWAVES),GAIN(NGDIM,NWAVES)
  DIMENSION SOTOT(NGDIM,NWAVES),SO(NXDIM,NZDIM,NWAVES),
+ DXOLD(NZDIM)
  COMMON/CGAINA/TEPP(2),XSTART,TEPP3
C
C-----
10 C P50GAI ROUTINE COMPUTES SUM OF OLD AND NEW INTENSITIES BY LINEAR
C INTERPOLATION OF SO MATRIX, THEN CALLS GAIN ROUTINE FOR
C RETURN OF GAIN VALUES
C-----
15 C THE PARAMETERS ARE
C
C NX THE NUMBER OF PROPAGATING MESH POINTS
C NXDIM THE X-DIMENSION OF THE PROPAGATING MATRIX
C NWAVES THE NUMBER OF PROPAGATING WAVES
C NZDIM THE Z-DIMENSION OF THE SO MATRIX
20 C NGDIM THE DIMENSION ALONG X OF SOTOT AND GAIN ARRAYS
C L THE Z-INDEX OF THE LAST LINE STORED IN SO
C L2 THE Z-INDEX OF THE NEXT LINE TO BE STORED IN SO
C ASR 3D AREA SWITCH
C DXMIN THE SMALLER DELTA-X AT THE OUTPUT MIRROR
25 C ZLEN THE DISTANCE BETWEEN MIRRORS
C VR1 THE VIRTUAL RADIUS OF CURV. FOR THE OUTPUT MIRROR
C VR2 THE VIRTUAL RADIUS OF CURV. FOR THE BACK MIRROR
C ZCUR THE CURRENT DISTANCE FROM THE OUTPUT MIRROR
C DXCUR THE CURRENT VALUE OF DELTA-X
30 C R1 PERCENT OF Z-INTERVAL TRAVERSED BETWEEN SO STORES
C DIA2 DIAMETER OF BACK MIRROR
C U PROPAGATING MATRIX
C SOTOT DUMMY MATRIX
C SO PAST INTENSITIES MATRIX
35 C DXOLD VECTOR STORING LAST PASS DX FOR EACH STORED SO LINE
C GAIN MATRIX OF COMPUTED GAIN VALUES (RETURNED)
C GAINS NAME OF GAIN ROUTINE (TYPED EXTERNAL ELSEWHERE)
C
C SUBPROGRAMS REQUIRED--
C GAINS (TO RETURN A SET OF GAIN VALUES FOR CURRENT Z)
C P50GET (TO FETCH A LAST-PASS INTENSITY VALUE FROM SO)
C
40 C 8/28/73 CREATED (NEW ROUTINE)
C-----
45 C ESTABLISH SHIFT PARAMETER, IF NEEDED
C
C ISHIFT=0
IF (L2.LT.L) GO TO 300
XSTART=DXMIN*(1.+ZLEN/VR1)*(1.+((ZLEN-ZCUR)/VR2)*
+ FLOAT((NX-1)/2))
XSTCUR=DXCUR*FLOAT((NX-1)/2)
ISHIFT=MAX1((XSTART-XSTCUR)/DXCUR,0.)
IF (ISHIFT.EQ.0) GC TO 300
55 C WHEN HEADING TOWARD BACK MIRROR, COMPUTE LAST-PASS
C
7300
7320
7340
7360
7380
7400
7420
7440
7460
7480
7500
7520
7540
7560
7580
7600
7620
7640
7660

```

```

60      C      INTENSITIES FOR REGION PRECEDING CURRENT MATRIX
      C
      DO 200 JWAIVE=1,NWAIVES
      DO 200 I=1,ISHIFT
      IX=I-ISHIFT
      CALL P50GET(IX,NX,NXDIM,L2,R1,DXCUR,SO(1,1,JWAIVE),DXOLD,XINT)
      SOTOT(I,JWAIVE)=XINT
200      C
65      C      FILL REMAINING (NX) LOCATIONS OF SOTOT WITH SUM OF
      C      INTERPOLATED OLD INTENSITIES AND COMPUTED NEW INTENSITIES
      C
300      DO 500 JWAIVE=1,NWAIVES
      DO 500 IX=1,NX
      I=IX-ISHIFT
      CALL P50GET(IX,NX,NXDIM,L2,R1,DXCUR,SO(1,1,JWAIVE),DXOLD,XINT)
      SOTOT(I,JWAIVE)=XINT+REAL(U(IX,JWAIVE))*2+AIMAG(U(IX,JWAIVE))*2
500      C
75      C      ADJUST SOTOT ARRAY IF ASR .GT. 0.
      C
      IF(ASR.LE.0.) GO TO 600
      IX=NX+ISHIFT
      ISENT=(IX+1)/2+ISHIFT
      DO 550 I=1,IX
      SOASR=ASR*ABS(FLOAT(I-ISENT))*DXCUR/DIA2
      DO 550 JWAIVE=1,NWAIVES
      SOTOT(I,JWAIVE)=SOASR*SOTOT(I,JWAIVE)
550      C
85      C      COMPUTE GAIN FOR EACH WAVE
      C
600      CALL GAINS(NX+ISHIFT,NGDIM,NWAIVES,SOTOT,GAIN)
      C
90      C      SHIFT GAIN MATRIX BACK TO NORMAL FORM
      C
      DO 700 JWAIVE=1,NWAIVES
      DO 700 I=1,NX
      IX=I+ISHIFT
      GAIN(I,JWAIVE)=GAIN(IX,JWAIVE)
700      RETURN
      END
95

```

```

SUBROUTINE P50GET(IX,NX,NXOIM,L,L2,R1,DXCUR,SO,DXOLD,XINT)
  DIMENSION SO(NXOIM+1),DXOLD(1)
  C---ASF TO YIELD EQUIVALENT X-INDEX FOR OTHER Z-POSITION
  EQUIV(I,DXLAST)=FLOAT(ICENT)-FLOAT(ICENT-I)*DXCUR/DXLAST
  C---ASF TO RETURN INTERPOLATED VALUE GIVEN POSITION RATIO
  XINTRP(R,X1,X2)=X1+R*(X2-X1)
  C
  C-----
  C P50GET RETRIEVES AN INTENSITY VALUE FROM THE SO MATRIX BY
  C 3-WAY LINEAR INTERPOLATION
  C-----
  C THE PARAMETERS ARE
  C
  C IX THE X-INDEX OF THE DESIRED INTENSITY RELATIVE TO CURRENT U
  C NX THE NUMBER OF PROPAGATING POINTS
  C NXOIM THE X-DIMENSION OF THE LAST-PASS MATRIX
  C L THE Z-INDEX OF THE START OF THE Z-INTERVAL
  C L2 THE Z-INDEX OF THE NEXT Z-STORED LINE (L+1 OR L-1)
  C R1 THE RATIO DESCRIBING CURRENT Z-POSITION IN THE INTERVAL
  C DXCUR DELTA-X FOR THE CURRENT Z-POSITION
  C SO THE LAST-PASS INTENSITY MATRIX
  C DXOLD VECTOR SAVING LAST PASS DELTA-X FOR L AND L2 POSITIONS
  C XINT RETURNED VALUE OF INTENSITY RETRIEVED FROM SO
  C
  C SUBPROGRAMS REQUIRED--NONE
  C
  C 8/28/73 CREATED (NEW ROUTINE)
  C-----
  C
  C COMPUTE INTENSITY FOR LINE L OF SO MATRIX
  ICENT=(NX+1)/2
  XI=EQUIV(I,IX,DXOLD(L))
  I=XI
  R2=XI-FLOAT(I)
  XINT1=0.
  IF(I.LE.0) GO TO 100
  XINT1=XINTRP(R2,SO(I,L),SO(I+1,L))
  100 CONTINUE
  C
  C CHECK FOR TRIVIAL CASE OF R1=0.
  IF(R1.LE.0.) XINT=XINT1
  IF(R1.LE.0.) GO TO 999
  C
  C COMPUTE INTENSITY FOR LINE L2 OF SO MATRIX
  XI=EQUIV(I,IX,DXOLD(L2))
  I=XI
  R3=XI-FLOAT(I)
  XINT2=0.
  IF(I.LE.0) GO TO 300
  XINT2=XINTRP(R3,SO(I,L2),SO(I+1,L2))
  300 CONTINUE
  C
  C INTERPOLATE IN Z TO OBTAIN INTENSITY VALUE

```

SUBROUTINE P50GET 74/74 OPT=1 FTN 4.0+P357 14.09.05. PAGE 2

60 C
C XINT=XINTRP(R1,XINT1,XINT2)
C
C RETURN WITH REQUIRED INTENSITY
C
999 RETURN
END

9640
9660
9680
9700
9720
9740
9760


```

SUBROUTINE PSBINT(NX,NXDIM,NNAVES,DXNEW,DXOLD,U,V)
  COMPLEX U(NXDIM,NNAVES),V(NXDIM,NNAVES)
  C
  C-----
  C PSBINT GIVEN A COMPLEX MATRIX WITH ONE MESH SPACING, INTERPOLATES
  C LINEARLY TO RETURN THE SAME SIZE MATRIX BUT WITH DIFFERENT
  C MESH SPACING
  C-----
  C THE PARAMETERS ARE
  C
  C NX NUMBER OF PROPAGATING MESH PRINTS
  C NXDIM X-DIMENSION OF PROPAGATING MATRIX
  C NNAVES NUMBER OF PROPAGATING WAVES
  C DXNEW MESH SPACING IN X OF MATRIX TO BE RETURNED
  C DXOLD ORIGINAL MESH SPACING
  C U ORIGINAL AND RETURNED PROPAGATING MATRIX
  C V DUMMY MATRIX
  C
  C SUBPROGRAMS REQUIRED--ACME
  C
  C 8/23/73 CREATED (NEW PROGRAM)
  C-----
  C
  XCENT=(NX+1)/2
  NXP=(NX+1)/2+1
  C
  C CREATE INTERPOLATED MATRIX (V) FROM VALUES IN U
  C
  DO 100 I=NXP,NX
    C---(XJ=EXACT INTERVAL POSITION IN U CORRESPONDING TO I IN V)
    C---(J=TRUNCATED VALUE OF XJ)
    C---(PRCENT=PERCENT VALUE FOR THE INTERPOLATION OF THE U-INTERVAL)
    XJ=XCENT-(XCENT-FLOAT(I))*DXNEW/DXOLD
    J=XJ
    PRCENT=AMOD(XJ,1.)
    C---(IP=VALUE OF I IN FIRST HALF OF V, BY SYMMETRY)
    C---(JP=VALUE OF J IN FIRST HALF OF U, BY SYMMETRY)
    IP=(NX+1)-I
    JP=(NX+1)-J
    C-----FOR EACH WAVE, COMPUTE BOTH INTERPOLATED POINTS IN V-----
    DO 100 IMAVE=1,NNAVES
      V(I,IMAVE)=(U(J+1,IMAVE)-U(J,IMAVE))*PRCENT+U(J,IMAVE)
      V(JP,IMAVE)=(U(JP-1,IMAVE)-U(JP,IMAVE))*PRCENT+U(JP,IMAVE)
    CONTINUE
  DO 200 IMAVE=1,NNAVES
    DO 200 V(NXP-1,IMAVE)=U(NXP-1,IMAVE)
  C
  C SHIFT FINAL VALUES BACK INTO U
  DO 500 I=1,NX
    DO 500 IMAVE=1,NNAVES
      U(I,IMAVE)=V(I,IMAVE)
  RETURN
  END

```

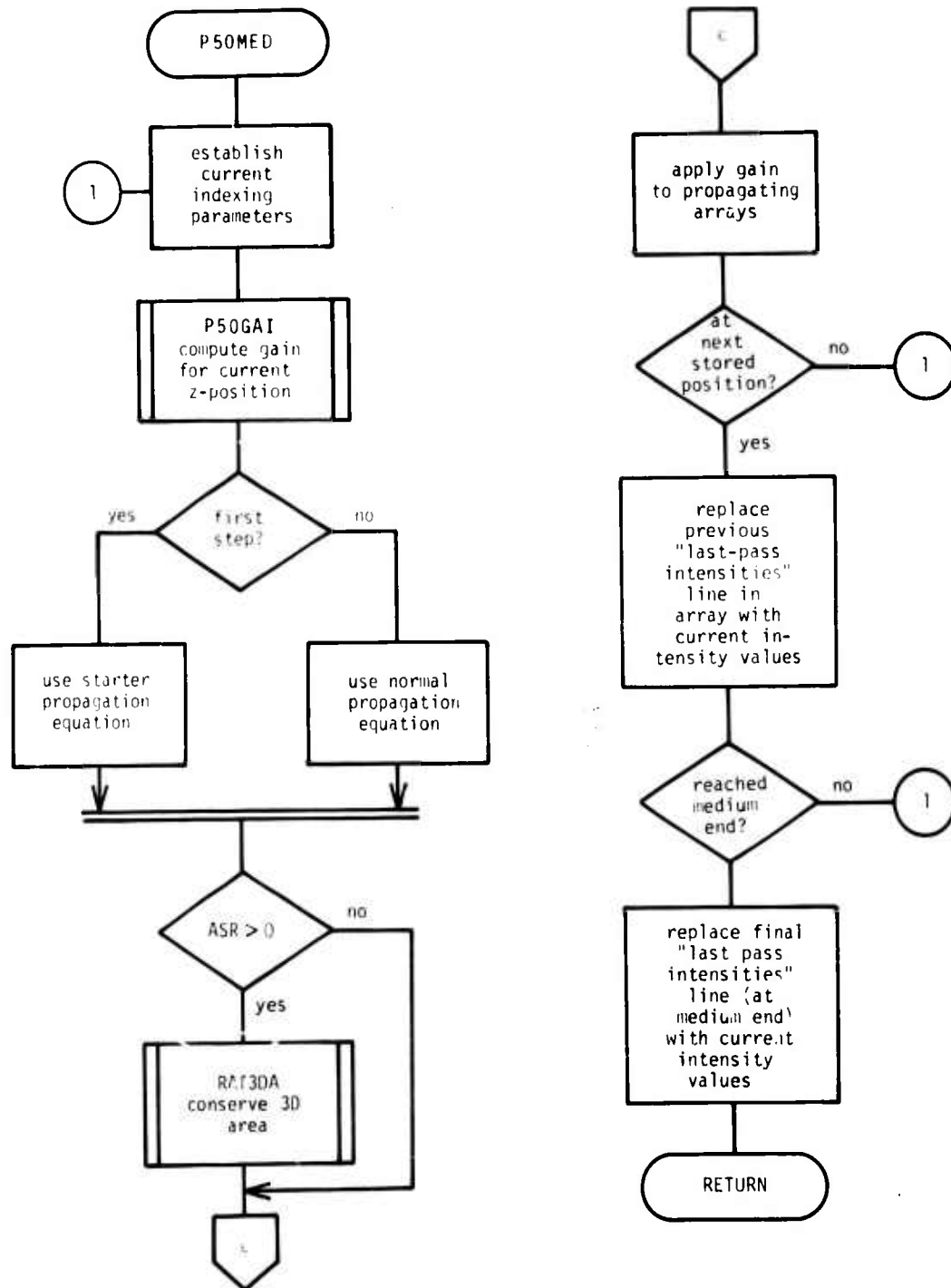


Fig. E3. P50MED logic flow diagram.

```

SUBROUTINE P50MED(NX,NXDIM,NWAVES,NZDIM,NGDIM,IGSKIP,NZD,
* NZSTPD,IOIR,ZSTART,ZFIN,ASR,DXMIN,ZLEN,VRI,VR2,DIA2,
* KK0,DXOLD,SCNEN,SOTOT,SO,T,U,V,GAIN,GAINS)
COMPLEX T(NXDIM,NWAVES),U(NXDIM,NWAVES),V(NXDIM,NWAVES),
* GAIN(NGDIM,NWAVES),GNX
DIMENSION KK0(NWAVES),DXOLD(NZDIM),SONEW(NXDIM,NWAVES),
* SOTOT(NGDIM,NWAVES),SO(NXDIM,NZDIM,NWAVES)
COMMON /CGAINA/TEPP(3),DXCUR

```

```

C
C-----
C P50MED PROPAGATES (NWAVES) WAVEFORMS THROUGH A MEDIUM
C-----
C THE PARAMETERS ARE
C-----

```

```

C NX THE NUMBER OF PROPAGATING MESH POINTS
C NXDIM THE X-DIMENSION OF THE PROPAGATING MATRIX
C NWAVES THE NUMBER OF PROPAGATING WAVES
C NZDIM THE Z-DIMENSION (2ND) OF THE SO MATRIX
C NGDIM DIMENSION ALONG X OF SOTOT AND GAIN ARRAYS
C IGSkip SKIP PARAMETER FOR GAIN ROUTINE CALL
C NZD NO. OF INTENSITY STORES (MINUS 1) IN SC ALONG Z-DIRECTION
C NZSTPD NO. OF PROP. STEPS TAKEN THRU MEDIUM BETWEEN STORES
C IOIR DIRECTION OF PROPAGATION
C .NE. -1 TOWARD BACK MIRROR
C .EQ. -1 TOWARD OUTPUT MIRROR
C ZSTART DISTANCE FROM OUTPUT MIRROR TO START OF PROPAGATION
C ZFIN DISTANCE FROM OUTPUT MIRROR TO END OF PROPAGATION
C ASR 3D PROPAGATION SWITCH (IF .GT. 0.)
C DXMIN SMALLER OF THE DELTA-X VALUES AT THE OUTPUT MIRROR
C ZLEN DISTANCE BETWEEN MIRRORS
C VRI VIRTUAL RADIUS OF CURVATURE OF OUTPUT MIRROR
C VR2 VIRTUAL RADIUS OF CURVATURE OF BACK MIRROR
C DIA2 DIAMETER OF BACK MIRROR
C KK0 VECTOR OF K=2*PI/LAMBDA, ONE VALUE FOR EACH WAVE
C*DXOLD VECTOR OF LAST PASS DELTA-X VALUES (ONE FOR EACH STORE)
C*SONEW DUMMY ARRAY
C*SOTOT DUMMY ARRAY
C*SO LAST PASS INTENSITY VALUES
C*T DUMMY ARRAY
C*U DUMMY ARRAY
C*V DUMMY ARRAY
C*GAIN DUMMY ARRAY
C GAINS NAME OF GAIN ROUTINE (TYPED EXTERNAL ELSEWHERE)
C (* ALTERED DURING COMPUTATION)

```

```

C SUBPROGRAMS REQUIRED---
C P50GAI (COMPUTES GAIN VALUES AT A Z-LOCATION)
C RAT3DA (CONSERVES 3D AREA, IF ASR .GT. 0)
C
C 8/29/73 CREATED FROM OUTLINE OF PRPGAI (PR20 ROUTINE)
C-----
C
C BEGIN PROPAGATION THROUGH MEDIUM
C-----

```

```

IGCNT=0
NXMI=NX-1

```

11800
11820
11840
11860
11880
11900
11920
11940
10920
10940
10960
10980
11000
11020
11040
11060
11080
11100
11120
11140
11160
11180
11200
11220
11240
11260
11280
11300
11320
11340
11360
11380
11400
11420
11440
11460
11480
11500
11520
11540
11560
11580
11600
11620
11640
11660
11680
11700
11720
11740
11760
11780
11800
11820
12000
12020
12040

```

60      IF (ZSTART.EQ.ZFIN) GO TO 999
        DZ=ABS(ZSTART-ZFIN)/FLOAT(NZD*NZSTPD)
C
C      PROPAGATE OVER DISTANCE (ZFIN-ZSTART) USING (NZD*NZSTPD) STEPS
C
C-----COMPUTE CURRENT (L) AND NEXT (L2) STORAGE INDICES FOR SO-----
        DO 500 IZD=1,NZD
          L=IZD
          IF (IDIR.EQ.(-1)) L=NZD+2-IZD
          L2=L+1
          IF (IDIR.EQ.(-1)) L2=L-1
          DO 300 J=1,NZSTPD
C-----COMPUTE CURRENT Z, CX, INTERP. RATIO, AND PROP. CONSTANTS---
            ZCUR=ZSTART+FLOAT((IZD-1)*NZSTPD+J-1)/FLOAT(NZD*NZSTPD)*
              (ZFIN-ZSTART)
            IF (IDIR.NE.(-1)) CXCUR=DXMIN*(1.+ZCUR/VR1)
            IF (IDIR.EQ.(-1)) CXCUR=DXMIN*(1.+ZLEN/VR1)*(1.+(ZLEN-ZCUR)/VR2)
            RI=FLOAT(J-1)/FLOAT(NZSTPD)
            IF (IDIR.NE.(-1)) F=ZCUR+VR1
            IF (IDIR.EQ.(-1)) F=(ZLEN-ZCUR)+VR2
            AA=1.-DZ/(2.*F)
            IF (J.NE.1) GO TO 50
C-----SAVE OX AND LINE OF CURRENT INTENSITIES FOR LATER SAVE-----
            DO 40 JWAIVE=1,NWAVES
              DO 40 I=1,NK
                SOME(I,JWAIVE)=REAL(U(I,JWAIVE))*2*AIMAG(U(I,JWAIVE))**2
              OXSAVE=OXCUR
50      C-----COMPUTE GAIN FOR FOLLOWING PROPAGATION STEP-----
          + CALL P56GAIN(X,NXOIM,NWAVES,NZDIM,NGOIM,L,L2,ASR,DXMIN,
          +   ZLEN,VR1,VR2,ZCUR,OXCUR,RI,DIA2,U,SOTOT,
          +   SO,DXOLD,GAIN,GAINS)
          ICGMT=ICGNT+1
          IF (.NOT.(IZD.EQ.1 .AND. J.EQ.1)) GO TO 200
C----- (VERY FIRST PROPAGATION STEP ONLY) -----
          DO 150 JWAIVE=1,NWAVES
            DELX=DZ/IXK0(JWAIVE)*OXCUR*OXCUR
            V(I,JWAIVE)=0.
            VINT,JWAIVE)=0.
          150 V(I,X,JWAIVE)=AA*(U(I,X,JWAIVE)+.5*DELX*(0.+1.))*
            + (U(I,X+1,JWAIVE)-2.*(U(I,X,JWAIVE)+U(I,X-1,JWAIVE)))
            GO TO 200
C----- (SUCCEEDING PROPAGATION STEPS) -----
          200 DO 250 JWAIVE=1,NWAVES
            DELX=DZ/IXK0(JWAIVE)*OXCUR*OXCUR
            DELXSQ=DELX*DELX
            DO 250 IX=2,NXK1
              250 V(IX,JWAIVE)=
                + AA/(1.+DELXSQ)*
                + (U(IX,JWAIVE)+AA*
                + (0.+1.)*DELX*(U(IX+1,JWAIVE)-2.*(U(IX,JWAIVE)+AA*
                + U(IX-1,JWAIVE)))+
                + DELXSQ*(U(IX+1,JWAIVE)-T(IX,JWAIVE)*AA+U(IX-1,JWAIVE)))
C----- AFTER A DZ STEP, CONSERVE 3D AREA (IF ASR.GT. 3) -----
          200 IF (ASR.LE.0.) GO TO 205
            IF (IDIR.NE.(-1)) OXNEXT=OXMIN*(1.+(ZCUR+DZ)/VR1)

```

```

115 IF (IDIR.EQ.(-1)) CXNEXT=
    + DXMIN*(1.+ZLEN/VR1)*(1.+ZLEN-ZCUR-OZ)/VR2)
    CALL RAT3DANX,NXCIN,NWAVES,DXNEXT,DXCUR,V,U)
285 CONTINUE
C-----MOVE ARRAYS DOWN AND APPLY GAIN-----
DO 290 JWAVE=1,NWAVES
DO 290 I=2,NXM1
    GNX=CEXP(OZ*CMPLX(.5*REAL(GAIN(I,JWAVE)),AIMAG(GAIN(I,JWAVE))))
    T(I,JWAVE)=U(I,JWAVE)*GNX
290 U(I,JWAVE)=V(I,JWAVE)*GNX
300 CONTINUE
C-----LOAD NEW LINE INTO PAST INTENSITIES MATRIX-----
DO 400 JWAVE=1,NWAVES
DO 400 I=1,NX
    SO(I,L,JWAVE)=SONEM(I,JWAVE)
    DXOLD(IL)=DXSAVE
500 CONTINUE
C
C      ADJUST V, SC, AND DXOLD MATRICES AT Z=ZFIN
DO 600 JWAVE=1,NWAVES
DO 600 I=1,NX
    V(I,JWAVE)=U(I,JWAVE)
    SO(I,L2,JWAVE)=REAL(U(I,JWAVE))*2+AIMAG(U(I,JWAVE))*2
600 IF (IDIR.NE.(-1)) CXCUR=DXMIN*(1.+ZFIN/VR1)
140 IF (IDIR.EQ.(-1)) CXCUR=DXMIN*(1.+ZLEN/VR1)*(1.+ZLEN-ZFIN)/VR2)
    DXOLD(IL2)=DXCUR
C
C      PROPAGATION TO Z=ZFIN COMPLETE
C
999 RETURN
END
1320J
1322J
1324J
1326J
1328J
1330J
1332J
1334J
1336J
1338J
1340J
1342J
1344J
1346J
1348J
1350J
1352J
1354J
1356J
1358J
1360J
1362J
1364J
1366J
1368J
1370J
1372J
1374J
1376J
1378J
1380J
1382J

```

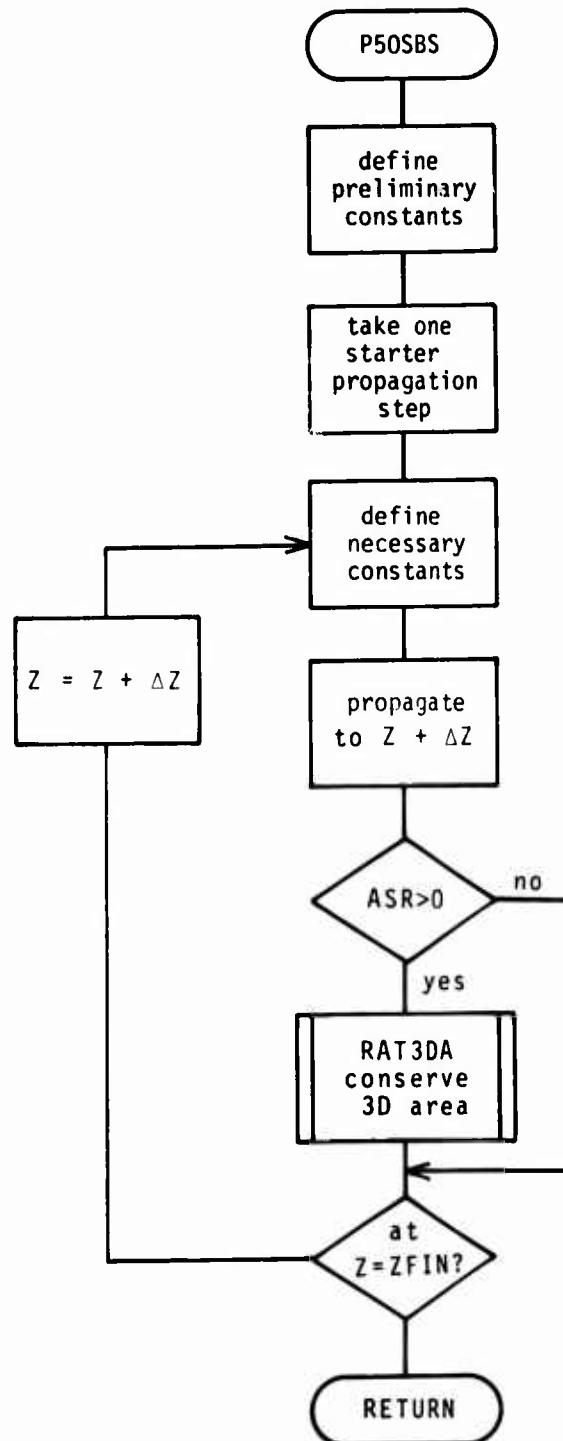


Fig. E4. P50SBS logic flow diagram.

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5      SUBROUTINE P50SBS(NWAVES,NX,NXDIM,XK0,ASR,DXMIR,
      *   VR,DZ,ZSTART,ZFIN,T,U,V)
      COMPLEX T(NXDIM,NWAVES),U(NXDIM,NWAVES),V(NXDIM,NWAVES)
      DIMENSION XK0(NWAVES)

10     C-----
      C P50SBS STEP-BY-STEP PROPAGATION OF (NWAVES) WAVEFORMS THROUGH
      C   FREE SPACE USING THE EXPANDING COORDINATE SYSTEM
      C   (ASSUMES CONSTANT DELTA-Z)
      C-----
      C THE PARAMETERS ARE
      C-----
      C NWAVES THE NUMBER OF PROPAGATING WAVES
      C NX THE NUMBER OF MESH POINTS ALONG X
      C NXDIM THE X-DIMENSION OF THE PROPAGATING MATRICES
      C XK0 VECTOR OF K=2*PI/LAMBDA FOR EACH WAVE
      C ASR 3D AREA CONSERVATION SWITCH, WHEN .GT. 0
      C DXMIR DELTA-X FOR MIRROR FROM WHICH PROPAGATION IS PROCEEDING
      C VR VIRTUAL RADIUS OF CURVATURE FOR MIRROR (SEE DXMIR)
      C DZ DELTA-Z
      C ZSTART DISTANCE FROM LAST MIRROR FOR START OF PROPAGATION
      C ZFIN DISTANCE FROM LAST MIRROR FOR FINISH OF PROPAGATION
      C* T DUMMY VECTOR USED IN PROPAGATING
      C* U WAVE VECTOR SUPPLIED TO AND RETURNED BY SUBPROGRAM
      C* V DUMMY VECTOR USED IN PROPAGATING
      C (* DENOTES A PARAMETER RETURNED IN ALTERED FORM)
      C
      C SUBPROGRAMS REQUIRED
      C RAT3DA (3D AREA CONSERVATION ROUTINE)
      C
      C 8/15/73 CREATED FROM NOTES AND PRPSBS STRUCTURE (PR20)
      C-----
      C
      C DEFINE PRELIMINARY CONSTANTS
      C
      C NXM1=NX-1
      C ZLEN=ZFIN-ZSTART
      C NZSTEP=ZLEN/DZ+.5
      C IF (NZSTEP-LE.0) GO TO 999
      C DZZ=ZLEN/FLOAT(NZSTEP)
      C
      C TAKE ONE STARTER PROPAGATION STEP
      C
      C-----
      C-----DEFINE CONSTANTS DEPENDENT ON Z-POSITION-----
      C ZCUR=ZSTART
      C DXCUR=DXMIR*(1.+ZCUR/VR)
      C F=ZCUR*VR
      C AA=1.-DZZ/(2.*F)
      C
      C-----PROPAGATE EACH WAVE TO ZSTART+DZ-----
      C
      C DO 150 J=1,NWAVES
      C DELX=DZZ/(XK0(J,WAVE)+DXCUR*DXCUR)
      C V(1,J,WAVE)=0.
      C V(NX,J,WAVE)=0.
      C DO 150 IX=2,NXM1
      C V(IX,J,WAVE)=AA*(U(IX,J,WAVE)+.5*DELX*(0.+1.))*I
      C
      C 150

```

```

60      C      + U(IX+1,JWAVE)-2.*U(IX,JWAVE)+U(IX-1,JWAVE)))
        C      IF(NZSTEP.EQ.1) GO TO 999
        C
        C      TAKE (NZSTEP-1) PROPAGATION STEPS
        C
        NZM1=NZSTEP-1
        DO 400 IZ=1,NZM1
        C-----DEFINE CONSTANTS DEPENDENT ON Z-POSITION-----
        ZCUR=FLOAT(IZ)*DZ+ZSTART
        DXCUR=DXMIR*(1.+ZCUR/VR)
        F=ZCUR+VR
        AA=1.-DZ/(2.*F)
        C-----DEFINE CONSTANT DEPENDENT ON WAVE NUMBER-----
        DO 400 JWAVE=1,NWAVES
        DELX=DZ/(XK0(JWAVE)*DXCUR+DXCUR)
        DELXSQ=DELX*DELX
        C-----SHIFT VALUES IN ARRAYS (I=U, U=V)
        DO 250 IX=1,NX
        T(IX,JWAVE)=U(IX,JWAVE)
        U(IX,JWAVE)=V(IX,JWAVE)
        C-----PROPAGATE ONE WAVE-----
        DO 300 IX=2,NXM1
        V(IX,JWAVE)=
        + AA/(1.+DELXSQ)*
        + (T(IX,JWAVE)*AA+
        + (0.+1.)*DELX*(U(IX+1,JWAVE)-2.*T(IX,JWAVE)*AA+U(IX-1,JWAVE))
        + DELXSQ*U(IX+1,JWAVE)-T(IX,JWAVE)*AA+U(IX-1,JWAVE)))
        C-----AFTER EACH WAVE HAS ADVANCED DZ, CONSERVE 3D AREA (IF ASR .GT. 0)
        IF(ASR.LE.G.) GO TO 400
        DXNEXT=DXMIR*(1.+ZCUR+DZ)/VR)
        CALL MAT3DAX(NX,NXDIM,NWAVES,DXNEXT,DXCUR,V,U)
        400 CONTINUE
        C
        C      AT ZFIN, SET U MATRIX TO ENDING VALUES
        C
        DO 500 JWAVE=1,NWAVES
        DO 500 IX=1,NX
        U(IX,JWAVE)=V(IX,JWAVE)
        C
        C      RETURN
        999 RETURN
        END
100

```



```

5      SUBROUTINE GAINA(NX,NXDIM,IMAVE,SOTOT,GAIN)
        COMPLEX GAIN(NXDIM,IMAVE)
        DIMENSION SOTOT(NXDIM,IMAVE)
        COMMON /CGAINA/ GZERO,XIZERO,XSTART,DXCUR
        C-----
        C GAIN ANALYTICAL GAIN ROUTINE
        C-----
        C THE PARAMETERS ARE
        C-----
10     C NX-----NUMBER OF X POINTS
        C NXDIM--DIMENSION (IN X) OF SOTOT
        C IMAVE--NUMBER OF PROPAGATING WAVES
        C SOTOT--SUMMED INTENSITIES MATRIX
        C GAIN---GAIN MATRIX (RETURNED)
        C GZERO SMALL SIGNAL GAIN
        C XIZERO SATURATION FLUX DENSITY
        C XSTART X-LOCATION (RELATIVE TO NOZZLE BANK) OF 1ST INTENSITY ELEMENT
        C DXCUR DELTA-X FOR INTENSITY MATRIX
        C-----
        C SUBPROGRAMS REQUIRED---NONE
        C-----
        C
25     DO 100 JMAVE=1,IMAVE
        DO 100 I=1,NX
            GAIN(I,JMAVE)=GZERO/(1.+SOTOT(I,JMAVE)/XIZERO)
        RETURN
    END
100
2360
2380
2400
2420
2440
2460
2480
2500
2520
2540
2560
2580
2600
2620
2640
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2700
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2740
2760
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2800
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2840
2860
2880
2900
2920

```

```

5      SUBROUTINE MIRROR(IMAVE,NX,NXDIM,U,V,XM)
        COMPLEX U(NXDIM,IMAVE),XM(NX),V(NX),A
        XMGTD(A)=SQRT(REAL(A)**2+AIMAG(A)**2)

13     C-----MULTIPLIES MIRROR MATRIX TIMES PROPAGATION MATRIX
        C-----
        C THE PARAMETERS ARE
        C IMAVE--THE NUMBER OF PROPAGATING WAVES
        C NX-----THE NUMBER OF X POINTS
        C NXDIM--THE X-DIMENSION OF THE PROPAGATION MATRIX
        C U-----INPUT/REFLECTED WAVE MATRIX (COMPLEX)
        C V-----DUMMY VECTOR (COMPLEX, DIM. AT LEAST NX)
        C XM-----MIRROR VECTOR (COMPLEX, DIM. AT LEAST NX)
        C
        C SUBPROGRAMS REQUIRED--NCNE
        C
        C CHANGED 3-26-73 (END POINTS DEFINED)
        C-----
        C
        NXM1=NX-1
        DO 230 JMAVE=1,IMAVE
          DO 220 I=2,NXM1
            AVCMAG=.25*XMGTD(U(I-1,JMAVE))*.5*XMGTD(U(I,JMAVE))
            *
            * .25*XMGTD(U(I+1,JMAVE))
            UREAL=REAL(U(I,JMAVE))
            UIMAG=AIMAG(U(I,JMAVE))
            IF(UREAL.EQ.0.) URP=0.
            IF(UREAL.NE.0.) URP=SIGN(1.,UREAL)*
            *
            * AVCMAG/SQRT((UIMAG/UREAL)**2+1.)
            IF(UIMAG.EQ.0.) UIP=0.
            IF(UIMAG.NE.0.) UIP=SIGN(1.,UIMAG)*
            *
            * AVCMAG/SQRT((UREAL/UIMAG)**2+1.)
            V(I)=CMPLX(URP,UIP)*XM(I)
          CONTINUE
          V(I)=U(1,JMAVE)*XM(I)
          V(NX)=U(NX,JMAVE)*XM(NX)
          DO 230 I=1,NX
            U(I,JMAVE)=V(I)
          CONTINUE
          RETURN
        END
220
230

```

```

SUBROUTINE NORM2D(IFILE,NX,NXDIM,INAVE,DX,U)
  COMPLEX U(NXDIM,INAVE)
  C-----
  C 5 NORM2D 2D NORMALIZATION ROUTINE
  C
  C 10 THE PARAMETERS ARE--
  C
  C 15 C IFILE--
  C      .LE.0 NORMALIZE, DON'T PRINT
  C      .GT.0 NORMALIZE, PRINT PARAMETERS ON FILE CODE IFILE
  C      .EQ.0 NUMBER OF X POINTS
  C      .GT.0 NUMBER OF PROPAGATION WAVES
  C      .GT.0 NUMBER OF PROPAGATING WAVES
  C      .GT.0 DELTA-X FOR MESH SPACING
  C      .GT.0 PROPAGATION MATRIX (COMPLEX, DIM NXDIM BY INAVE)
  C
  C 20 SUBROUTINES NECESSARY--AREA21
  C
  C 25 8/29/73 DELTA-X ARGUMENT SUBSTITUTED FOR X-ARRAY
  C-----
  DO 500 JNAVE=1,INAVE
    CALL AREA21(0,NX,NXDIM,1,2,1,1,DX,U(1,JNAVE),0.,AREA2D,A3)
    GAMMA=SQRT(AREA2D)
    XLOSS=1.-AREA2D
    DO 150 I=1,NX
      U(I,JNAVE)=U(I,JNAVE)/GAMMA
    150 IF (IFILE.GT.0) WRITE(IFILE,9000) JNAVE,XLOSS,AREA2D
    500 FORMAT(1H0,29H2D NORMALIZATION, WAVE NUMBER,13/
      + 5X,4HLOSS,E20.7/5X,17HAREA BEFORE NORM.,E20.7)
    RETURN
  END
  END

```

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```

5      SUBROUTINE PMROUT(IFILE,NX,NX2,ASR,DX,OMEGA,TLOSS,REFL,
        * U,PMRNF,PMROT)
        COMPLEX U(NX),A
        XINTY(A)=REAL(A)**2+AIMAG(A)**2

10     C-----
        C PMROUT--FOR ONE WAVE, COMPUTES POWER BEFORE AND AFTER MIRROR
        C THE PARAMETERS ARE
        C IFILE--PRINT OPTION
        C .LE. 0 DON'T PRINT
        C .GT. 8 PRINT POWER AT MIRROR, POWER OUT, AND POWER
        C DIFFERENCE ON FILE CODE IFILE
        C NX-----THE NUMBER OF INTERVALS ACROSS THE OUTPUT MIRROR FLAT
        C NX2-----THE NUMBER OF X POINTS
        C ASR-----30 AREA ADJUSTMENT FACTOR
        C .EQ. 0. 2D POWER COMPUTATION
        C .NE. 0. 3D POWER COMPUTATION
        C DX-----DELTA X FOR PROPAGATION VECTOR
        C OMEGA--MIRROR EDGE FALLOFF PARAMETER FOR OUTPUT MIRROR
        C TLOSS--POWER LOSS OF MIRROR (DECIMAL FRACTION)
        C REFL-----POWER REFLECTIVITY OF MIRROR
        C U-----PROPAGATION VECTOR (COMPLEX, DIM AT LST NX)
        C PMRNF--POWER BEFORE OUTPUT MIRROR
        C PMROT--POWER AFTER OUTPUT MIRROR

20     C SUBPROGRAMS REQUIRED--NONE

30     C CHANGED 3-26-73 (CALL TO AREA REMOVED, 2D/3D MADE OPTION)
        C 8/29/73 REFERENCE TO X-ARRAY DELETED

35     C-----
        CONST=(1.-REFL)*(1.-TLOSS)
        ICENT=(NX+1)/2
        PMRNF=0.
        PMROT=0.
        FFDIA=FLOAT(NX2)*DX+2.*OMEGA

40     C-----COMPUTE NEAR FIELD POWER AND POWER OUT-----
        DO 215 I=1,NX
            XDEL=ABS(FLOAT(ICENT-I)*DX)
            IF (ASR.EQ.0.) PSX=XINTY(U(I))*DX
            IF (ASR.NE.0.) PSX=XDEL*XINTY(U(I))*DX
            PMRNF=PMRNF+PSX
            IF (2.*XDEL.LT.FFDIA) PMROT=PMROT+CONST*PSX
            IF (2.*XDEL.GE.FFDIA) PMROT=PMROT+PSX
215    CONTINUE

50     C-----ADJUST FOR 3D FACTOR, IF NECESSARY-----
        IF (ASR.NE.0.) PMRNF=ASR*PMRNF
        IF (ASR.NE.0.) PMROT=ASR*PMROT
        C-----PRINT RESULTS, IF DESIRED-----
        PMDEL=PMRNF-PMROT
        IF (IFILE.GT.0) WRITE (IFILE,1000) PMRNF,PMROT,PMDEL
1000  FORMAT(1H6,5MPOWER/5X,17MNEAR FIELD POWER=E20.7/
        * 5X,26MOUTPUT PCWER AFTER MIRROR=E20.7/5X,17MPOWER DIFFERENCE=,
        * E20.7)

```

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74/74 OPT=1

SUBROUTINE PMROUT

5720
5740

RETURN
END

```

5      SUBROUTINE RAT3DA(NX,NXDIM,IWAVE,DXU,DXV,U,V)
        COMPLEX U(NXDIM,IWAVE),V(NXDIM,IWAVE)
        DIMENSION A(2)
        COMMON /RCUM/ RCUM3D(1)

10      C-----
        C RAT3DA--MODIFIES PROPAGATION MATRIX AT EACH DZ STEP TO
        C CONSERVE 3D AREA
        C
        C THE PARAMETERS ARE
        C NX-----THE NUMBER OF X POINTS
        C NXDIM-----THE X-DIMENSION OF THE PROPAGATION MATRIX
        C IWAVE THE NUMBER OF PROPAGATING WAVES
        C DXU-----DELTA-X FOR THE U-MATRIX
        C DXV-----DELTA-X FOR THE V-MATRIX
        C U-----PROPAGATION MATRIX (COMPLEX, DIM NXDIM BY IWAVE)
        C V-----PREVIOUS STEP PROPAGATION MATRIX (COMPLEX, DIM NXDIM BY IWAVE)
        C RCUM3D-CUMULATIVE RATIOS FOR EACH WAVE (REAL, DIM AT LST IWAVE)
        C
20      C SUBPROGRAMS REQUIRED--NCNE
        C
        C 8/30/73 2 DX VARIABLES SUBSTITUTED FOR X-ARRAY
        C-----
        C
25      DO 100 JWAVE=1,IWAVE
        A(1)=0.
        A(2)=0.
        ICENT=(NX+1)/2
        DO 50 I=1,NX
            XDELU=ABS(FLOAT(ICENT)-DXU)*DXU
            XDELV=ABS(FLOAT(ICENT)-DXV)*DXV
            A(1)=A(1)+(REAL(U(I,JWAVE))**2+AIMAG(U(I,JWAVE))**2)*XDELU
            A(2)=A(2)+(REAL(V(I,JWAVE))**2+AIMAG(V(I,JWAVE))**2)*XDELV
            RATIO=SQRT(A(2)/A(1))
            RCUM3D(JWAVE)=RCUM3D(JWAVE)*RATIO
        DO 100 I=1,NX
            U(I,JWAVE)=U(I,JWAVE)*RATIO
            V(I,JWAVE)=V(I,JWAVE)*RATIO
        CONTINUE
        RETURN
        END
30
35
40
50
100

```

```

SUBROUTINE SETMIR(NX,NX2,DX,XK0,REFL,RCURV,OMEGA,BETA,XM)
  COMPLEX XM(NX),CURV,TILT
  C-----
  C  SETMIR---SETS UP A MIRROR VECTOR
  C-----
  C  THE PARAMETERS ARE
  C  NX-----THE NUMBER OF X-POINTS ACROSS THE MIRROR
  C  NX2-----THE NUMBER OF INTERVALS ACROSS THE
  C  MIRROR CENTER NOT SUBJECT TO THE NORMAL FALLOFF EFFECT
  C  DX-----DELTA X
  C  XK0-----K = 2 PI / LAMBDA
  C  REFL---MIRROR REFLECTIVITY (POWER)
  C  RCURV---MIRROR RADIUS OF CURVATURE
  C  OMEGA---MIRROR EDGE FALLOFF PARAMETER
  C  BETA---MIRROR TILT ANGLE
  C  XM-----MIRROR VECTOR (COMPLEX, DIM. AT LST NX)
  C-----
  C  SUBPROGRAMS REQUIRED---NONE
  C-----
  C  CHANGED 2-8-73,3-1-73,3-28-73
  C  7/25/73  REMOVED FAR FIELD CAPABILITY AND X DEFINITION
  C  8/29/73  REFERENCE TO X-ARRAY DELETED
  C-----
  C  ISENT=(NX+1)/2
  C  NX2P=NX2-MOD(NX2,2)
  C  NX1=(NX-NX2P-1)/2
  C-----
  C  DEFINE MIRROR VALUE FOR EACH MATRIX LOCATION
  C-----
  DO 140 J=1,NX
    XDEL=FLOAT(J-ISENT)*DX
    C-----DETERMINE RADIUS OF CURVATURE COMPONENT-----
    IF (RCURV.GE.(1.E30)) CURV=1.
    IF (RCURV.LT.(1.E30)) CURV=
      + CEXP(-XK0*XDEL**2*(0.1)/RCURV)
    C-----DETERMINE MIRROR TILT COMPONENT-----
    TILT=CEXP(2.*XK0*BETA*XDEL*(0.1))
    C-----DETERMINE EDGE FALLOFF COMPONENT-----
    FALLOF=0.
    IF (J.GE.(NX1+1).AND.J.LE.(NX1+NX2P+1)) FALLOF=1.
    IF (OMEGA.EQ.0.) GO TO 130
    IF (J.LE.NX1) FALLOF=
      + EXP(-(FLOAT((NX1+1)-J)*DX/OMEGA)**2)
    IF (J.GE.(NX1+NX2P+2)) FALLOF=
      + EXP(-(FLOAT(J-(NX1+NX2P+1))*DX/OMEGA)**2)
    C-----COMPUTE MIRROR VECTOR VALUE-----
    XM(J)=SQRT(REFL)*FALLOF*CURV*TILT
  130 CONTINUE
  140 RETURN
  END

```

```

SUBROUTINE AREA21(IFILE,NPTS,NXDIM,NWAVES,ICMPLX,NCHAR,
* TITLE,DX,S,ASR,AREA2D,AREA3D)
  DIMENSION S(ICMPLX,NXDIM,NWAVES),TITLE(1)
  C-----
  C AREA21 COMPUTES AREAS FOR REAL OR COMPLEX MATRIX
  C-----
  C THE PARAMETERS ARE
  C-----
  C IFILE--OUTPUT FILE CODE
  C .LE. 0 DON'T PRINT AREAS
  C .GT. 0 PRINT TITLE AND AREA(S) SUMMARY
  C NPTS NUMBER OF POINTS ALONG X IN MATRIX
  C NXDIM THE FIRST (OR X-) DIMENSION OF THE MATRIX
  C NWAVES THE NUMBER OF PROPAGATING WAVES
  C ICMPLX-REAL/COMPLEX MATRIX OPTION
  C .EQ. 1 INPUT MATRIX IS REAL
  C .EQ. 2 INPUT MATRIX IS COMPLEX (USE INTENSITIES)
  C NCHAR THE NUMBER OF CHARACTERS IN THE TITLE SUPPLIED
  C TITLE THE HOLLERITH CR BCD TITLE TO BE PRINTED
  C DX-----DELTA-X FOR MESH SPACING
  C S-----INPUT MATRIX FOR WHICH AREA IS DESIRED
  C ASR 3D AREA MULTIPLIER
  C AREA2D 2D AREA (RETURNED)
  C AREA3D 3D AREA (RETURNED)
  C
  C SUBPROGRAMS REQUIRED--NONE
  C
  C 7/23/73 CREATED FROM #AREA#
  C 8/23/73 3D AREA FIX--STMT 180 + 2 MULTIPLIED BY ASR
  C 8/29/73 DELTA-X ARGUMENT SUBSTITUTED FOR X-ARRAY
  C-----
  C-----SETUP NECESSARY VARIABLES-----
  ICENT=(NPTS+1)/2
  INORDS=(NCHAR-1)/10+1
  IF(IFILE.GT.0) WRITE(IFILE,9050) (TITLE(I),I=1,INORDS)
  C
  C COMPUTE AREAS FOR EACH WAVE
  C
  DO 500 I=1,NWAVES
    AREA2D=0.
    AREA3D=0.
    C-----COMPUTE 2D AND 3D AREAS-----
    DO 100 J=1,NPTS
      XDEL=ABS(FLOAT(I-ICENT)*DX)
      IF(ICMPLX.EQ.1) VAL=S(I,I,I,NWAVE)
      IF(ICMPLX.EQ.2) VAL=S(I,I,I,NWAVE)**2+S(2,I,I,NWAVE)**2
      AREA2D=AREA2D+VAL
      AREA3D=AREA3D+VAL*XDEL
    100 CONTINUE
    AREA2D=AREA2D*DX
    AREA3D=AREA3D*DX*ASR
    C-----PRINT RESULTS IF DESIRED-----
    IF(IFILE.LE.0) GO TO 500
    IF(ASR.GT.0) WRITE(IFILE,9000) AREA3D
  500 CONTINUE
  9000
  9050

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SUBROUTINE AREA21 74/74 OPT=1 FTN 4.0+P357 09/27/73 14.18.55. PAGE 2

60 IF (ASR.LE.6.) WRITE (IFILE,9010) AREA2D
9009 FORMAT(5X,7H3D AREA,E20.7)
9010 FORMAT(5X,7H2D AREA,E20.7)
9050 FORMAT(1MC,7A1C)
500 CONTINUE
999 RETURN
END

19220
19240
19260
19300
19320
19340

```

SUBROUTINE RSTART(IFILE,IRCODE,IRTAG,NWAVES,NXDIM,NZDIM,
+ U,SO)
  DIMENSION IDUM(10),RDUM(10)
  DIMENSION SO(101,21,2)
  COMPLEX U(101,2)
  COMMON /FFNZ/ NZ
  C-----
  C RSTART---READS RSTART TAPE FOR PR SERIES
  C-----
  C THE PARAMETERS ARE
  C-----
  C IFILE--FILE CODE FOR SUMMARIZING RSTART PARAMETERS
  C LE. 0 DON'T PRINT
  C GT. 0 PRINT PARAMETERS ON FILE CODE IFILE
  C IRCODE--FILE CODE FROM WHICH RSTART PARAMETERS ARE TO BE READ
  C IRTAG--A TAG PARAMETER WHICH THE RSTART ROUTINE WILL SEARCH FOR
  C NWAVES--THE NUMBER OF WAVES TO BE TAKEN FROM RSTART FILE
  C NXDIM--THE X DIMENSION OF BOTH THE U AND SO MATRICES
  C NZDIM--THE Z DIMENSION OF THE SO MATRIX
  C U-----THE PROPAGATION MATRIX TO BE FILLED FROM RSTART FILE
  C SO-----THE PAST INTENSITIES MATRIX TO BE FILLED FROM RST. FILE
  C SUBPROGRAMS REQUIRED--ACNE
  C
  C CHANGED 1-25-73
  C CHANGED 9/6/73 SPECIAL COMMON FOR RETURN OF NZ VALUE
  C-----
  C-----READ IDENTIFICATION LABEL OF RSTART TAPE-----
  C
  REMIND IRCODE
  READ(IRCODE) TIME,DATE,SNMB,PROG,CASE
  FORMAT(1X,2A6)
  IF(IFILE.GT.0) WRITE(IFILE,1010) IRCODE,IRTAG,TIME,
+ DATE,SNMB,PROG,CASE
  1010 FORMAT(1H1,29MUSINC RSTART TAPE, FILE CODE , IS,
+ 11M, TO MATCH ,16/1H0,5X,19HTAPE IDENTIFICATION /1CX,4MTIME,
+ 5X,A6/10X,4MDATE,5X,A6/10X,5MSNMB,4X,A6/10X,7MPROGRAM,
+ 2X,A6/1CX,4MCASE,5X,F6.1)
  C
  C-----READ GOVERNING PARAMETERS FOR STORED INFORMATION-----
  C
  READ(IRCODE) IDUM,RDUM
  NX=IDUM(1)
  NZ=IDUM(2)
  NWAVE=IDUM(3)
  IF(IFILE.GT.0) WRITE(IFILE,1020) NX,NZ,NWAVE
  1020 FORMAT(1H0,41MGOVERNING PARAMETERS FOR TAPE INFORMATION /
+ 5X,3MNX=,15/5X,3MNZ=,15/5X,6H1NWAVE=,15)
  C
  C-----FIND INDICATED TAG FIELD AND READ INFORMATION-----
  C
  100 READ(IRCODE) IRTAG
  READ(IRCODE) ((U(I,J),I=1,NX),J=1,NWAVES)
  READ(IRCODE) ((SO(I,J,K),I=1,NX),J=1,NZ),K=1,NWAVES)
  IF(EOF(IRCODE)) 999,200

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FTN 4.0+P357

SUBROUTINE RSTART 74/74 OPT=1

200 IF(IITAG.NE.IRTAG) GO TO 100
999 RETURN
END

20560

60


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5      SUBROUTINE PGPLT2(IFILE,ISCALE,N,ICYC,NCHAR,LABEL,
        * X,NCHAR,LABELX,Y,NCHAR,LABELY)
        DIMENSION X(1),Y(1),LABEL(1),LABELX(1),LABELY(1)
        DATA BLANK,PLUS/1H ,1M+/
10      C-----PAGE PLOT ROUTINE WITH SCALING OPTION
        C
        C THE PARAMETERS ARE
        C
        C IFILE FILE CODE FOR PLOT
        C ISCALE-SCALING OPTION
        C .EQ.0 FULL PAGE PLOT, NO AXIS SCALING
        C .EQ.1 AXIS SCALING FOR CONVENIENT SCALE
        C N-----NUMBER OF POINTS IN X AND Y ARRAYS
        C ICYC---CYCLE PARAMETER FOR ARRAYS (I=1,N,ICYC)
        C NCHAR--NUMBER OF CHARS IN TITLING ARRAY (LABEL)
        C LABEL--TITLING ARRAY FOR PAGE PLOT
        C X-----X ARRAY (INDEPENDENT VARIABLE)
        C NCHAR--NUMBER OF CHARS IN X-AXIS LABEL
        C LABELX-X AXIS LABEL
        C Y-----Y ARRAY (DEPENDENT VARIABLE)
        C NCHAR--NUMBER OF CHARS IN Y AXIS LABEL
        C LABELY-Y AXIS LABEL
        C
        C SUBPROGRAMS REQUIRED---CSCALE
        C
        C 0/29/73 VERTICAL REGISTRATION PROBLEM FIXED ON Y-AXIS
        C 0/29/73 NULL PLOT LOGIC INSERTED BEFORE STMT 200
        C-----
        C-----TITLE PLOT-----
        NMWORDS=MIN0((NCHAR-1)/10+1,5)
        NMWORD=MIN0((NCHAR-1)/10+1,3)
        NMWORD=MIN0((NCHAR-1)/10+1,3)
        IF (NMWORDS.GT.0) WRITE(IFILE,3000) (LABEL(I),I=1,NMWORDS)
        IF (NMWORDS.LE.0) WRITE(IFILE,3010)
        C-----ESTABLISH SCALING PARAMETERS-----
        C
        C IF (ISCALE.LE.0) GO TO 100
        C-----CHOOSE CONVENIENT SCALES-----
        CALL CSCALE(X,11,N,ICYC,0,0,XLO,XINC)
        X RANGE=11.*XINC+XINC/10.
        RANGE=11.*XINC
        XINC=XINC/10.
        CALL CSCALE(Y,5,N,ICYC,0,0,YLO,YINC)
        Y RANGE=5.*YINC
        YINC=YINC/10.
        GO TO 200
        C-----USE WHOLE PAGE-----
100     XLO=1.E30
        XMI=-1.E30
        YLO=1.E30
        YMI=-1.E30
        DO 150 I=1,N,ICYC
2000    2100
        2100
        2200
        2220
        2240
        2260
        2280
        2300
        2320
        2340
        2360
        2380
        2400
        2420
        2440
        2460
        2480
        2500
        2520
        2540
        2560
        2580
        2600
        2620
        2640
        2660
        2680
        2700
        2720
        2740
        2760
        2780
        2800

        2800
        2900
        2920
        2940
        2960
        2980
        3000
        3020
        3040
        3060
        3080
        3100
        3120
        3140
        3160
        3180
        3200
        3220
        3240
        3260
        3280
    
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60      XLO=AMIN1(XLO,X(I))
      XHI=AMAX1(XHI,X(I))
      YLO=AMIN1(YLO,Y(I))
      YHI=AMAX1(YHI,Y(I))
      XINC=(XHI-XLO)/110.
      YINC=(YHI-YLO)/50.
      XINC=XHI-XLO+XINC
      YINC=YHI-YLO
      YINC=YHI-YLO
      IF (YHI-YLO.EQ. 0. .OR. YHI*.9999.GT.YLO) GO TO 200
      WRITE (IFILE,1500) YLO,YHI
      GO TO 999

70      200 WRITE (IFILE,1000) N,XINC,YINC, (LABELY(I), I=1,NXWORD)
      C
      C-----PRODUCE PGPLCT-----
      C
      YCURM=YRANGE+YLO+YINC/2.
      DO 300 IJ=1,51
      YCUR=(51.-FLOAT(IJ))/50.*YRANGE+YLO
      YCURP=YCURM
      YCURM=YCURP-YINC
      DO 270 I=1,111
      Z(I)=BLANK
      DO 280 I=1,N
      IF (Y(I).GT.YCURP.CR.Y(I)).LE.YCURM) GO TO 280
      INT=111.*(X(I)-XLC+XINC/2.)/XRANGE+1.
      Z(INT)=PLUS
      280 CONTINUE
      K=MOD((IJ-1),5)
      IF (K.EQ.0) WRITE (IFILE,1300) YCUR,Z
      IF (K.NE.0) WRITE (IFILE,1350) Z
      300 CONTINUE
      C-----COMPLETE LOWER AXIS LABELING-----
      DO 400 I=1,6
      VAL(I)=XLO+2.*FLOAT(I-1)*RANGE/11.
      DO 450 I=7,12
      VAL(I)=XLO+12.*FLCAT(I-7)+1.*RANGE/11.
      450 WRITE (IFILE,1400) VAL, (LABELX(I), I=1,NXWORD)
      999 RETURN
      3000 FORMAT(1M1,5A10)
      3010 FORMAT(1M1)
      1000 FORMAT(1X,17NUMBER OF POINTS=,I4,15X,12HX INCREMENT=,
      * E16.8,12X,12HY INCREMENT=,E16.8//5X,3A16)
      1300 FORMAT(1X,E16.8,3H -,111A1)
      1350 FORMAT(10X,2H1,111A1)
      1400 FORMAT(20X,111M1,9H-----),1M1/
      * 8X,6E20.8/17X,5E20.8,E14.6//76X,3A10)
      1500 FORMAT(1X,25I/1X),34HY-AXIS VALUES ARE APPROX. CONSTANT ,
      * 8H BETWEEN , E20.7, 4H AND , E20.7, 25(/1X)
      END

```

```

5      FUNCTION VALUE(IITYPE,GLOC)
        DIMENSION GLOC(2)
        C-----
        C-----RETURNS ONE OF SEVERAL VALUES
        C THE PARAMETERS ARE
        C IITYPE---OPTION IDENTIFYING TYPE OF VALUE TO BE RETURNED
        C  =0 THE VALUE OF GLOC(1)
        C  =1 REAL, OR THE VALUE OF GLOC(1)
        C  =2 IMAGINARY, OR THE VALUE OF GLOC(2)
        C  =3 MAGNITUDE OF GLOC ASSUMING GLOC COMPLEX NUMBER
        C  =4 INTENSITY OF GLOC ASSUMING GLOC COMPLEX NUMBER
        C  =5 PHASE ANGLE (RADIAN), -PI TO +PI OF GLOC
        C  =6 PHASE ANGLE (DEGREES, -180 TO +180) OF GLOC
        C GLOC---SUPPLIED MATRIX ELEMENT FOR WHICH THE VALUE IS TO BE FOUND
        C
        C SUBPROGRAMS REQUIRED---NONE
        C-----
        C-----
        C
        C IF (IITYPE.GT.1) GO TO 100
        C VALUE=GLOC(1)
        C RETURN
        C
        C GO TO (10,120,130,140,150,150), IITYPE
        C
        C 100 VALUE=GLOC(2)
        C RETURN
        C
        C 120 VALUE=SQRT(GLOC(1)**2+GLOC(2)**2)
        C RETURN
        C
        C 130 VALUE=GLOC(1)**2+GLOC(2)**2
        C RETURN
        C
        C 140 VALUE=-.5
        C RETURN
        C
        C 150 IF (GLOC(1).NE.0..CR.GLOC(2).NE.0.)
        C   + VALUE=ATAN2(GLOC(2),GLOC(1))
        C IF (IITYPE.EQ.6.AND.VALUE.NE.(-.5)) VALUE=VALUE*.296
        C RETURN
        C END

```

```

SUBROUTINE ALLOUT(IFILE,NPTS,ISKIP,NHAT,NCHAR,LABEL,
+ IC1,IO1,NC1,LBL1,A1,B1,IC2,IO2,NC2,LBL2,A2,B2,
+ IC3,IO3,NC3,LBL3,A3,B3,IC4,IO4,NC4,LBL4,A4,B4,
+ IC5,IO5,NC5,LBL5,A5,B5,IC6,IO6,NC6,LBL6,A6,B6,
+ IC7,IO7,NC7,LBL7,A7,B7)
+ALLOUT OUTPUT ROUTINE FOR MULTIPLE ARRAYS
  DIMENSION A1(IC1,NPTS),A2(IC2,NPTS),A3(IC3,NPTS),
+ A4(IC4,NPTS),A5(IC5,NPTS),A6(IC6,NPTS),A7(IC7,NPTS)
  DIMENSION B1(NPTS),B2(NPTS),B3(NPTS),B4(NPTS),B5(NPTS),
+ B6(NPTS),B7(NPTS)
  DIMENSION LBL1(1),LBL2(1),LBL3(1),LBL4(1),LBL5(1),
+ LBL6(1),LBL7(1),LABEL(1)
  DIMENSION CVAL(7),INDEX(7),IVAL(7),ILBL(21)
  IOPT(IMORD,N)=MOD(IMORD/10**(N-1),10)
  C-----SET UP INDICES FOR OPTIONS-----
  DO 2 I=1,7
  DO 2 J=1,7
  INDEX(I,J)=0
  DO 4 I=1,7
  IF (NHAT.GE.1) INDEX(I,1)=IOPT(IO1,I)
  IF (NHAT.GE.2) INDEX(I,2)=IOPT(IO2,I)
  IF (NHAT.GE.3) INDEX(I,3)=IOPT(IO3,I)
  IF (NHAT.GE.4) INDEX(I,4)=IOPT(IO4,I)
  IF (NHAT.GE.5) INDEX(I,5)=IOPT(IO5,I)
  IF (NHAT.GE.6) INDEX(I,6)=IOPT(IO6,I)
  IF (NHAT.GE.7) INDEX(I,7)=IOPT(IO7,I)
  C-----SET UP MATRICES FOR OUTPUT-----
  IF (NHAT.GE.1) CALL ONEOUT(IC1,NPTS,ISKIP,INDEX(1,1),A1,B1)
  IF (NHAT.GE.2) CALL ONEOUT(IC2,NPTS,ISKIP,INDEX(1,2),A2,B2)
  IF (NHAT.GE.3) CALL ONEOUT(IC3,NPTS,ISKIP,INDEX(1,3),A3,B3)
  IF (NHAT.GE.4) CALL ONEOUT(IC4,NPTS,ISKIP,INDEX(1,4),A4,B4)
  IF (NHAT.GE.5) CALL ONEOUT(IC5,NPTS,ISKIP,INDEX(1,5),A5,B5)
  IF (NHAT.GE.6) CALL ONEOUT(IC6,NPTS,ISKIP,INDEX(1,6),A6,B6)
  IF (NHAT.GE.7) CALL ONEOUT(IC7,NPTS,ISKIP,INDEX(1,7),A7,B7)
  C-----PRINT SPECIFIED MATRICES-----
  NCOL=0
  DO 38 I=1,NHAT
  IF (INDEX(2,I).LE.0) GO TO 39
  NCOL=NCOL+1
  IVAL(NCOL)=I
  CONTINUE
  38 IF (NCOL.LE.0) GO TO 300
  C-----POSITION COLUMN HEADINGS-----
  DO 48 I=1,NCOL
  J=IVAL(I)
  ISTRT=(I-1)*2+1
  IF (J.EQ.1) CALL LBLPCS(NC1,LBL1,ISTRT,ILBL)
  IF (J.EQ.2) CALL LBLPOS(NC2,LBL2,ISTRT,ILBL)
  IF (J.EQ.3) CALL LBLPOS(NC3,LBL3,ISTRT,ILBL)
  IF (J.EQ.4) CALL LBLPOS(NC4,LBL4,ISTRT,ILBL)
  IF (J.EQ.5) CALL LBLPOS(NC5,LBL5,ISTRT,ILBL)
  IF (J.EQ.6) CALL LBLPOS(NC6,LBL6,ISTRT,ILBL)
  IF (J.EQ.7) CALL LBLPOS(NC7,LBL7,ISTRT,ILBL)
  C-----PRINT LINES-----
  LINES=0

```



```

60      DO 190 I=1,NPTS,ISKIP
          IF (MOD(LINES,50).NE.0) GO TO 50
          NWORDS=(NCHAR-1)/10+1
          IF (NWORDS.GT.8) WRITE (IFILE,100) (LABEL(K),K=1,NWORDS)
          IF (NWORDS.LE.8) WRITE (IFILE,1010)
          KMAX=2*NCOL
          WRITE (IFILE,1020) (LBL(K),K=1,KMAX)
          LINES=LINES+1
          DO 78 J=1,NCOL
            K=IVAL(J)
            GO TO (61,62,63,64,65,66,67),K
            CVAL(J)=B1(I)
            GO TO 78
            CVAL(J)=B2(I)
            GO TO 78
            CVAL(J)=B3(I)
            GO TO 78
            CVAL(J)=B4(I)
            GO TO 78
            CVAL(J)=B5(I)
            GO TO 78
            CVAL(J)=B6(I)
            GO TO 78
            CVAL(J)=B7(I)
            GO TO 78
            CONTINUE
100      WRITE (IFILE,1030) I, (CVAL(K),K=1,NCOL)
          C
          C-----PAGE PLOTS FOR SPECIFIED MATRICES-----
          CONTINUE
          IF (INDEX(3,2).NE.0) CALL PGPLY2(IFILE,INDEX(3,2)-1,
            + NPTS,ISKIP,NCHAR,LABEL,B1,NC1,LBL1,B2,NC2,LBL2)
          IF (INDEX(3,3).NE.0) CALL PGPLY2(IFILE,INDEX(3,3)-1,
            + NPTS,ISKIP,NCHAR,LABEL,B1,NC1,LBL1,B3,NC3,LBL3)
          IF (INDEX(3,4).NE.0) CALL PGPLY2(IFILE,INDEX(3,4)-1,
            + NPTS,ISKIP,NCHAR,LABEL,B1,NC1,LBL1,B4,NC4,LBL4)
          IF (INDEX(3,5).NE.0) CALL PGPLY2(IFILE,INDEX(3,5)-1,
            + NPTS,ISKIP,NCHAR,LABEL,B1,NC1,LBL1,B5,NC5,LBL5)
          IF (INDEX(3,6).NE.0) CALL PGPLY2(IFILE,INDEX(3,6)-1,
            + NPTS,ISKIP,NCHAR,LABEL,B1,NC1,LBL1,B6,NC6,LBL6)
          IF (INDEX(3,7).NE.0) CALL PGPLY2(IFILE,INDEX(3,7)-1,
            + NPTS,ISKIP,NCHAR,LABEL,B1,NC1,LBL1,B7,NC7,LBL7)
          RETURN
1000     FORMAT(1H1,12A18)
1010     FORMAT(1H1)
1020     FORMAT(10G,4X,1H1,5X,7(1X,A10,A5)/)
1030     FORMAT(1X,15,5X,7E16.0)
          END
105

```

```

SUBROUTINE ONEOUT (ICMPLX,NPTS,ISKIP,INDEX,A,B)
  DIMENSION A(ICMPLX,NPTS),B(NPTS),INDEX(7)
  *ONEOUT RETURNS ONE MATRIX GIVEN A MATRIX
  C-----FIRST SET UP MATRIX-----
  DO 130 I=1,NPTS,ISKIP
    B(I)=VALUE(INDEX(1),A(1,I))
  C
  C-----HANDLE NORMALIZATION OPTION, IF REQUIRED-----
  C
  IF (INDEX(5).EQ.0) GO TO 300
  C-----DETERMINE NORMALIZING FACTOR (FACTOR)-----
  K=INDEX(6)
  GO TO (220,230,240),K
  220 J=ISKIP*((NPTS-1)/(2*ISKIP))+1
    FACTOR=B(J)
    GO TO 250
  230 FACTOR=B(1)
    DO 235 I=1,NPTS,ISKIP
      FACTOR=AMAX1(FACTOR,B(I))
    GO TO 250
  240 FACTOR=B(1)
    DO 245 I=1,NPTS,ISKIP
      FACTOR=AMIN1(FACTOR,B(I))
  245 FACTOR=AMIN1(FACTOR,B(I))
  250 CONTINUE
  C-----NORMALIZE ARRAY-----
  DO 270 I=1,NPTS,ISKIP
    IF (INDEX(5).EQ.1) B(I)=B(I)/FACTOR
    IF (INDEX(5).EQ.2.AND.FACTOR.NE.0.) B(I)=B(I)/FACTOR
  C
  C-----COMPUTE NORMALIZED AREA, IF REQUIRED-----
  C
  300 IF (INDEX(7).EQ.0) GO TO 999
    AREA=B.
    ICENT=(NPTS+1)/2
    DO 350 I=1,NPTS,ISKIP
      IF (INDEX(7).EQ.1) AREA=AREA+B(I)
      IF (INDEX(7).NE.1) AREA=AREA+B(I)*ABS(FLOAT(I-ICENT))
      B(I)=AREA
    CONTINUE
    DO 370 I=1,NPTS,ISKIP
      B(I)=ABS(2.*B(I)/E(NPTS)-1.)
  370 CONTINUE
  999 RETURN
  END

```

SUBROUTINE LBLPOS 74/74 OPT=1 PAGE 1

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```

SUBROUTINE LBLPOS(MCX,LBLX,ISTRT,ILBL)
  DIMENSION LBLX(1),ILBL(21)
  *LBLPOS LABEL POSITIONING ROUTINE FOR ALLOUT
  DATA IBL/1H /
  ILBL(ISTRT)=LBLX(1)
  IF(MCX.GT.13) ILBL(ISTRT+1)=LBLX(2)
  IF(MCX.LE.10) ILBL(ISTRT+1)=IBL
  RETURN
END

```

9740
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9980

APPENDIX F

GLOSSARY OF PRIMARY SSCP(ECS) NAMES

ALLOUT	Subroutine by which GPOP output is produced
AMPINT	Array for defining initial amplitude of waves
AREA21	Subroutine for computing area of a wave
ASR	Input variable defining pseudo-three-dimensional parameter
CASE	Input variable used for titling output
CASENO	Namelist block name for describing number of cases to be analyzed
CAVITY	Namelist block name for printing cavity description
CSCALE	Subroutine for determining printer plot scale increments
DIA1	Input variable defining diameter of output mirror
DIA2	Input variable defining diameter of back mirror
DXOLD	Array saving all DX values for each step of the last half-pass through the medium
GAIN	Array of gain and refractive index variations
GAINA	Subroutine defining GAIN array for medium propagation
GZERO	Input variable initializing g_0 for GAINA
IFILE	Input variable initializing normal output file code
INFOUT	Array defining output option for near field printout
IRCODE	Input variable describing file code from which restart information is to be read

IROUT	Input variable describing file code to which restart information is to be written
IRTAG	Input variable describing pass number of wave(s) to be taken as restart information
LBLPOS	Subroutine positioning column heading label for GPOP
MEDIUM	Namelist block name for printing medium description
MIRROR	Subroutine for reflecting waves from mirror
MIRRRS	Namelist block name for printing mirror descriptions
NCASES	Input variable setting number of cases to be analyzed
NORM2D	Subroutine for preserving 2D Area
NPASS	Input variable setting number of passes for a case
NWAVES	Input parameters defining the number of propagating waves
NWDIM	Dimensioning parameter for maximum number of waves that can be handled by the SSCP(ECS) or SSCP
NX	Input parameter defining the number of mesh points along the x-direction
NXC1	Computed parameter defining the number of x-intervals across the output mirror at start of pass
NXC2	Computed parameter defining the number of x-intervals across the back mirror
NXCOUT	Computed parameter defining the number of x-intervals across the output mirror at end of pass
NXDIM	Dimensioning parameter for maximum number of mesh points along x that can be handled by the FICP
NZDIM	Dimensioning parameter for maximum number of last-pass intensity stores possible
ONEOUT	Subroutine for defining vector from GPOP options
OUT1-OUT7	Arrays used by GPOP for defining values to be produced

P50GAI	Subroutine for computing set of gain values at a z-location
P50GET	Subroutine for retrieving a value from the last pass intensities matrix (SO)
P50INT	Subroutine for reducing the expanded waveform(s) to begin another pass
P50MED	Subroutine for propagating one way through a medium
P50SBS	Subroutine for propagating through an empty cavity (no medium) region
PGPLT2	Subroutine producing GPOP printer plot
PR51	Main program of SSCP(ECS)
PWROUT	Subroutine computing near field and output power
RAT3DA	Subroutine for preserving 3D Area
RCURV1	Input parameter defining the radius of curvature for the output mirror
RCURV2	Input parameter defining the radius of curvature of the back mirror
REFL1	Input parameter defining the power reflectivity of the output mirror
REFL2	Input parameter defining the power reflectivity of the back mirror
RSTART	Subroutine forming an input wave by restarting a previous run
RUNOPT	Namelist block name for printing run options
SETMIR	Subroutine for setting up a mirror vector
SO	Array storing last-pass intensity values
SONEW	Array storing current intensities until they can be stored
SOTOT	Array storing sum of old and new intensities

T	Array (dummy) used in propagation routines
TILT1	Input parameter defining mirror tilt angle of output mirror
TILT2	Input parameter defining mirror tilt angle of back mirror
TLOSS1	Input parameter defining power loss of output mirror
U	Array storing propagating waveforms
V	Array (dummy) used in propagation routines
VR1	Virtual image source radius of curvature for output mirror
VR2	Virtual image source radius of curvature for back mirror
VALUE	Subroutine computing one of several values for complex numbers
WAVES	Namelist block name for printing propagating wave characteristics
WOMEGA	Array defining gaussian ω for each input wave
X	Array defining physical position of each field point
XCENTR	Input parameter defining the x-value for the center of the propagation array
XIZERO	Input parameter defining I_0 for GAINA
XKZERO	Array storing K_0 , or $2\pi/\lambda$, for each wave
XLAMDA	Array defining λ for each wave
XMIR1	Array representing output mirror
XMIR2	Array representing back mirror
XWIDTH	Input parameter defining minimum spatial extent (in x) of the beam

ZLEN	Input parameter defining distance between the output and back mirrors
ZLENMD	Input parameter defining the length (along z) of the gain medium
ZMDLOC	Input variable describing position of medium in cavity

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