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ILS GLIDE SLOPE PERFORMANCE PREDICTION MULTIPATH SCATTERING

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16. Abstract

A mathematical model has been developed which predicts the performance of ILS glide slope systems subject to multipath scattering and the effects of irregular terrain contours. The model is discussed in detail and then applied to a test case for purposes of illustration. A complete listing of all computer programs has been appended to the report. A users' manual has been prepared under separate cover.

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PREFACE

The work presented in this report has been sponsored by the Federal Aviation Administration as part of a program to provide navigational aids for the safe landing of aircraft. The program has been concerned with the application of instrument landing aids, and in particular the development of models to predict the performance of localizer and glide slope antenna systems. The present report is concerned with the glide slope portion of instrument landing system, and the effects of airport topography on its performance.

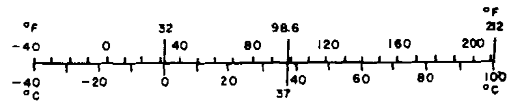
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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ILLUSTRATIONS

1. INTRODUCTION

A mathematical model has been developed for predicting the performance of image-type glide slope arrays. The basic theory is developed in the following section of this report. In Part A of that section a model of the glide slope multipath problem is developed while in Part B the techniques for dealing with irregular terrain profiles are outlined. In the final section of the report some illustrative numerical results are presented.

2. BASIC THEORY

PART A

The presence in the airport environment of such large man-made structures as aircraft hangars as well as such natural terrain features as hillsides can lead to glide slope course derogation through multipath scattering. We begin our treatment of glide slope siting problems by developing a model for predicting the amount of such multipath derogation. A typical situation is depicted in Figure 1.

The touchdown point on the centerline of the runway opposite the glide slope array is chosen as the origin of coordinates 0. The z-axis is chosen to be the vertical axis passing through the origin 0, while the x-and y-axes are parallel to and perpendicular to the centerline, respectively. The positive z-axis points out of the page (Figure 1). The ground plane is assumed to be perfectly conducting. Consequently, any deviations from nominal glide slope performance are attributable to the multipath scattering produced by the various structures (both natural and man-made). For simplicity, we will assume that all such structures are perfectly conducting.

In the situation depicted in Figure 1, the scatterer (perhaps a small hill) is illuminated by the glide slope array and scatters

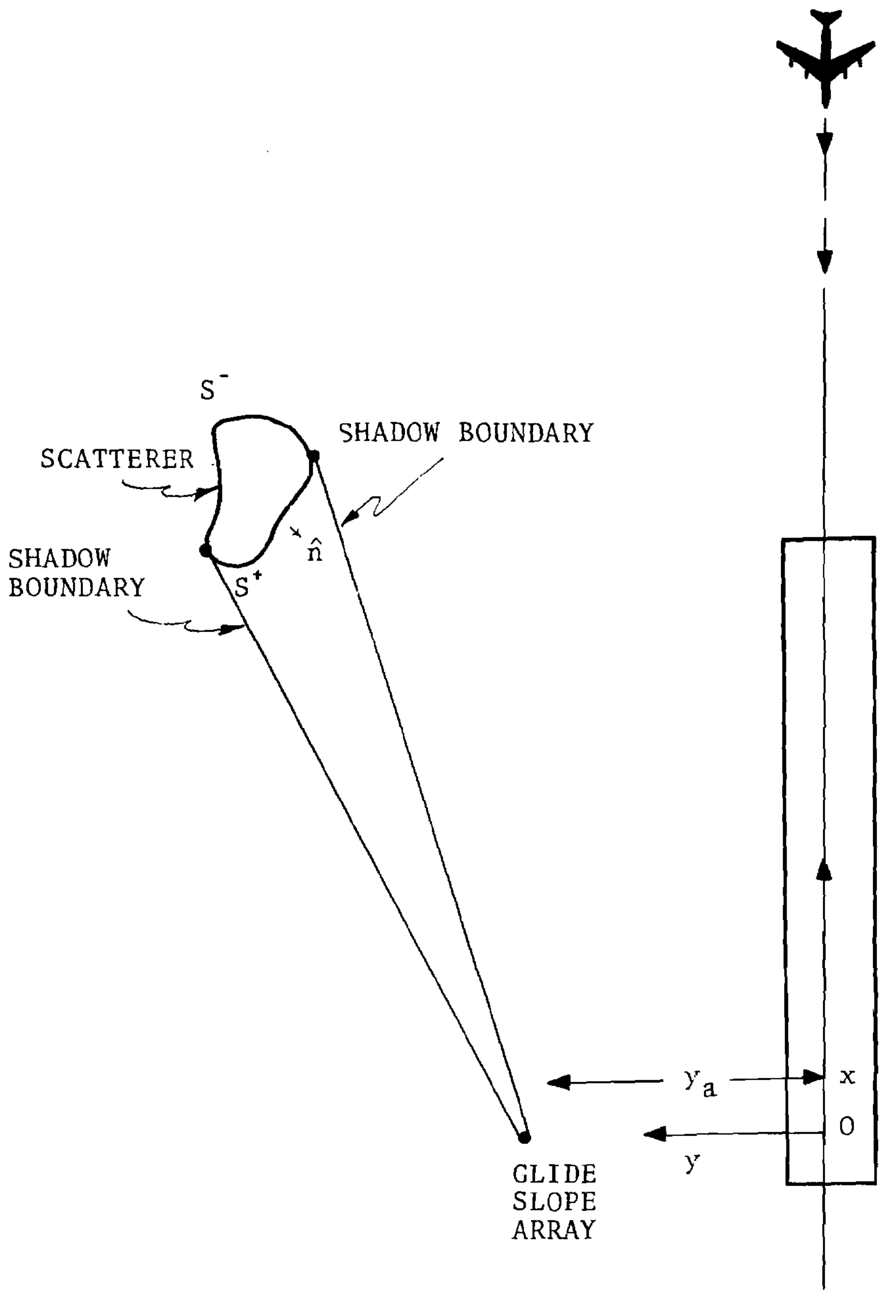

FIGURE 1. TYPICAL GEOMETRY FOR MULTIPATH SCATTERING

some of this signal back into the path of the approaching aircraft. We now proceed to calculate mathematical expressions for these scattered fields at the receiver. For convenience, we will work with magnetic field intensities.

For a perfect conductor, the surface current density K is given by:

$$\vec{K} = \hat{n} \times \vec{H} \quad , \tag{1}$$

where n is the local unit normal vector pointing out of the scattering surface and H is the total magnetic field,

$$\vec{H} = \vec{H}_i + \vec{H}_s, \tag{2}$$

where $\vec{H}_i$ is the incident and $\vec{H}_s$ the scattered field on the surface of the scattering structure. In terms of the surface current density $\vec{K}$, the scattered field $\vec{H}_s$ at the receiver is given by the following surface integral:

$$\vec{H}_s(\vec{r}_1) = \frac{1}{4\pi} \int_S \left[\vec{K}(\vec{r}) \times \vec{\nabla} G(\vec{r}_1, \vec{r}) \right] ds \tag{3}$$

In Equation (3), the vectors $\vec{r}_1$ and $\vec{r}$ denote, respectively, the position vector of the receiver and the position vector of some arbitrary source point on the surface of the scatterer relative to the origin of coordinates 0. The two-point Green's function $G(\vec{r}_1, \vec{r})$ is given by:

$$G(\vec{r}_1, \vec{r}) = \frac{e^{ik|\vec{r}_1 - \vec{r}|}}{|\vec{r}_1 - \vec{r}|} \tag{4}$$

where $k = 2\pi/\lambda$ and λ is the wavelength of the incident radiation. The integral is taken over the surface S of the scatterer.

We will adopt here the single scattering, physical optics approximation for the current density K. Specifically, we will assume that on those portions of the scattering surface not directly illuminated by the glide slope array, K is identically zero and that on the directly illuminated portions of the scattering surface, K is proportional to twice the tangential component of the incident magnetic field:

$$\vec{K} \equiv 0 \quad \text{on } S_- \tag{5}$$

$$\vec{K} = 2\,(\hat{n} \times \vec{H}_i) \quad \text{on } S_+ \tag{6}$$

where S_+ and S_- denote, respectively, the illuminated and unilluminated portions of the scattering surface S (see Figure 1). For the current distribution defined by Equations (5) and (6), Equation (3) becomes

$$\vec{H}_s(r_1) = \frac{1}{2\pi} \int_{S_+} \left[\hat{n}(\vec{r}) \times \vec{H}_i(\vec{r}) \right] \times \vec{\nabla} G(\vec{r}_1, \vec{r})\, ds. \tag{7}$$

The physical optics scattering model represented by equation (7) is based upon the existence of a sharp shadow boundary on the surface of the scattering structure. This assumption ignores such phenomena multiple reflections, surface waves, and diffraction but should provide reasonably accurate results as long as the surface features of the scattering structure do not vary greatly over dimensions which are small compared to the wavelength λ (about 3 feet at glide slope frequencies).

In principle, the solution to the problem at hand requires only that the magnet field H_i be determined. For simplicity, we will assume that the glide slope array is made up of electrically short dipoles. With this assumption, we in effect approximate by a cosine distribution the actual azimuthal pattern of the half-wave dipoles which make up glide slope arrays. This approximation should not be too restrictive and it does considerably expedite our calculations. Let $(0, y_a, h)$ denote the x, y, and z coordinates respectively of a typical dipole in the array and let (x, y, z) denote the coordinates of a point $\vec{r}$ at which we wish to know the magnetic field intensity H_a produced by the dipole at $(0, y_a, h)$. In our earlier glide slope performance prediction report,* it is shown that $\vec{H}_a(\vec{r})$ is given by

$$\vec{H}_a(\vec{r}) = \frac{ikJ_o}{4\pi} \frac{e^{ikD_1}}{D_1^2} \left[x\hat{e}_z - (z-h)\hat{e}_x \right] \tag{8}$$

where $\hat{e}_x$, $\hat{e}_y$, and $\hat{e}_z$ denote unit vectors in the x, y, and z directions respectively, J_o is a parameter which measures relative phase and amplitude, and D_1 is the distance from the antenna to the observation point r:

$$D_1 = \left[x^2 + (y-y_a)^2 + (z-h)^2 \right]^{1/2} \tag{9}$$

To take into account reflections from the ground plane (z = 0) we use simple image theory to obtain the image field $H_a^*(\vec{r})$:

$$\vec{H}_a^*(\vec{r}) = \frac{ikJ_o}{4\pi} \frac{e^{ikD_2}}{D_2^2} \left[x\hat{e}_z - (z+h)\hat{e}_x \right] \tag{10}$$

where D_2 is the distance from the image of the transmitting dipole to the field point $\vec{r}$:

$$D_2 = \left[x^2 + (y-y_a)^2 + (z+h)^2 \right]^{1/2} \tag{11}$$

The total field intensity H_i at $\vec{r}$ is just the sum of the direct ($\vec{H}_a$) and ground reflected ($\vec{H}_a^*$) signals:

$$\vec{H}_i(\vec{r}) = \vec{H}_a(\vec{r}) + \vec{H}_a^*(\vec{r}) \tag{12}$$

Note that on the ground plane (z = 0), the z component of $\vec{H}_i$ vanishes identically.

* ILS Glide Slope Performance Predictions, Vol. B, FAA-RD-74-157.B, S. Morin, D. Newsom, D. Kahn, L. Jordan, September 1974.

The field H_i determined by Equations (8), (10), and (12) can now be substituted into Equation (7) and the integral can be performed over the illuminated surface of the scattering structure to give the scattered field at the receiver location r_1. Actually, only the z component of the scattered field need be calculated since the receiving antenna responds primarily to the horizontal component of electric field which is proportional to the z component of the magnetic field. It should be noted that for a complete solution, the contribution of the image of the scattering structure must also be calculated. We will assume that the receiver is always in the far field of the scattering structure so that the following asymptotic form of the gradient of the Green's function is applicable:

$$\vec{\nabla} G(\vec{r}_1,\vec{r}) \approx - ik\ (\vec{r}_1-\vec{r})\ \frac{e^{ik|\vec{r}_1-\vec{r}|}}{|\vec{r}_1-\vec{r}|^2} \tag{13}$$

Substituting Euqations (8), (10), (12) and (13) into Equation (7) and taking the z-component of the resulting vector equation, we obtain the following expressions for $H_{sz}(r_1)$, the z-component of scattered magnetic field at the receiver point r_1:

$$H_{sz}(\vec{r}_1) = \frac{k^2 J_o}{8\pi^2} \left[I_1+I_2+I_3+I_4 \right] \tag{14}$$

where

$$I_1 = \int_{S_+} \frac{F_1}{D_1^2 R_1^2} e^{ik(R_1+D_1)}\ ds \tag{15}$$

$$I_2 = - \int_{S_+} \frac{F_2}{D_2^2\ R_1^2} e^{ik(R_1+D_2)}\ ds \tag{16}$$

$$I_3 = -\int_{S_+} \frac{F_1}{D_1^2 R_2^2} e^{ik(R_2+D_1)} ds \tag{17}$$

$$I_4 = \int_{S_+} \frac{F_2}{D_2^2 R_2^2} e^{ik(R_2+D_2)} ds \tag{18}$$

$$D_1 = \left[x^2 + (y-y_a)^2 + (z-h)^2\right]^{\frac{1}{2}} \tag{19}$$

$$D_2 = \left[x^2 + (y-y_a)^2 + (z+h)^2\right]^{\frac{1}{2}} \tag{20}$$

$$R_1 = \left[(X_1-x)^2 + (Y_1-y)^2 + (Z_1-z)^2\right]^{\frac{1}{2}} \tag{21}$$

$$R_2 = \left[(X_1-x)^2 + (Y_1-y)^2 + (Z_1+z)^2\right]^{\frac{1}{2}} \tag{22}$$

$$F_1 = n_2 x(Y_1-y) + \left[n_1 x + n_3(z-h)\right](X_1-x), \tag{23}$$

$$F_2 = n_2 x\ (Y_1-y) + \left[n_1 x + n_3(z+h)\right](X_1-x) \tag{24}$$

In Equations (14) through (24), the coordinates (X_1, Y_1, Z_1) denote the coordinates of the aircraft, (x, y, z) the coordinates of some source point on the surface of the scattering structure and (n_1, n_2, n_3) the components of the unit outward normal to the surface of the scatterer at the point (x, y, z). The integrals I_3 and I_4 represent the contributions of the image of the scattering structure in the ground plane $z = 0$. Note the following relationships among the four integrals:

$$\begin{aligned} I_1\ (X_1, Y_1, Z_1) &= -I_3\ (X_1, Y_1, -Z_1) \\ I_2\ (X_1, Y_1, Z_1) &= -I_4\ (X_1, Y_1, -Z_1) \end{aligned} \tag{25}$$

Consequently, when $Z_1 = 0$, $H_{sz}(\vec{r}_1) \equiv 0$ as it should be.

The direct numerical integration of the integrals I_1, I_2, I_3, and I_4 for an arbitrary scattering structure would in general require an inordinate amount of computer time. However, certain simplifying assumptions can be made which considerably expedite the evaluation of these integrals. Specifically, we will assume that any scattering surface can be adequately represented by a series of interconnecting plane facets. By definition, the unit normal vector $\hat{n}$ will be constant over each facet. The exact size, shape, and orientation of these facets will depend upon the surface characteristics of the particular scatterer. In turn, each facet can be broken up into a series of interconnected rectangular pieces. If these rectangular pieces are made small enough, the integrals I_1, I_2, I_3 and I_4 can be evaluated analytically for each piece and then the results summed over the whole surface of the scatterer to give H_{sz}. To illustrate these procedures, we will now evaluate the integral I_1 for an arbitrarily oriented rectangular plate. In the course of this evaluation, we will discuss the size restrictions on such plates.

In Figure 2, a rectangular facet typical of those making up the surface of some scatterer has been drawn. We will evaluate the integral I_1 of Equation (15) for such a facet in the Fraunhofer approximation. The unit vectors $\hat{\eta}$ and $\hat{\xi}$ lie in the plane of the facet, are orthonormal, and define the direction of the outward normal $\hat{n}$:

$$\hat{n} = \hat{\eta} \times \hat{\xi}$$

The center point of the facet (x_o, y_o, z_o) will be used as a local origin of coordinates for the integrations which are to be performed. The integral I_1 is given by

$$I_1 = \int_{S_+} \frac{F_1}{D_1{}^2 R_1{}^2} \quad e^{ik(D_1+R_1)} \quad ds \qquad (26)$$

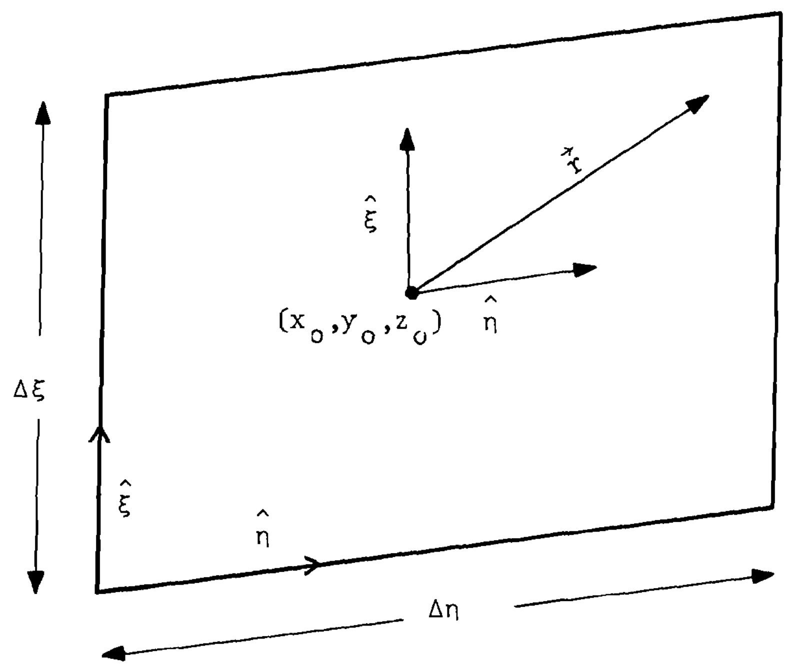

FIGURE 2. REPRESENTATION OF RECTANGULAR FACET

where

$$F_1 = n_2 x (Y_1 - y) + \left[n_1 x + n_3 (z-h) \right] (\overrightarrow{X}_1 - x) \qquad (27)$$

$$D_1 = \left[x^2 + (y-y_a)^2 + (z-h)^2 \right]^{1/2} \qquad (28)$$

$$R_1 = \left[(X_1-x)^2 + (Y_1-y)^2 + (Z_1-z)^2 \right]^{1/2} \qquad (29)$$

Clearly, the distances D_1 and R_1 denote, respectively, the length of the vector $\overrightarrow{D}_1$ from the antenna to a point (x, y, z) on the surface of the facet and the length of the vector $\overrightarrow{R}_1$ from the point (x, y, z) to the receiver. From Figure 2, it is seen that the vector D_1 can be represented as follows:

$$\overrightarrow{D}_1 = \overrightarrow{D}_{10} + \overrightarrow{r} \qquad (30)$$

where

$$\overrightarrow{D}_{10} = X_o \hat{e}_x + (y_o - y_a)\hat{e}_y + (z_o - h)\hat{e}_z \qquad (31)$$

and

$$\overrightarrow{r} = \eta\hat{\eta} + \xi\hat{\xi} \qquad (32)$$

and the ranges of the variables η and ξ are $-\frac{\Delta\eta}{2} \le \eta \le \frac{\Delta\eta}{2}$ and $-\frac{\Delta\xi}{2} \le \xi \le \frac{\Delta\xi}{2}$. From Equation (30), we have

$$D_1 = D_{10} \left(1 + \frac{r^2 + 2\overrightarrow{D}_{10} \cdot \overrightarrow{r}}{D_{10}^2} \right)^{1/2} \qquad (33)$$

Normally, D_{10} is on the order of thousands of feet and r is of the order of tens of feet so that the radical in Equation (33) can be expanded in powers of r/D_{10} to give D_1 approximately as a function of η and ξ. To terms of second order in r/D_{10}, we obtain

$$D_1 \approx D_{10} + \eta \cos\alpha + \xi \cos\beta + \frac{r^2}{2D_{10}} - \frac{(\hat{D}_{10} \cdot r)}{2D_{10}} \qquad (34)$$

where

$$\hat{D}_{10} = \vec{D}_{10}/D_{10} \tag{35}$$

$$\cos\alpha = D_{10}\cdot\hat{\eta} \tag{36}$$

$$\cos\beta = \hat{D}_{10}\cdot\hat{\xi} \tag{37}$$

The numbers $\cos\alpha$ and $\cos\beta$ are the direction cosines of D_{10} relative to $\hat{\eta}$ and $\hat{\xi}$. In the Fraunhofer approximation which we will use, it is assumed that the quatratic terms of Equation (33) are small compared to a wavelength for any point (x, y, z) on the surface of the facet so that we can write to a good approximation:

$$D_1 = D_{10} + \eta \cos\alpha + \xi \cos\beta \tag{38}$$

It can be shown that the largest value attainable by the quadratic terms in Equation (33) on the facet's surface is

$$\Delta = \frac{(\Delta\eta)^2}{8\ D_{10}} \sin^2\alpha + \frac{(D\xi)^2}{8\ D_{10}} \sin^2\beta + \frac{\Delta\eta\Delta\xi}{4}\left|\cos\alpha\ \cos\beta\right| \tag{39}$$

Equation (38) should provide a good approximation for the distance D_1 as a function of η and ξ as long as $\Delta\eta$ and $\Delta\xi$ are chosen so that Δ in Equation (39) is small compared to the wavelength λ. We will return to this important requirement later.

Similarly, the vector $\vec{R}_1$ can be represented as follows:

$$\vec{R}_1 = \vec{R}_{10} - \vec{r} \tag{40}$$

where $\vec{R}_{10} = (X_1 - x_o)\hat{e}_x + (Y_1 - y_o)\hat{e}_y + (Z_1 - z_o)\hat{e}_z$ (41)

Thus, in the Fraunhofer approximation, we find

$$R_1 \simeq R_{10} - \eta \cos\ \alpha - \xi \cos\delta \tag{42}$$

$$\cos \alpha = \hat{R}_{10} \cdot \hat{\eta} \tag{43}$$

$$\cos \delta = \hat{R}_{10} \cdot \hat{\xi} \tag{44}$$

where

$$\hat{R}_{10} = \vec{R}_{10}/R_{10} \tag{45}$$

In Equation (42), we have ignored terms of second order and higher in r/R_{10}.

One final approximation which we will make is that $\Delta\eta$ and $\Delta\xi$ are sufficiently small compared with D_{10} and R_{10}, that the variation of the amplitude function $F_1/D_1{}^2R_1{}^2$ in Equation (26) can be ignored This is normally an excellent approximation. Consequently, we will assume that for any point on the surface of the facet we can write

$$F_1/D_1{}^2R_1{}^2 \approx F_{10}/D_{10}{}^2R_{10}{}^2 \tag{46}$$

where F_{10}, D_{10}, and R_{10}, are the values of F_1, D_1, and R_1 at the center point (x_o, y_o, z_o).

Substituting Equations (38), (42), and (46) into Equation (26) yields the following approximate expression for I_1;

$$I_1 = \frac{F_{10}}{D_{10}^2 R_{10}^2} ei^{ik(D_{10}+R_{10})} \int_{-\Delta\eta/2}^{+\Delta\eta/2} e^{ik\eta(\cos\alpha - \cos\gamma)} d\eta \int_{-\Delta\xi/2}^{+\Delta\xi/2} e^{ik\xi(\cos\beta - \cos\delta)} d\xi \tag{47}$$

Performing the integrals indicated in Equation (47), we finally obtain the following approximate expression for I_1:

$$I_1 = \frac{4F_{10}}{D_{10}^2 R_{10}^2} \; \frac{e^{ik(D_{10}+R_{10})}}{k^2} \times \frac{\sin\left\{\frac{k\Delta\eta}{2}(\cos\alpha - \cos\gamma)\right\} \; \sin\left\{k\frac{\Delta\xi}{2}(\cos\beta - \cos\delta)\right\}}{(\cos\alpha - \cos\gamma)\;(\cos\beta - \cos\delta)} \tag{48}$$

A similar treatment of the integrals I_2, I_3, and I_4 ultimately lead to the following approximate expression for the scattered magnetic field intensity at the receiver due to the rectangular facet:

$$
\begin{aligned}
H_{sz}(\vec{r}_1) = {} & \frac{J_o}{2\pi^2} \frac{F_{10} e^{ik(D_{10}+R_{10})}}{D_{10}^2 R_{10}^2} \frac{\sin(kA\Delta\eta/2)\sin(kB\Delta\xi/2)}{A\ B} \\
& - \frac{J_o}{2\pi^2} \frac{F_{20} e^{ik(D_{20}+R_{10})}}{D_{20}^2 R_{10}^2} \frac{\sin(kA_1\Delta\eta/2)\sin(kB_1\Delta\xi/2)}{A_1 B_1} \\
& - \frac{J_o}{2\pi^2} \frac{F_{10} e^{ik(D_{10}+R_{20})}}{D_{10}^2 R_{20}^2} \frac{\sin(kA_2\Delta\eta/2)\sin(kB_2\Delta\xi/2)}{A_2 B_2} \\
& + \frac{J_o}{2\pi^2} \frac{F_{20} e^{ik(D_{20}+R_{20})}}{D_{20}^2 R_{20}^2} \frac{\sin(kA_3\Delta\eta/2)\sin(kB_3\Delta\xi/2)}{A_3 B_3}
\end{aligned}
\tag{49}
$$

where F_{10}, F_{20}, D_{10}, D_{20}, R_{10} and R_{20} denote the values of F_1, F_2 D_1, D_2, R_1, and R_2 at (x_o, y_o, z_o) and the parameters A, A_1, A_2, A_3, B, B_1, B_2, and B_3 are defined as follows:

$$A = \cos\alpha - \cos\gamma \qquad B = \cos\beta - \cos\delta \tag{50}$$

$$A_1 = \cos\alpha_1 = \cos\gamma \qquad B_1 = \cos\beta_1 - \cos\delta \tag{51}$$

$$A_2 = \cos\alpha - \cos\gamma_1 \qquad B_2 = \cos\beta - \cos\delta_1 \tag{52}$$

$$A_3 = \cos\alpha_1 - \cos\gamma_1 \qquad B_3 - \cos\beta_1 - \cos\delta_1 \tag{53}$$

and the angles appearing in Equations (50) through (53) are defined as follows:

$$\vec{D}_{10} = x_o\hat{e}_x + (y_o - y_a)\hat{e}_y + (z_o - h)\hat{e}_z \tag{54}$$

$$\vec{R}_{10} = (X_1 - x_o)\hat{e}_x + (Y_1 - y_o)\hat{e}_y + (Z_1 - z_o)\hat{e}_z \tag{55}$$

$$\vec{D}_{20} = x_o\hat{e}_x + (y_o - y_a)\hat{e}_y + (z_o + h)\hat{e}_z \tag{56}$$

$$\vec{R}_{20} = (X_1 - x_o)\hat{e}_x + (Y_1 - y_o)\hat{e}_y - (Z_1 + z_0)\hat{e}_z \tag{57}$$

and

$$\cos\alpha = \frac{\vec{D}_{10}}{D_{10}}\cdot\hat{\eta}\ , \quad \cos\beta = \frac{\vec{D}_{10}\cdot\hat{\xi}}{D_{10}} \tag{58}$$

$$\cos\alpha_1 = \frac{\vec{D}_{20}\cdot\hat{\eta}}{D_{20}}\ , \quad \cos\beta_1 = \frac{\vec{D}_{20}\cdot\hat{\xi}}{D_{20}} \tag{59}$$

$$\cos\alpha = \frac{\vec{R}_{10}\cdot\hat{\eta}}{R_{10}}\ , \quad \cos\delta = \frac{\vec{R}_{10}\cdot\hat{\xi}}{R_{10}} \tag{60}$$

and $$\cos\alpha_1 = \frac{\vec{R}_{20}\cdot\hat{\eta}}{R_{20}}\ , \quad \cos\delta_1 = \frac{\vec{R}_{20}\cdot\hat{\xi}}{R_{20}} \tag{61}$$

The total scattered field at the receiver is obtained by summing up the contributions from all of the rectangular facets which make up the surface of the scattering structure. Segmenting the surface of a scatterer into rectangular facets and then applying the approximate closed form solution in Equation (49) to each facet represents a far more efficient procedure for calculating the scattered field at the receiver than attempting to directly numerically integrate Equations (14) through (18).

We now return to the question raised earlier of the size restrictions upon the facets. Clearly, one would like to maximize the area of each facet in order to minimize computer running time. The principal restriction upon the size of the facets is that $\Delta\eta$ and $\Delta\xi$ must not be so large that the Fraunhofer approximation, upon which the approximate formula (49) is based, is violated. That is, the quadratic path length difference terms like those in Equation (34) must be small compared to the wavelength λ for all points on the surface of the facet to which Equation (49) is to be applied. Thus, in choosing appropriate values for $\Delta\xi$ and $\Delta\xi$, we are essentially faced with an optimization problem with a constraint. Specifically, we want to maximize the area $\Delta\eta\Delta\xi$ of the facet while keeping the quadratic path length difference terms less than some prescribed value. For example, for the path length D_1, the maximum value of the quadratic path length difference term is given by

$$\Delta = \frac{(\Delta\eta)^2}{8\ D_{10}} \sin^2\alpha + \frac{(\Delta\xi)^2}{8\ D_{10}} + \frac{\Delta\eta\Delta\xi}{4} \left|\cos\alpha\cos\beta\right| \tag{62}$$

Depending upon the sign of $\cos\alpha\cos\beta$, this value will be achieved at two of the four corners of the rectangular facet. At all other points, the quadratic path length terms will be less than Δ, but always positive. We can optimize our choice of $\Delta\eta$ and $\Delta\xi$ by maximizing $\Delta\eta\Delta\xi$ subject to the condition that Δ in Equation (62) be some fractional part of a wavelength. This problem has been solved in closed form using Lagrange multipliers. The optimization procedure must be applied to the quadratic path length difference terms affecting all four distances (D_1, D_2, R_1, R_2) and then from the resulting set of solutions the smallest values of $\Delta\eta$ and $\Delta\xi$ are chosen. A subroutine has been written to carry out the optimization procedure.

Of course, the scattered fields must be calculated for each dipole in the array, the parameter J_o being varied to take into account the exact phase and amplitude ratios among the various elements and, along with J_o, the height h and y-offset y_a of each element. Our program automatically offsets the elements of an array to correct for the effects of proximity phase lag. The y-coordinates of the elements are adjusted so that all dipoles are at the same slant distance from the touchdown point on the runway directly opposite the array.

Once all of the scattered fields have been calculated, the calculation of the difference in depth of modulation (D.D.M) at a given receiver location is straight forward. The scattered fields at the carrier frequency, 90Hz modulated frequency, and 150Hz modulated frequency are first added to the direct fields at those frequencies. By direct fields is meant the fields which would exist if the scatterers were not present. For example, if the ground plane is perfectly flat, the direct field for any one of the three frequencies at the receiver location r_1 is just the z-component of Equation (12).

$$H_{iz}(\vec{r}_1) = \frac{ikJ_o}{4\pi} X_1 \left[\frac{e^{ikD_1}}{D_1^{\,2}} - \frac{e^{ikD_2}}{D_2^{\,2}} \right] \tag{63}$$

where, here, D_1 and D_2 denote, respectively, the distance from the antenna to the aircraft and the distance from the image antenna to the aircraft, and X_1 is the x coordinate of the aircraft. If the ground plane is not perfectly flat or at least nearly so the direct fields are calculated differently. These alternate procedures will be discussed in the next section. In any case, once the total complex field amplitudes (direct plus scattered summed for all dipoles in the array) have been found, the DDM is calculated as follows: let H_c, H_{150}, and H_{90} denote the total complex amplitudes at the carrier frequency, the 150 Hz modulated frequency, and the 90 Hz modulated frequency. In terms of these complex amplitudes, the difference in depth of modulation is given by:

$$\text{D.D.M.} = \text{Re}\left(\frac{H_{150} - H_{90}}{H_c}\right) \tag{64}$$

where Re denotes the real part of the complex number. Full scale deflection (150 microamps) corresponds to a D.D.M. of .175 for the glide slope. Consequently, the C.D.I. (course deviation indication) is given by

$$\text{C.D.I.} = 857.14 \ \text{Re}\left(\frac{H_{150} - H_{90}}{H_c}\right) \text{microamps} \tag{65}$$

PART B

In Part A of this section, we developed techniques for estimating glide slope performance degradation due to multipath scattering. Once the scattered fields produced by the various scattering structures in the airport environment have been calculated, they are added to the direct fields at the corresponding frequencies and from these total fields, the C.D.I. is calculated using Equation (65). The direct field at the particular frequency is just the field which would be detected at the receiver in the absence of the scattering structures. If the ground plane is otherwise perfectly flat or nearly so, the direct field is given according to simple image theory by Equation (63).

$$H_{iz} = \frac{ikJ_o}{4\pi} X_1 \left[\frac{e^{ikD_1}}{D_1^2} - \frac{e^{ikD_2}}{D_2^2} \right] \quad (63)$$

where D_1 and D_2 are, respectively, the distance between the receiver and the transmitting dipole and between the receiver and the image of the dipole. On the other hand, if the terrain profile exhibits significant irregularities such as downgrade; or drop offs along the line of sight between the aircraft and the antenna mast, Equation (63) cannot be used and the techniques developed in our earlier glide slope performance prediction model must be used.

In the report ILS Glide Slope Performance Prediction, Vol. B (FAA-RD-74-157.B), we developed mathematical procedures for calculating the ground reflected signals resulting from irregular terrain profiles such as the one depicted in Figure 3. The detailed calculations will not be repeated here, However, the updated computer program contains the subroutines for performing these calculations. One simply inputs the shape of the terrain profile along the line of sight between the aircraft and the antenna mast, and the subroutines

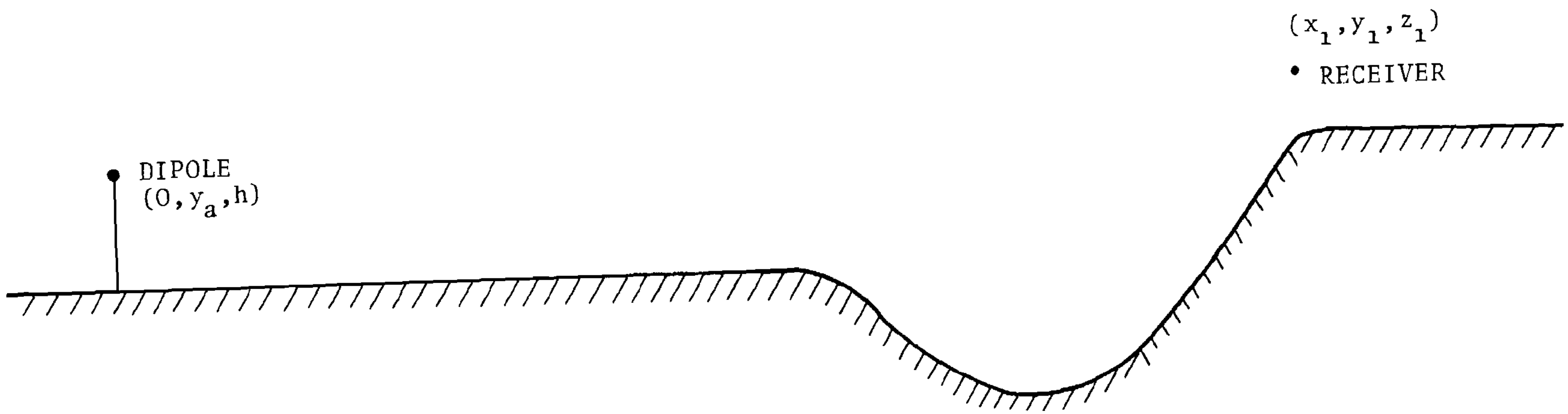

FIGURE 3. TYPICAL PROFILE OF ONE-DIMENSIONAL TERRAIN VARIATION

will generate the ground reflected signals at the carrier frequency. 90Hz modulated frequency, and the 150Hz modulated frequency. These signals are then combined with the incident signals directly from the antennas to give what we have been calling the direct fields, the fields which would be measured at the reeeiver assuming that no scatterers (hangars, hillsides, etc.) were present. These direct signals are then combined with the scattered signals calculated using the techniques of Part A and the resulting total signals are used in Equation (65) to calculate C.D.I. Again, if the terrain profile is perfectly flat or nearly so, Equation (63) can be used to calculate the direct signals.

3. NUMERICAL RESULTS

Before presenting some sample numerical results illustrating the predictions of our model, we will first review the characteristics of the three main types.of image glide slope arrays; the null reference, the sideband reference, and the capture effect arrays.

The null reference array is the simplest of the image glide slope systems. It consists of two transmitting antennas whose heights are in the ratio of 2:1. The upper antenna is fed sideband only signal, the 150 Hz and the 90 Hz components being of equal amplitude but 180° out of phase. The lower antenna is fed both carrier and sideband. The carrier signal is nominally 40% modulated. The ratio of the sideband currents in the upper antenna to the sideband currents in the lower antenna is typically 0.3. The sideband ratio of 0.3 would nominally yield a 1.4° course width (full deflection 0.7° above or below the glide path). Let

I_c, I_{150}, and I_{90} denote the current amplitudes fed to the antennas at the carrier frequency, the 150 Hz modulated frequency, and the 90 Hz modulated frequency, respectively. The null reference array parameters discussed above can be summarized as follows:

Carrier Antenna	Sideband Antenna
Height = h	Height = 2h
$I_c = 1$	$I_c = 0$
$I_{150} = 0.4$	$I_{150} = 0.12$
$I_{90} = 0.4$	$I_{90} = -0.12$

Note that all current amplitudes have been normalized relative to the carrier current amplitude ($I_c = 1$).

The sideband reference array employs two transmitting dipoles whose heights are in the ratio of 3:1. If the lower antenna is positioned at 1/2 the height of the lower antenna of the null reference array and if the upper antenna is positioned at 3/4 of the height of the upper antenna of the null reference array, the same glide angle is produced. Modulated carrier (40% modulated) is fed to the lower antenna. Both antennas are fed separate sideband signals. The separate sideband signals fed to the two antennas are equal in amplitude but are 180° out of phase. The amplitude ratio of the separate sideband signal to the carrier sideband signal is typically 0.3. This ratio produces a nominal course width of 1.4° as in the case of the null reference array. The sideband reference parameters are summarized below.

Lower Antenna	Upper Antenna
Height = h	Height = 3h
$I_c = 1$	$I_c = 0$
$I_{150} = 0.28$	$I_{150} = 0.12$
$I_{90} = 0.52$	$I_{90} = -0.12$

Note that the I_{150} and I_{90} current amplitudes given above for the lower antenna represent the sums of the carrier sideband and separate sideband signsls (I_{150} = .4 - .12 = .28, I_{90} = .4 + .12 = .52). All current amplitudes have been normalized relative to the carrier signal amplitude.

The capture effect glide slope array consists of three transmitting antennas whose heights are in the ratios of 1:2:3. If the lower and middle antennas are set at the same heights as the null reference antennas, the same glide angle is produced. We will not treat the clearance signal which provides a strong fly up signal at low approach angles but has little effect upon the glide angle and course width. Concerning the primary signal, the modulated carrier is fed to both the lower and middle antennas. The modulated carrier fed to the middle antenna has half the amplitude and is 180° out of phase with the modulated carrier fed to the lower antenna. The carrier signals are nominally 40% modulated. In addition, all three antennas are fed separate sideband signals. The separate sideband signals fed to the lower and upper antennas have half the amplitude and are 180° out of phase with the separate sideband signal fed to the middle antenna. The ratio of the separate sideband signal fed to the middle antenna to the carrier sideband signal in the lower antenna is typically 0.3. This ratio yields nominally a course width of 1.4° as in the case of the null reference array. The capture effect array parameters are summarized below.

Lower Antenna	Middle Antenna
Height = h	Height = 2h
I_c = 1	I_c = -0.5
I_{150} = 0.34	I_{150} = -0.08
I_{90} = 0.46	I_{90} = -0.32

Upper Antenna

Height = 3h

I_c = 0

I_{150} = -0.06

I_{90} = 0.06

Note that the I_{150} and I_{90} current amplitudes given above represent the sums of the carrier sideband and separate sideband signals. Again, all values have been normalized relative to the carrier amplitude in the lower antenna.

It should be noted here that our computer program automatically offsets the elements of each glide slope array to correct for the effects of proximity phase lag. The y coordinates of the elements are adjusted so that all dipoles are at the same slant distance from the touchdown point on the runway directly opposite the array. For each array, one element is held fixed while the other elements are offset relative to the fixed one. For the null reference and sideband reference arrays, the lower element is held fixed while for the capture array, the middle element is held fixed. The amount of the offset for each dipole can be calculated approximately in the following manner. Let y_a and h denote, respectively, the y-coordinate and height of the fixed antenna element. The y-displacement, ε, of any other element in the array relative to the fixed one is given approximately by:

$$\varepsilon = \frac{h^2 - H^2}{2y_a} \tag{66}$$

where H is the height of the element which is to be offset.

For the present study, the wavelength λ was set at 3 feet. All arrays were positioned 300 feet from the centerline of the runway. The heights of the array elements were set at 14.33 feet and 28.66 feet (approximately 5λ and 10λ) for the null reference array, 7.17 feet and 21.5 feet (approximately 2.5λ and 7.5λ) for the sideband reference array, and 14.33 feet, 28.66 feet, and 42.99 feet (approximately 5λ, 10λ, and 15λ) for the capture effect array. Under normal circumstances, a glide angle of 3° would be produced by all three arrays.

To illustrate the performance of our multipath model, the glide slope course deragation caused by a large, flat reflecting surfaee (perhaps the side of a large hangar or the side of a hill) has been calculated. The structure was taken to be 300 feet long and 100 feet high and was oriented parallel to the runway centerline. The structure was positioned 200 feet from the runway centerline in the y-direction, on the opoosite side of the centerline from the glide slope array. The near edge of the structure was displaced 1000 feet in the x-direction from the touchdown point. The geometry of the configuration is depicted in Figure 4.

In Figures 5, 6, and 7 are plotted the C.D.I. signal as a function of the horizontal distance from touchdown for each of the three arrays for the arrangement depicted in Figure 4. In each case, the receiver followed the nominal 3^{o} zero C.D.I. hyperbola. The results for all three arrays are very similar. Our model predicts large high frequency, alternating fly up and fly down signals near the end of the flight path roughly between 1700 feet and 1800 feet from touchdown. This region in fact corresponds almost exactly to the region of specular reflection as predicted by geometrical optics. Note that the excursions are large enough to saturate the receiver over much of the affected range (full scale deflection = 150 microamps). The excursions are clearly highly localized and damp out very rapidly as the aircraft leaves the specular reflection zone. The narrowness of the pattern (i.e., the lack of broadening due to diffraction and the rapid damping of the side lobes) is undoubtedly attributable to the large size of the scatterer relative to the scattering wavelength.

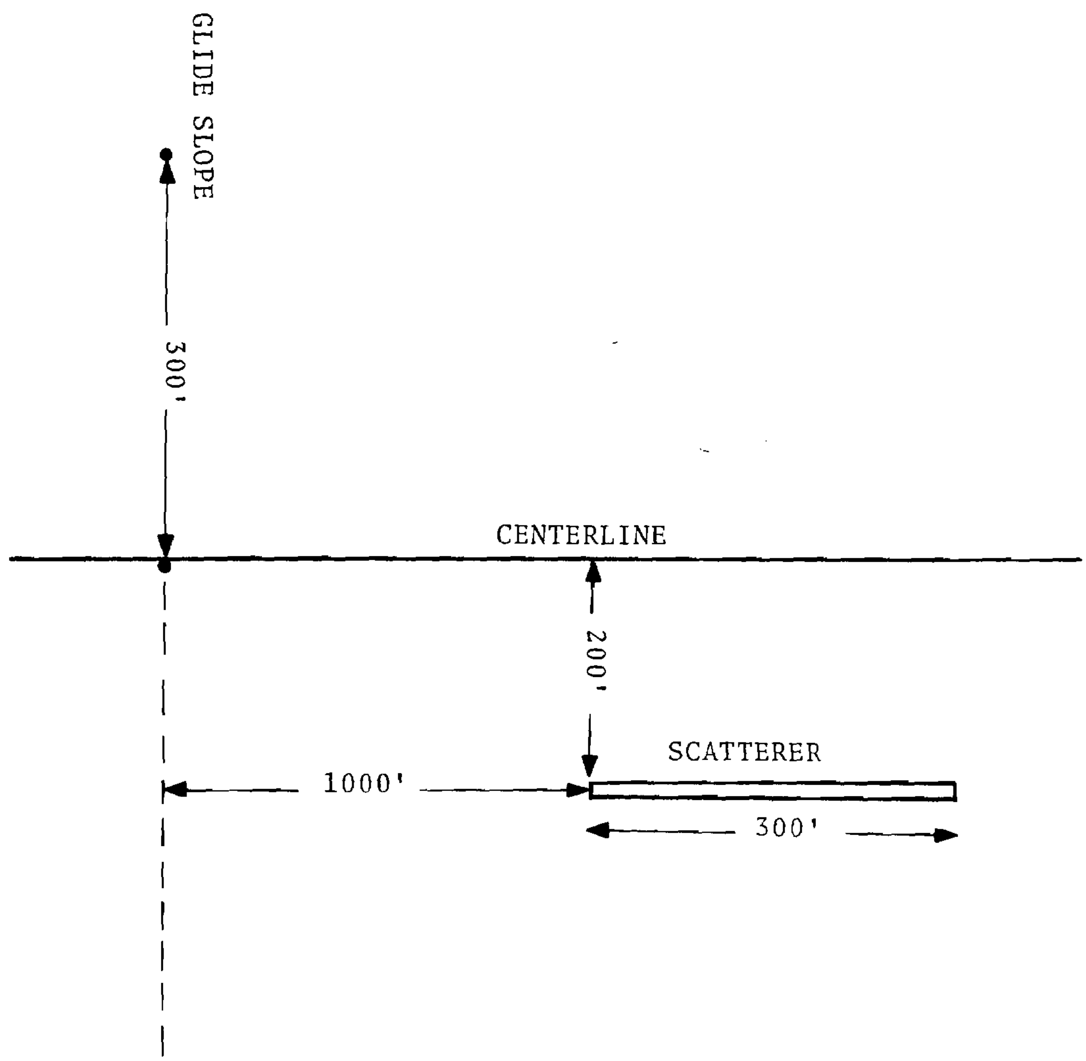

FIGURE 4. OVERVIEW OF A MULTIPATH CONFIGURATION

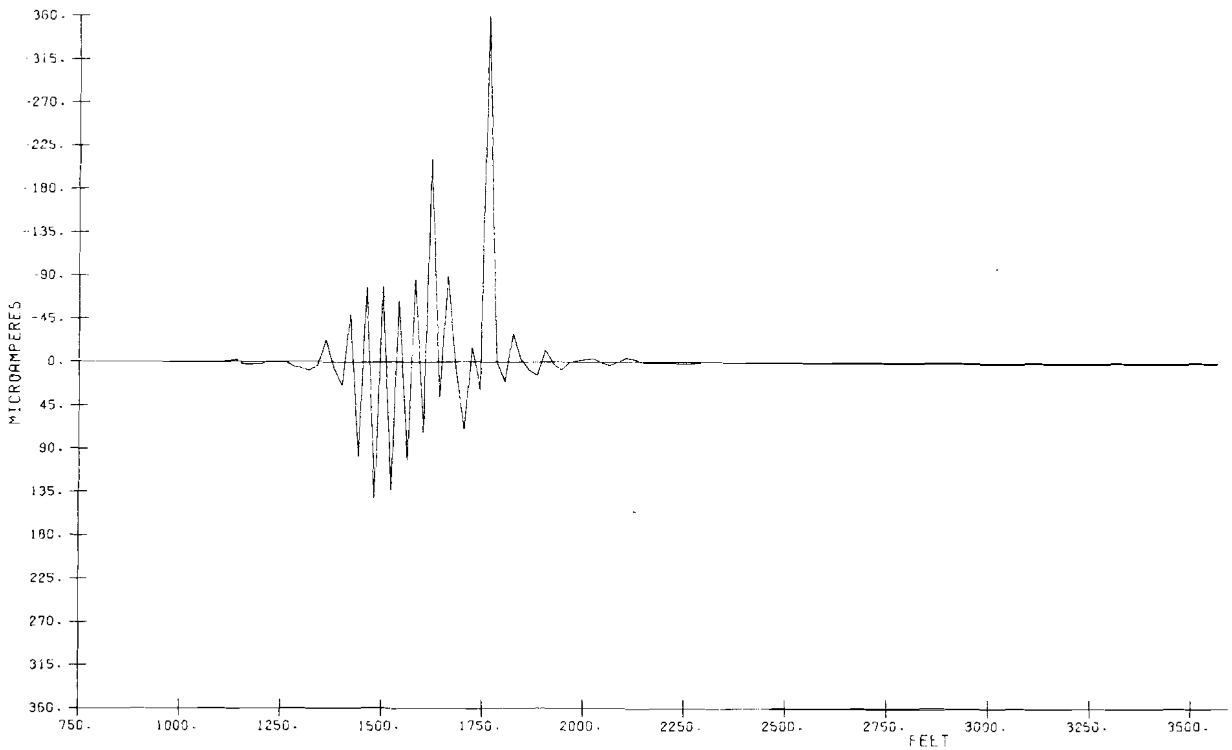

FIGURE 5. NULL REFERENCE ARRAY, FLYABILITY RUN

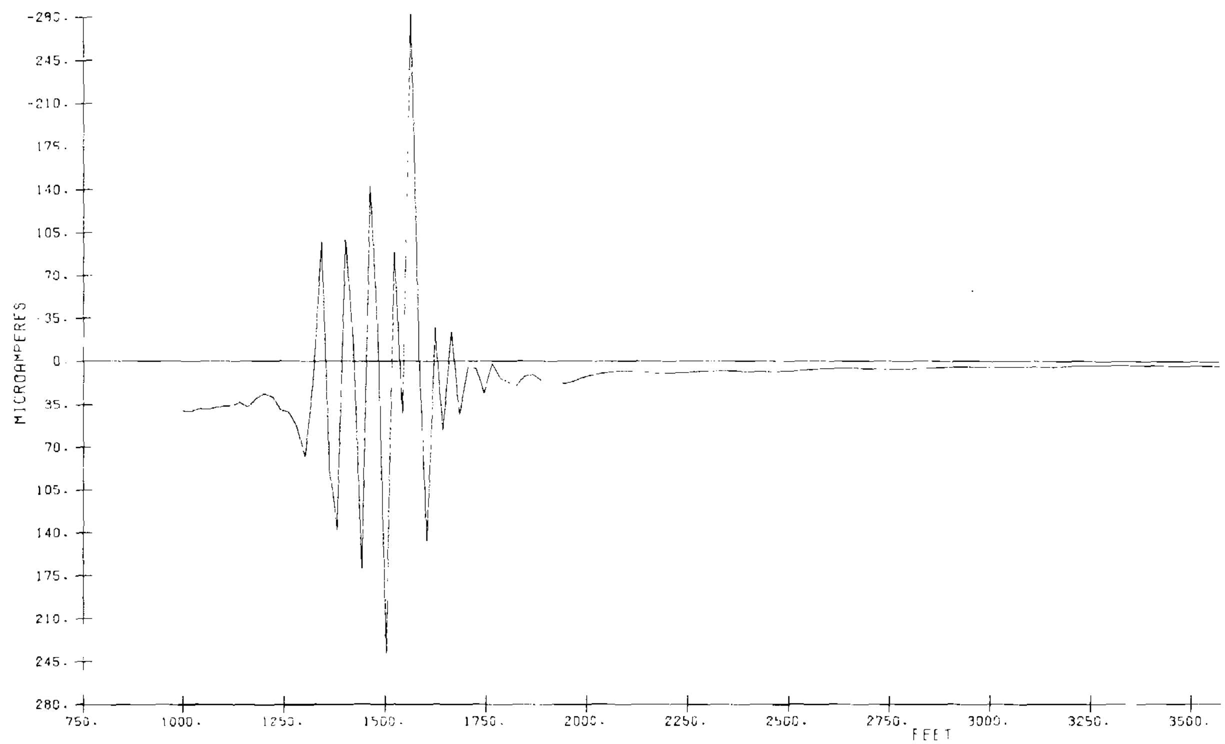

FIGURE 6. SIDEBAND REFERENCE ARRAY, FLYABILITY RUN

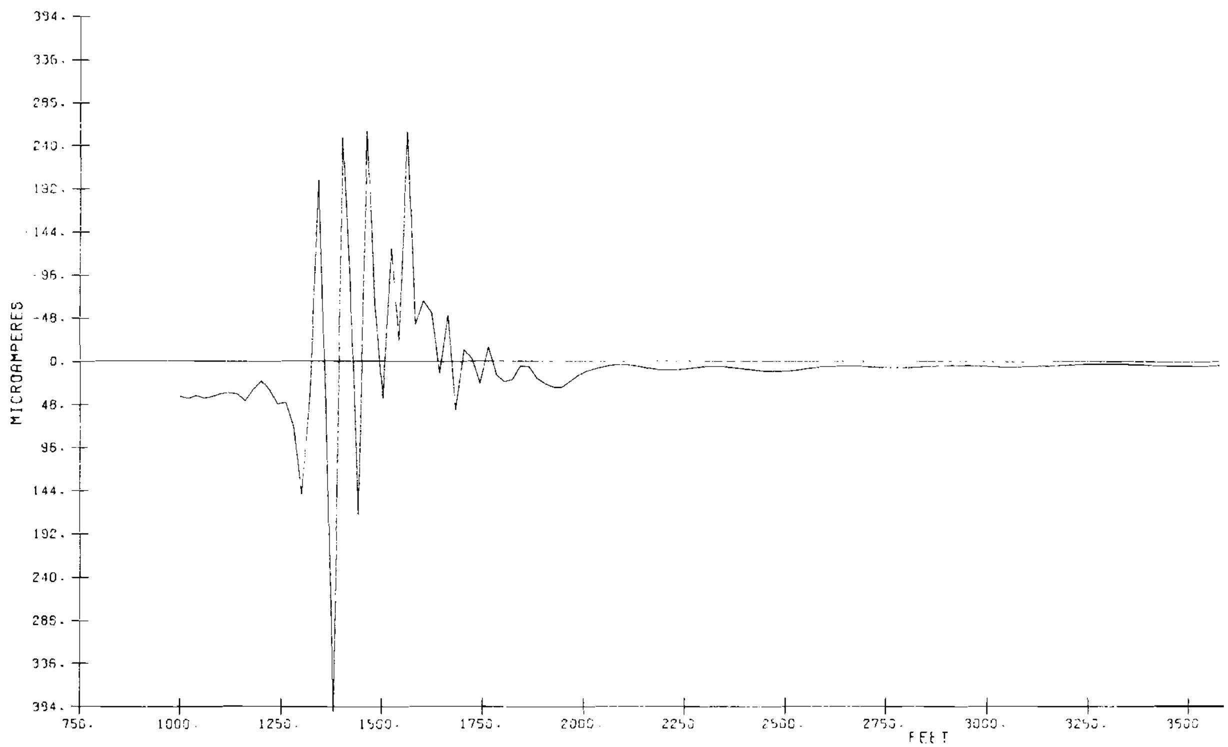

FIGURE 7. CAPTURE EFFECT ARRAY, FLYABILITY RUN

PROGRAM ILSVEN.F4

```
      DIMENSION ILABL(8)
      DIMENSION IPTDAT(33)
      COMMON /PLXT/ NRP,RXMN,RXMX,RXFT,RXLT,RYMN,RYMX,RYFT,RYLT,
     1RZMN,RZMX,RZFT,RZLT,RTMN,RTMX,RTFT,RTLT,
     2AIMN,AIMX,AIFT,AILT,ARMN,ARMX,ARFT,ARLT,
     3ADIN,ADIX,ADIF,ADIL,
     4ADRN,ADRX,ADRF,ADRL
      EQUIVALENCE (IPTDAT(1),NRP)
      IMPLICIT COMPLEX (C)
      DIMENSION X(20),Y(20),Z(20)
      DIMENSION CF1(20),CF2(20),CF3(20)
      IMPLICIT DOUBLE PRECISION (D)
      COMMON /REC/RX,RY,RZ,RT,NSIZE
      REAL LAMBDA
      COMMON /GROUND/ K,X1(20),Z1(20),X2(0/20),Z2(0/20),IEL
      COMMON /ANT/AX,AY,AZ,LAMBDA,DAK,DPI
      COMMON /VAL/ HR,HI
C
C        THIS VALUE OF TWO PI IS INITIALIZED THIS WAY TO AVOID USING
C BLOCK DATA
      DPI=6.283185307179586476
C
C        THIS OPENS THE OUTPUT FILE
      CALL OFILE(1,'STRIP')
C
C        THIS SUBROUTINE OPENS THE FLIGHT PATH FILE AND RETURNS WITH
C THE FLIGHT PATH PLOT LABEL (ILABL) AND TIME CONSTANT (TAU)
C THE FILE WAS SET UP WITH JOVRAX SO THIS SUBROUTINE AND INPUT ARE
C USED TO FACILITATE MODIFACTIONS
      CALL IF(ILABL,TAU)
1000  FORMAT(8A5,F)
      WRITE(1,1000) ILABL,TAU
C
C        THIS SECTION INITIALIZES SOME CONSTANTS
      NRP=0
C
C        THIS SECTION INPUTS THE GROUND STRIPS DECSRIPTIONS
      CALL IFILE(20,'GRND')
      READ(20,1000) ILABL
      WRITE(1,1000) ILABL
      READ(20) K,X1,Z1,X2,Z2
      CALL RELEAS (20)
C
C        THIS SECTION INPUTS THE ANTENNA FILE NAME TO BEUSED
C AND THEN INPUTS THE ANTENNA ELEMENT DESCRIPTIONS
      WRITE(5,2001)
2001  FORMAT(' INPUT ANTENNA FILE NAME:',$)
      READ(5,2000) ILBL
2000  FORMAT(A5)
      CALL IFILE(20,ILBL)
      READ(20,1000) ILABL
      WRITE(1,1000) ILABL
      READ(20) LAMBDA,NEL,(X(I),Y(I),Z(I),CF1(I),CF2(I),CF3(I),I=1,NEL)
```

```
      WRITE(1) LAMBDA,NEL,(X(I),Y(I),Z(I),CF1(I),CF2(I),CF3(I),I=1,NEL)
      CALL RELEAS (20)
      SQRT2L=1./SQRT(2.*LAMBDA)
      TEMP2=LAMBDA
      DAK=DPI/DBLE(LAMBDA)
      SAK=SNGL(DAK)
C
C         THIS IS THE MAIN LOOP FOR THE SIMULATION.  THE RECEIVER
C LOCATION IS READ IN BY INPUT.  THE DATA IS IN COMMON 'REC'
C THE INPUT BEING DONE BY JOVRAX.  IF THERE ARE NO MORE RECEIVER
C POINTS THE SUBROUTINE RETURNS TO 200.
201   CALL INPUT($200)
C
C         THIS SECTION INITIALIZES THE COMPLEX AMPLITUDES FOR
C THE RECEIVED FIELD AS FOLLOWS:
C         CFR1    CARRIER WITH 'REAL' GROUND
C         CFR2    150 HZ SIDEBAND WITH 'REAL' GROUND
C         CFR3    90HZ SIDEBAND WITH 'REAL' GROUND
C         CFS1    CARRIER WITH 'IDEAL' FLAT GOUND PLANE
C         CFS2    150HZ WITH 'IDEAL' GROUND
C         CFS3    90 HZ.ITH 'IDEAL' GROUND
      CFR1=(0.,0.)
      CFR2=(0.,0.)
      CFR3=(0.,0.)
      CFS1=(0.,0.)
      CFS2=(0.,0.)
      CFS3=(0.,0.)
      R2=SQRT(RX*RX+RZ*RZ)
C
C         THIS LOOP IS OVER THE ELEMENTS OF THE ANTENNA
C THE COMPLEX FIELDS ARE SUMMED IN CFR1,CFR2 ETC.
      DO 3 IEL=1,NEL
C
C         THESE ARE THE LOCATION COORDINATES OF THE ANTENNA ELEMENTS
C AND CONSTANTS USED IN THE STRIP INTEGRATION
      AX=X(IEL)
      AY=Y(IEL)
      AZ=Z(IEL)
      DELX=RX-AX
      DELY=RY-AY
      DELZ=RZ-AZ
      DR=DSQRT(DELX*DELX+DELY*DELY+DELZ*DELZ)
      R=SNGL(DR)
      DR=DR*DAK
      IL=DR/DPI
C
C         THIS SECTION INITIALIZES  HR AND HI TO INCLUDE THE
C SEMI-INFINITE REAR GROUND PLANE
       TEMP2=DR-DBLE(FLOAT(IL))*DPI
      TEMP=R2+AZ
      F1=SQRT(TEMP*TEMP+AY*AY)
      F2=-RX*TEMP/(R2*F1)
      TC=SQRT(1.+AY*AY/(TEMP*TEMP))
```

```
      TD=TC*AZ
      R1=R2*TC
      S=SQRT((1./R2+1./AZ)/(TC*TC*TC))
      G=RX/(TD*TD*R1*R1*S)
      TEMP=SAK*F1
      SF=SIN(TEMP)
      FC=COS(TEMP)
      TEMP=AZ*G/DAK/F2
C
C         HR AND HI ARE THE REAL AND IMAGINARY PARTS OF THE COMPLEX
C 'GAIN' FACTOR OF THE GROUND SURFACE SCATTERING TO THE RECIEVER
C LOCATION
      HR=-TEMP*(SF+FC/(DAK*TD))
      HI=TEMP*(FC-SF/(DAK*TD))
C
C         THIS SUBROUTINE SUMS THE 'GAIN' FACTOR FOR EACH STRIP OF
C THE GROUND SURFACE
      CALL SCAT
C
C         THIS SECTION INCLUDES THE EFFECT OF THE DIRECT RADIATION FROM
C THE ANTENNA ELEMENT AT THE RECEIVER
      HR=HR*SQRT2L
      HI=HI*SQRT2L
      TEMP=DELX/(R*R)
      SF=SIN(TEMP2)
      FC=COS(TEMP2)
C
C         CTEMP IS THE COMPLEX GAIN FACTOR INCLUDING ALL RADIATION FROM
C THIS ELEMENT
      CTEMP=CMPLX(-TEMP*SF+HR-HI,TEMP*FC+HR+HI)*.5/LAMBDA
C
C         THIS SECTION ACCUMULATES THE FIELDS OF THE VARIOUS FREQUENCIES
      CFS1=CFS1+CTEMP*CF1(IEL)
      CFS2=CFS2+CTEMP*CF2(IEL)
      CFS3=CFS3+CTEMP*CF3(IEL)
      ALPH=SAK*2.*AZ*RZ/R
      CTEMP=TEMP*.5/LAMBDA*CMPLX(-SF,FC)*
     1CMPLX((1.-COS(ALPH)),-SIN(ALPH))
      CFR1=CFR1+CTEMP*CF1(IEL)
      CFR2=CFR2+CTEMP*CF2(IEL)
      CFR3=CFR3+CTEMP*CF3(IEL)
3     CONTINUE
      WRITE(1,2003) RX,RY,RZ,RT,CFR1,CFR2,CFR3,CFS1,CFS2,CFS3
2003  FORMAT(4F,/,6E13.6,/,6E13.6)
      GO TO 201
C
C         THIS IS THE TERMINATION SECTION.  THE INITIAL RECORD ON
C THE OUTPUT FILE IS WRITTEN AND THE PROGRAM TERMINATES.
200   CALL RELEAS (1)
      CALL EXIT
      STOP
      END
```

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CONSTANTS

0	203622077325	1	156042055061	2	000000000001	3	51651224[illegible]	4	000000000000
5	000000000024	6	436451642100	7	000000000000	10	000000000000		

COMMON

NRP	/PLXT	/+0	RXMN	/PLXT	/+1	RXMX	/PLXT	/+2	RXFT	/PLXT	/+3	RXLT	/PLXT	/+4
RYMN	/PLXT	/+5	RYMX	/PLXT	/+6	RYFT	/PLXT	/+7	RYLT	/PLXT	/+10	RZMN	/PLXT	/+11
RZMX	/PLXT	/+12	RZFT	/PLXT	/+13	RZLT	/PLXT	/+14	RTMN	/PLXT	/+15	RTMX	/PLXT	/+16
RTFT	/PLXT	/+17	RTLT	/PLXT	/+20	AIMN	/PLXT	/+21	AIMX	/PLXT	/+22	AIFT	/PLXT	/+23
AILT	/PLXT	/+24	ARMN	/PLXT	/+25	ARMX	/PLXT	/+26	ARFT	/PLXT	/+27	ARLT	/PLXT	/+30
ADIN	/PLXT	/+31	ADIX	/PLXT	/+32	ADIF	/PLXT	/+33	ADIT	/PLXT	/+34	ADRN	/PLXT	/+35
ADRX	/PLXT	/+36	ADRF	/PLXT	/+37	ADRL	/PLXT	/+40	RX	/REC	/+0	RY	/REC	/+1
RZ	/REC	/+2	RT	/REC	/+3	NSIZE	/REC	/+4	K	/GROUND	/+0	X1	/GROUND	/+1
Z1	/GROUND	/+25	X2	/GROUND	/+51	Z2	/GROUND	/+76	IEL	/GROUND	/+123	AX	/ANT	/+0
AY	/ANT	/+1	AZ	/ANT	/+2	LAMBDA	/ANT	/+3	DAK	/ANT	/+4	DPI	/ANT	/+6
HR	/VAL	/+0	HI	/VAL	/+1	IPTDAT	/PLXT	/+0						

SUBPROGRAMS

FORSE.	.JBFF	OFILE	IF	ALPHO.	ALPHI.	FLOUT.	FLIRT.	IFILE	BINWR.	RELEAS	SQRT	DSGF	DFD.2	SNGL
INPUT	DSQRT	DFM.2	DFM.4	DFA.2	DFM.6	DFMN.2	IDINT	FLOAT	DFM.0	DFS.0	SIN	COS	DFD.4	DFA.4
DFS.4	SCAT	CMPLX	CFD.0	CFM.2	CFM.0	EXIT								

SCALARS

DPI	6	TAU	1017	NRP	0	K	0	ILBL	1020
LAMBDA	3	NEL	1021	I	1022	SQR12L	1023	TEMP2	1024
DAK	4	SAK	1025	CFR1	1026	CFR2	1030	CFR3	1032
CFS1	1034	CFS2	1036	CFS3	1040	R2	1042	RX	0
RZ	2	IEL	123	AX	0	AY	1	AZ	2
DELX	1043	DELY	1045	RY	1	DELZ	1047	DR	1051
R	1053	IL	1054	TEMP	1055	F1	1056	F2	1057
TC	1060	TD	1061	R1	1062	S	1063	G	1064
SF	1065	FC	1066	HR	0	HI	1	CTEMP	1067
ALPH	1071	RT	3	RXMN	1	RXMX	2	RXFT	3
RXLT	4	RYMN	5	RYMX	6	RYFT	7	RYLT	10
RZMN	11	RZMX	12	RZFT	13	RZLT	14	RTMN	15
RTMX	16	RTFT	17	RTLT	20	AIMN	21	AIMX	22
AIFT	23	AILT	24	ARMN	25	ARMX	26	ARFT	27
ARLT	30	ADIN	31	ADIX	32	ADIF	33	ADIL	34
ADRN	35	ADRX	36	ADRF	37	ADRL	40	NSIZE	1

ARRAYS

ILABL	1072	IPTDAT	0	X	1102	Y	1126	Z	1152
CF1	1176	CF2	1246	CF3	1316	X1	1	Z1	25
X2	51	Z2	76						

ADIF	3										
ADIL	3										
ADIN	3										
ADIX	3										
ADRF	3										
ADRL	3										
ADRN	3										
ADRX	3										
AIFT	3										
AILT	3										
AIMN	3										
AIMX	3										
ALPH	142	143									
ANT	16										
ARFT	3										
ARLT	3										
ARMN	3										
ARMX	3										
AX	16	89	92								
AY	16	90	93	104	106						
AZ	16	91	94	103	107	109	114	142			
CF1	11	53	54	139	145						
CF2	11	53	54	140	146						
CF3	11	53	54	141	147						
CFR1	75	145	149								
CFR2	76	146	149								
CFR3	77	147	149								
CFS1	78	139	149								
CFS2	79	140	149								
CFS3	80	141	149								
CMPLX	136	143									
COS	113	132	143								
CTEMP	136	139	140	141	143	145	146	147			
DAK	16	58	59	97	114	119	120				
DBLE	58	102									
DELX	92	95	130								
DELY	93	95									
DELZ	94	95									
DPI	16	21	58	98	102						
DR	95	96	97	98	102						
DSQRT	95										
EXIT	156										
F1	104	105	111								
F2	105	114									
FC	113	119	120	132	136	143					
FLOAT	102										
G	110	114									
GROUND	15										
HI	17	120	129	136							
HR	17	119	128	136							
I	53	54									
IEL	15	85	89	90	91	139	140	141	145	146	147
IF	30										

IFILE	38	50											
IL	98	102											
ILABL	1	30	32	39	40	51	52						
ILBL	48	50											
INPUT	65												
IPTDAT	2	8											
K	15	41											
LAMBDA	14	16	53	54	56	57	58	136	143				
NEL	53	54	65										
NRP	3	8	35										
NSIZE	13												
OFILE	24												
PLXT	3												
R	96	130	142										
R1	108	110											
R2	81	103	105	108	109								
REC	13												
RELEAS	42	55	155										
RT	13	149											
RTFT	3												
RTLT	3												
RTMN	3												
RTMX	3												
RX	13	81	92	105	110	149							
RXFT	3												
RXLT	3												
RXMN	3												
RXMX	3												
RY	13	93	149										
RYFT	3												
RYLT	3												
RYMN	3												
RYMX	3												
RZ	13	81	94	142	149								
RZFT	3												
RZLT	3												
RZMN	3												
RZMX	3												
S	109	110											
SAK	59	111	142										
SCAT	124												
SF	112	119	120	131	136	143							
SIN	112	131	143										
SNGL	59	96											
SQRT	56	81	104	106	109								
SQRT2L	56	128	129										
TAU	30	32											
TC	106	107	108	109									
TD	107	110	119	120									
TEMP	103	104	105	106	111	112	113	114	119	120	130	136	143
TEMP2	57	102	131	132									
VAL	17												
X	10	53	54	89									

```
 1      C
 2      C       THIS SUBROUTINE OPENS THE FLIGHT PATH FILE AND INPUTS THE
 3      C FLIGHT PATH PLOT LABEL AND THE INERTIAL TIME CONSTANT
 4      C
 5      C       THIS SUBROUTINE INPUTS THE RECEIVER LOCATION
 6      C COORDINATES OF THE NEXT POINT ON THE FLIGHT PATH.  IF THERE
 7      C ARE NO MORE POINTS THE SUBROUTINE EXITS TO THE
 8      C END RETURN POINT
 9            SUBROUTINE IF(ILABL,TAU)
10            DIMENSION ILABL(8)
11            COMMON/REC/ DUM(4),NSIZE
12            CALL JOVSET(1,'PATH.DAT',NS)
13            WRITE(5,1000) NS
14      1000  FORMAT(I5,' RECORDS IN PATH.DAT',/)
15            NSIZE=(NS-8)/4
16            CALL JOVWI(1,ILABL,8,0)
17            CALL JOVWI(1,TAU,1,0)
18            RETURN
19            END

CONSTANTS

0     000000000001    1     502032444134    2     422032420100    3     000000000000    4     000000000010

GLOBAL DUMMIES

ILABL   66          TAU     67

COMMON

DUM     /REC    /+0     NSIZE   /REC    /+4

SUBPROGRAMS

JOVSET  INTO.   INTI.   JOVWI

SCALARS

IF      70          NS      71          NSIZE   4           TAU     67

ARRAYS

ILABL   66          DUM     0


DUM       11
IF         9
ILABL      9     10     16
JOVSET    12
JOVWI     16     17
NS        12     13     15
NSIZE     11     15
REC       11
TAU        9     17
```

```
 1000P       13       14
```

```
      1              SUBROUTINE INPUT($)
      2              COMMON /REC/ RX(4),NSIZE
      3              IF(NSIZE .LE. 0) RETURN 1
      4              CALL JOVWI(1,RX,4,0)
      5              NSIZE=NSIZE-1
      6              RETURN
      7              END

   CONSTANTS

   0       000000000001     1       000000000004     2       000000000000

   COMMON

   RX      /REC    /+0      NSIZE   /REC    /+4

   SUBPROGRAMS

   JOVWI

   SCALARS

   INPUT   36               NSIZE   4

   ARRAYS

   RX      0
```

```
 INPUT        1
 JOVWI        4
 NSIZE        2        3        5
 REC          2
 RX           2        4
```

```
C
C         THIS SUBROUTINE SUMS THE EFFECTS OF THE STRIPS THAT MAKE
C UP HE GROUNDSURFACE.  THERE ARE 'K' STRIPS DESCRIBED IN COMMON
C GROUND AS FOLLOWS:
C         X1(I)    THE X-COORDINATE OF THE LEADING EDGE OF THE I'TH STRIP
C         Z1(I)    THE Z-COORDINATE OF THE LEADING EDGE OF THE I'TH STRIP
C         X2(I)    THE X-COORDINATE OF THE ENDING EDGE OF THE I'TH STRIP
C         Z2(I)    THE Z-COORDINATE OF THE ENDING EDGE OF THE I'TH STRIP
      SUBROUTINE SCAT
      COMMON /REC/ RX,RY,RZ
      COMMON /ANT/AX,AY,AZ
      COMMON /GROUND/ K,X1(20),Z1(20),X2(0/20),Z2(0/20),IEL
      COMMON /SEG/ XX1,ZZ1,XX2,ZZ2,N
C
C         THESE ARE INITIAL VALUES FOR THE PARAMETERS USED IN SHADOWING
      SLOPE=-1.
      PHIE=-1.
C
C         THIS IS THE LOOP OVER THE STRIPS
      DO 1 I=1,K
C
C         THESE ARE THE VALUES TO BE USED IN THE STRIP
C INTEGRATION SUBROUTINE
C         XX1      LEADING X-COORDINATE
C         ZZ1      LEADING Z-COORDINATE
C         XX2      TRAILING X-COORDINATE
C         ZZ2      TRAILING Z-COORDINATE
      XX1=X1(I)
      ZZ1=Z1(I)
      XX2=X2(I)
      ZZ2=Z2(I)
C
C         THIS IS A TEST TO SEE IF THE SUMMATION OVER THE GROUND
C STRIPS HAS REACHED THE RECEIVER LOCATION.  IF IT HAS THE SUMMATION
C IS STOPPED.  THIS IS TO GIVE THE EFFECT OF FOWARD LOOKING RECEIVER
C ANTENNA PATTERN.
      IF( XX1 .GE. RX) GO TO 6
C
C         IF THE RECIEVER IS LOCATED OVER THE MIDDLE PORTION OF A STRIP
C THE STRIP WILL BE INTEGRATE ONLY UP TO THE VALUE OF THE
C RECEIVER X-COORDINATE
      IF(XX2 .LE. RX) GO TO 5
      ZZ2=ZZ1+(RX-XX1)*(ZZ2-ZZ1)/(XX2-XX1)
      XX2=RX
    5 CONTINUE
C
C         THIS SECTION DOES THE SHADOWING.  IF PART OR ALL OF THE STRIP
C IS IN THE SHADOW OF A PREVIOUS STRIP, THIS STRIP WILL BE ELIMINATED
C OR MASKED TO GIVE THE EFFECT OF SHADOWING.
      DELX=XX2-AX
      IF(DELX .LE. 0.) GO TO 3
      PHIE=(AZ-ZZ2)/DELX
      IF(SLOPE .LT. 0.) GO TO 3
```

```
            IF(PHIE .GE. SLOPE) GO TO 1
            PHIB=(AZ-ZZ1)/(XX1-AX)
            IF( PHIB .LE. SLOPE) GO TO 3
            IF( XX1 .EQ. XX2) GO TO 4
            A=(ZZ2-ZZ1)/(XX2-XX1)
            B=ZZ1-A*(XX1-AX)
            XX1=(AZ-B)/(A+SLOPE)+AX
      4     ZZ1=-SLOPE*(XX1-AX)+AZ
      C
      C        THIS SUBROUTINE WILL INTEGRATE OVER THE STRIP THE
      C COMPLEX 'GAIN' EFFECT OF THIS STRIP WILL BE ADDED TO HR AND HI
      C IN COMMON 'VALL'
      3     CALL SUM
            SLOPE=PHIE
      1     CONTINUE
      6     RETURN
            END
```

CONSTANTS

0	201400000000

COMMON

RX	/REC /+0	RY	/REC /+1	RZ	/REC /+2	AX	/ANT /+0	AY	/ANT /+1
AZ	/ANT /+2	K	/GROUND/+0	X1	/GROUND/+1	Z1	/GROUND/+25	X2	/GROUND/+51
Z2	/GROUND/+76	IEL	/GROUND/+123	XX1	/SEG /+0	ZZ1	/SEG /+1	XX2	/SEG /+2
ZZ2	/SEG /+3	N	/SEG /+4						

SUBPROGRAMS

SUM

SCALARS

SCAT	143	SLOPE	144	PHIE	145	1	146	F	0
XX1	0	ZZ1	1	XX2	2	ZZ2	3	FX	0
DELX	147	AX	0	AZ	2	PHIB	150	A	151
B	152	RY	1	RZ	2	AY	1	IEL	123
N	4								

ARRAYS

X1	1	Z1	25	X2	51	Z2	76

A	58	59	60							
ANT	11									
AX	11	50	55	59	60	61				
AY	11									
AZ	11	52	55	60	61					
B	59	60								
DELX	50	51	52							
GROUND	12									
I	20	28	29	30	31					
IEL	12									
K	12	20								
N	13									
PHIB	55	56								
PHIE	17	52	54	67						
REC	10									
RX	10	37	42	43	44					
RY	10									
RZ	10									
SCAT	9									
SEG	13									
SLOPE	16	53	54	56	60	61	67			
SUM	66									
X1	12	28								
X2	12	30								
XX1	13	28	37	43	55	57	58	59	60	61
XX2	13	30	42	43	44	50	57	58		
Z1	12	29								
Z2	12	31								
ZZ1	13	29	43	55	58	59	61			
ZZ2	13	31	43	52	58					

1P	20	54	68	
3P	51	53	56	66
4P	57	61		
5P	42	45		
6P	37	69		

```
C
C        THIS SUBROUTINE INTEGRATES OVER THE SURFACE STRIP DEFINED
C BY X1,Z1,X2,Z2 IN COMMON 'SEG', TO GIVE THE FIELD EFFECT
C OF THEANTENNA ELEMENT IN COMMON 'ANT' AT RECIEVER DEFINED
C IN COMMON 'REC'.  THE VARIABLES ARE AS FOLLOWS:
C        AX       ANTENNA X-COORDINATE
C        AY       ANTENNA Y-COORDINATE
C        AZ       ANTENNA Z-COORDINATE
C        LAMBDA   WAVELENGTH OF CARRIER
C        AK       TWO*PI/LAMBDA
C        DPI      TWO*PI (DOUBLE PRECISION)
C        RX       RECEIVER X-COORDINATE
C        RY       RECEIVER Y-COORDINATE
C        RZ       RECEIVER Z-COORDINATE
C        HR       REL PART OF 'GAIN' FACTOR
C        HI       IMAGINARY PART OF 'GAIN' FACTOR
C        X1       LEADING EDGE OF STRIP'S X-COORDINATE
C        Z1       LEADING Z-COORDINATE
C        X2       TRAILING EDGE X-COORDINATE
C        Z2       TRAILING Z-COORDINATE
C THE INTEGRATION IS PERFORMED BY A MODIFIED TRAPIZOID RULE.
C THE SPACING BETWEEN POINTS ALONG THE VARIABLE OF INTEGRATION
C IS VARIED BY THE RATE OF CHANGE OF THE INTEGRAND.
      SUBROUTINE SUM
      COMMON /SEG/ X1,Z1,X2,Z2,N
      DOUBLE PRECISION A1,A2,B1,B2,XL,AY2
      REAL  JR,JI,JOR,JOI,JNR,JNI
      REAL LAMBDA
       DOUBLE PRECISION AK,DPI,DR
      COMMON /ANT/AX,AY,AZ,LAMBDA,AK,DPI
      COMMON /REC/RX,RY,RZ
      COMMON /VAL/HR,HI
      REAL L3,L10
C
C        THIS IS THE INITIALIZATION SECTION
      AY2=DBLE(AY)*DBLE(AY)
      AKK=SNGL(AK)
      SE=Z2-Z1
      CE=X2-X1
C
C        XMAX IS THE LENGTH ALONG THE SURFACE OF THE STRIP
      XMAX=SQRT(SE*SE+CE*CE)
C
C        THESE ARE THE SIN AND COS OF THE ANGLE THE STRIP MAKES WITH
C A HORIZONTAL PLANE
      SE=SE/XMAX
      CE=CE/XMAX
      JR=0.
      JI=0.
C
C        XL IS THE VARIABLE OF INTEGRATION.  IT IS THE DISTANCE
C LONG THE SURFACE OF THE STRIP STARTING FROM THE LEADING EDGE
      XL=0.
```

```
      NX=1
      IT=0
C
C        THESE ARE THE LOWER ANF UPPER BOUNDS FOR THE SPACING BETWEEN
C POINTS ALONG THE VARIABLE OF INTEGRATION
      L3= LAMBDA/24.
      L10=20.*LAMBDA
      A1=RX-X1
      A2=RZ-Z1
      B1=X1
      B2=Z1-A2
      A=A1
      TEMP=A2
       A= SQRT(A*A+TEMP*TEMP)
      B=B1
      TEMP=B2
      B= SQRT(B*B+TEMP*TEMP)
      TEMP=A+B
      DR=DSQRT(DBLE(TEMP)*DBLE(TEMP)+DBLE(AY*AY))
      C=DR
      DR=DR*AK
      I=DR/DPI
      F=DR-DBLE(FLOAT(I))*DPI
      C=C/TEMP
      D=C*B
      R=C*A
       S=SQRT((1./A+1./B)/C/C/C)
      G=A1/D/D/R/R/S
      TEMP=G/(AKK*D)
      CE=COS(F)
      SE=SIN(F)
      JOR=G*CE-TEMP*SE
      JOI=G*SE+TEMP*CE
      AP=(-A1*CE-A2*SE)/A
      BP=(B1*CE+B2*SE)/B
C
C        FP IS THE DERIVATIVE OF THE PHASE FUNCTION
C OF THE INTEGRAND
      FP=ABS((AP+BP)/C)
C
C        DL IS DELTA XL
      DL=L3/FP
      IF(DL .GT. L10) DL=L10
      IF(DL .LT. L3) DL=L3
      XL=XL+DL
C
C        THIS IS THE LOOP OVER THE SURFACE OF THE STRIP.  XL IS
C INCREMENTED BY DL (OF VARIABLE SIZE) UNTIL THE END OF THE STRIP
C IS REACHED (XMAX)
    1 CONTINUE
C
C        THIS SECTION CALCULATE VARIOUS TERMS USED IN EVALUATING THE
C INTEGRAND.  THE AMPLITUDE AND PHASE FUNCTION
```

```
C ARE EVALUTATED SEPARATELLY.  THE DERIVATIVE OF THE PHASE FUNCTION
C IS EVALUATED TO DETERMUINE THE SIZE FOR DELTA X
      DLSE=DL*SE
      DLCE=DL*CE
      A1=A1-DLCE
      A2=A2-DLSE
      B1=B1+DLCE
      B2=B2+DLSE
      A=A1
       TEMP=A2
      A= SQRT(A*A+TEMP*TEMP)
      B=B1
      TEMP=B2
      B= SQRT(B*B+TEMP*TEMP)
      TEMP=A+B
      DR=DSQRT(DBLE(TEMP)*DBLE(TEMP)+DBLE(AY*AY))
      C=SNGL(DR)/TEMP
      DR=DR*AK
      I=DR/DPI
C
C         THIS IS THE PHASEE ANGLE "MODULO TWO PI"
      F=DR-DBLE(FLOAT(I))*DPI
      D=C*B
      R=C*A
      S=SQRT((1./A+1./B)/C)/C
      G=A1/(D*D*R*R*S)
C
C         THIS IS THE AMPLITUDE FUNCTION
      TEMP=G/(AKK*D)
      CF=COS(F)
      SF=SIN(F)
C
C         THIS IS THE REAL PART OF THE INTEGRAND FOR THE
C INTEGRATION VARIABLE VALUE OF XL
      JNR=G*CF-TEMP*SF
C
C         THIS IS THE IMAGINARY PART
      JNI=G*SF+TEMP*CF
      TEMP=DL
C
C         THESE ARE THE REAL AN IMAGINARY PARTS OF THE THE SUMMATION
C OF THE TRAPIZOIDS MAKING UP THE APPROXIMATION TO THE INTEGRAL
      JR=JR+(JOR+JNR)*TEMP
      JI=JI+(JOI+JNI)*TEMP
       IF(IT .NE. 0) GO TO 2
      JOR=JNR
      JOI=JNI
      AP=(-A1*CE-A2*SE)/A
       BP=(B1*CE+B2*SE)/B
C
C         FP IS THE DERIVATIVE OF THE PHASE FUNCTION
      FP=ABS((AP+BP)/C)
C
```

```
C       DL IS DELTA X AND IS LIMITED BY THE BOUNDS L3,L10
        DL=L3/FP
        IF(DL .GT. L10) DL=L10
        IF(DL .LT. L3) DL=L3
        NX=NX+1
C
C       THE VARIABLE OF INTGRATION IS INCREMENTED AND IF THE END OF THE
C STRIP IS REACHED THE LAST TRAPIZOID IS ADDED
        XL=XL+DL
        IF( XL .LT. XMAX) GO TO 1
        DL=XMAX+DL-XL
        XL=XMAX
        IT=1
        GO TO 1
C
C       THIS SECTION ADDS THE FIELD EFFECT FROM THE STRIP TO THE
C TOTAL FIELD SUM AND TEH SUBROUTINE TERMINATES
2       CONTINUE
        N=NX
        TEMP=((Z1-AZ)*CE-X1*SE)/2.
        HR=HR+JR*TEMP
        HI=HI+JI*TEMP
        RETURN
        END
```

CONSTANTS

```
0        205600000000
```

COMMON

X1	/SEG	/+0	Z1	/SEG	/+1	X2	/SEG	/+2	Z2	/SEG	/+3	N	/SEG	/+4
AX	/ANT	/+0	AY	/ANT	/+1	AZ	/ANT	/+2	LAMBDA	/ANT	/+3	AK	/ANT	/+4
DPI	/ANT	/+6	RX	/REC	/+0	RY	/REC	/+1	RZ	/REC	/+2	HR	/VAL	/+0
HI	/VAL	/+1												

SUBPROGRAMS

DBLE	DFM.0	SNGL	SQRT	DSQRT	DFA.0	DFMM.2	DFD.2	ILIGT	FLOAT	DFS.0	DFD.6	COS	SIN	DFM.4
DFM.6	DFA.4	DFD.4	ABS	DFAM.2	DFS.2									

SCALARS

SUM	1064	AY2	1065	AY	1	AKK	1067	AK	4
SE	1070	Z2	3	Z1	1	CF	1071	X2	2
X1	0	XMAX	1072	JR	1073	J1	1074	XL	1075
NX	1077	IT	1100	L3	1101	LAMBDA	3	L10	1102
A1	1103	RX	0	A2	1105	RZ	2	HJ	1107
B2	1111	AZ	2	A	1113	TEMP	1114	H	1115
DR	1116	C	1120	I	1121	DP1	6	F	1122
D	1123	R	1124	S	1125	G	1126	CF	1127
SF	1130	JOR	1131	JO1	1132	AP	1133	KP	1134
FP	1135	DL	1136	DLSE	1137	DLCE	1140	JOR	1141

JNI 1142 N 4 HR 0 HI 1 AX 0
RY 1

A	65	67	71	79	80	87	115	117	121	130	131	154
A1	26	61	65	81	87	111	115	132	154			
A2	26	62	66	87	112	116	154					
ABS	92	158										
AK	29	30	37	74	124							
AKK	37	82	135									
ANT	30											
AP	87	92	154	158								
AX	30											
AY	30	36	72	122								
AY2	26	36										
AZ	30	64	179									
B	68	70	71	78	80	88	118	120	121	129	131	155
B1	26	63	68	88	113	118	155					
B2	26	64	69	88	114	119	155					
BP	88	92	155	158								
C	73	77	78	79	80	92	123	129	130	131	158	
CE	39	42	47	87	88	110	154	155	179			
CF	83	85	86	136	141	144						
COS	83	136										
D	78	81	82	129	132	135						
DBLE	36	72	76	122	128							
DL	95	96	97	98	109	110	145	161	162	163	168	170
DLCE	110	111	113									
DLSE	109	112	114									
DPI	29	30	75	76	125	128						
DR	29	72	73	74	75	76	122	123	124	125	128	
DSQRT	72	122										
F	76	83	84	128	136	137						
FLOAT	76	128										
FP	92	95	158	161								
G	81	82	85	86	132	135	141	144				
HI	32	181										
HR	32	180										
I	75	76	125	128								
IT	55	151	172									
JI	27	49	150	181								
JNI	27	144	150	153								
JNR	27	141	149	152								
JOI	27	86	150	153								
JOR	27	85	149	152								
JR	27	48	149	180								
L10	33	60	96	162								
L3	33	59	95	97	161	163						
LAMBDA	28	30	59	60								
N	25	178										
NX	54	164	178									
R	79	81	130	132								
REC	31											
RX	31	61										
RY	31											
RZ	31	62										
S	80	81	131	132								

SE	38	42	46	87	88	109	154	155	179					
SEG	25													
SF	84	85	86	137	141	144								
SIN	84	137												
SNGL	37	123												
SQRT	42	67	70	80	117	120	131							
SUM	24													
TEMP	66	67	69	70	71	72	77	82	85	86	116	117	119	120
	121	122	123	135	141	144	145	149	150	179	180	181		
VAL	32													
X1	25	39	61	63	179									
X2	25	39												
XL	26	53	98	168	169	170	171							
XMAX	42	46	47	169	170	171								
Z1	25	38	62	64	179									
Z2	25	38												

1P	103	169	173
2P	151	177	

PROGRAM MOLE.F4

```
      DIMENSION ILABL(8)
      DIMENSION IPTDAT(33)
      COMMON /PLXT/ NRP,RXMN,RXMX,RXFT,RXLT,RYMN,RYMX,RYFT,RYLT,
     1RZMN,RZMX,RZFT,RZLT,RIMN,RTMX,RIFT,RTLT,
     2AIMN,AIMX,AIFT,AILT,ARMN,ARMX,ARFT,ARLT,
     3ADIN,ADIX,ADIF,ADIL,
     4ADRN,ADRX,ADRF,ADRL
      EQUIVALENCE (IPTDAT(1),NRP)
      IMPLICIT COMPLEX (C)
      DIMENSION X(20),Y(20),Z(20)
      DIMENSION CF1(20),CF2(20),CF3(20)
      IMPLICIT DOUBLE PRECISION (D)
      COMMON /REC/RX,RY,RZ,RT,NSIZE
      REAL LAMBDA
      COMMON /ANT/AX,AY,AZ,LAMBDA,DAK,DPI
      COMMON /VAL/ HR,HI
      COMMON /GRND/ P(3,4),A(3)
C
C        THIS VALUE OF TWO PI IS INITIALIZED THIS WAY TO AVOID USING
C BLOCK DATA
      DPI=6.2831853071795864769
      WRITE(5,2001)
2001  FORMAT(' INPUT FILE NAME:',$)
      READ(5,2000) ILBL
2000  FORMAT(A5)
      CALL IFILE(20,ILBL)
      WRITE(5,2002)
2002  FORMAT(' OUTPUT FILE NAME:',$)
      READ(5,2000) ILBL
      CALL OFILE(1,ILBL)
      READ(20,1000) ILABL,TAU
      WRITE(1,1000) ILABL
      DO 3 I=1,2
      READ(20,1000) ILABL
3     WRITE(1,1000) ILABL
1000  FORMAT(8A5,F)
      READ(20) LAMBDA,NEL,(X(I),Y(I),Z(I),CF1(I),CF2(I),CF3(I),I=1,NEL)
      WRITE(1) LAMBDA,NEL,(X(I),Y(I),Z(I),CF1(I),CF2(I),CF3(I),I=1,NEL)
      DAK=DPI/DBLE(LAMBDA)
201   READ(20,2005,END=200) RX,RY,RZ,RT,
     1CFR1,CFR2,CFR3,CFS1,CFS2,CFS3
2005  FORMAT(4F,/,6E13.6,/,6E13.6)
      READ(5,3000) P
3000  FORMAT(3G)
      DO 5 I=1,NEL
      AX=X(I)
      AY=Y(I)
      AZ=Z(I)
      CTEMP=(0.,0.)
      CALL INTR2(CTEMP)
      CT=CTEMP*CF1(I)
      CFR1=CFR1+CT
      CFS1=CFS1+CT
```

```
                CT=CTEMP*CF2(I)
                CFR2=CFR2+CT
                CFS2=CFS2+CT
                CT=CTEMP*CF3(I)
                CFS3=CFS3+CT
                CFR3=CFR3+CT
          5     CONTINUE
                WRITE(1,2005) RX,RY,RZ,RT,CFR1,CFR2,CFR3,CFS1,CFS2,CFS3
                GO TO 201
          C
          C       THIS IS THE TERMINATION SECTION.  THE INITIAL RECORD ON
          C THE OUTPUT FILE IS WRITTEN AND THE PROGRAM TERMINATES.
          200   CALL RELEAS (1)
                CALL EXIT
                STOP
                END

CONSTANTS

0     203622077325     1     150042055061     2     000000000024     3     000000000001     4     000000000000
5     000000000000

COMMON

NRP     /PLXT  /+0    RXMN    /PLXT  /+1    RXMX   /PLXT  /+2    RXFT    /PLXT  /+3    RXLT   /PLXT  /+4
RYMN    /PLXT  /+5    RYMX    /PLXT  /+6    RYFT   /PLXT  /+7    RYLT    /PLXT  /+10   RZMN   /PLXT  /+11
RZMX    /PLXT  /+12   RZFT    /PLXT  /+13   RZLT   /PLXT  /+14   RTMN    /PLXT  /+15   RTMX   /PLXT  /+16
RTFT    /PLXT  /+17   RTLT    /PLXT  /+20   AIMN   /PLXT  /+21   AIMX    /PLXT  /+22   AIFT   /PLXT  /+23
AILT    /PLXT  /+24   ARMN    /PLXT  /+25   ARMX   /PLXT  /+26   ARFT    /PLXT  /+27   ARLT   /PLXT  /+30
ADIN    /PLXT  /+31   ADIX    /PLXT  /+32   ADIF   /PLXT  /+33   ADIL    /PLXT  /+34   ADRN   /PLXT  /+35
ADRX    /PLXT  /+36   ADRF    /PLXT  /+37   ADRL   /PLXT  /+40   RX      /REC   /+0    RY     /REC   /+1
RZ      /REC   /+2    RT      /REC   /+3    NSIZE  /REC   /+4    AX      /ANT   /+0    AY     /ANT   /+1
AZ      /ANT   /+2    LAMBDA  /ANT   /+3    DAK    /ANT   /+4    DPI     /ANT   /+6    HR     /VAL   /+0
HI      /VAL   /+1    P       /GRND  /+0    N      /GRND  /+14   IPTDAT  /PLXT  /+0

SUBPROGRAMS

FORSE.  .JBFF   ALPHO.  ALPHI.  IFILE   OFILE   FLOUT.  FLIRT.  BINWR.  DBLE    DFD.2   END.    ALLIO.  IWTR2   CFN.2
RELEAS  EXIT

SCALARS

DPI     6          ILBL    363        TAU     364        I       365        LAMBDA  3
NEL     366        DAK     4          RX      0          RY      1          RZ      2
RT      3          CFR1    367        CFR2    371        CFR3    373        CFS1    375
CFS2    377        CFS3    401        AX      0          AY      1          AZ      2
CTEMP   403        CT      405        NRP     0          RXMN    1          RXMX    2
RXFT    3          RXLT    4          RYMN    5          RYMX    6          RYFT    7
RYLT    10         RZMN    11         RZMX    12         RZFT    13         RZLT    14
RTMN    15         RTMX    16         RTFT    17         RTLT    20         AIMN    21
AIMX    22         AIFT    23         AILT    24         ARMN    25         ARMX    26
ARFT    27         ARLT    30         ADIN    31         ADIX    32         ADIF    33
ADIL    34         ADRN    35         ADRX    36         ADRF    37         ADRL    40
```

```
NSIZE    4              HR       0              HI       1

ARRAYS

ILABL    407            IPTDAT   0              X        417            Y        443            Z        467
CF1      513            CF2      563            CF3      633            F        0              G        13
```

ADIF	3								
ADIL	3								
ADIN	3								
ADIX	3								
ADRF	3								
ADRL	3								
ADRN	3								
ADRX	3								
AIFI	3								
AILI	3								
AIMN	3								
AIMX	3								
ANT	15								
ARFI	3								
ARLI	3								
ARMN	3								
ARMX	3								
AX	15	46							
AY	15	47							
AZ	15	48							
CF1	11	37	38	51					
CF2	11	37	38	54					
CF3	11	37	38	57					
CFR1	40	52	61						
CFR2	40	55	61						
CFR3	40	59	61						
CFS1	40	53	61						
CFS2	40	56	61						
CFS3	40	58	61						
CT	51	52	53	54	55	56	57	58	59
CTEMP	49	50	51	54	57				
DAK	15	39							
DBLE	39								
DPI	15	21	39						
EXIT	67								
GRND	17								
HI	16								
HR	16								
I	33	37	38	45	46	47	48	51	54	57
IFILE	26								
ILABL	1	31	32	34	35				
ILBL	24	26	29	30					
INTR2	50								
IPTDAT	2	8							
LAMBDA	14	15	37	38	39				
N	17								
NEL	37	38	45						
NRP	3	8							
NSIZE	13								
OFILE	30								
P	17	43							
PLXT	3								
REC	13								

RELEAS	66				
RT	13	40	61		
RTFT	3				
RTLT	3				
RTMN	3				
RTMX	3				
RX	13	40	61		
RXFT	3				
RXLT	3				
RXMN	3				
RXMX	3				
RY	13	40	61		
RYFT	3				
RYLT	3				
RYMN	3				
RYMX	3				
RZ	13	40	61		
RZFT	3				
RZLT	3				
RZMN	3				
RZMX	3				
TAU	31				
VAL	16				
X	10	37	38	46	
Y	10	37	38	47	
Z	10	37	38	48	

3P	33	35			
5P	45	60			
200P	40	66			
201P	40	62			
1000P	31	32	34	35	36
2000P	24	25	29		
2001P	22	23			
2002P	27	28			
2005P	40	42	61		
3000P	43	44			

```
 1        SUBROUTINE NORMAL(V1,V2,V3,V4,R)
 2        DIMENSION V1(1),V2(1),V3(1),V4(1)
 3        X1=V2(1)-V1(1)
 4        X2=V3(1)-V1(1)
 5        Y1=V2(2)-V1(2)
 6        Y2=V3(2)-V1(2)
 7        Z1=V2(3)-V1(3)
 8        Z2=V3(3)-V1(3)
 9        X=Y1*Z2-Y2*Z1
10        Y=Z1*X2-Z2*X1
11        Z=X1*Y2-Y1*X2
12        R=SQRT(X*X+Y*Y+Z*Z)
13        V4(1)=X/R
14        V4(2)=Y/R
15        V4(3)=Z/R
16        RETURN
17        END
```

GLOBAL DUMMIES

V1	133	V2	134	V3	135	V4	136	R	137

SUBPROGRAMS

SQRT

SCALARS

NORMAL	141	X1	142	X2	143	Y1	144	Y2	145
Z1	146	Z2	147	X	150	Y	151	Z	152
R	137								

ARRAYS

V1	133	V2	134	V3	135	V4	136

NORMAL	1							
R	1	12	13	14	15			
SQRT	12							
V1	1	2	3	4	5	6	7	8
V2	1	2	3	5	7			
V3	1	2	4	6	8			
V4	1	2	13	14	15			
X	9	12	13					
X1	3	10	11					
X2	4	10	11					
Y	10	12	14					
Y1	5	9	11					
Y2	6	9	11					
Z	11	12	15					
Z1	7	9	10					
Z2	8	9	10					

```
      DOUBLE PRECISION FUNCTION DIST(X,Y)
      DIMENSION X(1),Y(1)
      DOUBLE PRECISION R,TEMP
      R=0.
      DO 1 I=1,3
      TEMP=X(I)-Y(I)
    1 R=R+TEMP*TEMP
      DIST=DSQRT(R)
      RETURN
      END
```

```
GLOBAL DUMMIES

X      56             Y      57

SUBPROGRAMS

DFM.2   DFAM.2  DSQRT

SCALARS

DIST    60            R      62            I      64            TEMP    65

ARRAYS

X      56             Y      57
```

```
DIST       1    8
DSQRT      8
I          5    6
R          3    4    7    8
TEMP       3    6    7
X          1    2    6
Y          1    2    6
```

```
1P         5    7
```

PROGRAM INT2.F4

```
      SUBROUTINE INTR2(CTEMP)
      DATA DX,DY/23.,40./
      DIMENSION XTA(3),ZTA(3)
      DOUBLE PRECISION D10,D20,R10,R20
      COMPLEX A,B
      DOUBLE PRECISION DR1,DR2
      COMPLEX CTEMP,CCT,CCX,CCY,CCX0
      REAL N,LAMBDA,N1,N2,N3
      COMMON /GRND/ P(3,4),N(3)
      EQUIVALENCE (N(1),N1),(N(2),N2),(N(3),N3)
      DOUBLE PRECISION DAK,DPI
      COMMON /REC/ XR,YR,ZR
      COMMON /ANT/XA,YA,ZA,LAMBDA,DAK,DPI
      EQUIVALENCE (P11,P(1,1)),(P12,P(1,2)),(P21,P(2,1))
      EQUIVALENCE (P24,P(2,4)),(P31,P(3,1)),(P34,P(3,4))
      LOGICAL TEST
      DATA TEST/.TRUE./
      IF(TEST) CALL NORMAL(P11,P12,P(1,4),N(1),TEMP)
      TEST=.FALSE.
      ZA2=2.*ZA
      TPI=SNGL(DPI)
      AK=SNGL(DAK)
      CTEMP=(0.,0.)
      DELX=DX
      DG0=DIST(P(1,1),P(1,2))
      IX=DG0/DELX
      IF(IX .LT. 0) IX=-IX
      IF(IX .LT. 1) IX=1
      IX=((IX+1)/2)*2
      DELX=DG0/FLOAT(IX)
      XTA(1)=(P(1,2)-P(1,1))/DG0
      XTA(2)=(P(2,2)-P(2,1))/DG0
      XTA(3)=(P(3,2)-P(3,1))/DG0
      DG0X=XTA(1)*DELX
      DG0Y=XTA(2)*DELX
      DG0Z=XTA(3)*DELX
      DG1=DIST(P(1,1),P(1,4))
      DELZ=DY
      IZ=DG1/DELZ
      IF(IZ .LT. 0) IZ=-IZ
      IF(IZ .LT. 1) IZ=1
      IZ=((IZ+1)/2)*2
      DELZ=DG1/FLOAT(IZ)
      ZTA(1)=(P(1,4)-P(1,1))/DG1
      ZTA(2)=(P(2,4)-P(2,1))/DG1
      ZTA(3)=(P(3,4)-P(3,1))/DG1
      DG1X=ZTA(1)*DELZ
      DG1Y=ZTA(2)*DELZ
      DG1Z=ZTA(3)*DELZ
      DO 1 IXX=1,IX
      FX=FLOAT(IXX)-.5
      XS=P(1,1)+FX*DG0X
      YS=P(2,1)+FX*DG0Y
```

```
ZS=P(3,1)+FX*DG0Z
DO 2 IZZ=1,IZ
FZ=FLOAT(IZZ)-.5
XS=XS+FZ*DG1X
YS=YS+FZ*DG1Y
ZS=ZS+FZ*DG1Z
CC6=XR-XS
CC7=XS-XA
TEMP=YR-YS
TEMP2=ZR-ZS
TEMP3=ZR+ZS
DR1=DBLE(CC6*CC6)+DBLE(TEMP*TEMP)
DR2=DR1+DBLE(TEMP3*TEMP3)
DR1=DR1+DBLE(TEMP2*TEMP2)
R12=DR1
R22=DR2
R10=DSQRT(DR1)
R20=DSQRT(DR2)
R1=R10
R2=R20
TEMP=YS-YA
TEMP2=ZS-ZA
TEMP3=ZS+ZA
DR1=DBLE(CC7*CC7)+DBLE(TEMP*TEMP)
DR2=DR1+DBLE(TEMP3*TEMP3)
DR1=DR1+DBLE(TEMP2*TEMP2)
D12=DR1
D22=DR2
D10=DSQRT(DR1)
D20=DSQRT(DR2)
D1=D10
D2=D20
F10=N2*XS*(YR-YS)+(N1*XS+N3*(ZS-ZA))*(XR-XS)
F20=F10+N3*(XR-XS)*ZA2
COSA=(XTA(1)*CC7+XTA(2)*(YS-YA)+XTA(3)*(ZS-ZA))/D1
COSA1=(XTA(1)*CC7+XTA(2)*(YS-YA)+XTA(3)*(ZS+ZA))/D2
COSG=(XTA(1)*CC6+XTA(2)*(YR-YS)+XTA(3)*(ZR-ZS))/R1
COSG1=(XTA(1)*CC6+XTA(2)*(YR-YS)+XTA(3)*(ZR+ZS))/R2
COSB=(ZTA(1)*CC7+ZTA(2)*(YS-YA)+ZTA(3)*(ZS-ZA))/D1
COSB1=(ZTA(1)*CC7+ZTA(2)*(YS-YA)+ZTA(3)*(ZS+ZA))/D2
COSD=(ZTA(1)*CC6+ZTA(2)*(YR-YS)+ZTA(3)*(ZR-ZS))/R1
COSD1=(ZTA(1)*CC6+ZTA(2)*(YR-YS)+ZTA(3)*(ZR+ZS))/R2
CH=COSA-COSG
CH1=COSA-COSG1
CH2=COSA1-COSG
CH3=COSA1-COSG1
C=COSB-COSD
C1=COSB-COSD1
C2=COSB1-COSD
C3=COSB1-COSD1
D10=D10*DAK
D20=D20*DAK
R10=R10*DAK
```

```
      P20=R20*DAK
      ID=D10/DPI
      D1=D10-DBLE(FLOAT(ID))*DPI
      ID=D20/DPI
      D2=D20-DBLF(FLOAT(ID))*DPI
      ID=R10/DPI
      R1=R10-DBLE(FLOAT(ID))*DPI
      ID=R20/DPI
      R2=R20-DBLE(FLOAT(ID))*DPI
      TEMP=F10*SIN(AK*CH*DELX*.5)*SIN(AK*C*DELZ*.5)/(CH*C*D12*R12)
      CTEMP=CTEMP+TEMP*CEXP(CMPLX(0.,D1+R1))
      TEMP=F10*SIN(AK*CH1*DELX*.5)*SIN(AK*C1*DELZ*.5)/(CH1*C1*D12*R22)
      CTEMP=CTEMP-TEMP*CEXP(CMPLX(0.,D1+R2))
      TEMP=F20*SIN(AK*CH2*DELX*.5)*SIN(AK*C2*DELZ*.5)/(CH2*C2*D22*R12)
      CTEMP=CTEMP-TEMP*CEXP(CMPLX(0.,D2+R1))
      TEMP=F20*SIN(AK*CH3*DELX*.5)*SIN(AK*C3*DELZ*.5)/(CH3*C3*D22*R22)
      CTEMP=CTEMP+TEMP*CEXP(CMPLX(0.,D2+R2))
    2 CONTINUE
    1 CONTINUE
      CTEMP=CTEMP*2./(TPI*TPI)
      ICC=IX*IZ
      RETURN
      END
```

CONSTANTS

0	000000000000	1	000000000000	2	000000000001	3	000000000002

GLOBAL DUMMIES

CTEMP	1341

COMMON

P	/GRND	/+0	N	/GRND	/+14	XR	/REC	/+0	YR	/REC	/+1	ZR	/REC	/+2
XA	/ANT	/+0	YA	/ANT	/+1	ZA	/ANT	/+2	LAMBDA	/ANT	/+3	DAK	/ANT	/+4
DPI	/ANT	/+6	N1	/GRND	/+14	N2	/GRND	/+15	N3	/GRND	/+16	P11	/GRND	/+0
P12	/GRND	/+3	P21	/GRND	/+1	P24	/GRND	/+12	P31	/GRND	/+2	P34	/GRND	/+13

SUBPROGRAMS

NORMAL	SNGL	DIST	D	IFIX	FLOAT	DBLE	DFA.0	DFAM.0	DSQRT	[illegible]	DFD.2	[illegible]	[illegible]	DFS.0
SIN	CEXP	CMPLX	CFM.0	CFD.4										

SCALARS

INTR2	1347	DX	1350	DY	1351	TEST	1352	P11	0
P12	3	TEMP	1353	ZA2	1354	ZA	2	TPI	1355
DPI	6	AK	1356	DAK	4	CTEMP	1341	DELX	1357
DG0	1360	IX	1361	DG0X	1362	DG0Y	1363	DG0Z	1364
DG1	1365	DELZ	1366	IZ	1367	DG1X	1370	DG1Y	1371
DG1Z	1372	IXX	1373	FX	1374	XS	1375	YS	1376
ZS	1377	IZZ	1400	FZ	1401	CC6	1402	XR	0

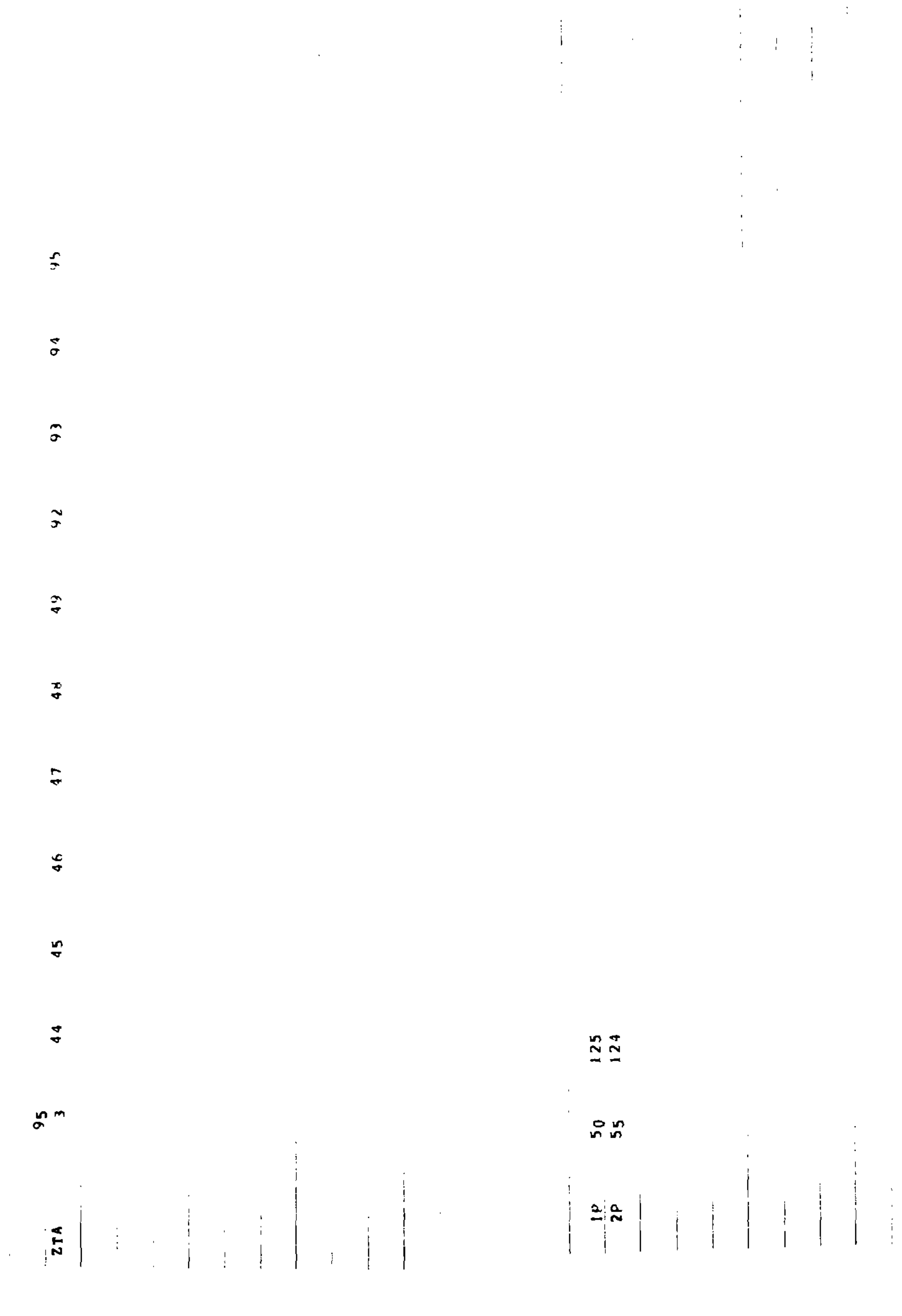
CC7	1403	XA	0	YB	1	TEMP2	1404	ZB	2
TEMP3	1405	DR1	1406	DR2	1410	R12	1412	R22	1413
R10	1414	R20	1416	R1	1420	R2	1421	YA	1
D12	1422	D22	1423	D10	1424	D20	1426	D1	1430
D2	1431	F10	1432	N2	15	N1	14	N3	16
F20	1433	COSA	1434	COSA1	1435	COSG	1436	COSG1	1437
COSB	1440	COSB1	1441	COSD	1442	COSD1	1443	CH	1444
CH1	1445	CH2	1446	CH3	1447	C	1450	C1	1451
C2	1452	C3	1453	ID	1454	ICC	1455	GAMMA	3
P21	1	P24	12	P31	2	P34	13		

ARRAYS

XTA	1456	ZTA	1461	P	0	N	14

A	5									
AK	22	116	118	120	122					
ANT	13									
B	5									
C	100	116								
C1	101	118								
C2	102	120								
C3	103	122								
CC6	60	65	90	91	94	95				
CC7	61	77	88	89	92	93				
CCT	7									
CCX	7									
CCXO	7									
CCY	7									
CEXP	117	119	121	123						
CH	96	116								
CH1	97	118								
CH2	98	120								
CH3	99	122								
CMPLX	117	119	121	123						
COSA	88	96	97							
COSA1	89	98	99							
COSB	92	100	101							
COSB1	93	102	103							
COSD	94	100	102							
COSD1	95	101	103							
COSG	90	96	98							
COSG1	91	97	99							
CTEMP	1	7	23	117	119	121	123	126		
D	25									
D1	84	88	92	109	117	119				
D10	4	82	84	104	108	109				
D12	80	116	118							
D2	85	89	93	111	121	123				
D20	4	83	85	105	110	111				
D22	81	120	122							
DAK	11	13	22	104	105	106	107			
DBLE	65	66	67	77	78	79	109	111	113	115
DELX	24	26	30	34	35	36	116	118	120	122
DELZ	38	39	43	47	48	49	116	118	120	122
DG0	25	26	30	31	32	33				
DG0X	34	52								
DG0Y	35	53								
DG0Z	36	54								
DG1	37	39	43	44	45	46				
DG1X	47	57								
DG1Y	48	58								
DG1Z	49	59								
DIST	25	37								
DPI	11	13	21	108	109	110	111	112	113	114	115
DR1	6	65	66	67	68	70	77	78	79	80	82
DR2	6	66	69	71	78	81	83			
DSQRT	70	71	82	83						

DX	2	24												
DY	2	38												
F10	86	87	116	118										
F20	87	120	122											
FLOAT	30	43	51	56	109	111	113	115						
FX	51	52	53	54										
FZ	56	57	58	59										
GRND	9													
ICC	127													
ID	108	109	110	111	112	113	114	115						
INTR2	1													
IX	26	27	28	29	30	50	127							
IXX	50	51												
IZ	39	40	41	42	43	55	127							
IZZ	55	56												
LAMBDA	8	13												
N	8	9	10	18										
N1	8	10	86											
N2	8	10	86											
N3	8	10	86	87										
NORMAL	18													
P	9	14	15	18	31	32	33	37	44	45	46	52	53	54
P11	14	18												
P12	14	18												
P21	14													
P24	15													
P31	15													
P34	15													
R1	72	90	94	113	117	121								
R10	4	70	72	106	112	113								
R12	68	116	120											
R2	73	91	95	115	119	123								
R20	4	71	73	107	114	115								
R22	69	118	122											
REC	12													
SIN	116	118	120	122										
SNGL	21	22												
TEMP	18	62	65	74	77	116	117	118	119	120	121	122	123	
TEMP2	63	67	75	79										
TEMP3	64	66	76	78										
TEST	16	17	18	19										
TPI	21	126												
XA	13	61												
XR	12	60	86	87										
XS	52	57	60	61	86	87								
XTA	3	31	32	33	34	35	36	88	89	90	91			
YA	13	74	88	89	92	93								
YR	12	62	86	90	91	94	95							
YS	53	58	62	74	86	88	89	90	91	92	93	94	95	
ZA	13	20	75	76	86	88	89	92	93					
ZA2	20	87												
ZR	12	63	64	90	91	94	95							
ZS	54	59	63	64	75	76	86	88	89	90	91	92	93	94


ZTA
95
3
44
45
46
47
48
49
92
93
94
95
1P
2P
50
55
125
124

PROGRAM GLDCDI.F4

```
      DIMENSION ILABL(8)
      DIMENSION IPTDAT(33)
      COMMON /PLXT/ NRP,RXMN,RXMX,RXFT,RXLT,RYMN,RYMX,RYFT,RYLT,
     1RZMN,RZMX,RZFT,RZLT,RTMN,RTMX,RTFT,RTLT,
     2AIMN,AIMX,AIFT,AILT,ARMN,ARMX,ARFT,ARLT,
     3ADIN,ADIX,ADIF,ADIL,
     4ADRN,ADRX,ADRF,ADRL
      EQUIVALENCE (IPTDAT(1),NRP)
      IMPLICIT COMPLEX (C)
      DIMENSION X(20),Y(20),Z(20)
      DIMENSION CF1(20),CF2(20),CF3(20)
      IMPLICIT DOUBLE PRECISION (D)
      COMMON /REC/RX,RY,RZ,RT,NSIZE
      REAL LAMBDA
      COMMON /GROUND/ K,X1(20),Z1(20),X2(0/20),Z2(0/20),IEL
      COMMON /ANT/AX,AY,AZ,LAMBDA,DAK,DPI
      COMMON /VAL/ HR,HI
C
C       THIS VALUE OF TWO PI IS INITIALIZED THIS WAY TO AVOID USING
C BLOCK DATA
      DPI=6.28318530717958647б9
      WRITE(5,2001)
2001  FORMAT(' INPUT FILE NAME:',S)
      READ(5,2000) ILBL
2000  FORMAT(A5)
      CALL IFILE(20,ILBL)
      WRITE(5,2002)
2002  FORMAT(' OUTPUT FILE NAME:',S)
      READ(5,2000) ILBL
      CALL OFILE(1,ILBL)
      WRITE(1) IPTDAT
      READ(20,1000) ILABL,TAU
      WRITE(1,1000) ILABL
      DO 3 I=1,2
      READ(20,1000) ILABL
3     WRITE(1,1000) ILABL
1000  FORMAT(8A5,F)
      READ(20) LAMBDA,NEL,(X(I),Y(I),Z(I),CF1(I),CF2(I),CF3(I),I=1,NEL)
201   READ(20,2005,END=200) RX,RY,RZ,RT,
     1CFR1,CFR2,CFR3,CFS1,CFS2,CFS3
2005  FORMAT(4F,/,6E13.6,/,6E13.6)
C
C       AFTER THE FIELDS HAVE BEEN ACCUMULATED FOR ALL THE ELEMENTS
C THE CDI'S ARE CALCUATED
C       ACDR     CDI FOR THE GROUND SUFACE
C       ACDI     CDI FOR 'IDEAL' GROUND PLANE
      ACDR=857.14*REAL((CFR2-CFR3)/CFR1)
      ACDI=857.14*REAL((CFS2-CFS3)/CFS1)
C
C       NCRP IS THE COUNT OF THE RECEIVERPOINTS
      NRP=NRP+1
      IF(NRP .NE. 1) GO TO 4
C
```

```
C       THIS SECTION INITIALIZES THE MAXIMUM AND MINIMUM VALUES
C OF THE VARIOUS RANGE AND DOMAIN VARIABLES.  THESE ARE
C USED IN THE PLOTTING PROGRAM TO SCALE THE PLOTS.  AFTER THE
C RUN IS FINISHED THEY WILL BE OUTPUT IN PLACE OF THE
C INITIAL DUMMY RECORD
      ADDI=ACDI
      ADDR=ACDR
      T0=RT
      ADIX=ACDI
      ADIN=ACDI
      ADIF=ACDI
      ADRX=ACDR
      ADRN=ACDR
      ADRF=ACDR
      RXFT=RX
      RYFT=RY
      RZFT=RZ
      RTFT=RT
      AIFT=ACDI
      ARFT=ACDR
      RXMN=RX
      RXMX=RX
      RYMN=RY
      RYMX=RY
      RZMN=RZ
      RZMX=RZ
      RTMN=RT
      RTMX=RT
      AIMX=ACDI
      AIMN=ACDI
      ARMX=ACDR
      ARMN=ACDR
C
C       THIS SECTION UPDATES THE MAXIMUM AND MINIMUM VALUES
4     CONTINUE
      RXLT=RX
      RYLT=RY
      RZLT=RZ
      RTLT=RT
      AILT=ACDI
      ARLT=ACDR
      IF(RX .LT. RXMN) RXMN=RX
      IF(RX .GT. RXMX) RXMX=RX
      IF(RY .LT. RYMN) RYMN=RY
      IF(RY .GT. RYMX) RYMX=RY
      IF(RZ .GT. RZMX) RZMX=RZ
      IF(RZ .LT. RZMN) RZMN=RZ
      IF(RT .GT. RTMX) RTMX=RT
      IF(RT .LT. RTMN) RTMN=RT
      IF(ACDI .GT. AIMX) AIMX=ACDI
      IF(ACDI .LT. AIMN) AIMN=ACDI
      IF(ACDR .GT. ARMX) ARMX=ACDR
      IF(ACDR .LT. ARMN) ARMN=ACDR
```

```
      CON=EXP((T0-RT)/TAU)
C
C        THIS  SECTION SIMULATE THE EFFECT OF THE ELECTICAL AND
C MECHANICAL 'INERTIA' OF THE ILS
C RECEIVER SYSTEM FOR DYNAMIC SIMULATION
      T0=RT
      ADDI=CON*(ADDI-ACDI)+ACDI
      ADDR=CON*(ADDR-ACDR)+ACDR
      IF(ADDI .LT. ADIN) ADIN=ADDI
      IF(ADDI .GT. ADIX) ADIX=ADDI
      ADIL=ADDI
      IF(ADDR .LT. ADRN) ADRN=ADDR
      IF(ADDR .GT. ADRX) ADRX=ADDR
      ADRL=ADDR
C
C        THIS IS THE OUTPUT OF THE REAL AND 'IDEAL' , STATIC
C AND DYNAMIC CDI'S WWITH THE RECEIVER COORDINATES
      WRITE(1,2003) RX,RY,RZ,RT,ACDI,ACDR,ADDI,ADDR
 2003 FORMAT(8F)
      GO TO 201
C
C        THIS IS THE TERMINATION SECTION.  THE INITIAL RECORD ON
C THE OUTPUT FILE IS WRITTEN AND THE PROGRAM TERMINATES.
 200  CALL RELEAS (1)
      ENCODE (9,2006,ILABL(1)) ILBL
 2006 FORMAT(A5,'.DAT')
      CALL DEFINE FILE(1,25,I,ILABL(1))
      WRITE(1#1) IPTDAT
      CALL RELEAS (1)
      CALL EXIT
      STOP
      END
```

CONSTANTS

0	203622077325	1	150042055061	2	000000000024	3	000000000061	4	212554433656
5	000000000031								

COMMON

NRP	/PLXT	/+0	RXMN	/PLXT	/+1	RXMX	/PLXT	/+2	RXFT	/PLXT	/+3	RXLT	/PLXT	/+4
RYMN	/PLXT	/+5	RYMX	/PLXT	/+6	RYFT	/PLXT	/+7	RYLT	/PLXT	/+10	RZMN	/PLXT	/+11
RZMX	/PLXT	/+12	RZFT	/PLXT	/+13	RZLT	/PLXT	/+14	RTMN	/PLXT	/+15	RTMX	/PLXT	/+16
RTFT	/PLXT	/+17	RTLT	/PLXT	/+20	AIMN	/PLXT	/+21	AIMX	/PLXT	/+22	AIFT	/PLXT	/+23
AILT	/PLXT	/+24	ARMN	/PLXT	/+25	ARMX	/PLXT	/+26	ARFT	/PLXT	/+27	ARLT	/PLXT	/+30
ADIN	/PLXT	/+31	ADIX	/PLXT	/+32	ADIF	/PLXT	/+33	ADIL	/PLXT	/+34	ADRN	/PLXT	/+35
ADRX	/PLXT	/+36	ADRF	/PLXT	/+37	ADRL	/PLXT	/+40	RX	/REC	/+0	RY	/REC	/+1
RZ	/REC	/+2	RT	/REC	/+3	NSIZE	/REC	/+4	K	/GROUND	/+0	X1	/GROUND	/+1
Z1	/GROUND	/+25	X2	/GROUND	/+51	Z2	/GROUND	/+76	ISL	/GROUND	/+123	AX	/ANT	/+0
AY	/ANT	/+1	AZ	/ANT	/+2	LAMBDA	/ANT	/+3	DAF	/ANT	/+4	DPI	/ANT	/+5
HR	/VAL	/+0	HI	/VAL	/+1	IPTDAT	/PLXT	/+0						

SUBPROGRAMS

FORSE., .JBFF ALPHO. ALPHI. IFILE OFILE BINWR. FLOUT. FLIFT. END. READ CFO.2 EXP CF?.2 REFRAS
VADDR. DEFINE RECNO. RANAC. EXIT

SCALARS

DPI	6	ILBL	567	TAU	570	I	571	LAMBDA	3
NEL	572	RX	0	RY	1	RZ	2	RI	3
CFR1	573	CFR2	575	CFR3	577	CFS1	601	CFS2	603
CFS3	605	ACDR	607	ACDI	610	GRP	0	ADDI	611
ADDR	612	T0	613	ADIX	32	ADIN	31	ADIF	33
ADRX	36	ADRN	35	ADRF	37	RXFT	3	RYFT	7
RZFT	13	RTFT	17	AIFT	23	ARFT	27	RXMN	1
RXMX	2	RYMN	5	RYMX	6	RZMN	11	RZMX	12
RTMN	15	RTMX	16	AIMX	22	AIMN	21	ARMX	26
ARMN	25	RXLT	4	RYLT	10	RZLT	14	RTLT	20
AILT	24	ARLT	30	CON	614	ADIL	34	ADRL	[illegible]
NSIZE	4	K	0	IEL	123	AX	0	AY	1
AZ	2	DAK	4	RR	0	RI	1		

ARRAYS

ILABL	616	IPTDAT	0	X	626	Y	652	Z	676
CF1	722	CF2	772	CF3	1042	X1	1	Z1	25
X2	51	Z2	76						

ACDI	48	59	62	63	64	72	82	83	93	103	104	113	124
ACDR	47	60	65	66	67	73	84	85	94	105	106	114	124
ADDI	59	113	115	116	117	124							
ADDR	60	114	118	119	120	124							
ADIF	3	64											
ADIL	3	117											
ADIN	3	63	115										
ADIX	3	62	116										
ADRF	3	67											
ADRL	3	120											
ADRN	3	66	118										
ADRX	3	65	119										
AIFT	3	72											
AILT	3	93											
AIMN	3	83	104										
AIMX	3	82	103										
ANT	16												
ARFT	3	73											
ARLT	3	94											
ARMN	3	85	106										
ARMX	3	84	105										
AX	16												
AY	16												
AZ	16												
CF1	11	38											
CF2	11	38											
CF3	11	38											
CFR1	39	47											
CFR2	39	47											
CFR3	39	47											
CFS1	39	48											
CFS2	39	48											
CFS3	39	48											
CON	107	113	114										
DAK	16												
DEFINE	133												
DPI	16	21											
EXIT	136												
EXP	107												
GROUND	15												
HI	17												
HR	17												
I	34	38	133										
IEL	15												
IFILE	26												
ILABL	1	32	33	35	36	131	133						
ILBL	24	26	29	30	131								
IPTDAT	2	8	31	134									
K	15												
LAMBDA	14	16	38										
NEL	38												
NRP	3	8	51	52									
NSIZE	13												

OFILE	30											
PLXT	3											
REAL	47	48										
REC	13											
RELEAS	130	135										
RT	13	39	61	71	80	81	92	101	102	107	112	124
RTFT	3	71										
RTLT	3	92										
RTMN	3	80	102									
RTMX	3	81	101									
RX	13	39	68	74	75	89	95	96	124			
RXFT	3	68										
RXLT	3	89										
RXMN	3	74	95									
RXMX	3	75	96									
RY	13	39	69	76	77	90	97	98	124			
RYFT	3	69										
RYLT	3	90										
RYMN	3	76	97									
RYMX	3	77	98									
RZ	13	39	70	78	79	91	99	100	124			
RZFT	3	70										
RZLT	3	91										
RZMN	3	78	100									
RZMX	3	79	99									
TO	61	107	112									
TAU	32	107										
VAL	17											
X	10	38										
X1	15											
X2	15											
Y	10	38										
Z	10	38										
Z1	15											
Z2	15											

3P	34	36			
4P	52	88			
200P	39	130			
201P	39	126			
1000P	32	33	35	36	37
2000P	24	25	29		
2001P	22	23			
2002P	27	28			
2003P	124	125			
2005P	39	41			
2006P	131	132			

PROGRAM GLDPLT.F4

```
      DIMENSION ITYPE(3,2)
      DATA ITYPE/'STATI','C VAL','UES','DYNAM','IC VA','LUES'/
      DATA PID,PRD/'CDID','THEOD'/
      DIMENSION SPACE(4),IAX(2,3)
      DATA SPACE/1.,2.,2.5,5./
      DATA IAX/'DEGRE','ES',' FEET','     ','SECON','DS'/
      DATA PRX,PRY,PRZ,PRT,PAI,PAR/
     1'RX','RY','RZ','RT','CDI','THEO'/
      DIMENSION IPTDAT(33)
      COMMON /PTXXN/NRP,RXMN,RXMX,RXFT,RXLT,RYMN,RYMX,RYFT,RYLT,
     1RZMN,RZMX,RZFT,RZLT,RTMN,RTMX,RTFT,RTLT,
     2AIMN,AIMX,AIFT,AILT,ARMN,ARMX,ARFT,ARLT,
     3ADIN,ADIX,ADIF,ADIL,ADRN,ADRX,ADRF,ADRL
      EQUIVALENCE (IPTDAT(1),NRP)
      DIMENSION ILABL(8)
      DATA XLEN,YLEN,ITIC/20.,8.,21/
      DIMENSION DY1(2000)
      DIMENSION DX(2000),DY(2000)
      NAMELIST /FRED/ YLENG,YDEL,YSC,DMIN,DMAX,DEL,IP,XSC
      CALL PLOTS(IBUF,360,16)
3     WRITE(5,1006)
1006  FORMAT(' INPUT FILE NAME AND AXIS TYPES:',$)
      READ(5,1005) NAME,ISX,ISY,BOUND
1005  FORMAT(A5,I,I,F)
      IF(ISY .LT. 1) GO TO 204
      IF(ISY .GT. 2) GO TO 204
      IF(ISX .LT. 1) GO TO 204
      IF(ISX .GT. 3) GO TO 204
      CALL PLOT(0.,-12.,-3)
      CALL PLOT(0.,1.,-3)
      I=0
      CALL IFILE(20,NAME)
      READ(20) IPTDAT
      WRITE(3,1002) NRP
1002  FORMAT(' THERE ARE',I5,' RECEIVER POINTS.',/)
      WRITE(3,1003)
1003  FORMAT(14X,'MIN',9X,'MAX',9X,'FIRST',8X,'LAST',/)
1004  FORMAT(1X,A5,1X,4F12.4)
      WRITE(3,1004) PRX,RXMN,RXMX,RXFT,RXLT
      WRITE(3,1004) PRY,RYMN,RYMX,RYFT,RYLT
      WRITE(3,1004) PRZ,RZMN,RZMX,RZFT,RZLT
      WRITE(3,1004) PRT,RTMN,RTMX,RTFT,RTLT
      WRITE(3,1004) PAI,AIMN,AIMX,AIFT,AILT
      WRITE(3,1004) PAR,ARMN,ARMX,ARFT,ARLT
      WRITE(3,1004) PID,ADIN,ADIX,ADIF,ADIL
      WRITE(3,1004) PRD,ADRN,ADRX,ADRF,ADRL
      GASU=0.
      GASU=0.
      GACN=0.
      DO 7 II=1,3
      READ(20,100) ILABL
      WRITE(3,101) ILABL
101   FORMAT(1X,8A5)
```

```
100   FORMAT(8A5)
      CALL SYMBOL(0.,0.,.2,ILABL,90.,40)
7     CALL PLOT(.3,0.,-3)
      CALL SYMBOL(0.,0.,.2,ITYPE(1,ISY),90.,15)
      CALL PLOT(2.,0.,-3)
1     READ(20,1000,END=2) X,Y,Z,T,C,R,CD,RD
1000  FORMAT(8F)
      TEMP=SQRT(X*X+Y*Y)
      IF((TEMP .LT. 3500.) .OR. (TEMP .GT. 20720.)) GO TO 60
      GASU=GASU+C
      GASD=GASD+CD
      GACN=GACN+1.
60    CONTINUE
      I=I+1
      GO TO (300,301) ISY
300   CONTINUE
      DY(I)=C
      DY1(I)=R
      GO TO 302
301   DY(I)=CD
      DY1(I)=RD
302   CONTINUE
      GO TO (200,201,202) ISX
200   DX(1)=ATAN2(Z,SQRT(X*X+Y*Y))*57.2953
      GO TO 199
201   DX(I)=X
      GO TO 199
202   DX(I)=T
      GO TO 199
199   IF(I .NE. 1) GO TO 198
      DMIN=DX(I)
      DMAX=DX(I)
198   DMIN=AMIN1(DMIN,DX(I))
      DMAX=AMAX1(DMAX,DX(I))
1001  FORMAT(5X,3F)
      IF( I .LT. 2000) GO TO 1
2     IF(I .LT. 2) GO TO 3
      YLENG=AMAX1(AIMX,ABS(BOUND),-AIMN,6.)
      IF(ABS(BOUND) .LT. 1.E-4) GO TO 10
      YDEL=YLENG
      GO TO 11
10    YLENG=AMAX1(YLENG,ARMX,-ARMN)
      YDEL=FLOAT(IFIX(YLENG/YLEN))
      YLENG=YDEL*YLEN
11    CALL AXIS3(0.,0.,-YLENG,YLENG,YDEL,YLEN,
     1'MICROAMPERES',12,0,0.,YSC)
      IP=IFIX(ALOG10(DMAX-DMIN))-1
      POW=10.**IP
      DO 120 J=1,4
      DEL=SPACE(J)*POW
      IT=IFIX(DMAX/DEL-1.)+1-IFIX(DMIN/DEL)
      IF(IT .LT. ITIC) GO TO 121
120   CONTINUE
```

```
121   DMIN=FLOAT(IFIX(DMIN/DEL))*DEL
      DMAX=FLOAT(IFIX(-.1+DMAX/DEL)+1)*DEL
      IP=-IP+1
      IF(IP .LT. 0) IP=0
      CALL AXIS3(0.,0.,DMAX,DMIN,DEL,-XLEN,IAX(1,ISX),7,IP,0.,XSC)
      CALL PLOT(0.,YLEN/2.,-3)
      CALL PLOT(XLEN,0.,2)
      WRITE(5,FRED)
      CALL PLOT((DX(1)-DMIN)/XSC,DY(1)/YSC,3)
      WRITE(3,1001) DX(1),DY(1),DY1(1)
      GASU=GASU*.7/GACN/150.
      GASD=GASD*.7/GACN/150.
      WRITE(3,1007) GASU,GASD,GACN
1007  FORMAT(' STATIC MEAN ANGLE ERROR=',E,/
     1' DYNAMIC MEAN ANGLE ERROR=',E,10X,'COUNT=',F6.0)
      DO 4 J=2,I
      WRITE(3,1001) DX(J),DY(J),DY1(J)
4     CALL PLOT((DX(J)-DMIN)/XSC,DY(J)/YSC,2)
      IF(BOUND .LT. 0.) GO TO 8
      ISW=2
      CALL PLOT((DX(1)-DMIN)/XSC,DY1(1)/YSC,3)
      DO 6 J=2,I
      CALL PLOT((DX(J)-DMIN)/XSC,DY1(J)/YSC,ISW)
6     ISW=5-ISW
8     CALL PLOT(XLEN+2.,-5.,-3)
      GO TO 3
204   CALL PLOT(3.,0.,999)
      CALL EXIT
      STOP
      END
```

CONSTANTS

0	000000000550	1	000000000020	2	204600000000	3	000000000000	4	201400000000
5	000000000024	6	176631463146	7	207550000000	10	000000000050	11	177463146314
12	000000000017	13	202400000000	14	217503600000	15	214665400000	16	206712271430
17	204400000000	20	163643334272	21	466230351236	22	406332042644	23	426454020100
24	000000000000	25	000000000014	26	175631463146	27	000000000007	30	000000000002
31	000000000003	32	200546314631	33	210454000000	34	203500000000	35	202600000000
36	000000001747								

COMMON

NRP	/PTXXN /+0	RXMN	/PTXXN /+1	RXMX	/PTXXN /+2	RXFT	/PTXXN /+3	RXLT	/PTXXN /+4
RYMN	/PTXXN /+5	RYMX	/PTXXN /+6	RYFT	/PTXXN /+7	RYLT	/PTXXN /+10	RZFT	/PTXXN /+11
RZMX	/PTXXN /+12	RZFT	/PTXXN /+13	RZLT	/PTXXN /+14	RTMN	/PTXXN /+15	RTMX	/PTXXN /+16
RTFT	/PTXXN /+17	RTLT	/PTXXN /+20	AIMN	/PTXXN /+21	AIMX	/PTXXN /+22	AIFT	/PTXXN /+23
AILT	/PTXXN /+24	ARMN	/PTXXN /+25	ARMX	/PTXXN /+26	ARFT	/PTXXN /+27	ARLT	/PTXXN /+30
ADIN	/PTXXN /+31	ADIX	/PTXXN /+32	ADIF	/PTXXN /+33	ADIL	/PTXXN /+34	ADRN	/PTXXN /+35
ADRX	/PTXXN /+36	ADRF	/PTXXN /+37	ADRL	/PTXXN /+40	IPTOAT	/PTXXN /+0		

SUBPROGRAMS

FORSE. .JBFF ALLIO. PLOTS ALPHO. ALPHI. INTO. INTI. FLOUT. FLIFT. PLOT IFILE [illegible] SYMBOL END.
SQRT ATAN2 AMIN1 AMAX1 ABS FLOAT IFIX AXIS3 ALOG10 EXP2.2 [illegible] EXIT

SCALARS

PID	1230	PRD	1231	PRX	1232	PRY	1233	PRZ	1234
PRT	1235	PAI	1236	PAR	1237	XLEN	1240	YLEN	1241
ITIC	1242	YLENG	1243	YDEL	1244	YSC	1245	[illegible]	1246
DMAX	1247	DEL	1250	IP	1251	XSC	1252	[illegible]	1253
NAME	1254	ISX	1255	ISY	1256	[illegible]	1257	I	1260
NRP	0	RXMN	1	RXMX	2	RXFT	3	RXLT	4
RYMN	5	RYMX	6	RYFT	7	RYLT	10	RZMN	11
RZMX	12	RZFT	13	RZLT	14	RTMN	15	RTMX	16
RTFT	17	RTLT	20	AIMN	21	AIMX	22	AIFT	23
AILT	24	ARMN	25	ARMX	26	ARFT	27	ARLT	30
ADIN	31	ADIX	32	ADIF	33	ADIL	34	ADRN	35
ADRX	36	ADRF	37	ADRL	40	GASD	1261	GASG	1262
GACN	1263	II	1264	X	1265	Y	1266	Z	1267
T	1270	C	1271	R	1272	CD	1273	RD	1274
TEMP	1275	POW	1276	J	1277	IT	1300	ISW	1301

ARRAYS

ITYPE	1302	SPACE	1310	IAX	1314	IPTDAT	0	[illegible]	1322
DY1	1332	DX	5252	DY	11172				

ABS	91	92												
ADIF	10	45												
ADIL	10	45												
ADIN	10	45												
ADIX	10	45												
ADRF	10	46												
ADRL	10	46												
ADRN	10	46												
ADRX	10	46												
AIFT	10	43												
AILT	10	43												
AIMN	10	43	91											
AIMX	10	43	91											
ALOG10	100													
AMAX1	87	91	95											
AMIN1	86													
ARFT	10	44												
ARLT	10	44												
ARMN	10	44	95											
ARMX	10	44	95											
ATAN2	77													
AXIS3	98	111												
BOUND	23	91	92	125										
C	59	63	70											
CD	59	64	73											
DEL	19	103	104	107	108	111								
DMAX	19	85	87	100	104	108	111							
DMIN	19	84	86	100	104	107	111	115	124	127	129			
DX	18	77	79	81	84	85	86	87	115	116	123	124	127	129
DY	18	70	73	115	116	123	124							
DY1	17	71	74	116	123	127	129							
EXIT	134													
FLOAT	96	107	108											
FRED	19	114												
GACN	49	65	117	118	119									
GASD	47	64	118	119										
GASU	48	63	117	119										
I	31	67	70	71	73	74	77	79	81	83	84	85	86	87
	89	90	122	128										
IAX	4	6	111											
IBUF	20													
IFILE	32													
IFIX	96	100	104	107	108									
II	50													
ILABL	15	51	52	55										
IP	19	100	101	109	110	111								
IPTDAT	9	14	33											
ISW	126	129	130											
ISX	23	27	28	76	111									
ISY	23	25	26	57	68									
IT	104	105												
ITIC	16	105												
ITYPE	1	2	57											

J	102	103	122	123	124	128	129					
NAME	23	32										
NRP	10	14	34									
PAI	7	43										
PAR	7	44										
PID	3	45										
PLOT	29	30	56	58	112	113	115	124	127	129	131	133
PLOTS	20											
POW	101	103										
PRD	3	46										
PRT	7	42										
PRX	7	39										
PRY	7	40										
PRZ	7	41										
PTXXN	10											
R	59	71										
RD	59	74										
RTFT	10	42										
RTLT	10	42										
RTMN	10	42										
RTMX	10	42										
RXFT	10	39										
RXLT	10	39										
RXMN	10	39										
RXMX	10	39										
RYFT	10	40										
RYLT	10	40										
RYMN	10	40										
RYMX	10	40										
RZFT	10	41										
RZLT	10	41										
RZMN	10	41										
RZMX	10	41										
SPACE	4	5	103									
SQRT	61	77										
SYMBOL	55	57										
T	59	81										
TEMP	61	62										
X	59	61	77	79								
XLEN	16	111	113	131								
XSC	19	111	115	124	127	129						
Y	59	61	77									
YDEL	19	93	96	97	98							
YLEN	16	96	97	98	112							
YLENG	19	91	93	95	96	97	98					
YSC	19	98	115	124	127	129						
Z	59	77										

1P	59	89						
2P	59	90						
3P	21	90	132					
4P	122	124						
6P	128	130						
7P	50	56						
8P	125	131						
10P	92	95						
11P	94	98						
60P	62	66						
100P	51	54						
101P	52	53						
120P	102	106						
121P	105	107						
198P	83	86						
199P	78	80	82	83				
200P	76	77						
201P	76	79						
202P	76	81						
204P	25	26	27	28	133			
300P	68	69						
301P	68	73						
302P	72	75						
1000P	59	60						
1001P	88	116	123					
1002P	34	35						
1003P	36	37						
1004P	38	39	40	41	42	43	44	45	46
1005P	23	24						
1006P	21	22						
1007P	119	120						

```
      SUBROUTINE AXIS3(X0,Y0,AMAX,AMIN,DELA,AINCH,BCD,NCR,NDEC,PWR,DELD)
      DIMENSION BCD(1)
      HT = .10
      DELX=SIGN(DELA,(AMAX-AMIN))
      W1=0.
      W2=0.
      W3 = 0.
      NEXP = 0
      NCH=IABS(NCR)
      IF(PWR.NE.0.) NEXP = 6
      CINCH=ABS(AINCH)
      IF(ABS(AMAX-AMIN)+ABS(DELX).LT.1.E-3) GO TO 50
      IF((AMAX-AMIN)/(DELX+1.E-5).GT.3.*CINCH) DELX = (AMAX-AMIN)/CINCH
      IF(NCR.LT.0) W3 = 1.
      NUM=IFIX((AMAX-AMIN)/DELX+1.9)
      ANC=CINCH/FLOAT(NUM-1)
      IF(AINCH.LT.0.)GO TO 5
      W2=1.
      GO TO 10
    5 W1=1.
   10 CALL PLOT(X0,Y0,3)
      DELD=DELX/10.**PWR/ANC
      ANUM=AMIN-DELX
      X=0.
      Y=0.
      XM=0.
      DO 40 I=1,NUM
      ANUM=ANUM+DELX
      II=0
   25 IF(ABS(ANUM)/10.**II.LT.1.)GO TO 20
      II=II+1
      GO TO 25
   20 IF(ANUM.LT.0.)II=II+1
      IF(ABS(ANUM).LT.1.) II=II+1
      IMORE=NDEC+1
      II=II+IMORE
      IF(IFIX(W1)*I.EQ.1) HT = AMIN1(HT ,ANC/FLOAT(II+2))
      CENTER = FLOAT(II)*HT/(1.+W1)
      OFF = .05
      XC = X - CENTER + W2*(W3*(.30+CENTER) - .15)
      IF(XC.LT.XM)XM=XC
      YC = Y - W1*(HT + .15 - W3*(HT+.3)) - W2*OFF
      CALL PLOT(X0+X,Y0+Y,2)
      CALL PLOT(X0+X+.1*W2,Y0+Y+.1*W1,3)
      CALL PLOT(X0+X-.1*W2,Y0+Y-.1*W1,2)
      CALL NUMBER(X0+XC,Y0+YC,HT,ANUM,0.,NDEC)
      CALL PLOT(X0+X,Y0+Y,3)
      X=X+ANC*W1
      Y=Y+ANC*W2
   40 CONTINUE
      BST = (CINCH - FLOAT(NCH+NEXP)*.12)/2.
      XXC = W1*(X0 + BST) + W2*(X0 + XM - OFF + W3*(2.*CENTER+.44))
      YYC = W1*(Y0 + YC - .17 + W3*(HT + .22) ) + W2*(Y0 + BST)
```

```
      CALL SYMBOL(XXC,YYC,.12,BCD,90.*W2,NCH)
      IF(PWR.EQ.0.) RETURN
      CALL WHERE (XQ,YQ,XXCX)
      CALL SYMBOL(XQ,YQ,.12,5H * 10,90.*W2,5)
      CALL WHERE (XQ,YQ,XXCX)
      X = XQ + (XXC-.08-XQ)*W2
      Y = YQ + (YYC+.08-YQ)*W1
      CALL NUMBER(X,Y,.09,PWR,90.*W2,-1)
      RETURN
   50 DELN = 1.E-3*10.**PWR/CINCH
      N=NCR/5
      WRITE(5,1000) AMAX,AMIN,DELA,PWR,(BCD(I),I=1,N)
 1000 FORMAT(1H0,27HINSUFFICIENT RANGE FOR AXIS ,
     1/,1X,4G,/,1X,13A5)
      CALL EXIT
      RETURN
      END
```

CONSTANTS

0	175631463146	1	167406111564	2	160517426542	3	201746314631	4	000000000003
5	201400000000	6	174631463146	7	177463146314	10	176463146314	11	000000000002
12	000000000000	13	175753412172	14	177702436560	15	176534121727	16	176702436560
17	201244030540	20	000000000000	21	000000000005	22	175507534121	23	175560507534

GLOBAL DUMMIES

XO	656	YO	657	AMAX	660	AMIN	661	DELA	662
AINCH	663	BCD	664	NCR	665	NDEC	666	PWR	667
DELN	670								

SUBPROGRAMS

SIGN IABS ABS IFIX FLOAT PLOT EXP3.2 EXP2.2 AMIN1 NUMBER SYMBOL WHERE ALLIN. ALPHO. ALPHI.
EXIT

SCALARS

AXIS3	673	HT	674	DELX	675	DELA	662	AMAX	660
AMIN	661	W1	676	W2	677	W3	700	DEXP	701
NCH	702	NCR	665	PWR	667	CINCH	703	AINCH	663
NUM	704	ANC	705	XO	656	YO	657	DELN	670
ANUM	706	X	707	Y	710	XN	711	I	712
II	713	IMORE	714	NDEC	666	[illegible]	715	OFF	716
XC	717	YC	720	BST	721	XXC	722	YYC	723
XQ	724	YQ	725	XXCX	726	N	727		

ARRAYS

BCD	664

ABS	11	12	30	34									
AINCH	1	11	17										
AMAX	1	4	12	13	15	65							
AMIN	1	4	12	13	15	23	65						
AMIN1	37												
ANC	16	22	37	48	49								
ANUM	23	28	30	33	34	46							
AXIS3	1												
BCD	1	2	54	65									
BST	51	52	53										
CENTER	38	40	52										
CINCH	11	13	16	51	63								
DELA	1	4	65										
DELN	1	22	63										
DELX	4	12	13	15	22	23	28						
EXIT	68												
FLOAT	16	37	38	51									
HT	3	37	38	42	46	53							
I	27	37	65										
IABS	9												
IFIX	15	37											
II	29	30	31	33	34	36	37	38					
IMORE	35	36											
N	64	65											
NCH	9	51	54										
NCR	1	9	14	64									
NDEC	4	35	46										
NEXP	8	10	51										
NUM	15	16	27										
NUMBER	46	61											
OFF	39	42	52										
PLOT	21	43	44	45	47								
PWR	1	10	22	55	61	63	65						
SIGN	4												
SYMBOL	54	57											
W1	5	20	37	38	42	44	45	48	52	53	60		
W2	6	18	40	42	44	45	49	52	53	54	57	59	61
W3	7	14	40	42	52	53							
WHERE	56	58											
X	24	40	43	44	45	47	48	59	61				
X0	1	21	43	44	45	46	47	52					
XC	40	41	46										
XM	26	41	52										
XQ	56	57	58	59									
XXC	52	54	59										
XXCX	56	58											
Y	25	42	43	44	45	47	49	60	61				
Y0	1	21	43	44	45	46	47	53					
YC	42	46	53										
YQ	56	57	58	60									
YYC	53	54	60										