

AFAL-TR-75-183

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MULTIWALL RADOME ANALYSIS PROGRAM

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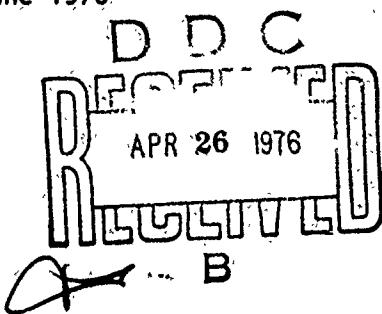
Air-to-Ground Analysis Group  
Reconnaissance and Weapon Delivery Division



February 1976

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Final Report for Period June 1974 to June 1975.



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Abstract continued:

from the geometry program, RADOME, serves as input to the flat-panel program. The flat-panel program then calculates the electrical transmission and reflection parameters of the radome for each ray. These parameters may then be used with a suitable free-space antenna pattern simulation program, and the resultant antenna pattern in the presence of the radome can be computed.

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FOREWORD

The computer program in this report was written for the Air Force Avionics Laboratory's Electronically Agile Radar (EAR) program. The work was performed by personnel from the Air-to-Ground Analysis Group, Mr. Richard M. Reeves, Group Leader, Analysis and Evaluation Branch, Reconnaissance and Weapon Delivery Division. Mr. Robert M. Blumgold was the principal investigator. Special acknowledgment is due Dr. James McDougal of the Air-to-Air Analysis Group, Mrs. Georgeanne Chitwood of the Air-to-Ground Analysis Group, and to Mr. Clyde Hoots of the Brunswick Corp., Marion, Va., for their valuable assistance during this study.

Publication of this report does not constitute Air Force approval of the report findings or conclusions. It is published only for the exchange and stimulation of ideas.

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## LIST OF SYMBOLS

$x_{at}, y_{at}, z_{at}$	Antenna coordinates of point of interest
R	Magnitude of the vector from antenna phase center to point of interest
$\theta_e, \theta_a$	Antenna elevation and azimuth scan angles
$\lambda$	Wavelength
D	Antenna aperture
$x_{ij}, y_{ij}, z_{ij}$	Antenna coordinates of the i, j element, where i and j are the row and column number respectively
$\alpha_{ij}, \beta_{ij}, \gamma_{ij}$	Are the direction cosines from each element to point of interest
$R_{ij}$	Vector from i, j element to point of interest
$x_r, y_r, z_r$	Coordinate system used in defining radome contour
$y_i, z_i$	Coordinates of radome stations
$\Delta YR_i$	y axis location of radome station i relative to the antenna phase center
$\alpha'$	Angle between the antenna phase center to point of interest and the YR axis
$z_{ir}$	Z coordinate of radome station i
$x_a, y_a, z_a$	Antenna coordinate system
$\theta$	Rotation angle about the YR axis
$\theta_I$	Initial rotation angle about the YR axis
$\Delta\theta$	Incremental change in the rotation angle about the YR axis
$x_0, y_0, z_0$	Radome coordinates of the antenna phase center
$\alpha_j, \beta_j, \gamma_j$	Direction cosines of illuminated area of the radome
$x_{\theta j}, y_{\theta j}, z_{\theta j}$	Are the components of the vector from the antenna phase center to the radome surface
$TMAG_{\theta j}$	Magnitude of the vector from the antenna phase center to the illuminated area of the radome

$x_{mn}$ , $y_{mn}$ , $z_{mn}$	Coordinates of array elements
$m$ , $n$	Antenna array element row and column numbers respectively
$\alpha$ , $\beta$ , $\gamma$	Direction cosines for the point of interest relative to the antenna phase center
$\alpha_{ij}$ , $\beta_{ij}$ , $\gamma_{ij}$	Direction cosines of the ray from each element to the illuminated area of the radome
$B_i - B_n$	Least squares fit coefficients for radome contour
$n_R$	Unit normal to radome surface (radome coordinates)
$n_A$	Unit normal to radome surface (antenna coordinates)

SECTION I  
INTRODUCTION

1. GENERAL

This technical report describes a digital computer analysis program which will calculate the electrical transmission and reflection properties of a multiwall radome. The radome program may be used with a suitable antenna program to estimate the effects of the radome on the antenna pattern.

The analysis program is comprised of two programs, a radome-geometry program, RADOME, and a flat-panel analysis program, WAVES2. The radome-geometry program calculates the incidence angle for each ray (a ray represents the radiated RF power from each antenna element) at the radome wall. The output from the geometry program serves as an input to the flat-panel program. The flat-panel program, WAVES2, calculates the electrical transmission and reflection parameters of the radome for each ray, using the input from RADOME. These parameters may then be used with a suitable free-space antenna pattern simulation program, and the resultant antenna pattern in the presence of the radome can then be computed.

This technical report documents the radome-geometry program, RADOME, and the necessary modifications to the flat-panel program, WAVES2. A complete description of the flat-panel program may be found in AFAL-TR-67-191.

## 2. DEFINITION OF THE PROBLEM

The specific problem which generated the radome analysis program involved position fixing accuracy using an aircraft forward-looking multimode radar. For example, a position fix is to be made of a ground target at location "A" (Figure 1). The antenna electrical boresight is steered to the estimated azimuth,  $\theta_a$ , and elevation,  $\theta_e$ , of the target. Then by using the antenna's monopulse patterns, an accurate measurement of the target's location relative to the antenna electrical boresight may be determined. However, due to the distortion of the antenna's free-space pattern in the presence of the radome, an error exists in determining the azimuth and elevation location of the target relative to the steered direction of the antenna electrical boresight. Therefore, to minimize the measurement inaccuracies it is desirable to estimate the antenna pattern in the presence of the radome and use this information to correct the measurement of target location.

A table of correction terms may be generated by using the radome analysis program and a suitable antenna pattern simulation program. A set of azimuth and elevation scan angles can be used as inputs to the geometry program, RADOME, to generate the incidence angles for the ray from each element in the antenna array and the information stored on magnetic tape. The magnetic tape storage is required because of the large number of rays involved and the computation time required. The incidence angle information from RADOME on the magnetic tape is then input to the flat-panel program, WAVES2. In the WAVES2 program the transmission and reflection parameters are calculated for each element in the antenna array for given antenna electrical boresight azimuth and elevation angles. Transmission and reflection parameters calculated by

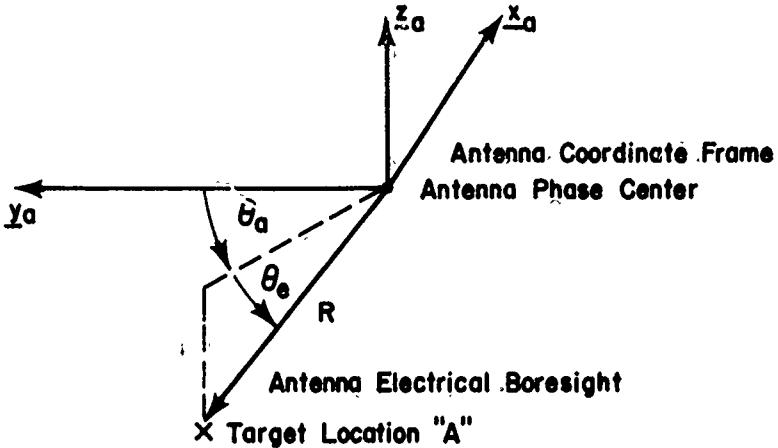


Figure 1. Position Fix

the WAVES2 program can then serve as inputs to a suitable antenna pattern simulation program, and a table of correction terms (i.e., boresight shift) can be generated and subsequently used to correct the measurement of the target's azimuth and elevation location.

### 3. REPORT ORGANIZATION

This technical report is divided into eight sections. Section two describes items included in the documentation, method of analysis, equations involved, geometry, input and output parameters. Section three gives the variables, common, labeled common, dimension, and data statements for the main program and all subroutines. Section four outlines the input deck structure, defines the required data, and establishes the format of the input data cards. Section five presents a sample problem with a typical set of data describing the radome, gives the user's output requirements, lists the printout, and describes the data stored on magnetic tape for later use. Flowcharts and program listings have been included. Section six describes the Flat-Panel Program and Section seven offers recommendations for best utilization of the routine.

SECTION II  
DEVELOPMENT OF THE RADOME-GEOMETRY PROGRAM (RADOME)

1. METHOD

The RADOME program applies the techniques of ray tracing to an antenna array and a multiwall radome, and calculates the incidence angles of antenna radiation at the radome inner surface. The incidence angles are needed to compute reflection and transmission parameters which were accomplished by program WAVES2.

2. DERIVATION OF EQUATIONS

The rectangular coordinates of the point of interest (a point at which the antenna boresight is directed) are computed from the given scan angles of the antenna's electrical boresight. The antenna coordinate system is defined by a unit vector,  $\underline{y}_a$ , normal to the face of the antenna array, a unit vector  $\underline{x}_a$ , which is parallel to the face of the array and at a right angle to  $\underline{y}_a$ , and a unit vector  $\underline{z}_a$ , parallel to the array face and perpendicular to  $\underline{x}_a$  and  $\underline{y}_a$ . The azimuth angle,  $\theta_a$ , is defined in the plane determined by  $\underline{x}_a$  and  $\underline{y}_a$ . The elevation angle  $\theta_e$  is defined in a plane perpendicular to the one formed by  $\underline{x}_a$  and  $\underline{y}_a$ .

The location of the antenna array elements is computed in antenna coordinates, one quadrant of the array at a time. The central elements of the array are spaced one quarter of a wavelength from the phase center of the array. The antenna aperture is assumed to be circular, with the elements arranged in a rectangular grid out to the aperture's edge. The maximum number of rows and columns is specified as a user

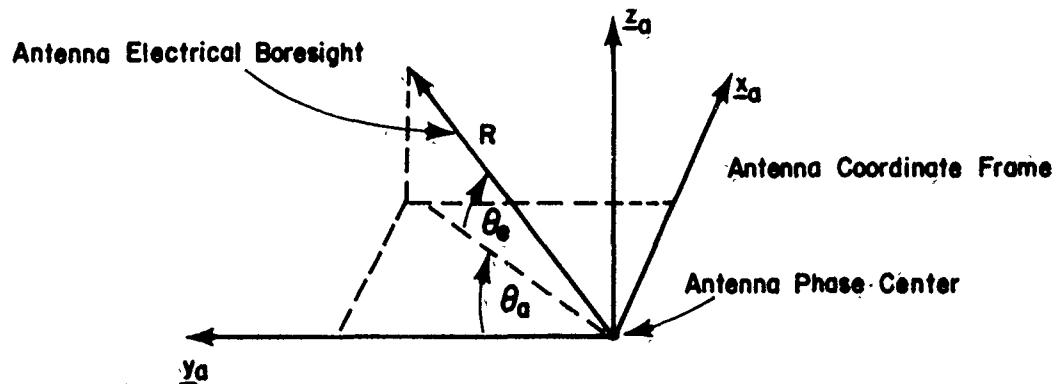


Figure 2. Antenna Scan Angles

Then,

$$x_{at} = R \cos\theta_e \sin\theta_a \quad (1)$$

$$y_{at} = R \cos\theta_e \cos\theta_a \quad (2)$$

$$z_{at} = R \sin\theta_e \quad (3)$$

input. The coordinates of those elements that are contained within a given aperture radius are stored for later use (Figure 3).

The antenna coordinate system is a rectangular coordinate system with its origin at the antenna phase center. In antenna coordinates the location of the  $(i,j)$ -element is denoted by  $x_{ij}, y_{ij}, z_{ij}$ .

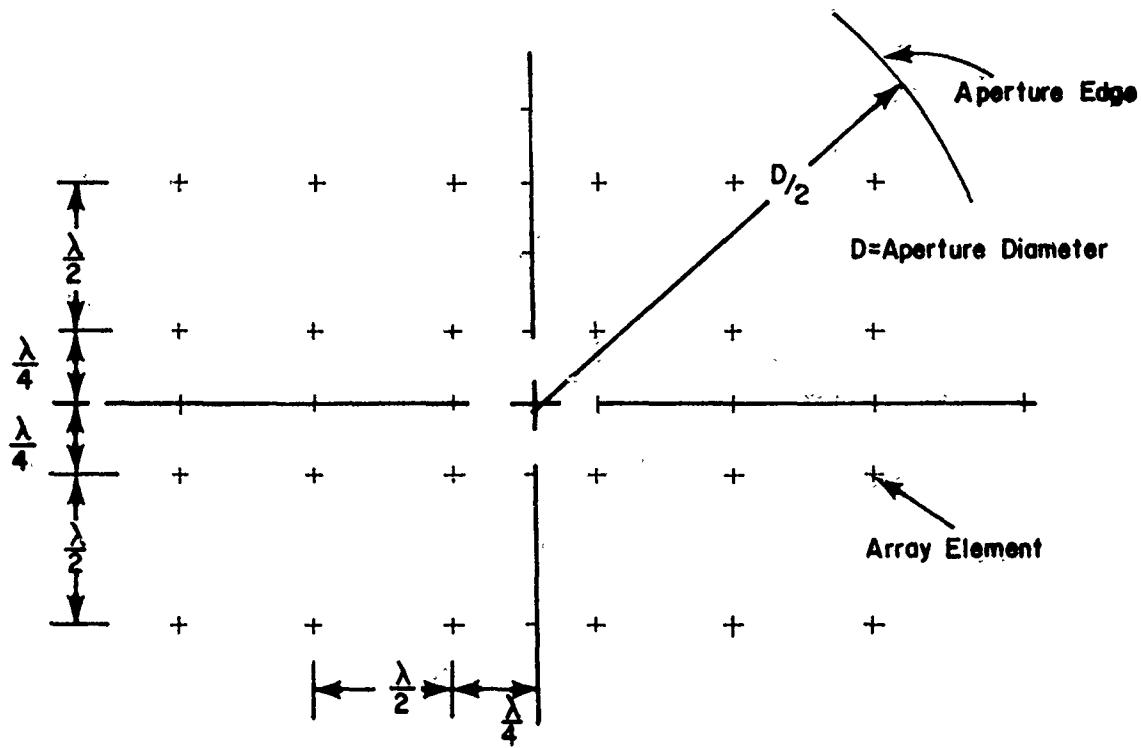


Figure 3. Array Element Geometry

The direction cosines of a ray from array element  $(i,j)$  to the point of interest are determined as follows:

$$\alpha_{ij} = \frac{(x_{at} - x_{ij})}{|R_{ij}|} \quad (4)$$

$$\beta_{ij} = \frac{(y_{at} - y_{ij})}{|R_{ij}|} \quad (5)$$

$$\gamma_{ij} = \frac{(z_{at} - z_{ij})}{|R_{ij}|} \quad (6)$$

where

$$|R_{ij}| = \left[ (x_{at} - x_{ij})^2 + (y_{at} - y_{ij})^2 + (z_{at} - z_{ij})^2 \right]^{1/2} \quad (7)$$

and       $i$  = row number  
 $j$  = column number

The radome is a body of revolution over the complete window area. The radome contour is generated by rotating the curve (Figure 4), representing the outside mold line, about the YR axis. Coordinates of the radome contour  $y_i$  and  $z_i$  are given by the manufacturer in tabular form. Data cards containing the  $y_i$  and  $z_i$  coordinates of points on the radome contour are used as inputs to the computer program. Usually, points are spaced more closely together on the YR axis nearer the front of the radome. The radome axis, YR, and the antenna axis,  $y_a$ , are assumed to be parallel. (Due to program storage limitations it is necessary to store only the coordinates of the radome surface that will encompass the projected surface area of the antenna aperture in the given scan direction.)

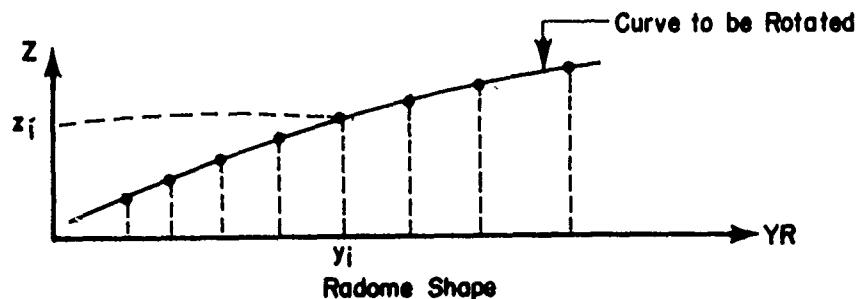


Figure 4. Radome Outside Mold Line Contour

The angle ( $\alpha'$ ) between a ray from the central area of the antenna aperture and the YR axis is used to determine the region where this ray passes through the radome's surface (Figure 5). The angle ( $\alpha'$ ) is determined from the following equations.

$$x = x_{at} - x_{II} \quad (8)$$

$$y = y_{at} - y_{II} \quad (9)$$

$$z = z_{at} - z_{II} \quad (10)$$

$$|R| = [x^2 + y^2 + z^2]^{1/2} \quad (11)$$

$$\alpha' = \cos^{-1} \left[ \frac{y}{|R|} \right] \quad (12)$$

The interval  $\Delta YR_i$  on the YR axis is obtained by subtracting the YR coordinate of the  $i$ th radome contour point from the antenna's phase center location.

$$\Delta YR = Y_a - y_i \quad (13)$$

Beginning with the first point of the radome contour near the tip, points are tried until the quantity  $Z = \Delta YR_i \tan(\alpha')$  is less than the Z coordinate of the  $i$ th radome contour point. Once this point is determined, i.e.,  $(Z_i - Z) > 0$ , the sixty radome contour points that are symmetric about this central point are determined and used to encompass

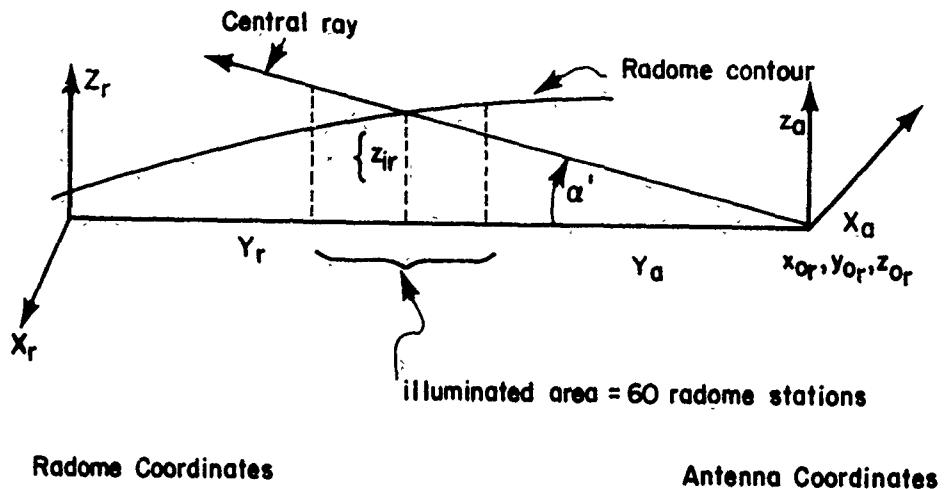


Figure 5. Radome Area Illuminated by the Antenna

the projected area of the antenna aperture. The value of sixty points was chosen from empirical results. If the points are too close to the tip of the radome, then we choose sixty points beginning with the point closest to the radome tip as we progress toward the rear of the radome. Similarly, if the points are too close to the rear, then sixty points are used beginning with the last point and working forward.

The surface region of the radome encompassing the projected area of the antenna aperture in a given scan direction is determined through the use of the following equations (Figure 6).

$$\theta = \theta_I + \Delta\theta \quad (14)$$

where  $\theta_I$  is the initial rotation angle about the YR axis, and  $\Delta\theta$  is the incremental change in the rotation angle

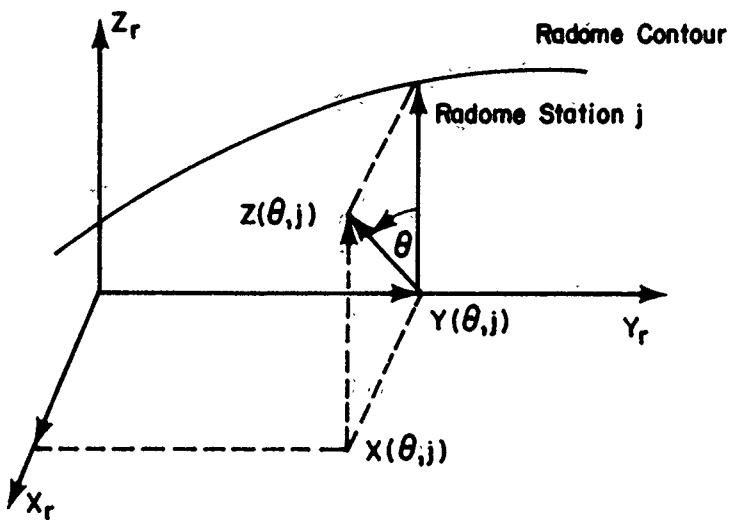


Figure 6. Radome Station Coordinates

The program allows ninety values of  $(\theta)$ . The incremental change ( $\Delta\theta$ ) is a user-supplied input, and a suggested value based on empirical results is two degrees. The initial value of the rotation angle ( $\theta_I$ ), also supplied by the user, is chosen on the basis of  $(\Delta\theta)$  and by program results so that the determined region of the radome encompasses the projected antenna aperture area.

Thus, provision is made for as many as sixty radome surface elements (radially) and by ninety surface elements (rotationally), or 5400 possible surface elements defining the projected aperture area of the antenna on the radome's surface. In general, the projected antenna aperture will occupy less than this number of radome surface elements.

The required surface region of the radome is determined by the following equations:

$$x(\theta, j) = z_j \sin \theta \quad (15)$$

$$y(\theta, j) = y_j \quad (16)$$

$$z(\theta, j) = z_j \cos \theta \quad (17)$$

where

$y_j, z_j$  are the coordinates of the  $j$ th point on the radome contour

The antenna coordinates of the region of interest are determined as follows:

$$x_{\theta j} = -(x(\theta, j) - x_0) \quad (18)$$

$$y_{\theta j} = y_0 - y(\theta, j) \quad (19)$$

$$z_{\theta j} = z(\theta, j) - z_0 \quad (20)$$

where

$x_0, y_0, z_0$  are the radome coordinates of the antenna phase center

The direction cosines of the illuminated area of the radome relative to the antenna phase center are:

$$\alpha_j = \frac{x_{\theta_j}}{TMAG\theta_j} \quad (21)$$

$$\beta_j = \frac{y_{\theta_j}}{TMAG\theta_j} \quad (22)$$

$$\gamma_j = \frac{z_{\theta_j}}{TMAG\theta_j} \quad (23)$$

$$TMAG\theta_j = [x_{\theta_j}^2 + y_{\theta_j}^2 + z_{\theta_j}^2]^{1/2} \quad (24)$$

The antenna elements to the illuminated area direction-cosines are:

$$\alpha_{m,n} = \frac{\Delta x_{m,n}}{|R_{m,n}|} \quad (25)$$

$$\beta_{m,n} = \frac{\Delta y_{m,n}}{|R_{m,n}|} \quad (26)$$

$$\gamma_{m,n} = \frac{\Delta z_{m,n}}{|R_{m,n}|} \quad (27)$$

where

$$\Delta x_{m,n} = x_{\theta_j} - x_{m,n} \quad (28)$$

$$\Delta y_{m,n} = y_{\theta_j} - y_{m,n} \quad (29)$$

$$\Delta z_{m,n} = z_{\theta_j} - z_{m,n} \quad (30)$$

$$R_{m,n} = [(\Delta x_{m,n}^2 + \Delta y_{m,n}^2 + \Delta z_{m,n}^2)]^{1/2} \quad (31)$$

for which

$$x_{\theta_j}, y_{\theta_j}, z_{\theta_j}$$

are the antenna coordinates  
of a subelement of the il-  
luminated area

$$x_{m,n}, y_{m,n}, z_{m,n}$$

are the antenna coordinates  
of each element in the an-  
tenna array

and

$$m, n$$

are the row and column number  
of the antenna elements

The next step is to find the radome subelement intersected by a ray in the boresight direction from each antenna element. For each element in the antenna array, a search of the illuminated area of the radome surface is made, beginning with the first radome station. The direction cosines from the element to the radome surface are compared to those of the central ray. If the direction cosines are within a given tolerance, i.e., the two rays are pointing in approximately the same direction, then this point on the radome surface is used to indicate where the ray passes through the radome. The direction cosine for the angle between the ray from the element to the surface and the central ray is

$$DC = \alpha \alpha_{ij} + \beta \beta_{ij} + \gamma \gamma_{ij} \quad (32)$$

where  $\alpha, \beta, \gamma$  = direction cosines for the central ray, and  
 $\alpha_{ij}, \beta_{ij}, \gamma_{ij}$  = direction cosines of the ray from the element  
to the window area.

The ray is parallel to the antenna electrical boresight when "DC" is equal to one. The tolerance is set to slightly less than one. And, the coordinate of the radome surface that is used is the point where "DC" is greater than the given tolerance.

Next, the normal to the surface of the illuminated area is determined for each coordinate where a ray intersects the radome surface. A least squares curve fitting routine (CURFIT) is used to fit the radome outside mold contour data to a sixth degree polynomial in radome coordinates (Figure 2). A transformation is then made to antenna coordinates, so that

$$f(y) = B_0 + B_1 y + B_2 y^2 + B_3 y^3 + B_4 y^4 + B_5 y^5 + B_6 y^6 \quad (33)$$

An equation in  $x, y, z$  can be found for the surface of the illuminated area of the radome, when given that the radome is a body of revolution (Figure 7). Thus,

$$R = f(y) \quad (34)$$

$$x^2 + z^2 = R^2 \quad (35)$$

$$x^2 + z^2 = f^2(y) \quad (36)$$

$$x^2 + z^2 - f^2(y) = 0 \quad (37)$$

$$F = x^2 + z^2 - f^2(y) \quad (38)$$

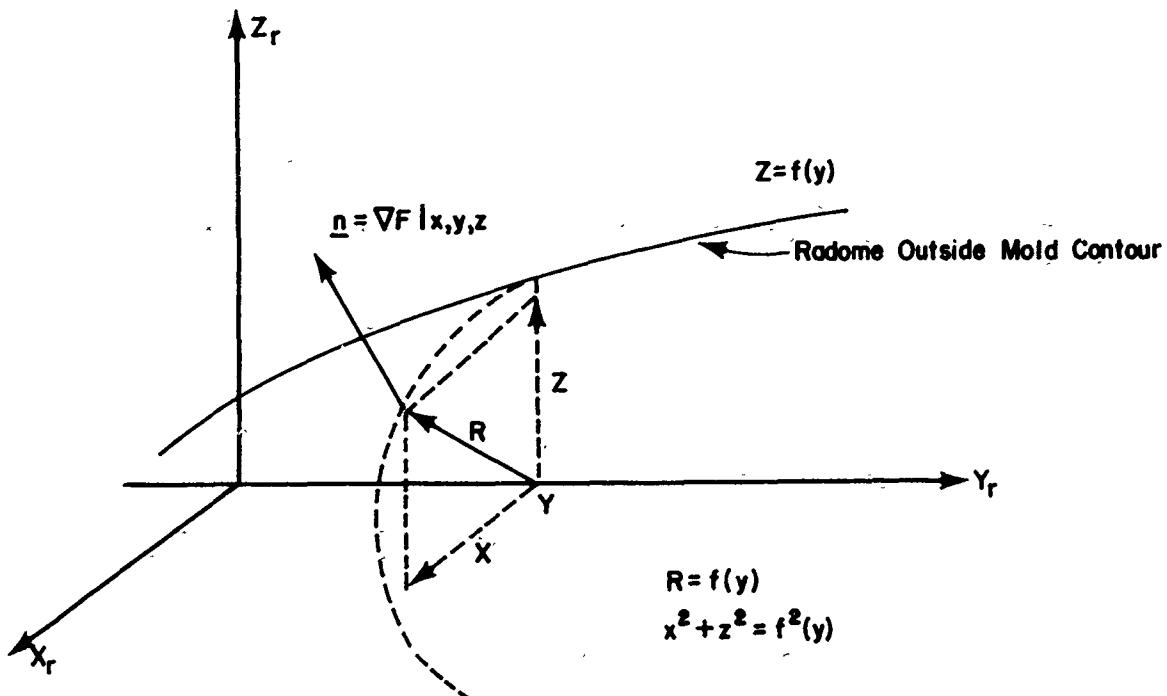


Figure 7. Determination of Normal to Radome Surface

The normal to the surface is given by

$$\underline{N} = \nabla F$$

$$\underline{N} = 2 \times \underline{i} + 2 z \underline{k} - 2 f(y) \left( \frac{df(y)}{dy} \right) \underline{j} \quad (39)$$

where

$$\frac{df(y)}{dy} = B_1 + 2B_2y + 3B_3y^2 + 4B_4y^3 + 5B_5y^4 + 6B_6y^5 \quad (40)$$

To obtain the unit normal, first define

$$\underline{N}^* = 1/2 \underline{N} = x \underline{i} + z \underline{k} - f(y) \frac{df(y)}{dy} \underline{j} \quad (41)$$

$$|\underline{N}^*| = \left\{ x^2 + z^2 + \left[ f(y) \frac{df(y)}{dy} \right]^2 \right\}^{1/2} \quad (42)$$

Then the unit normal, in radome coordinates, is stated by

$$\underline{n}_R = \frac{\underline{N}^*}{|\underline{N}^*|} = \alpha_{iR} \underline{i}_R + \beta_{jR} \underline{j}_R + \gamma_{kR} \underline{k}_R \quad (43)$$

In antenna coordinates, the unit normal is

$$\underline{n}_A = \alpha_{iA} \underline{i}_A + \beta_{jA} \underline{j}_A + \gamma_{kA} \underline{k}_A \quad (44)$$

The incidence angle of the ray from each element to the radome surface is determined by taking the dot product of the unit vector from the array element to the surface, and the normal to the surface at the point of intersection. Thus,

$$x_{ij} = \underline{r}_{ij} \cdot \underline{n}_A \quad (45)$$

$$\theta_{ij} = \cos^{-1}(x_{ij}) \quad (46)$$

where  $r_{ij}$  is the unit vector of the ray from the  $i, j$ , element to the intersection point on the surface

$n_a$  is the unit normal curve at the point of intersection

and  $\theta_{ij}$  is the incidence angle for the ray from an array element.

The sequence of events we have described in this section is programmed in RADOME. The end product is the incidence angle of each ray at the radome surface. This is used in program WAVES2 to calculate reflection and transmission properties of the radome for each ray.

### 3. INPUT

Program I/O (Input/Output) is described in Section III and examples are given in Section V. Briefly, the input consists of the following items:

- a. Number of radome stations
- b. Initial rotation angle, incremental angle, and total number of angles
- c. Antenna elevation and azimuth scan angles
- d. Antenna phase center location in radome coordinates
- e. Number of computer runs to be made
- f. Wavelength
- g. Aperture radius
- h. Maximum number of rows and columns in the antenna array
- i. Radome outside mold station coordinates

4. OUTPUT

Program output is in the form of a tabular printout:

- a. Row and column number for each array element whose ray passes through the radome wall
- b. Incidence angle for each ray
- c. Number of rays passing through the radome wall
- d. Elevation and azimuth scan angles
- e. Number of radome stations
- f. Initial rotation angle, incremental angle, and number of angles
- g. Antenna phase center location in radome coordinates

SECTION III  
GENERAL ANALYSIS PROGRAM DESCRIPTION

1. THE MAIN PROGRAM

The analysis program is written in FORTRAN IV for a CDC 6600 CYBER 74, operating under SCOPE 3.4.1. The main program is primarily an executive routine which calls a series of subroutines. The subroutines are organized into the following functional groups:

1. Antenna element location, ARRAY
2. Element to point of interest direction cosines, DIRET
3. Window area surface coordinates, SFILE
4. Illuminated radome stations, START
5. Element to radome direction cosines, DIRER
6. Normal to window area, NORM
7. Incidence angles, INCID

The Main Program, PROGRAM RADOME (INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE7), is a routine which reads the following input variables:

NSEC, number of radome stations  
ANGI, initial rotation angle  
ANGD, incremental rotation angle  
NANG, number of angular positions  
THEL, elevation scan angle  
THAZ, azimuth scan angle  
COMMON FILE (60,90,3), NSEC,ANGI,ANGD,NANG,AX,AY,AZ

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COMMON/BLK1/TGTX,TGTY,TGTZ

COMMON/BLK3/ABGET(45,45,3)

COMMON/BLK20/SW2

AX,AY,AZ antenna phase center location in radome coordinates

2. SUBROUTINES

a. ARRAY

COMMON/BLK2/EFILE(45,45,3),NUMM,NUMN

COMMON/BLK12/RMAX

COMMON/BLK13/IMAX,JMAX

COMMON/BLK20/SW2

DATA XLAMDA/1.2/

DATA RR/18.0/

NUMM,NUMN - maximum allowable number of rows and columns in  
the antenna array

RMAX - radius of antenna aperture

IMAX,JMAX - actual number of rows and columns in the antenna  
array

XLAMDA - wavelength (inches)

RR - aperture radius (inches)

EFILE - file of element locations

b. DIRET

COMMON/BLK1/TGTX,TGTY,TGTZ

COMMON/BLK2/EFILE(45,45,3),NUMM,NUMN

COMMON/BLK3/ABGET(45,45,3)

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COMMON/BLK12/RMAX

COMMON/BLK13/IMAX,JMAX

TGTX,TGY,TGZ - antenna coordinates of point of interest

NUMM,NUMN - maximum allowable number of rows and columns  
in the array

ABGET - file of array element to point of interest  
direction cosines

RMAX - maximum radius of antenna aperture

IMAX,JMAX - maximum number of rows and columns in the  
array

c. SFILE

COMMON FILE (60,90,3),NSEC,ANGI,ANGD,NANG,AX,AY,AZ

COMMON/BLK4/XY(200),XZ(200)

COMMON/BLK5/NSTART,NFIN

COMMON/BLK20/SW2

DIMENSION FX(90),FY(90),FZ(90)

FILE - file of antenna coordinates of window area

NSEC - number of radome stations

ANGI - initial rotation angle

ANGD - rotation angle increment

NANG - number of incremental angles

AX,AY,AZ - radome coordinates of antenna phase center

XY,XZ - files of radome stations, Y and Z co-  
ordinates

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NSTART,NFIN - beginning and ending window area radome  
station numbers  
SW2 - switch set false after first run  
FX,FY,FZ - radome coordinates of window area

d. START

COMMON FILE (60,90,3),NSEC,ANGI,ANGD,NANG,AX,AY,AZ  
COMMON/BLK2/EFILE(45,45,3),NUMM,NUMN  
COMMON/BLK3/ABGET(45,45,3)  
COMMON/BLK4/XY(200),XZ(200)  
COMMON/BLK5/NSTART,NFIN

FILE - defined in SFILE  
NSEC - "  
ANGI - "  
ANGD - "  
NANG - "  
AX,AY,AZ - "  
XY,XZ - "  
EFILE - defined in ARRAY  
NUMM,NUMN - "  
ABGET - defined in DIRET  
NSTART,NFIN - defined in START

e. DIRET

COMMON FILE (60,90,3),NSEC,ANGI,ANGD,NANG,AX,AY,AZ  
COMMON/BLK2/EFILE(45,45,3),NUMM,NUMN

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```
COMMON/BLK3/ABGET(45,45,3)
COMMON/BLK5/NSTART,NFIN
COMMON/BLK6/IFILE(45,45),JFILE(45,45)
COMMON/BLK8/FILEE(45,45,3)
COMMON/BLK12/RMAX
COMMON/BLK13/IMAX,JMAX
DATA TOL/.99939/
```

FILE	-	defined in SFILE
EFILE	-	defined in ARRAY
NUMM,NUMN	-	defined in ARRAY
ABGET	-	defined in DIRET
NSTART	-	defined in START
NFIN	-	defined in START
IFILE	-	file of radome stations for ray intersections
JFILE	-	file of the number of angular increments for a given radome station ray intersection
FILEE	-	file of direction cosine, for each ray
RMAX	-	defined in ARAY
IMAX	-	defined in ARRAY
JMAX	-	defined in ARRAY
TOL	-	if the direction cosine of the difference in the direction of the point of interest and a particular coordinate of the window area is greater than TOL then this coordinate is used to obtain the point where the ray passes through the radome surface

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f. NORM

COMMON FILE (60,90,3),NSEC,ANGI,ANGD,NANG,AX,AY,AZ

COMMON/BLK2/EFILE(45,45,3),NUMM,NUMN

COMMON/BLK5/NSTART,NFIN

COMMON/BLK6/IFILE(45,45),JFILE(45,45)

COMMON/BLK13/IMAX,JMAX

DIMENSION FILEEN(45,45,3)

EQUIVALENCE (EFILE,FILEN)

COMMON/BLK10/LT

DATA BN/ /

DATA B1/ /

DATA B6/ /

FILE	-	defined in SFILE
NSEC	-	"
ANGI	-	"
ANGD	-	"
NANG	-	"
AX	-	"
AY	-	"
AZ	-	"
NUMM	-	defined in ARRAY
NUMN	-	"
NSTART	-	defined in START

NFIN	-	defined in START
IFILE	-	defined in DIRER
JFILE	-	"

g. INCID

COMMON/BLK2/EFILE(45,45,3),NUMM,NUMN  
COMMON/BLK4/XY(200),XZ(200)  
DIMENSION FILEN(45,45,3)  
EQUIVALENCE(EFILE,FILEN)  
COMMON/BLK8/FILEE(45,45,3)  
COMMON/BLK9/XINCID(45,45)  
COMMON/BLK10/LT  
COMMON/BLK13/IMAX,JMAX

EFILE,NUMM,NUMN	-	defined in ARRAY
XY,XZ	-	defined in SFILE
IFILE,JFILE	-	defined in DIRER
FINEN	-	defined in NORM
EFILE	-	defined in ARRAY
FILEE	-	defined in DIRER
XINCID	-	file of incidence angles for each ray passing through the radome wall
LT	-	defined in NORM
IMAX,JMAX	-	defined in ARRAY
IMAX	-	defined in ARRAY
JMAX	-	defined in ARRAY

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- |       |  |
|-------|--|
| FILEN | - file of normals for ray/radome intersection, for those rays passing through the radome wall (in antenna coordinates) |
| LT    | - used to test the value of IFILE in DIRER   |
| EFILE | - defined in ARRAY   |
| BN    |  |
| B1    |  |
| B2    |  |
| B3    | coefficients of six-degree polynomial fit of radome's outside mold line contour  |
| B4    |  |
| B5    |  |
| B6    |  |

SECTION IV  
MAIN PROGRAM INPUT

The input deck structure is shown in Figure 8.

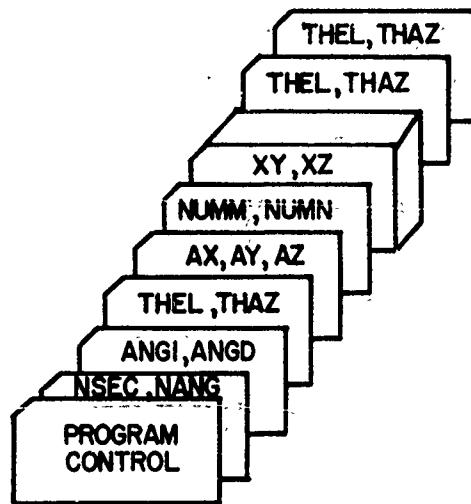


Figure 8. Input Deck Structure

Data Definitions are as follows:

VARIABLE	-	DESCRIPTION	FORMAT
NSEC	-	number of radome stations	2I5
NANG	-	number of circumferential radome divisions	2I5
ANGI	-	initial rotation angle in degrees	2F10.5
ANGD	-	angular increment	
THEL	-	antenna elevation scan angle in degrees	2F10.4
THAZ	-	antenna azimuth scan angle in degrees	
AX,AY,AZ	-	radome coordinates of antenna phase center	3F10.4

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NUMM	- maximum allowable antenna row number	2I2
NUMN	- maximum allowable antenna column number	
XY,XZ	- radome contour coordinates in radome coordinates	2F10.4

SECTION V  
USER'S GUIDE

1. PROGRAM CONTROL

To use the radome analysis program for a given problem, the user must set up the input deck and control cards.

A sample problem is presented in this section. Also shown is how specific sections of that problem are related to the sample input. The printed output of the sample program is included.

The following control card deck structure is presented as a guide to the user. The control card structure is applicable to CDC 6600 CYBER 74 SCOPE 3.4.1.

The radome program has been previously stored on a permanent file. The ATTACH card requests the program. A LABEL card is used to make available a magnetic tape for data storage. The data is first written onto a permanent file that has been requested by a REQUEST card. The source decks are transferred to a program library by the UPDATE card. The program is then compiled (FTN), loaded (LGO), and finally cataloged. The cataloged file is rewound and then copied to magnetic tape (Figure 9a).

On subsequent runs there is a difference in the control cards to allow extending the data on the magnetic tape. The radome program is attached along with the permanent file containing the old data. The

tape label is read and the program transferred to the library file by the UPDATE card. The first set of information on the permanent file is skipped, the program compiled, loaded, and executed. The data on the permanent file is extended, the file rewound, and then the entire file copied onto magnetic tape (Figure 9b).

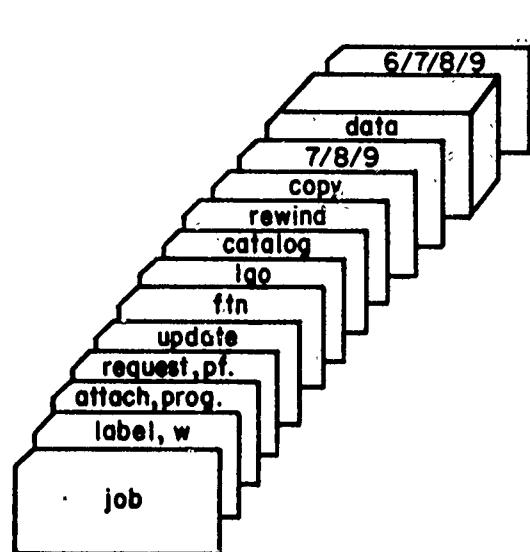


Figure 9a. First Update Deck  
in Program Control

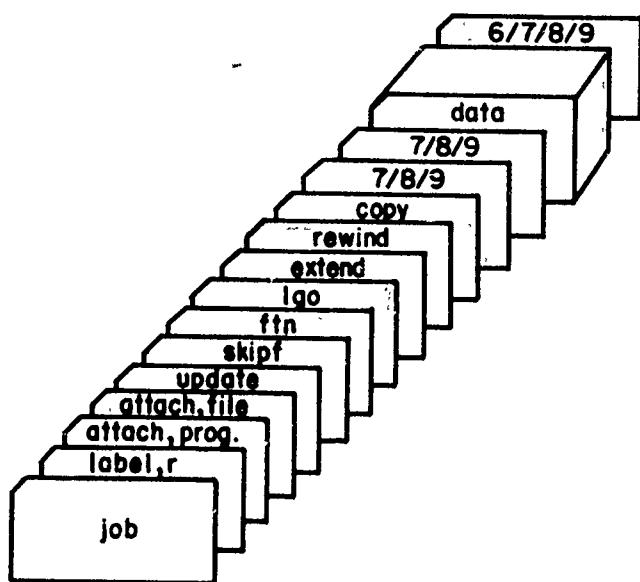


Figure 9b. Second Update Deck  
in Program Control

## 2. SAMPLE PROBLEM

A cut is to be made in the azimuth plane. The first step consists of using the Main Program routine, in which the following variable values are used:

1. Number of radome stations equals 117 (NSEC=117)
2. Initial rotation angle equals 0.0 (ANGI=0.0)
3. Number of angular intervals about radome equals 90 (NANG=90)
4. Angular interval equals -4.0 degrees (ANGD=-4.0)

The number of computer runs, i.e., sets of azimuth and elevation scan angles has been set at 3 (NRUN=3). Elevation, and azimuth scan angles (THEL,THAZ) are inputs, one set per card, three cards per run.

## 3. SAMPLE INPUT

Proceeding to the subroutines, we will have inputs as outlined in the following.

### a. ARRAY

Wavelength of interest in inches, XLAMDA

DATA XLAMDA/1.2/

Maximum aperture radius in inches, RR

DATA RR/18.0/

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Maximum allowable number of rows and columns in the array, respectively (45,45)

NUMM = 45

NUMN = 45

b. SFILE

Coordinates of the radome contour for radome station I=1, 117

XY(1) = Y1

XZ(1) = Z1

XY(117) = Y117

XZ(117) = Z117

c. Data Input Format

Card No.	Variable(s)	Format
1	NSEC,NANG	2I5
2	ANGI,ANGD	2F10.5
3	THEL,THAZ	2F10.5
4	AX,AY,AZ	3F10.4

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5	NUMM,NUMN	2I2
6-122	XY(I),XZ(I)	2F10.4
123	THEL,THAZ	2F10.5
124	THEL,THAZ	2F10.5

- d. The steps given in Section V are shown as flowcharts in Figures 10, 11, and 12. Final printout from our example problem follow the flowcharts.

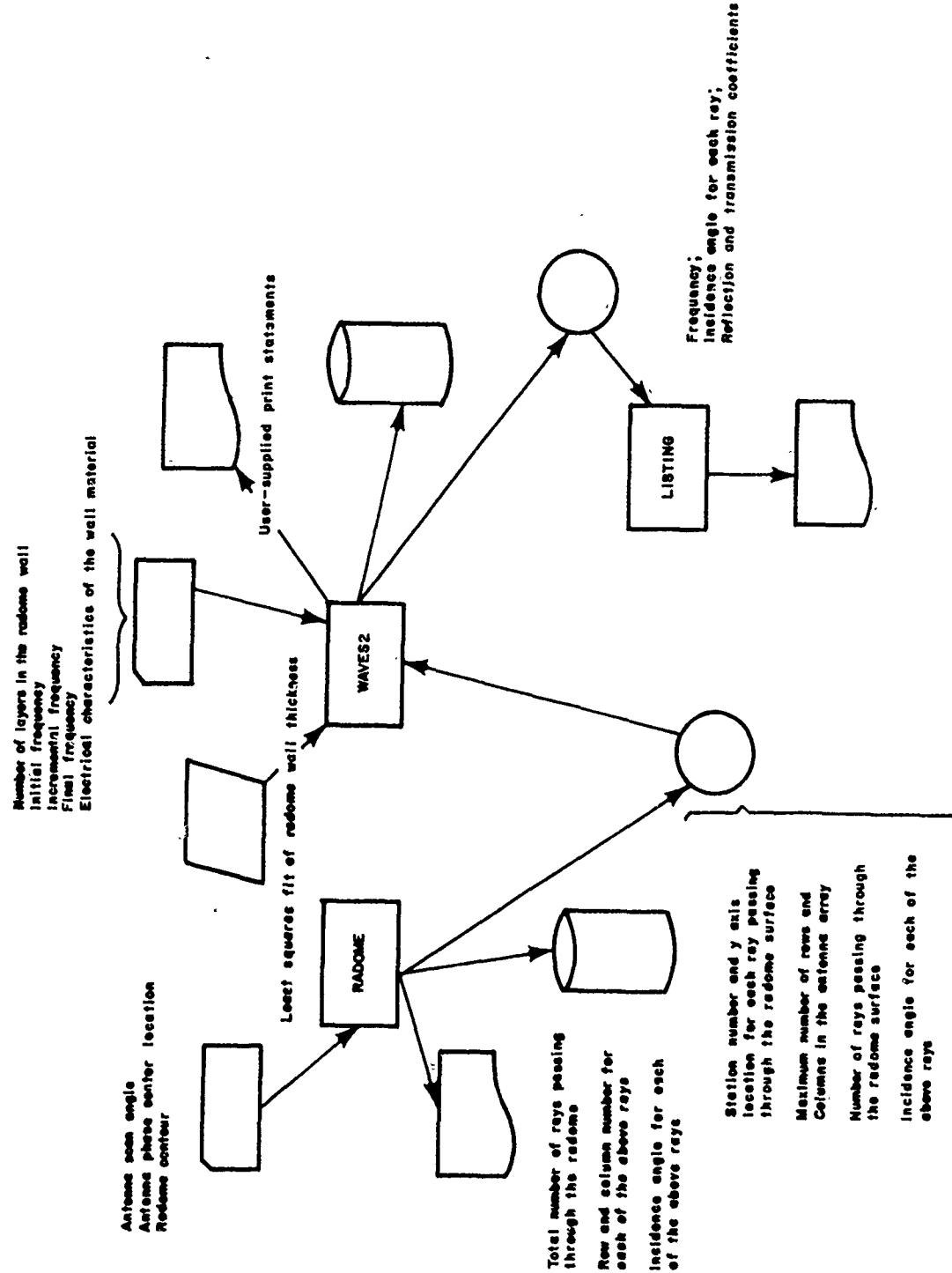


Figure 10. System Flow Chart.

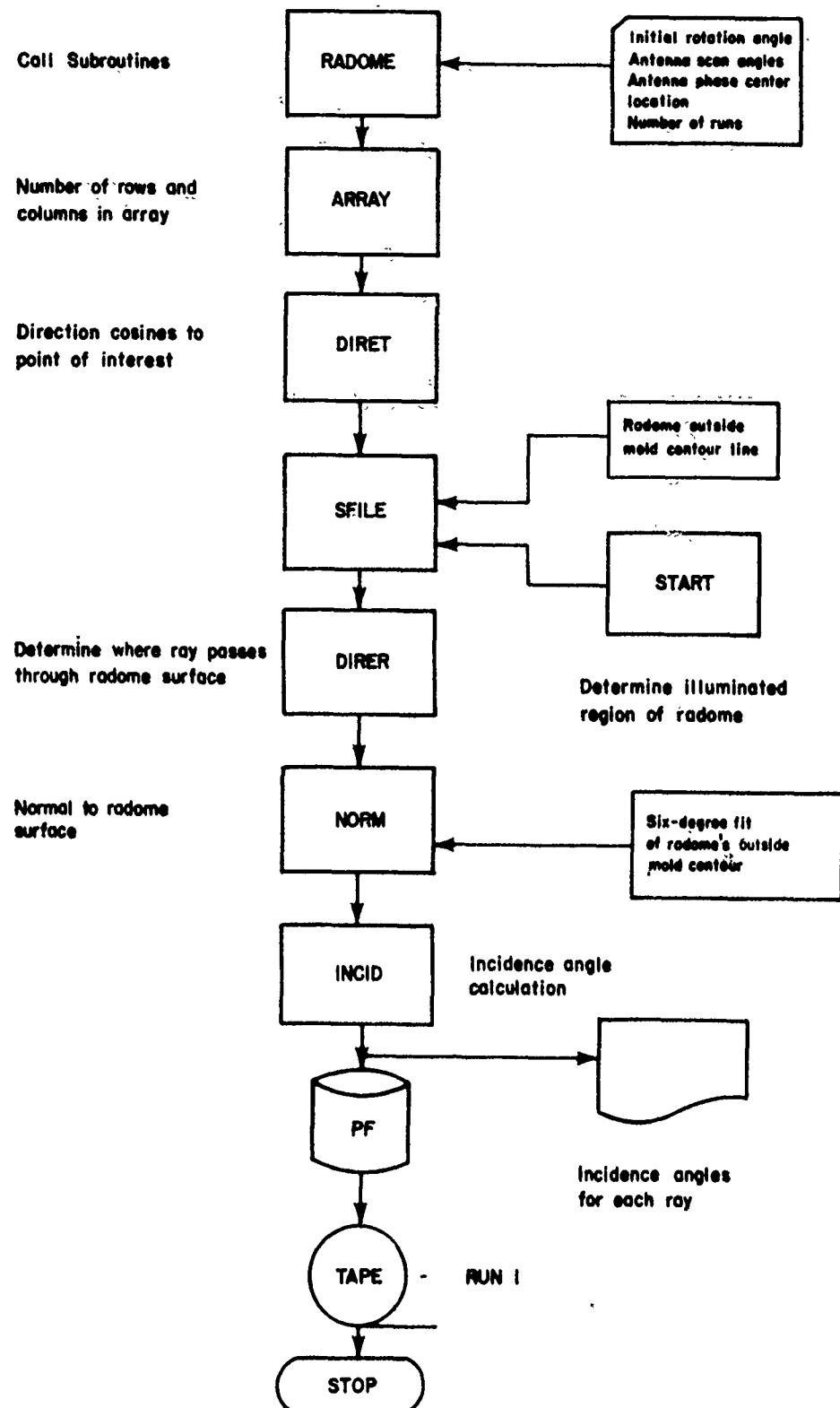


Figure 11. Radome-Geometry Program Flow Chart

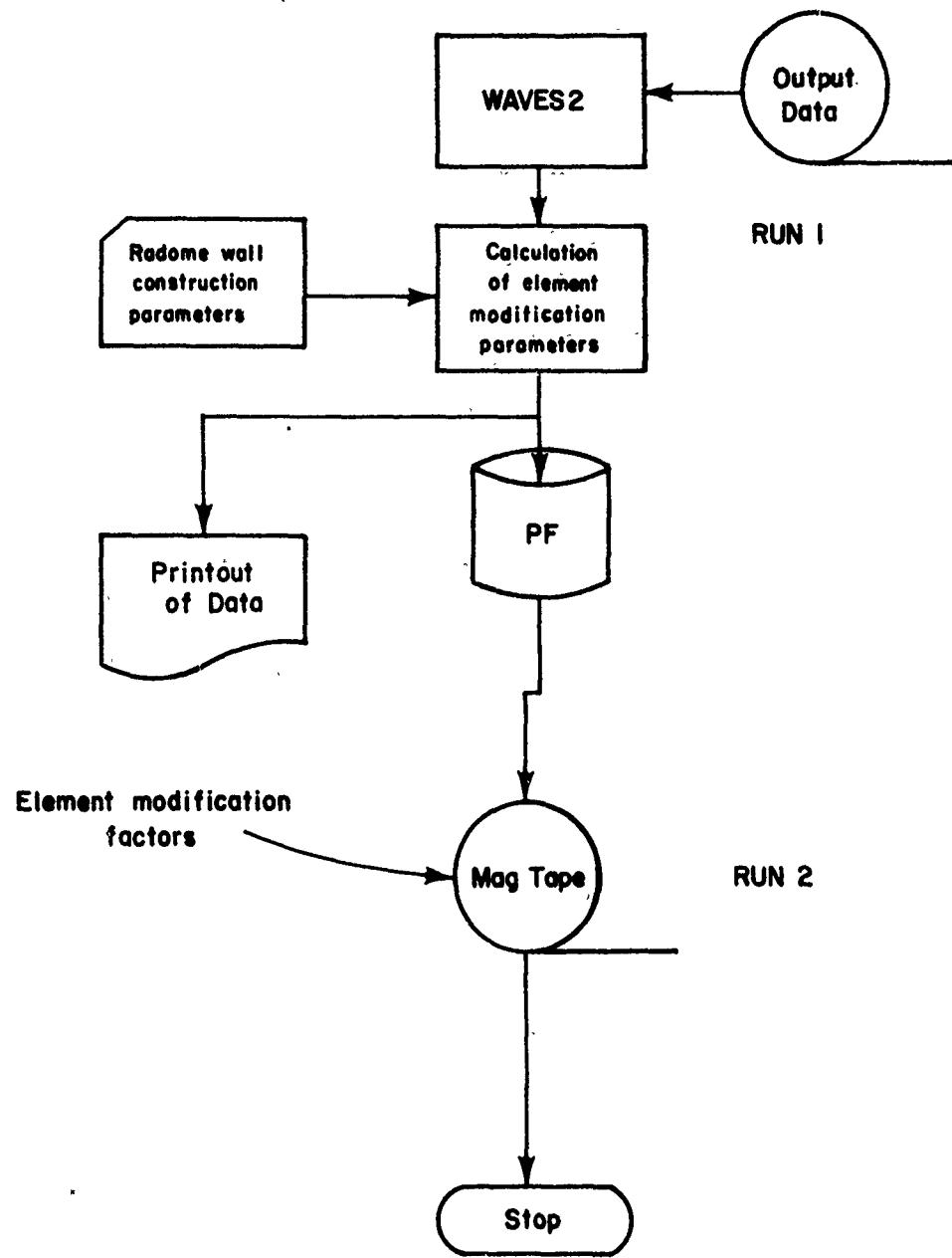


Figure 12. WAVES2 Program Flow Chart

#### SAMPLE OUTPUT

```

      PROGRAM RADOME
      COMMON FILE(I,11,31),HREC,NREC,NREC,I,IGT,TGT,Z
      COMMON/BLK1/T,X,T,Y,TGT,Z,NANG,AZ,AZ,AZ
      COMMON/BLK2/SW2
      C READ INPUT PARAMETERS
      C NSEC=TOTAL NUMBER OF RADOME SECTIONS
      C ANG1=INITIAL ROTATION ANGLE
      C ANG2=INCREMENTAL ANGLE ROTATION
      C NANG=NUMBER OF ANGULAR POSITIONS
      C R=THEL/THAZ ARE TGT RANGE,EL AND AZ ANGLES
      C AX,AZ,AZ ARE THE ANTENNA PHASE CENTER LOCATIONS IN RADOME COORDINATES
      C
      LOGICAL SW2
      NFNU=0
      SW2=.TRUE.
      READ(5,100)NSEC,NANG
      100 FORMAT(2I5)
      READ(5,200)ANG1,ANGD
      200 FORMAT(2F10.2)
      1 CONTINUE
      NRUN=NRUN+1
      READ(5,210)THEL,THAZ
      210 FORMAT(2F10.4)
      R=1.E06
      WRITE(7)THEL,THAZ
      PPRINT(6,13)NSEC,NANG,ANG1,ANGD,R,THEL,THAZ
      130 FORMAT(1HG,*NSEC=*,I3,2X,NANG=*,I3,2X,*ANG1=*,I10-4,2X,
      *THEL=*,F10.4,2X)
      1*THAZ=*,F10.4)
      IF(.NOT.SH2) GO TO 141
      READ(5,101)AX,AZ,AZ
      110 FORMAT(1I10)
      141 CONTINUE
      PPRINT(14,1)AX,*AY,*AZ
      140 FORMAT(15,15)AX,AY,AZ
      PRINT(15,15)AX,AY,AZ
      150 FORMAT(2F10.4)
      C COMPUTE TGT LOCATION IN ANTENNA COORDINATES
      THELR=THEL*(1.14159/180.)
      THAZR=(THEL*13.14159/180.)
      TGTX=R*COS(THELR)*SIN(THAZR)
      TGY=R*COS(THELR)*COS(THAZR)
      TGTZ=R*SIN(THELR)
      PRINT(16,16)TGTX,TGY,TGTZ
      160 FORMAT(1X,*TGTX*,E10.4,*TGY=*,E10.4,*TGTZ=*,E10.4*)
      C INPUT ANTENNA ELEMENT SPACING IN ANTENNA COORDINATES
      CALL ARRAY
      CALL DIRECT
      C SUBROUTINE SFILE GENERATES THE XYZ COORDINATES OF THE SURFACE IN ANT.
      CALL SFILE
      CALL DTREP
      CALL HORN
      CALL INCID
      SW2=.FALSE.
      IF(NRUN.NE.3) GO TO 1
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ROUTINE 120AY  
 COMMON/ALK2/FILE(45,45,3),NUM4,NUMN  
 C140V/ALK12/PMAX  
 COMMON/ALK12/IMAX,JMAX  
 COMMON/BLK20/SW2  
 LOGICAL SW2  
 DATA XLAMDA/1.20/  
 RMAX-RR  
 IF(L-NOT,SW2) GO TO 101  
 READIS,100 NUMM,NUMN  
 100 FORMAT(2I12)  
 101 CONTINUE  
 PRINT16,1101NUMM,NUMN  
 110 FORMAT(1HO,\*NUMM=\*,I2,\*NUMN=\*,I2)  
 PRINT16,800RMAX,XLAMDA  
 800 FORMAT(1HO,\*RMAX=\*,F11.3,\*XLAMDA=\*,F11.5)  
 XX=XLAMDA/4.  
 DO 129 II=2,NUMM,2.  
 IF (XX.GT.RMAX) GO TO 130  
 XX=XX+XLAMDA/2.  
 120 CONTINUE  
 130 IMAX=II-2  
 JMAX=II-2  
 25 600 PRINT(6,600) IMAX,JMAX  
 600 FORMAT(1H0,\*JMAX=\*,I2,\*JMAX=\*,I2)  
 DO 1000 I=1,IMAX  
 DO 1001 J=1,JMAX  
 EFILC(I,J,1)=1000.  
 EFILC(I,J,2)=1000.  
 EFILE(I,J,3)=1000.  
 1001 CONTINUE  
 1000 CONTINUE  
 XX=XLAMDA/4.  
 35 XZ=XLAMDA/4.  
 L=0  
 DO 140 I=2,IMAX,2  
 DO 153 J=2,JMAX,2  
 EFILE(I,J,1)=XX  
 EFILE(I,J,2)=0.0  
 EFILC(I,J,3)=I2  
 X=EFILC(I,J,1)  
 Y=EFILE(I,J,2)  
 Z=EFILE(I,J,3)  
 R=SQR(X\*\*2+Y\*\*2)  
 IF (R.GT.PMAX) GO TO 170  
 XX=XX+(XLAMDA/2.)  
 L=L+1  
 150 CONTINUE  
 170 XX=XZ+(XLAMDA/2.)  
 140 CONTINUE  
 LL=4L  
 PPRINT(6,900) LL  
 PPRINT(6,900) "TOTAL NUMBER OF ELEMENTS = ",LL  
 900 C  
 C JMAX=JMAX-1

```

SUBROUTINE 1824Y    74774   NMT=7          FTN 4.2+180      03/27/75  11:05:38.    PAGE F
      70  700  I=7,J=MAX,2
      D3  210  J=2,J=MAX,2
      EFILE(I,J,1)=FFILE(I,J+1,1)
      EFILE(I,J,2)=0,0
      EFILE(I,J,3)=EFILE(I,J+1,3)
      210  CONTINUE
      C   DO LOWER LEFT QUAD
      JMAX=JMAX+1
      IMAX=IMAX-1
      DO 300  I=1,IMAX,2
      D0  310  J=2,JMAX,2
      EFILE(I,J,1)=EFILE(I+1,J,1)
      EFILE(I,J,2)=0,0
      EFILE(I,J,3)=EFILE(I+1,J,3)
      310  CONTINUE
      300  CONTINUE
      C   DO LOWER RIGHT QUAD.
      JMAX=JMAX-1.
      DO 400  I=1,JMAX,2
      D0  410  J=1,JMAX,2
      EFILE(I,J,1)=EFILE(I,J+1,1)
      EFILE(I,J,2)=0,0
      EFILE(I,J,3)=EFILE(I,J+1,3)
      400  CONTINUE
      400  CONTINUE
      IMAX=IMAX+1
      JMAX=JMAX+1
      DO 500  I=1,IMAX,5
      D0  510  J=1,JMAX,5
      X1=EFILE(I,J,1)
      Z1=EFILE(I,J,3)
      R1=SQR((X1**2+Z1**2)**2)
      IF(R1.GT.RMAX) GO TO 500
      PRINT16,700,I,J,EFILE(I,J,1)*EFILE(I,J,2),EFILE(I,J,3)
      700  FORMAT1H0,I1X,I2+3X,I2+3I,5
      510  CONTINUE
      500  CONTINUE
      RETURN
      END
      101
      102

```

REGISTER ALLOCATION  
1. REGISTERS ASSIGNED OVER THE LOOP BEGINNING AT LINE 28

SUBROUTINE DIRET 74/74 OPT=2

<pre>       SUBROUTINE DIRET       COMMON/BLK1/TGTY, TGZ       COMMON/BLK2/FFL,(45,45,3),NUMM,NUMN       COMMON/BLK3/ABGET(45,45,3)       COMMON/BLK12/RMAX       COMMON/BLK13/JMAX,JMAX       C THIS SUBROUTINE CALCULATES THE DIRECTION COSINES FROM EACH       C ELEMENT TO THE TARGET.       PRINT 130       FORMAT(1X,/1X,* DIRECTION COSINES FROM I,J, ELEMENT TO TGT  */)       10    DO 100 I=1,TMAX       100   DO 110 J=1,JMAX       X=EFILE(I,J,1)       Z=EFILE(I,J,3)       P=SOR(TX**2+TY**2)       IF PR.GT.RMAX) GO TO 100       TX=TGTX-EFILE(I,J,1)       TY=TGTY-EFILE(I,J,2)       TZ=TGZ-EFILE(I,J,3)       XMAG=SQRT(TX**2+TY**2+TZ**2)       ABGET(I,J,1)=TX/XMAG       ABGET(I,J,2)=TY/XMAG       ABGET(I,J,3)=TZ/XMAG       110  CONTINUE       100  CONTINUE       00  300 I=1,JMAX,5       X1=EFILE(I,J,1)       Z1=EFILE(I,J,3)       R1=SOR(TX**2+TY**2)       IF R1.GT.RMAX) GO TO 300       PRINT(16,10) I,J,ABGET(I,J,1),ABGET(I,J,2),ABGET(I,J,3)       120  FORMAT(1X,/1X,* ABGET(*,212,*),*1X,F10.4,3X,F10.4)       100  CONTINUE       300  CONTINUE       RETURN       END   </pre>	<pre>       DIRET    ?       DIRET    3       DIRET    4       DIRET    5       DIRET    6       DIRET    7       DIRET    8       DIRET    9       DIRET   10       DIRET   11       DIRET   12       DIRET   13       DIRET   14       DIRET   15       DIRET   16       DIRET   17       DIRET   18       DIRET   19       DIRET   20       DIRET   21       DIRET   22       DIRET   23       DIRET   24       DIRET   25       DIRET   26       DIRET   27       DIRET   28       DIRET   29       DIRET   30       DIRET   31       DIRET   32       DIRET   33       DIRET   34       DIRET   35       DIRET   36       DIRET   37       DIRET   41       DIRET   42   </pre>
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SUBROUTINE SFILS      PRTN      NPTN      RTN 6.7.0 PRTN      01/7/77/PRTN      11.06.19.      PAGE
      SUBROUTINE SFILS
      FILE(6,20,1)NSEC,ANGI,ANGL,NANG,AX,AY,AZ
      C
      COMMON /LX/XX(1200),XZ(1200)
      COMMON /LK5/NR-1581,NHIN
      COMMON /LK20/SK2
      DIMENSION FX(200),FY(900),FZ(900)

      C READ CONTOUR LINE XYZ
      LOGICAL SW2
      IF (.NOT. SW2) GO TO 101
      DO 10 I=1,NSEC
      READING,110)XY(I),XZ(I)
  110  FORMAT(2E10.4)
  100  CONTINUE
  101  CONTINUE
      102  CONTINUE
      CALL START
      C GENERATE IN RADOME COORDINATES, SURFACE XYZ
      ANGL=ANGI
      L=1
  20   DO 120 I=NSTART,NFIN
      DO 130 J=1,NANG
      ANGL=ANGI*(3.14159/180.)
      FZ(J)=XZ(I)*COS(AMGR)
      FX(J)=XZ(I)*SIN(AMGR)
      FILE(L,I,J)=FX(J)
      FILE(L,I,J+1)=XZ(I)
      FILE(L,I,J+2)=Y(I)
      FILE(L,I,J+3)=FZ(J)
      ANGL=ANGI+ANGL
  130  CONTINUE
      ANGL=ANGI
      L=L+1
  120  CONTINUE
      DO 200 I=1,60,10
      DO 210 J=1,90,10
      PRINT (6,30) FILE(I,J,1),FILE(I,J,2),FILE(I,J,3)
  300  FORMAT(1X,3E10.4)
  200  CONTINUE
  210  CONTINUE
      C TRANSFORM THE DATA TO ANTENNA COORDINATES
      DO 150 I=1,60
      DO 140 J=1,NANG
      FILE(I,J,1)=-(FILE(I,J,1)-AX)
      FILE(I,J,2)=AY(FILE(I,J,2))
      FILE(I,J,3)=FILE(I,J,3)-AZ
  140  CONTINUE
  150  CONTINUE
      PRINT 450          XXYZ OF SURFACE IN ANTENNA COORDINATES
  450  FORMAT(1X,/1X,*      450
      DO 320 I=1,60,5
      DO 310 J=1,90,10
      T1=FILE(I,J,1)
      T2=FILE(I,J,2)
      TMAG=SQR(T1**2+T2**2+TZ**2)
      A=TX/TMAG
      B=TY/TMAG
      G=TZ/TMAG
      PRINT(6,400)FILE(I,J,1),FILE(I,J,2),FILE(I,J,3),A,B,G
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      SFILF 59

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SUBROUTINE SFILE	76774	OPT=2	FTN 4.2+P380	03/27/75	11.06.19.	PAGE
407	FORMAT(IX,3T1R,4,3X,3F17.5)					
510	CONTINUE		SFILE	60		
520	CONTINUE		SFILE	61		
	RETURN		SFILE	62		
63	END		SFILE	66		
			SFILE	67		

REGISTER ALLOCATION:  
3 REGISTERS ASSIGNED OVER THE LOOP BEGINNING AT LINE 40

SUBROUTINE START	74/74	OPT=2	FTN 4.2+P360	03/27/75	11-06-22.	PAGE
C	SUBROUTINE START			START	2	
5	THIS SUBROUTINE DETERMINES THE GENERAL PEGION TO BEGIN THESEARCH			START	3	
	COMMON FILE(5,90,1),NSEG,ANGI,ANGD,NANG,A,X,Y,AZ			START	4	
	COMMON/BLK2/FILE(45,45,3),NUMH,NUMN			START	5	
	COMMON/BLK3/ARGET(45,45,3)			START	6	
	COMMON/BLK4/XW(200,200,X2(200))			START	7	
	COMMON/BLKS/NSTART,NFIN			START	8	
	A=ACOS(ABGET(12,2,2))			START	10	
10	PRINT(16,200)ABGET(12,2,2)			START	11	
200	FORMAT(1H0,*ABGET=*,F11.5)			START	12	
	DO 100 I=1,NSEC			START	13	
	XYX=A,Y-XYC(I)			START	14	
	Z=XYX*TAN(A)			START	15	
	XF(IZ-LT,XZ(I)) GO TO 110			START	16	
15	CONTINUE			START	17	
110	NSTART=1			START	18	
	PRINT(16,210)I			START	19	
210	FORMAT(1H0,*I=*,I3)			START	20	
	DO 130 J=1,30			START	21	
	NSTART=NSTART-1			START	22	
	IF(INSTART.LT.1)GO TO 140			START	23	
20	CONTINUE			START	24	
130	IF(NFIN.LT.NSEC) GO TO 150			START	25	
	NFIN=NSEC			START	26	
25	NSTART=NSEC-59			START	27	
	GO TO 150			START	28	
140	NSTART=NSTART+1			START	29	
	NFIN=NSTART+59			START	30	
30	CONTINUE			START	31	
	PRINT(16,120)NSTART,NFIN			START	32	
	FORMAT(1X/1X,NSTART=*,I3,*NFIN=*,I3)			START	33	
	RETURN			START	34	
	END			START	35	

SUBROUTINE DIFFR	76/74	9P12	FTN 4.2+P390	03/27/75	11.05.74.	PAGE
SPROUTING DIFFR				DIFFR	2	
C				DIFFR	1	
C THIS SUBROUTINE CALCULATES THE DIJECTION COSINES FROM EACH				DIFFR	4	
C FILE IN THE SURFACE AND COMPARES THIS NUMBER TO				DIFFR	5	
C THAT OF THE GIVEN ELEMENT TO THE TGT				DIFFR	6	
C COMMON FILE(I,0..10,3), NSFC, ANG1,ANG2, NANG, X, AY, AZ				DIFFR	7	
C COMMON/BLK2/FILE(45,45,3), NUMH, NUMN				DIFFR	8	
C COMMON/BLK3/ABGET(45,45,3)				DIFFR	9	
C COMMON/BLKS/NSTART, NFIN				DIFFR	10	
C COMMON/BLK5/FILE(45,45,3)				DIFFR	11	
C COMMON/BLK6/FILE(45,45,3)				DIFFR	12	
COMMON /BLK12/RMAX				DIFFR	13	
COMMON /BLK13/JMAX, JMAX				DIFFR	14	
DATA TOL/.99939/				DIFFR	15	
CALL SECONC(1)				DIFFR	16	
PPINIT(6,180) TOL = *.F10.6)				DIFFR	17	
FORMAT(H,* TOL = *.F10.6)				DIFFR	18	
L=0				DIFFR	19	
DO 100 M=1,JMAX				DIFFR	20	
DO 110 N=1,JMAX				DIFFR	21	
X=EFILE(M,N,1)				DIFFR	22	
Z=EFILE(M,N,3)				DIFFR	23	
R=SQRT(X**2+Z**2)				DIFFR	24	
IF(R.GT.RMAX) IFILE(M,N)=1000				DIFFR	25	
IF(R.GT.RMAX) GO TO 110				DIFFR	26	
DO 120 I=1,60				DIFFR	27	
DO 130 J=1,NANG				DIFFR	28	
ESX=FILF(I,J-1)-EFILE(M,N,1)				DIFFR	29	
ESY=FILF(I,J-1)-EFILE(M,N,2)				DIFFR	30	
ESZ=FILF(I,J-1)-EFILE(M,N,3)				DIFFR	31	
XMAGES=ORTI(ESX**2+ESY**2+ESZ**2)				DIFFR	32	
ALPHAE=ESY/XMAGES				DIFFR	33	
BETTA=ESY/XMAGES				DIFFR	34	
SAMMA=ESZ/XMAGES				DIFFR	35	
FILE(M,N,1)=ALPHA				DIFFR	36	
FILE(M,N,2)=BETTA				DIFFR	37	
FILE(M,N,3)=GAMMA				DIFFR	38	
OC=ABGET(M,N,1)*ALPHA+ABGET(M,N,2)*BETTA+ABGET(M,N,3)*GAMMA				DIFFR	39	
IF(OC .LT. TOL ) GO TO 170				DIFFR	40	
II=NSTART+I-1				DIFFR	41	
I=I+1				DIFFR	42	
LL=HOD(I,5)				DIFFR	43	
IF(LL.NE.0)GO TO 500				DIFFR	44	
140 PRINT(6,160) M,N,I,J,DC				DIFFR	45	
160 FORMAT(1HO,*,RAY(*,I2*,*,I2,*)) INTERSECTS SECTION(*,I3,*,*I3,				DIFFR	46	
1*) DC= *.F8.5)				DIFFR	47	
500 IFILF(M,N)=I				DIFFR	48	
JFILE(M,N)=J				DIFFR	49	
GO TO 110				DIFFR	50	
170 CONTINUE				DIFFR	51	
C THIS IS A TEST FOR INTERSECTION WITH THE SURFACE				DIFFR	52	
130 IFILE(M,N)=1000				DIFFR	53	
120 CONTINUE				DIFFR	54	
150 FORMAT(6,150) M,N,I,IL				DIFFR	55	
162 IEN TOL *.F11.5)				DIFFR	56	

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SUBROUTINE	DIREC	76/74	0PT=2	FIN 4.240780	03/27/75	11-06-26.	PAGE
110	CONTINU			DIREC	59		
100	CONTINU			DIREC	60		
	CALL SFCO'01172'			DIREC	51		
	DLT=12-11			DIREC	62		
	POINT*,DELT			DIREC	63		
	RETURN			DIREC	64		
	END			DIREC	65		

09



	SUBROUTINE	NORM	74/74	OPT=2	FTN 4.2+P380	03/27/75	11.06.29	PAGE
63	CONTI4UF	CONTI4UF	110	CONTI4UF				6n
	PRINT 160	PRINT 160	160	FORMAT(IHA),*FILE OF DIRECTION COSINES FOR NORMAL OF EL..M.,N*,/)				NOPH 61
	K1=3							NOPH 62
	DO 150 P/1,IMAX							NOPH 63
	DO 150 N=1,IMAX							NORM 64
	IF I1.ILF(M,N).GT.LT) G9 TO 160							NORM 65
65	K1=K1+1							NORM 66
	K2=MOD(K1,10)							NOPH 67
	IF IX2.GT.0 GO TO 160							NORM 68
	PRINT(6,70)N,M,FILEN(M,N,1)*FILEN(M,N,2)*FILEN(M,N,3)							NORM 69
70	FORMAT(IX,*ELEMENT(I,I2,*,*),T2,*),*,E11.5)		170					NORM 70
	CONTINUE		160					NORM 71
	CONTINUE		150					NOPH 72
	RETURN							NORM 73
	END							NORM 74
								NORM 75
								NORM 76
								NORM 77
								NORM 78
								NORM 79

PAGE

	FORMAT	PAGE
1	SUBROUTINE INCID	74/74
2	COMMON/BLK2/FILE(45,45,3),NUMM,NUMN	INCIO
3	COMMON/BLK4/X1(200)*X2(200)	INCIO
4	COMMON/BLK6/FILE(45,45),FILE(45,45)	INCIO
5	DIMENSION FILE(45,45,3)	INCIO
6	EQUVALENCE (FILE,FILE1)	INCIO
7	COMMON/BLK8/FILE(45,45,3)	INCIO
8	COMMON/BLK9/XINCID(45,45)	INCIO
9	COMMON/BLK10/EL	INCIO
10	COMMON/BLK13/JMAX,JMAX	INCIO
11	C FILEM CONTAINS THE DIR COSINES FOR THE NORMAL OF EA. EL.	INCIO
12	C FILEC CONTAINS THE DIR COSINES FOR THE EL TO RADOME VECTOR	INCIO
13	PRINT 300	INCIO
14	FORMAT (1H0,* INCIDENT ANGLE DIRECTION COSINE AND ANGLE (DEG) *)	INCIO
15	K3=0	INCIO
16	DO 100 M=1,IMAX	INCIO
17	DO 110 N=1,JMAX	INCIO
18	IF(IFILE(M,N).GT.LIXIXINCIO(M,N)).NE.1000..	INCIO
19	IF(IFILE(M,N).LT.1).LT.200	INCIO
20	LIXINCID(M,N)=FILEE(M,N,1)+FILEN(M,N,1)+FILEN(M,N,2)+	INCIO
21	1+FILEE(M,N,3)+FILEN(M,N,3)	INCIO
22	XCGR=ACOS(XINCID(4,M))	INCIO
23	XDEG=XDEGR*(180./3.14159)	INCIO
24	K3=K3+1	INCIO
25	K4=MOD(K3,5)	INCIO
26	IF (K4.GT.0) GO TO 200	INCIO
27	PRINT (6,120) M,N,XINCID(M,N),XDEG	INCIO
28	FORMAT (1H0,*INCID(*I2,*7,*I2,*4,*F11.5,1X,E11.5)	INCIO
29	CONTINUE	INCIO
30	110 CONTINUE	INCIO
31	100 CONTINUE	INCIO
32	PRINT (6,4,0) K3	INCIO
33	400 FORMAT (1H0,*NUMBER OF BISTATIC ANGLES =*,I4)	INCIO
34	WRITE (7) IMAX,JMAX,K3,XINCID,FILE,XY	INCIO
35	RETURN	INCIO
	END	INCIO

SECTION VI  
FLAT-PANEL ANALYSIS PROGRAM (WAVES2)

1. ADAPTING THE RADOME PROGRAM

Thus far, the radome analysis program has been one of geometry, i.e., determining the incidence angles for rays passing through the radome wall; there remains the task of determining how the radome wall modifies the electrical parameters of each ray. To accomplish this, first, a flat-panel analysis program (Krueger, AFAL-TR-67-191, Sep 67) is used to calculate the following:

- Power reflection coefficient
- Electrical angle after reflection
- Insertion loss
- Insertion phase delay

Our original flat-panel program required input via data cards containing incidence angles and material thickness. But, due to the increasing number of rays considered, input via data cards became prohibitive, and modification of the flat-panel program was required. The program was modified to read the required input data from magnetic tape. Such inputs consisted of the following:

- Coefficients of the six-degree polynomial fit of the radome
- The radome's outside mold line contour
- Maximum number of row and column elements in the array
- Incidence angles and their total number
- Radome station number where each ray passes through
- Coordinate of radome surface where each ray passes through the surface

A printout of these inputs follows.

WAVES2 PRINTOUT

REVIEWS

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PAGE 1

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PROGRAM WAVFS2      74/74   OPT=1
      FTN 4.2+P780   03/27/75  16.17.02.

      PROGRAM WAVFS2(INPUT,OUTPUT,I
      1 TAPF9,TAPF10)
      5      S=INPUT,TAPE6=OUTPUT,TAPF6,
      10      COMPLEX X4,K1,K,TE,TM2,PH1,RE,P1,TM1,TE,ZSC,
      15      IMTSC,RTMSC,TMSC,TEZSC,TAN,P1,TAN,P1,R2,R3,R4,AH,AHS,GE,C
      20      MN,CE5,CMS,BE,"M",TEST,QNS,PHIK
      25      COMPLEX A(15),XU(15),K4,M4,GFT,CM1,Y(10),YNAOMSRD(30),ZN
      30      DIMENSION BTA(2025),THETA(2025),D120,(K(120,30),KE(20,30),F(
      35      20,30),
      40      2TEZ(30),TMZ(30),PHI(30),RPA(30),ITE(30),TTH(30),TRSC(30),
      45      2RTMSC(30),RMSC(30),TTMSC(30),TESC(30),E(12,2),AH(2,2),AES(12,2),
      50      JCE(12,2),CM(12,2),CES(2,2),CMS(2,2),BE(2,2),BM(2,2),BES(12,2),BMS(12,2)
      55      4),INT(20),MA(120),K(30),AIS(1242),FSTRIP(30),
      60      DIMENSION XINCID(45,45),
      65      DIMENSION XFILE(45,45),XY(200),T(2025),
      70      IFILE(45,45),
      75      TMEETER CAEXIT
      80      LOGICAL SW1
      85      DATA BN*/3.141592/
      90      DATA BNN*/39076000E+03/
      95      DATA B2*/-23368916E-02/
      100     DATA B3*/-463008203E-04/
      105     SW1=.TRUE.,
      110     CONTINUE
      115     JC=0
      120     CAEXIT=0
      125     IM=CHPLX(0.0,1.0)
      130     READ(I)THEL,THAZ
      135     IF(IEOF(I))NE.0.)CALL EXIT
      140     READ(1)IMAX,JMAX,K3,XINCID,INFILE,XY
      145     WRITE(10)THEL,THAZ
      150     WRITE(10)IMAX,JMAX,K3,XINCID
      155     PRINT(10H,903)THEL,THAZ
      160     903    FORMAT(10H,903)THEL,* ,F10.4,1X,* ,THAZ*,* ,F10.4)
      165     MM=0
      170     JJ=K3
      175     DO 900 900-11=1,IMAX
      180     DO 910 910-J1=1,JMAX
      185     IF(XINCID(I1,J1).GT.999.) GO 10-910
      190     MH=MH+1
      195     GET(MH)=ACOS(XINCID(I1,J1))
      200     BE1,MH=BETA(MH)*(180./3.141591)
      205     T(MH)=XY(CFILE(I1,J1))
      210     CONTINUE
      215     910   CONTINUE
      220     900..  CONTINUE
      225     LCN1=0
      230     621  CGNTINE
      235     LCNT=LCNT+1
      240     IF(JD.EQ.JJ)GO TO 777
      245     IF(.NOT.SW1) GO TO 950
      250     READ(5,500)NL,N$FINC,FIN1,FTIN
      255     CONTINUE
      260     950   CONTINUE
      265     RETA(1)=BETA(LCN1)
      270     MA(1)=0
      275     MA(12)=0
      280     T2=TLCLNT+*2
      285     T3=T(LCN1)+*3
      290     D(1)=(BN+92712+B3*T3)*.001*2.54
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PROGRAM WAVES2    74/74   OPT=1          FTN 4-24P3A0      03/27/75  16.17.02. PAGE
145      2(NJ),K',1,KM1           WAVES2      154
        K(NJ)=KE1           WAVES2      155
        KU(NJ)=KM1           WAVES2      155
29  CONTINUEF           WAVES2      157
        FJJ=F1
27  F1=FJJ+FINC
        IF (F1.GT.FIN)CAEXIT=CAEXIT+1
        OLAM=2.*9776/FJJ
        TEZ(NL+1)=1.
        TMZ(NL+1)=1.
        TEZC(NL+1)=0.
        TMZSC(NL+1)=0.
        PHI(NL+1)=0.
        DO 1 L=1,NB
        THETA(L)=PI*BETA(L)/180.
        DO 2 J=L,NL
        R=REAL(KA(JJ))
        IF(R-MA(JJ).EQ.-1.)GOTO 33
        IF(ER.LT.0.)CALL RLICK(A(J),KU(JJ),D(JJ),OLAM)
33  CONTINUE
        KJJ=KU(JJ)*KA(JJ)
        TMZ(J)=CSORT(K(JJ)-SIN(THETA(L))*SIN(THETA(L))/(
        (KA(JJ)*COS(THETA(L)))+((KA(JJ)*COS(THETA(L)))*
        SIN(THETA(L))-SIN(THETA(L))*SIN(THETA(L))))-OLAM
        PHI(J)=PI*U(JJ)-CSORT(K(JJ)-SIN(THETA(L))*SIN(THETA(L)))
        IF(J.JE.11) GOTO 3
        RIE(J)=TEZ(JJ)-1./JY/(TEZ(JJ)+1.0)
        RIM(J)=(TMZ(JJ)-1./0Y)/(TMZ(JJ)+1.0)
        RTE(J)=EQ(NL)GOTO 51
        RTESSC(JJ)=(TEZSC(JJ)-1.0)/(TEZSC(JJ)+1.0)
        RMSC(JJ)=(TMZSC(JJ)-TMZSC(JJ)-1.0)/(TMZSC(JJ)+1.0)
        GOTO 96
3  CONTINUE
        RTE(J)=(TEZ(JJ)-TEZ(J-1))/(TEZ(JJ)+TEZ(J-1))
        RM(J)=(TMZ(JJ)-TMZ(J-1))/(TMZ(JJ)+TMZ(J-1))
        IF(J.EQ.NL)GOTO 5
        RTESSC(JJ)=(TEZSC(JJ)-TEZSC(JJ-1))/(TEZSC(JJ)+TEZSC(JJ-1))
        RMSC(JJ)=(TMZSC(JJ)-TMZSC(JJ-1))/(TMZSC(JJ)+TMZSC(JJ-1))
        GOTO 96
5  ER=CEXP(-IM*PHI(JJ))
        EP1=CEXP(IM*PHI(JJ))
        TAN=(EP1*EM1)/(EP1*EM1)
        RTE(J)=(TEZSC(JJ)*TAN-TEZSC(JJ-1))/(TEZSC(JJ)*TAN+TEZSC(JJ-1))
        RMSC(JJ)=(TMZSC(JJ)*TAN-TMZSC(JJ-1))/(TMZSC(JJ)*TAN+TMZSC(JJ-1))
        GOTO 96
6  CONTINUE
        TM(J)=RTE(J)+1.0
        RTE(J)=RTE(J)+1.0
        RTESSC(JJ)=(TMZSC(JJ)+RMSC(JJ)+1.0)
        RMSC(JJ)=(TMZSC(JJ)+RMSC(JJ)+1.0)
        GOTO 96
165      S
        ER=CEXP(-IM*PHI(JJ))
        EP1=CEXP(IM*PHI(JJ))
        TAN=(EP1*EM1)/(EP1*EM1)
        RTE(J)=(TEZSC(JJ)*TAN-TEZSC(JJ-1))/(TEZSC(JJ)*TAN+TEZSC(JJ-1))
        RMSC(JJ)=(TMZSC(JJ)*TAN-TMZSC(JJ-1))/(TMZSC(JJ)*TAN+TMZSC(JJ-1))
        GOTO 96
166      6
        CONTINUE
        TM(J)=RTE(J)+1.0
        RTE(J)=RTE(J)+1.0
        RTESSC(JJ)=(TMZSC(JJ)+RMSC(JJ)+1.0)
        RMSC(JJ)=(TMZSC(JJ)+RMSC(JJ)+1.0)
        GOTO 96

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ROUTINE PLC	7/17/74	NOTE	PY: 0.200100	0177775	10.17.4A.	PAGE
SUBROUTINE PLC(K,E,KH,D,O,OLAM)			RLC	2		
COMPLEX KE,KH,IN,ET			RLC	3		
FR=ATMAG(KE)			RLC	4		
R=PCAL (KF)			RLC	5		
D=SEAL (KM)			RLC	6		
G=ATMAG (KM)			RLC	7		
IN=CMPLEX(0.,1.)			RLC	8		
PZ3.14159265			RLC	9		
F=(29977.6/OLAM)/1000.			RLC	10		
A=F/FR			RLC	11		
YI=YBA			RLC	12		
A=(IA*-1.)/A-			RLC	13		
YDEN=..+Q*QA*A			RLC	14		
YR=G/DEN			RLC	15		
YI=G*QA/YDEN			RLC	16		
VI=YI*YI			RLC	17		
Y=CMPLEX(YR,-YI)			RLC	18		
KE=YOLAM/(10*E2*4*E0)			RLC	19		
KH=CHPLX(1.,0,0)			RLC	20		
RETURN			RLC	21		
END			RLC	22		

FTN 4.2+P360 03/27/75 16:17:52. PAGE 1

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SUBROUTINE-INTERP- 7474  OPT=1
      COMPLEX KF1,KM1,C,C1,D,D1
      ERMX=REAL(C1)
      ERMIN=REAL(C1)
      ETMAX=ATMAGC1
      ETMIN=ATMAGC1
      URMX=REAL(B1)
      URMIN=REAL(B1)
      UTMX=ATMAGD1
      UTMIN=ATMAGD1
      IF(ABS(B-B1)>.0815) GO TO 030
      FRAC=(B1-F1)*(B-B1)
      GO TO 31
  30  FRAC=0.0
  31  CONTINUE
  15   ERMED=FRAC*(ERMAX-ERMIN)
        EIRED=FRAC*(EIHAM-EIHM)
        URMED=FRAC*(URMAX-URMIN)
        UIRED=FRAC*(UIHAM-UIHMIN)
        ER=ERMIN+ERMED
        EI=EIHM+EIRED
        UR=URMIN+URMED
        UI=UHMIN+UIRED
        KE1=MPLX(ER,EI)
        KM1=MPMLX(UR,UI)
        RETURN
      END

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SUBROUTINE STRIPS(YLN,F1,NFS)
      NP174          FTN 4.2+P380          03/27/75  10-11-1975

      C--NSETS NUMBER OF DATA SETS INCLUDED WITH THIS RUN
      C   FMIN LOWER FREQUENCY LIMIT IN GHZ.
      C   FMAX UPPER FREQUENCY LIMIT IN GHZ.
      C   DELF FREQUENCY INCREMENT IN GHZ.
      5   DX STRIP SPACING IN CM.
      C   H STRIP WIDTH IN CM.
      C   G-- RELATIVE SHEET CONDUCTANCE IN MH PER SQUARE
      C   TH STRIP THICKNESS IN CM.
      10  C   D2 SPACING BETWEEN CUTS IN CM.
      C   ESUB RELATIVE DIELECTRIC CONSTANT OF SUBSTRATE
      C   TSUB SUBSTRATE THICKNESS IN CM.
      C   GN CUT WIDTH IN CM.
      C   CSC SHUNT CAP ACROSS ZL DUE TO X-POL. DIELECTRIC STRIPS IN PICOFARADS
      15  C   CF CONSTRUCTION FACTOR =0 IF NO ORTHOGONAL ARRAY PRESENT
      C   M3 TERM4,R,T,ZS,REFLC,ZCSC,YL,YLN(30)
      C   COMPLEX FM,FMK,B,SUM1,SUM2,SUM3,SUM4,SUM5,RS,ZL,E,TERM1,TERM2,TERM3
      C   DIMENSION REFLR(190),REFLI(90),FI(30)
      NSETS=1
      NFSET=1
      20  DO 10-NSET=1,NSETS
      READ(5,1) FMIN, FMAX, DELF,DX,H,G,TH,DZ,ESUB,TSUB,GN,CF
      1  FORMAT(8E10.6,/5F10.6,1X,I1)
      1  IF(DELF .GT. 0.0) GO TO 210
      WRITE(6,215)
      205 FORMAT(5H,FREQUENCY INCREMENT MUST BE A POSITIVE REAL NUMBER)
      210 IF (W.GT.0.0.AND.(DX-H).GT.0.0) GO TO 220
      WRITE(6,215)
      215 FORMAT(6H STRIP SPACING MUST BE GREATER THAN STRIP WIDTH AND BOTH
      35  H MUST BE POSITIVE NUMBERS)
      220 IF(WH.GT.0.0) GO TO 230
      WRITE(6,225)
      225 FORMAT(42H STRIP THICKNESS MUST BE A POSITIVE NUMBER)
      40  GO TO 40
      230 FPI=2.-3.14159265
      SIGA= 100.*G/377.*TH
      IF((DZ-GM).GT.0.0.OR.GH.EQ.0.0)GO TO 232
      45  WRITE(6,231)
      231 FORMAT(43H CUT SPACING MUST BE GREATER THAN CUT WIDTH)
      46  GO TO 46
      232 IF(GH1235.237.240
      235 WRITE(6,236)
      236 FORMAT(29H GAP WIDTH CANNOT BE NEGATIVE)
      50  GO TO 40
      237 DZ=-1.0
      C=0.325
      A=W4.0
      CSQ=0.0
      ESUB=1.0
      55  GO TO 245
      240 CALL CSQAE(ESUB,TSUB,DZ,GM,N,DX,ESUBE,CSQ,A,C,TH)

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SUBROUTINE STRIPS      74/74    OPT=1          FTN 4.2+P580    03/27/75   16.17.34.   PAGE
                                                               - - - - -
  245 IF(FCF-.NE.0)A=A/(1.0-0.31*W.)           STRIPS      59
  246 CSS=(CSU1)-1.0)*TSUB/(1.0*FP12)           STRIPS      60
  247 CSC=XWY/(14.6*WY)                         STRIPS      61
  248 WRITE(15,2)FM1N, FMAX, DELF, DX, V,G, TH,DZ, STGHA, GW,CSQ,CSU, TSUR, STRIPS
  249 ZESURE                                         STRIPS      62
  250
  251 FORMAT (120H FREQUENCY SCAN FRC4, F10.3,1.7H GHZ TO, F10.3,21H GHZ IN 1 STRIPS
  252 INCREMENTS OF, F10.3,4H CM, /24H SPACING BETWEEN STRIPS, F10.3,3H CM STRIPS
  253 3,13H STRIP WIDTH=F10.6,3H CM, /23H REL SHEET CONDUCTOR, F10.6,3H CM STRIPS
  254 4,16H MMOS PER SQUARE, / 12H STRIP THICKNESS, F10.6,3H CM, / 13H CUT STRIPS
  255 SPACING=F10.6,3H CM, / TH SIGMA=E12.6,14H MHO PER METER,/
  256 11H GAP WIDTH=F10.6,3H CM/                          STRIPS      63
  257 628H SERIES CAPACITANCE, F10.6,11H PICOFARADS, /36H SHUNT CAPACITANC STRIPS
  258 7E DUE TO SUBSTRATE, F10.6,11H PICOFARADS, 21H SUBSTRATE THICKNESS, F10.6,7 STRIPS
  259 8, F10.6,3H CM, /35H SUBSTRATE REL DIELECTRIC CONSTANT=F10.6,1 STRIPS
  260 931H EFFECTIVE DIELECTRIC CONSTANT=F18.6,1 STRIPS      71
  261 IF (FC .EQ. 0) WRITE(6,5)                         STRIPS      72
  262 IF (FC .EQ. 1) WRITE(6,6)                         STRIPS      73
  263 IF (FC .EQ. 2) WRITE(6,7)                         STRIPS      74
  264
  265 5 FORMAT (13H LAYER CONSTRUCTED WITH NO ORTHOGONAL ARRAY)
  266 6 FORMAT (15H ORTHOGONAL ARRAY IN SAME PLANE AS BASE ARRAY)
  267 7 FORMAT (4SH ORTHOGONAL ARRAY PLACED ON TOP OF BASE ARRAY)
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  269 88
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  271 41 CONTINUE
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  273 42 CONTINUE
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  275 43 CONTINUE
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  277 44 CONTINUE
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PAGE: 116-17-54
ROUTINE: STRIPS    7474   OPT=1
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115      IF(GAU>1.0)HMS=LT-1.0F-6) G    0 1,
          SUM3=SUM3+TCPMS
          GO TO 14
          N3=N-N1
          SUMG=(0.5,0.0)
120      N=N2
          16      N=N+1
          FM=FLOAT(N)
          DFN4=SQR((1.0D0*X*SPHI-FPI2*FN)**2-BDX*BDX)
          TERM4=CMLXTM4,LT,1.0E-6) GO TO 17
          SUM4=SUMA+TER4
          GO TO 16
          N=N-16
          17      NM=N-N2
          SUM52=0.0*(CEXP(CMLXL(0.0,-BETA*A*CPHI)))/(BDX*CPHI)
          FM=(ISUM1+SUM2+SUM3+SUM4+SUM5)
          F=EMPLX(1.0,-SIGNA(FP12*F*0.652E-03))
          FP12=0.0)/(FP12*A*A+BETA*BETA)+FM
          FK=(L,0.0,0)
          BFMK/FM
          81AGCAB5(B)
          P=B/(L(FP12*ATAN2(AIMAG(B),REAL(B)))
          R2H=(360.0/FP12)*ATAN2(AIMAG(R),REAL(R))
          RMAG=CABR
          RDR=-20.0*ALOG10(RMAG)
          T=1.-R
          THAG=CABS(T)
          TPH=(360.0/FP12)*ATAN2(AIMAG(T),REAL(T))
          TDR=-20.0*ALOG10(STHAG)
          145      FLOSS=1.-RMAGRAG-MAG*THAG
          ZS30=FP12*(1.-R)/(R*CPHI)
          XL=AIMAG(ZS)
          X1=XL*4.+C/92
          FLL=XL/FP12*XL
          150      Y0=50.*FP12/XL
          SCR=10.0
          ZC=CMPLX(60.0*FP12/CPHI,0.0)
          ZO=CMPLX(60.0*FP12/CPHI,0.0)
          RL=60.*FP12*DX/(WG)
          RL=RL*DZ(14.,R*CG)
          155      IF (CF-EQ.1) PL=PL*(1.0-0.31*W/DX)
          IF (CF-EQ.2) PL=RL*(1.0-0.592*W/DX)
          IF (IN1,NE.0).OR.(IN2,NE.0) RL=2.0*FLOAT(N1+N2)*RL
          Q=XL/RL
          IF (GW.EQ.0.0)GO TO 260
          XCSQ=1.0E+03/(FP12*FC*CSQ)
          GO TO 265
          260      XCSD=0
          265      IF(CSS-EQ.0.0)IGO TO 270
          ZONE=RLR+(XL*ZC**2*FC*CSS)
          ZL=CMPLXR(LR,XCSQ*XCSS*ZDEN,-XCSQ-XCSS*(RL*RL+XL*XL*XCSS)/ZDEN)
          GO TO 275
          270      ZL=CMPLXR(LR,-XCSQ+XL)
          IF(CF-NE.0) GO TO 100
          REFLC=(ZL-ZOC)/(ZL+ZOC)
          275      IF(CF-NE.0) GO TO 100
          GO TO 170
          170      STRIPS 116
          STRIPS 117
          STRIPS 118
          STRIPS 119
          STRIPS 120
          STRIPS 121
          STRIPS 122
          STRIPS 123
          STRIPS 124
          STRIPS 125
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AFAL-TR-75-183

```

      SUBROUTINE STRIPS      74/74   ONT=1
      FTN' 4.0+P360      01/7775  16.17.54.

      GO TO 101
      100 2GSCMPLX(0.0,-1.0E+3/(FP12*F*GSC*CPH))
      ZL = ZL+2CSC(ZL+CSC)
      REFLC=(ZL-2OC)/(ZL+2OC)
      CONTINUE
      101 REFLC(12F)=REAL(REFLC)*SCR
      REFLC(12F)=AIMAG(REFLC)*SCR
      YL=1.0/ZL
      YLN(NFS)=YL*2OC
      F1(NFS)=F
      NFS=NFS+1
      F=F+DELF
      IF(F.E.E.FMAX) GO TO 41
      IF(F.E.E.NFS-1) GO TO 105
      40 CONTINUE
      RETURN
      END

```

```

PAGE 10
FTN 4.74-2360 03/27/75 18.16.10.

--- SUBROUTINE CSQARE 74/74 OPT=1

      SUBROUTINE CSQARE(ESUB,TSUB,nz,cm,m,ox,esure,csq,rho,c,th)
      INTEGER CFP
      RSQ=M*W/16.0
      H=(DZ+CM)/4.0
      X1=GM/2.0
      5      -12*DT/2.0
      10     C=SQRT((H+HH*X1)+X1*X2-X2*X1)/(H-X1)
            A=(C+SQRT((C+CRS0)*((2.0*H-C)*SQRT((1.0*H+C)*SQR((2.0*H-C)*(2.0*H+C)*((2.0*H+C)*(2.0*H+C)*RSQ)))))/((C-S)*RSQ)
            CRS0=((H-C)*(H+C))/((H+C)*(H+C)+RSQ))
            A2=C*SQR((((H-C)*(H+C))-A*(H+C))/((H+C)*(H+C)))/((1.0-A))
            T=X2/2C
            F=(ABS(T-1.0)*LT-1.1E-6)*GO TO 2C
            H=H**T
            GO TO 10
            15    20   F=C*(1.0+A)/(1.0-A)
            X1C=F*SORT((FF+H*H*C*C)
            PHI=ALG(A)
            20   -(ESUB-1.0)/(ESUB+1.0)
            RS=B*B
            25   -B*B*5*(1.0-B)*PHI
            PHN=(1.0-B)*PH1
            PHO=M/6.0
            XX2=2.0*H*C
            XX3=2.0*H-C
            25   X1S=XX*X2
            X2S=XX*X3
            Z=2.0*TSUB+RHO
            30   ZS=Z*Z
            P1=SORT(ZS+C*C)
            P2=SORT(ZS*X2S)
            R3=SORT(ZS*X3S)
            PHP=BN*ALOG((R1+C)*(XX3+R3)/(R1-C)*(XX2+R2))+PHN
            UPHN/PHP
            PHN=PHP
            IF(TABS(U-1.0).LT.1.0E-6)GO TO 40
            35   BN=BN*BS
            Z=2+2.0*TSUB
            GO TO 39
            40   45   ESUBE=PH1/PHN
            RE0(5,1)CFP
            1 FORMAT(12)
            45   -IF(CFP.FT.1)GO TO 45
            -ESUE=2.0*ESUE-1.0
            PHN=PH1/ESUBE
            CSQ=(DZ*C)/(0.90*D*EPUN)
            CSQ=CSQ+.085*WOTHGN
            50   CONTINUE
            END

```

### 3. THE LISTING PROGRAM

The "listing" program will read the magnetic tape containing the flat-panel program outputs, and print out the electrical parameters required for each array element. The program list consists of the following for a given antenna array row or column:

- (I,J) - array row and column numbers, respectively
- - incidence angle in degrees
- RTE - reflection loss in dB for vertical polarization (power)
- ANGLE - electrical angle after reflection
- TTT - transmission loss for vertical polarization in dB (power)
- Angle - insertion phase delay (Deg)
- RTM - reflection loss for horizontal polarization dB (power)
- ANGLE - phase angle in electrical degrees after reflection
- TTM - insertion loss for horizontal polarization in dB (power)
- ANGLE - insertion phase delay in electrical degrees for horizontal polarization

#### a. WAVES2 INPUTS

The required data cards are:

1. Input magnetic tape from flat-panel program
2. One data card, on which will be entered:

In column 5: 1 = row output

2 = column output

and in columns 9 and 10: array row or column desired

Final printout of the array element modification parameters follows.

b. WAVES2 OUTPUT :-

PROGRAM MATN 7177, NR 1

RTN 4.70140 04/15/76 07.15.27. PAGE

```
PROGRAM MAIN(INPUT,OUTPUT,TAPES=INPUT,TAPE6=OUTPUT,TAPER)
C
DIMENSION XINC(10)(45,45)
1.2 IN COL 5 = ROW, COL AND 3 AND 10 ARE ROW OR COL NUM.
PCANIS,SGIS)KOP,NUM
PRINT(6,*10)
      5
      90
READ(5,*,ITHEL,THAZ
IF EOF(5,NE=0,)CALL EXIT
PRINT(6,*01THEL,THAZ
RECD(5)IRAX,JMAX,KJ,XINCIO
PRINT(6,*01IMAX,JMAX,K3
PRINT(6,*640)
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THEL=0.0000 THAZ=-5.0000

NL=1F-ROKS=49 NUM OF COLS=44 NUM OF VISIBLE DAYS=19

ROW, COL	FREQUENCY (GHZ)	INCIDENCE ANGLE (DEG)	PFF (COL1)	ANGLE (DEG)	TTF (DEG)	ANGLE (DEG)	RTH (DBI)	ANGLE (DEG)	VTH (DEG)	ANGLE (DEG)
44, 1	9.70	73.351	14.97	119.48	.79	-145.22	27.14	292.16	.25	-140.87
44, 2	9.70	73.331	14.97	119.34	.53	-139.75	30.79	299.11	.25	-142.55
44, 3	9.70	73.252	15.11	119.46	.73	-135.17	27.27	292.22	.25	-140.76
44, 4	9.70	73.252	13.89	127.62	.62	-139.30	30.95	299.80	.25	-142.43
44, 5	9.70	73.423	14.61	119.47	.71	-135.26	26.99	292.11	.25	-141.00
44, 6	9.70	73.423	16.53	127.14	.63	-139.43	30.62	293.60	.25	-142.69
44, 7	9.70	72.888	14.81	118.91	.69	-134.42	27.29	291.67	.25	-139.92
44, 8	9.70	72.888	13.75	127.37	.62	-138.26	30.81	293.32	.25	-141.57
44, 9	9.70	73.559	15.22	120.09	.70	-136.06	27.31	292.75	.25	-141.49
44, 10	9.70	75.529	9.23	129.32	.63	-140.28	31.14	301.41	.25	-143.19
44, 11	9.70	72.842	14.88	118.93	.69	-134.38	27.37	291.70	.25	-139.86
44, 12	9.70	72.842	16.62	125.93	.62	-138.21	30.90	298.42	.25	-141.50
44, 13	9.70	73.695	15.05	120.05	.71	-136.14	27.08	292.69	.25	-141.68
44, 14	9.70	73.695	13.05	129.71	.54	-140.35	30.88	301.05	.25	-143.39
44, 15	9.70	72.505	14.93	118.93	.69	-134.36	27.43	291.72	.25	-139.80
44, 16	9.70	72.605	15.67	126.07	.61	-135.31	30.98	298.50	.25	-141.45
44, 17	9.70	73.845	14.83	120.02	.72	-135.22	26.84	292.59	.25	-141.90
44, 18	9.70	72.700	17.52	122.75	.64	-140.49	30.59	300.67	.25	-141.82
44, 19	9.70	72.700	14.42	116.40	.70	-133.28	27.00	291.05	.25	-139.32
44, 20	9.70	72.700	17.31	122.34	.62	-137.16	30.32	295.58	.25	-140.45
44, 21	9.70	74.009	14.69	120.00	.73	-136.31	26.57	292.48	.25	-142.11
44, 22	9.70	74.009	13.29	120.27	.65	-140.22	30.27	300.22	.25	-143.16
44, 23	9.70	72.700	14.41	118.40	.70	-137.23	26.99	292.59	.25	-141.90
44, 24	9.70	72.700	17.90	122.87	.62	-137.25	30.30	296.57	.25	-141.82
44, 25	9.70	74.002	15.40	120.67	.71	-137.20	27.26	293.51	.25	-142.49
44, 26	9.70	74.002	19.81	131.01	.64	-147.54	31.27	303.45	.25	-142.42
44, 27	9.70	72.528	14.39	118.22	.70	-132.89	27.07	290.89	.25	-138.95
44, 28	9.70	72.528	17.03	123.36	.62	-135.82	30.33	295.10	.25	-140.37
44, 29	9.70	74.261	15.14	120.84	.73	-137.41	26.87	293.38	.25	-142.19
44, 30	9.70	74.263	19.28	131.33	.65	-142.81	30.63	302.92	.25	-144.65
44, 31	9.70	72.430	14.05	117.94	.70	-132.27	26.83	290.52	.25	-138.57
44, 32	9.70	72.430	17.97	122.19	.62	-137.17	26.96	293.13	.25	-140.19
44, 33	9.70	74.775	14.53	120.73	.73	-137.64	26.04	293.01	.25	-143.62
44, 34	9.70	74.775	17.03	120.95	.65	-137.19	29.12	293.55	.25	-139.79
44, 35	9.70	72.261	15.14	120.84	.72	-137.85	26.53	291.25	.25	-143.41
44, 36	9.70	72.263	19.28	131.33	.63	-137.74	29.45	301.02	.25	-140.94
44, 37	9.70	74.032	14.54	120.74	.76	-137.66	26.11	293.04	.25	-143.56
44, 38	9.70	74.773	16.97	129.76	.66	-142.16	29.93	301.64	.25	-144.36
44, 39	9.70	72.421	13.46	117.67	.73	-133.35	26.23	289.97	.25	-138.18
44, 40	9.70	72.421	16.48	120.52	.65	-135.22	29.12	293.55	.25	-140.52
44, 41	9.70	72.421	13.27	117.80	.72	-137.85	25.76	292.68	.25	-141.93
44, 42	9.70	72.437	16.93	121.33	.63	-137.35	29.45	301.34	.25	-140.94
44, 43	9.70	74.733	14.54	120.74	.73	-137.68	26.22	289.74	.25	-137.63
44, 44	9.70	74.733	17.97	122.19	.66	-137.17	29.02	293.96	.25	-140.19
44, 45	9.70	72.421	13.46	117.67	.73	-133.35	26.23	289.97	.25	-138.18
44, 46	9.70	72.421	16.48	120.52	.65	-135.22	29.12	293.55	.25	-140.52
44, 47	9.70	72.437	13.27	117.80	.72	-137.85	25.76	292.68	.25	-141.93
44, 48	9.70	72.437	16.93	121.33	.63	-137.35	29.45	301.34	.25	-140.94
44, 49	9.70	74.733	14.54	120.74	.73	-137.68	26.22	289.74	.25	-137.63
44, 50	9.70	74.733	17.97	122.19	.66	-137.17	29.02	293.96	.25	-140.19
44, 51	9.70	72.421	13.46	117.67	.73	-133.35	26.23	289.97	.25	-138.18
44, 52	9.70	72.421	16.48	120.52	.65	-135.22	29.12	293.55	.25	-140.52
44, 53	9.70	72.437	13.27	117.80	.72	-137.85	25.76	292.68	.25	-141.93
44, 54	9.70	72.437	16.93	121.33	.63	-137.35	29.45	301.34	.25	-140.94
44, 55	9.70	74.733	14.54	120.74	.73	-137.68	26.22	289.74	.25	-137.63
44, 56	9.70	74.733	17.97	122.19	.66	-137.17	29.02	293.96	.25	-140.19
44, 57	9.70	72.421	13.46	117.67	.73	-133.35	26.23	289.97	.25	-138.18
44, 58	9.70	72.421	16.48	120.52	.65	-135.22	29.12	293.55	.25	-140.52
44, 59	9.70	72.437	13.27	117.80	.72	-137.85	25.76	292.68	.25	-141.93
44, 60	9.70	72.437	16.93	121.33	.63	-137.35	29.45	301.34	.25	-140.94
44, 61	9.70	74.733	14.54	120.74	.73	-137.68	26.22	289.74	.25	-137.63
44, 62	9.70	74.733	17.97	122.19	.66	-137.17	29.02	293.96	.25	-140.19
44, 63	9.70	72.421	13.46	117.67	.73	-133.35	26.23	289.97	.25	-138.18
44, 64	9.70	72.421	16.48	120.52	.65	-135.22	29.12	293.55	.25	-140.52
44, 65	9.70	72.437	13.27	117.80	.72	-137.85	25.76	292.68	.25	-141.93
44, 66	9.70	72.437	16.93	121.33	.63	-137.35	29.45	301.34	.25	-140.94
44, 67	9.70	74.733	14.54	120.74	.73	-137.68	26.22	289.74	.25	-137.63
44, 68	9.70	74.733	17.97	122.19	.66	-137.17	29.02	293.96	.25	-140.19
44, 69	9.70	72.421	13.46	117.67	.73	-133.35	26.23	289.97	.25	-138.18
44, 70	9.70	72.421	16.48	120.52	.65	-135.22	29.12	293.55	.25	-140.52
44, 71	9.70	72.437	13.27	117.80	.72	-137.85	25.76	292.68	.25	-141.93
44, 72	9.70	72.437	16.93	121.33	.63	-137.35	29.45	301.34	.25	-140.94
44, 73	9.70	74.733	14.54	120.74	.73	-137.68	26.22	289.74	.25	-137.63
44, 74	9.70	74.733	17.97	122.19	.66	-137.17	29.02	293.96	.25	-140.19
44, 75	9.70	72.421	13.46	117.67	.73	-133.35	26.23	289.97	.25	-138.18
44, 76	9.70	72.421	16.48	120.52	.65	-135.22	29.12	293.55	.25	-140.52
44, 77	9.70	72.437	13.27	117.80	.72	-137.85	25.76	292.68	.25	-141.93
44, 78	9.70	72.437	16.93	121.33	.63	-137.35	29.45	301.34	.25	-140.94
44, 79	9.70	74.733	14.54	120.74	.73	-137.68	26.22	289.74	.25	-137.63
44, 80	9.70	74.733	17.97	122.19	.66	-137.17	29.02	293.96	.25	-140.19
44, 81	9.70	72.421	13.46	117.67	.73	-133.35	26.23	289.97	.25	-138.18
44, 82	9.70	72.421	16.48	120.52	.65	-135.22	29.12	293.55	.25	-140.52
44, 83	9.70	72.437	13.27	117.80	.72	-137.85	25.76	292.68	.25	-141.93
44, 84	9.70	72.437	16.93	121.33	.63	-137.35	29.45	301.34	.25	-140.94
44, 85	9.70	74.733	14.54	120.74	.73	-137.68	26.22	289.74	.25	-137.63
44, 86	9.70	74.733	17.97	122.19	.66	-137.17	29.02	293.96	.25	-140.19
44, 87	9.70	72.421	13.46	117.67	.73	-133.35	26.23	289.97	.25	-138.18
44, 88	9.70	72.421	16.48	120.52	.65	-135.22	29.12	293.55	.25	-140.52
44, 89	9.70	72.437	13.27	117.80	.72	-137.85	25.76	292.68	.25	-141.93
44, 90	9.70	72.437	16.93	121.33	.63	-137.35	29.45	301.34	.25	-140.94
44, 91	9.70	74.733	14.54	120.74	.73	-137.68	26.22	289.74	.25	-137.63
44, 92	9.70	74.733	17.97	122.19	.66	-137.17	29.02	293.96	.25	-140.19
44, 93	9.70	72.421	13.46	117.67	.73	-133.35	26.23	289.97	.25	-138.18
44, 94	9.70	72.421	16.48	120.52	.65	-135.22	29.12	293.55	.	

46-359	9.74	77.277	17.57	124.74	.71	-142.55	26.73	301.11	.27	-165.17	
46-359	9.70	72.361	12.46	117.94	.7	-142.55	26.23	291.24	.26	-171.37	
46-359	9.66	72.361	15.74	119.94	.6	-143.45	27.42	291.54	.26	-136.99	
46-359	9.70	75.295	18.34	120.74	.81	-137.31	25.24	292.72	.27	-146.34	
46-359	9.70	75.295	17.77	123.32	.71	-142.55	26.92	300.37	.27	-165.18	
46-359	9.70	72.161	11.93	117.53	.67	-142.43	24.93	249.39	.25	-136.63	
46-359	9.80	—	72.151	—	14.37	.53	-142.15	27.21	291.64	.24	-146.21
46-359	9.70	75.294	13.31	120.74	.43	-137.92	25.23	292.71	.27	-146.35	
46-359	9.68	—	75.254	—	17.75	.71	-142.95	26.90	300.35	—	-146.19
46-359	9.70	72.307	21.35	117.66	.91	-128.41	24.71	249.10	.25	-136.42	
46-359	9.50	72.307	14.23	117.66	.70	-132.26	27.04	290.58	.25	-138.61	
46-359	9.70	75.297	13.92	120.75	.61	-137.92	25.22	292.71	.27	-146.37	
46-359	9.60	72.352	21.77	120.28	.71	-142.57	26.89	300.33	.25	-146.00	
46-359	9.70	72.352	21.14	118.04	.96	-127.33	24.00	286.62	.25	-136.39	
46-359	9.80	72.352	13.33	117.80	.73	-131.04	26.13	289.38	.25	-137.97	
46-359	9.70	75.307	15.91	120.75	.81	-137.92	25.20	292.70	.27	-144.88	
46-359	9.80	75.307	17.75	120.75	.71	-132.97	26.87	300.31	.27	-146.22	
46-359	9.70	72.558	21.92	118.25	.68	-122.39	23.71	286.15	.25	-136.65	
46-359	9.80	72.558	23.13	117.70	.75	-131.73	25.83	299.00	.25	-136.26	
46-359	9.70	76.995	12.05	121.53	.97	-138.43	22.66	292.15	.30	-146.71	
46-359	9.60	76.995	13.41	125.83	.83	-143.80	25.94	297.54	.29	-146.72	
46-359	9.70	72.510	20.50	118.65	.92	-126.26	23.21	286.78	.26	-136.69	
46-359	9.80	72.510	22.96	117.63	.73	-129.97	23.17	289.35	.25	-137.81	
46-359	9.70	77.119	11.92	121.63	.99	-138.52	22.48	292.13	.31	-146.88	
46-359	9.80	77.119	23.25	125.27	.84	-143.66	25.74	297.39	.29	-146.40	
46-359	9.70	72.529	9.99	119.19	.97	-125.17	22.67	286.81	.26	-135.83	
46-359	9.80	72.529	11.78	117.63	.82	-128.79	24.50	289.05	.25	-137.22	
46-359	9.70	77.242	21.79	121.74	1.00	-138.54	22.30	292.12	.31	-147.04	
46-359	9.80	77.242	25.30	123.80	.93	-135.73	23.33	297.25	.30	-149.08	
46-359	9.70	72.762	9.61	119.49	2.00	-125.22	22.35	286.17	.26	-135.93	
46-359	9.80	72.762	21.97	118.03	.84	-126.87	24.16	289.17	.25	-137.93	

THFL = 0.0000 THATZ = 5.0100

NUM OF ROWS=44 --- NUM OF COLS=44 --- NUM OF VISIBLE PAYS = 12

MENT FREQ	INCIDENCE	RTE	ANGLE	TTE	ANGLE	RIM	ANGLE	TTM	ANGLE
ROW, COL.	(HZ)	(DB)	(DEG)	(DB)	(DEG)	(DB)	(DEG)	(DB)	(DEG)
1, 14	9.70	71.036	13.74	116.74	.68	-129.04	27.43	289.46	.24
1, 14	9.70	71.033	-16.79	119.23	.50	-122.64	30.0	292.54	.24
2, 44	9.70	71.006	13.74	115.74	.68	-129.04	27.43	289.46	.24
2, 44	9.70	71.033	16.70	117.23	.50	-122.64	30.0	292.54	.24
3, 44	9.70	71.024	13.77	116.75	.63	-129.05	27.41	289.46	.24
3, 44	9.70	71.024	16.70	119.22	.60	-132.65	30.17	292.52	.24
4, 44	9.70	71.024	13.77	116.75	.68	-129.05	27.41	289.46	.24
4, 44	9.70	71.024	16.70	119.22	.50	-132.65	30.17	292.52	.24
5, 44	9.70	71.071	13.72	116.77	.68	-129.07	27.33	289.45	.24
5, 44	9.70	71.071	16.72	116.77	.60	-122.68	30.05	292.48	.24
6, 44	9.70	71.071	13.72	116.77	.68	-129.07	27.33	289.45	.24
6, 44	9.70	71.071	16.72	119.18	.60	-122.68	30.05	292.48	.24
7, 44	9.70	71.120	13.67	116.79	.69	-129.10	27.25	289.44	.24
7, 44	9.70	71.120	16.56	119.25	.60	-132.71	30.00	292.44	.24
8, 44	9.70	71.120	13.67	116.79	.69	-129.10	27.25	289.44	.24
8, 44	9.70	71.120	16.56	119.25	.60	-132.71	30.00	292.44	.24
9, 44	9.70	71.012	13.59	116.75	.69	-128.75	27.24	289.33	.24
9, 44	9.70	71.012	16.59	118.84	.60	-132.35	29.94	292.15	.24
10, 44	9.70	71.056	13.54	116.72	.69	-128.78	27.17	289.32	.24
10, 44	9.70	71.056	16.37	118.81	.60	-132.35	29.85	292.12	.24
11, 44	9.70	71.137	13.67	116.79	.69	-129.10	27.25	289.44	.24
11, 44	9.70	71.137	16.22	118.75	.60	-132.71	30.00	292.44	.24
12, 44	9.70	71.137	13.46	116.76	.69	-128.82	27.24	289.44	.24
12, 44	9.70	71.137	16.22	118.75	.60	-132.82	27.03	292.44	.24
13, 44	9.70	70.768	13.27	116.53	.70	-127.85	29.71	292.05	.24
13, 44	9.70	70.768	16.37	118.81	.61	-122.35	29.85	292.12	.24
14, 44	9.70	71.137	13.46	116.76	.70	-128.82	27.03	292.44	.24
14, 44	9.70	71.137	16.22	118.75	.61	-132.82	29.71	292.05	.24
15, 44	9.70	71.137	13.46	116.76	.70	-128.82	27.03	292.44	.24
15, 44	9.70	71.137	16.22	118.75	.61	-132.82	29.71	292.05	.24
16, 44	9.70	71.002	13.05	116.53	.70	-127.85	29.78	292.04	.24
16, 44	9.70	71.002	16.37	118.81	.61	-122.35	29.85	292.12	.24
17, 44	9.70	71.002	13.05	116.53	.70	-127.85	29.78	292.04	.24
17, 44	9.70	71.002	16.37	118.81	.61	-122.35	29.85	292.12	.24
18, 44	9.70	71.036	13.21	116.57	.70	-127.88	29.81	292.04	.24
18, 44	9.70	71.036	16.22	118.77	.61	-131.42	29.71	292.05	.24
19, 44	9.70	71.199	13.05	116.66	.71	-127.95	29.78	292.04	.24
19, 44	9.70	71.199	16.52	119.53	.62	-121.38	29.64	291.36	.24
20, 44	9.70	71.036	13.21	116.57	.70	-127.88	29.81	292.04	.24
20, 44	9.70	71.036	16.22	118.77	.61	-131.42	29.71	292.05	.24
21, 44	9.70	71.149	13.19	116.58	.70	-127.89	29.84	292.03	.24
21, 44	9.70	71.149	16.52	119.53	.62	-131.43	29.71	292.05	.24
22, 44	9.70	71.149	13.05	116.66	.71	-127.95	29.78	292.04	.24
22, 44	9.70	71.149	16.52	119.53	.62	-121.38	29.64	291.36	.24
23, 44	9.70	71.036	13.21	116.57	.70	-127.88	29.81	292.04	.24
23, 44	9.70	71.036	16.22	118.77	.61	-131.42	29.71	292.05	.24
24, 44	9.70	71.036	13.21	116.57	.70	-127.88	29.81	292.04	.24
24, 44	9.70	71.036	16.22	118.77	.61	-131.42	29.71	292.05	.24
25, 44	9.70	71.213	12.64	116.96	.72	-128.15	26.03	288.99	.24
25, 44	9.70	71.213	15.43	117.86	.64	-131.77	26.03	289.07	.24
26, 44	9.70	71.036	13.21	116.57	.70	-127.88	29.81	292.04	.24
26, 44	9.70	71.036	16.22	118.77	.61	-131.42	29.71	292.05	.24
27, 44	9.70	71.419	14.79	117.25	.67	-110.58	27.63	290.08	.24
27, 44	9.70	71.419	17.56	117.25	.67	-127.05	25.22	285.74	.24
27, 44	9.70	71.543	11.59	117.24	.79	-121.77	27.05	290.05	.24
27, 44	9.70	71.543	14.37	117.24	.68	-130.64	27.05	290.05	.24
28, 44	9.70	71.657	11.79	117.34	.80	-127.09	25.04	288.75	.24
28, 44	9.70	71.657	14.05	117.31	.68	-130.70	27.26	290.01	.24
29, 44	9.70	71.877	11.60	117.55	.62	-127.17	24.71	288.77	.25

## SECTION VII

### RECOMMENDATIONS FOR FURTHER REFINING THE PROGRAM

The following are suggested as subsequent tasks:

1. Verify the radome analysis program by using detailed design and measured data on an existing radome.
2. Obtain a suitable antenna simulation program and interface it with the radome program. Use the radome and antenna simulation programs to estimate the distortion of the antenna pattern due to the radome interference.
3. Verify the results from (2) above using measured data.
4. Perfect the radome simulation program with regard to core storage requirements and central processor time.
5. Document the radome/antenna simulation program as obtained using the foregoing steps.

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